Handbook of Ecological Restoration

Volume 1
Principles of Restoration

Edited by
Martin R. Perrow
ECON
University of East Anglia
and
Anthony J. Davy
University of East Anglia

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2 • Rationale for restoration

JOHN CAIRNS JR

INTRODUCTION

While the world's economic systems have enjoyed unprecedented expansion, ecological systems have been degraded and diminished at an appalling rate. For example, Dahl (1990) notes that approximately 117 million acres of wetlands have been lost in the United States since the 1780s. Excluding Alaska, this wetland loss is approximately 53% (Dahl, 1990). The National Research Council (1992) estimates 4.3 million acres of degraded lakes in the United States and 3.2 million miles of rivers and streams that would benefit from restoration. The degradation of aquatic ecosystems is usually not uniformly distributed throughout most political units, as the loss of wetlands in the United States illustrates (Fig. 2.1). This complicates the funding of and responsibility for aquatic ecosystem restoration. Public awareness that human society's practices are unsustainable was raised significantly at a global scale by the report of the World Commission on Environment and Development (1987). However, awareness must be accompanied by changed behaviour, and there is scant evidence that substantive changes have occurred.

Adults who spent their childhoods in dysfunctional families report that they were unaware of behaviours other than the ones they experienced. Many of these individuals have been fortunate enough to find a model of behaviour other than the dysfunctional one and have incorporated the changed behaviours into their adult lives. First, however, they had to become aware of a different model before they learned of a viable, superior and alternative paradigm. Similarly, a dysfunctional relationship between humans and the environment is the norm in today's society, and ecological restoration and rehabilitation are the exceptions. Clearly, dysfunctional relationships are not sustainable. Human society, thus, appears to prefer one enormous risk of producing an unsustainable planet to the series of continuing behavioural adjustments that would be necessary in the transitional period before sustainability can be achieved. Even then, constant adjustment would be necessary since nature is a pulsating system. Adjustment to such a system requires constant change based on a knowledge of the amplitude, duration and quality of the changes; this knowledge is lacking for most of the world's ecosystems. This argument might suggest to some that no restoration be carried out until the knowledge base improves. However, numerous case histories (see examples in this volume and National Research Council, 1992) provide persuasive evidence that ecological restoration of damaged ecosystems results in markedly improved ecological attributes with the present state of knowledge. Of course, methodology and models can be improved, but the present loss of species and habitat requires immediate remedial measures.

The biosphere supports human society, and human society should both protect the environment and restore it in return. This relationship is healthy and sustainable. A primary reason for ecological restoration is to provide models of alternative, less destructive relationships between humans and natural systems.

WHY SHOULD WE CARE?

Compelling reasons for carrying out ecological restoration

As Bradshaw (1983) notes, 'The acid test of our understanding is not whether we can take ecosystems

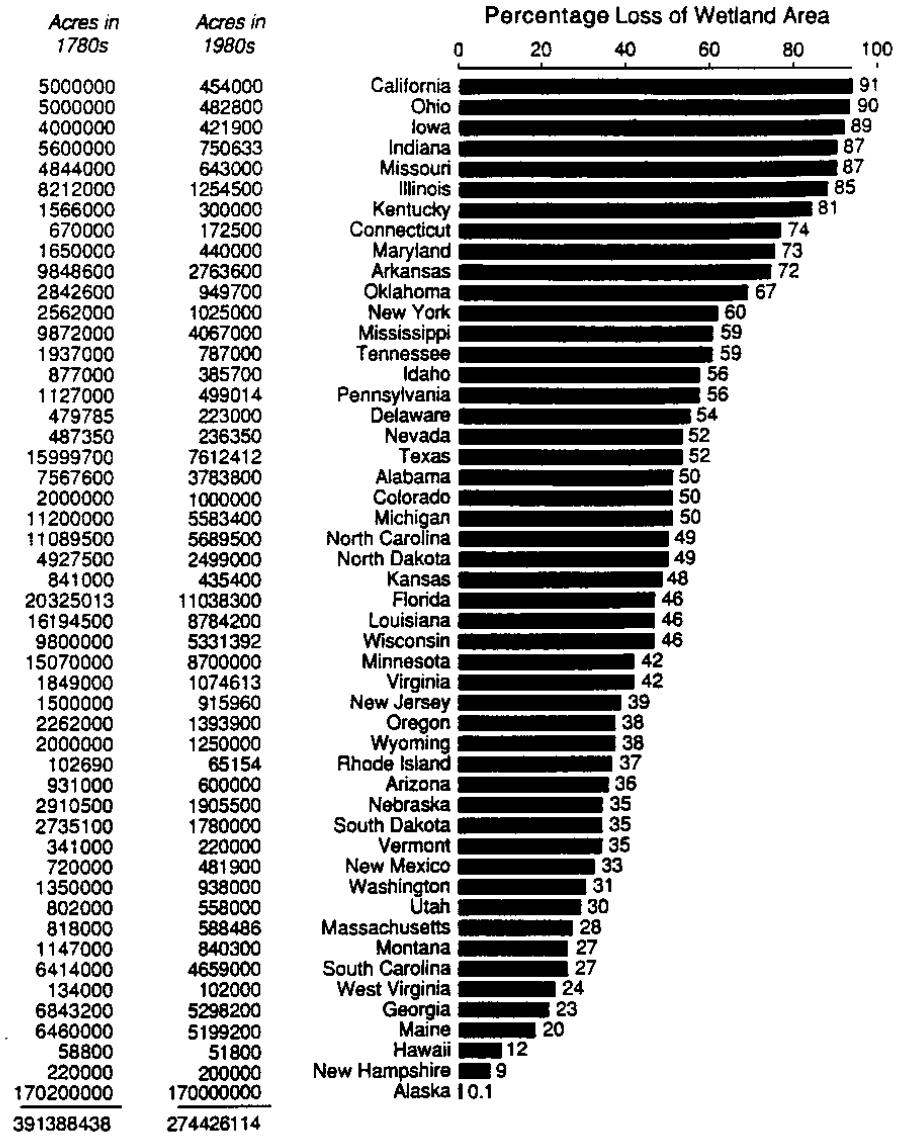

Fig. 2.1. A comparison of wetland area in the USA in the 1780s and 1980s (left), and the percentage of wetland area lost by the 1980s (right). All data courtesy of the US Fish and Wildlife Service.

to bits on pieces of paper, however scientifically, but whether we can put them together in practice and make them work.' If the basic planning in a restoration project is done correctly, ten years or less may often be enough for nature to take over. If the ecological stressors are removed, nature usually does quite well with recovery from damage. Cairns (1998*a*) believes that human society as currently known will not survive if ecological restoration and preservation are not widely practised. There are also ethical responsibilities for both future generations and the other species with which humans share the planet (e.g. Cairns, 1998*b*). Hawken *et al.* (1999) believe that natural capital is the basis for all other forms of capital and should be accumulated. Of course, political instability could result from

continued bad water management (e.g. Postel, 1999). Cairns (1994) believes that ecological restoration proclaims a new, improved relationship of human society to natural systems – humans are both the guardians of natural systems and their dependants.

There are some very compelling reasons for carrying out ecological restoration.

1. Human society must protect and enhance the delivery of ecosystem services (e.g. Daily, 1995, 1997). From a political standpoint, this reason may be the most persuasive since many people grasp the value of life-support systems. The danger of emphasising this reason is that ecosystems might be viewed as commodities rather than living systems that deserve compassionate treatment regardless of the services they provide. 'Short-termism' may override long-term planning as it often does in overharvesting fish stocks.
2. Human society's practices are the best indication of its ethos or set of guiding beliefs. Ecological restoration is a positive statement of co-operation with natural systems. Preserving those systems still undamaged and protecting those restored would be an even more positive statement, especially if accompanied by major restorative efforts for presently damaged systems.
3. The ability to estimate the cost of restoration will be markedly improved as the number of projects increases. When the full cost of ecological restoration is better documented, it may well act as a deterrent to further damage because the dollar costs can be incorporated into comparisons of alternative actions. These full cost numbers will also enable the amount of money in restoration bonds to be determined with more precision.
4. Having restoration projects in each ecoregion, and preferably in each major area of the country, will provide demonstrations for local citizens, and this visibility will vastly increase environmental literacy.

Linkages between human and environmental health

As was the case for human health, publications on environmental health have been initially preoccupied with symptoms resulting from toxicity, stress (e.g. thermal) or physical conditions (e.g. increased suspended solids). Just as the medical focus for humans has gone beyond mere absence of symptoms to consideration of the attributes of health and well-being, environmental health is experiencing the same paradigm shift. Not surprisingly, evidence for numerous, significant linkages is becoming more and more apparent.

Kaplan (1983) remarks that nature is important to people and an important ingredient in a quality life. Wilson (1993) believes that humans still rely on nature's rules, even in the minority of peoples who have existed for more than one or two generations in wholly urban environments. Earlier, Wilson (1984) described *biophilia* as 'the innately emotional affiliation of human beings to other living organisms'. Wilson (1993) believes that biophilia is not a single instinct, but a complex set of learning rules. Ulrich (1993) goes further to propose that evolution selects those individuals who both learn and retain associations and practices related to natural systems that enhance the prospects of survival. However, Ulrich (1993) is also careful to analyse biophobic responses, which are reminders of the severe penalties resulting from dangerous interactions with various species or habitats. Human ancestors must have been fairly adept at risk analysis.

DESTRUCTIVE ACTIONS AND PHILOSOPHIES

Preference for enormous risk compared to a series of behavioural adjustments

Human society's preference for one enormous risk compared to a series of behavioural adjustments suggests that such actions occur because human society does not have enough information. However, Orr & Ehrenfeld (1995) believe that human society has enough information but is in denial. Numerous examples exist, such as cigarette smoking, unhealthy diets, sexually transmitted diseases, and various forms of addictions. Hardin (1999) discusses this myopia with regard to human population size and affluence. Ehrlich & Ehrlich (1996) believe that misinformation is a major factor in the anti-science

backlash. Publications espousing protection of the biosphere have been generally available for decades (e.g. Caldwell, 1972) and have influenced many people (but not enough) to preserve the biosphere. Clearly, something more than sound reasoning is needed because much damage to biospheric integrity has occurred in the nearly three decades since Caldwell's book was published. Environmental historian McNeill (2000) notes that, for the first time in human history, human society has altered ecosystems with increased intensity, on large scales, and with much speed. This larger problem is the one that those interested in restoring ecosystems face at the outset of the twenty-first century.

Disassociation from, and reassociation with, nature

The rate of ecological damage and degradation dramatically exceeds the rate of ecological restoration and rehabilitation, clearly indicating a problem in human society's relationship with natural systems. Cairns (1994) views ecological restoration as a re-establishment of a harmonious relationship between human society and natural systems. The desire for a deep connection with nature still exists, as evidenced by the popularity of ecotourism, nature channels on television, bird-and whale-watching, and the like. Why does human society abuse the natural systems it still loves? The classic paper of White (1967) describes the alienation in terms of human cultural history. Nash (1982) adds to the discussion that this separation from nature resulted from human cultural development. Hamilton & Cairns (1961) also discuss the diminished relationship, although in a somewhat less ecological context. More recently, Abram (1996) traces the damaged relationship with natural systems to the development of written language. If this hypothesis is valid, then personal computers and the internet may have deepened the separation.

In Canada, the United States, Australia, and some other parts of the 'developed world', people still glorify the pioneer spirit, which includes the conquest of nature, but often at the expense of indigenous peoples and species. Poet Walt Whitman (1967) celebrates the felling of primeval forests and the damming of rivers. However, John Muir and David Thoreau were both advocating a spiritual relationship with nature long before urban sprawl encroached upon the semi-wild places, and people (who had never worked for a living with their hands) emerged from the urban areas in huge 'suburban utility vehicles' to play pioneer.

These degrees of 'apartness' appear minor when compared to the exemptionalist position of some economists (e.g. Simon, 1983): technology, ingenuity and creativity free human society from the iron laws of nature that restrict other species. In Genesis, God instructs humans to be fruitful and multiply; fill the land and conquer it; dominate the fish of the sea, the birds of the sky, and every beast that walks the land. However, the human relationship with other creatures should not be based on a position of human dominance as some Christians interpret this injunction (see Bradshaw, this volume).

Janzen's (1988) efforts to restore the Guanacaste dry forest in Costa Rica (see also Janzen, volume 2) is a splendid example of a reassociation with nature following a disassociation from nature. Arguably, the most important feature is that the restoration occurred in a country with a modest per capita income and was supported by its president and the local citizenry. This effort puts inhabitants of wealthier countries to shame when they claim they cannot afford ecological restoration. This restoration was also robust science, and Janzen received a number of awards (e.g. Craaford Prize, Blue Planet Prize) for what he terms biocultural restoration.

Diamond (1999) relates the advancement of various human societies to the biota available for domestication. These ties to domesticated animals outside of agriculture are remarkably strong. For example, Beck & Myers (1996) report that companion animals (pets) reside in 56% of the households in the United States. Wilson (1984) notes that more people visit zoos each year than attend all professional sporting events. Anderson *et al.* (1992) provide persuasive evidence that pet ownership significantly lowers systolic blood pressure in both men and women.

Association with plants is also viewed as beneficial, even in the workplace (e.g. Randall *et al.*, 1992). Lewis (1996) describes the therapeutic benefits of

gardening as a means of improving mental health. Not surprisingly, humans experience benefits from landscapes (e.g. Korpela & Hartig, 1996) and have preferences for various types of landscapes (e.g. Purcell *et al.*, 1994). An important finding for restoration ecologists is that benefits appear to cover quite a range of cultures (e.g. Hull & Revell, 1989).

This admittedly cursory survey of the literature shows that ecological restoration would satisfy human psychological needs and provide valuable health benefits. Why, then, is it not more common?

War, terrorism, peace and restoration

War damages ecosystems in a variety of ways. Younquist (1997) describes the environmental warfare unleashed by Saddam Hussein during the so-called Gulf War in the early 1990s, and Earle (1992) recounts the damage a year later. Myers & Kent (1999) have an excellent discussion of environmental degradation caused by refugees from military conflict. War also diverts resources from such activities as environmental protection and restoration. Cairns (2000) states that sustainability, as now envisioned, cannot be achieved in the absence of peace. Even terrorism might well divert resources that otherwise would be used for ecological restoration. The Tofflers' (1993) disquieting book persuasively argues that society is prepared for neither twenty-first century war or peace, but they do see possibilities for the latter.

A grim picture indeed! But, as Hippocrates (*c.* 400-377 BC) noted: 'He will manage the cure best who foresees what is to happen from the present condition of the patient.' Restoration ecologists cannot avoid the obstacles hampering their activities nor be paralysed by their magnitude. If human society is to have a quality future, ecological destroyers must be restrained and ecological healers encouraged! As Nobel Laureate Joshua Lederberg (quoted in Garrett, 1994) stated: 'Nature is not benign . . . The survival of the human species is *not* a preordained evolutionary program.' Ecological healers have a major role to play in the continued survival of the human species. However, hope should include more than mere survival! A quality life should be the objective, and in this context, ecological restoration will be enormously useful if a major effort is launched in time!

Restoring society's economic perspective

Most of human society has become obsessed with growth – more shopping malls, highways and other anthropogenic artifacts. Arguably, the most outspoken advocate of growth was economist Julian Simon:

> We have in our hands now – actually in our libraries – the technology to feed, clothe, and supply energy to an ever-growing population for the next 7 billion years . . . Even if no new knowledge were ever gained . . . we would be able to go on increasing our population forever. (Quoted in Bartlett, 1998.)

Since one might well question the soundness of the growth described by Simon over such a long period on a finite planet, attempts have been made to dull the misgivings of those who question the growth policy by using the terms 'smart growth' or 'managed growth'. For example, the President's Council on Sustainable Development (1996) states (p. 92): 'While some growth is necessary, it is the nature of the growth that makes the difference.' Growth is clothed in a battle of words, but the basic problem is that growth displaces other species, fragments habitats, and generally damages ecological health and integrity.

The well-being of cultures and societies is shaped by short-term, competitive 'needs'. Ironically, much environmental damage is financed by government subsidies (e.g. Myers & Kent, 1999). Merely reducing or eliminating these subsidies would markedly reduce the pressures on restoration ecologists and simultaneously leave more habitat to use as a source of recolonising species for damaged ecosystems. Arguably, the integrity of ecosystems and the human communities and societies associated with them are closely linked. Economist Gordon Tullock (1994) has studied the economic systems of non-human societies, which have been in place for a longer time period than humans have been on the planet. The striking feature of these societies to an environmental biologist is that no money is used,

natural capital is protected, and almost no material is produced that cannot be reincorporated into natural systems. In fact, most 'wastes' are eagerly sought by one or more other species. Moreover, the practices of these non-human societies are sustainable, as demonstrated by their long history of success. Each of these species would probably have continued for countless more generations were it not for human interference. Whatever ecological damage these non-human societies do is easily repaired by the natural resiliency of natural systems. Assisted recovery (i.e. ecological restoration) is generally unnecessary.

Selfish, short-term view

Although most people can see the value of an ecological life-support system, it appears that a selfish, short-term view is responsible for continuing ecological damage and failure to repair much of the damage. It is highly probable that most readers of this volume will be able to find a damaged ecosystem near their residence, but only a fortunate few will have comparable access to a sizable, robust ecosystem with a high degree of ecological integrity. This volume offers abundant answers to 'How should we restore damaged ecosystems?' and much evidence that is persuasive to professionals in the field of ecological restoration in answer to 'Why should we . . . ?' Other contributors have attempted to answer 'Why don't we . . . ?' I can only speculate on why the general public has not embraced ecological restoration. Ecological restoration is basically the healing of unhealthy, wounded natural ecosystems. However, awareness of any but the grossest damage requires a fairly high level of ecological literacy that is not common in society as a whole. Two imperatives are most likely to cause a major paradigm shift that will lead to widespread restoration of damaged ecosystems: (1) a substantial increase in ecological literacy in both the general public and its representatives and (2) ecological damage so severe that even the ecologically illiterate are aware of it. Homer (*The Iliad*) was well aware of this: 'Once damage has occurred, even a fool can understand it.' Havel, a poet in Czechoslovakia who later became President of that country, attributed society's inaction to other paradigms (Havel, 1992):

> What a paradox for our generation that man, the greater collector of information, has all the knowledge about the dangers facing the species, but is almost incapable of acting, because the knowledge is either too poorly organized or because it is rendered useless due to the paradigms that govern our lives.

It seems obligatory for restoration professionals to give at least 10% of their working time to increase societal literacy as rapidly as possible. However, the resistance to major paradigm shifts is fierce, so professionals must be prepared to cope with widespread major ecological disequilibrium with far fewer recolonising species than are now available. A disquieting prospect at best, but not improbable. Lest this seem unduly pessimistic, it is noteworthy that environmental emergencies are the recurring themes in interviews with world-renowned scientists (Newbold, 2000). Jane Lubchenco's presidential address in 1997 to the American Association for the Advancement of Science calls for 'a more effective, interdisciplinary . . . effort on the environment.' Ehrlich (1997) strongly endorses working with a variety of other disciplines, including economics, in order to understand what is driving human decisions on resource use and even further '*how to change some aspects of human behaviour*' (emphasis his). Arguably, if resource use does not change, ecological restoration does not have a bright future.

In order to influence resource use, one must be able to convince such administrators as the County Planning Officer of Lancashire, UK, or the Town Manager of Blacksburg, VA, USA, that repairing damaged ecosystems is a sensible, civic responsibility. Working with local officials might be termed the 'bottom – up' approach. However, bioregional planning that is essential to effective ecological restoration also requires a 'top – down' approach to ensure integrated environmental management. Clearly, no single approach will produce the necessary imperatives. These imperatives, working through people's lives and livelihoods, must be continually addressed. A number of books on these seemingly obvious points were written in the last half of the century,

but have not yet produced a paradigm shift that results in an ethos (a guiding set of values) on societal responsibility for repairing damaged ecosystems.

WHAT CAN BE ACCOMPLISHED?

Fortunately, abundant case histories of ecological restoration and rehabilitation exist. One interesting example from a historic perspective is the restoration and recovery of the Thames Estuary (Gameson & Wheeler, 1977). In the mid nineteenth century, the condition of the Thames had become so foul that sheets soaked in disinfectant were hung in the Houses of Parliament in an attempt to counteract the stench. By 1858, the smell at Westminster had become so overpowering that its control became a matter of strong personal interest to Members of Parliament, and interceptor sewers were constructed. In addition to this historic example, the National Research Council (1992) volume cites some interesting case histories of aquatic ecosystem restoration. More recent restoration examples are given in this volume and in many of the journals cited in the literature sections of the individual chapters.

The National Research Council (1992, pp. 354–355) recommends that inland and coastal wetlands in the United States be restored at a rate that offsets any further loss of wetlands and contributes to an overall gain of 10 million wetland acres by the year 2010. This number represents less than 10% of the total number of acres of wetlands in the United States lost in the last 200 years. The recommendation for restoration of rivers and streams in the United States is 400 000 miles within the next 20 years (from 1992). The recommended magnitude of this restoration represents approximately 12% of the 3.2 million miles of streams and rivers in the United States and was recommended because it is comparable to the miles of streams and river affected by point source and urban runoff. Excluding the North American Great Lakes, as well as flood control and water supply reservoirs, the report recommends that 1 million acres of lakes be restored, in association with wetland and river restoration, by the year 2000, increasing to 2 million acres in the long term. These figures and dates illustrate the magnitude of the undertaking. Data on progress toward these goals are not easily gathered nor has enough time elapsed except on phase 1 of the lake restoration; however, this limited information does depict the magnitude of the problem for just the United States.

CONSTRAINTS ON RESTORATION

Ethical problems in ecological 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 on human society's set of guiding beliefs? At its worst, ecological restoration could be used as another justification for continued damage to natural systems (e.g. as the equivalent of a repair shop for automotive damage). Furthermore, the rate of ecological destruction on a global level is so enormous that the comparatively few attempts to repair ecological damage are dwarfed by comparison. Indeed, there are some ethical problems associated with ecological restoration.

1. Most ecological restoration is carried out (through management) to repair damage caused by human mismanagement. If management is the disease, how can it be the cure? Noss (1985) states: '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 habitats of a different kind. For example, created wetlands may replace an upland forest, or an upland forest may be destroyed to create a 'replica' of the savanna that once occupied a particular 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 deserves more caution than it has been given.
3. At the current state of knowledge, restoration projects are likely to have unforeseen outcomes. Ecological restoration carried out by the most skilled professionals will occasionally, perhaps frequently, omit some very important variables. Or, episodic

events may occur at inconvenient times. Some of the unforeseen results may offset any ecological benefits likely to result from a particular restoration project.

4. 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 a species capable of co-existing with human society may be hampered. 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.
5. Similarly, if ecological restoration is carried out on an extremely large scale, human-dominated successional processes could become the 'norm'.
6. Finding sources of recolonising 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 colonise naturally?

Global climate change

Damaged ecosystems are likely to recover or be restored most quickly when climatic conditions suit the species that once inhabited them. Conditions unsatisfactory for recolonisation by once resident species provide an excellent opportunity for exotic, invasive species. Significant climate change is likely to destabilise already damaged ecosystems further and to lessen the recolonisation by appropriate species from undamaged sites. In fact, significant climate change will almost certainly damage healthy ecosystems. Ecological restoration may be nearly impossible in a period of appreciable climate change.

In this instance, policy change could make a substantial difference. As Retallack (1999) notes, the United States is responsible for nearly 25% of total greenhouse gas emissions, despite having only 4% of the world's population. The United States emits five times the global average – more than any other country in the world (Retallack & Bunyard, 1999). A poll released in October 1998 by the World Wildlife Fund notes that 57% of Americans believe climate change is already happening, 79% support the Kyoto Agreement to reduce greenhouse gases, and over 66% think that the United States should act now, unilaterally, to reduce carbon dioxide emissions. Results of this poll are remarkable support for the position of mainstream scientists worldwide. Delay in fulfilling the voluntary commitment the United States made at the 1992 Rio Conference (to reduce its greenhouse gas emissions to 1990 levels by the year 2000) shows that this obviously was an empty promise. Precautionary action is now essential. As the Romans maintained: 'Bis dat qui cito dat' – one gives doubly who gives quickly. Climate change could quickly spiral out of control (Bunyard, 1999). A destabilised climate would undoubtedly cause a refugee crisis (e.g. Foley, 1999) that would worsen the environmental crisis and adversely affect ecological restoration.

Hostile lawsuits

Space does not permit extensive coverage of lawsuits, vandalism, and other attempts to block ecological restoration. In the aggregate, they deserve serious attention. One example of a lawsuit concerns a ranching group's attempt to block the reintroduction of the Mexican grey wolf into the US Southwest (Taugher, 1999*a*). The New Mexico Cattle Growers Association sued the US Fish and Wildlife Service to block the reintroduction, claiming the captive-bred wolves contained the genes of dogs or coyotes and were not deserving of a reintroduction effort. Biologists noted that the wolves were living only in zoos and sanctuaries pending release and that new DNA testing techniques established no evidence for the ranchers' claim. Even with this ruling, at least five wolves were shot to death after the reintroduction. Taugher (1999*b*) also notes that the Rio Grande silvery minnow, listed as an endangered species in the United States in 1993, has suffered serious habitat reduction since then. The problem of restoring a declining river ecosystem and meeting the water demand of irrigation for farmers and a burgeoning urban population has led to a call by US Senator Pete Domenici to restore upstream habitat now unsuitable for the minnow to justify rendering

presently suitable downstream habitat unsuitable (for details, see Editorial, 2000; Soussan 2000). To further complicate this situation, the US Bureau of Reclamation asserts that there have been misrepresentations of facts on water supply issues by the Middle Rio Grande Conservancy District senior staff (Gabaldon & Leutheuser, 2000). This brief summary depicts an illustrative and complicated legal issue in which ecological restoration may often be invoked – in this case, justifying damage to presently suitable habitat for an endangered species on the assumption that ecological restoration will make a presently unsuitable habitat suitable and that the endangered species will successfully recolonise the restored area.

The global commons and environmental quality control of private property

The National Research Council (1992) recommends ecological restoration at the landscape level whenever possible. However, restoration projects are often approached piecemeal. Part of this problem is due to fragmentation through assignment of government agencies to a portion of environmental management. As Leopold (1990) notes: 'Each agency acts as if it is the only flower facing the sun.' Each government agency and most of human society is looking at ecosystems in terms of the uses that might be made of them, including alternative uses that might threaten the ecosystem's existence. No organisation is responsible for maintaining the integrated processes and relationships that collectively make an ecosystem what it is and make sustainable use possible.

Restored ecosystems are more likely to be self-maintaining if restoration is carried out at the landscape level (e.g., National Research Council, 1992). Landscape-level restoration will almost always involve public property (especially where hydrologic systems are concerned) and a mixture of organisational and personal private property. Consequently, another formidable barrier to a landscape approach is the inevitable conflicts between environmental protection and property rights. The individual property owner with a small wetland is likely to be irate when told that filling, draining or altering the wetland in major ways is illegal. This property, the owner sometimes says, is private 'and I will do as I wish with my property'. However, private property rights are not sacred, even in societies with strong views on this subject. Each person lives not only on private property, but in a larger ecological landscape shared with others. So, a key question (at which environmental literacy, ethics, and human institutions such as law and economics interact) is: To what extent should individual, organisational or national behaviour and attitudes be modified for the betterment of others of the human species and for other species as well?

Hardin's (1968) classic paper and numerous subsequent publications describe the inequities that occur in the use and abuse of the commons. Hardin suggests that private property ownership is one way of avoiding the tragedy, since it gets rid of the destructive competition between common-ground users. On the other hand, the insistence of many property owners that they have the right to do whatever they choose with their private property often damages adjacent or even distant ecosystems. Much more attention should be given to the many different systems in which use and maintenance of commons were ensured up to quite recent times. That these problems have existed for at least 4000 years is evidenced by the inclusion of several laws in the famous Code of Hammurabi that dealt with the use of irrigation water (Postel, 1999). Why restore any damaged ecosystem if misuse of the commons and/or private property can, in a short period of time, erase the labour of years or decades? However, these problems are not insurmountable, as documented by Janzen's (1988) Guanacaste Forest restoration and a substantial number of other projects (e.g. the Adobe Creek restoration of a salmon run by a group of high-school students [described in Cairns, 1998*a*]).

All zoning ordinances restrict property rights, and examples can be found in the news of cases where the proper balance between property rights and common good is delimited. Ecological restoration should not be impaired by practices on private land. Plans for constructing an incinerator for hazardous waste next to an elementary school predictably are met with fierce resistance. They are both in the same airshed, and unrestricted exercise

of property rights on one property may unilaterally devalue the property rights of others in the same airshed. Helicopter flights in the Grand Canyon create noise that historically has never existed in the Grand Canyon. If, hypothetically, a proposal were made to permit the construction of a fast-food restaurant opposite a war memorial, a public outcry would be quite predictable.

OVERCOMING THE CONSTRAINTS AND SETTING CRITERIA FOR SUCCESS

Responsibility for restoration

Clearly, ecosystem restoration without concomitant protection of unimpaired ecosystems would be senseless (e.g. Woodwell, 1994). However, for this discussion, the key issue becomes: how does one prevent restored ecosystems from being re-damaged? The only possible means is continual, direct surveillance and monitoring of the health of the ecosystem while maintaining equal vigilance on proposed or actual activities that threaten ecosystem health. This design requires a system of ecosystem guardians for each restored or undamaged ecosystem.

Ecosystem protection and restoration will require the collaboration of ordinary citizens who can be especially attentive to the actions and proposed actions of individuals and organisations that might threaten the ecosystem. In addition, skilled professionals who can gather the hard evidence necessary for policy and regulatory decisions are needed. Paul R. Ehrlich (pers. comm.) has recommended that professional biologists tithe their time on projects beneficial to the general well-being of ecosystems and, consequently, human society. In the case of restoration and the maintenance of ecosystem health, this donation of expertise could well be extended to engineers, chemists, economists, sociologists, and people from almost any other discipline.

A number of scientific measurements, some well within the capabilities of highly motivated but relatively untrained individuals, can furnish very useful information. The Save Our Streams program, administered by Trout Unlimited, provides one example. Regrettably, most of these measurements are at the population or community level, and there are relatively few, generally accepted measurements of integrity or condition at the ecosystem or landscape level. Measurements that do exist tend to be experimental, require skilled professionals for reliable measurement and analysis, or are generally quite expensive.

In examining various measurements of ecosystem integrity, primarily for large river systems of the world, Cairns (1997) suggests that examination of a selected list of practices and guiding beliefs of human society might accurately predict the general health and condition of the ecosystems in which these societies live. For example, if economic development is the highest value of a particular society, one would not expect ecosystems to fare well. If human society is not willing to modify its present behaviour (e.g. living on floodplains and expecting engineering solutions for protection, and wishing to move water where people are rather than people to where water is), it is quite likely that society will live in managed, rather than natural, ecosystems. This drawback is not intended to denigrate scientific measurements of ecological integrity or to hamper further development in this area. It is, rather, to suggest that, since the fate of natural systems is in the hands of human society, the practices and guiding beliefs of this society must be examined as a useful means of predicting the condition of ecosystems associated with that particular society.

Responsibility after restoration

Any ecosystem, including restored ecosystems, can be damaged at any time. Ideally, early-warning monitoring systems (see Holl & Cairns, this volume) will detect a deviation from established quality control criteria in time to take remedial action before serious damage is done. Ecological restoration is an investment in the future and deserves the same level of stewardship that a financial investment receives.

Paying for restoration

Holl & Howarth (2000) give a detailed analysis of how to pay for ecological restoration. However, if the owner of the damaged ecosystem has disappeared or

no owner exists because the damage occurred on common ground, the government must intervene and furnish money. All natural resources in any state require maintenance, so financial support must always be available. The ecological infrastructure (i.e. natural resources) has just not fared well in the cash flow. Since the methods and procedures for ecological restoration are now reliable and sound, the big challenge is to devise a sustainable ecological infrastructure maintenance system!

How to restore

Reflections on methods and successes

The Kissimmee River restoration and other case histories serving as illustrations in the National Research Council (1992) report will encourage other regions to engage in ecological restoration by providing evidence of capabilities for restoration. Whether the cost and effort involved will dissuade citizens from doing so remains to be seen. Evidence in publications by Caldwell (1972), the National Research Council (1992, 1996), the National Academy of Engineering (1994, 1996, 1997), Odum (1989), Passmore (1974) and Hardin (1993) show heightened concern.

The first step in re-evaluating human society's relationship with natural systems will be to quantify rates of ecological damage and repair. The establishment of bioregions in which such evidence is gathered would facilitate this process and simultaneously furnish local citizens with evidence that they can confirm personally. Additionally, since degrees of ecological damage or repair require considerable professional judgement, it will be necessary to establish a qualified 'blue-ribbon committee' of ecologists knowledgeable in the determination of both ecosystem health and degree of ecological restoration. It would be advisable for these groups to use criteria and standards that are as homogeneous as the differences between and among bioregions permit. A national blue-ribbon committee could furnish both information and judgement to the regional committees. This group should be responsible for continually modifying and revising criteria and standards when enough new knowledge is available to justify revision from a scientific perspective.

BEGIN CHANGES NOW

Logic suggests that the present rate of population growth and concomitant ecological destruction cannot continue indefinitely without severe effects on human quality of life. Either human society will reexamine its relationship with natural systems and alter society's impact on them, or, eventually, natural processes will regulate human society's numbers and level of affluence. The first goal should almost certainly be to ensure that the rate of ecological damage does not exceed the rate of ecological repair or restoration. However, achieving a balance between destruction and repair merely increases the probability that situations will get no worse unless the population continues to grow. Ensuring a net gain in quality ecosystems is a more desirable goal, especially if the human population size is stabilised or even decreased over the long term. These actions would enhance the accumulation of ecological capital, such as old-growth forests, topsoil and species, through habitat improvement. The longer human society waits to discuss and examine its relationship with natural systems, the less likely it will be that quality ecosystems will be available as models or that species will be available to recolonise damaged ecosystems. The rate of ecosystem damage should be exceeded by the rate of ecosystem restoration and an overall net gain should be made annually in ecological capital and robust ecosystems with an exemplary level of ecological integrity.

The global ecological blight directly affects people, their homes, their surroundings, the attitudes of others in their areas, and their whole livelihoods. The mission of restoration ecologists is to diminish, perhaps even eliminate, this blight. This mission goes well beyond an interesting academic problem – it addresses the core of the human condition. Planning officers and policy officials are derelict in their responsibilities if they ignore the deteriorating condition of the planet's ecological life-support system. These imperatives were sufficiently unobvious to citizens and their legislative representatives that numerous books were written to draw attention to them. In 1992, the Union of Concerned Scientists (1992) issued the *World scientists' warning to humanity* which is signed by a huge number of world renowned

scientists, including many Nobel Laureates. There is much to do and the time to do it is now!

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