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Achieving Sustainable Use of Renewable Resources

A. A. Rosenberg, M. J. Fogarty, M. P. Sissenwine,
J. R. Beddington, J. G. Shepherd

Sustainable use is a widely accepted goal for renewable resource management. It "meets the needs of the present without compromising the ability of future generations to meet their own needs" (1). However, natural variability, scientific uncertainty, and conflicting objectives (or values) can cause difficulties in achieving sustainable resource use. In a recent Policy Forum article, Ludwig *et al.* (2) argued that claims of sustainability should not be trusted and that populations are inevitably overexploited (often irreversibly), in part because scientific consensus on resource status cannot be attained. We maintain that the history of fisheries management provides both positive examples of sustainable resource use and lessons for future improvements. Our conclusions have the potential for broader application to other renewable resources. Specifically, we argue that (i) there is a sound theoretical and empirical basis for sustainable use, (ii) overexploitation is not inevitable or necessarily irreversible nor is it generally the result of inadequate scientific advice, and (iii) the tradition of open-access management systems coupled with risk-prone management decisions under uncertainty are the principal obstacles to achieving sustainability. We conclude that sustainable use of renewable resources can be attained.

Theoretical and Empirical Basis for Sustainable Yield

The scientific basis for sustainable use of renewable marine resources evolved during the first half of this century to counter the prevailing view that oceanic resources were inexhaustible (3). Hjort *et al.* (3) defined the "optimum catch" (later called the maximum sustainable yield) as the yield taken under the maximum rate of production. This concept is based on a fundamental

ecological principle—density-dependent population regulation. As the abundance of a density-regulated population is reduced by harvesting, per capita net production increases, until the population cannot compensate for additional mortality. There is extensive documentation of compensatory changes in fecundity, maturation, individual growth, and survival rate for marine populations (4). The production generated through compensation, which is known as "surplus production," can be harvested on a sustainable basis. Because the amount of surplus production depends upon how much the population is reduced by harvesting, there are feasible sustainable yields ranging from zero as population size approaches zero, to some maximum occurring at an intermediate level of population size.

Marine populations typically vary widely under fluctuating environmental conditions, and the implications of variability have received considerable attention in the development of sustainable harvesting strategies (5). In a randomly varying environment, theory predicts a probability distribution of sustainable yields at each level of population abundance. Harvest rates sustainable under one set of environmental conditions may not be sustainable, however, if a directional shift in the environment occurs. Environmental effects and harvesting interact with respect to population production. In the development of a sustainable harvest policy, both environmental conditions and exploitation rates must be taken into account. Directional changes in environmental conditions pose a major challenge to the development of sustainable harvesting policies. Monitoring programs designed to measure population trajectories and selected environmental variables have been implemented in many areas to track these shifts.

Harvesting a sustainable yield does not imply that the catch will be constant, nor is sustainable yield synonymous with maximum sustainable yield (MSY). Ludwig *et al.* incorrectly equated sustainable use in general with the specific difficulties of estimating a single optimal yield which can be harvested every year (6). The dangers of removing a constant catch from a fluctuating resource have long been appreciated (7), and few harvesting regimes of this type

are in place for major fisheries in North America and Europe. The exceptions are cases where precautionary catch quotas are set to facilitate monitoring of fisheries where there is little information on which to base management decisions. The most common fishery management strategy specifies a constant harvest rate. The amount removed through harvesting will therefore vary as population size fluctuates. For example, of 95 regulated fishery resources in the United States, none are managed by constant catch strategies. A strategy of maintaining a constant fishing mortality rate is used for two-thirds of the resources, and "overfishing" is defined by scientific consensus as a rate in excess of sustainability (8). In Europe, fishery managers have also focused on a target harvest rate. The International Council for the Exploration of the Sea annually provides European Community and other managers with options based on a range of alternative harvest rates by consensus of scientists from about 20 countries, for about 100 fishery resources.

Problems and Remedies

Despite the general validity of the concept of sustainability and many examples of sustainable use of fishery resources (9), there are also many instances of overexploitation. In the United States, approximately 45% of 156 populations for which an assessment of resource status is available are currently classified as overutilized; within European waters, 59% of 78 stocks have been classified as overutilized (10). Of these, however, few have been exploited to the point where a viable fishery is no longer possible. Uncertainty in resource status and in the ecological processes that control population dynamics have undoubtedly led to inadequate scientific advice in some cases. However, overexploitation often results from the failure of resource managers to follow scientific advice. For example, postmortem analyses of declines of pelagic fish populations by Saetersdal (11) contrasts the sequence of consensus scientific advice with actual management decisions. Managers consistently allowed higher catch levels than indicated by consensus scientific advice. For haddock on Georges Bank, off the New England coast, a relatively stable domestic fishery was sustained from its inception in the 1930s until the arrival of foreign fishing fleets in the 1960s. When the harvest rate was allowed to increase markedly against scientific advice, the stock declined to a much lower level (12). Stock declines are not necessarily irreversible. Many instances of stock rebuilding following depletion and a subsequent reduction in fishing have been documented (13). Among the most dramatic examples are the broad-scale

A. A. Rosenberg and M. P. Sissenwine are in the Office of the Senior Scientist, National Marine Fisheries Service Headquarters, 1335 East West Highway, Silver Spring, MD 20910. M. J. Fogarty is with the Northeast Fisheries Science Center, National Marine Fisheries Service, Woods Hole, MA 02543. J. R. Beddington is with the Renewable Resources Assessment Group, Imperial College of Science and Technology, 8 Prince's Gardens, London, SW7 1NA, United Kingdom. J. G. Shepherd is with the Directorate of Fisheries Research, Ministry of Agriculture, Fisheries and Food, Pakefield Road, Lowestoft, Suffolk, United Kingdom.

recoveries in fish populations documented in the North Atlantic following the curtailment of fishing during the first and second world wars.

Historically, marine fish populations were considered to be too vast to be depleted by harvesting. As a result, the burden of proof that regulation was necessary to sustain renewable resources was placed on resource managers (14). Further, de facto open-access systems in which entry to the fishery was unrestricted were prevalent. In open-access systems, the cost of harvesting is driven up by participants competing to catch a limited supply of the resource. The inevitable result is for the economic value of the resource to be dissipated (15). The solution to this problem is to recognize that property rights must be well defined and that rights imply duties and responsibilities (16). Under open access, no property rights to the resource exist and overexploitation is highly probable.

Substantial progress has been made in addressing factors that have jeopardized sustainable use in the past. Management in most developed countries has evolved toward systems that control access to fishery resources, although the process is far from complete. In addition, New Zealand, Canada, Iceland, Australia, and the United States among other countries have adopted systems that grant individual quotas in some fisheries. These quotas are transferable and eliminate competition among fishers for the resource. These systems can promote more economically viable fisheries (17). Open-access resource use is still a major problem in developing countries, which now account for more than over half of the global fisheries harvest.

Evolving Trends in Scientific Advice

The inherent variability in the dynamics of marine fish stocks, the difficulty and expense of measuring abundance and demographic parameters of widely distributed populations, and the complexity or high dimensionality of ecological systems virtually assure uncertainty in resource status. When confronted with uncertainty, fishery managers have been under enormous pressure to allow continued harvest levels and scientific advice has been discounted (18). Considerable progress has been made, however, in directly confronting uncertainty and in developing probabilistic approaches to providing management advice (19). Risk assessments that explicitly consider variability in resource abundance and productivity have become an integral component of scientific advice to managers. Formal risk assessments are now routinely incorporated

in many stock evaluations in the United States, Canada, Europe, and New Zealand. Resource managers in some areas now often make conservative decisions in the face of uncertainty (10). International management agencies and commissions such as the International Whaling Commission have adopted methods that explicitly account for uncertainty (20). The resulting scientific advice is framed in terms of the probability of certain outcomes under alternative management actions. There are important examples of relatively new fisheries in which access and fishing effort have been controlled from the start and in which scientific advice and management policy have been integrated to achieve sustainable harvesting (21).

The experience in fishery management suggests that the problems in achieving sustainable resource use are challenging but not insurmountable. To meet these challenges we must address fundamental economic biases against sustainability, particularly in open-access management regimes; continue the development and application of methods that directly integrate sources of uncertainty into scientific advice; and learn from past management failures and successes. Sustainable development is achievable if scientific advice based on biological, social, and economic considerations is an integral part of the development of policies for renewable resource use.

REFERENCES AND NOTES

- World Commission on Environment and Development, *Our Common Future* (Oxford Univ. Press, Oxford, 1987), p. 393.
- D. Ludwig, R. Hilborn, C. Walters, *Science* **260**, 17 (1993).
- J. Hjort, G. Jahn, P. Ottestad, *Hvalradets Skr.* **7**, 92 (1933); M. Schaefer, *Inter-Am. Trop. Tuna Comm. Bull.* **1**, 25 (1954). For a detailed review, see T. D. Smith, in *Fish Population Dynamics*, J. Gulland, Ed. (Wiley, New York, 1988), p. 1.
- Empirical data is reviewed in B. Rothschild, *Dynamics of Marine Fish Populations* (Harvard Univ. Press, Cambridge, MA, 1986); R. A. Myers, J. Bridson, N. J. Barrowman, *Can. Tech. Rep. Fish. Aquat. Sci.*, in press; P. M. Mace and M. P. Sissenwine, *Can. Spec. Publ. Fish. Aquat. Sci.*, in press; C. W. Fowler, in *Current Mammalogy*, H. Genoways, Ed. (Plenum, New York, 1987), pp. 401–441. The appropriate null model is density independent; compensation and sustainability should not be assumed on a priori grounds.
- J. R. Beddington and R. M. May, *Science* **197**, 463 (1977); R. M. May, J. R. Beddington, J. W. Horwood, J. G. Shepherd, *Math. Biosci.* **42**, 219 (1978); M. P. Sissenwine, M. J. Fogarty, W. J. Overholtz, in *Fish Population Dynamics*, J. Gulland, Ed. (Wiley, New York, 1988), p. 129.
- Ludwig *et al.* (2) refer to optimum yield and MSY interchangeably with sustained yield. There are in fact many sustainable harvest levels, not just the maximum.
- W. E. Ricker, *J. Fish. Res. Board Can.* **15**, 991 (1958); P. A. Larkin and W. E. Ricker, *ibid.* **21**, 1 (1964); A. Tautz, P. A. Larkin, W. E. Ricker, *ibid.* **26**, 1715 (1969).
- A. A. Rosenberg, Ed., "Defining Overfishing—Defining Stock Rebuilding," *NOAA Tech. Memo. NMFS-F/SPO-8* (1993).
- W. Aron, D. Fluharty, D. McCaughran, J. F. Roos, *Science* **261**, 813 (1993). Many other examples of stable fisheries can be identified.
- "Our Living Oceans: Report on the Status of U.S. Living Marine Resources, 1992," *NOAA Tech. Memo. NMFS-F/SPO-2* (1992). "Report 1991 on the Common Fisheries Policy" (Commission of the European Communities, Brussels, 1991).
- G. Saetersdal, *Rapp. P. V. Reun. Cons. Int. Explor. Mer* **177**, 505 (1980).
- R. Hennemuth and S. Rockwell, in *Georges Bank*, R. Backus, Ed. (MIT Press, Cambridge, MA, 1987), p. 430.
- Some examples among many possible of stock recovery following enactment of stringent regulations include the Atlantic striped bass [R. A. Richards and D. G. Deuel, *Mar. Fish. Rev.* **49**, 2 (1987)], Georges Bank herring and mackerel ["Status of the Fishery Resources off the Northeastern United States for 1992," *NOAA Tech. Memo. NMFS-F/NEC-95* (1992)], North Sea herring ["Report of the Advisory Council on Fishery Management," *Int. Counc. Explor. Sea. Coop. Res. Rep.* **193**, 43 (1993)], and many marine mammal populations [K. R. Allen and G. P. Kirkwood, in *Fish Population Dynamics*, J. A. Gulland, Ed. (Wiley, New York, 1988)]. It is, however, possible that some substocks have been eliminated and that genetic diversity has been reduced.
- M. P. Sissenwine, in *Recreational Fisheries*, No. 11, R. Stroud, Ed. (Sport Fishing Institute, Washington, DC, 1987), pp. 203–204; R. Peterman, *Can. J. Fish. Aquat. Sci.* **47**, 2 (1990).
- H. S. Gordon, *J. Policy Econ.* **62**, 124 (1954); C. W. Clark, *Mathematical Bioeconomics: The Optimal Management of Renewable Resources* (Wiley, New York, 1976); C. Clark, in *Ecological Economics*, R. Costanza, Ed. (Columbia Univ. Press, New York, 1991), pp. 319–330; M. Graham [*The Fish Gate* (Faber, London, 1943)] provided an early description of the economic nature of the overfishing problem.
- D. W. Bromley [*Environ. Res. Econ.* **2**, 1 (1992)] defined open-access systems as those in which property rights have not been defined or management or enforcement has been ineffective. This is sometimes inappropriately equated with the "tragedy of the commons" defined by G. Hardin [*Science* **162**, 1243 (1968)].
- D. G. Maloney and P. H. Pearce [*J. Fish. Res. Board Can.* **36**, 859 (1979)] provided the economic rationale for one property-rights system, individual transferable quotas (ITQs). M. Sissenwine and P. Mace [*Fish. Bull. U.S.* **90**, 147 (1992)] review some of the problems experienced in implementing ITQs.
- M. P. Sissenwine and A. A. Rosenberg, *Fisheries*, in press.
- J. G. Shepherd and J. McGlade, *Techniques for Biological Assessment in Fisheries Management* (Forschungszentrum Julich GmbH, Julich, Germany, 1992).
- G. P. Donovan, Ed., *The Comprehensive Assessment of Whale Stocks: the Early Years* (International Whaling Commission, Cambridge, United Kingdom, 1989); N. M. Young, Ed., *Examining the Components of a Revised Management Scheme* (Center for Marine Conservation, Washington, DC, 1993).
- Good examples are the Falkland Islands squid fishery described by J. R. Beddington, A. A. Rosenberg, J. A. Crombie, and G. P. Kirkwood [*Fish. Res.* **8**, 351 (1990)] and M. Basson and J. R. Beddington [*Can. Spec. Publ. Fish. Aquat. Sci.*, in press] and Australian demersal fisheries described by K. J. Sainsbury [*Int. Counc. Explor. Sea Mar. Sci. Symp.* **193**, 301 (1991)].
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