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An Epitaph for the Concept of Maximum Sustained Yield[1]

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About 30 years ago, when I was a graduate student, the idea of managing fisheries for maximum sustained yield was just beginning to really catch on. Of course, the ideas had already been around for quite a while. Baranov (1918) was the first to combine information on growth and abundance to develop a catch equation, and Russell (1931) and Graham (1935) brought the dynamic pool model to the forefront, but they were working from a base of natural history and fishery biology that had been growing for several decades.

By the late 1930s, in North America, the conservation movement was in full cry and fisheries, like other resources, were being illuminated in the glow of the Gospel of Efficiency (Hays 1969). In dozens of states and provinces, fish and game regulations were proliferated, commercial fisheries were increasingly documented, and there was a growing awareness of the necessary scientific base for management. Thompson and Bell (1934) came to the conclusion that too much fishing effort was at the heart of the halibut problem; Hile (1936) produced his classic on the cisco in Wisconsin; and the first steps were being taken to restore the Fraser River sockeye from the effects of overfishing and the Hell's Gate blockage.

The ten years following World War II were the golden age for the concept of maximum sustained yield. Ricker (1948) produced his famous "green book," the first version of his handbook (Ricker 1958); Fry (1947) developed the virtual population idea; and Schaefer (1954) proposed his method for estimating surplus production under nonequilibrium conditions. The literature crackled with new information and new ideas. The solidification of the concept of MSY, its application to fisheries here, there, and everywhere, was just under way. World fisheries catch was a mere 20 million tons, and there were signs in lots of places of irreligious practices such as harvesting more or less than should be harvested. In a mood of excitement about opportunities, coupled with determination to do it properly, the FAO emerged as a major actor in the international fisheries scene.

It was in consequence of this flowering of activity that the graduate students of those days had a missionary zeal about them, and as more than one wit has said, "They had a fine vocabulary of stained glass language." Briefly, the dogma was this: any species each year produces a harvestable surplus, and if you take that much, and no more, you can go on getting it forever and ever (Amen). You only need to have as much effort as is necessary to catch this magic amount, so to use more is wasteful of effort; to use less is wasteful of food. Basically, it was a puritanical philosophy in which the supreme powers were pretty harsh on people who enjoyed themselves rather than doing precisely the Right Thing. Armed with scientific knowledge about the number of fishermen and technological advances, the

[1] Keynote address to the American Fisheries Society Annual Meetings, Dearborn, Michigan, September 19–24, 1976.

manager could use regulations to prevent the catch from exceeding the maximum, even if it meant telling fishermen they could only use bare hooks from sailboats on alternate Tuesdays between 6 and 7 p.m. The various laws of supply and demand, marginal revenue, alternative options, and psychological dissatisfaction, were mostly misty mumblings of the social sciences. It was generally assumed that the fishermen would look after themselves. Moreover, it was assumed that the animals were well aware of what was being organized for them as their role in the scheme of things. Organisms were allowed to breed with those of their own species, or interact with individuals of other species, but not in ways that might upset the maximum sustained yield.

As I am sure you realize, I am considerably dramatizing the way it was; but, when speaking in retrospect, one is usually to be allowed that privilege. Certainly, it is to be understood that the people who generated these ideas were appropriately modest and were well aware of the dangers of oversimplification. Their protégés were perhaps no less critical, but in selling the idea to administrators it was essential to make the main argument forcefully. And this they did, with clear conscience, for they all knew that the main idea was correct and it was only necessary to do a bit more research, to get a bit more experience, and then the basic theme could be appropriately fine tuned to perfection.

Like all religious movements, the doctrine of MSY had effects on other doctrines, and the most notable was the impact on traditional limnology. For almost 100 years, working from a European base, limnologists had been developing holistic schemes of trophic status in which fish were part of a complex community for which the rate of harvest was best expressed in pounds per acre or kilos per hectare. I vividly recall being proselytized by Bill Kennedy, a disciple of the new doctrine of population dynamics, about the futility of the old-fashioned limnological approaches of my Master's degree supervisor, Don Rawson, just as I am sure that most others of my year class can remember similar arguments about the limnology versus fisheries approaches. The Langlois-Van Oosten debate about Lake Erie was typical (Van Oosten 1948; Langlois 1954). The believers in MSY had little patience for the systematics of zooplankton or the subtleties of lake classification. The fish, they argued, were the integrators of their environment and the object of our crass interest. "Study the Fish" was the motto.

In addition to their disrespect for traditionalists, the proponents of MSY were highly intolerant of heretical views. Most of you may never have heard of Harden Taylor, who reviewed the fisheries of Maryland (1951) and concluded that the inexorable laws of economics could curtail the rates of harvesting long before any species of fish was faced with extinction. His message was that the fish could recover from whatever we were likely to do to them and, with dollars being the real yield, what was so special about MSY? I vividly recall the frigid silence with which he was greeted whenever he got up to speak.

The emphasis on population dynamics gained increasingly in strength, and throughout the forties and fifties both the theory and practice of maximum sustained yield became widespread. The basic idea was enshrined in national policy documents, incorporated in international treaties, and, in effect, became synonymous in most people's minds with sound management. Most fishery managers and politicians engaged in a steady dialogue of explaining why they had to compromise a bit on MSY for "social reasons" but, in so doing, they usually sounded apologetic. They *knew* they were sinning.

Statisticians, of course, had a heyday, because the estimation of population parameters inevitably involved sampling, and woe betide the budding young fishery manager who could not master the mysteries of regression and analysis of variance! (Just as it should be, I might say, for there's nothing more dangerous than a man who doesn't appreciate the limitations of his data, unless it's a mathematician who hasn't any data.)

In short, the mid-fifties were a fine time to be a fisheries biologist because you could be so single-minded about your job. The object was to get out there and get the harvest of the maximum sustained yield, and there was a healthy bag of theoretical and statistical tools to draw on. Or at least that's the way it seemed to an impressionable young guy like me.

The crowning achievement of the whole movement was the magnificent work of Beverton and Holt (1957). Their book did four important things: (1) it brought everything together (which in itself was important); (2) it produced a theory of fishing which illustrated that for each specified rate of fishing there is an age of entry corresponding to *a* maximum sustained yield, and that there are therefore as many maxima as there are rates of fishing, all provided, of course, that recruitment is constant; (3) it provided a stock-recruitment relation if recruitment wasn't constant, a relation which could be coupled with the simple theory to give a self-regenerating model of an exploited population; and (4) it anticipated a large number of refinements to the model system, by speculating on such things as spatial variation in the values of parameters, movements of fish within the exploited area, and the relationships among food consumption, the availability of food, and the density and growth of the fish population. Much of this was far ahead of its time when it was published and, indeed, some of it is today still ahead of the time. It is no wonder that Benny Schaefer remarked to Ray Beverton long ago that he "liked his book of flute music."

Since that time much has been done in preparing variations on the basic themes. For example, Cushing (1973) put one of the finishing touches on the whole picture by his distinction between "growth overfishing" (catching them younger than is consistent with MSY at a given level of effort), and "recruitment overfishing" (catching more than will be replaced).

Today, many more people have assimilated the MSY paradigms, or at least the elementary ones, and using such primers as Gulland's (1969) handbook, are daily grinding through the rituals of estimating F, k, and l_∞ and wishing they could get M in some other way than by subtraction. As a matter of fact, many of them are using computer programs for all their calculations, so they are saved the numbing hours of arithmetic that paralyzed the older generation.

Unfortunately, most of them don't see the buried phrase in Gulland's manual: ". . . it is very doubtful if the attainment of the maximum sustained yield from any one stock of fish should be the objective of management except in exceptional circumstances."

In many ways, it is a pity that now, just when the concept of maximum sustained yield has reached a worldwide distribution and is on the verge of worldwide application, it must be abandoned. But that's the way it goes with the things we believe.

THE BIOLOGICAL COMPLICATIONS

No one can deny that hypothetical animal populations can produce hypothetical maximum sustained yields, but the same cannot be said of real animal populations that are really being harvested. For most species the critical age for harvesting is close to first age of maturity, reflecting the common biological characteristic of animals: that, as maturity approaches, growth in weight is rapid and natural mortality is low. It is thus inevitable that for most kinds of fishing gear, as fishing intensity increases to levels close to the MSY that can be sustained by recruitment, spawning populations will be predominantly made up of fish that are young and first time spawners. In consequence of this and perhaps other qualitative changes in the spawning population, the quality of eggs deposited may be reduced. This has been documented for a number of species of fishes (Nikolsky 1965; Bagenal 1973), and is probably a widespread effect of harvesting. Moreover, with the reduction in the number of spawning age classes, a failure in egg or larval survival for any reason is potentially far more catastrophic in its effect on long-term abundance. Clupeid fisheries are prime examples. Thus, MSY involves greater elements of potential instability than are characteristic of unexploited stocks.

The obvious ways out of these problems are: (1) to obtain information on pre-recruit abundance that can be used as an early warning signal that effort should be reduced; and/or (2) NOT to go for MSY, but for something less that involves a lesser element of risk and that is an optimum in a narrow biological sense (Doubleday 1976); and/or (3) considering much more sophisticated techniques for optimization and adaptive control in fisheries management (Walters 1975; Walters and Hilborn 1976).

The only appropriate response for the manager who is committed to MSY is to devise a system for quick curtailment of effort when there is a recruitment failure. If this system works, prayers for recovery are likely to be more successful. Without quick reduction of effort, stock recovery is likely to be influenced by the mysterious phenomena of depensatory mortality, which are probably related to the effects of predation (perhaps including fishing) at low prey densities (Neave 1954; Larkin 1973; Holling 1973; and an important paper by Clark 1974). Once depressed to certain levels, populations either become extinct, or persist at a low level where they await some happy coincidence of favorable effects before exploding to a higher equilibrium abundance. Catastrophe theory is, of course, interesting (e.g., Jones and Walters 1976), but it is cold comfort for a manager who doesn't know how long he will have to wait until he can again have his MSY.

Another general concern is the likelihood that in the range over which a population or stock of a species occurs, there will be genetic variability with local subpopulations or substocks adapted to the local environment they occupy. We need to know about each of these subpopulations if we are going to harvest each of them in an appropriate way. This is especially so in the circumstances that, except in general terms, the people who harvest the fish do not initially consult the regulators in detail about what kind of gear is going to be used, or where and when they are going to use it.

Pacific salmon are a prime example being, in the aggregate, a group of subpopulations with different capacities for supporting harvests. With the fishery only imperfectly regulated, and with the added problem that some stocks are fished jointly, it is small wonder that we now have an odd assortment of salmon substocks, a lower annual production of salmon, and concern for the future of what we have left, which is now less than one-half of what we had a century ago. (There is a substantial literature. A good starting point is the group of papers edited by Simon and Larkin 1972.)

Loftus (1976) has recently presented a large body of evidence to suggest that this phenomenon of removal of less productive components of natural populations is probably much more widespread than has generally been realized. In Pacific salmon, of course, since the spawning areas are discrete and conspicuous, it is rather obvious when a substock disappears. When the substocks are lake trout or whitefish, the losses may not be as apparent, but may nevertheless be just as real. In fact, the phenomenon is probably a very general one and the recent paper by Wellington (1976) discusses it in relation to insects! Moreover, as Ricker (1973) pointed out, in a period when a fishery is getting started, because the stock is larger than it would be at MSY, a given level of effort in an expanding fishery catches more than a similar level of effort after stabilization. Combined with the elimination of more vulnerable substocks, the illusion of a larger than actual MSY is exaggerated. If there is such a thing as an MSY, then, it must be the yield that the residue of a population can continue to support when its less productive components have been reduced below their individual MSYs. Putting it another way, it may be necessary to compromise MSY in order to preserve genetic variability.

For the purpose of the present discussion, it is to be stressed that in virtually all fisheries that have been prosecuted in the world today, fisheries scientists have not controlled to a high degree of refinement, the technique, amount, and distribution of fishing effort. It is therefore inevitable, in my view, that fishing has eliminated some substocks, and this applies to herring, or cod, or ocean perch, as much as to salmon or lake trout. Indeed, I would argue that it is best to assume that it is true of all species until it is demonstrated to be otherwise.

To recapitulate, for even a single species population it does not seem likely that an MSY based on the analysis of the historic statistics of a fishery is really attainable on a sustained basis. If there is an MSY, it is a yield associated with a high risk of recruitment failure in a population in which the less productive substocks have been depressed or eliminated.

It is also to be underlined that this same process applies to mixtures of species that are caught in the same gear. Many of the world's fisheries are based on catching more than one species in the same gear at the same time. For these fisheries, *species* of lower productivity are progressively eliminated or pushed close to extinction as the fishery harvests the more productive species to the level of their supposed MSY. The ultimate effect of using gear that harvests many species must be to reduce a community to whatever can persist when the most productive species is/are harvested to MSY rates. The saga of the Great Lakes is a sufficient reminder (Regier et al. 1969; Smith 1968). For mixed fisheries, then, if there is such a thing as MSY, it must be that harvest that can be sustained when the less productive *species* have been eliminated or reduced below their MSYs.

It is a relatively easy exercise in algebra to combine a bunch of yield equations to sort out what mesh size will give the maximum sustained *aggregate* yield for any given level of effort, but to imagine techniques of fishing that would get the MSY for each species is mind-boggling. It would be necessary to regulate, from the outset of a fishery, where, when, and how much of what kind of gear was to be used, and using that gear in some way that harvested each substock of species in proportion to its capacity to sustain a yield. To accomplish this objective would almost certainly require research and management expenditures that were greater than the value of the resources to be harvested.

Moreover, it would still assume that species were ecologically separate, feeding neither on the same foods, nor on each other, which is, of course, not so. Since Volterra (1931) looked at the theory of relations between competing species and between predators and their prey, an abundant literature has documented that a lot of things are theoretically possible, but that field observations to confirm what actually happens are few and far between. The recent paper by Lett and Koehler (1976) is probably a landmark in that it provides enough evidence to convince the most skeptical that mackerel and herring are party to a highly complex interrelationship. If this is typical, and there is no reason to suppose it isn't, then it is truly impossible to imagine the scientific effort that would be required to manage a community of fishes species by species, each for an MSY in the context of its associations with other species.

As an aside, but an important aside, it is also useful to remind ourselves of the realities of contemporary statistics on fisheries. While it is true that the statistics of the world's fisheries are better now than they have ever been, it is also true that they are still incomplete and riddled with guesses, inadvertent errors, omissions, and even, perhaps, some perjuries. They are generally, as a statistician would say, more precise than accurate, and that's saying something when you bear in mind that the imprecision of fisheries statistics is notorious. Management from this sort of factual basis requires a certain flair.

In short, just considering fish population dynamics, there is precious little prospect of achieving MSY either for one species or for any number of species in the aggregate. A large recent literature on modelling abundantly demonstrates that a wide variety of unexpected consequences can flow from what seem to be simple management strategies. With the benefit of simulation techniques we can see just how difficult it is even to manage systems that are simplified versions of nature. In another 20 years, the understanding of community dynamics may have proceeded to the point that we could be rather cute at manipulating species compositions while preserving the stability and qualitative integrity of aquatic communities. But we are a long distance from that goal now, and to the extent we can see it, it seems improbable that the perfect strategy would be to take MSY from each species.

Meanwhile, the limnologists who were shunted aside by management biologists 20 to 30 years ago, have been plugging away at their studies of whole aquatic ecosystems, and by a rather direct route have converged on much the same conclusion. Since Hrbacek et al. (1961) and Brooks and Dodson (1965) demonstrated that fish influence the species composition of the zooplankton community, a substantial series of papers has confirmed that the species assemblage at each trophic level is profoundly influenced by the predation imposed from the level above. To any modern day limnologist, the impact of fishing on fish communities is, in general terms, much as would be expected from consideration of the effect of adding fish to a community of zooplankters, or even, perhaps, from adding zooplankters to a community of phytoplankters. On this basis, there is little doubt that in many parts of the world the species assemblages of fishes that we observe today must be profoundly different in their composition and interrelationships from the assemblages of a century ago, and so are the communities of organisms on which the fish feed. From this perspective, to speak of an MSY for any one of the fish species in effect argues that somehow or other the interrelations among the species won't have any effect. While this could be true in the short-term, it is difficult to imagine in the long-term. From the viewpoint of fish communities, the S in MSY, for any species, can't possibly mean more than 50 to 100 years. It certainly isn't forever and ever.

There is one redeeming feature. Leaving aside such considerations as pollution and climatic change, it seems likely that the total production of aquatic systems is more or less constant, albeit distributed among different species. To the degree that we could be completely flexible about what we eat, it is conceivable that for a particular community of species, we could speak of the maximum sustained yield of organisms above a specified size; it being understood that, as the size went down, the MSY would go up. Biologically, that's about the only concept of maximum sustained yield that can stand up in the light of contemporary evidence. It might even suggest that perhaps the preferable technique of harvesting is to take the same proportion of everything above a certain size.

In summary, from a biological point of view the concept of MSY is simply not sufficient. Nevertheless, it should be stressed that it provides a valuable rough index of production potential. As a first rough cut at management policy for major commercial species, MSY is probably acceptable. But once the level of MSY is attained, it should be expected that it may not be sustained.

THE ECONOMIC IMPLICATIONS

Once Michael Graham (1935) had pointed out that the same equilibrium catch could be taken at two different levels of effort, the way was open for economic analysis of commercial fisheries. Scott Gordon (1954) made the first thorough study, and by 1965, Christy and Scott had produced "The Common Wealth in Ocean Fisheries." It was apparent that what happened in fisheries made less than economic sense. In the first place, the economists told us, the real yield from fisheries is not fish, but dollars. While I wouldn't want to try to eat a can of dollars in tomato sauce, it's easy to see what they were getting at—if you owned all the rights to fish in the sea, and you wanted to make money, you wouldn't necessarily want to take the MSY. You'd take the amount of fish that would make you the most profit.

More technically, depending on the relation between yield and effort, and depending on how much the price goes up as the supply goes down, there is a level of harvesting associated with maximum sustained economic revenue. Since the same catch can be taken at two levels of effort, it is obviously more economically rewarding to fish at the lower level of effort. From the perspective of the individual fisherman, this is a fine prospect because he makes a good living.

In the real world, what happens is that more fishermen are attracted into the business, the individual fishermen try harder, and in a very short time the paradise of maximum economic revenue is lost. Left to its own devices, one might suppose that this system would come to its economic senses, ultimately reverting to some equilibrium that would probably *not* be the biological MSY (Clark 1971), but which at least looked healthy to an economist. Unfortunately, fishermen vote; and once a person has become a fisherman, he can almost be counted on to vote against anyone who doesn't help him continue to be a fisherman and ensure him a decent standard of living. From such simple human responses there may flow a long mane of hairy subsidies which directly or indirectly sustain an economic monstrosity. There are almost as many examples as there are fisheries in the world.

Thus, to an economist, the concept of biological maximum sustained yield has an entirely different meaning—it isn't a holy duty, but an indicator of biological pressure, and only one of many factors influencing the smooth running of economic systems. An economist may be more than somewhat irritated when there is an insistence on achieving MSY. He has his own holy duties to perform.

The best way of reconciling the MSY and economic religions has been held to be the limitation of entry into a commercial fishery; if there is a continued regulation of the *number* of fishing units and their fishing power, then at least MSY can be taken inexpensively. But, inasmuch as commercial fisheries have not been so regulated and are not characterized by regulation of entry, it is true today that commercial fisheries generally are close to or have gone beyond their biological MSYs to lower levels, and that commercial fisheries generally are not a source of great joy to economists.

Bearing in mind also that some fisheries are international, and that different countries have different economies, a stage is set in which differing economic monstrosities combine to generate the biggest monstrosities of them all—the world's international fisheries.[2]

As an aside, it is to be noted that, when it comes to international negotiations, MSY is something of a mixed blessing. On the one hand it may be presented as an appeal for rational long-term resource use, conceivably the sort of case the fish might make if they were present at the bargaining table. On the other hand, if you plead for MSY for protection, you may be stuck with achieving it as an obligation. Inasmuch as your own national economic disorders are not necessarily going to be cured by taking MSY, you can end up being nicely hoisted in your own petard.

Turning to recreational fisheries, it has long been evident that MSY is not the best economic strategy. With the object being to maximize recreation, it has proven difficult for economists to pinpoint just what the economic values are, but it is nevertheless clear that MSY has rather little relevance. At one extreme anglers may take the MSY ten times over from a suburban small pond which is routinely stocked from a hatchery for the benefit of old-age pensioners and their grandchildren. At another extreme anglers may be required to use only the less efficient lures and gear, and to wait their turn to enjoy the recreational benefits, even though their combined efforts won't take a fraction of the MSY. Wrapped in questions of aesthetics, ethics, distribution of catch, and the various mystiques of angling, it is little wonder that MSY has rather little meaning in recreational fisheries.

And when commercial and recreational fisheries collide, there is potentially no limit to the confusion surrounding economic discussions. In the last analysis, the comparison is between two equations, one of which, the recreational one, contains a variable called X which assumes values of zero to infinity, depending on who you ask. In this debate, MSY is a useful anchor for the commercial interests, but a dead weight to the sports fishermen.

To summarize, for economists MSY is interesting, perhaps, but irrelevant except as a potential constraint.

OPTIMUM YIELD

It was with these kinds of undercurrents that about 10 years ago many people began to have misgivings about MSY, and about maximum economic return, and started to speak of maximizing other things. Just as fish serve economic ends, economics serve social ends, and therefore the objective should be to get a maximum sustained yield of social benefits. In consequence, in recent years economists have been busy trying to put dollar signs on all sorts of social activities and, in some instances, may have even deluded themselves into thinking they have succeeded. But, as you and

[2] The International Commission for Northwest Atlantic Fisheries has recently made some decisions that will prove to be of major historic interest. Total allowable catches have been reduced below levels of MSY. The development of the double quota system in ICNAF has been spoken of as a "blunt instrument that has the effect of bringing about a reduction in fishing effort" (remarks by Donald L. McKernan *in* Mundt 1975), which suggests that in some international circumstances you can control entry by controlling effort by using quotas. While this may be true in the ICNAF area, it is a doubtful proposition *within* a country such as Canada, and it remains to be seen whether Canada will limit entry in her east coast fisheries and, if so, try to do it by a system of quotas. It doesn't seem likely it would work.

I know, humans are sufficiently perverse that the only way to judge whether *they* perceive that the social benefits exceed the social costs is to listen to what they say and see how they vote.

From all this sugary murk there crystallized, like fudge, the concept of optimum yield, in which optimum is whatever you wish to call it. In his superlative summary of this Society's Symposium on Optimum Sustainable Yield, Philip Roedel (1975) defined *optimum yield* as

> a deliberate melding of biological, economic, social, and political values designed to produce the maximum benefit to society from a given stock of fish;

and *optimum sustained yield* as a subset of *optimum yield* defined as

> a deliberate melding of biological, economic, social, and political values designed to produce the maximum benefit to society from stocks that are sought for human use, taking into account the effect of harvesting on dependent or associated species.

I do not know what these definitions mean. First, optimum seems to come about from "deliberate" melding, rather than from inadvertent melding. It is somewhat akin to the idea of being a virgin by intent. To say the least, the concept is potentially subject to abuse, and would almost certainly be used primarily as a way of justifying a political course of action. Indeed, it brings clearly to mind the very practices of a generation ago which were the target of the missionaries for MSY.

Second, the two definitions together imply that what you do to a single stock is called "optimum," whereas what you do to a community of species is called "optimum sustained," the idea apparently being that for a single species you may wish to take more than the level you could sustain. Unfortunately, though, the definition of *optimum sustained yield* doesn't say anything about sustaining anything.

Inasmuch as these definitions are virtually meaningless, it is fortunate that Roedel spelled out how they would "likely work out in the real world," so that we can see how really meaningless they are. Without going into each of his ten points in detail, suffice it to say that sometimes optimum yield will be almost zero; other times it will be MSY except when it is more; still other times it will be maximum net economic yield; and for some species it will be all they can stand without becoming extinct.

Rather evidently, as a summarizer and editor of the Symposium, Roedel was struggling in one of the first concerted efforts to find an alternative to MSY, and the result, predictably perhaps, was an eclectic mishmash that was all things to all people. Nevertheless, his summation provided some bases for some concepts for the future.

First, the optimum yield concept recognizes the fact that, because species are interrelated and jointly fished, it is difficult, if not impossible, to contrive for MSY for each. For trawl fisheries, especially in the tropical seas, this is the only realistic attitude (Marr 1976).

Second, it has at last been recognized that there is no obligation to harvest a species just because it is there. After all, if you think about it, there is a good crop of robins to be harvested, and a potential yield from cats and dogs, if protein is the only consideration. The point is made dramatically by considering sport fisheries in which the object is to maximize recreation, and in which the elitist would argue that the maximum yield of benefits comes from the least efficient gear used with the greatest skill to produce the smallest catch at the greatest personal satisfaction. Taking underwater photographs of fish could be even better, for the less consumptive the use of the resource, the more who can enjoy it.

Third, in recognizing the need for joint consideration of biological, economic, social, and political factors, Roedel's definition used the word "deliberate." To me, "deliberate" means that someone will not only *deliberate*, but in so doing will *document* the reasons for the decisions made. If there is one sure criticism to be made of what we have done in the past, it is that we have compromised on MSY and have not objectively documented why we did so. It is crucial for future development of the concept of optimum yield that there be a rigorous attempt to record why particular decisions were taken.

In my view, the major stumbling block in all concepts of optimum sustained yield as discussed at the Law of the Sea Conference and elsewhere, is that they have yet to provide an operational basis for making decisions. The chances that your optimum is my optimum are nearly zero. This difficulty flows from the fact that natural systems are sufficiently diverse and complex that there is no single, simple recipe for harvesting that can be applied universally. When there is added in the complexity and variety of social, economic, and political systems, the number of potential recipes is just too enormous to be easily summarized by simple dogma.

Perhaps the best we can hope for is a general statement of principles with accompanying guidelines that should be applied in the hope of ensuring that we will trend in the best direction. This seems to be the intent of the draft United States "Fishery Conservation and Management Act of 1976," as outlined in the Report of the Committee of Conference on H.R. 200. Inasmuch as this document advocates "optimum yield," the definition of optimum yield is crucial, and it is the amount of fish:

(A) which will provide the greatest overall benefit to the Nation, with particular reference to food production and recreational opportunities; and
(B) which is prescribed as such on the basis of the maximum sustainable yield from such fishery, as modified by any economic, social, or ecological factor.

In short, it's a recipe for achieving heaven or hell, and what is achieved will depend on how the definition is variously interpreted.

OPTIONS FOR THE FUTURE

The foregoing has demonstrated, I hope, that MSY is not attainable for single species and must be compromised: (1) to reduce the risk of catastrophic decline and reduction of genetic variability; and (2) to accommodate the interactions among the species of organisms that comprise aquatic communities. Moreover, MSY is not necessarily desirable from an economic point of view, and is certainly not so in the circumstances of unlimited entry. We are therefore struggling with rubber-edged concepts such as optimum yield and wondering about ways of managing in the future.

Basically, there are two extreme paths that might be followed, and each presumes an underlying political philosophy. If one starts from a purely technocentric model for human society, then it is quite clear what to do. You measure the various biological risks and set rates of harvesting by species, area, season, type of gear, and so on, bearing in mind what it costs to get the information you need and the risk you take of having incomplete information. You then set the number of fishermen and their fishing power, and place the rest of the fishermen in other activities that are seen as gainful for the state. This approach is technically complicated, but socially simple, and would probably appeal to people who like order.

The alternative extreme path is to intervene as little as possible, only provided that the fish should be protected from total extermination by advanced technologies. This path is also clearly marked. You set permissible catches at moderately safe levels of biological risk and then let the economic and social problems resolve themselves within the biological restraints. Specifically, you do NOT subsidize fishermen or the construction of their vessels; you do NOT provide any incentive for people to stay in the fishing business, NOR do you discourage them from staying in if that's what they want to do. In short, you put your trust in what economists would call natural market forces, and you hope that politicians will live up to their reputations for not keeping their promises. This approach is technically relatively simple and socially chaotic, and appeals to people who prize individual initiative.

In between these two extremes there is a wide spectrum of alternatives that are variously labelled as "middle-of-the-road" philosophies. They are characterized by various mixes of orderliness and initiative, by national policies that are sufficiently vague and/or complicated as to allow quite contradictory actions in different places at the same time, or at different times in the same place, and that in essence preserve future options by maximizing flexibility and confusion. The current Canadian approach is typical (Anonymous 1976), for it says (in only 302 words) that the goals are to maximize food production, preserve ecological balance, allocate access optimally, provide for economic viability and growth, optimize distribution and minimize instability in returns, ensure prior recognition of economic and social impact of technological change, minimize dependence on paternalistic industry and government, and protect national security and sovereignity—it being kept in mind that there is no priority implied in the order things are listed; that there are interactions in the objectives; and that trade-offs and compromise will be necessary. These goals are striking in implying that there is no single optimum policy, for as we all know, one cannot optimize for two things at the same time, let alone a dozen. They are humorous because they so accurately reflect the real difficulties of managing human affairs.

After having had so much fun in commenting on what others have done, I regret that I don't have an inspired personal vision for the future. My personal preference is for a technocentric approach, with the fish first, the economics second, and the social problems a distant third—something we must resolve, and quickly, with sympathy and good sense. I believe our first obligation is to our grandchildren, that we should be quite stern about abusing resources, and almost equally stern about being inefficient economically, if only to save on energy resources. I have this bias because I belong to a particular year class—for which I can't take credit or blame. Representatives of the more recent year classes, particularly Carl Walters and Henry Regier, have contributed much to my reeducation and ensuing middle-aged ambivalence.

FAREWELL TO MSY

Whatever lies ahead in the development of new concepts for harvesting the resources of the world's fresh waters and oceans, it is certain that the concept of maximum sustained yield will alone not be sufficient. The concept has served an important service. It arrived just in time to curb many fisheries problems. To appreciate what MSY has done, we need only ask what the world's fisheries would have looked like today if the concept had not been developed and advocated with such fervor. The fish, I'm sure, would shudder to think of it. Like the hero of a western movie, MSY rode in off the range, caught the villains at their work, and established order of a sort. But it's now time for MSY to ride off into the sunset. The world today is too complex for the rough justice of a guy on a horse with a six-shooter. We urgently need the same kind of morality, but we also need much more sophistication.

Accordingly, I tender the following epitaph:

M. S. Y.
1930s–1970s

Here lies the concept, MSY.
It advocated yields too high,
And didn't spell out how to slice the pie.
We bury it with the best of wishes,
Especially on behalf of fishes.
We don't know yet what will take its place,
But hope it's as good for the human race.

R. I. P.

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