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Policy Forum

Introduction: the conservation of wild living resources

The paper that is the subject of this forum was the product of a 1994 workshop to review the set of principles originally proposed by Holt and Talbot (1978). The workshop was mainly composed of ecologists, but included some social scientists. Its aim was the development of a set of normative statements about the principles that ought to guide human use of wild living resources. Not all of the principles are explicitly normative, but they do all reflect a subjective, albeit scientifically informed, view of what ought to be. The first principle, for example, is cast as a statement of fact rather than a goal: 'Maintenance of healthy populations of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.' But it reflects the view that demand for wild living resources should be constrained to allow their survival.

The principles were first published in *Ecological Applications* (Mangel *et al*., 1996) and, as here, were the subject of a forum. Comments were invited from T.E. Lovejoy, R. Hilborn, F.H. Wagner, A.D. McCall, C. Folke and C.W. Clark. Not surprisingly, given the similarity in background between members of the workshop and the commentators, the principles were broadly endorsed. Since both the authors of the principles and the commentators include some of the most respected scientists in the management and conservation of wild resources, the scientific content of the principles ought to be taken seriously. Indeed, one aim in making these principles the subject of a policy forum in *Environment and Development Economics* is precisely to bring them to the attention of policy-makers.

A second aim reflects a rather different concern. It is that the principles, for all that they urge respect for the values of different societies, reflect the preferences of a largely North American group of scientists. These scientists do not normally have to choose between survival today and protection of the choices open to future generations, and may not even be aware of the nature of the trade-offs confronting many societies. There is considerable evidence (discussed in an earlier forum in this journal, centred on Arrow *et al*., 1996) that social preferences are sensitive to income. Normative statements of the type embodied in at least the first two principles may not, therefore, travel very well. The forum accordingly includes invited comments not just from those based in the North, but also from those based in the South.

Charles Perrings
Editor

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Principles for the conservation of wild living resources*

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ABSTRACT. We describe broadly applicable principles for the conservation of wild living resources and mechanisms for their implementation. These principles were engendered from three starting points. First, a set of principles for the conservation of wild living resources (Holt and Talbot, 1978) required reexamination and updating. Second, those principles lacked mechanisms for implementation and consequently were not as effective as they might have been. Third, all conservation problems have scientific, economic, and social aspects, and although the mix may vary from problem to problem, all three aspects must be included in problem solving. We illustrate the derivation of, and amplify the meaning of, the principles, and discuss mechanisms for their implementation.

The principles are:

Principle I: Maintenance of healthy populations of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.

* Reprinted with permission from *Ecological Applications* **6**(2): 338–362. Copyright 1996, Ecological Society of America. This paper is the result of a workshop organized and sponsored by the Marine Mammal Commission and held 6–9 March 1994 at Airlie House, Virginia, USA. Each author prepared an informal discussion paper for the workshop and participated in drafting one or more principles. Full addresses of authors are available from the Marine Mammal Commission, 1825 Connecticut Avenue, N.W., Room 512, Washington, D.C. 20009, USA.

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Principle II. The goal of conservation should be to secure present and future options by maintaining biological diversity at genetic, species, population, and ecosystem levels; as a general rule neither the resource nor other components of the ecosystem should be perturbed beyond natural boundaries of variation.

Principle III. Assessment of the possible ecological and sociological effects of resource use should precede both proposed use and proposed restriction or expansion of ongoing use of a resource.

Principle IV. Regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part and must take into account the ecological and sociological influences that directly and indirectly affect resource use.

Principle V. The full range of knowledge and skills from the natural and social sciences must be brought to bear on conservation problems.

Principle VI. Effective conservation requires understanding and taking account of the motives, interests, and values of all users and stakeholders, but not by simply averaging their positions.

Principle VII. Effective conservation requires communication that is interactive, reciprocal and continuous.

Mechanisms for implementation of the principles are discussed.

Introduction

The natural world is in crisis. Wild living resources are depleted at increasing rates, the ecosystems upon which they depend are generally perturbed, and consumption of resources by a growing human population generally increases. Because the human condition directly depends upon a sound and functioning natural environment, there is great jeopardy from global ecological decline. The challenge to humanity is to fundamentally change the way it interacts with the ecological systems that directly and indirectly support it. Failure to do so could result in the collapse of existing socio-economic systems and irreversible declines in the quality of life in both developed and developing countries. The time has arrived to develop a different working relationship between people and natural resources.

Holt and Talbot (1978) described a set of principles for the conservation of wild living resources. These were developed through a series of workshops held in 1974 and 1975. However, partly because that work did not include an explicit set of mechanisms for implementation, those principles do not appear to have been effectively used or widely adopted. Consequently, the Marine Mammal Commission sponsored a series of consultations with scientists and resource managers throughout the world from 1992 to 1994 to obtain global perspectives on wild-living-resource conservation. The Marine Mammal Commission also sponsored a workshop in March 1994 to: (1) determine why the 1978 principles have not been employed more widely or effectively; (2) develop more effective guiding principles for the conservation of wild living resources; and (3) describe mechanisms for implementation of those principles.

In this paper we review, amend, and expand on the 1978 principles. Special emphasis is placed on implementation of the principles in management and conservation schemes, because the noblest intentions are meaningless if they are not adopted as actual, functioning policy. The best possible relationship between humans and nature safeguards the viability of all biota and the ecosystems of which they are a part and on which they depend, while allowing human benefit (for present and future generations) through various uses. Conservation thus includes the consumptive and non-consumptive use of resources (management) and the preservation of critical resources so that future options can be kept open and so that normal ecological structure and function may continue. The challenge is to determine the appropriate balance between the health of resources and ecosystems and the health and quality of human life. This balance requires understanding the broad range of issues that is the focus of this paper.

The 1978 principles

The principles for the conservation of wild living resources published in 1978 (Holt and Talbot, 1978: 14–15) were:

The consequences of resource utilization and the implementation of principles of resource conservation are the responsibility of the parties having jurisdiction over the resource or, in the absence of clear jurisdiction, with those having jurisdiction over the users of the resource. The privilege of utilizing a resource carries with it the obligation to adhere to the following general principles:

1. The ecosystem should be maintained in a desirable state such that
   a. consumptive and non-consumptive values could be maximized on a continuing basis,
   b. present and future options are ensured, and,
   c. the risk of irreversible change or long-term adverse effects as a result of use is minimized.
2. Management decisions should include a safety factor to allow for the fact that knowledge is limited and institutions are imperfect.
3. Measures to conserve a wild living resource should be formulated and applied so as to avoid wasteful use of other resources.
4. Survey or monitoring, analysis, and assessment should precede planned use and accompany actual use of wild living resources. The results should be made available promptly for critical public review.

In the early 1970s most resource managers behaved as if it were possible to manage the use of living resources in a relatively sustainable and predictable way; the only question was how to achieve that sustainable yield. The philosophy was that each resource had a maximum or optimum sustainable yield level and that the measurement and calculation of the appropriate levels were feasible if enough natural history and demography of the resource were known. Thus, resource conservation was regarded primarily as a biological problem, and the key to maximum sustained use was information about the species or stocks and their ecosystems, as well as analysis of biological data to develop appropriate management regimes.

The perspective is far different today. First, there are few unexploited living resources in the world and many resources are heavily overexploited. Second, while there are different views about "sustainable use" of renewable resources, even those who argue that it is possible admit that our performance over the recent past has been poor. For example, at least 42% of the fishery stocks in the United States are over-exploited (Anonymous, 1991; Rosenberg *et al.*, 1993). Third, the belief of the 1970s—that for management purposes one could assume that ecosystems were stable, closed, and internally regulated and behaved in a deterministic manner—has been replaced by recognition that ecosystems are open, in a constant state of flux, usually without long-term stability, and affected by many factors originating outside of the system. Fourth, there is increased recognition of the role of social and economic factors in determining whether a management regime will be successfully implemented, regardless of how sound it is scientifically. Indeed, successes in protecting or restoring populations of terrestrial wildlife have involved key elements of the biological and ecological knowledge of the species and its ecosystem, coupled to various social processes, including public support (Robinson and Bolen, 1989).

It is now clearly understood that conservation problems have scientific, economic, and social components, although the particular mix will vary according to circumstances. It is imperative to account for all of these aspects if the conservation effort is to be successful (Cole-King, 1994). Thus, effective conservation almost always requires understanding specific motivations of the users of the resources. Because humans cannot effectively control ecosystems, and often cause great damage in trying to do so, human action and the social processes that affect it must be addressed in order to conserve wild living resources.

The principles and mechanisms

We have arrived at seven principles, grown out of the 1978 principles, taking into account intervening developments in relevant fields. Most importantly, we include potential mechanisms for implementing the principles. These principles are guidelines for attaining a persistent relationship between humanity and wild living resources. The mechanisms are not protocols for how to do what needs to be done, but a check list of key questions that must be addressed.

Principle I. Maintenance of healthy populations of wild living resources in perpetuity is inconsistent with unlimited growth of human consumption of and demand for those resources.

There is no question that infinite growth is impossible in a finite system. The human population cannot continually expand without eventually overwhelming its base of natural resources. Thus, the underlying and most critical aspect of any effort to conserve wild living resources is to slow down and eventually decrease human per capita demand for resources. Without that step, continued population growth and resource use must lead to disaster. It is almost certain that the only practicable way to reduce human per capita resource demand is to stabilize and then decrease the human population.

As obvious as this may appear, this principle must be explicitly stated because of the current focus on "sustainability." The Brundtland Commission Report *Our common future* (World Commission on Environment and Development, 1987) and its successor, *Caring for the earth: a strategy for sustainable living* (IUCN / UNEP / WWF, 1991) appear to be unaware of (or to simply ignore) the relationship between human population growth and environmental deterioration. When humans use resources in ways that allow natural processes to replace what is used, sustainability is achieved. That is, living off of nature's "interest," rather than its "capital," is key to any concepts of sustainability and good resource management. This approach, combined with a stable or decreasing human demand on resources, is a prerequisite to effective conservation of wild living resources. Even then, direct sustainable management of target species may have unsustainable indirect effects.

The following mechanisms will help implement this principle:

(1) *Recognize that the total impact of humans on wild living resources is the product of human population size, per capita consumption, the impact on the resource of the technologies applied, and incidental taking and habitat degradation caused by other human activities. Take appropriate actions that recognize these characteristics.*

Ehrlich and Holdren (1974) called this "$I = PAT$," where I is total environmental impact, P is population size, A is level of affluence (a measure of consumption of goods), and T is a measure of technological sophistication and its impact. This relationship indicates the overall potential for environmental impact of a society. Although in many developing nations the human population continues to grow at a rapid pace, the overall impact may be ameliorated by lower affluence and lesser technological impact. Indeed, some levels and kinds of industrial development may actually reduce pressure on natural resources. Conversely, more industrialized, developed nations may have impacts out of proportion to their smaller population sizes or growth rates because of great individual consumption and use of more advanced technologies (Ehrlich and Ehrlich, 1990).

With no other constraints, in a finite world with finite resources, the sheer numerical increase in the human population must eventually strengthen the security of resources and human life. But long before that population size is reached, increasing technological capabilities along with inappropriate institutional arrangements and goals may lead to catastrophic declines in wild living resources. Furthermore, the problem goes beyond resource use. Recent sociological work has revealed a connection between large-scale, human-induced environmental pressures and threats to national and international security such as revolution and rebellion (e.g., Goldstone, 1991; Homer-Dixon 1994).

Some groups believe that the only way to conserve wild living resources is to prevent access by the people to the species and their ecosystems. Perhaps more to the point, aside from general agreement with the notion that there is a human population problem, managers of wild living resources have often not seen the human population issue as something directly part of their profession and activities. In the past, the concepts and practices of wild-living-resource conservation proceeded as if the human population problem can be ignored in day-to-day planning and actions. This is no longer feasible (Meffe *et al.*, 1993; Brouha, 1994; Pulliam and Haddad, 1994; Hodges, 1995), and population growth must be recognized as a critical conservation problem, both in training and actions of resource managers.

(2) *Recognize that if urban areas and other intensely used land areas were more*

efficient, safer, and more pleasant, there would be a greater chance of conserving wild living resources.

By the end of this century the urban population will increase to >75% of the population in developed countries and ≈40% in the developing countries. In 1950 only a few urban areas had populations of $>4 \times 10^6$ people, but by 2000 it is likely there will be 57 cities in this category. In 1950 the largest urban area in the world (New York and Northeastern New Jersey) had 12.3×10^6 people. In 1990 the five largest urban areas exceeded this, and the largest, Tokyo–Yokohama, numbered $>20 \times 10^6$ people (United Nations, 1989). When urban environments are unpleasant, residents are more likely to attempt to leave cities, either permanently to create new urban areas (urban sprawl), or temporarily, for vacations, putting pressure on living resources and their habitats. If cities were more pleasant and liveable, the chances for conserving wild living resources would likely improve. Similarly, if the use of wild lands for vacations is not too consumptive, then those lands become more valuable to society and may be more likely to be conserved. As a consequence, those interested in conservation have a vested interest in improving urban environments as well as reducing the rate of human population growth.

As urbanization increases, the local (and sometimes global) effects on the environment increase. Because cities are commonly located near rivers and the coast, urban sprawl often covers the good agricultural land that occurs on river flood plains and coastal wetlands, which are important habitats for domesticated and wild plants and animals. We must again find ways to make cities liveable, with pleasing features to protect health and improve well-being, with fewer effluents polluting the air and water, or exported as solid waste to more remote areas. Finally, improving the liveability of cities must be done in a manner that does not place undue burden on resources elsewhere.

Principle II. The goal of conservation should be to secure present and future options by maintaining biological diversity at genetic, species, population, and ecosystem levels; as a general rule neither the resource nor other components of the ecosystem should be perturbed beyond natural boundaries of variation.

Living resources and their ecosystems have an evolutionary history that shaped current ecosystem structure (Fowler and MacMahon, 1982). Modern human use of these systems has been conducted for only centuries (or millennia) at most. To be effective, management must work within the constraints of natural law: fundamental physical laws and biological dynamics constrain human institutions and desires, not the reverse (Meffe, 1993). In this principle we recognize that resource use should be guided by the goals of maintaining the fullest possible range of options for future generations and of minimizing changes in the structure and dynamics of populations and ecosystems that cannot be fully reversed within one human generation. Even then, this condition cannot guarantee persistence if the ecosystem experiences a sequence of catastrophic, but natural, shocks.

As noted many years ago, all forms of life modify their environments

(White, 1967). Civilization as we know it could not have evolved without transforming ecosystems, and even some of the earliest civilizations caused considerable environmental degradation (Hong *et al.*, 1994) and mass extinctions (Steadman, 1995). However, the capabilities of modern technology dictate that we be explicitly aware of their effects on natural systems, and of the potential reduction or loss of biodiversity at all levels (Hughes and Noss, 1992).

The following mechanisms will help implement this principle:

(1) *Manage total impact on ecosystems and work to preserve essential features of the ecosystem.*

The most effective management is of human impact. Most habitats have already been exposed to long-term human impact, and human activities will generally be conducted in ecosystems that have a litany of problems, which may already include extreme stress from pollutants—and/or that the ecosystem is too small or too highly fragmented, that important species have been lost, or that invasive species are present. Consequently, managing impacts will be difficult under most circumstances. The extensive linkages and the amorphous nature of the boundaries between habitats make it important to develop as integrated a regional plan as possible so as to include the management of human activities as well as management of components of the ecosystem. In addition, it is imperative that management agencies work together and that managers learn to work with multiple agencies.

By identifying things that are critical to a given ecosystem (such as nutrient dynamics, life history parameters of critical species, need for migratory pathways, and/or major external threats and opportunities) one can design a management plan that accommodates a wide variety of human uses while preserving that which is most critical for the continued viability of the ecosystem. But a distinction must be made between managing a living resource with an ecosystem approach and managing an ecosystem. An individual species or population as a resource may be managed while taking into account its interactions with other elements of its ecosystem. This is resource management with an ecosystem approach. Managing ecosystems, on the other hand, means managing the entire system by integration of ecological, economic, and social factors to control the biological and physical systems (Wood, 1994). Currently, this is difficult to do as an informed activity (Slocombe, 1993) because the concepts are ill defined, great uncertainty exists about most ecosystems, and methods are just developing. Although realistic methods for comprehensive ecosystem management are not fully developed, basic rules and principles are emerging (Grumbine, 1994; Meffe and Carroll, 1994) and resource managers must think in multi-species and functional terms.

(2) *Identify areas, species, and processes that are particularly important to the maintenance of an ecosystem, and make special efforts to protect them.*

Contributions of local populations to total population persistence are not uniform across space or time. Some locations act as sources of individuals, who then migrate to other areas, while other locations act as sinks, which cannot maintain themselves indefinitely (Pulliam, 1988). Such systems of metapopulations are collections of populations connected by periodic or regular movement of individuals, and typically exist across habitat patches of heterogeneous quality. Source populations are important reservoirs of colonists for other sites. Even if they play extremely important ecological roles, sink populations must decline over time unless they are supported by immigration from source areas. Thus, source areas are disproportionately valuable. In fact, protection of sink areas without protection of their sources is likely to result in extinction.

Process-oriented conservation, where efforts are made to protect functional attributes of a system, is critical. Because of constraints imposed by limited resources and time, some allocation of effort should go to targeting critical processes. Process-oriented conservation (such as maintaining burn regimes in fire-dependent ecosystems, or reintroducing predators where they have been removed) involves an important shift in the paradigm of resource managers from targeted stocks to targeted functions. This change is imperative, especially for marine fisheries systems and other cases of regular harvest from wild stocks.

(3) *Manage in ways that do not further fragment natural areas.*

Habitat fragmentation has two components: (1) loss of total habitat area and (2) distribution of remaining habitat into smaller, more discontinuous parcels. The consequences of fragmentation range from loss of gene flow, through interruption of source–sink dynamics, to loss of species (Harris, 1984; Saunders *et al.*, 1991). Recent theoretical work (Tilman *et al.*, 1994) shows that even moderate habitat destruction can lead to delayed but certain extinction of the dominant species in the remaining habitat. Because habitat fragmentation is so widespread, its avoidance should be a major emphasis in resource management plans.

(4) *Maintain or mimic patterns of natural processes, including disturbances, at scales appropriate to the natural system.*

The proper definition of temporal or spatial scale is generally based on the scale of appropriate natural disturbances (e.g., fires, landslides, storms, floods), pertinent biological processes (e.g., herbivory, disease, foraging, reproduction), and dispersal characteristics and capabilities of the component populations. Populations evolve in the milieu of natural disturbances and natural variation, and their resilience is determined by adaptation to these evolutionary patterns (Holling, 1973; Wiens and Milne, 1989). Management should be cognizant of such evolutionary adaptations, especially with regard to dependency on disturbances (Starfield *et al.*, 1993). Long-term field work is needed to differentiate between baseline variation and rare catastrophes (Trivelpiece *et al.*, 1990; Young and Isbell, 1994).

The life history patterns of species illustrate the importance of understanding and structuring exploitation to mimic natural processes. The survival of long-lived species with low growth rates, delayed maturation, and small litter size depends upon high adult survivorship, and (usually) multiple reproductive episodes (Congdon *et al.*, 1993). Such species include primates, elephants, cetaceans, sea turtles, sharks, many freshwater turtles, lake trout, and many large bids. These species have evolved a life history strategy that requires females to have many years of reproductive opportunity in order to have a high probability of reproductive success. By increasing the mortality rate or being size selective and removing the larger, older individuals, the average life-span will decrease and hence there is a greater chance that the population will not be able to persist in the presence of naturally occurring environmental fluctuations. Compensatory efforts such as hatchery rearing or headstart programs, designed to increase recruitment rates, address only the symptoms, not the underlying causes of declines (Frazier, 1992; Meffe, 1992). In contrast, short-lived species with high reproductive rates are typically heavily influenced by environmental fluctuations as well as harvest. These species can decline and disappear before the problem is recognized, so that special monitoring effects are needed.

(5) *Avoid disruption of food webs, especially removal of top or basal species*

The food web is one of the structuring agents of natural communities (Pimm, 1991). Recent work (Naeem *et al.*, 1994) demonstrated that communities with reduced diversity in the food web performed (e.g., in terms of community respiration, decomposition, nutrient retention, plant productivity, and water retention) more poorly than those with higher diversity. Consequently, disruption of food webs through addition or elimination of species can be a destabilizing force.

Predators can affect the abundance and types of prey populations, and prey availability in turn influences the abundance and types of predators. Indirect or cascading influences may also be important, although they are rarely investigated. For example, endemic Hawaiian plants of the genus *Hibiscadelphus* became extinct or nearly extinct because of the extinction of several species of the Hawaiian honeycreepers, which were their pollinators (Diamond, 1989). Similarly, a predator may feed upon a prey species that is an important herbivore on one or more plant species. Removal of the predator allows populations of the herbivore to expand and reduce or eliminate some or all of the plant populations (Pimm, 1991). Such indirect effects are felt throughout the food web. Introduction of species alien to a system frequently results in disruption of food webs. This is especially critical when the alien species is an effective predator on native species or if introduction releases it from its native predators, parasites, or pathogens. It then has the opportunity to greatly alter the new system.

(6) *Avoid significant genetic alteration of populations.*

Although we still lack definite rules that relate genetic variation to persistence of populations (Lande and Barrowclough, 1987; Burgman *et al.*, 1993), it is likely that reduction of genetic variation and/or genetic alteration of populations will generally reduce the ability of organisms to adapt to changing environmental conditions. Law *et al.* (1993) document the genetic impacts of commercial fisheries. Such changes are critically important when they lead to over-harvesting in the application of conventional resource management. Also, because existing genetic variation provides an important mechanism for organisms to respond to natural and human-induced change, there is great virtue—if not necessity—in maintaining that variation.

(7) *Recognize that biological processes are often nonlinear, are subject to critical thresholds and synergisms, and that these must be identified, understood, and incorporated into management programs.*

Nonlinearity and threshold effects are pervasive in biological systems. For example, a pathogen may suddenly become a plague once it reaches a threshold density; reproduction may not occur until population densities pass a threshold high enough for individuals to find each other; and populations of a given species may only be viable above some critical threshold of patch (habitat) size, below which a refuge is ineffective. Such effects are all non-linear—a small change in a variable may have a large effect—and can occur suddenly and unexpectedly (May and Oster, 1976). If not anticipated, they can seriously affect management programs. Similarly, synergisms—interactive effects of different agents in which the total cooperative effect is positive and greater than the sum of the individual effects—can have far-reaching influences on conservation (Young, 1994). For example, seals in the North Sea may have been weakened by pollution, which allowed their decimation in 1988 by viral disease (Harwood and Hall, 1990).

The implications of nonlinearity and thresholds are that increases in harvest or other interventions should occur incrementally and take into account that lags may occur before effects are manifested. In addition, adequate monitoring, which can provide the factual basis for rapid changes in policy should evidence suggest that a nonlinear effect is acting or a threshold crossed, is essential.

Principle III. Assessment of the possible ecological and sociological effects of resource use should precede both proposed use and proposed restriction or expansion of ongoing use of a resource.

The concept of a “right to use the resource” must be changed to the “privilege to use the resource.” Even in the case of privately owned resources, owners must recognize the potential effects of resource use far from their own location and be held accountable for adverse effects.

The intention of this principle is to make clear that demonstrating that resource use will not be damaging is the responsibility of those who want to use it. It is based on the recognition (regarding proposed use) that behaving in a risk-averse manner may avoid losses or unacceptable risks, achieve equity among user groups and between generations, and (regarding proposed restriction) avoid overcapitalization and drastic decreases in harvest rates. If parties cannot agree on what “assessment” means, then use must be delayed or curtailed to protect the resource and to minimize the tendency to use delaying tactics while continuing to use the resource.

Implementing this principle for activities already underway or planned requires monitoring to verify that use does not or will not have unacceptable effects. In many, if not most, cases it will not be possible to accurately predict the effects of various types and levels of resource use on the targeted resource of other ecosystem components. Because it is generally prohibitively costly, if not impossible, to assess and monitor every system variable that could be affected by resource use, the essential task is to identify a representative subset of species and ecosystem variables and processes that are most likely to change in detectable ways in response to resource use. Managers must design and execute monitoring programs that will enable possible adverse effects to be detected before they reach harmful levels. Like management programs, monitoring programs should be periodically reviewed and modified as necessary, to better meet the desired goals.

The following mechanisms will help implement this principle:

(1) *Identify uncertainties and assumptions regarding natural history, size, and productivity of the resource, and its role in the ecosystem.*

Traditional use of natural resources was based on the beliefs that (1) owners of resources have the right to do whatever they want with the resources; (2) if a resource is not owned by someone, it can be used by anyone; and (3) use cannot be restricted unless some individual or entity with legal standing objects and can show that it, its property, or the public welfare is being affected adversely by the activity. These may have been reasonable tenets when resource use was small in comparison to resource availability and the resource users were part of the local community and routinely interacted with community members. Problems arose and became more serious, however, as human populations, expectations of life style, per capita consumption rates, and technology for recovering, transporting, and marketing resources grew and as users are increasingly not part of the local community (e.g., foreign fishing fleets or international forest companies). Consequently, one often observes unregulated use of common property resources and management systems that require the public or the responsible regulatory agency to show that resource use is having some type of unacceptable effect, before use can be limited or regulated. These characteristics almost inevitably lead to: (1) competition for access to resources; (2) development of resource-use industries faster than development of knowledge concerning the resource and its ecosystem; (3) overcapitalization of the industry; (4) over-exploitation and depletion of the resource; (5) damage, waste, or loss of other components of the ecosystem; (6) loss of capital investment and related socio-economic impacts because the long-term yield is far below the exploitation capacity that has developed; and (7) managing the industry to protect capital investment and minimize short-term socio-economic impacts, rather than to maintain the resource at a level providing long-term benefits.

To prevent or minimize the risk of such outcomes, it is imperative to identify the possible biological, ecological, and socio-economic effects of resource use and incorporate them in the planning or exploratory phase of resource development. This must occur before there is significant capital investment and before the scope or scale of use begins to approach potentially harmful levels. The assessments should clearly identify and indicate the possible consequences of uncertainties and assumptions concerning the natural history, size, and productivity of the resource and its role in the ecosystems. To be useful, assessment of proposed activities must usually come from ecosystems that are perturbed from their natural state; otherwise the range of observations may be too narrow to identify functional relationships among components. For example, in order to predict the effect of certain harvesting strategies, it may be necessary to harvest. In order to minimize risk, this should be done cautiously and in conjunction with adequate monitoring and a management structure that will respond quickly to problems.

(2) *Identify major ecological and socio-economic uncertainties and assumptions.*

Use of wild living resources often proceeds without knowledge or consideration of possible effects on the target resource or other components of the ecosystem. As a result, many resources have been and are being severely over-exploited. In addition, utilization of a resource often results in waste of other resources (e.g., discard of non-target species in commercial fisheries, Alverson *et al*., 1994), and damage or destruction of the ecosystem.

Various aspects of this problem have been recognized and addressed, at least partially. Many cities have zoning laws that prohibit owners from using their land in ways that would directly or indirectly reduce the value of adjacent properties. Similarly, many local, state, and national governments have enacted laws requiring that the possible effects of development activities be identified and considered before the activity is authorized. Legislation such as the U.S. Marine Mammal Protector Act of 1972 prohibits consumptive use of wild living resources until it can be shown that, taking into account the health and stability of the ecosystem, the proposed use, by itself and in conjunction with other activities, would not disadvantage the species or stock. Provisions for assessing and avoiding possible adverse environmental impacts appear in a number of international agreements (Wallace, 1994). Such procedures should be used to ensure that uncertainties and assumptions concerning possible ecological and socio-economic effects are considered before there is irreversible biological change or significant capital investment.

(3) *Analyze how the resource and other ecosystem components might be affected by proposed use if the assumptions are not valid.*

Assessments of the possible effects of resource use should clearly identify (1) the data and assumptions upon which they are based, (2) uncertainties concerning the reliability of the data or validity of the assumptions, (3) possible consequences of the planned action(s) if the assumptions or assessments are not valid, (4) possible measures that could be taken to reduce the risk of long-term or irreversible effects, and (5) the nature and extent of the research and monitoring programs that would be required to reduce uncertainties to acceptable levels and to verify that the proposed actions do not have unacceptable effects. In general, management plans should incorporate a range of the possible states of the ecosystem and the consequences if the basis of the management plan is wrong, and they should provide contingencies that can be implemented in case of failure.

It is generally appropriate to assume that, until proven otherwise, use of wild living resources will have unacceptable effects on both the target resource and on other components of the ecosystem. This changes the working hypothesis from "use of the resource will have no effect" to "use of the resource will have serious effects." It also changes the burden of proof from those responsible for conserving the resource to those who want to use the resource. An example of this mechanism is provided by the Commission for and the Scientific Committee for the Conservation of Antarctic Marine Living Resources. In 1991 the Commission adopted a conservation measure requiring that members intending to develop new fisheries in the Convention Area notify the Commission at least 3 months in advance of the Commission's next regular meeting and provide information on the proposed fishery, including an assessment of its possible impacts on dependent and associated species. In 1993 the Commission extended the provisions of this conservation measure regarding new fisheries to developing fisheries for which there is insufficient information to estimate potential yield and potential impacts on dependent and related species. The conservation measure requires that a data-collection plan be formulated and updated annually by the Scientific Committee. It also requires that each member active in the fishery or intending to authorize a vessel to enter the fishery must annually prepare and submit a research and fishery operations plan to the Commission, for review by the Scientific Committee and the Commission. In addition, the measure requires that each vessel participating in an exploratory fishery carry a scientific observer to ensure that data are collected in accordance with the data-collection plan.

(4) *When available information is insufficient to make informed judgments, authorize activities contingent upon development and approval of an information-acquisition plan that will ensure that the level of resource use does not increase faster than does knowledge of the size and productivity of the resource and its relationships with other ecosystem components.*

Resource use can be structured to provide information about the resource. Effective monitoring and experimental management help minimize the chance of long-term adverse effects on the resource and related components of the ecosystem. Management strategies should also be designed to minimize impacts on people and communities whose livelihood depends directly upon current use of a particular resource. In general, greater weight should be afforded to short-term socio-economic considerations when developing management strategies for existing resource-use industries (e.g., commercial fisheries and lumber industries) than for designing strategies for new or developing industries for which there is little or no existing socio-economic dependency. In the latter case, greater weight should be afforded to long-term biological considerations. However, all management strategies should include safety factors, commensurate with the degree of uncertainty (e.g., Frederick and Peterman, 1995), to ensure that authorized activities will not seriously reduce future options.

The plan for acquiring data and information during resource use should clearly identify the data and underlying assumptions, the possible consequences of any uncertainties concerning the validity of the assessment(s), and the additional baseline studies, deliberate perturbation experiments, or monitoring programs proposed to be carried out to resolve the uncertainties. The plan should take into account the response times of the target and associated species. Finally, the observers associated with data collection must be independent of the organization and preferably the country that is financing the program.

(5) *Require those most likely to benefit directly from use of a wild living resource to pay the costs of (a) developing the information-acquisition plan, (b) implementing the information-acquisition plan and (c) managing use of the resource. Only when the general public receives notable benefit is it appropriate for public monies to pay the costs.*

Users should be expected to pay for the acquisition of information as part of the cost of business. Thus, an appropriate share of the cost of the programs for research, assessment, monitoring, and management should be borne by the primary beneficiaries of those programs. In some cases, this may be the general public; in others, it may be particular individuals, corporations, or communities. When the general public is a beneficiary, it is appropriate for part of the costs to be covered by public monies, rather than solely by individuals. For example, women with ovarian cancer are beneficiaries of taxol from yew trees and consequently some public monies are appropriate for the development of taxol chemotherapy.

(6) *Be prepared for unexpected events because the natural world is highly complex and stochastic, and human understanding of it always contains uncertainty.*

We lack a comprehensive, predictive understanding of the impacts of human disruption on ecological systems. Because not all effects of various events can be predicted or anticipated, we must acknowledge that unexpected events will occur, and we should be prepared to act when such events arise.

If more were known about a particular ecosystem, the ability to make accurate predictions about the response of that system to perturbation would increase. However, the inherent complexity of ecosystems will preclude ever gaining complete predictive knowledge of any system. Therefore, it must be recognized that uncertainty is a fundamental part of working with ecosystems. Before policy makers and the public at large can embrace, understand, and accept uncertainty, scientists themselves must do so. Scientists must replace ecological certainty with honest assessments of uncertainty, and avoid presenting "facts" that have weak empirical bases, are subject to multiple interpretations, or have been contradicted outright.

Furthermore, rather than focusing mainly on Type I errors by reporting P values from statistical tests, scientists should also calculate the statistical power of their conclusions (Peterman, 1990; Peterman and M'Gonigle, 1992), or use Bayesian statistics (Howson and Urbach, 1993) to calculate different degrees of belief in alternative hypotheses, or use resampling methods to describe distributions of outcomes and associated confidence levels (Crowley, 1992).

It is appropriate to use uncertainty to advantage rather than view it as something to be minimized. Almost any prediction or measurement regarding a natural system will contain variation and thus will have upper and lower bounds of confidence. This should be explicitly recognized and internalized into management prescriptions rather than ignored. Uncertainty should be incorporated into management programs in the context of the goals of the program, rather than dismissed as ignorance or noise, or used as an excuse to postpone management because not enough is yet known about the system. Long-term persistence of the resource has to receive the benefit of the doubt whenever uncertainty exists: uncertainty is a warning to exploit cautiously.

Principle IV. Regulation of the use of living resources must be based on understanding the structure and dynamics of the ecosystem of which the resource is a part and must take into account the ecological and sociological influences that directly and indirectly affect resource use.

Although they are linked, ecological and economic systems are governed by different regulatory mechanisms and are based on fundamentally different currencies. Ecological systems typically function under internal and external constraints: prey species are checked by predator species; nutrient availability is a function of decay processes; herbivory is limited by anti-herbivore toxins. It is difficult for a single component to dominate an ecological system unless other components are fundamentally altered. Furthermore, the important biological properties are understood through a hierarchy of scales of analysis. At a local level, predators may check the growth of herbivores by occasionally eliminating local populations, but at the scale of metapopulation, herbivores and their predators persist through immigration and re-colonization.

Most economic systems, on the other hand, are based on continual growth and expansion, involve generally abstract currencies, are regulated largely by supply and demand, and are often managed as though they were free of constraints from resource availability or waste disposal. Because of this lack of apparent constraints, a major resource-conservation problem is that resource use is driven largely by economic considerations, and often there is little constraint or feedback until the resource is overexploited. Economic growth, however well-intentioned, is not environmental policy (Arrow *et al.*, 1995).

Effective living-resource management must be based first on understanding of the structure and dynamics of the natural system and of the constraints presented by that system and by natural laws, and then provide feedback to regulate economic systems within those constraints. Because the finite limits to resource use are based on natural, not human, law, and since exceeding those limits will eventually have catastrophic effects on both the ecological and the economic systems, they must be identified clearly.

Managers should take account of the impact of decisions about resource use on the market. In addition, managers must consider those ecological functions that do not have market value, but that have value to human society and that serve to maintain ecosystem integrity and function; ecosystem functions derive value from their role in satisfying human wants and needs and desires to leave ecosystems "pristine" (Ehrlich and Mooney, 1983).

The following mechanisms will help implement this principle:

(1) *Allocate the use of wild living resources on the basis of the ecological capabilities of the species involved and their assessed value to society.*

The use of a wild living resource must be compatible with the best available assessment of its capabilities to withstand that use. For example, heavy harvest of adults of a long-lived, slowly maturing, slowly reproducing species such as sea turtles or various rhinoceros species is incompatible with their persistence and cannot be allowed. Similarly, extensive logging of old-growth forest removes that age group from the landscape, eliminating its availability to species dependent upon it, and thus is incongruent with maintaining ecosystem and species diversity.

Allocating resources on the basis of their assessed value to society ensures that it will not be possible to change things in such a way as to make any one person better off without making someone else worse off. The estimation of such value is difficult but not impossible (Knetsch, 1990; Coker and Richards, 1992) and the unwillingness to make estimates underlies many resource disputes.

The values that living resources have to society incorporate all possible uses, including their existence value as components of an intact ecosystem. Thus the value of ecological resources includes their utilitarian value in direct production or consumption and their indirect value as components of ecosystems from which society derives a range of benefits: their amenity value, their aesthetic, scientific, and information value, and the value they have in preserving options to future generations and in enabling members of the present generation to preserve a "way of life" that is valued. The true economic value of living resources must include all of these, and is generally much greater than the immediate market or financial value of the resources. Thus, a broad range of ecosystem attributes needs to be valued, ideally in an empirical and comprehensive manner, and one in which tradeoffs can be assessed (Knetsch, 1990).

(2) *Provide incentives to the users of living resources that correspond to the value those resources have to society. Ensure that these incentives promote conservation, and constrain all privilege of access to guarantee this.*

Developing positive incentives for conservation by resource users is essential, and effort is needed in this direction. In addition, those who derive benefit from the use of resources should be confronted with the true cost of their actions. It is analogous to the "polluter pays principle," but generalizes to cover all uses of living resources, and recognizes that the users and uses of resources may be very diverse. Users of living resources should be faced with the cost of those activities, even if they are responding to demands generated in the marketplace.

(3) *Ensure that institutions and property rights are consistent with conservation, including questions of tenure and access.*

Property rights and security of tenure, which are social institutions associated with the use of wild living resources, are of primary importance to the incentives facing individual users. The lack of well-defined property rights ("open access"), and the uncertainty of continued access are among the strongest disincentives to conservation. We do not advocate any particular regime of property rights, nor any particular set of institutions. But property rights and institutions should be constructed that, so far as is possible, achieve (1) internalization of costs that are now external to and ignored by markets for resources, (2) regulation of access to common property resources so that the resources will persist, and (3) security of tenure for the users of living resources, as long as they use the resources within socially acceptable constraints.

User property rights come with associated user societal responsibilities and conservation constraints that cannot be ignored. Users should pay for the right of access to public resources, to help assure responsible treatment of the resource, and to help fund conservation.

Under some circumstances, property rights and security of tenure may influence individuals to act in a conservative manner because it is advantageous for them to do so. (There are cases in which rights and tenure have led to degradation of the resource. The best known example is the way in which farmers have failed to preserve the productive capacity of their soils; Pimentel *et al.*, 1995.) However, property rights and security of tenure are not sufficient. We still need a management structure that incorporates a multitude of values, accounts for ecosystem interactions and uncertainties, and establishes a conservative value system to protect the common resource.

(4) *Protect the welfare of future generations by ensuring that the value of biotic and abiotic resources does not decrease over time.*

Exploitation in an ecological–economic system is fair to future generations if benefits do not decline over time and other components of the system are not adversely affected. This requires that the value of the assets of the ecosystem, including existence value, do not decrease. Three conclusions follow. First, conservation of the value of biotic and abiotic resources is essentially the same as conservation of the opportunities open to society. Second, trade-offs in the allocation of resources are possible and it may be possible to substitute some human-made capital for some ecological resources. Because species vary in their roles in the ecosystem, the loss of (or changes in) some are of greater consequence than in others. Essentially non-commensurable and poorly defined notions of relative productivity or relative importance can no longer be used. In a world of scarce resources, it is unhelpful to proceed from the premise that all resources are equally valuable. As unpleasant as this reality is, it must be faced or decisions will be abrogated, with the untenable result that economic interests will be given priority over biological reality and constraints. Third, there are limits to the substitutability between human-made capital and ecological resources, and whenever these limits might be approached we must act to preserve the ecological resources.

Although the practice of discounting involves ethical judgments about the responsibility that the present generation bears for future generations (Clark, 1990), it will not generally be appropriate to address the problem of intergenerational equity via the discount rate. An ethically neutral discount rate exists, but in practice it may not be possible to estimate this rate and it is also not possible to enjoin private users of resources to associate with this rate. When economic activities have the potential to cause irreversible environmental damage that permanently reduces the welfare of future generations, priorities of the present generation must be placed behind those of future generations.

(5) *Recognize the possible consequences of uncertainty and act accordingly*.

There are many different sources of uncertainty in ecological and economic systems. They include (1) uncertainty due to lack of information concerning the natural history, demography, and dynamics of the resource; (2) uncertainty concerning possible second-order effects due to lack of information concerning numerical and functional relationships among related species and populations; (3) uncertainty due to unpredictable, stochastic, or evolutionary change in either population or ecosystem parameters; and (4) uncertainty caused by basing decisions on best estimates when variance is large.

Given the pervasive uncertainty about ecological and economic dynamics, and the limits on our ability to control the joint ecological–economic system, management decisions should include wide safety margins to minimize the risks of irreversible change or long-term adverse effects. The existence of uncertainty should be addressed directly in the strategy for conserving living resources. Uncertainty should not be a cause for inaction, and biological uncertainty should not be allowed as an excuse to permit other factors to dominate decision making. More particularly, it should not be possible for a group of users of ecological resources to conduct what are, in effect, experiments on the behavior of ecosystems on which all society depends, unless an informed society accepts and is adequately insured against the consequences. In addition, management should enable the system to be probed in order to learn about it, and should adapt with changes in the available information.

(6) *Promote adaptive management*

Resource management should be adaptive, not prescriptive. Consequently, managers must be willing and able to amend management policies and practices as often and as quickly as necessary, and this must include a willingness to abandon management paradigms and to admit mistakes when evidence so dictates. The management process must always be accountable to the full range of stakeholders, and should be continually appraised according to biological, economic, and social targets. Since an important part of management is a strategy for learning about the systems concerned, management policy and programs should be designed in part to help acquire information needed to determine the size and productivity of the resource and its functional relationships with other components of the ecosystem. Management programs also should include predetermined responses to observe declines or other changes that signal unexpected and unacceptable responses to resource use. Managerial procedures must allow change in the face of new information, and provide economic incentives that encourage users to extract and to share information.

Principle V. The full range of knowledge and skills from the natural and social sciences must be brought to bear on conservation problems.

Although biology must remain central for the conservation of living resources, other disciplines are important and input from them can be crucial. In particular, a critical step toward achieving successful conservation is to incorporate knowledge from the social sciences, including evaluation of information from those engaged in using resources, residents in or visitors to natural areas, and those otherwise familiar with resources. "The full range" in this principle refers not only to the variety of relevant disciplines, but also to the full depth of each.

The following mechanisms will help implement this principle:

(1) *Invoke the full range of relevant disciplines at the earliest stage possible.*

The breadth of relevant knowledge and skills should be involved in the preparation of legislation and in formulating and implementing policy, including prior assessment of the issues, decision making, resolving conflicts, and monitoring and evaluating the execution of policy. This will often require breaking down long-standing and rigid institutional, professional, and personal barriers.

Effective linkages among scientific, economic, and social disciplines—and between all of these and executive authorities at all levels—are hindered by the absence of a common currency of "language." The same words (e.g., "conservation") are commonly applied by practitioners of different professions to distinctly different concepts. As far as practicable, a common language must evolve to facilitate discourse about practical conservation. It is unrealistic, however, to expect that the numerous professions and disciplines will keep in step. It is therefore essential that concepts are explicitly and clearly defined, that mutual understanding between the professions be enhanced, and that, as far as practicable, a unique meaning be ascribed to each term in discourse between the "expert" groups and the authorities.

(2) *Recognize that science is only one part of living-resource conservation and is limited to investigating and objectively describing certain kinds of phenomena and processes.*

Science provides basic knowledge about the world and offers ways to gain additional knowledge and insight. What science can and cannot do needs to be clearly communicated to the public and decision makers. For example, science can be used to set the boundaries of activities consistent with conservation goals, including the uncertainty of those boundaries, but science cannot dictate where in the envelope society should operate. Similarly, science, by itself, is not capable of making judgments about aesthetics or ethics. Science can tell us about the likely biological outcome of a decision or action, but not which, of all outcomes, we should value more highly. Scientists are value-laden in a host of ways, some of which may be "invisible" both to the scientists and to the public; thus, care must be taken to avoid mixing the values of scientists with the knowledge of scientists. Trust and credibility can only be maintained and enhanced (or, in some cases, reestablished) if this is done. For science to be relevant, it must be germane to the contemporary issues of decision making. For science to become more policy relevant, scientists must know how policy processes work, how to participate effectively in them (Clark, 1993; Meffe and Viederman, 1995), and how to differentiate between science and policy (actual knowledge and value judgments). This may necessitate a change in the way that science is done (Huenneke, 1995; Underwood, 1995).

The ongoing debate concerning global warming illustrates the point. Available information is insufficient to demonstrate beyond reasonable doubt that average temperatures are increasing worldwide. Similarly, available information is insufficient to determine precisely to what extent various human actions are either causing or contributing to global warming or what the eventual ecological and socio-economic consequences will be. Some scientists interpret the available information differently and, based on their interpretations, advocate different actions. Some do not differentiate clearly between known facts and uncertainties. As a result, neither the general public nor decision makers have a clear understanding of what is and is not known or the possible alternative courses of actions and their biological and social-economic consequences.

This does not mean that scientists should not make value judgments or advert particular policies or programs based on their judgments. Rather, scientists must take extreme care to differentiate between scientific fact and value judgment, so that both the public and the policy makers are aware of the facts, the uncertainties, and the possible consequences of alternative actions.

(3) *Require comprehensive consultations because virtually all conservation issues have biological, economic, and social implications; ignoring any of these may lead to conflicts that will impair effective conservation.*

Consultations should be used to ensure that all stakeholders are aware of the options and their possible consequences. Such consultants are also desirable at the stage of establishing the conservation criteria themselves. Since practitioners of the various professions are commonly among the stakeholders of the resource in question, both directly as users and indirectly as paid consultants or research-grant recipients, the arrangements for consultations should recognize this.

There are examples of traditional uses that have not degraded the local ecosystem (Posey, 1993) and it is important to learn from those indigenous cultures that have used resources in relatively non-destructive ways. Thus, relevant indigenous expertise should be sought, evaluated, and, where appropriate, incorporated into conservation policy.

Principle VI. Effective conservation requires understanding and taking account of the motives, interests, and values of all users and stakeholders, but not by simply averaging their positions.

A consistent shortcoming of wild-living-resource policy has been the failure to understand and systematically incorporate the basic motives of all users and stakeholders (Kellert, 1984) and the ways that human–environment interactions are reflected in the social and cultural discourse (Palsson, 1991). Values (aesthetic, ethical, ecological) that vary among stakeholders can lead to divisive conflict, particularly when policy makers fail to take into account the primary motivations of major participants. Some stakeholders may be willing to accept a great range of risk to the resource, while others may be unwilling to accept any risk. Furthermore, what is considered unacceptable risk will vary in time and will depend upon available alternatives. The most effective means for satisfactorily resolving such conflict is by ensuring full participation of all relevant stakeholders in the decision-making process and conducting systematic assessments of all living-resource values.

Human groups have three foci that are fundamental in understanding and developing policies for conservation (Kellert and Clark, 1991). The cultural focus considers the basic assumptions regarding the values and motives for using wild living resources. The socio-structural focus emphasizes community authority, power, and property relations associated with the allocation and use of resources. The institutional-regulatory focus stresses the character of formal organizations charged with the responsibility for giving expression to and implementing policies. Historical failures in recognizing the importance of these foci are legion, and have resulted in major conservation deficiencies and misallocation of biotic, financial, and other human resources (Gunderson, 1985; Vidal, 1993).

The following mechanisms will help implement this principle:

(1) *Whenever possible, create incentives by delegating property rights to the "lowest" relevant community or societal level consistent with the scale of the resource involved.*

Increased tenancy and property rights for wild living resources among local and community stakeholders can enhance incentives for their conservation (Berkes, 1985; Bromley, 1991), even in cases where such resources are part of the "commons" (Monbiot, 1994). Giving management responsibility to local stakeholders, particularly at the community level, fosters accountability and increases motivation for conservation, particularly if a close connection exists between conservation actions and the benefits of those actions. In many cases, there will be a direct local payoff to conservation through activities such as wildlife viewing; this strategy is being used in Uganda to conserve gorillas (Nowak, 1995). In other cases, however, the wildlife themselves will never have direct economic value and the challenge is to ensure that those who can least afford it are not forced to pay for the conservation activity (Eltringham, 1994). For example, the cost of the conservation of giant pandas in China includes new reserves, moving timber companies and their workers, and providing financial incentives to locals to resettle (O'Brien *et al.*, 1994). The Chinese government agreed to cover ≈15% of the cost, with the remainder secured from outside sources. The continued existence of pandas should be of interest and value to the world community, so that a worldwide campaign for support would be a reasonable part of the solution.

Delegation of responsibility to the local community can also diminish resentment toward government officials, who are often viewed as having little stake in the preservation of traditional community institutions or resources. Increasing local control can additionally foster participation of stakeholders in the formulation of conservation policy. The difficulty with this approach is that individuals and corporations involved in use of the resource may not be tied to a specific spatial location, and after local resources are overutilized, new sources will be sought. For example, in the successive overexploitation of whale stocks in the North Atlantic, whaling fleets moved from the Barents Sea to Iceland to the Arctic as locally developed controls were instituted (Hjort, 1933; Smith, 1994).

Local control has a number of advantages when the users and the effects of use are local. These include (1) maximizing incentives for local managements; (2) increasing the security of tenure and property rights among communities and stakeholders involved; and (3) forcing the development of co-management institutions among local and national authorities and relevant stakeholders. Regional, national, or international control will be required if the resource or effects of its use transcend the smaller political boundaries.

(2) *Develop conflict-resolution mechanisms to minimize strife over resources among competing stakeholders.*

Almost all conservation problems will involve many different constituencies. For example, conservation of tropical rain forests involves the historical forest dwellers, the local farmers living in isolation, inhabitants of small villages (which may be long established or recently developed), the rural/urban population living in large villages or cities adjacent to forests, high-level government employees and decision makers who live in large cities removed from the forest, groups (such as timber or mining concerns) with special interests in the forest, judges and legislators who determine the laws and enforcement of those laws concerning the forest, and foreign groups with conservation or commodity interests in the forest. In the marine environment, a similar diversity of stakeholders exists, sometimes at the "micro" level. For example, some individuals use mobile harvest gear, which can damage or destroy the fixed gear used by other stakeholders.

Three main paradigms describing resource use are the "conservation paradigm," with the objective of conservation and maintenance of the resource; the "rationalization paradigm," with the objective of economic performance and productivity; and the "social paradigm," with the objective of community welfare and social equity (Charles, 1992). It is natural that users operating within different paradigms may come into conflict, for which different resolutions are possible (Charles, 1992).

Thus, giving authority to the local communities can foster compassion and conflict among varying constituents involved in or affected by policies and their implementation. Such an enhanced democratic process may result in an increasingly volatile policy-making environment. In the long run this may result in more effective and equitable living-resource allocation, but is likely to require an enhanced capability for resolving conflicts among competing constituencies, for example by use of trained mediators. By passing more responsibility for conflict resolution to local and community levels, government authorities at higher levels (bureaucracies), legislatures, and the courts will be relieved of some of the burden. This will also reduce protracted interagency discussions, efforts to influence political decisions, and the polarization that results when court or policy decisions or the enactment of laws create clear winners and losers. Such polarization inevitably results in temporary solutions, as losers pursue advantage in the next round.

(3) *Ally science with policy making independent of the interests of resource users.*

Scientific and technical data about wild living resources are often interpreted to support the interests of stakeholders or subordinated to protect political interest. Science used in policy will likely not work if scientific consensus is forced, as often happens in the scientific committees of international commissions (Mangel *et al.*, 1993), and policy itself is most effective when it is built on broad consensus. Better employment of scientific data can increase the capacity of policy makers to explore the full range of options. This preferable policy-making process can be undermined when scientists are subordinated by political interests, made largely accountable to managers, or retained by stakeholders to support their perspectives. By placing science in closer proximity to policy makers, independent of management and stakeholder interests, the value of scientific information can be considerably increased. Potential conflicts in advice among “expert” sectors should be resolved insofar as possible before advice is presented to legislators, courts, or other authorities. Where expert views are not resolved, assumptions, uncertainties, and risks should be clearly presented. Expert views should be subject to broad-based peer review. For the reasons noted earlier (see *Principle V*; mechanism 2, above), scientists should be careful to differentiate between scientific fact and judgments regarding management practices or policies. Failure to do so can jeopardize the credibility of science and the scientist and allow decision makers to avoid being fully accountable for their decisions.

(4) *Require that policy makers be held accountable for the use of the best possible data and analyses in setting policy.*

Because of inherent uncertainty in ecological, economic, and social systems, changes are required in the way decision options are evaluated. First, decision makers should go beyond examining how uncertainties may affect the potential distribution of outcomes, and focus on how uncertainties may influence the choice of one decision over another, given the management objective. Second, society must judge the quality of decisions not only on the basis of observed outcomes, but also on the quality of the data and the process used in making a decision. Third, the decision process must be documented in a transparent manner, to allow the policy maker and technical specialists involved to be held accountable for their decisions and advice. Fourth, effective policy may require taking actions that are sub-optimal in the short term, in order to generate long-term information that will improve future management or will ease the social and economic costs of policy change. For example, an experiment in groundfish currently underway in Australia (Sainsbury, 1991; McAllister and Peterman, 1992) should generate useful information on the relative likelihood of different hypotheses about community structure and dynamics; this knowledge will improve future management.

Scientists are not the center of policy making and should not be used for setting the goals of the community. Policy makers should neither ask for firm conclusions when they do not exist, nor interpret scientific results to suit preferred policy outcomes. Scientists must characterize risks and uncertainties in terms a lay person can respond to, and indicate realistic time frames in which risks may occur or uncertainties be resolved. It is the responsibility of scientists to ensure that the executive summaries and other abstracts of scientific assessments likely to be reviewed by policy makers and the public give full expression to uncertainties and risks.

(5) *Insofar as possible, establish agreed-upon criteria and procedures to guide decision making on conservation measures at all levels, in order to reduce the scope for influence by political or special interests.*

A decision that is arrived at by the application of predetermined and well-reasoned rules is less susceptible to being overridden by special interests. Too often, limits concerning the use of a resource are a compromise between what is viewed by scientists as justifiable given the available data and what is demanded by the interest groups. Limits on use are therefore often based on socio-economic factors rather than biological considerations, usually resulting in a decline of the resource. Methods to avoid this problem must be developed.

One possible method is to ensure that all stakeholders are aware of the uncertainties and the potential long-term consequences of uncertainties concerning the possible costs and benefits of resource use. In addition, stakeholders should have a common understanding of what constitutes evidence of unacceptable use-related effects and should agree beforehand on what will be done if evidence of such unacceptable effects becomes apparent. In the case of fisheries, for example, it could be agreed that a fixed decline in catch per unit of effort (or some other index or monitored variable) constitutes evidence of an unacceptable effect and that if this is observed, it will automatically trigger a fixed reduction in fishing effort, or some other management response. Establishment of such predetermined decision rules can reduce the risk of short-term socio-economic considerations overriding long-term biological and ecological considerations. Computer simulations can be used to help evaluate and select such appropriate decision rules. As with any management scheme, the status of the resource and related ecosystem components should be kept under review, and the management plan should be revised if it does not work as expected.

(6) *Ensure that formal institutions responsible for giving expression to policies and implementing conservation programs have temporal and spatial perspectives consistent with the ecological character of the resources and organizational structures that are (1) flexible and problem-oriented; (2) accountable, visible, and performance-oriented with clear, measurable, and explicit objectives; (3) team-oriented, participatory, and interdisciplinary, employing consensual decision-making; and (4) capable of learning and corrective feedback (i.e., are adaptive).*

Institutions often lack spatial and temporal definitions of their missions congruent with that of users, stockholders, or the ecology of the resource (Kellert and Clark, 1991). For example, the cumulative impact of many discrete actions often has ecosystem effects not compatible with management focus on a single fiscal year or a single location. Failure can take a number of forms, including failures of integration or of specificity, failures of scale and priority, and failures of feedback. Many policy failures can be tied to incomplete specification of organizational goals, incentive and reward deficiencies, conflicting directives and organizational objectives, limited competence and training, conflicting interests and agendas, lack of enforcement capability, fragmented decision-making and accountability, rigid and defensive communication structures, poor public involvement, or lack of high-quality information (Dowell and Wange, 1986). Understanding the organizational behavior of regulatory institutions is thus a key to improving the effectiveness of conservation policy (Yaffee, 1982; Clarke and McCool, 1985).

Various internal and external factors affect organizational behavior. Internal factors include goals and objectives, standards and measures of performance, incentive and reward systems, leadership and authority structures, information and communication flows, specialization and role relationships, culture, and ideology. External factors include the sources of funding, ally and adversarial relationships, the influence of politicians, public perception, and the media. We require clearer and more explicit institutional problem definition, enhanced organizational coordination and cooperation, fuller participation of all relevant interests, greater accountability and incentives for success, and increased institutional adaptability and learning capacity. Successful conservation requires reconciliation of spatial and temporal perspectives among management agencies, relevant stakeholders, and the ecological character of the resource.

Principle VII. Effective conservation requires communication that is interactive, reciprocal, and continuous.

Effective communication can greatly enhance prospects for effective conservation by allowing stakeholders to understand the problems and the potential results of alternative courses of action. Communications among scientists, the public, and decision makers are sometimes problematic. Two-way, interactive, open, ongoing communication serves all interests better by bringing expectations into alignment. There is virtually unlimited opportunity for misunderstanding through failed communication, so substantial effort is required to ensure effective communication.

The following mechanisms will help implement this principle:

(1) *Ensure that communication is targeted to the audience and is based on mutual respect and sound information.*

Mutual respect requires clear, objective, and honest presentations with breadth and depth tailored to the target audience. Where differences of language and culture exist, it is important that all involved make an effort to overcome them. The same is true of communications among those specialized in different disciplines. Practitioners have professional cultures, and without an appreciation of such cultural differences, communications will be more difficult and less productive.

A higher information content at the outset of communication, with clearly stated goals and objectives, will reduce misinterpretations. Scientific assessments should specify in ecological and socio-economic terms the causes and effects of the conservation problem and the costs, benefits, and risks of different solutions. Where uncertainties exist, these should be clearly communicated, together with potential consequences, so as not to undermine the credibility and usefulness of science and scientists in the policy process (Bolin, 1994). An iterative, two-way process is essential to identify misperceptions and needs for clarification. For example, the scientific process involves ongoing testing and self-correction, whereas decision makers must act decisively, and with assurance, within relatively short time frames. Similarly, the standard of proof for a scientist may differ considerably from that required by a court of law.

(2) *Require internal and external review to verify objectivity and results.*

Since the credibility of communications will erode unless the contents are independently verified, each practitioner must be responsible for ensuring the validity of information communication. Just as a scientist should submit to peer review, a journalist should check with different sources. Policy-makers and managers should be responsible for ensuring that assessments are based on sound information and receive external review. The review process should extend to those well versed in socio-economic and biophysical disciplines, and familiar with the particular operational circumstances. Regular review deepens understanding of issues and uncertainties, and of different professional cultures. In addition, it highlights changes in scientific and technical understanding and the results of policies made and decisions taken.

(3) *Inform and motivate the public and motivate regarding conservation.*

The motivations of stakeholders ultimately determine the success of conservation efforts. Information should be provided to enhance the public's capacity to render informed and intelligent opinions consistent with conservation. Too often, input is solicited at too late a stage for policy makers to take the views of the public into account. Similarly, often too little attention is given to educating the public about what to expect from management and from the resources themselves.

Educational programs at all levels should emphasize transdisciplinary problem definition and solving. Forums that encourage interaction and feedback are more likely to reveal unstated assumptions and values, clarify objectives, and highlight areas of uncertainty than forums that do not encourage such interaction. Recognizing that people learn differently, the same information needs to be presented to different target audiences in different ways. Development of professional skills should include training in the appropriate use of specialized communications techniques and technologies. Funding for communications training and communications should be included in the costs of conservation programs.

(4) *Develop institutions and procedures to facilitate transdisciplinary analysis and communication that informs decision makers.*

More attention must be paid to developing the skills necessary to facilitate transdisciplinary communication. To participate in such communication effectively, one needs a basic understanding of how questions are approached in different disciplines. Managers and research institutions should define terms of reference and procedures for transdisciplinary studies that foster interaction and balanced products. The academic community should promote transdisciplinary problem-solving among students and develop criteria for tenure and promotion that reward transdisciplinary work.

Models, when perceived as quantitative descriptions of current understanding, can be an especially effective form of communication. They can help create a common language and explore the consequences of the best-understood information, in order to communicate the likely outcomes of alternative actions and help in the search for trade-offs. For example, models have been used to understand, in the absence of critical data, mobbing in Hawaiian monk seals (Starfield *et al.*, 1995), and to choose management strategies in response to this behavior (Ralls and Starfield, 1995). Similarly, a population model for management of the saiga antelope (Milner-Gulland, 1994) allows users to evaluate the possible impacts of different management strategies and shows the importance of considering climatic fluctuations when choosing harvest levels.

Summary

All conservation problems have scientific, social, and economic aspects. The relative mix will vary, but it is essential to recognize all three components. Furthermore:

• A basic component of almost every conservation problem is human population growth and resource consumption.
• At this time, true ecosystem management is not yet practical, but an ecosystem approach in which one thinks comprehensively in terms of the interconnectedness of effects is mandatory.
• Individuals active in conservation should develop an understanding of all relevant fields, as appropriate, in order to communicate more effectively with colleagues.
• Conservation problems do not have simple solutions and one must avoid thinking that the next technique (e.g., food-web theory, GIS, DNA finger-printing) will complete the tool-kit for resource conservation.
• Uncertainty must imply conservatism, but in a manner that promotes improved understanding.
• The disparity between economic and ecological time scales presents a great challenge because the economic system responds to change much faster than the ecological system; that is, biological systems are constrained by much slower time scales than economic systems. Furthermore, modern communications allow economic decisions to be made far from the actual location of the conservation problem, with no local community input, and to be implemented rapidly. Analytical means and management institu-

tions capable of ensuring that the extremely rapid economic time scales do not overtake the biological ones are required.

• Many of the values attached to living resources that are commonly seen as non-economic are economic in that people are willing to commit resources on the basis of such values. Resources have scientific, ecological, aesthetic, and functional values that are not expressed in the market place. Adequately identifying and effectively measuring all relevant consumptive and non-consumptive values of varying stockholders is a non-trivial and complex matter, but it must be undertaken. Not all species or ecosystems are equally valuable and this requires facing the "agony of choice".

• Conservation requires a transparent process of decision making that engenders public faith in the credibility of the process and thereby brings the public and decision makers to better understanding the desirability, from all perspectives, of maintaining the resource, particularly when it is subject to continued use.

• Decision makers should be evaluated on their decision process and on the data they use, rather than merely on the outcome. The process must be capable of fairly taking into account different values and interests, defining and responding to specific problems at appropriate temporal and spatial scales, and adapting quickly to new information and analyses.

• Effective policy may require taking actions that are sub-optimal in the short term, in order to generate information that will improve future utilization and conservation.

• Understanding the organizational behavior of regulatory institutions is a key to improving the effectiveness of conservation policy, and institutional accountability is fundamental to effective conservation.

• Although good scientific input is essential if one is to address successfully most conservation problems, it is usually not sufficient in and of itself, and scientists should not be asked to set the policy goals of and values for the community. Scientific consensus, while it is highly desirable, should not be forced and policy makers should neither ask for firm conclusions when they do not exist nor incorrectly interpret scientific results to support preferred policy outcomes.

• The concept of a "right to use the resource" must be changed; it must be seen as the "privilege to use the resource." Users should pay for the right of access to public resources, in order to assure funding for conservation activities, management, and data collection and to reduce chances of misuse of the resource. Positive incentives for conservation are as important as paying for the right to use the resource.

• The initial hypothesis concerning the possible effects of resource use should be that until proven otherwise resource use will damage the resource and the related ecosystem. The burden of proof should be shifted from the regulatory body having to show that use will have a detrimental effect to the user to show that use will not have a detrimental effect.

• Procedures for dispute resolution must avoid the dangers of management based on averaging the positions of all stakeholders.

• Two-way, open, interdisciplinary, and transparent communication can greatly aid conservation efforts, and such communication must be based on mutual respect.

Treating wild living resources as has been done in the past is untenable for the long term. The fundamental relationship between people and the rest of nature needs to be rethought, and policies developed that fully recognize the realities of the biophysical constraints under which humans must function. The principles and mechanisms presented here provide the guidance for such a change and it is now time to put them into action to prevent degradation and ultimate destruction of the natural resources and ecosystems on which the human species depends.

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Preservation and strong sustainability

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If sheer complexity of approach can save the world's wild biota, then the principles presented by Mangel *et al.* will be effective. Seven principles and thirty-four mechanisms for implementation will challenge the capacities of resource managers in the most developed nations—what are the prospects in developing countries, where much of the remaining terrestrial wild resources are to be found? As Mangel *et al.* make clear, there has been a significant increase in our knowledge of both ecological systems and their interaction with the economic domain since the original principles were published by Holt and Talbot in 1978. An increase in complexity seems to be one result of this new knowledge. The attempt to move from broad principles to specific mechanisms is important, but we should not ignore the challenge this presents for practical implementation.

These comments will be written from an environmental economist's point of view, and there are some aspects of Mangel *et al.* where economics will offer a different perspective. But there is a basic point to be made: if we are aiming for sustainable development and there are indeed critical living resources, then *preservation* is the issue. The economics of strong sustainability is the fundamental point in this commentary.

Mangel *et al.* touch on the issue of property rights (III.1, as well as IV.3) but are unclear on the basic reason why wild biota tend to be overexploited, which is that natural resources yield economic rents, i.e. profits that exceed 'ordinary' returns to capital owing to the scarcity of the resource. Unless ownership is vested, there is a strong incentive for overexploitation. This is a particular problem for a fugitive resource like fish, where open access rapidly leads to rent dissipation and may lead to collapse of the stock. The basic point from resource economics is that inadequate resource management is not only inefficient, it actually leads to declines in total income (Gordon, 1954). The dissipation of resource rents in most of the world's fisheries is symptomatic of exceedingly bad policies from a purely economic point of view, let alone an ecological one.

The article swerves towards the naïve when it argues in I.2 that pressures on wild biota would decline if cities were more efficient, safe and pleasant. The raw demographic fact is that the developing world will be predominantly urbanized early in the next century, according to UN projections. From an economist's viewpoint this is 'revealed preference': cities in developing countries may be unsafe and unpleasant, but they evidently offer greater prospects for income than the countryside. This is not an argument, however, for ignoring the problems of cities. Most studies show that there is an untapped willingness to pay for better amenities in cities; there may also be a global externality argument, since crowding poor, undernourished people together in unsanitary conditions is a recipe for the evolution of new infectious diseases.

Principle IV.2 invokes the 'polluter pays principle' in a manner that will be mystifying to most economists, when it suggests that 'those who derive benefit from the use of resources should be confronted with the true cost of their actions' (p. 55). This is presumably an argument about externalities, but needs to be made much clearer. The reason a pollution tax is efficient is that it assigns a cost directly to the source of the externality, thereby yielding the correct incentives for the polluter—is there an analogous situation with respect to the exploitation of wild resources?

One of the pervasive aspects of the exploitation of wild resources is the existence of subsidies. This is hinted at by Mangel *et al.* but nowhere made explicit. Governments often subsidize with the best of intentions, to preserve a distinctive way of life or reduce regional disparities, for instance, but the political economy of subsidization suggests that this is generally misguided: subsidies typically miss their target (e.g. subsidizing the factory fishing ship more than the craft fisherman), strain the treasury, encourage over-investment and create strong rent-seeking lobbies that are hostile to reform. Subsidies are a major problem for fisheries. Safina (1995) suggests that worldwide subsidies to fishing may be as much as $54 billion; even if this is a factor of two or three too high, it is an impressive number.

Subsidies are particularly damaging to the sustainable management of living resources. By creating a rent-seeking client group, there is strong pressure to ignore the evidence that may exist that a resource stock is being overexploited. This is essentially the story of the collapse of the Canadian cod fishery.

Conservation of a living resource is often synonymous with preservation of its habitat, particularly for terrestrial biota. This brings us to the economics of preservation. It is an eminently reasonable proposition to many economists that there are critical elements of the natural endowment, i.e. that human welfare and even the basis of life can be seriously damaged by the loss of certain key resources (this is termed 'strong sustainability' by Pearce *et al.* (1989)). Biological diversity is arguably such a key resource, and the preservation of wild ecosystems is arguably the only practical means to conserve it.

Designing the optimal level of preservation of wild areas, and designing the means to achieve this, both present challenges to standard economics. Economic models are typically not well adapted to examining questions of spatial scale, and yet the preservation of habitat is precisely a question of the amount of contiguous natural area that must be protected. Many economic models assume reversibility, and so the irreversibility inherent in species loss is also a challenge. Above all, most economic models assume substitutability, so that marginal amounts of one resource may be traded off for another. The notion that a resource like biological diversity does not have substitutes presents further difficulties for standard economic analysis.

The way to deal with these challenges may simply be for economists to recognize comparative advantage: rely on the natural sciences to tell us what kinds and what amounts of natural habitat must be preserved, and ask economists to design the most efficient policies for achieving preservation. This is a task to which economics is well suited, and it means that the sorts of indicators of sustainable development that economists have been developing can be extended in a natural manner. Pearce *et al.* (1996) suggest that indicators of strong sustainability involve the answers to two questions: (i) Was the target amount of the non-substitutable resource preserved? (ii) Was the total value of the substitutable assets (natural and human-made) preserved? A negative answer to either question is an indicator of non-sustainability.

This approach to the conservation of wild living resources has a beguiling simplicity, but it must also account for another difficulty: living resources have both local and global importance. Preservation of natural areas necessarily implies that local populations will have their use of these resources restricted. The conservation literature (see, e.g., Barbier *et al.*, 1990) strongly suggests that means must be found for these local populations to benefit directly from preservation (through a share of ecotourism proceeds, for instance), or else the incentives to poach and otherwise over-exploit will dominate.

One of the global aspects of preservation has been examined empirically by Ruitenbeek (1992). This study compared the local benefits of the preservation of a rainforest (non-timber products, watershed protection, etc.) in Cameroon with the local costs. The excess of costs over benefits represents what Ruitenbeek calls the 'rainforest supply price': the amount that the presumed global beneficiaries of preservation must be willing to pay in order to make preservation a paying proposition for Cameroon.

New work by Hamilton (1997) examines the preservation questions from a theoretical viewpoint. If a nation (or community) feels that it is unlikely to appropriate any benefits from the preservation of a rainforest, then its optimal strategy is to maximize the present value of welfare (assumed to be a function of consumption only) via the exploitation of the rainforest. If resource rents are greater on virgin forest than on secondary forest, this optimal strategy will amount to progressive exploitation of the virgin forest until it is exhausted, combined with sustainable exploitation of the logged-over areas by cropping secondary forest at its natural rate of growth.

If, on the other hand, the rainforest problem is to maximize global (rather than local) welfare, then the theoretical problem becomes one where the welfare function also includes the preferences of foreigners for the existence of virgin rainforest. Assuming that there is some critical value of the amount of virgin rainforest (technically, unbounded marginal utility for foreigners as some critical level of resource is approached), then the globally optimal solution to the resource management problem is indeed to conserve some amount of virgin forest, while exploiting secondary growth sustainability.

The only problem with the global optimum from the resource owner's viewpoint is that they are poorer—at each point in time, national income will be lower on the globally optimal path than on the purely locally optimal path. The conclusion of this analysis seems obvious: preserving resources of global importance is going to require transfers of income if it is to succeed (otherwise the resource owner will simply opt for the local optimum). These income transfers can come in the form of ecotourism fees, but these may be insufficient in the case of preserving large, remote areas of wild resources. Explicit income transfers, linked to preservation targets, may be the only way to preserve sufficient wild resources.

Mangel *et al.* are correct to remind us of the complexity and subtlety involved in managing wild living resources. However, thinking about the incentive structures that countries and ordinary people face must be the starting-point if we are to succeed in conserving wild resources. From this policy perspective the 'targets of opportunity' should be subsidy reform and an equitable global mechanism that will transfer income to pay for the preservation of wild resources.

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Missing the biodiversity boat

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Mangel *et al.* have sought to describe broadly applicable principles for the conservation of wild living resources and mechanisms for their implementation. Strangely, this document, prepared by a cadre of some of the world's leading ecologists, somehow neglected to discuss biodiversity, much less take full advantage of the principles incorporated within the Convention on Biological Diversity (CBD). The CBD is the world's leading environmental agreement, with over 165 State Parties. Though it has not yet been ratified by the USA, the US Government is deeply involved in its progress. Further, it contains a number of broadly applicable and politically accepted principles for the conservation of wild living resources and mechanisms for their implementation.

While the CBD deals with more than the conservation of wild living resources, it still provides a global framework for conservation. Indeed, the first objective of the Convention is the conservation of biological diversity. Its two other objectives deal with sustainable use of biological resources and equitable sharing of benefits arising from such use. These three objectives together provide the necessary framework for biological resource management.

Yes, the 1978 principles needed some modification. Principle 1a, for example, that 'consumptive and non-consumptive values could be maximized on a continuing basis', gives insufficient attention to the reality that such values involve trade-offs and that they cannot both be maximized at the same time. Two of the other original principles, however, have been more successful. The second has entered the environmental jargon as 'the precautionary principle', and the fourth is the basis of what has become known as 'adaptive management'.

The new principles are something of an improvement on the 1978 principles, but they are still more a recipe for 'jobs for the boys and girls' than real principles and mechanisms for resource management. They call for so much research that virtually nothing would ever get done. Furthermore, they demand very optimistic conditions, for example, decreasing human per capita demand for resources. And the 'mechanisms' seem to be more like corollaries, seeking to expand on the principles but without really providing mechanisms that might be implementable and relevant.

The paper is quite incorrect in stating (pp. 43–4) that *Caring for the Earth* (IUCN/UNEP/WWF, 1991) ignored the relationship between human population and environmental deterioration. In fact, an entire chapter was devoted to 'keeping within the Earth's carrying capacity', with details about intensity of energy use, relations between human population and resource consumption, and so forth. It included details on actions to increase awareness about the need to stabilize resource consumption and population, integrate resource consumption and population issues in national development policies and planning, develop, test and adopt resource-efficient methods and technologies, tax energy and other resources in high-consumption areas, encourage 'green consumerism' movements, improve maternal and child healthcare, and double family planning services.

By contrast, the new principles in Mangel *et al.* offer no practical mechanisms for actually doing something about the principle (with which, by the way, we agree). Simply recognizing problems is not good enough, and the conclusion ('we must again find ways to make cities liveable, with pleasing features to protect health and improve well-being, with fewer effluents polluting the air and water, or exported as solid waste to more remote areas. Finally, improving the liveability of cities must be done in a manner that does not place undue burden on resources elsewhere' (p. 45)) sounds like little more than a pious hope. Further, is it really the case that the only way of reducing per capita resource demand is to decrease the human population? While decreasing human population is a laudable and necessary measure, it is clear that the most intensive resource use is by relatively small numbers of highly consumptive individuals, especially in the industrialized countries (Redclift, 1987; Durning, 1992).

Principle II is simply a rephrasing of the first objective of the CBD, but it carries with it a few problems that seem to be ignored. First, fundamental physical laws and biological dynamics do not constrain human institutions and desires, however much we may wish that it were so. Throughout our history as a species, human institutions and desires have always tried to go beyond these fundamental physical laws and biological dynamics, which helps explain the cyclical nature of so many of the relationships between people and resources.

The paper contends that it is imperative that management agencies work together and that managers learn to work with multiple agencies.

Again, a laudable objective, but anyone who has worked with either management agencies or managers will recognize how unlikely it is that this imperative will be met in any but the rarest of situations.

Thus the paper seems strangely out of tune with some of the modern concerns in conservation, such as the impact of globalization, problems of scale, distribution of costs and benefits, and the need to decentralize management. On the contrary, the paper argues for what appears to be a highly centralized approach with many simultaneous imperatives and no guidance on priorities.

The paper adopts uncritically the theoretical work by Tilman *et al.* (1994) which argues that 'even moderate habitat destruction can lead to delayed but certain extinction of the dominant species in the remaining habitat'. But that is likely to be the case only if the habitat destruction is permanent rather than cyclical; evidence from many parts of the world indicates that habitat changes often are cyclical, especially in tropical forests (Spencer, 1966; Turner *et al.*, 1991; Boyden, 1992).

Principle III essentially calls for environmental impact assessment, which has now been widely accepted as a principle and is enshrined in the CBD. Yet the CBD goes further in its desire to assess not only the effects of resource use, but the underlying causes of biodiversity loss (Vorhies, 1996). The authors call for the concept of a 'right to use the resource' to be changed to the 'privilege to use the resource' (p. 49), which is an interesting distinction. But perhaps more important is the right and the ability to exclude others from using a resource.

No indication is given in the paper that some assessment of costs and benefits should be part of management programmes and monitoring programmes. If the costs of these efforts are prohibitive, then they will not happen, or at least will not happen for very long.

The concept of traditional use under III.1 is far from an accurate representation across cultures. This parody of traditional use ignores the numerous adaptive mechanisms that were developed by human societies in virtually all parts of the world to ensure that the desires of individuals did not put societies at risk (Bennett, 1976; Suzuki and Knudtson, 1992; Alcorn, 1993; Carmichael *et al.*, 1994). Indeed, the traditional societies seem to have been far better at this than is the modern consumer society, where feedback between the impacts of resource use and human behaviour is virtually absent; much of the most interesting work in community-based resource management is based on the strong feedback mechanisms of traditional practices (Western and Wright, 1995).

However, many of the mechanisms suggested by Mangel *et al.* seem to be appropriate only for industrial-level forms of exploitation. They may be relevant for highly capitalized forms of resource exploitation that can absorb the high costs of research, management, and monitoring, especially fisheries on the high seas. The information acquisition plan advocated in III.4, for example, might work for some commercial fisheries and the timber industry, but has little relevance to the millions of individual resource managers in most of the world. And calling for observers associated with data collection to be independent of the resource management institution and the country that is financing the programme again seems relevant for only a very narrow spectrum of wild living resources and for a small segment of the resource users.

Under III.5, Mangel *et al.* state that 'women with ovarian cancer are beneficiaries of taxol from yew trees and consequently some public monies are appropriate for the development of taxol chemotherapy' (p. 53), surely a *non sequitur*. One could as logically argue that pharmaceutical firms should pay for such development, with costs recovered by charging the patients whose lives are saved. Taxol chemotherapy has the characteristics of a private good and is surely in demand. Thus it could be sold through the market system. What the yew taxol example really demonstrates is a rather different point, namely, that public monies should be devoted to conserving biological diversity because of the possibility that additional such discoveries may be made in the future. This is called by economists the 'option value' of biodiversity.

Many of the mechanisms proposed also seem to be aimed at the wrong target. For example, it seems unlikely that stock harvesters will stop focusing on stocks and instead focus on processes, as called for under II.2. The stock harvesters, such as fishermen or foresters, inevitably must focus on their stocks; but the regulators who set catch or harvest limits might indeed be the appropriate ones to focus on the processes. In such cases, economists recommend tradable quotas with the regulators setting the total quota and the harvesters allocating this quota through the market.

Under principle IV, managers are encouraged to consider ecological functions that do not have market values but have wider social values. However admirable this may be, managers of forests and fisheries, for example, invariably are judged by production. Perhaps the consideration of the non-market values is more appropriately placed in the hands of legislators and policy-makers than of managers, as such considerations inevitably involve social choice. If social values are to be considered by resource managers, mechanisms need to be developed to account for the production of these values.

Principle IV.1 advocates allocating the use of wild living resources based on their 'assessed value to society'. But this is a very fuzzy concept indeed, as society is made up of numerous interest groups who may have mutually contradictory ideas about the value of, for example, forests. A logging company will see a forest in terms of its timber values, while a conservation organization may see the same forest in terms of its biodiversity values, and downstream farmers may see the forest primarily in terms of its watershed protection values (McNeely, 1996). Some of these values may be incompatible, but all are legitimate expressions of society. To expect all trade-offs to be neutral seems highly unrealistic, and indeed the major conflicts in resource management are over the distribution of benefits and costs.

Perhaps the most important point made by the paper is under IV.6, calling for the promotion of adaptive management. This is clearly a highly relevant idea, and in fact has characterized resource management for thousands of years. Far more attention needs to be given to the practical requirements of adaptive management.

Under V.3, it was very helpful to see discussion of traditional uses that have not degraded local ecosystems, but this discussion should have been greatly expanded. Not all traditional uses are sustainable, and in fact most societies appear to have been characterized by cyclical relationships with their environment, often involving violent conflicts with neighbours (Edgerton, 1992; Keeley, 1996).

Since many of the mechanisms call for highly centralized structures, it was interesting to note that VI.1 seems to move in the opposite direction, toward delegating property rights to the lowest level consistent with the scale of the resource involved. This seems to be a highly relevant principle, but in fact is returning to the situation that characterized many pre-industrial societies. While it may not be incorrect to call this 'giving management responsibility to local stakeholders, particularly at the community level' (p. 60), it might be more appropriate to consider it to be 'returning management responsibility' to these stakeholders. Further, community management is likely to be based on less sophisticated mechanisms than those envisioned by Mangel *et al.*

Under VI.3, the paper strangely argues against clear-cut decisions over resource allocation, instead advocating a constant series of compromises, contending that clear-cut decisions inevitably cause polarization which results in only temporary solutions. But surely this is not supported by history, as clear-cut decisions such as the establishment of protected areas have been effective in the long term and have been critical in conserving biodiversity. Conflicts between local communities and multinational corporations, for example, may not be resolvable as series of compromises, but will require some clear and courageous decisions.

Principle VI.6 provides a list of politically correct characteristics of formal institutions. These sound terrific, but have yet to stand the test of time. Further, the important role of informal institutions is ignored.

We have been somewhat critical of this effort. But this should not be taken as an indication that we disagree with its general thrust. Rather, our concern is with the unrealistic 'mechanisms' that are proposed for implementing the principles. Worse, the paper also ignores significant international agreements, the most important being the CBD, that have been agreed through a long series of negotiations. The CBD and other environmental agreements are developing a global language for conservation with political acceptability, but merit no mention by Mangel *et al.* Is it not better to support existing global processes than to develop new principles in isolation from political realities?

The imperatives that are called for in this paper would be wonderful if they were possible, but the paper is naïve about what can be accomplished in the modern world. Such ivory-tower sermonizing may go down well in academic circles, but is unlikely to have much impact in the real-world conflicts faced by the vast majority of farmers, foresters, and fisherfolk in most of the world.

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Some issues in the conservation of wild living resources

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The paper by Mangel *et al.* is a stimulating and authoritative document, rich in ideas and prepared by some of the world's leading experts on the subject. In the ensuing text, I attempt to elaborate on a few specific points raised by the authors.

Importance of economic, social and ecological interactions

The systems-based and multidisciplinary approach recommended by the authors is the most promising framework available. The conservation of wild living resources is an important element of sustainable development—the declared objective of most nations in the aftermath of the

United Nations Conference on Environment and Development and Agenda 21. While no consensus has emerged as yet on a practical definition of sustainable development, there is increasing agreement that the concept must include three vital dimensions: the economic, social and environmental (see, e.g., Munasinghe, 1993). Thus, it is encouraging to see that the paper clearly recognizes the need to analyse and understand wild living resources in the broader context of interlinked physical, ecological and socio-economic systems (see elements of principles III–VI). While critical of previous approaches to 'sustainable management' of such resources, the authors nevertheless accept that the concept of 'conservation' must go beyond a strictly preservationist approach. In particular, the emphasis placed on the social aspects (e.g. by including the interests of all stakeholders and users; see principle VI), as well as reliance on the economic viewpoint (e.g. through the consideration of property rights and land tenure; see principle IV), support this contention.

In this context, two recent publications (Hanna and Munasinghe, 1995a, b) highlight several points relating to the critical and interactive role played by stakeholders and property rights in the use of natural resources. First, the effectiveness of the governance of environmental resources depends on the degree of match between socio-economic and ecological systems, especially in terms of scale. Coordination and consistency of governance regimes across scales is also important. Second, the degree of equity in property rights regimes tends to create incentives that could either improve or worsen environmental stewardship, which in turn will affect the resilience of ecological systems. Third, some current resource management problems could benefit from lessons learned from traditional resource management systems and ecological knowledge resident in indigenous cultures. Fourth, the absence of feedback linkages between environmental and social systems leads to overuse of the former. Governance regimes which enhance feedback information concerning environmental damage, and speed up human behavioural responses, help to limit such damage. Finally, poverty, population pressures and degradation of environmental resources are linked in complex ways (see below).

Sustainability of ecosystems across different spatial and temporal scales

The paper correctly advocates the need to maintain biodiversity at the genetic, species, population and ecosystem levels (principle II). It is interesting to explore the sustainability implications of the wide range of spatial and temporal scales that characterize these various levels of biodiversity (see, e.g., Munasinghe and Shearer, 1995).

An operationally useful concept of sustainability must refer to the persistence, viability and resilience of organic or biological systems, over their 'normal' lifespan. In other words, the lifetime of purely physical entities (e.g. a proton or the Milky Way) are not especially relevant to a discussion of sustainable development. In this ecological context, sustainability is linked with both spatial and temporal scales, as shown in Figure 1 (Munasinghe, 1996). The x axis indicates lifetime in years and the y axis shows linear size (both in logarithmic scale). The central dot represents an individual human being having a longevity and size of the order of 100

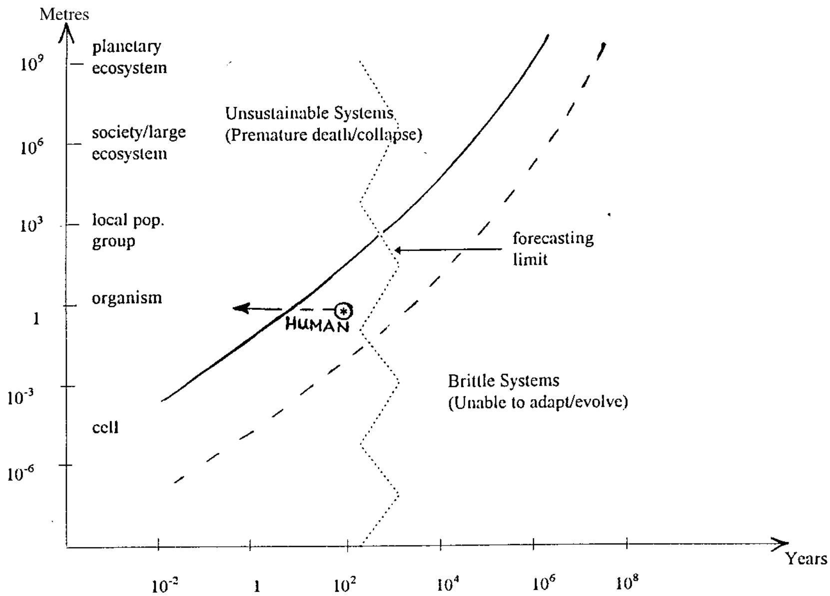

Figure 1. *Spatial and temporal aspects of sustainability. Source: Munasinghe (1996).*

years and 1 metre, respectively. The diagonal band shows the expected or 'normal' range of lifespans for a nested hierarchy of living systems starting with single cells and culminating in the planetary ecosystem. The bandwidth accommodates the variability in organisms as well as longevity.

Environmental changes that reduce lifespans below the normal range imply that external conditions have made the systems under consideration unsustainable. In short, the region above and to the left of the normal range denotes premature death or collapse. At the same time, it is unrealistic to expect any system to last for ever. Indeed, each subsystem of a larger super-system (such as single cells within a multicellular organism) generally has a shorter lifespan than the super-system itself. If subsystem lifespans increase too much, the encompassing super-system is likely to lose its plasticity and become 'brittle', as indicated by the region below and to the right of the normal range. In other words, it is the timely death and replacement of subsystems that facilitates successful adaptation, resilience and evolution of larger systems (Holling, 1973).

We may summarize the foregoing by arguing that sustainability requires biological systems to be able to enjoy a normal lifespan and function normally, within the range indicated in the figure. Thus, leftward movements would be especially undesirable. For example, the horizontal arrow might represent a case of infant death, indicating an unacceptable deterioration in human health and living conditions. However, extended longevity involving a greater than normal lifespan would not be a matter for particular concern.

In this context, the conservation requirement set out in the paper with regard to the larger-scale systems seems ambitious from a practical standpoint; for example, such systems will require long-term predictions, and forecasting up to a timescale of even several hundred years is rather imprecise. Thus, it is important to improve the accuracy of scientific models and data, in order to make very long-term predictions of sustainability (or its absence) more convincing, especially in the context of persuading decision-makers to spend large sums of money to reduce unsustainability. One way of dealing with uncertainty, especially if the potential risk is large, relies on a precautionary approach, i.e. avoiding unsustainable behaviour while studying the issue more carefully (as advocated in principle II).

Per capita consumption, population and natural resource degradation

The last sentence in the first paragraph under principle I asserts that 'the only practicable way to reduce human per capita resource demand is to stabilize and then decrease the human population' (p. 43). This proposition is misleading and detracts significantly from the overall content of the paper. No convincing evidence exists to link *per capita* natural resource demand with population size. Even the link between *total* resource use and population is complex and cannot be captured adequately by a simple statement.

First, as somewhat belatedly admitted later in the paper, high levels of per capita consumption are as much to blame for resource depletion as is simple population growth. By focusing exclusively on population control at the outset, the sentence establishes a bias. In a world where a mere 15 per cent of the world's population in the high-income economies consume over sixteen times as much as the almost 60 per cent of global population in the low-income countries (and will do so for the foreseeable future), the growth rates both of per capita consumption and of population should be matters of far greater concern among the former group than the latter (see World Bank (1996) for per capita income data). In this respect, the paper seems to adopt a rather 'Northern' and polemic viewpoint on a sensitive South–North issue, perhaps inadvertently (and not surprisingly, given the preponderance of Northern authors). This is likely to distract, if not reduce the impact of the paper on Southern audiences. Such an outcome would be unfortunate, since the rest of the paper does make an important contribution, and the great bulk of the world's biodiversity does lie in the developing countries.

Second, environmental degradation, population and poverty are known to form a nexus with complex interactions. The poor are the most frequent victims of both pollution and resource degradation. At the same time, there are circumstances in which the landless poor are forced to encroach on fragile lands, eventually degrading their environment (see, e.g., Munasinghe and Cruz, 1994). Population growth itself depends on many factors, including not only the highly visible elements like family planning programmes, but also deeper underlying factors such as education level (especially of women), the status of women, family income, access to basic needs and financial security (Dasgupta, 1993). Thus, the paper misdirects attention by unduly highlighting a simplified direct link between population growth and the loss of wild living resources.

Third, a simple mathematical exposition suggests that the relationship between population and damage to natural resources is not necessarily as straightforward as asserted in the paper. Consider a society which has a population P and a stock of wild living resources W. One useful indicator of the sustainability of wild living resources would be the ratio $R = W/P$. More specifically, one might seek a development path in which this ratio was non-decreasing.[1] Thus, sustainability would require that $dR/dt \geqslant 0$. A more convenient sustainability criterion may be defined as:

$$S = (dR/dt)/R = [(d/dt)(W/P)]/(W/P) \geqslant 0.$$

It is possible to decompose the measures S to show the distinct effects of growth in resource stocks and growth in population. Assuming that $W = W(P,t)$ and $P = P(t)$, we obtain:

$$S = [(\partial W/\partial t)/W] - \{[(dP/dt)/P][1 - e]\}; \text{ where } e = (\partial W/\partial P)/(W/P).$$

Clearly, the first term [...] is positive if $(\partial W/\partial t) > 0$; that is, S rises as wild living resource stocks increase over time, holding population constant. However, the sign of the second term {...} depends on the signs of both (dP/dt) and $(1-e)$. Thus, reducing the population $(dP/dt < 0)$ will increase sustainability S, only if $e < 1$. The opposite condition $e > 1$ is more likely to prevail if W/P is low to begin with and $\partial W/\partial p$ is relatively high: for example, if mild population growth stimulates greater efforts towards protecting and increasing resource stocks. One example might be a community living in an arid area. If the human population dwindles, the natural progress of desertification could well proceed unimpeded. By contrast, a growing and thriving population (with increasing income levels) is likely to devote more efforts towards environmental protection, ensuring that the condition $e > 1$ is maintained.

The foregoing argument may be summarized as follows. While it is 'fashionable' to automatically assume that people are a threat to natural resources, it is also possible to make a case for considering human beings themselves as a valuable resource that will help to ensure a higher level of sustainability of natural resource stocks. In other words, human attitudes towards the environment and their patterns of economic activity are at least as important as the number of people.

We conclude by observing that if both per capita resource demand and population are examined more even-handedly, some promising options for conservation of wild living resources may emerge. The general context of the discussion is that economic growth is a prime imperative for developing countries, especially ones with large numbers of poor and destitute people. Recently, several researchers have postulated the existence of a so-called environmental Kuznets curve along a country's development

[1] More generally, if the greening of the system of national accounts permits the measure of national wealth to be redefined to include the value of all stocks of living and non-living resources, as proposed in Scott (1956) and Hamilton (1991), then total wealth per capita becomes a useful indicator of overall sustainability. If this ratio is non-decreasing, then development is sustainable (or *weakly* sustainable, since it is assumed that produced assets are highly substitutable for natural assets).

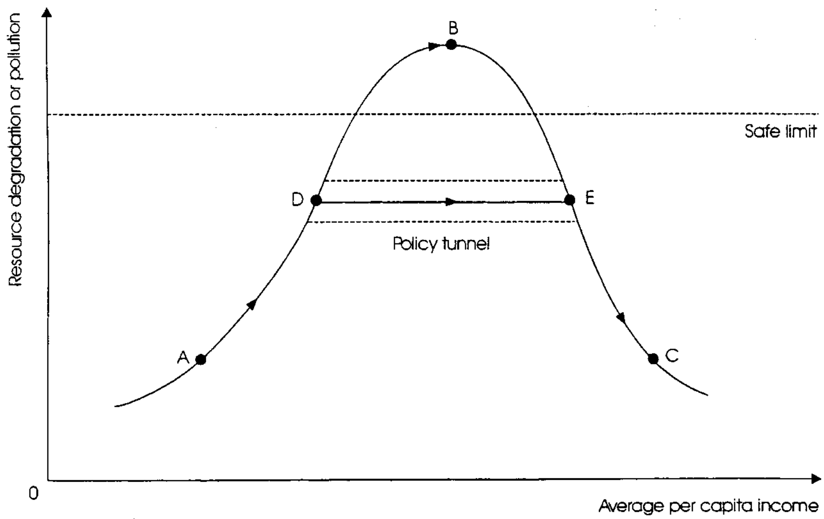

Figure 2. *Tunnelling through the environmental Kuznets curve. Source: Munasinghe (1995).*

path—where resource degradation will increase initially with per capita income growth and then eventually decline, thus exhibiting the characteristic inverted-U shape shown in Figure 2.

Suppose that we graph some measure of the depletion of wild living resources along the vertical axis, against income per capita (conventionally measured).[2] For example, Panayotou (1995) has shown such a relationship between the rate of deforestation and income per capita, using cross-sectional empirical data from forty-one tropical countries. The key policy conclusion is that even if such a curve characterized past growth, there is no reason for developing countries passively to accept 'historical determinism' along their future development path. Thus, a poor country starting at A need not feel obliged to pass through the peak of environmental degradation at B, in order to reach C. The effective articulation of growth-oriented policies with appropriate complementary measures that address (a) policy distortions, such as subsidized prices for resources used in production, (b) market failures, such as pollution externalities, and (c) institutional constraints, such as inadequately defined property rights, could help to alter the structure of growth and limit environmental harm (Munasinghe and Cruz, 1994). In effect, lower-income countries could learn from the experience of wealthier nations and adopt policies that permitted them to 'tunnel' though the curve (along the path DE in Figure 2). By staying within the safe environmental limits, much of the biodiversity would be conserved, while income per capita rose. This might not be the

[2] Some researchers have argued that if national income was correctly measured—for example, by adjusting for environmental effects using 'green national accounting'—then the environmental Kuznets curve phenomenon would disappear.

case if the conventional path ABC was followed, e.g., it might imply initial destruction of primary forest areas which would be reafforested much later with secondary growth, as in many developed countries.

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Marine fisheries: two macro-constraints

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The article in question deals primarily with wild living resources in the oceans, so this critique confines itself to the marine realm. It does not take issue with the main arguments presented, which are fine by and large. Rather, it expands on the overall theme by raising two further dimensions of the conservation challenge.

1. Ecosystem-level disruptions

As the paper emphasizes, we need to give much more attention to ecosystem-level disruptions. Yet we know all too little about ocean ecosystems, let alone the environmental impacts of what we are doing to them, especially in terms of pollutants.

Water-borne contaminants are thought to have been involved with the 1987–8 deaths of perhaps 50 per cent of dolphin populations along eastern shorelines of the United States. The creatures died ostensibly because they had been weakened by pollutants, whereupon they became all the more susceptible to viruses and bacteria (Joyce, 1989). During the same period a number of belugas or white whales died in the St Lawrence estuary, their bodies revealing high concentrations of DDT, PCBs, mercury, cadmium, carcinogenic chemicals and other toxins, causing most of the whales to succumb ultimately to septicaemia. Further north many humpback whales died too, partly at least because of eating mackerel containing toxic algae. Also during the same period, perhaps two-fifths of seals in the Baltic and North Seas died because of rampant viral disease and bioaccumulative pollutants (Brown, 1994). In addition, there have been more than forty tumour epizootics in fish populations of the United States seaboard, over half of them involving liver neoplasms, a tumour type associated with pollutants. In similar fashion, half of all marine turtles examined in the Caribbean and Pacific have revealed tumours (Fowler, 1990).

There has been a whole series of further die-offs of marine fauna attributable to heavy metals, toxic chemicals and other lethal pollutants (Stigliani *et al.*, 1991; Colborn *et al.*, 1996). Serious as they have been, they are surely a small portent of what lies ahead. Coastal zones are highly favoured for settlements by human communities, with often deleterious effects for offshore marine communities. The Caribbean Sea, for instance, is where one-sixth of the world’s oil is produced or shipped. Supertankers, plus offshore oil rigs, inject more than 100 million barrels of oil into the sea each year.

In recent years too, there have been several near-shore phytoplankton blooms. The number and extent of these blooms seem to be increasing.

Episodes have occurred around Europe, along the United States' east coast, in the western Pacific and in the Indian Ocean. The cause seems to be nutrient-loading through anthropogenic emissions of nitrogen and phosphorus, possibly in conjunction with toxic chemicals (Anderson, 1994).

Yet another disruption lies with the 'bleaching' of coral reefs, manifested through a series of episodes since the early 1980s, notably in the Caribbean but also around Taiwan, the Maldives, Australia and Hawaii, indeed in virtually all tropical waters that feature coral reefs. The bleaching causes extensive morbidity and mortality throughout coral communities. The causes probably lie with global warming or white-band disease, or the two working in synergizing unison, perhaps together with other catalyzing factors (Goreau and Hayes, 1994). Like the other die-offs, these bleachings surely represent a whole chorus of 'marine canaries' warnings of something widely amiss in marine ecosystems.

Then there is the disruption to ecosystems stemming from human exploitation, or overexploitation, of marine species. Through their fish harvests, humans are already accounting for 24–35 per cent of all diatom production in coastal and continental-shelf sectors of the marine realm (Pauly and Christensen, 1995). Again, this must have major repercussions for associated biotas in the seas, though regrettably the situation has not been appraised in any but preliminary terms.

A still more disruptive factor lies with the warming that is already overtaking the oceans—a probable harbinger of the greenhouse effect. Water temperature has a profound influence on food stocks. Colder sectors of the oceans, notably areas of upwellings where currents meet, are exceptionally productive; and these areas are utilized by many mammal and bird species as well as fish species for seasonal if not year-round feeding (Klinowska, 1989). One might suppose that those species (whales, birds) that are accustomed to roaming widely around the oceans could readily migrate in response to global warming. But the situation may not be so straightforward (von Bismarck *et al.*, 1996). What if the environmental circumstances to which these communities are adapted cannot be replicated elsewhere?

Consider the case of krill, which plays a key role in the food chain of the greatest aggregation of whales, seals and seabirds in the world, located in the Southern Ocean. A single hectare of the Southern Ocean can sustainably produce more than one tonne of animal protein per year in the form of krill, while total krill productivity is around 250 million tonnes per year, or well over two-and-a-half times the annual yield of the world's fisheries. This phenomenon reflects a number of localized conditions, notably the convergence of warm and cold currents in the Southern Ocean, leading to a nutrient-rich upwelling around the shores of Antarctica. Under the impact of the greenhouse effect, the site of the currents' convergence would need to move southwards. It would be unable to do so, because of the Antarctic land mass in the way. How far the upwelling would continue anyway, with a much warmer current from the north washing up against a somewhat warmer current in the south, is difficult to say. But the upwelling, with all it means to krill productivity and dependent communities, could be significantly disrupted.

Apart from temperature increase, a number of other physical changes predicted for the oceans in a globally warmed world have the potential to drastically influence marine biotas. Such physical changes include shifts in salinity, pH, turbulence, storms, sea ice and global circulation patterns. Moreover, it is likely that multiple and macro-level changes will not overtake the oceans in linear and readily predictable fashion. Rather, the record shows that climate change generally and ocean reactions in particular tend to occur in irregular fashion, often through a series of leaps (Broecker, 1987).

These 'jump effects' and their threshold responses, with potential breakpoints of irreversible injury to marine ecosystems, occur when environmental conditions change in a manner or on a scale and with a speed to which ecosystems are not adapted. They may well have been absorbing ecological stresses over a long period without much outward sign of damage, until they reach a disruption level at which a jump event becomes increasingly likely and ultimately inevitable. Alternatively stated, the stresses build up covertly over a number of years, before suddenly revealing themselves with critical impact. When the stresses are removed, the ecosystem may not return to its former equilibrium state, no matter how much we may try to restore the injury. Instead it may well settle into a new equilibrium, one that could be less appropriate for marine biotas.

Another pronounced change for ocean ecosystems could stem from depletion of the ozone layer. Every 1 per cent loss of ozone allows roughly 2 per cent more UV-B light to reach Earth's surface. The radiation over much of the Southern Ocean could rise by 5–20 per cent, even as much as 50 per cent, early next century, together with smaller losses elsewhere (Machijani and Gurney, 1995). Increasing radiation slows the process of photosynthesis in phytoplankton in the oceans' surface layers. Just a 5 per cent increase can cut their lifetime by half, while a 10 per cent increase causes them to die off almost entirely (Hoffman, 1987; Kerr and McElroy, 1993). Indeed, few groups of organisms are more susceptible to UV-B injury than phytoplankton.

A phytoplankton decline would be especially harmful in the rich marine ecosystem surrounding Antarctica, precisely the area where UV-B radiation may be most pronounced due to the ozone hole. Were the phytoplankton to decline, the herbivorous krill would be immediately affected—and then the many other creatures that depend upon krill, namely, fish, squid, penguins, seals, whales and other animal life in the Southern Ocean.

All this would be imposed, moreover, on ocean ecosystems that have already been grossly disturbed. After the great whales of the Southern Ocean were drastically reduced in numbers, other krill-eaters multiplied and moved in to fill the ecological space. Today krill is consumed by an increased abundance of smaller whales (minkes), seals (notably the crabeater seal) and seabirds (notably several penguin species), plus humans. In the year 1900 the great whales were probably consuming 190 million tonnes of krill per year, but today they are estimated to account for only 40 million tonnes. Meanwhile seals have increased their numbers, expanding their consumption of krill from 50 to 130 million tonnes per year, and seabirds roughly the same (El-Sayed, 1994; Safina, 1997).

In addition, a phytoplankton decline would carry marked consequences for phytoplankton's role in the global carbon cycle. The oceans are thought to absorb about half of all carbon emitted into the global atmosphere each year, a prime part being played by the photosynthetic activities of phytoplankton. Were their communities to be unduly depleted, their carbon-take-up capacities would in turn be reduced. In turn again, this could lead to less carbon being absorbed at the oceans/atmosphere interface, with all that could mean for the scope and onset of the greenhouse effect—with, in turn yet again, all manner of further repercussions for marine ecosystems generally.

2. Perverse subsidies

Marine fisheries are strongly characterized by what can be called perverse subsidies, viz. subsidies that exert adverse impact in the long run on both the economy and the environment (Myers, forthcoming). The fisheries produced a harvest in 1994 of 84.5 million tonnes, down from a peak of 86.4 million tonnes in 1989. The decline, which has reportedly continued through 1996, is regrettable from economic and environmental standpoints (see below), and through several sociocultural factors. Some 20 million fishermen and their families, or as many as 100 million people, depend on sea fishing for their livelihood. Seafood is the source of half of all animal protein consumed by humans, supplying greater amounts of animal protein for human consumption than do beef and poultry combined (FAO, 1995; see also Norse, 1993; Weber, 1994).

Since 1950 the world's marine fish catch has increased almost fivefold. But a steady forty-year growth appears to have topped out and even declined from the 1989 peak. If the catch were measured by value instead of by weight, the decline would be even more marked: as the most valuable stocks are fished out, fishermen tend to hunt other, less valuable species. Marine fisheries as a whole are considered to be exploited 20 per cent beyond what is currently sustainable, and most fisheries are in serious decline or commercially extinct (Holden, 1994; Van Dyke *et al.*, 1994; FAO, 1995).

Prominent among the reasons for this regrettable situation are perverse subsidies. Once fishermen's livelihoods are in danger through overfishing, governments provide plentiful incentives for them to catch still more rather than fewer fish, thus exacerbating the problem. State supports help to pay for more and larger boats, longer nets and more sophisticated equipment all round, even extending to radar and remote-sensing devices.

The 1994 catch was worth $70 billion at dockside (Safina, 1995). Yet the fishing effort to land the catch—boats with their crews, equipment, etc.—cost $124 billion. The difference between that figure and the value of the catch, viz. $54 billion, was almost entirely made up of government subsidies, notably price controls, fuel-tax exemptions, low-interest loans, and outright grants for gear and other infrastructure (Safina, 1994; Weber, 1994; Thorpe *et al.*, 1995).

These subsidies are supplied largely to preserve fishermen's jobs. Regrettably, they have long induced investors to finance more industrial fishing ships than the fish stocks could possibly sustain. During 1970–90, the world's fishing fleet grew at twice the rate of the global catch, doubling in both ships' numbers and tonnage. This armada finally achieved twice the capitalized capacity needed to extract what the oceans could sustainably produce, being an amount at least 20 per cent less than today's harvest.

Because this excessive capacity has rapidly depleted fish stocks, profitability has plunged, reducing the value of ships on the market. Unable to sell their chief assets without major financial loss, owners of the vessels keep on fishing, or rather overfishing, in order to repay their loans. They are caught in an economic trap. In response, they have mobilized enormous political pressure on governments to refrain from cutting fishing quotas (FAO, 1995; Safina, 1995).

The economic costs are substantial. If, in the case of the United States, the principal fish species in question were allowed to rebuild to their long-term potential, sustainable harvesting would add $8 billion to the US economy and provide some 300,000 jobs. Within US federal waters, today's catch is worth only half what it would be if fish stocks were allowed to recover. The worldwide loss through fisheries decline is reckoned to be $15–30 billion per year. If fish populations were restored and properly managed, at least 20 million tonnes, or 24 per cent of the 1994 marine catch, could be added to the annual harvest (FAO, 1995).

Fortunately, there are signs of some improvement in the situation. Iceland has recently cut back its domestic fishing by 50 per cent. The European Union is planning to decommission 40 per cent of its fishing vessel capacity, whereupon its fisheries could, if allowed to rebuild, eventually yield a further $2.5 billion worth of fish a year. At present the Union spends nearly $600 million a year on fishing subsidies, almost all of it to expand the already bloated fishing fleets. Why not use the $600 million to retrain fishermen who are put out of work through reduced catches—whether reduced through declining stocks or through policy shifts?

Similarly, the Canadian government is spending almost $1 billion to supply other employment for its 35,000 fish workers laid off through a government effort to restore depleted fish stocks. If governments feel politically obliged to make payments to their fishermen, they would do far better to create incentives such as retraining for alternative employment than to foster ever-greater capacity to chase ever-fewer fish (Weber, 1994; Cairncross, 1995).

At the same time that governments cut back on subsidies, they could issue a limited number of tradable fishing rights to individual fishermen. Not only would this help to curb overfishing and boost fishermen's incomes. It would mean that those persons obliged to leave the industry would receive implicit compensation by being able to sell their rights to those who remain. This approach has been tried with some success in Australia and New Zealand (Safina, 1997).

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Through privilege and precaution: rediscovering the conservation ethic

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Social change is rampant. Cities expand. Industries displace farmers. The hinterland's limited resources fuel a growing population's appetite for more goods. Some observers recognize, however, that the very social, political and economic fabric is at risk. A warning bell sounds. Among those sounding the alarm are economists, engineers, sociologists, natural scientists, administrators, health practitioners, philosophers and politicians. The programmes they advocate are wide-ranging, impinging on immigration, trade, industrial development, child labour, food quality, and corporate structures. A new crusade to save the environment begins.

Where and when are we? Perhaps surprisingly, this describes turn-of-the-century America, from 1890 to 1920, when the Conservation Movement experienced its golden age as a political force.[1] Westward expansion had reached its physical limits. The movement pursued, as an ideal, doctrines that promoted what we today might call 'sustainable development'. It was in those conditions, almost a century ago, that US President Taft stated, 'A great many people are in favor of conservation, no matter what it means'.[2] Conservation had become a matter of the highest personal ethics. The Conservation Movement showed, if nothing else, that a strong conservation ethic was a sufficient (and probably necessary) condition for promoting social change.

Muddling through this century, however, we find that the 'conservation ethic' has often been eclipsed by a predilection for fancy 'conservation tools'. In many respects, the 1978 Principles for the Conservation of Wild Living Resources (Holt and Talbot, 1978) generated unprecedented interest in the tools of conservation. The 1978 principles, which were relatively simple and invoked objectives such as 'ecosystem maintenance', 'maximization of consumptive and non-consumptive values', 'minimization of risks', 'establishment of safety factors', and 'avoidance of wasteful use', challenged us to find policy tools that could meet these objectives. And our toolkit expanded profoundly. We have seen attempts to achieve maximum sustainable yield. We have seen debt-for-nature swaps, en-

[1] Historical accounts of the Conservation Movement are discussed in some detail in Osborn (1948), Cross (1953), Hays (1959), and Barnett and Morse (1963).
[2] *Outlook*, 14 May 1910, p. 57 as cited by Ise (1920: 373).

vironmental taxation, and tradable quotas. We have seen privatization of national parks. We have seen buffer zones and we have seen restrictions on international trade. Examples of the tools of conservation surround us: they have become the gadgetry of the conservation ethic.

But we have also seen continued failure to meet the objectives inherent in the 1978 principles. Ecosystems are not being maintained, safety factors are ignored, species extinction persists at an unprecedented level, and our very global life-support systems are under threat. In many developing countries, the depletion of wild resources exacerbates poverty and inequality (Lonergan, 1993; Ruitenbeek, 1996). Moreover, conflict and political unrest is becoming increasingly linked to ecological degradation (Homer-Dixon, 1991). Either we have been using the wrong set of tools, or we have been using the right set for the wrong objectives. A re-examination of both the tools and objectives of conservation was in order, and the 1992–4 consultations by the Marine Mammal Commission provided a needed forum.

The opening description of turn-of-the-century America might also describe almost any developing country in turn-of-the-millennium Earth. The parallels seem conspicuously similar. It would therefore be gratifying if the 1996 principles of Mangel *et al.* formed the basis for a New Conservation Movement, in which the principles became a platform for political change that embodied conservation as an underlying *ethic*. Are the 1996 principles up to such a monumental task?

The short answer is, ‘Probably not.’ An important addendum, however, is that the 1996 principles *do* provide some hitherto ignored (or perhaps underemphasized) opportunities for rediscovering the conservation ethic.

Conservation tools

Much of the *stated* rationale for developing new principles had to do with the failure of the 1978 principles to see effective implementation. The 1996 principles therefore provide a very ‘tool-oriented’ approach, which to a large degree is intended to complement the 1978 principles. Indeed, the range of conservation tools discussed in Mangel *et al.* is incredibly broad—it ranges from population policy to environmental monitoring—and this in itself is quite welcome as an acknowledgement of the interdependence of disciplines.

We can recognize, within the 1996 principles, a number of important management and planning tools that have been gaining favour in both the theoretical and applied literature. Among these are:

1. *User-pays principle*. ‘Require those most likely to benefit directly from use of a wild living resource to pay the costs of [information acquisition and management]’ (p. 53).

2. *Precautionary principle*. ‘Long-term persistence of the resource has to receive the benefit of the doubt whenever uncertainty exists: uncertainty is a warning to exploit cautiously’ (p. 54).

3. *Valuation*. ‘The values that living resources have to society incorporate all possible uses, including their existence value as components of an intact ecosystem’ (p. 55).

4. *Harvesting to gain information*. '[T]o predict the effect of certain harvesting strategies, it may be necessary to harvest' (p. 51).

All of these tools are important components of a strategy that is intended to conserve wild living resources. This 'tool-like' orientation is manifest not only in specific recommendations. Indeed, the entire set of 1996 principles may be regarded as at tool. Mangel *et al.* point out that 'These principles are guidelines ... The mechanisms are not protocols ... but a check list of key questions that must be addressed.'

Checklists are useful, and this checklist is among the most comprehensive and well thought out we have seen in a long time. But checklists often suffer from a common failing: they provide little guidance in priority-setting. Generally, the longer the checklist, the more likely it is that it will result in contradictory prescriptions. For example, the direct and immediate action that may be necessary to protect a threatened ecosystem under principle II may be completely inconsistent with the prolonged participatory consultation process implied by principle VI. In developing countries, such potential inconsistencies may be only a minor inconvenience. Enough money may be thrown at a problem, to consider the breadth and depth of all items on a checklist, and stakeholders may be reasonably satisfied that there are adequate checks and balances in decision-making structures.

But the story is quite different in many developing countries, and it will be a significant challenge to implement these principles. Where financial and human resources are scarce, and where institutions and public accountability are weak, it will not generally be possible for countries to work their way through the checklist. Even if a good attempt is made, it will not always be clear how to interpret conflicting prescriptions from different tools. Many developing countries, for example, have tried their hand at resource accounting. It has typically taken between five and ten years to gather information and put some modest institutional capacity in place to interpret these data; but policy prescriptions arising from this information often differ. Under such circumstances, the policy outcomes may depend critically on which tools one uses, or on which of the seven principles one concentrates. From a developing-country perspective, it then seems reasonable to ask, 'Are any of these principles more important than the others?'. The authors, unfortunately, make no such prescriptions.

Conservation ethics

I presume that the reason for not setting priorities is simply that it would have required too great a value judgment. Mangel *et al.* state, for example, that 'scientists must take extreme care to differentiate between scientific fact and value judgment', and there is a persistent reluctance throughout the article to proffer value judgments. Some will regard this as noble objectivity while others will no doubt regard it as scientific cowardice. The one advantage to this position, however, is that we can presumably accept the first sentence of the article, 'The natural world is in crisis,' as scientific fact. The moral gravity of this crisis is then a topic for philosophical, as opposed to scientific, debate.

Although the 1996 principles have little explicit to say about such moral judgments, they do provide some potential entry points. In my view, the article implies two such entry points that might receive higher priority in developing countries:

1. *The ethic of privilege.* Mangel *et al.* assert that ‘the concept of a “right to the resource” must be changed to the “privilege to use the resource” ’ (p. 49). This change in the treatment of resource ownership may well be the single most important shift in thinking that any society can make.

2. *The ethic of precaution*. The article, in multiple guises, prescribes strategies that involve the ability to accommodate uncertainty: ‘use must be delayed or curtailed to protect the resource’ (p. 49); ‘It is generally appropriate to assume that, until proven otherwise, use of wild living resources will have unacceptable effects on both the target resource and on other components of the ecosystem’ (p. 51); ‘Resource management should be adaptive, not prescriptive’ (p. 57). This shift in focus from ‘deterministic’ systems to ‘uncertain’ systems provides scope for a precautionary stance in all decision-making.

The challenges to developing countries in embracing these ethics may seen insurmountable. Property-right regimes are in shambles in many developing states. Current institutional frameworks often tend to reward ‘non-adaptive’ management that is easily monitored through well-defined indicators. Innovation is not usually rewarded, and delays are discouraged. How, in such a context, can such ethics (or the tools implied by such ethics) grab a foothold? Two opportunities present themselves.

First, there are attempts in many developing countries to rationalize property rights; these provide new opportunities for introducing the concept of ‘privilege’. In Indonesia, for example, forest licenses were withdrawn in record numbers when rehabilitative efforts were not followed to the letter by licensees. Throughout the developing world, common-property regimes are replacing ‘open access’ regimes in attempts to improve stewardship.

Second, reforms associated with political decentralization provide opportunities for introducing adaptive institutions at local levels. This decentralization, which typically involves increasing the political or economic autonomy of states or towns, has commenced in many developing countries and will likely continue over the coming decades. In some cases, the new institutions are simply smaller versions of the centralized models. In others, the new institutions may be more closely modelled on traditional structures, such as Ghana’s chieftaincy systems. In either event, the fresh starts offer opportunities for introducing precautionary approaches to resource management that may have been difficult under previous institutional structures.

Neither of these opportunities—property-right reforms and political decentralization—exist in most developed countries. Property-right regimes tend to be well entrenched and, more often than not, we are in a position of dismantling rather than creating new institutional structures. The best opportunity to rediscover the conservation ethic may therefore belong to developing countries.

In closing, while on a recent trip to India, I discussed the 1996 principles with a number of Indian colleagues. Shri V.K. Mistra, the Managing Director of the National Tree Growers Cooperative Federation, remarked that, 'the 1996 principles should be easier to implement in developing countries than elsewhere, because people in developing countries inherently have a stronger conservation ethic'.[3] If he is correct, then a New Conservation Movement may indeed take hold.

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The principle of fair sharing of costs and benefits from conservation is missed elsewhere

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The starting-point of the paper by Mangel *et al.* is the threat to wild living resources, occurring at increasing rates, and its negative effect on human conditions which depend directly upon a 'sound and functioning natural environment' (p. 41). Based on this assumption, the paper develops well-known conservation principles for ensuring an appropriate balance between ecosystems health and quality of human life.

Working with principles, the paper does not seek to provide either a full diagnosis of the scale and scope of this threat to the natural world or normative proposals on specific ecological problems.

[3] Personal communication, 14 October 1996, Anand, India

Although these principles are to some extent already recognized by those engaged in conservation measures, the paper is a comprehensive approach to them. The most important aspects of the difficulties of designing and applying conservation measures are dealt with in detail.

One may also point out the principles behind these principles. That is, the lack of quantitative, local and specific aspects of wild living resources conservation requires the recognition of underlying principles to define these broader conservation principles. The authors seem very comfortable with these underlying principles, which cut across all seven conservation principles, and which can be identified as follows:

- Human population growth is the major driving force for the increasing depletion of wild living resources.
- Securing wild living resources for present and future generations is the most important goal for their conservation.
- Uncertainty about the ecological and social effects of the depletion of wild living resources requires the adoption of precautionary measures.
- Scientific appraisal, even if it is carried out with a multidisciplinary approach, cannot displace democratic political debate.
- Regulation of conservation must take into account social (here with a broader economic meaning) factors by consensus-building, information-sharing, institutional strength and external review.

There are, however, important issues, not covered by these principles, which deserve attention in order to make them more useful for setting up general guidelines for conservation efforts.

The paper is not precise about the relationship between consumption and population growth trends. It concentrates on the growth of a local population directly 'consuming' wild living resources, rather than the consumption pattern adopted in the rich regions, of importing sustainability by indirect consumption of natural goods and services. Although the authors sometimes recognize this, population growth is always the key phrase to specify depletion's driving forces. The last sentence of the first paragraph of principle 1 either states that or it is really misleading. Population growth in highly populated countries is always emphasized as being a critical problem, whereas the same deep concern is not shown for growing consumption levels in rich societies. As a principle, such an imprecise balance has to be further developed. It must be noted that this differentiation between regions in terms of natural capital consumption is usually found within a country and not only between countries.

There is no dispute about the importance of securing wild living resources for the people of today and tomorrow. The current generation can pursue conservation patterns which ensure critical ecosystem functions for future generations. The paper itself is about just that intertemporal equity issue. However, no mention whatsoever is made of the differences between people in the current generation. While the future generation may be seen as something like a homogeneous and collective resource owner, differences among contemporaries cannot be avoided in terms of property rights and resulting costs and benefits. The preservation of people X's natural assets generates benefits and costs for people X and quite often a large and free benefit to other peoples. This issue is only addressed in one single, simple example in principle VI.1, in order to illustrate property rights assignment in a context of affordability. In this Chinese example, of the conservation of giant pandas, worldwide financial support is 'reasonable' since local people are poor and not because rich people are free riders. Intragenerational equity is invoked rather than efficient criteria for bearing the conservation costs.

Knowledge of the ecological and social effects of the depletion of natural assets is the key factor for determining the criticality of a resource and, consequently, for defining the resulting conservation measures and cost-sharing. Therefore, uncertainty cannot be a principle but is rather the question at which the principles are aimed. To stress the need to take uncertainty into account is just to get back to the primal question and not a guide to conservation measures. If a society is unsure that a resource is critical, can it apply the precautionary principle?

As the paper discusses, science and political debates have to be pluralistic and participative. However, stakeholders must reach a conclusion about criticality if participation is to lead to a solution that resolves conflicts. Precautionarity is closely linked to criticality, otherwise stakeholders cannot reach agreement. At some stage during the best participative practice, people have to be assertive on criticality and minimize precautionarity.

That is particularly true when one agrees with the paper's major point about taking account of social factors for regulation. This point takes the paper's perspective away from traditional preservation to a more realistic conservation view. Regulation is, therefore, the ultimate result of conflict resolution. Whether this is control- or market-oriented, the paper confirms that governments have a duty to enforce regulation contracts in order to maintain critical ecosystem functions. Consequently, strong institutions have to be built to design and apply regulation.

However, people's different perceptions of the values of natural assets and their services cannot be denied. Welfare is a matter of economic perception. Time preference and the bundle of current goods making up welfare perception vary between communities.

A community in which basic needs are already attained can easily change its current consumption pattern of natural services and perceive a growing value in time for them. Rate of exploitation and criticality, as basic economics tells us (and it cannot be easily challenged in this particular), will be dependent on these economic perceptions about natural assets and their substitutes in production and consumption in time.

However, low-income communities are not dependent on natural assets for their own sake. They do not deplete wild living resources through stupidity or lack of intertemporal concerns. In fact, they understand their equity dilemma very well. They are there at the frontier because of lack of opportunity. Rich communities have reached mature ecological consciousness, with sound ecological regulation, only after reaching acceptable welfare levels or after overcoming critical levels of well-being. This does not mean that there is such a thing as the inverted-U curve dictating conservation efforts, but only that the social system as a whole has to be acceptable before conservation conflicts may find ways to reach solutions in a participative manner based on a high value perception for the environment. The sad side is that many communities may fail to solve their intertemporal dilemma since critical ecological functions can be depleted in the struggle to achieve the critical welfare level. A smoother way to solve the conservation conflict may never occur.

Bearing this in mind, we should pose ourselves other questions:

- How can these communities build scientific and institutional strengths to deal with that intertemporal challenge if the current social environment is the source of scientific and institutional weakness?
- Can we properly address the issue of conservation by conservation measures alone?
- Do the answers for conservation arise only from conservation regulation?
- Can we preserve the natural environment without changing the social environment?

Whether in the context of of developing countries or developing regions within a country, what we see today are external agencies filling the gap in the fragile scientific and institutional base of the poor communities, in which stocks of wild living resources are still large and, consequently, at increasing rates of depletion. Despite what is often their good faith and goodwill, they are fixing up their environmental agendas. These agendas cannot reflect social factors and ecological constraints since external donors cannot easily understand local needs and the environment from which participative mediation should arise. Apart from specific well -documented cases, the results are always the same: no conflict solution, no institutional strength and no regulation enforcement.

External agencies and donors could do more for conservation where scientific and institutional strength are lacking. Their best option could be to look more at the sources of ecological losses from the social environment and put free financial resources at the disposal of these local communities to control the ecological implications. That is, more effort should be devoted to the social environment and less emphasis given to conservation programmes and projects. These activities could be funded through compensation from rich countries in return for environmental services captured by them, rather than by ecologically correct donations.

A local community which sees a school, a water system, a hospital or any other welfare gain from proper and just valuation of its natural assets, resembling external benefits generated by it, will be prone to capture this value and use it as a mediation device for solving conservation conflicts. Without such an ambitious, and certainly not trivial, approach, the paper's principles will lack the effectiveness to change reality. The principle of fair sharing of costs and benefits from conservation is missed elsewhere.

On the principles of conservation and *utilization* of wild living resources

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Generally, there are three basic driving forces behind species decline and the threat of extinction of wild living resources.

1. Economic and biological *overexploitation*. The earliest analyses discussed 'open access' harvesting (Warming, 1911; Gordon, 1954). However, as Clark (1973) showed, even when harvesting is perfectly controlled (exclusive ownership) by a long-term profit-maximizing resource owner, a high opportunity cost of the capital, a high price/cost ratio of the yield and a low natural growth rate of the species could make extinction an optimal economic policy. See also the contribution by Spence (1975). As is well known, Gordon, Clark and Spence were analysing marine resources.
2. *Disinvestment* in biological resources. Typically, this approach stresses competition for natural habitats (Swallow, 1990; Brown *et al*., 1993; Swanson, 1994). Rather than being overexploited, species are undercut according to this type of reasoning (Hanna and Munasinghe, 1995). The disinvestment approach is usually formulated in the context of terrestrial resources, which, unlike marine resources, are subject to competition for 'niches'; i.e., their habitats may be converted to alternative uses (e.g. agricultural land). The opportunity cost of land is therefore an important factor in determining the degree of habitat degradation. When it is high relative to the consumptive as well as the non-consumptive value of the species there will be pressure for habitat degradation and species extinction.
3. The *institutional* dimension. This approach stresses the specification and functioning of the property rights of the resources as the basic factor determining to what extent biological resources can be exploited in a sustainable way. What matters for species conservation and utilization is the presence of 'a well-specified property rights regime and a congruency of that regime with its ecological and social context' (Hanna and Munasinghe, 1995: 4).

To some degree, these three broad categories overlap. For example, economic and biological overexploitation when there are no property rights ('open access') is a mix of categories 1 and 3. Because humans interact with oceanic species mainly through harvesting (in addition to pollution), this exploitation scheme is the basic driving force behind the depletion of the world's fishery stocks. On the other hand, the disinvestment process leading to habitat fragmentation and habitat loss plays a very important role when it comes to the decline of land-based wild species. This process, driven by social and economic conditions and often triggered by high population pressure and/or a high opportunity cost of the land, is often reinforced by lack of social congruency over the resources and land-use. So habitat degradation and terrestrial-species decline frequently take place under a mix of categories 2 and 3.

The threat of wild species extinction and habitat conversion/fragmentation are also seen as basically an economic and social problem in the conservation principles of Mangel *et al.* Generally, they understand conservation problems as having scientific, economic and social components, although the particular mix will vary according to circumstances. However, they clearly state the increased recognition of the role of social and economic factors in determining the degree of success in protecting terrestrial wildlife and whether a management regime will be successfully implemented. This is a difference compared to the earlier principles of Holt and Talbot (1978) which Mangel *et al.* build on. They therefore place a special emphasis on the implementation of the principles in management and conservation schemes, because 'the noblest intentions are meaningless if they are not adopted as actual, functioning policy' (p. 41).

I clearly agree with the weight they put on economic and social conditions, and I basically agree with the principles. However, I think that they stress overexploitation too much as a problem behind terrestrial species decline. For example, I feel that they are wrong when they say that 'there are few unexploited living resources in the world and many resources are heavily overexploited'. This holds for most fishing stocks, but as I understand it, most of the living terrestrial resources, particularly in Third World countries, are not exploited. Some of them are threatened, not because of overexploitation, but because of habitat loss and habitat fragmentation, i.e. the disinvestment process. I therefore think that principle I is wrong when it states that 'Maintenance of healthy populations ... is inconsistent with unlimited ... demand'. I would say quite the opposite, that a high demand and therefore a high consumptive as well as non-consumptive value of the resources, can often work in the direction of safeguarding the species as the opportunity cost of the habitat then becomes relatively small (for an analysis, see Swanson, 1994; Schulz and Skonhoft, 1996).

It is therefore not surprising to find that the utilization aspect is very much in the background in the principles. In my opinion, however, conservation must to a large extent 'pay its way' through utilization and exploitation of the wild species. This is particularly so in Third World countries where species and habitat conservation should contribute to sustaining the economy of the local people living with the wildlife. Species conservation must to a large degree also include utilization, and there must be a compatibility of the use of the protected areas with the surrounding lands in order to survive the pressure to convert protected areas to other uses. In what follows, I shall elaborate a little on this and discuss some results from recent analysis of conservation policy in Third World countries, with reference to conservation of large mammals in sub-Saharan Africa.

The establishment of national parks and other protected areas in the sub-Saharan countries has probably helped prevent part of biodiversity and wildlife from being destroyed by development and land conversion. On the other hand, the conservation policy has had some adverse effects which work in the direction of threatening the wildlife in the long term. First, the acquisition of land for establishing the parks has often directly displaced rural communities and curtailed their access to natural resources that traditionally were theirs. Land for cultivation and pasture has been lost, and anti-poaching laws have turned the old practice of subsistence hunting into a crime. Secondly, the local people have generally not obtained any significant part of the revenues from the commercial park activities (traditional wildlife viewing and safari tourism, and in some instances hunting for sport) (Marks, 1984; Kiss, 1990; Swanson and Barbier, 1992). As a consequence, local communities have to a large extent been alienated from the wildlife. Furthermore, since they bear the costs of conservation without obtaining any significant benefit from it, it is easy to understand why a rather negative attitude to wildlife preservation has emerged among the rural people. Combined with a dense and fast-growing human population and a scarcity of arable land, this frequently translates into direct involvement in illegal encroachment, in the form of hunting and harvesting within parks and reserves as well as in other restricted areas. It also undermines their opposition to, or concern about, illegal activities carried out by others.

The above-described land-use policy and management practice are today's stylized-facts situation and reflect the traditional Western, colonial view of wildlife conservation. It is recognized that this policy is not viable in the long run, as illegal utilization of wildlife and wildland has become an ever-increasing threat to conservation. Changes are therefore necessary. One obvious policy option is to give the local people parts of the revenues from the various park activities. In other words, redistribute some of the profit from the park authorities and involve the local people in the park management. Some integrated conservation and development projects have been implemented, the best-known being the Campfire project in Zimbabwe (see, e.g., Kiss, 1990; Swanson and Barbier, 1992). The programme has been fairly successful in handing over the decision-making process to the local people, and has generated enough revenues to contribute substantially to the local economy.

Giving back to the local people particularly user rights in the form of harvesting can also work. Hunting quotas represent incentives to reduce illegal harvesting. More important, however, is what takes place in the basic production activities of the local people living close to the wildlife, namely, agriculture and livestock production. The viability of these activities is essential for wildlife conservation and has a twofold effect. On the one hand, as already indicated, higher prices of agricultural products are a threat to wildlife as they increase the opportunity cost of habitat land and therefore lead to pressure for conversion of land to agriculture and livestock production (Schulz and Skonhoft, 1996). On the other hand, better economic conditions for these activities reduce the incentives for illegal hunting as the opportunity cost of poaching increases (Skonhoft and

Solstad, 1996; see also Brown *et al.*, 1993). The net effect of changing productivity and profitability conditions in the agropastoral activities is therefore generally unclear and will vary according to circumstances.

The agriculture sector and agropastoral activities illustrate the fact that there may often be conflict between development for the rural poor and conservation of wild species. There can be utilization possibilities, but the wild species do not pay their way. I feel that Mangel *et al.* discuss these conflicts too little. More generally, I think that they do not take into account the often very different social and economic conditions associated with conservation problems in Third World countries compared to the rich, industrialized countries.

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Alternatives to the regulatory approach to biodiverse habitat conservation

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At a March 1994 workshop organized by the Marine Mammal Commission, participants agreed that 'maintenance of healthy populations of wild living resources in perpetuity' is of overriding importance and also 'is inconsistent with unlimited growth of human consumption of and demand for those resources'. In addition, a consensus appears to have been reached that taxes and other economic instruments cannot be relied on to safeguard biological diversity, and therefore that 'regulation of the use of living resources' is essential.

As workshop participants certainly would agree, the current state of biodiversity regulation leaves much to be desired. For example, a survey of natural forests in eighty countries reveals that only 6 per cent is officially protected (WWF, 1996). Even if that share were double and the money needed for effective management were raised, the vast majority of natural habitats would remain exposed to encroachment. Furthermore, there is widespread disenchantment with the regulatory approach to habitat conservation, even within organizations involved in attempts to apply that approach.

The difficulties of creating and maintaining official protected areas in the developing world are illustrated by the case of Machalilla National Park, on the coast of Ecuador. The region has been inhabited continuously for millennia and, when the reserve was set up in the early 1970s, local property owners were promised payment for the land being taken from them. However, few of those individuals ever have received anything. This would have been a simple, though regrettable, instance of uncompensated confiscation had the government taken effective action to enforce its formal claims on resources. But it did not. As of the early 1990s, only sixteen guards and other employees were assigned to Machalilla Park, which according to official maps measures 467 square kilometres. Cattle grazing and fuelwood collection continue in virtually every accessible part of the reserve. Indeed, the argument could be made that, in Machalilla's case, public sector 'protection' has accelerated environmental degradation since resource users, many of whom formerly had an ownership stake, now regard the area as a free, or open access, resource (Southgate, in press).

Experience with Machalilla and many other 'paper parks' has yielded the clear lesson that regulating the use of ecosystems and species is unlikely to be successful in Africa, Asia, and Latin America. Habitat conservation, then, hinges on reducing the incentives for geographical expansion of agriculture and other sectors of the rural economy.

One way to diminish incentives is to offer payments reflecting natural habitats' non-market environmental values. Neither existing payments for keeping tropical habitats intact (Pearce, 1996) nor payments that the pharmaceutical industry might offer to conserve areas where genetic raw material is collected (Simpson *et al.*, 1996) are very large. By contrast, the global climatic change induced by deforestation could well outweigh, in economic terms, the benefits resulting from using more tropical land to raise crops and livestock. If releasing a ton of carbon into the atmosphere creates $20 in damages and if clearing a single hectare results in 100–200 tons of emissions, then leaving natural vegetation undisturbed is worth $2,000–4,000 per hectare, over and above whatever values are attached to watershed services and biodiversity conservation (Brown and Pearce, 1994). Amounts in this range greatly exceed the prices at which frontier holdings normally change hands (Schneider, 1995; Southgate, in press).

Notwithstanding these findings, exchange between firms and individuals who gain when forests are left standing and those who benefit from land-use change continues to be a rare event, mainly because carbon emissions remain lightly taxed and regulated. Unless and until this situation changes, agreements to sequester carbon in natural forests will continue to be a novelty, involving an environmental organization here and a well-intentioned company there making limited amounts of money available for the protection of relatively small tracts of land.

Another way to reduce geographic expansion of the agricultural economy is to intensify crop and livestock production, by strengthening agricultural research and extension networks, which yield and disseminate technological improvements, and also by making other investments. Intensification lowers costs of production for all farmers and ranchers, including those located in remote areas. But at the same time, commodity supplies increase, which causes market-clearing prices to fall. Almost always, costs do not fall as much as prices along agricultural frontiers. As a result, land clearing abates and, with time, people who already have settled on the frontier choose to abandon their farms and ranches, which are reclaimed by natural vegetation.

Agricultural intensification clearly has caused the sector's extensive margin to recede in the United States. The area used to raise crops and livestock in the country reached a maximum around 1920. Since then, productivity has risen dramatically, due to the development of hybrid corn and other technological improvements and also because of investments in roads and other infrastructure. At prevailing crop prices, which reflect low production costs in the Midwestern bread-basket, cash grain production is uneconomical from New York to Alabama. Accordingly, much of the land in that part of the country which was farmed up to a generation ago is now covered with maturing forests.

Results of regression analysis of the causes of deforestation in the Brazilian Amazon (Reis and Guzmán, 1994) sometimes are used to bolster the claim that intensification can lead to land-clearing in the developing world. Indeed, those results reveal a link between increased crop output and deforestation at the county (*municipio*) level. But in no way does this disprove that raising agricultural productivity tends to arrest farmers and ranchers' encroachment on natural habitats. Consistent with what Reis and Guzmán (1994) have found, intensification should cause cropland and pasture to expand at the expense of forestry in inframarginal areas—centrally located *municipios* in the case of the Brazilian Amazon. At the same time, though, agricultural land use should be diminishing in more remote places. If the latter impact outweighs the former, then the overall relationship between agricultural productivity increases and deforestation is negative.

That there is, in fact, a negative linkage is indicated by the findings of another regression study, one in which national-level data are used. In particular, Southgate (1994) has found that a 1 per cent increase in agricultural yields can offset nearly four-fifths of the land-clearing induced by 1 per cent population growth. Alternatively, 1 per cent yield growth can compensate for the deforestation that would result from 6 per cent growth in agricultural exports.

But investment in research, extension, local road networks, and other wealth needed for agricultural intensification will not guarantee the survival of tropical forests and other natural habitats any more than park protection will if the root causes of poor economic performance in the developing world remain unaddressed.

These root causes are revealed by a line of criticism of neoclassical growth theory that arose at about the same time that Repetto *et al.* (1989) and others were beginning to complain about the omission of natural resource depletion from national macroeconomic accounts. In a seminal contribution, Romer (1986) has emphasized that neoclassical models, originally developed during the 1950s, lack explanatory power largely because they neglect human capital. More recently, Olson (1996) has pointed out that discrepancies between poor countries' economic performance and how rich countries are faring cannot be explained in terms of access to technology and the availability of machinery and other physical capital. Slow growth and low living standards in places like the former Soviet Union, he argues, result mainly from the waste and misallocation of existing assets, which in turn have to do with the feebleness of institutional arrangements for enforcing contracts and protecting property rights. Capitalism's undergirding institutions are similarly weak in many parts of Africa, Asia, and Latin America. Moreover, technology remains underexploited and utilization of physical capital is poor because the education and health services available to large segments of the population are deficient.

Although Olson (1996) does not focus specifically on natural resources, his work furnishes an intriguing perspective on the lack of environmentally sustainable economic progress in, say, the Latin American countryside. There is no denying that the environmental endowments of Brazil, Venezuela, and many other countries in the Western Hemisphere are superior to what one finds elsewhere. Also, the legacy of inadequate human capital formation in the region weighs most heavily on rural areas. It is reasonable to conclude, then, that living standards are low in the countryside because a shortage of human skills causes abundant natural resources to be wasted. Furthermore, excessive deforestation, farming practices that exhaust soils, and other forms of resource depletion are best interpreted as a persisting environmental symptom of having placed too little emphasis on improved education, public health, and related services.

The encouraging implication to draw from all this is that improving the economic prospects of people who currently are apt to be agents of deforestation ought to contribute to diminished pressure on Latin America's natural habitats. That is, making better education and health services available in rural areas should enable more individuals to find more remunerative jobs, usually outside of agriculture. Fewer rural people should find that their best options in life come down to subsisting on a smallholding, migrating to an urban slum in the hope of finding some sort of employment (informal more often than not), or moving to agriculture's extensive margin.

By the same token, one cannot be optimistic about economic progress and biodiversity conservation in the Latin American countryside in the absence of accelerated human capital formation. In general, rural poverty will continue to be widespread, agricultural development will be sluggish, and rural people will never refrain from colonizing accessible natural habitats. Even where it is made available, the technology required for the sustainable intensification of crop and livestock production will be under-utilized. Efforts to pay for carbon sequestration and other environmental services provided by forests will be severely hampered by the costs of preventing encroachment by agricultural colonists. Likewise, efforts to police park boundaries will not withstand the human onslaught unleashed if poverty continues to grip the countryside.

Valid though they are in many respects, the criticisms directed by environmentalists against unbridled economic growth sometimes suffer from a flawed understanding of economic performance. Ironically, their mistake is very similar to what Romer (1986) and others see as a limitation of neoclassical growth models. Environmentalists certainly would not neglect the role of natural resources and are sensitive to the costs associated with resource depletion. But they, like an earlier generation of economists, seem to be fixated on physical assets: biological populations, machinery, and so forth. As a result, they ignore the sustainable economic development that results from formation of other forms of wealth, most notably human capital. Likewise they fail to appreciate that human capital formation, not ambitious schemes to extend and to fortify park boundaries, must be the centrepiece of an integrated strategy for habitat conservation and economic progress in the developing world.

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