The Precautionary Principle in North Pacific Groundfish Management

by Grant Thompson

During the past 10 years, the precautionary principle has emerged as an increasingly popular concept which has has been applied to the areas of environmental law and resource management on both a national and international level. The precautionary principle was first referred to in an official setting at the Second International Conference on the Protection of the North Sea, held in London in 1987. Regulation of marine pollution was the subject, and the precautionary principle was advanced in an attempt to shift the burden of proof from the regulatory authority to the polluter. Basically, the precautionary principle holds that the existence of scientific uncertainty regarding the precise effects of human activities on the natural environment constitutes legitimate grounds for constraining such activities rather than for pursuing them.

Recent years have witnessed a number of calls for extension of the precautionary principle to fishery management. At the international level, such calls have been featured in several agreements developed under the auspices of the United Nations (U.N.), including the Code of Conduct for Responsible Fisheries developed by the U.N. Food and Agriculture Organization (the FAO Code of Conduct), the Rio Declaration of the U.N. Conference on Environment and Development (the Rio Declaration), and the U.N. Convention on the Law of the Sea Relating to the Conservation and Management of Straddling Stocks and Highly Migratory Fish Stocks (the Straddling Stocks Agreement). Interestingly, although each of these agreements advocates the precautionary principle's use, none of them provides an operational definition of the term as it applies or should apply to fishery management. In an effort to begin filling this void, a Technical Consultation on the Precautionary Approach to Capture Fisheries was convened in 1995 by the Government of Sweden in cooperation with the FAO (the FAO Technical Consultation). While the FAO Technical Consultation succeeded in providing some broad insights into what a precautionary approach to fishery management might look like, it too stopped short of giving an operational definition.

At the national level, the Magnuson Fishery Conservation and Management Act (MFCMA) has guided marine fishery management in the United States since 1976. Although the MFCMA does not mention the precautionary principle specifically, it contains provisions which seem to bear directly on this principle. For example, National Standard 1 of the MFCMA mandates both the prevention of overfishing and the achievement of optimum yield. The *602 Guidelines*, published in 1989 as the National Oceanic and Atmospheric Administration's official interpretation of National Standard 1, require each fishery management plan (FMP) to specify an "objective and measurable definition of overfishing" incorporating "appropriate consideration of risk" and a delineation of "management measures necessary to prevent overfishing." In the 4 years following publication of the *602 Guidelines*, more than 100 definitions of overfishing were submitted and approved for use in FMPs across the country, including an overfishing definition for the groundfish fisheries of the North Pacific.

To ensure that the various definitions established under the *602 Guidelines* were adequate to prevent overfishing, the National Marine Fisheries Service convened a special panel (the Overfishing Definitions Review Panel) in 1993 to review these definitions. The report of the Overfishing Definitions Review Panel, published in 1994, contained several general recommendations which bear on the application of the precautionary principle to fishery management. In addition, the report made specific recommendations for modifying the overfishing definition used in the groundfish fisheries of the North Pacific. At about the same time, the Scientific and Statistical Committee of the North Pacific Fishery Management Council (NPFMC) made its own suggestions for modifying the North Pacific groundfish overfishing definition. As a result of the suggestions made by the Overfishing Definitions Review Panel and the Scientific and Statistical Committee, the NPFMC revised its definition of overfishing for the North Pacific groundfish fisheries in June 1996. The revised definition provides a clear exposition of the precautionary principle as it relates to fishery management. This article presents three questions fundamental to developing a precautionary approach to fisheries management and a set of possible answers based on the revised definition of overfishing for the North Pacific groundfish fisheries.

Three questions to be answered

1. What should be the relationship between intended catch *targets* and absolute catch *limits*? On the one hand, the two concepts could be synonymous. Assuming that an optimal harvest level exists, it could be argued that any catch, no matter how small, in excess of that optimal level should not be tolerated, meaning that the optimal level is not only the intended target but also an absolute upper limit. However, such an argument is impractical because it implies an impossible level of precision in the management process. Instead, it should be assumed that there is almost no chance of the actual catch matching the target *exactly*; rather it will be off by some amount, either plus or minus. If it is understood that the target harvest level will sometimes be overshot by small amounts due to random chance, it makes sense to draw a distinction between an intended catch target and an absolute catch limit, the former being an amount to which management is trying to come as close as possible, the latter implying a cap on the permissible amount by which the target can be exceeded accidentally without jeopardizing the stock's long-term productive capacity. The intended target is associated with the optimum level of harvest, while the absolute limit is associated with the boundary of the danger zone. Harvesting at a rate greater than that corresponding to the target would be expected to result in suboptimal fishery performance over the long term, but would not be expected to do irreversible damage to the stock's innate productive capacity provided the harvest rate corresponding to the absolute catch limit is not exceeded.

The FAO Code of Conduct suggests that nations should determine "stock specific *target* reference points" and "stock specific *limit* reference points" (emphasis added). Likewise, the Overfishing Definitions Review Panel report states that "it is important to make distinctions between the management targets and overfishing definition thresholds." However, neither report is very specific as to how these objectives should be accomplished.

2. What should be the relationship between stock size and catch? In other words, is it appropriate to harvest a constant proportion of the stock regardless of the stock's size, or should the harvest rate change in the event that the stock becomes depleted? Much of the literature on optimal harvesting argues in favor of a constant harvest rate independent of stock size. However, it seems unlikely that such an argument can be considered valid in the case where stock size becomes extremely small, for even if a particular stock could be safely harvested at a certain rate across a large range of stock sizes, few would suggest maintaining the same harvest rate in the event that the stock was on the brink of extinction.

The Overfishing Definitions Review Panel report suggests that harvest rates should be defined "using a combination of a maximum fishing mortality rate, a precautionary biomass level below which the maximum allowable fishing mortality rate is reduced, and an absolute minimum biomass threshold." However, the values associated with these rates and levels are not specified.

3. What should be the management response to a given level of uncertainty surrounding estimates of key population parameters? Scientists are rarely, if ever, certain regarding the precise long-term effects of a particular fishing level on a given fish stock. Scientists may have data and analyses which permit a description of the most likely effects, but such descriptions are inevitably associated with some potentially high level of uncertainty. If the level of uncertainty is great, any particular level of fishing could be too low, thus foregoing harvests available in the short term, or too high, thus diminishing the level of harvests achievable in the long term. In some parts of the country, fishery managers have had difficulty rejecting the claims of resource users who feel that a lack of scientific certainty diminishes the Government's right to constrain harvests. So, if the amount of uncertainty regarding a stock's productivity happens to increase, should the target catch level change as well, and if so, by how much and in which direction?

The FAO Code of Conduct advises that "in implementing the precautionary approach, States should take into account, *inter alia*, uncertainties relating to the size and productivity of the stocks." Likewise, the FAO Technical Consultation concluded that "a precautionary approach to fishery management would implicitly account for uncertainty by being more conservative." Again, however, specifics are lacking.

New policy in the North Pacific

Management of groundfish in the U.S. EEZ (Exclusive Economic Zone) 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 MFCMA. During the first several years of management under the MFCMA, 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. Responding to publication of the *602 Guidelines*, the 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. In June 1996 the NPFMC moved to address shortcomings of the existing OFL definition as well as ambiguities in the relationship between ABC and OFL when it approved a pair of amendments to redefine both ABC and OFL in the FMPs for North Pacific groundfish. 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 article focuses on how the new definitions of ABC and OFL on the top tier in the hierarchy relate to the precautionary principle. In general, the top tier deals with the three previously posed questions as follows.

What should be the relationship between intended catch targets and absolute catch limits? Answer: Intended target catches (ABC) should be well below the levels at which the stock's long-term productive capacity might be jeopardized (OFL).

What should be the relationship between stock size and catch? Answer: Depleted stocks should be harvested at a lower relative rate than healthy stocks.

What should be the management response to a given level of uncertainty surrounding estimates of key population parameters? Answer: Greater uncertainty regarding a stock's productivity should correspond to greater caution in setting the target catch rate.

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 inadvertantly 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

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— 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

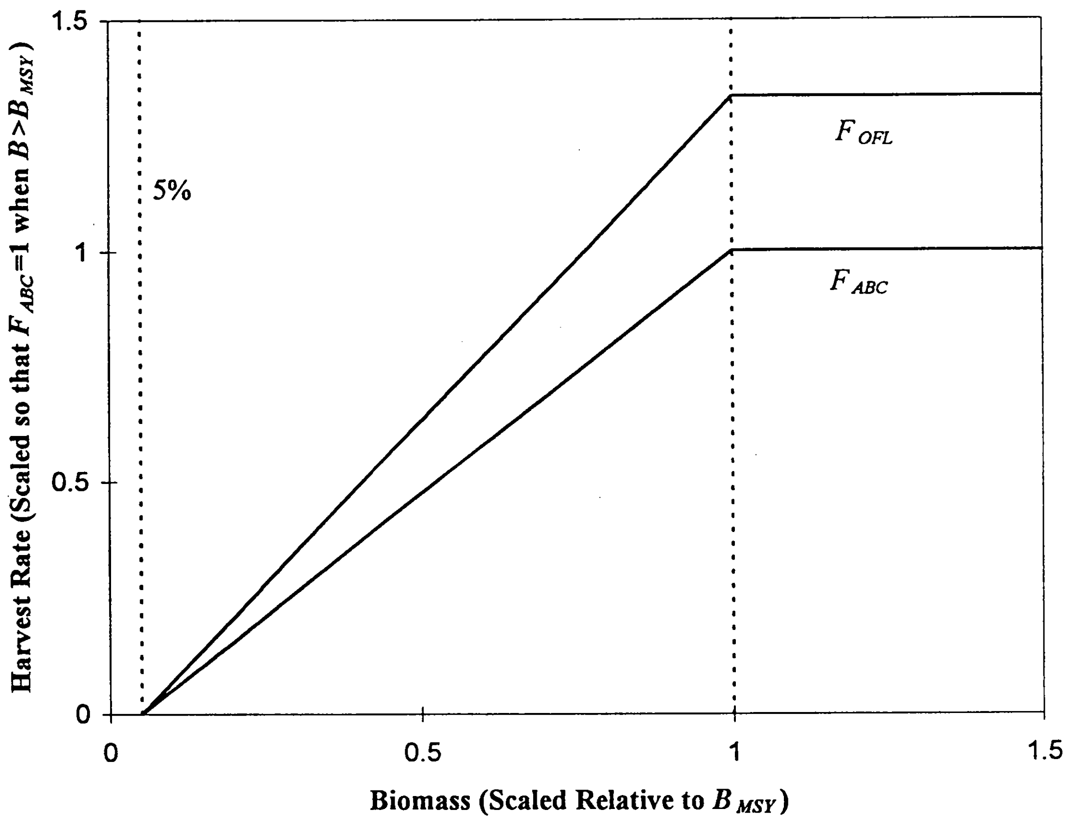


Figure 1. Overfishing rate F_{OFL} and target rate F_{ABC} in terms of biomass *B*.

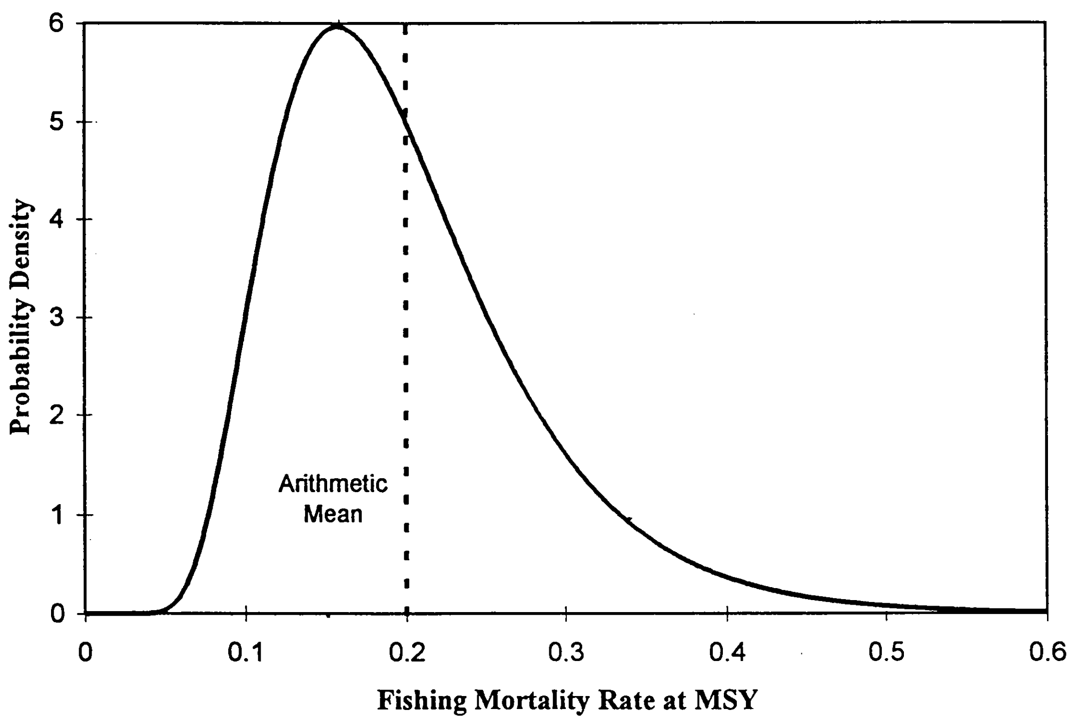


Figure 2. Probability density function of the fishing mortality rate at maximum sustainable yield (MSY) with an arithmetic mean equal to 0.2 and a coefficient of variation equal to 0.4.

Table 1. The harmonic means of the four probability density functions (pdfs) in Figure 3.				
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**

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 probabilities can be expressed in the form of the curve shown in Figure 2. Such a curve is called a probability density function or pdf. 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 or 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. 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. 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 Table 1.

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

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

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.

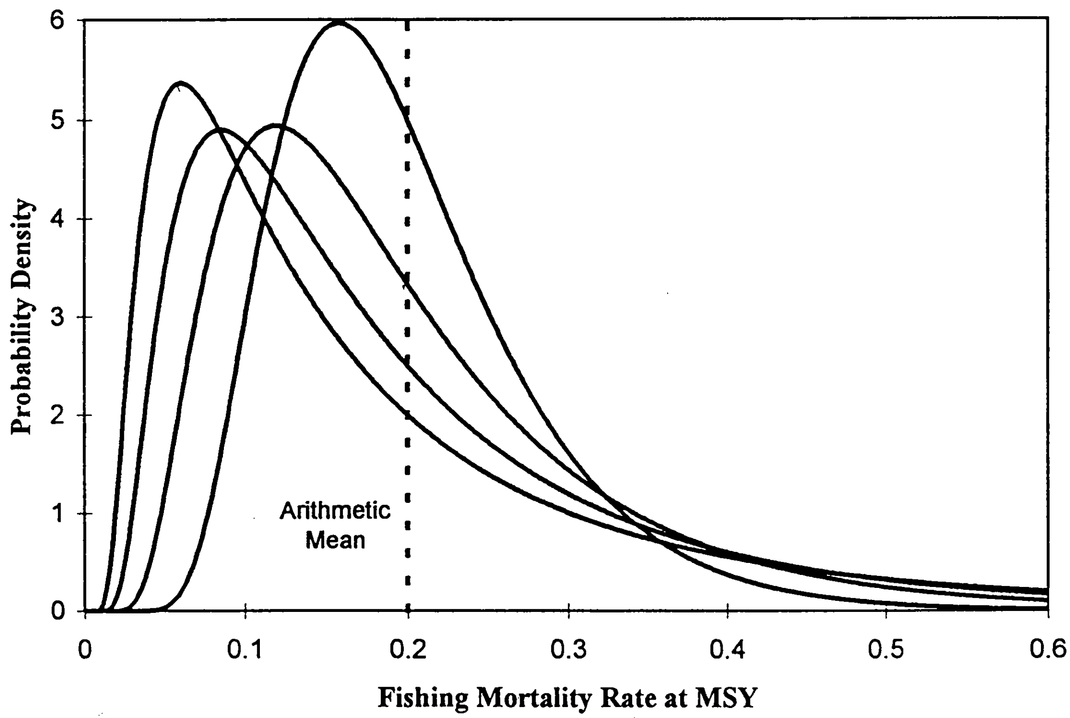


Figure 3. Probability density functions of the fishing mortality rate at maximum sustainable yield (MSY) with coefficients of variation equal to 0.4, 0.6, 0.8, and 1.0 (right to left in order of the peaks of the curves).

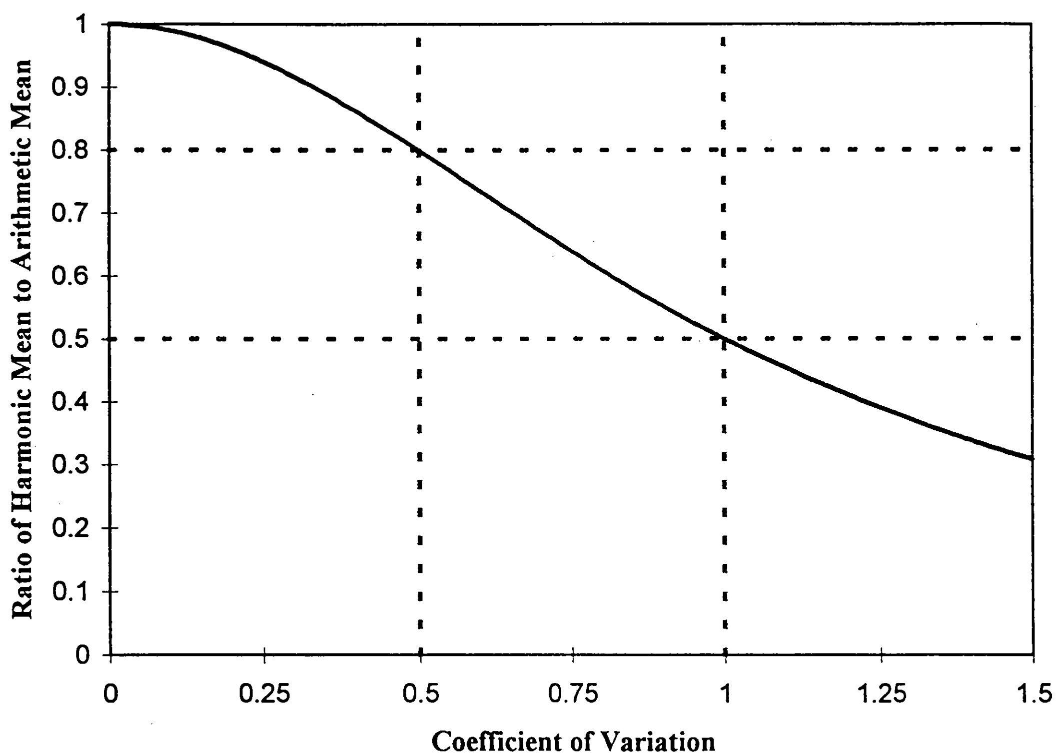
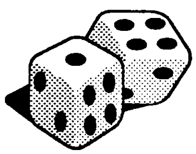


Figure 4. Ratio of harmonic mean to arithmetic mean as a function of the coefficient of variation (CV), with special cases of CV=0.5 and CV=1.0 highlighted.

Conclusion

The new ABC/OFL definitions for North Pacific groundfish constitute a significant step toward translating the precautionary principle into practical and easily interpretable terms. By clearly separating intended catch targets from absolute catch limits, by lowering harvest rates for depleted stocks, and by requiring greater caution in the presence of uncertainty, the new definitions provide a framework for realizing National Standard 1 of the Magnuson Fishery Conservation and Management Act: prevention of overfishing while achieving optimum yield.



Definitions of statistical terms

Probability density function (pdf): A description of the probability associated with different values of a variable. For example, in a coin flip the probability of tossing "heads" is 50% and the probability of tossing "tails" is 50%. As another example, in tossing a six-sided die the probability of tossing a "1" is 16.667% and the probability of tossing something other than a "1" is 83.333%. The probabilities in a pdf must always sum to 100%.

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.

Coefficient of variation (CV): For a random variable X, the coefficient of variation is the standard deviation of X divided by the arithmetic mean of X. The standard deviation, in turn, is a measure of the average amount by which the various possible values of X differ from the arithmetic mean. A bit more precisely, the standard deviation is the square root of the average squared difference between the various possible values of X and the arithmetic mean. For the coin flip example (above), the CV is given by

$$\left(\frac{1}{48}\right)\sqrt{\frac{(72-48)^2 + (24-48)^2}{2}} = 0.500$$

while for the die toss example (above), the CV is given by

$$\left(\frac{1}{32}\right)\sqrt{\frac{(72-32)^2 + 5(24-32)^2}{6}} = 0.559$$