2003:50–61 | ETHICS IN SCIENCE AND ENVIRONMENTAL POLITICS ESEP | Published June

PAPER

Ethical issues in ecological restoration

John Cairns, Jr.*

Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA

ABSTRACT: The acid test of humankind's relationship to natural systems is the degree to which ecological damage caused by humans is repaired by humans. Technology and science are available, so the remaining stimulus needed for implementation of ecological restoration is the ethical responsibility to do so. Ecological restoration can be regarded as enlightened self-interest for humankind since it increases both natural capital and ecosystem services. However, well-designed ecological restoration projects should have a major ethical component since the future of non-human life forms on Earth requires more than self-interest. Although the field of science has provided various rationales for ecological restoration, ethical issues associated with such activities must also be considered. If, as seems likely, human society and natural systems are co-evolving, restoration of damaged ecosystems will improve both ecological and human health. The term 'ecosocietal restoration' emphasizes this close relationship. However, if ecological restoration considers only human needs and does not emphasize ecological integrity, human-dominated ecosystems could become the norm. Such domination is already marked but the relationship could easily worsen. This article lists seven major ethical issues in ecological restoration. This list is not encyclopedic but illustrative. Finally, there are five questions that human society must address that require robust scientific information to make a sound ethical judgment.

KEY WORDS: Eco-ethics · Sustainability · Ecological restoration · Co-evolution · Species extinction

We must share in the action and passion of our time for fear of being judged not to have lived.
Former US Supreme Court Chief Justice Oliver Wendell Holmes

The art of living consists not so much in complicating simple things as in simplifying those that are not.
Frances Hertel

INTRODUCTION

The science of restoring damaged ecosystems has been covered in many publications, but this article provides some illustrative examples of ethical issues in the restoration process. Persuasive reasons exist for believing that precise replication of the predamaged condition of an ecosystem is highly unlikely, though not totally out of the question (Cairns 1989, Hobbs & Norton 1996). The most persuasive reason that predamaged conditions are not attainable is that the sequence of previous climatic and biological events is unlikely to be repeated. There is ambivalence between saving nature for both present and future enlightened use by humankind (i.e. sustainable use of the planet) and saving natural systems because humankind has an ethical responsibility for the fate of the 30+ million species with which it shares the planet. This ambivalence is quite evident in the proposed principles for the new Earth Charter, which is being proposed as a guide for local, regional, national, and international efforts to protect natural systems.[1] Stone (1988) believes that this quest is for a single coherent and complete set of

[1]Details are available in a special issue of *Earth Ethics* (Smith 1996)

*Email: jcairns@vt.edu

principles suitable for addressing all moral quandaries. If one views the planet's ecological life support system (natural capital and ecosystem services) as essential to the survival of humankind, there should be no ethical ambivalence.

Therefore, restoration ecologists have a number of restoration options: (1) assembling a naturalistic plant and animal community that closely resembles the structure and function of the ecosystem in its predisturbed condition, but without the identical species once present; it may be possible to use all of the predisturbance species that are still available, together with other species, to produce a naturalistic community more closely resembling the predisturbance community, (2) constructing an ecosystem more able to withstand anthropogenic effects, since these are probably what damaged the ecosystem now being repaired, and (3) allowing natural recovery processes to determine the outcome, which most likely will include exotic and pioneer species that may not replace lost services and perhaps will have deleterious effects on adjacent ecosystems. As Berger (2003, pers. comm.) points out, '…achievement of that outcome may take eons, or may produce a different stable state than manifested by, or tended toward by the ecosystem destroyed'. All these options must be considered in the context of human society's dependence on ecosystem services (those ecological functions that are useful to human society) for survival, as well as humankind's ethical responsibility for the survival of non-human life forms.

The considerable attention given to sustainable use of the planet in recent years has increased the chronological scope of restoration policy, and increasing global interdependence, both ecological and economic, has enormous policy implications for the geographic dimensions of restoration policy. The National Research Council (2003) report distinguishes between the products of science (knowledge or data generated by research) and the approach required to meet the needs of decision makers. Although the geographic scale is not global, the processes used to support restoration, such as priority setting, identifying science gaps, and communicating research results, are quite similar. Since this is a large-scale undertaking, it deserves serious attention. In addition, natural selection judges harshly the misallocation or unsustainable use of resources. Finally, humankind must remember its ethical responsibility for the damage done to natural systems and make reparations accordingly (e.g. Cairns 2002).

GENESIS OF ETHICAL ISSUES

Humans cannot eradicate all species. Berger (2003, pers. comm.) cautions, '…if all domesticated species were annihilated, the billions of people who depend on them for survival would likely starve…'. Such losses would fatally injure human society as presently known (Cairns 1994, 1995a). If human society does not acknowledge its dependence on ecological life support systems, it will lose the species that cannot resist or tolerate present practices and be left with those that can. Unwanted species (e.g. invasive exotics) also pose a major threat that may be as serious for natural systems as loss of species. Baskin (1996) provides an excellent discussion of the problem of squelching the rising tide of unwanted species. Protection of indigenous species may well be as threatened by invasive exotic species as by anthropogenic stress.

On the other hand, a compassionate relationship with natural systems would preserve and possibly enhance ecosystem services, which surely are essential for sustainable use of the planet. It is also a *sine qua non* that human society will not support large-scale protection of the environment or landscape-level ecological restoration unless the justification for doing so is both compelling and persuasive.

With some exceptions, the purely religious approach generally maintains that all species were created, as humans were, and, therefore, deserve both compassion and esteem (Cairns 1995b). Obviously, human society has not acted as if this is a widespread, deeply held belief. If human society cannot survive without the services provided by ecosystems, the need to change the relationship with them is very compelling!

A beginning can be made by illustrating the services currently recognized as provided by natural systems. A future possibility is that, as ecological literacy improves, every function of natural systems will be regarded as a service. Illustrative ecosystem services include: (1) capture of solar energy and conversion into biomass that is used for food, building materials, and fuel, (2) decomposition of wastes such as sewage, (3) regeneration of nutrients in forms essential to plant growth (e.g. nitrogen fixation), (4) storage, purification, and distribution of water (e.g. flood control, drinking water purification, transportation, etc.), (5) generation and maintenance of soils, (6) control of pests by insectivorous birds, bats, insects, etc., (7) provision of a genetic library for development of new food and drugs through both Mendelian genetics and bioengineering, (8) maintenance of breathable air, (9) control of both microclimate and macroclimate, (10) provision of buffering capacity to adapt to changes and recover from natural stresses such as famine, fire, pestilence, (11) pollination of plants, including agricultural crops, by insects, bats, etc., and (12) aesthetic enrichment from vistas, recreation, and inspiration.

GENESIS OF THE IDEA THAT HUMAN SOCIETY AND NATURAL SYSTEMS ARE CO-EVOLVING

Cairns (1996) asserts that human society has been dependent for most of its existence on an ecological life support system that provides a variety of services. Cairns (1994, 1995a, c, 1996, 1997a) has further postulated that human society and natural systems are co-evolving. Raven & Johnson (1986) have defined co-evolution as the simultaneous development of adaptations in two or more populations, species, or *other categories* [emphasis mine] that interact so closely that each is a strong selective force on the other.

The Agricultural and Industrial Revolutions have provided a variety of technological services that supplement the ecological life support system. In recent years, the demand for natural resources, the encroachment of industrial and agricultural systems on natural systems, and the wastes of human society have endangered the ecological component of the life support system. If sustainable use of the planet is the goal (meaning not depriving future generations of either of these life support systems), then the demand for technological services must be restrained so that ecological services are not threatened or damaged.

Schneider & Londer (1984) indicate that climate and life are co-evolving. The World Commission on Environment and Development report (1987) and Cairns[2] discuss sustainable use of the planet with the clear implication that present usage will not result in sustainability. Vitousek et al. (1986) note that humans appropriate approximately half of the photosynthesis on the planet; this percentage is surely a rather large share for one species out of many millions. The effect of this imbalance on the ecological life support system is not clear, but losing so much photosynthetic energy to humans must be damaging. Until the effects are clear, this rate of use should not be exceeded. As Flannery (1994) notes in the dedication of his book to the Australasians, 'if they are to preserve their unique natural heritage, their newly forged nations must cease to be the realms of the future eaters.' Until sustainability is achieved, all are 'future eaters' and, in order to cease being so, must learn to cherish fellow species and natural systems and to actively care for them.

If human society will acknowledge its dependence on ecological services, then it is admitting that loss of these services can have an adverse effect upon humankind (e.g. Cairns & Bidwell 1996a, b). Wilson (1987) has noted that, if humans and other large vertebrates were to disappear, the 'little things that run the world' (e.g. invertebrates) would not be seriously endangered and some, arguably, would thrive. However, if the 'little things that run the world' disappeared entirely, humans and other large invertebrates would be seriously threatened and probably driven to extinction because of the absence of the services 'the little things' provide.

Unquestionably, humans can affect other species sharing the planet by depriving them of habitat (e.g. water or other vital resources), exposing them to toxic substances, over-harvesting breeding stock, and the like. Since each entity (human society and natural systems) can affect the other both beneficially and adversely, the relationship fits the definition of co-evolution. Therefore, it seems eminently reasonable to determine whether this relationship, as it now exists, will lead to sustainability. If not, perhaps the relationship can be improved so that use of the planet over the next decade, millennium, or more would permit more humans and other species to live a quality life than would otherwise happen with the present relationship. This concept leads to a number of issues involving both science and ethics. One of the most important issues concerns determining the conditions to be met in order to achieve sustainability (Cairns 1997b).

THE ROLE OF SCIENCE AND ETHICS IN SETTING SOCIETAL GOALS

Both science and ethics are involved in making decisions on environmental assessment. Ideally, they are called into play sequentially (Suter 1993), i.e. a subjective human perception of a problem leads to objective scientific investigation of the causes and possible management actions; then, alternate actions and their projected costs and benefits are evaluated for effectiveness and congruence with other societal goals. As this process of impact assessment and management is applied to larger areas, longer time frames, and more complex and interconnected problems, distinguishing ethical claims from scientific ones becomes increasingly difficult because the uncertainty inherent in scientific information increases with the scale of the environmental problem.

A decision that seems to be empirically based to some scientists may seem to be based on ethics to others — because, while some professionals judge the uncertainty of the scientific data acceptable, others judge it excessive. Tolerance of scientific uncertainty and tolerance of risk are both proper subjects for debate before decisions are made. However, they are

[2]See Cairns J Jr (2002) Goals and conditions for a sustainable world. ESEP Book 1. Inter-Research, Oldendorf/Luhe, Germany. Available at http://www.int-res.com/journals/esep/esepbooks/CairnsEsepBook.pdf

linked — acting with an intolerance of uncertainty often demands a high tolerance for risk. For example, there is uncertainty about the precise degree of temperature change due to anthropogenic greenhouse gases, which is being used as a justification for inaction. However, this intolerance may result in humankind being exposed to more severe consequences than it would be if precautionary measures had been taken to reduce greenhouse gas production.

Science makes probabilistic statements about the nature of the world but does not offer a course of action. Science also helps to define problems and gather information about the extent and severity of environmental change and clarifies the links between environmental change and human self-interest. The basic ethical question here becomes: Does human self-interest differ from that of ecological integrity? An increased ability to measure those ecological functions that, in the aggregate, constitute the ecological life support system upon which human society depends would, arguably, provide increasingly convincing evidence to support the process of restoring and conserving natural systems. While this information is essential to effective management action, this scientific data cannot set goals.

Ethics, politics, and priorities are involved in setting goals. Is there a consensus about what society should do? Political action based on underlying ethical beliefs emerges as a result of consensus. In addition, there is never enough money to do all the ecological preservation and maintenance that would benefit human society over the long term. Ranking desirable goals and expediting some, while delaying others, is thus a political process.

ETHICAL PROBLEMS IN ECOSOCIETAL RESTORATION

Does restoration ecology represent a new trend in human society's relationship with natural systems, enhancing a benign co-evolution? Or, are restoration ecologists merely running a group of environmental 'body shops' that repair damaged ecosystems without appreciable effect on either rates of ecological destruction or human society's guiding beliefs? Even if so, environmental consultants and their firms should carry out ecological restoration at every opportunity because it adds to the body of knowledge on restoration methodology and costs. At worst, ecological restoration could be used as another justification for continued damage to natural systems. Furthermore, the global rate of ecological destruction is so enormous that the comparatively few attempts to repair ecological damage are dwarfed by comparison. Indeed, there are similarly daunting ethical problems associated with ecological restoration.

1. Most ecological restoration is carried out to repair damage caused by human mismanagement. If management is the disease, how can it be the cure? Noss (1985) has said, 'This is the irony of our age: "hands on" management is needed to restore "hands off" wilderness character.'

2. Some mitigative restoration is carried out on relatively undamaged habitat of a different kind. For example, created wetlands may replace an upland forest or an upland forest may be destroyed to attempt to replicate the wetland that once occupied a particular lowland area. Logically, this secondarily damaged habitat should be replaced by yet another mitigative action. Sacrificing a relatively undamaged habitat to provide mitigative habitat of another kind may well cause ecological harm. However, created wetlands, for example, do have ecological value (Atkinson & Cairns 2001)

3. The ecological life support system is viewed as a commodity. A homocentric viewpoint would justify viewing the system as a commodity. An ecocentric view would emphasize the system's intrinsic value and natural rights. Sustainability ethics attempts to combine a homocentric and ecocentric viewpoint.

4. At the current state of knowledge, restoration projects are likely to have unforeseen outcomes. For example, they may provide an opportunity for invasive exotic species to become established in areas in which they had difficulty in doing so.

5. Well-meaning restoration efforts may displace the species best able to tolerate anthropogenic stress. By attempting to return an ecosystem to its predisturbance condition, the evolution of the species capable of co-existing with human society may be hampered. For example, some species might otherwise develop a resistance to anthropogenic stresses. Attempts to manipulate the environment in such a way as to promote the success of one or two species may impede both the natural successional process and also exclude other species that would otherwise be there. For example, restoring a stream to favor trout may not optimize conditions for a wide variety of aquatic invertebrates.

6. Similarly, if ecological restoration is carried out on an extremely large scale, human-dominated successional processes could become the norm. For example, ecological reserves might be lost that preserve endangered and threatened species that may one day be extremely useful.

7. Finding sources of recolonizing species for damaged ecosystems is increasingly difficult. Should one remove them from quality ecosystems and risk damaging that ecosystem or use pioneer species or, worse yet, exotics with the hope that the more desirable species will eventually colonize naturally?

Ethical problem #1 — Human management: the cure or the disease?

Quammen (1996) discusses the biotic impoverishment caused by ecosystem fragmentation, and Darlington (1943) observes that restriction of area often limits both the number and kind of animal species in isolated faunas. An ecological landscape, Quammen (1996) notes, is like a tapestry that, when fragmented, is not what it once was. Ecological fragmentation due to barriers such as highways, parking lots, power line right of ways, airports, and ubiquitous housing developments is so commonplace in developed countries such as the US and much of Europe that it is accepted as a norm.

At the State University of New York at Binghamton, a major campus road must be crossed by salamanders on the way to their spawning grounds. The roadside curbs are sufficiently high to represent an extremely difficult exit barrier for the salamanders once they are on the roadway, while initially falling off a curb might well cause significant skin damage. Fortunately, environmentally sensitive persons installed ramps so that the salamanders have a more accommodating means to cross the roadway. When I visited in 1994, the roadway itself had been closed during the annual spawning migration, and presumably still is during the mating season.

Forman et al. (2003) provide a superb analysis of the ecological problems caused by roads. It illustrates the conflict inherent in simultaneously pursuing two goals that are incompatible: (1) optimizing the benefits of an expanding road system, such as economic growth, more jobs, better access to schools, hospitals, and the like, and the ability to live at some distance from one's place of employment, and (2) the wish to preserve the natural environment and reduce the threats to it as well, such as improved air quality, reduced traffic congestion, or preserved land from encroaching development. In short, too many human artifacts impair ecological integrity. Forman et al. (2003) provide a well-structured, useful synthesis for resolving one of the current major problems, i.e. attempting to optimize two goals simultaneously.

Continents are, in a sense, large ecological islands made up of a mosaic of habitats with isolating barriers such as lakes, rivers, escarpments, and the like. However, generally, ecological corridors permit species movement or transport from one area to another. Given the degree to which ecological islands have been created on continents and the degree to which holes in the ozone layer, acid rain, and transport of hazardous chemicals over considerable spatial scales have occurred, barriers exist to both invasion and successful colonization of damaged ecosystems. Ecological restoration must necessarily be a crucial component of enlightened management for sustainable use of the planet.

The National Research Council (1992) notes that restored ecosystems are more likely to be self-regulating at the landscape level. This statement is a reiteration of the well-established phenomena of island biogeography — namely, that large islands generally contain more species than small islands. The seminal publication authored by MacArthur & Wilson (1967) notes that all systems have a decolonization rate (i.e. species are lost from that area), and this phenomenon must be offset by a countervailing colonization rate, which produces a dynamic equilibrium. Discussed at length by MacArthur & Wilson (1967), this equilibrium cannot be maintained unless invading species have access to all areas that are losing species. This process is more likely to occur at the landscape level than between isolated patches that have significant anthropogenic barriers between them.

In short, given the effect of humans on ecosystems, enlightened management is the only viable solution to reach sustainability. For example, human society might develop ecological management-derived solutions to avoid creating ecological islands by fragmenting ecosystems through planning at a landscape or ecoregional level.

Ethical problem #2 — Mitigative destruction of ecosystems

In Gunnison, Colorado, an airport taxiway affected existing wetlands, so mitigative (replacement) wetlands were established west of the airport near the sewage treatment plant. These wetlands were adjacent to already existing wetlands but, had they been located on a grouse mating ground or some other crucial habitat, a reasonable person might question the justification, even though the intent was the replacement of a particular lost habitat type. This issue will require robust professional judgment — prescriptive government regulations should be avoided.

When mitigative restoration elsewhere replaces a wetland that has been lost due to some developmental activity, the replacement may cause ecological damage to another habitat or ecosystem. If total ecological destruction exceeds total ecological repair, then the ecological damage has merely been shifted to another location. Arguably, the effort has not increased the quality or health of regional ecosystems collectively (bioregions), but merely replaced one habitat with another (National Research Council 1992).

Decision makers need to get in a mental helicopter and rise above a highly localized situation to question whether the ecological landscape has been improved by the effort. Sometimes, mitigation is viewed as purchasing or donating by setting aside a quality ecosystem in another location as a substitute for damage that has occurred. However, nothing has been added to the total ecological capital of the region. Merely agreeing to protect an already existing ecosystem as compensation for proposed damage of another does not increase ecological capital. If the ecologically damaging development proceeds before mitigation occurs, ecological capital will diminish during the restoration period, which may be many years (National Research Council 1992).

Ethical problem #3 — The resource/commodity trap

In the US and much of the rest of the world, the term 'natural resources' is commonly used when referring to natural systems or ecosystems. *Webster's New International Dictionary* defines a resource as 'a means of supplying a want; stock that can be drawn on; means of support.' In this view, the products of natural systems are treated as commodities with a marketplace value that is relatively easily calculated. In some cases, the harvest from natural systems can be replaced with technological alternatives, i.e. natural wood can be replaced with plastics (although petroleum does have biological origins) and whale meat can be replaced by soybean derivatives from agribusiness.

Another view is expressed by F. Henry Lickers, Director of the Department of the Environment for the Mohawk Council of Akwesasne, Cornwall, Ontario (1990, pers. comm.): Earth is humankind's mother and should not be treated as a commodity. In this view, preventing ecological damage is a moral/ethical obligation. If accidental damage occurs, healing it is a cultural imperative (e.g. Leopold 1966) if one believes ecosystems have intrinsic value beyond their usefulness to humans. This is a subjective value as opposed to the 'objective' commodity context.

Clearly, some ecological restoration can be carried out within a commodity context. For example, a clear-cut forest could be revegetated with the goal of yet another harvest.

> Although a clear-cut forest could be revegetated for commercial ends, that would probably entail the replanting of a single species, or at most a small number of species, which is not ecological "restoration." In other words, trees could be recreated in this manner, but not a forest. Were an effort made to truly restore a multi-species, multi-age forest ecosystem, that would undoubtedly not be cost-effective for commercial forestry purposes. (Berger 2003, pers. comm.)

Although this type of restoration is perceived to have a fairly certain outcome, the time required is not easy to predict accurately. In any case, human society's relationship with natural systems is dramatically different from that espoused by Lickers. If natural systems are viewed as commodities, is restoration to predamage ecological condition justified? Is restoration likely to be supported by a society viewing natural systems as commodities?

In terms of sustainability, progress in thinking should move from respect to esteem to acknowledgement of dependence upon the planet's ecological life support system. Respect is optional. Esteem means highly regarded and, thus, less likely to be viewed as optional. Dependence means humankind cannot do without it. This progress in thinking would place societal and individual behavioral norms in quite a different context than the resource/commodity point of view. However, policy must be based on how people behave (i.e. pragmatic and realistic). As pointed out by Berger (2003, pers. comm.), 'Policy can also be normative and prescriptive as well; or it can be ameliorative and corrective in intent, i.e. neither may be "based on how people behave," but on how we want them behaving' in particular contexts. This situation does not mean abandoning efforts to move toward an actively caring model for natural systems, but, rather, is an acknowledgement that, on the path to this model, human society must be able to recognize some short-term benefits.

If the natural systems being restored are viewed as commodities that can be harvested, exploited, or altered in some major way, then restoration management practices must be altered accordingly (e.g. the repair of a clear-cut forest with one or a few species). This point of view will likely be incompatible with restoration for the purpose of increasing habitat for rare and endangered species and the like. In addition, such systems are not likely to be self-regulating, thus increasing management costs and efforts.

In the commodity context, the concept of 'restoration of natural systems' might not justify the name and might be more analogous to agricultural systems or forestry systems with regular harvesting. Even though the level of complexity might be greater following repair, the term 'ecological restoration' would probably be inappropriate. Although this idea will be unpalatable to most ecologists, it may well be one that is more and more accepted by society in general as population pressures increase in the 21st century. If this is to be avoided, the educational system must do a better job in ensuring environmental literacy in all disciplines!

Perhaps the commodity model could be replaced by one of compassion. If compassion and esteem are to be afforded to future generations and natural systems (including the other species with which humans share the planet), as well as compassion for presently living individuals, ecological restoration can be carried out in a sustainable use of the planet context. This would reduce or eliminate the resources available per capita problem hypothetically depicted in Fig. 1 if human population size and level of affluence are stabilized in time. The intersection point is now purely theoretical. Quality of human life, resilience of natural systems, and so on, need extensive discussion and evaluation before even a crude but reliable intersection point can be determined. However, having compassion in one category modifies achievable compassion in the other categories, making sustainability possible only when all three are in balance. As Fig. 2 shows, focusing on compassion in only one or two categories is not enough. Sustainability requires a balance of all three categories. This also means making some difficult ethical choices and decisions that can be avoided if one isolates each of these areas from the others. Surely, isolating interactive components is not an effective way of either carrying out ecological restoration or achieving sustainable use of the planet.

Ethical problem #4 — Uncertainty of outcome

A colleague once wore a tee shirt that was captioned 'Life is uncertain — eat dessert first!' Clearly, uncertainty about the future of social security in the US, the rate of global climate change, the number of humans simultaneously living on the planet in the 21st century, the stock market, and most other areas of living is uncomfortably high. Human society's lives are neither risk-free nor precisely predictable. Uncertainty accompanies almost every prediction (Lemons 1996), not only in ecological restoration activities but other areas of science as well. As Yogi Berra has reputedly stated, 'predictions are unreliable — especially about the future.'

Ecological restoration also will have unforeseen outcomes, even when carried out by the most skilled professionals. Important variables may be omitted; episodic events such as floods or droughts may occur at inconvenient times; exotic invaders may appear abruptly; and, almost certainly, the sequence of biological and meteorological events that resulted in the characteristics of the ecosystem before it was disturbed will not be repeated. One may take comfort in the high probability that the repaired ecosystem will almost always be ecologically superior to the damaged ecosystem. Furthermore, a healthy ecosystem is almost certainly going to provide more services to human society than the damaged ecosystem.

Habitat restoration also should dampen the rate of biotic impoverishment (loss of species), which reduces uncertainty about the delivery of ecosystem services. However, present rates of species loss will almost certainly have effects now difficult to predict. Diamond (1994) discusses species losses in an extremely broad paleontological context. However, for this discussion, evidence on 'recent losses' is instructive.

Diamond (1994) estimates that 171 species and subspecies of birds are known to have become extinct

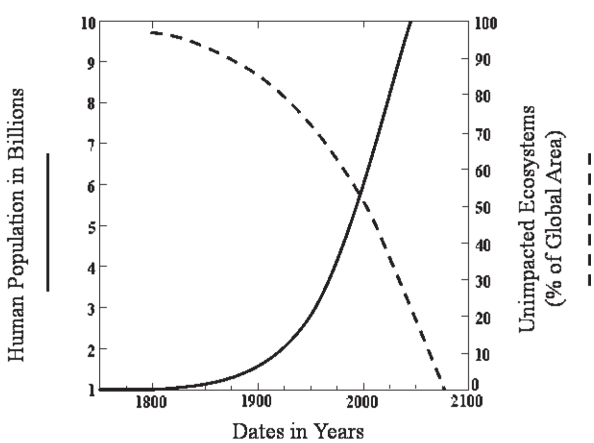

Fig. 1. Theoretical relationship between human population numbers and unimpacted natural systems. Figures given are speculative

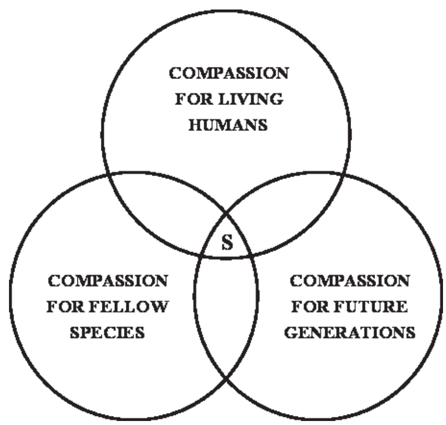

Fig. 2. Three pillars of sustainable use of the planet (S). Ecological restoration requires compassion for fellow species and will leave a more habitable planet for future generations. It will also demonstrate a compassion for living humans by improving the quality of the planet's ecological life support system and by making damaged ecosystems more esthetically pleasing by making them more naturalistic. Both ecological restoration and sustainable use of the planet are acts of compassion if viewed from an ecocentric standpoint, or acts of enlightened self-interest if viewed from a homocentric standpoint

since the year 1600. Of this total, 155 species and subspecies, or more than 90 %, lived and became extinct on islands. Hawaii alone lost 24 species and subspecies. Roughly 20 % of the world's species of birds are confined to islands; therefore, nine-tenths of the historical bird extinctions have occurred in island ecosystems holding one-fifth of the total species. Diamond (1994) focused on terrestrial systems surrounded by water, although other kinds of ecological islands exist (e.g. a forest surrounded by grassland), and analyzed not only the effects of humans upon island species but also the effects of ecosystem collapse upon human societies.

Mt. Kilimanjaro in Africa, a mountain ecosystem surrounded by a totally different plains ecosystem, is also an ecological island, as is Lake Malawi, which is surrounded by land. A patch of wetland surrounded by California freeways and freeway exits is just as much an ecological island as an island off the coast. Some species have access; others do not. Getting there can be hazardous and surviving there, if the area is small, is less likely than it is on either a large island, such as Australia, or an even larger land mass such as Eurasia.

Uncertainty about the effects of species loss will be reduced if recolonization occurs. Some articles in the popular press suggest natural recovery of ecosystems may be noteworthy, but reaching the predisturbance condition is unlikely. For example, McKibben (1995) discusses the reforestation of the eastern US. Some evidence indicates partial recovery of the forests themselves and, sometimes, much of the life they once supported. In such instances, however, Berger (2003, pers. comm.) points out that '…few trees are comparable in height and girth to those of the aboriginal forest, and certainly certain species, such as the chestnut, are now missing'. McKibben (1995) discusses 'quick devastation, quick recovery,' but this is not always true ecologically. For example, large oil spills may cause damage that cannot be quickly overcome. If recolonization is achieved by species not present before ecological damage occurred, the uncertainty about the outcome may remain high. Berger (2003, pers. comm.) continues, 'If the species are not the same, then assuredly we do not have perfect structural (species) restoration, but we may have a restoration of certain if not many important species and some ecosystem functions'.

Since 1961, I have worked intermittently at Rocky Mountain Biological Laboratory, situated at the mining town of Gothic, Colorado, which was abandoned by all but one inhabitant and his dog in the late 1800s when the early promise of mining proved illusory. Converted into a biological station in the 1930s, this area has since been occupied during summer by varying numbers of biologists, rarely exceeding 250. In recent years, between two and four people have been wintering there. Thus, the Laboratory had a period of intense use with accompanying dramatic changes in the ecosystem, followed by disuse, and, subsequently, over half a century of occupation by persons likely to inhabit the area with as little disruption to the native plants and animals as possible. In spite of this nearly ideal opportunity for recovery, the ecosystem does not resemble the predisturbance ecosystem, nor is it likely to in the foreseeable future. Recovery is not automatic, but is rather an accident of climate, soil, and economics (McKibben 1995). Assisted recovery (restoration) '…is also dependent on the success of restoration planning, implementation/management, and the cooperation of natural forces' (Berger 2003, pers. comm.).

In addition, many species of wildflowers in the southern Appalachians have not returned (McKibben 1995), almost 100 years after the forests were last cut. While some species may return, they must come from elsewhere or be brought there by human management. The fewer barriers to the recolonization of species, the more likely natural recovery to some semblance of predisturbance conditions will occur. Landscape fragmentation makes recolonization difficult, even if the original species remain in the region.

Ethical problem #5 — Displacement of species best able to tolerate anthropogenic stress

Well-meaning ecological restoration efforts might eliminate those species that had initially colonized disturbed areas and were able to tolerate anthropogenic stress. The restoration efforts might replace tolerant species with species intolerant of the present practices of human society; these intolerant species will subsequently be eliminated unless human society alters its present behavior. Some species that are needed most for long-term sustainable use of the planet are almost certainly included in the group of species with poor resistance to present practices (for example, species that control 'pests' or pollinate plants). These species are in the most need of protection and are, collectively, the ones most needed to provide a vast array of services useful to human society. These species may not yet even be recognized as valuable to the interdependent web of life because, in many cases, they have not received scientific names. If they are not even named, it is unlikely that substantive information is available about their ecological functions, some or possibly all of which are of unperceived value.

Unquestionably, many of these intolerant species control population densities of those species that resist human control (i.e. pests). They may do so by preying upon them, successfully competing with them for space or nutrients, or by favoring other competitive species. On the other hand, if human society's practices and behavioral norms are not changed, ecological restoration carried out with species sensitive to anthropogenic effects will result only in a repetition of the ecological disasters that necessitated the restoration in the first place. For example, restoration with species intolerant of oil spills is useless if oil spills continue.

It is difficult to accept that damaged ecosystems may not be restored to some naturalistic assemblage of plants and animals resembling the predisturbance condition. This realization is especially unpleasant if it means the loss of restored habitat essential to the maintenance of a bioregion or landscape. Probably most important is the strong possibility that ecosystems tolerant of anthropogenic stress may not furnish ecological services that bear a close resemblance to those furnished by the indigenous ecosystem before it was damaged. Most ecologists would undoubtedly choose the restoration model that closely resembles the predisturbance condition. However, if there is no assurance that the conditions that caused the damage are unlikely to be repeated, society will cease to support ecological restoration efforts; the present level of support is hardly overwhelming.

It is distressing to think that species that are removed as landscapes are restored might actually turn out to be quite desirable some day. However, the species that might be removed in favor of establishing predisturbance species are not those that would be eliminated from the larger landscape. For example, r-selected species are highly tolerant of disturbance and, thus, are doing very well in frequently disturbed landscapes. In the future, society might have uses for some species that are currently defined as weeds (e.g. tobacco has found practical value in biotechnology). Adaptive management must incorporate new scientific evidence, but it must be done in a systematic and orderly fashion.

An additional important ethical problem arises relative to restoration and climate change. Climate change, for example, will flood restored wetlands as sea level rises and obliterate them. The ethical problem becomes whether to restore an ecosystem, even if it will only function in the short term, or whether to put the money to other valid ecological purposes. Additional related problems concern how much money should be put into restoration, how to prioritize resources for restoration, how much of a social/political furor should be created if society fails to get itself on a sustainability trajectory (one in which rates of resource restoration are greater than or equal to rates of destruction), and how to sanction those who wantonly destroy nature and fail to restore it.

Ethical problem #6 — Should human-dominated successional processes become the norm?

Without question, if ecological restoration with species able to tolerate anthropogenic stress is chosen, whatever successional processes result will be human-dominated (i.e. exogenously managed). Even if the practices that caused the ecological damage are reduced, the damaged ecosystem still may not be repaired to the predisturbance condition in both structure and function.

Substantial portions of most countries' landscapes are human-dominated (i.e. urbanized, developed, nonwild). As a consequence, these ecosystems will almost certainly be inhabited by species that are resistant to, or tolerant of, human activities and which will invade the ecologically damaged areas even if there are ongoing restoration attempts. Additionally, exotic species often thrive in stressed or altered ecosystems and are likely to invade areas that are undergoing ecological restoration.

Continual management is needed to keep exotics under even partial control during some ecological restoration attempts. Nonsuch is a 14.5-acre island in Bermuda. Even with its small size, intensive continual management is necessary to keep the exotic species inhabiting most of the other portions of the Bermudan system from overwhelming the indigenous species (e.g. Bermuda cedar, yellow-crowned night heron) being reestablished on Nonsuch. The restoration effort is valuable because it demonstrates the difficulties of restoring a portion of a landscape with severe anthropogenic stress (e.g. non-native plants established on the mainland, whose seeds are transported by birds that roost on Nonsuch at night) that is dominated by exotics, although this stress is not directly exerted on the island.

The lesson of this restoration effort is that human-dominated successional processes would clearly be the norm if it were not for continual intervention by researchers, land managers, government officials, and environmentalists on behalf of the reestablished indigenous species. There are several justifications for making this restoration effort: (1) Bermudians should always be able to see what their country once looked like before intensive occupancy by humans; (2) indigenous species characteristic of the islands should be maintained so that, if recolonization efforts were to be undertaken elsewhere in the Bermudan system, colonizing species would be available; (3) it is always helpful when examining ethical and scientific questions, such as the ones posed in this discussion, to have some hard evidence of the difficulties involved and the degree of management necessary (e.g. during my visit decades ago, two employees worked full time removing exotics; Wingate 1988, pers. comm.).

Ethical problem #7 — Obtaining recolonizing species for damaged ecosystems without damaging quality ecosystems

In many parts of the world, ecological landscapes are heavily dominated by human society's artifacts — highways, power lines, shopping malls, altered land contours — and the number of relatively pristine ecosystems is small and diminishing. Even these relatively untouched ecosystems are threatened by airborne contaminants (such as acid rain), waterborne contaminants, or exotics living in greatly altered ecosystems. Habitat fragmentation has reduced genetic diversity for many species, and other problems are associated with diminished habitat area. As a consequence, one is reluctant to remove indigenous species from quality habitats for the purpose of recolonizing areas that have been damaged, even when the probability of success is fairly high. Removing a number of individuals of an already diminished population would have a variety of adverse effects, and moving too few might result in unsuccessful recolonization.

Obviously, considerable ethical judgment will be necessary in making these decisions about recolonizing species, and, inevitably, the decisions will not be the same from one site to another. These issues must be discussed and evaluated before the restoration is ever started so that the risk to the species sources are explicitly stated and the probability of success is related to the risks of doing further damage.

On the other hand, if recolonization is successful, another potential source of recolonizing species for other damaged ecosystems will have been established. However, microhabitat differences are often difficult to detect and may be responsible for the success or failure in a recolonization effort.

The National Research Council (2003) has provided a useful review of the Critical Ecosystem Studies Initiative (CESI), a project launched by the US Department of the Interior to provide scientific information to advise restoration decision making and to guide its own land management responsibilities for South Florida ecosystem restoration. However, CESI should be a useful information source about the complexities of large-scale restoration projects. CESI's most important contribution to the ecological restoration process is the graphic depiction of organization, cost sharing, and sums of money involved in major restoration projects.

FAKING NATURE

A small but insistent group has suggested that ecological restoration (as opposed to natural ecological recovery) is 'faking nature' (e.g. Elliot 1997). Most species modify their environment to some extent, but none on the scale of humans, particularly over the last few centuries. In addition, ecosystems are dynamic, so change is the norm rather than the exception. Species that adapt to the changes survive; those that do not become extinct. Finally, ecosystem restoration is based on natural processes subsidized in various ways by humankind (for example, use of hatcheries to reestablish a fishery).

The ultimate goal of ecological restoration is to produce a naturalistic, self-regulating community of plants and animals. Ideally, human assistance should only be required for the initial stages; that is, until the ecosystem becomes self-regulating. If the ultimate goal is to have natural processes take over, how can the assistance be considered 'faking nature'? An important criterion for restoration success is the degree to which the restored system accumulates natural capital and provides ecosystem services of benefit to a majority of species, not just humans.

Many ecosystems being restored will require subsidies for a considerable time period, but ultimately, in evolutionary time, all will become self-regulating, although they may not always be perceived as beneficial to humankind. Stated another way, if humans became extinct, all ecosystems would become self-regulating, just as they have become self-regulating following a number of mass extinctions that occurred before humans appeared on the planet. However, future self-regulation measures may not favor humans as much as present ecosystems have in the last centuries. The fact that humans are responsible for the present biotic impoverishment (species extinctions) does not diminish, in the long term, the prospects for ultimate recovery when the stressor (humankind) disappears.

CONCLUSIONS

This discussion has offered a few illustrative examples of the interface between science and ethics with regard to ecological restoration. Some of the questions that human society must address follow.

1. Is a world consisting entirely of human-dominated ecosystems desirable?

2. If not, under what circumstances should restoration to predisturbance be chosen or rejected?

3. If ecological restoration is carried out with species tolerant of anthropogenic activities, ecosystems will not resemble the predamaged conditions, and their services may not correspond with those of the ecosystem in the predisturbance condition. What information is needed to make an informed judgment in this situation?

4. Is it possible to have sustainable use of the planet for 1000 or more years and under conditions not appreciably worse than those at present if ecological repair does not equal the rate of ecological destruction?

5. Does sustainable use of the planet mean ecosystems that fill minimal expectations of services and other amenities or, in addition to quantity, is quality an expected attribute of sustainability?

Other questions raised by Berger (2003, pers. comm.) that are beyond the scope of this article include: How can fraudulent restoration efforts, which are completed merely to give cover to developers, be detected and prevented? Do environmental consulting firms that offer and promise mitigative restoration often serve merely to facilitate development? Who should pay for restoration? Does society need to adopt a variant of 'the polluter pays' principle to this problem? Other important ethical problems regarding restoration include determining when to discontinue a restoration effort — when is restoration done and regarded as a success — and when monitoring should cease (Holl & Cairns 2002).

These serious ethical questions are but a few of the many that cannot be answered by science but will require robust scientific information in order to make a satisfactory judgment. Ecological and environmental literacy for the general population and its representatives must be greatly improved to deal with these complex multivariate issues. Furthermore, both the temporal and spatial scales are much greater than those with which most political systems are accustomed to coping. The complexity level of the problems requires multidimensional approaches. While the challenge is great, the opportunity for systems level science and thinking has never been greater, nor has human society's stake on the outcome.

Acknowledgements. I am indebted to K. Cairns for typing the first draft of this manuscript and to D. Donald for her usual skillful editorial assistance in preparing this manuscript for publication. H. Cairns Chambers prepared the two figures. J. Berger provided useful comments on the manuscript.

LITERATURE CITED

Atkinson RB, Cairns J Jr (2001) Plant decomposition and litter accumulation in depressional wetlands: functional performance of two wetland age classes that were created via excavation. Wetlands 21(3):354–362

Baskin Y (1996) Curbing undesirable invaders. BioScience 46(10):732–736

Cairns J Jr (1989) Restoring damaged ecosystems: Is predisturbance condition a viable option? Environ Prof 11:152–159

Cairns J Jr (1994) Ecological restoration: re-examining human society's relationship with natural systems. The Abel Wolman Distinguished Lecture. US National Academy of Sciences, Washington, DC

Cairns J Jr (1995a) Eco-societal restoration: re-examining human society's relationship with natural systems. Annals of Earth 13(1):18–21

Cairns J Jr (1995b) Respect for the inherent worth of each individual versus the web of life: an unresolved conflict. Spec Sci Tech 18:294–301

Cairns J Jr (1995c) Re-examining human society's relationship with natural systems: maintaining ecosystem services and sustainable use. Corp Environ Strat 3(1):69–74

Cairns J Jr (1996) Determining the balance between technological and ecosystem services. In: Schulze PC (ed) Engineering within ecological constraints. National Academy Press, Washington, DC, p 13–30

Cairns J Jr (1997a) Global co-evolution of natural systems and human society. Rev Soc Mex Hist Nat 47:217–228

Cairns J Jr (1997b) Defining goals and conditions for a sustainable world. Environ Health Perspect 105(11): 1164–1170

Cairns J Jr (2002) Rationale for restoration. In: Davy AJ, Perrow MR (ed) Handbook of ecological restoration, Vol. 1: principles and restoration. Cambridge University Press, Cambridge, p 10–23

Cairns J Jr, Bidwell JR (1996a) Discontinuities in technological and natural systems caused by exotic species. Biodiversity Conserv 5:1085–1094

Cairns J Jr, Bidwell JR (1996b) The modification of human society by natural systems: discontinuities caused by the exploitation of endemic species and the introduction of exotics. Environ Health Perspect 104(11):2–5

Darlington PJ Jr (1943) Carabidae of mountains and islands: data on the evolution of isolated faunas, and on atrophy of wings. Ecol Monogr 13:1

Diamond JM (1994) Ecological collapses of ancient civilizations: the golden age that never was. Bull Am Acad Arts Sci XVLII(5):37–59

Elliot R (1997) Faking nature: the ethics of environmental restoration. Routledge, London

Flannery TF (1994) The future eaters: an ecological history of the Australasian lands and people. George Braziller, New York

Forman RTT, Sperling D, Bissonette JA, Clevenger AP, Cutshall CD, Dale VH, Fahrig H, France R, Goldman CR, Heanue K, Jones JA, Swanson FV, Turrentine T, Winter TC (2003) Road ecology: science and solutions. Island Press, Washington DC

Hobbs RA, Norton DA (1996) Commentary: towards a conceptual framework for restoration ecology. Restoration Ecol 4(2):93–110

Holl KD, Cairns J Jr (2002) Monitoring and appraisal. In: Davy AJ, Perrow, MR (eds) Handbook of ecological restoration, Vol. 1: principles and restoration. Cambridge University Press, Cambridge, p 411–432

Lemons J (ed) (1996) Scientific uncertainty. Blackwell Science, Cambridge, MA

Leopold A (1966) A Sand County almanac, with essays from Round Rivers. Ballantine Books, New York

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press, Princeton, NJ

McKibben B (1995) An explosion of green. Atl Mon 275(4): 61–75

National Research Council (1992) Restoration of aquatic ecosystems: science, technology, and public policy. National Academy Press, Washington, DC

National Research Council (2003) Science and the greater everglades ecosystem restoration. National Academy Press, Washington, DC

Noss RF (1985) Wilderness recovery and ecological restora-

tion: an example for Florida. Earth First 5(8):18–19
Quammen D (1996) The song of the dodo: island biography in an age of extinction. Scribner, New York
Raven PH, Johnson GB (1986) Biology. Times Mirror/Mosby College Publishing, St. Louis, MO
Schneider SH, Londer R (1984) The co-evolution of climate and life. Sierra Club Books, San Francisco, CA
Smith JA III (1996) Earth charter. Earth Ethics 7:3–4
Stone C (1988) Earth and other ethics. Harper and Row Publishers, New York
Suter GW II (ed) (1993) Ecological risk assessment. Lewis Publishers, Boca Raton, FL
Vitousek PM, Ehrlich PR, Ehrlich AH, Matson PA (1986) Human appropriation of the products of photosynthesis. BioScience 36:368–373
Wilson EO (1987) The little things that run the world (the importance and conservation of invertebrates). Conserv Biol 1(4):344–346
World Commission on Environment and Development (1987) Our common future. Oxford University Press, Oxford

Editorial responsibility: Mary Batson (Managing Editor), Oldendorf/Luhe, Germany

Submitted: February 21, 2003; Accepted: June 18, 2003
Proofs received from author(s): June 23, 2003
Published on the web: June 24, 2003