Essays

Ecological Sustainability as a Conservation Concept

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Abstract: *Neither the classic resource management concept of maximum sustainable yield nor the concept of sustainable development are useful to contemporary, nonanthropocentric, ecologically informed conservation biology. As an alternative, we advance an ecological definition of sustainability that is in better accord with biological conservation: meeting human needs without compromising the health of ecosystems. In addition to familiar benefit-cost constraints on human economic activity, we urge adding ecologic constraints. Projects are not choice-worthy if they compromise the health of the ecosystems in which human economic systems are embedded. Sustainability, so defined, is proffered as an approach to conservation that would complement wildlands preservation for ecological integrity, not substitute for wildlands preservation.*

Sustentabilidad Ecológica como Concepto de Conservación

Resumen: *Ni el concepto clásico de manejo de recursos, ni el concepto de cosecha máxima sostenida son aplicables en biología de la conservación contemporanea, no antropocéntrica y ecológicamente informada. Como una alternativa, proponemos una definicion ecológica de sustentabilidad que es mas acorde con la conservación biológica: alcanzar las necesidades humanas sin comprometer la salud de los ecosistemas. Además de las restricciones familiares de costo-beneficio en las actividades económicas humanas, solicitamos agregar las restricciones ecológicas: Proyectos no deberán ser seleccionados si comprometen la salud de los ecosistemas en los cuales se desarrollan actividades económicas humanas. La sustentabilidad, así definida, se sugiere como una aproximación a la conservación que complementaría la conservación de áreas silvestres para la integridad ecológica, sin sustituirla.*

Introduction

Like *biodiversity*, *sustainability* is a buzz word in current conservation discourse. And like biodiversity, sustainability evokes positive associations. According to Allen and Hoekstra (1993:98), "everyone agrees that sustainability is a good thing." Both sustainability and biodiversity, however, are at grave risk of being coopted by people primarily concerned about things other than biological conservation. Noss (1995:26) notes that "virtually everyone who has used the term [sustainability] seems to have had 'human needs and aspirations' as their primary concern." Angermeier (1994) and Angermeier and Karr (1994) point out that local biodiversity can be artificially increased (at least temporarily) by introducing nonindigenous species into a biotic community; and, indeed, sport fishers more concerned about angling opportunities than about biological conservation have cloaked their argument for introducing nonindigenous game fish to the Great Lakes in the mantle of enhanced biodiversity (Thomas 1995).

One response would be for conservation biologists to write both biodiversity and sustainability off as hopelessly tainted terms. We believe a better response would be to try to define them in ways that facilitate biological conservation and expand conservation options. Con-

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cepts (and the terms that label them) are tools. Within the limits of their etymologies and lexical definitions, terms can be defined to suit the needs and purposes of a particular discipline—conservation biology, in this case. Noss (1995) has sharpened the concept of biodiversity for purposes of biological conservation, arguing that while local biodiversity may be artificially increased, sensitive native species may go extinct, as a result, through competitive exclusion by weedy cosmopolitan exotics—thus diminishing landscape diversity regionally and species diversity globally. In accordance with a suggestion by Lélé and Norgaard (1996)—that scientists reflect upon and make their own values and biases clear—we try to reshape the concept of sustainability for purposes of biological conservation. And the "discourse" of the "like-minded community" that our discussion "privileges" (Lélé & Norgaard 1996) is the international, ethnically diverse community of conservation biologists. Our discussion of the concept of sustainability is stipulative rather than descriptive. Lélé and Norgaard (1996) point out that sustainability means many different things to many different people. We are concerned less, however, with how the concept of sustainability is variously interpreted—explicitly or implicitly—and more with how it might best be crafted to serve conservation desiderata.

Two familiar conservation-related concepts sprouting from the sustain radical can be immediately identified: (maximum/optimum) sustained yield and sustainable development. We give shape to a third sustain-rooted conservation concept: ecological sustainability. For purposes of biological conservation, we suggest that the concept of ecological sustainability be sharply distinguished from both sustained yield and sustainable development. Both sustained yield and sustainable development, on the other hand, are associated with the human use and/or inhabitation of nature. As a member of the sustain family of conservation-related concepts and in deference to common usage, ecological sustainability should, therefore, also be crafted for conserving the biota of ecosystems that are humanly inhabited and economically exploited. Other concepts, such as ecological integrity, might more appropriately guide the conservation of biodiversity reserves (Woodley et al. 1993; Angermeier & Karr 1994; Westra 1994; Noss 1995).

Salwasser (1990) initiated a debate in this journal about the extent to which the concept of sustainability should guide conservation biology. He argues that achieving sustainability should be the principal goal of conservation biology (Salwasser 1990). Though Salwasser (1990:214) proposes "to put some flesh on the skeleton of the concept of sustainability," his discussion is more programmatic than substantive. He provides no clear definition of sustainability; instead, he mostly criticizes the not-in-my-backyard attitude and the lack of effective policies to curb resource demand and encourage recycling, while insinuating that wildlands preservation may be a quixotic conservation strategy in a world that is already overpopulated (with no end to exponential human population growth yet in sight).

Salwasser's proposal was not warmly welcomed by orthodox conservation biologists. For example, Noss (1991:120) inveighs against "the paradigm shift" from "wilderness preservation to sustainable management" that he understands Salwasser (1990) and others (Brown 1988; USDA Forest Service 1989; Callicott 1990*a*) to be advocating. Noss's hostility is not unwarranted. Salwasser (1990) proffers the sustainability philosophy of conservation (however it might eventually be specified) as a successor not only to the traditional "crop-oriented" but also to the traditional "preservation-oriented" conservation philosophy. Although in respect to conservation desiderata, the concept of wilderness is problematic (Guha 1989; Callicott 1992; Denevan 1992; Gomez-Pompa & Kaus 1992; Cronon 1995), we certainly do not propose that every nook and cranny of the biosphere be humanly inhibited and exploited, provided such inhabitation and exploitation be ecologically sustainable. On the contrary, in sharp contrast to Lélé and Norgaard (1996), who demean this conservation stratagem as "police and prohibit," we emphatically endorse the establishment of biodiversity reserves (the bigger and more numerous the better), understood as areas from which human habitation and economic activities are largely if not completely excluded in order to provide habitat for viable populations of other species. Sustainably inhabiting and using some areas and establishing biodiversity reserves in others should be regarded as complementary, not as either competing or mutually exclusive, approaches to conservation. Particularly sensitive species, interior species, and species that may come into conflict with *Homo sapiens* need habitat that is not rendered unfit for them by human residency and/or human economic activities. We propose that ecological sustainability be the guiding conservation concept for those areas that remain humanly inhabited and economically exploited.

We develop the concept of ecological sustainability in contradistinction to the two more familiar conservation-related concepts derived from the sustain radical—sustained yield and sustainable development—with which it is liable to be confused. We then link ecological sustainability to another emerging conservation concept, ecosystem health. And we argue that although biological integrity may well serve as a conservation norm for areas that are preserved or protected, ecosystem health may serve as a complementary conservation norm for those humanly inhabited and used areas that we can deem to be ecologically sustainable. Finally, for purposes of illustration, we review some examples of ecologically sustainable humanly inhabited and economically exploited ecosystems.

Ecosystem health, as we explain, provides an ecological norm in reference to which the sustainability of a variety of human economic goals, determined by different groups with different cultural values and attitudes, can be measured. As Lélé and Norgaard (1996:355) note, lexically "sustainability is simply the ability to maintain something undiminished over some time period." Constraints that limit the ability to maintain something undiminished over some time period come in all shapes and sizes—economic, political, social, physical, chemical, and biological. We restrict our discussion to the ecological constraints on the ability to maintain various culturally selected economic activities. We propose that ecological sustainability, as a conservation concept, be understood to be the maintenance, in the same place at the same time, of two interactive "things": culturally selected human economic activities and ecosystem health. The spatial scale of ecological sustainability can vary from the watershed to the biosphere. The temporal scale of ecological sustainability can also vary from the proverbial seven generations to the indefinite future.

Sustained Yield and Sustainable Development

As Salwasser (1990) and Callicott (1990*b*) indicate, two conservation philosophies dominated the first three quarters of the twentieth century: resource conservation (resourcism) and wilderness preservation (preservationism). Resourcism is thoroughly anthropocentric: nature is valued only to the extent that it is humanly useful. In the resourcist view, some "natural resources" (such as fossil fuels) are assumed to be finite and nonrenewable; others (such as metals) are assumed to be finite, but recyclable; and still others (such as usable trees, huntable wildlife, and edible fishes) are regarded as indefinitely renewable, either through natural or artificial propagation. One primary desideratum of resource conservation is to achieve sustained yield of these renewable natural resources—be they Douglas firs, white tailed deer, or sockeye salmon. Biotic communities and ecosystems are valued only incidentally. If their existence is acknowledged at all, they are treated as the machinery that produces the goods.

Larkin (1977:1) characterizes the concept of sustained yield thus: "any species each year produces a harvestable surplus, and if you take that much and no more, you can go on getting it forever and ever." In addition to the recruitment rates of the targeted species populations, the theoretical models of sustained yield are complicated by such biological variables as the growth rates and optimum harvest sizes and ages of the targeted organisms (Larkin 1977). Without criticizing resourcism per se, Larkin (1977) reviews the biological, ecological, and socioeconomic factors that render the concepts of maximum and optimum sustained yield problematic. But even if the concept of sustained yield were to be successfully operationalized, it would hardly be adequate for biological—as opposed to resource—conservation. Most species are not harvestable resources. And most of the species in danger of genetic impoverishment, local extirpation, and global extinction are not at risk because they are being over harvested, but because their habitats are being polluted and destroyed (Ehrlich 1988).

As sustained yield is historically wedded to resourcism, the more recently fashioned concept of sustainable development is betrothed to neoclassical economics, although environmental and ecological economists are rising to speak out against the marriage (Costanza & Daly 1992). In the vernacular, *development* often means the wholesale replacement of wild biotic communities with tract houses, shopping malls, office buildings, industrial "parks," and pavement. The term is also often used to refer to a shift from subsistence-oriented foraging or agrarian economies (many of which are ecologically sustainable) to money-oriented, market economies—as when "Third World" nations are said to undergo "development." Development thus commonly denotes urbanization, the industrialization of agriculture, and, more abstractly, an expanding market economy. Hence, it is not surprising that *sustainable development* has been interpreted to mean sustaining (at least until the next election) economic growth (Clinton & Gore 1992). So interpreted, the concept is antithetical to the concerns of conservation (Willers 1994). It implies an indefinite expansion of areas covered by lifeless manufactured materials (such as concrete, glass, asphalt, and lumber) or by living monocultures of domesticated plants (such as eucalyptus trees, soy beans, and maize), and a corresponding indefinite shrinkage of diverse forests, grasslands, and other undeveloped landscapes, many of them humanly inhabited by foragers and subsistence agriculturists (O'Neal et al. 1995).

Hoping to rescue the concept of sustainable development from conflation with indefinitely sustained economic growth, Costanza and Daly (1992) carefully distinguish between economic growth and economic development. In their account, growth consists of "pushing more matter-energy through the economy," whereas development consists of "squeezing more human want satisfaction out of each unit of matter-energy that passes through" (Costanza & Daly 1992:43). Unsustainable economic growth is tantamount to increased throughput, sustainable economic development is tantamount to increased efficiency.

We might add that a no-growth conception of sustainable development should also involve a reassessment of human wants. Suppose people started wanting fewer material goods (such as superfluous gadgets and appliances) and more amenities (such as clean air and water) and services (such as education and information). Jobs would be created (in fields such as ecological restoration and computer programming), and profits would be made. That would be economic development. But it would be achieved less through efficiency than through a demand-driven shift from an environmentally destructive manufacturing/consuming economy to an environmentally benign amenity/service economy.

Another aspect of steady-state sustainable development might involve the concentration and miniaturization of the human sphere. Suppose people started wanting to more densely inhabit cozier spaces proximate to pedestrian-scaled shops, restaurants, saloons, theaters, and other urban attractions. Suburban and exurban sprawl would be reversed; and the living space available for non-human species might increase proportionately. Further, the need for transportation would be reduced, also reducing all the untoward environmental consequences of manufacturing and powering automobiles.

Beginning with the Brundtland Report (World Commission on Environment and Development 1987) and culminating in the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, economic development and environmental quality have been positively linked. Sustainable development has thus been commonly understood to mean economic development that does not appreciably harm the natural environment (World Resources Institute 1992). The definition of sustainable development in *Our Common Future*—"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"—has been widely accepted as authoritative (Willers 1994:43). Note, however, that this definition includes no reference to environmental quality, biological integrity, ecosystem health, or biodiversity.

Further, the axiom of substitutability, fundamental to neoclassical economics, makes the definition of sustainable development in the Brundtland Report—a definition that is rapidly becoming standard—particularly ominous, from a conservation point of view. In the world according to neoclassical economics, as a heavily exploited natural resource becomes scarce its price increases, making investment in finding or inventing a substitute increasingly attractive (Barnett & Morse 1963). From this point of view, there is no reason to conserve any particular natural resource. When we begin to run short of copper for making telephone wires, someone will (as indeed someone did) invent fiber-optics. Such accumulated anecdotal evidence suggests that market forces will always stimulate the discovery or invention of substitutes for any natural resource—from petroleum to Madagascar periwinkles. According to this way of thinking, we can, therefore, meet the needs of the present by rapidly exploiting current organic natural resources to commercial if not to biological extinction and bequeath a legacy of wealth and technology and a culture of business and inventiveness to future generations—by means of which they can meet their own needs. As Willers (1994) suggests, in the Brundtland Report, sustainable development means pretty much business as usual.

Ecological Sustainability

Although technological optimists may suppose that substitutes for the current inventory of natural resources can be discovered or invented, no one, to our knowledge, has suggested that substitutes for ecological services—such as pollination, nitrogen fixation, water purification, and so on—can be invented. Indeed, some ecologists and conservationists have pointed out that it is preposterous to suppose that engineers can devise artificial substitutes for the ecological processes and functions in the economy of nature that provide free services to the human economy (Ehrlich 1989; Kaufmann 1995). Though it has been the subject of strident criticism by conservationists (Robinson 1993*a*; Willers 1994), another influential international document, *Caring for the Earth*, (International Union for the Conservation of Nature and Natural Resources/United Nations Environmental Program/The World Wide Fund for Nature 1991) provides a more conservation-friendly account of sustainability than does *Our Common Future*. Its subtitle is "A Strategy for Sustainable Living," not "a strategy for sustainable development." Sustainable living, as opposed to sustainable development, might be understood as human economic activity that does not seriously disrupt ecological processes and functions; or, alternatively, as devising artificial ecosystems (human economies) that are symbiotically adapted to proximate natural ecosystems as sketched by Jackson (1980; 1987).

Following a suggestion by Robinson (1993*b*), we propose that the goal of biological conservation be pursued on two fronts simultaneously. The first approach is consonant with the century-old American preservationist tradition and depends principally on biodiversity reserves. Classic preservationism was, with few exceptions (Muir 1916), valuatively anthropocentric. Areas were set aside primarily for human recreation, aesthetic enjoyment, and spiritual elevation (Foreman 1995*a*). Biological conservation was a side effect (Foreman 1995*b*). The contemporary preservationist approach differs from its early twentieth-century antecedent in being biocentric (Noss 1995). The biota is valued for its own sake. Accordingly, priority is assigned to biological conservation over recreation and other non-consumptive human uses of protected areas, and reserves are selected, delimited, connected, and managed in accordance with the best available science, irrespective of their conventional recreational, esthetic, or spiritual appeal (Foreman et al. 1992). Though use-oriented, the second approach is not an extension of the century-old resourcist tradition. Rather, it emerges from a more recently evolved conception of nature as a hierarchically integrated set of ecosystems (Allen & Starr 1982; O'Neill, et al. 1986; Allen & Hoekstra 1992) in which human economies are inescapably embedded (Costanza & Daly 1992; Allen & Hoekstra 1993).

We propose that ecological sustainability be the paradigm for this second approach to biological conservation. This approach is complementary to—not a substitute for—the contemporary preservation-oriented approach. Human economic activities have traditionally—in theory, at least—been limited by an economic constraint: the bottom line. A proposed development, be it a hydroelectric impoundment in the Amazon or a shopping mall in Arizona, is deemed unworthy of undertaking if its costs will exceed its returns on investment. Following Charles (1994), we suggest that, in addition to this familiar economic constraint, human activities also be judged by an ecologic constraint: ecological sustainability. A proposed economic venture—be it the reestablishment of harvestable herds of native ungulates on the North American great plains or the creation of an agroforest in Thailand—should be deemed unworthy of undertaking not only if its costs exceed its benefits, but if it will compromise the health of the (relatively) macroscale ecosystems in which it is embedded and the (relatively) microscale ecosystems on which it is imposed.

This ecological interpretation of sustainability thus interfaces with another inchoate conservation concept, ecosystem health. The concept of ecosystem health, however, is also in process of refinement and elaboration (Costanza et al. 1992; Callicott 1995; Rapport et al. 1995). The coupling of ecological sustainability and ecosystem health is parallel to the coupling of biological preservation and ecological integrity by Angermeier and Karr (1994) and Noss (1995). Following Angermeier and Karr (1994), let ecological integrity denote the historic species composition and structure of biotic communities. Humanly inhabiting and economically exploiting an area will necessarily compromise its ecological integrity, except if such inhabitation and exploitation be extremely diffuse, surgical, or primitive (Robinson 1993*a*). A mesoscale ecosystem may remain healthy, however, even when the mesoscale complement of species it comprises have been altered to suit human specifications (Rapport 1995*a*; Rapport 1995*b*). That is, ecological processes such as primary production, nutrient retention and cycling, nitrogen fixing, soil stabilizing, water purification, etc., can occur normally when less desirable species are carefully replaced by more desirable ones (desirability to be determined politically and economically) (Rapport 1995*a*; Rapport 1995*b*). We therefore suggest that sustainable human inhabitation and economic land use (and water use) be understood as inhabitation and use that may to some degree compromise ecological integrity—the less so the better—but that may not appreciably compromise ecosystem health.

Ecological sustainability and its associated norm, ecosystem health, have both anthropocentric and ecocentric value dimensions. Humanly inhabited and economically exploited ecosystems produce not only instrumentally valuable goods (food, fodder, thatch, fuel wood), but, if healthy, they may also afford instrumentally valuable services (clean air, potable water, flood control, crop pollination, various amenities). In sharp contrast to Lélé and Norgaard (1996:357), who dismiss the idea that "Earth's natural processes and biodiversity [are] inherently good, even if there were no human beings on the planet to benefit from these phenomena" as being "absurd when presented so baldly," we assert that ecosystems and their component processes are intrinsically as well as instrumentally valuable. Noss (1995:26) notes that "sustainability need not be interpreted anthropocentrically.... A biocentric or holistic concept of sustainability focuses on sustaining natural ecosystems and all their components for their own sake, with human uses included only when they are entirely compatible with conservation of the native biota and natural processes." We agree with this statement, with the proviso that the "components" of ecosystems are understood to be ecological processes, not the several sets of species that compose various biotic communities. In our account of ecological sustainability, the components of biotic communities and the native biota may be intrinsically valued, but only subordinately or secondarily to the extent that they are functional moments in ecosystems, whereas in our account of ecological integrity, as in that of Angermeier and Karr (1994), Westra (1994), and Noss (1995), the components of biotic communities and the native biota have primary, unqualified intrinsic value. This ecocentric valuation—from the perspective of the ecological sustainability/ecosystem health conceptual complex—principally of ecosystems and ecological processes is not arbitrary. It devolves from a hierarchical ecosystem world view in which ecological entities are defined and delimited in terms of trophic-dynamic processes and functions, such as nutrient cycling, not in terms of interacting populations of organisms (Allen & Starr 1982; O'Neill et al. 1986; Allen & Hoekstra 1992). Allen and Hoekstra (1992:92) provide a dramatic illustration of the difference between the population-community and ecosystem perspectives in ecology:

> The community structure of forests in the southeastern United States was radically altered by the blight that removed the American chestnut as a critical component of the canopy of the eastern deciduous biome... Meanwhile, the contemporary record at the end of the last century gives no indication that ecosystem function in those same places was altered one jot, even at the height of the epidemic. The chestnut, as indicated by simulation studies, seems to have been merely one workable alternative for primary production and energy capture.

If Allen and Hoekstra have their facts straight, from the point of view of community ecology the chestnut blight was an ecological disaster, whereas from the point of view of ecosystem ecology it was virtually a nonevent. Other canopy dominants stepped forward to take over the erstwhile role of the chestnut in primary production, nutrient recruitment, soil stabilization, etc.

Noss (1995:21) explains the distinction between the health of ecosystems and the integrity of biotic communities in logical terms: "health is necessary for integrity, [but] it is not sufficient," while ecological integrity is sufficient for ecosystem health, but not necessary (Westra 1994). And Noss's hypothetical illustration of the difference is more extreme than Allen and Hoekstra's (1992) historical illustration: "One can imagine many ecosystems that are quite healthy yet lack integrity. A tree farm, for example, might be considered healthy if it vigorously adds biomass, but it surely lacks integrity. Many species could be lost from an ecosystem before any overt signs of ill-health are evident; but with each loss of a native species the integrity of the ecosystem declines" (Noss 1995:21).

The real world is one. Historically, however, ecologists have modeled it in two fundamentally different ways, biologically and thermodynamically (Elton 1927; Lindeman 1942). According to the "bottom up" biological approach, the fundamental entities treated by ecology are organisms, aggregated into gene-exchanging species populations, interacting in biotic communities (Begon et al. 1986). The extirpation of a species population or extinction of a species globally, from the point of view of community ecology, is a signal event; it represents the erasure of a fundamental bio-ecological unit (Wilson 1992). According to the "top down" thermodynamical approach, the fundamental entities treated by ecology are ecosystems, the components of which are not organisms, species populations, and biotic communities, but multi-scaled interacting processes, such as photosynthesis, energy transfer from one trophic level to the next, and nutrient cycling (Allen & Starr 1982; O'Neill et al. 1986; Allen & Hoekstra 1992). The specific identity of the organisms that are moments in these processes is incidental and the loss or replacement of one by another is often of little consequence (except when function is interrupted and impaired) and therefore of little ecological interest or concern (Allen & Hoekstra 1993). These two approaches to ecology, biologic and thermodynamic, are not competing, but complementary. They are two equally valid ways of modeling the same reality.

We propose a corresponding doctrine of complementarity in conservation biology. The norm for biodiversity reserves, in which human inhabitation and use are severely restricted, should be ecological integrity. The norm for sustainably inhabited and used ecosystems should be ecosystem health.

Applications

How can these conservation concepts be applied in the real world? Like the neo-preservationist program (Foreman et al. 1992), ecological sustainability in humanly inhabited and economically exploited ecosystems is a long-range conservation goal that can only be achieved, given where we have to start, gradually and incrementally. The global biosphere reserve initiative embodies, in a microcosm, the complementary, two-front approach to conservation that we are recommending here. The biosphere reserve model differs from the classic national park, wildlife sanctuary, or designated wilderness area model by including, in addition to a strictly protected core area, humanly inhabited and economically exploited buffer and transition zones (von Droste 1988). The core zones of a global system of biosphere reserves are intended to slow the loss of biological diversity and integrity. The buffer and transition zones of biosphere reserves can complement the core zones in two ways: by insulating the cores from various outside threats, and by serving as laboratories for exploring ecologically sustainable forms of human livelihood. We hope that, eventually, protected areas will be enlarged as envisioned in the Wildlands Project (Foreman et al. 1992). We also hope that all the remaining humanly inhabited and economically exploited regions of the Earth will eventually be humanly inhabited and economically exploited sustainably. In the meantime, we suggest that, by way of a start, the conservation norm for the humanly inhabited and economically exploited buffer and transition zones of biosphere reserves be ecological sustainability, as defined here in terms of ecosystem health.

Establishing biosphere reserve cores, although politically the most difficult, is technically the least difficult part of setting up a biosphere reserve program. One identifies hot spots (Lydeard & Mayden 1995) and excludes as much area as possible from human habitation and uses that might degrade them (Noss 1995). We do not mean to minimize the challenge of effectively managing core zones of biosphere reserves, especially if they remain small and subject to the effects of illegal human encroachment, air and water borne industrial pollutants, and invasive nonindigenous species. But the challenge of figuring out ecologically sustainable economic activities for the matrices surrounding biosphere reserve cores—the buffer and transition zones—has been daunting (Batisse 1993). Nevertheless, there are some examples of ecologically sustainable ways of humanly inhabiting and economically exploiting ecosystems, and we mention a few to illustrate the ecological sustainability/ecosystem health conceptual complex in action.

An example of sustainable forestry may be found on the Menominee Indian reservation in northeastern Wisconsin. The 100,000 ha Menominee forest, managed by Menominee Tribal Enterprises, produces more sawlogs than the contiguous 265,000 ha Nicolet National Forest, managed by the U.S. Forest Service (Davis 1997). Yet the selectively harvested old-growth Menominee forest has more large, late-successional trees (characteristic of the Northern Hardwoods-Hemlock-White Pine association), is more dense, and has a more diverse mix of species than the adjoining national forest (Alverson et al. 1994;

Davis 1997). The presence of large organisms and species diversity is indicative of ecosystem health (Rapport 1995*a*; 1995*b*). Preservation of the historic biotic community structure and harvest of forest products in perpetuity are the express priorities of Menominee forest management, to which turning a profit for Menominee Tribal Enterprises is subordinate (Davis 1997).

In the humid northeastern hill region of India, forest dwellers have employed a traditional method of shifting agriculture called *jhum* for centuries (Ramakrishnan 1992). Traditional jhum agriculture employs mixed cropping practices that are both economically and ecologically sustainable. As the system has evolved, a wide variety of cultivars form multiple layers of leaves, with a high leaf area index, topped by a canopy; underground, a similarly tiered root mass optimizes water and nutrient uptake (Ramakrishnan 1992). These artificial ecosystems are punctuated by fallows colonized by uncultivated species on a 10-year cycle. Jhum agroecosystems are characterized by indicators of ecosystem health as identified by Rapport (1995*a*; 1995*b*)—species diversity, complex community structure, high rates of primary productivity, and accumulation of biomass—that are comparable to those in old field uncultivated plant formations (Ramakrishnan 1992).

Agroforestry combines cultivation of tree species with annual and perennial crops. Deep rooted trees make subsurface nutrients available to annuals, while legumes supply their neighbors with nitrogen (National Research Council 1993). In addition to the ecological services they provide, the woody species composing these artificial ecosystems may be chosen to provide fodder for livestock. A particular type of agroforestry, practiced on several farms in Nigeria, is called alley cropping in which annual crops, such as maize, are grown between rows of trees or shrubs that build and hold topsoil and recruit and retain nutrients (Plucknett 1992). Soil stability and nutrient recruitment and cycling are, again, indicators of ecosystem health (Rapport 1995*a*; Rapport 1995*b*).

In the U.S. Midwest "conventional" dairy and beef operations—characterized by high inputs of fossil fuels, fertilizers, and pesticides for growing row crops and large enclosed pastures for continuous grazing—lead to soil compaction and losses from the soil of organic matter, nutrients, and microorganisms (National Research Council; 1989). Increased compaction and reduced organic matter in the soil reduce water infiltration and retention and increase runoff, disrupting the normal hydrology at the landscape scale in which the cultivated and continuously grazed patches are embedded (National Research Council 1989). Loss of soil microorganisms impedes the breakdown of crop residues and animal waste, and, therefore, disrupts nutrient cycling (National Research Council; 1989). These are all indications of ecosystem dysfunction or ill health (Rapport 1995*a*; Rapport 1995*b*).

Several farmers in southern Minnesota have converted from such conventional methods to a regime called the *management intensive grazing system*, in which land is relieved of row crops and continuous grazing and converted to pasture divided into paddocks (Land Stewardship Project 1995). Animals are rotated between paddocks, based on farmers' observations of stand quality. Preliminary studies indicate that timely movement of animals prevents overgrazing. Prevention of overgrazing reduces soil compaction and erosion. Elimination of chemical fertilizers, pesticides, and herbicides and reduced soil compaction allows microorganisms to flourish, thereby restoring normal decomposition of animal waste and plant detritus, thus restoring normal nutrient cycling. Reduced soil compaction improves water infiltration and retention, thus restoring normal hydrologic processes. Farmers practicing management intensive grazing note an increase in the diversity of plant species in their pastures and observations of increased numbers of grassland birds suggest that these pastures are being used as nesting sites. Soil stability and flocculation, hydrologic modulation, nutrient retention and cycling, complex community structure, and biological diversity at every scale—from microorganisms to migratory avifauna—are all, once more, indications of ecosystem health (Rapport 1995*a*; Rapport 1995*b*).

Conclusion

For nearly a century conservation philosophy has been divided into two schools of thought, resourcism and preservationism. These two philosophies of conservation are mutually incompatible. The former understood conservation to mean maximum sustained yield of renewable resources (along with equitable distribution of the spoils), the latter understood conservation to mean excluding human habitation and economic exploitation from remaining areas of undeveloped nature. From the point of view of contemporary conservation biology, classic resourcism is hopelessly reductive and ignores nonresources (Ehrenfeld 1976), whereas classic preservationism is driven by nonbiological concerns—for such things as scenery, solitude, and recreation (Foreman 1995*a*). More recently, preservationism has been retooled and adapted to conservation biology (Foreman et al. 1992; Foreman 1995*b*). Although they may still be scenic and inspiring, national parks, designated wilderness areas, and the other legacies of the historic nature preservation movement now have another, more vital conservation role to play—reservoirs of biodiversity and ecological integrity (Foreman et al. 1992; Foreman 1995*a*; Foreman 1995*b*). We endorse the goal of the Wildlands Project, which is to expand the areas from which human habitation and economic exploitation are largely excluded. But we think conservation efforts should also target the extensive areas that are humanly inhabited and economically exploited.

Resourcism is beyond rehabilitation as a contemporary philosophy of biological conservation. Instead, we suggest a new approach to conserving humanly inhabited and economically exploited ecosystems under the rubric of *ecological sustainability*. The neo-preservationist approach to conservation is informed principally by population biology and evolutionary and community ecology. It aims to preserve ecological integrity (Angermeier & Karr 1994; Noss 1995) and biodiversity at every organizational level (Noss 1990). The sustainability approach is informed principally by hierarchy theory and more generally by ecosystem ecology and aims at preserving ecosystem health; that is, normal ecological processes and functions, irrespective of which species perform them. But just as a whole and complete science of ecology must integrate the community and ecosystem perspectives (Allen & Hoekstra 1992), so must a whole and complete conservation biology embrace both preserving biodiversity and ecological integrity, on the one hand, and sustaining ecosystem health, on the other. For the sake of clarity, we have illustrated these complementary approaches to biological conservation in reference to reserve cores and their humanly inhabited and exploited matrices, respectively, but biodiversity and sustainability, ecological integrity and ecosystem health are not unrelated. Areas that retain their biological diversity and ecological integrity are quite likely to comprise healthy ecosystems (Noss 1995), and one indicator of ecosystem health is biological diversity (Rapport 1995*a*; Rapport 1995*b*).

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