Motivations for the Restoration of Ecosystems

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Abstract: *The reasons ecosystems should be restored are numerous, disparate, generally understated, and commonly underappreciated. We offer a typology in which these reasons—or motivations—are ordered among five rationales: technocratic, biotic, heuristic, idealistic, and pragmatic. The technocratic rationale encompasses restoration that is conducted by government agencies or other large organizations to satisfy specific institutional missions and mandates. The biotic rationale for restoration is to recover lost aspects of local biodiversity. The heuristic rationale attempts to elicit or demonstrate ecological principles and biotic expressions. The idealistic rationale consists of personal and cultural expressions of concern or atonement for environmental degradation, reengagement with nature, and/or spiritual fulfillment. The pragmatic rationale seeks to recover or repair ecosystems for their capacity to provide a broad array of natural services and products upon which human economies depend and to counteract extremes in climate caused by ecosystem loss. We propose that technocratic restoration, as currently conceived and practiced, is too narrow in scope and should be broadened to include the pragmatic rationale whose overarching importance is just beginning to be recognized. We suggest that technocratic restoration is too authoritarian, that idealistic restoration is overly restricted by lack of administrative strengths, and that a melding of the two approaches would benefit both. Three recent examples are given of restoration that blends the technocratic, idealistic, and pragmatic rationales and demonstrates the potential for a more unified approach. The biotic and heuristic rationales can be satisfied within the contexts of the other rationales.*

Key Words: climate change, ecological restoration, natural capital

Motivaciones para la Restauración de Ecosistemas

Resumen: *Las razones por la que los ecosistemas deben ser restaurados son numerosas, dispares, generalmente poco sustentadas, y comúnmente poco apreciadas. Ofrecemos una tipología en la que estas razones—o motivaciones—son ordenadas entre cinco razonamientos: tecnocrático, biótico, heurístico, idealista y pragmático. El razonamiento tecnocrático se refiere a la restauración que es llevada a cabo por agencias gubernamentales u otras grandes organizaciones para satisfacer misiones y mandatos institucionales específicos. El razonamiento biótico de la restauración es la recuperación de aspectos perdidos de la biodiversidad local. El razonamiento heurístico intenta extraer o demostrar principios ecológicos y expresiones bióticas. El razonamiento idealista consiste de expresiones personales y culturales de la preocupación o reparación de la degradación ambiental, reencuentro con la naturaleza y/o cumplimiento espiritual. El razonamiento pragmático busca recuperar o reparar ecosistemas por su capacidad de proporcionar una amplia gama de servicios y productos naturales de la que dependen las economías humanas y para contrarrestar extremos en el clima causados por la pérdida de ecosistemas. Proponemos que la restauración tecnocrática, como se concibe y practica actualmente, es muy corta en su alcance y debiera ampliarse para incluir al razonamiento pragmático, cuya importancia apenas comienza a ser reconocida. Sugerimos que la restauración tecnocrática es demasiado autoritaria, que la restauración idealista esta muy restringida por la falta de fortalezas administrativas, y que una mezcla de los dos enfoques podría beneficiar a ambas. Proporcionamos tres ejemplos recientes de restauración que combinan los razonamientos tecnocrático, idealista y pragmático y demuestran*

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el potencial para un enfoque más unificado. Los razonamientos biótico y heurístico pueden ser satisfechos en el contexto de los otros razonamientos.

Palabras Clave: cambio climático, capital natural, restauración ecológica

Introduction

Ecological restoration is an elective initiative that fosters the sustainable recovery of ecosystems that have been degraded, damaged, or destroyed. Restoration returns an ecosystem to its historic trajectory and recovers its former biotic expressions to the extent that contemporary conditions allow (Clewell 2000*a*; SER 2004). The restoration movement has captured the imagination of conservationists globally and the serious attention of professional resource managers, ecologists, and the environmentally informed public. Substantial public funding has underwritten numerous restoration efforts, many scholarly works have been written, professional associations have formed, and numerous conferences conducted. Nongovernmental agencies (NGOs) are deeply involved in restoration, and citizen volunteers have devoted countless hours to projects. Ecological restoration for gain has even been hailed as a major growth industry of the future (Cunningham 2002). In spite of such interest, insufficient synthesis and justification has been provided to answer the fundamental question (Aronson & Van Andel 2005), Why is it important, or worthwhile, to restore ecosystems?

Various philosophical writings—some of which we explore—describe benefits that accrue from restoration without specifically identifying them as fundamental motivations to restore ecosystems. Cairns (2002) suggests a comprehensive assessment of the rationale to restore; however, his text is really a compelling exhortation for expanding the scale of restoration work worldwide. Hobbs and Norton (1996) explore several reasons for restoration without attempting a full synthesis. Descriptions of restoration projects frequently ignore the why of the project and imply that the need for restoration is inherently obvious and its intentions are noble. The underlying reasons to restore remain understated and unappreciated.

Here, we attempt to synthesize the answers to the question of why ecosystems should be restored. We recognize five general rationales or motivations for restoring ecosystems: technocratic, biotic, heuristic, idealistic, and pragmatic. These are not mutually exclusive categories, but they comprise a typology that facilitates their systematic description. Two contrasting paradigms weave their way through these rationales and add tension to their descriptions. In one, humans stand apart from nature and exploit it. Ecological restoration is considered a technical task to be imposed on nature by institutional authority to satisfy societal values. The opposing paradigm posits that humans comprise an inseparable subset of nature and that nature and culture sustain each other. The act of ecological restoration is mutually beneficial and is as restorative to restorationists as it is to ecosystems.

Technocratic Rationale

Technocratic restoration is undertaken by government agencies and other large institutions to recover the social values that were once provided by ecosystems prior to suffering environmental impacts. For the most part, the social values pertain to water quantity and quality issues, associated erosion control, wildlife habitat, and endangered species protection. Much technocratic restoration is conducted on public lands, either in-house by agency personnel or outsourced by design firms, environmental engineering firms, small companies that specialize in ecological restoration, or sometimes to universities or NGOs. The lion's share of technocratic restoration has been conducted on both public and private lands to satisfy permit conditions that mandate compensatory mitigation. Mitigation is a strategy required by government agencies to compensate for unavoidable adverse environmental impacts and losses. Mitigation has been practiced in the United States for three decades, where it is the major source of employment for restoration practitioners. Recently, mitigation has been conducted in Europe under the auspices of the European Union (Mercer 2005).

Ecological restoration is not in itself mitigation. Rather, it is one way of compensating for environmental damage caused by public works projects and private developments. Satisfactory ecological restoration has been accomplished in the context of compensatory mitigation (Munro 1991; Clewell 1999; Clewell et al. 2000). However, many compensatory mitigation efforts that have been touted by agency personnel and other proponents as "ecological restoration" could only qualify as subsets of full-fledged and longer-term restoration projects as recognized by the Society for Ecological Restoration International (SER 2004).

Technocratic restoration is essential for managing large and complex endeavors, such as the Kissimmee river restoration in Florida (Cummins & Dahm 1995). Such projects require governmental coordination of the many contractors engaged, and agency oversight for the disbursement of public funds and for assurances that a maze of relevant laws and regulations are satisfied. For less-ambitious projects, technocratic restoration provides a similar framework for project management, fiscal accounting, legal council, administrative consistency, and powers of enforcement.

Public agencies that conduct, sponsor, or issue permits for ecological restoration generally dictate the goals, objectives, performance standards, and strategies of restoration projects. An agency is thereby assured that its restoration projects conform to its mission and policies and ultimately to the enabling legislation that governs it. Uniformity in project design across projects is maintained by an agency for internal convenience and to strengthen its capacity to defend itself against legal challenges initiated by regulated interests and environmental organizations, particularly in respect to mitigation. Consequently, technocratic restoration is almost universally accomplished in an authoritative, top-down manner. This situation causes an undesirable bifurcation between agency personnel who design ecological restoration projects or approve restoration plans in their offices and restoration practitioners who conduct the restoration on site.

To agency personnel and the public they serve, the rationale for ecological restoration is embodied in the mission of their agency, such as improvement of parkland, wildlife habitat, endangered species habitat, and water quality. To the restoration practitioner, the rationale for technocratic restoration is the satisfaction of governmental stipulations in contracts, permits, and consent orders. In other words, the role of the restoration practitioner is technical rather than creative. It is not conducive to forming a strong bond between culture and nature. In addition, the public is sometimes effectively excluded from technocratic restoration planning and is seldom offered the opportunity to become engaged in restoration work because of liability issues and the exigencies of quality control, timeliness, and budget. Consequently, local stakeholders tend to under appreciate restoration projects and their public benefits.

Public agencies commonly treat ecological restoration as if it were civil engineering with finite endpoints. This practice simplifies determinations of compliance by contractors and permit holders with agency requirements. However, ecosystems are dynamic entities lacking finite endpoints whose trajectories are governed in part by complex, stochastic events. For this reason, ecological restoration does not lend itself to an engineering paradigm. Restoration remains feasible only if it satisfies institutional mandates.

Biotic Rationale

Ecological restoration is, or should be, scientifically informed by ecological principles and knowledge. Organizing principles of ecological science have contributed significantly to the biotic rationale, particularly the concepts of biodiversity. The perpetuation of biodiversity is an oft-cited reason for conducting ecological restoration. The predilection for conserving local biodiversity is a cherished value, not only among biologists and environmentalists, but also across much of the public sector in many cultures and countries. Among the best-known examples of restoration dedicated to fostering biodiversity are those intended to benefit rare and endangered species (Bowles & Whelan 1994; Falk et al. 1996). Other projects are designed to perpetuate threatened biotic communities, such as those occurring in coral reefs (Lirman & Miller 2003). Much attention has been directed at the genetic level of organization to conserve local ecotypes and thus assure species fitness (Montalvo et al. 1997). Other attention has been given to restoring biodiversity at the landscape level, particularly in Europe. For example, major effort has gone into restoring sustainable rural landscapes consisting of socioecological ecosystems such as species-rich chalk meadows (Willems 2001).

Heuristic Rationale

The heuristic rationale of ecosystem restoration is to elucidate ecological principles from ecosystems undergoing restoration and to serve as a pedagogic aid in ecological science. Bradshaw (1987) proposes that ecological restoration could serve as an "acid test" for ecology, noting that restoration projects allow experimental resolution of conflicting theories of ecosystem development. Harper (1987) foresees that restoration experiments would give insights into ecological processes. He suggests that the reassembly of ecosystems during restoration could resolve questions such as whether or not increases in genetic composition or species diversity could lead to ecosystem stability and resilience or the roles of mutualists and animals in shaping plant communities. A recent book, edited by Temperton et al. (2004), is the principal outcome to date of this approach.

The growing literature in restoration ecology is largely devoid of papers that attempt to elaborate the principles of community ecology from studies at ecological restoration projects (Palmer et al. 1997). One likely reason is the difficulty of establishing replicate plots at heterogeneous project sites. Another is the difficulty in isolating the effects of single variables. Restoration generally requires continuing aftercare, and postinstallation manipulations can destroy experimental designs. Although such studies may eventually be forthcoming, restoration ecologists to date have largely been content to tease data from restoration sites that resolve more narrowly defined questions or that evaluate restoration strategies and methods. The expansion of ecological science is rarely sufficient motivation to initiate a restoration project. Instead, restoration ecologists have availed themselves of the research opportunities that projects established for other reasons provide. In summary, the heuristic rationale for ecological restoration has generated more promise than product.

Restoration conducted to demonstrate ecological science has been similarly limited in extent. John Curtis restored examples of Wisconsin's major ecosystems at the University of Wisconsin Arboretum for teaching purposes (Jordan 2003). Faculty at DuPage College, Illinois, restored a prairie on campus as an outdoor laboratory in environmental science. Other schoolyard restorations have been installed with pedagogic acclaim. Full-fledged restoration sites—particularly those operated as environmental stewardship projects by The Nature Conservancy and similar NGOs—have provided significant firsthand opportunities for environmental education at all educational levels. In spite of such efforts, the heuristic rationale for conducting restoration appears to be more derivative and opportunistic than a principal motivation for initiating restoration projects.

Idealistic Rationale

People are attached to wild areas in the same way farmers love their land. An angler may become attached to a favorite lake, or a small landholder may revere a patch of woods that provides fuel wood for the hearth. Others in the local community may share an attachment, and these wild places may become foci for cultural activities. The local community may fight to preserve and protect such places from external threats and may provide management to assure their integrity. Lacking this psychological attachment, natural areas are taken for granted, and the benefits that may accrue from them go unacknowledged. Little impetus exists to protect and preserve such underappreciated lands.

Some of the earliest attempts at ecological restoration were initiated and conducted by local volunteers who took their attachment to wild lands to another level. Many such practitioners and others perceive ecological restoration as an effective palliative to reconcile people with our often-destructive relationship with nature. We recognize four elements of a cultural, personal, or spiritual nature that comprise the idealistic rationale. Ecosystems are not treated as commodities in need of repair but as inseparable aspects of culture. In short, restoration conducted for idealistic reasons affirms the synthesis of nature and culture.

Idealistic elements of the rationale for restoration are woven throughout Aldo Leopold's writings (Meine & Knight 1999) and were thoroughly developed by William Jordan (2003), who continues to write eloquently on these themes. Idealistic restoration projects are largely conducted by local stakeholders in a casual manner that is unfettered by time limitations, strict budgets, and institutional constraints. Although projects may be conducted on public lands and with public funding, project control is largely retained by the practitioners who actually do the work. Many of them are volunteers rather than paid professionals. They may be supported by institutions such as private land trusts, botanical gardens, or local governmental bodies. The leisurely pace of restoration and dependence on volunteer labor reduce restoration costs. However, project work is generally limited in spatial scale. It is also largely limited to projects that do not require expensive equipment or detailed design work. This kind of restoration project is often approached in a hit-or-miss manner, without adequate attention to baseline data, monitoring, or documentation. Despite its obvious drawbacks, this casual approach has garnered considerable success and public notice for some projects (Stevens 1995). The four elements in idealistic ecological restoration are atonement for environmental damage, reentry into nature, renewal of the nexus between nature and culture, and spiritual renewal.

Atonement for Environmental Damage

Many private individuals who volunteer in restoration projects are motivated in part by their abhorrence of past or ongoing environmental damage. The act of restoration can be identified as a ritual of atonement for living in a culture that is responsible for causing morally unacceptable environmental degradation (Jordan 1994; Higgs 1997). In addition, restoration shelters the practitioner from the environmental despair that is pervasive among preservationists because restoration repairs environmental damage and imbues the practitioner with optimism and a sense of expiation. Jordan (1990, 1992*b*) explains that restoration reverses the alienation of culture from nature, which in turn is "...the real root of ecological catastrophe." Ecological restoration is especially attractive to those whose cultural roots stem from the Protestant Reformation. Jordan (1992*b*) suggests that the need for a ritualized expression of atonement is particularly needed in this large segment of Christian culture that has minimized ritual and the comfort it lends to people in despair. Restoration projects in Europe, and in the southern hemisphere (South Africa, Australia, New Zealand) are correspondingly concentrated in Protestant regions, with some exceptions, such as Spain. Additional factors of course influence the geography of restoration. For example the engineering or "nature development" aspects of Dutch culture may override the influence of their predominant religion.

Reentery into Nature

A strong impetus exists among many people of urbanized and highly technical cultures to seek respite in nature, whether in a context of meditation, contemplation, or recreation. This tendency was described by Eisenberg (1998) in terms of a universal cultural polarity between the "tower" and the "mountain." The tower represents the epitome of urban culture and artifice in many cultures and over many millennia (cf. the Tower of Babylon in ancient Mesopotamia). The mountain, by contrast, represents the ideal of nature both in western and eastern traditions. The Biblical Garden of Eden from which humans were expelled and yearn to return was thought to be located on a mountain.

The concept of wilderness in North America embraces this metaphor of the mountain and combines it with a longing to return from the tower to a mythical Eden, as represented for many by pre-European settlement landscapes. The underlying goal is to rediscover an acceptable midpoint in which becalmed nature remains present, and potent, but does not overwhelm a certain sense of security and well-being (Jordan 1992*a*; Turner 1994). Arcadia is the name given to such a place. To formalize this idea, the act of restoring ecosystems becomes a contemporary ritual or performance by which we approach the Arcadian ideal. Jordan (1991) explains that restorationists try to reduce the Arcadian ideal to practice—to reinhabit nature and bring it inside our "living space" or *oecumene*. In Europe the goal of restoration is only very rarely conceived as some archaic or presettlement condition—Neolithic or Paleolithic. Much more often, the reference is rather a rural, partly agricultural landscape with managed and unmanaged patches in the matrix, as was characteristic in the Middle Ages and right up to the second half of the twentieth century in many regions. This Arcadian ideal is much more realistic in socioecological terms, but it encounters obstacles related to social trends (rural exodus, urban sprawl) and economic policies of host countries and the European Union.

Restoration offers a mutually beneficial relationship between humans and nature where postmodern people savor a hands-on interaction with nature that involves something other than sports or tourism. William Jordan considers this—in a North American context—to be the most important attribute of ecological restoration, moreso than any tangible ecosystem benefits—and he called restoration a way of celebrating our relationship with nature. He noted that hiking, canoeing, hunting, and similar activities do not represent a full reentry into nature; instead, they exploit nature. He asserts that ecological restoration represents full and unselfconscious participation with nature. Alternatively, it can be seen as a ritualistic performance or form of theater in which we act out our relationship with nature to reinforce a new idea or vision we wish to embrace and transmit to others (Jordan 1986, 1987, 1989).

Renewal of the Nexus between Nature and Culture

Most indigenous tribal people and other traditional cultures have been disrupted by the vicissitudes of modern civilization. With their cultural identity shattered, many tribal people have been set adrift in an unfamiliar urban milieu. The traditional lands on which they depended for all their needs were exploited for extractive resources or otherwise ruined. Indigenous people have been expelled from Arcadia and forced to take residence in the tower (Eisenberg 1998). Some ecological restoration projects attempt to restore cultural ecosystems and traditional cultures simultaneously by engaging tribal members in projects designed for this dual purpose. Rogers-Martinez (1992) insists that the restoration of a cultural landscape requires the concurrent restoration of culture and that the two are inseparable. This theme has been treated in depth by Janzen (1988, 1992, 1998, 2002), Bonnicksen (1988), House (1996), Higgs (1997), and others. Ecological restoration has been initiated in rural India to recover and expand sacred groves that are revered by tribal peoples of Hindu tradition as the homes of deities (Ramakrishnan 1994; Desai 2003). In this context, ecological restoration becomes an extension of religious practice for tribal people who participate in restoration and as an exercise in upholding religious tradition for other practitioners who facilitate these projects.

Spiritual Renewal

The act of restoring ecosystems is a kind of meditation or yoga for some people, perhaps unintentionally so at first, during which the practitioner suddenly realizes that he or she is an active and vital participant in ecosystem processes. This intuitive realization is an epiphany that effects or contributes to spiritual renewal. Clewell (2001) described it as an encounter with immanent divinity. The experience is personal and subjective and thus differs from reentry into nature or renewal of the nexus between nature and culture, as described above, which is more of a social ritual whereby people reach into their collective subconscious to a mythic level of awareness. In contrast, spiritual renewal that arises from restoration practice is individualistic and is not equated with traditional religious practice.

Pragmatic Rationale

We began this essay with the statement that ecological restoration is an elective process that gratifies human values. Now we identify two elements comprising the pragmatic rationale—restoration of natural capital and the restitution of anthropogenic climate change—that someday may be recognized as mandatory reasons to restore ecosystems. Without restoration conducted specifically for these reasons, human well-being will suffer, and the planet will become less habitable. The current rate of environmental destruction is leading to this eventuality. Surprisingly, in the literature on ecological restoration, the pragmatic approach is the least well developed of all, despite being the most compelling for a broad, international constituency.

Restore Natural Capital

Natural capital, as we use that term, consists of sustainable ecosystems and ecological landscapes from which humans derive services and products that improve their economic well-being without costs of production (Daly & Farley 2004). A few examples of these services are the detention of potential flood waters, erosion control, protection of recharge areas, and transformations of excess nutrients. Natural products include timber, seafood, rangeland, and fuel wood (Costanza 1991; De Groot 1992; Daily 1997; Alcamo et al. 2003).

Previously, discussions on this topic were directed almost exclusively to the conservation of remaining "wild" nature, to avoid seeing it transformed to short-term uses of dubious durable benefit (Balmford et al. 2002). However, our remaining stock of natural capital is already too low to support many national economies or to provide on a sustainable basis the benefits and well-being sought by average citizens everywhere on this increasingly crowded planet (Cairns 1993; Repetto 1993; Wyant et al. 1995; Clewell 2000*b*; Milton et al. 2003).

The rationale for restoring natural capital rests on three propositions: First, nature sustains us (Leopold 1949). People of all cultures depend on the natural products and services derived from natural ecosystems to provide much (or all) of their sustenance and well-being. Second, economic well-being is contingent upon the availability and sustainability of natural capital at or above existing levels (Costanza & Daly 1992; Daly & Farley 2004). A reduction in the quantity or quality of natural ecosystems lowers living conditions. Conversely, an increase in the quantity or quality of natural ecosystems would improve living conditions. Third, ecological restoration is the only option for appreciably improving the quality and augmenting the inventory of natural ecosystems.

The third proposition assumes that ecosystems—undisturbed and restored—provide a range of natural services and products of economic consequence that are available without costs of production. Most of these same services and products can be provided by intentionally managed lands, such as agroforests, improved pastures, and forest plantations. Such lands, though, and the engineered and "designer" ecosystems that were created therein, are simplified in terms of ecological complexity. They provide a narrower array of natural services and products, and they may be expensive to manage and maintain in the middle and long term. In general, they are much more vulnerable to external shocks and outright collapse.

Intensively managed lands provide more of the particular service or product for which they are administered; however, that benefit may be reduced or entirely defrayed by secondary impacts caused by management. For example, managed lands are commonly cleared of their native cover, irrigated or ditched and drained, and given applications of agrichemicals. Consequences of management may include depressed water tables, increased amplitude of stream discharge, and heightened levels of nutrients, contaminants, and suspended solids in receiving waters. In addition, intensively managed lands are relatively prone to colonization by generalist species—many of them nonnative or invasive—at the expense of desirable species that require more complex, specialized habitat.

Efforts to restore natural capital may require massive programs initiated by governments and international institutions. Implementation of such national programs can bring about positive socioeconomic consequences (e.g., job creation and training, and social fabric weaving) and possibly reduce social estrangement and political unrest. In this context, the designation of ecological restoration as a growth industry by Cunningham (2002) assumes credence.

Ameliorate Climate

In their powerful but little-known paper, Schneider and Kay (1994) argue that the biosphere is particularly efficient in the dissipation of energy from solar radiation as heat from the Earth's surface through transpiration and metabolic activities. Stated in terms of the second law of thermodynamics, organisms generate more entropy than physical systems (Ulanowicz & Hannon 1987). This assertion was supported by evidence (data from an aircraft-mounted thermal infrared multispectral scanner [TIMS]) of considerably lower surface temperatures in old-growth forests relative to clearcuts, regeneration, roads, and quarries in Oregon (U.S.A.) (Holbo & Luvall 1989; Luvall & Holbo 1991). Surface temperature variability was further documented with TIMS data recorded along flight lines over several life zones of tropical rainforests in Costa Rica (Luvall 1990). Similar results were predicted from climatological modeling that assumed the conversion of Amazonian tropical rainforest to degraded pasture (Shukla et al. 1990). Pastures were predicted to be from 1° to 3° C warmer and to have lower precipitation and evapotranspiration, more prolonged dry seasons, and greater potential for fire than forests. In addition, pasture grasses would have shallower and sparser root systems than forest trees, and the moisture storage capacity of the soil would be reduced. Results of these studies suggest that vegetation cover regulates climate and mature, complex ecosystems regulate climate more effectively than younger or less complex ecosystems.

Globally, simplification and outright removal of ecosystems are occurring rapidly at an increasing rate. Correspondingly, the capacity of the biosphere to regulate temperature, precipitation, and other climatic parameters is reduced. Schneider and Kay (1994) posit that as ecosystems mature, they develop increasingly complex structures with greater diversity and more hierarchical levels with which to abet energy degradation. As succession progresses, ecosystems capture more energy, exhibit more energy flow, and develop more and longer cycles of energy and materials with less leakage—all in accordance with the second law of thermodynamics and with Eugene Odum's seminal hypotheses on the "strategy of ecosystem development" (Odum 1969).

In short, Schneider and Kay (1994) assert that the biosphere functions to dissipate energy and thereby maintains temperatures at levels that can sustain life in all of its manifested forms. Conversely, reductions in its complexity may reduce the capability of the biosphere to regulate temperature within acceptable limits. Deteriorating climatic conditions, massive species extinctions, and ecosystem collapse are potential consequences.

Dissipative capacity is contingent upon species richness. The more energy is partitioned among species, the more pathways are available for energy degradation. The climatic regime of the entire planet is therefore dependent on species richness and on the capacity of large numbers of coexisting species to maintain the effectiveness of energy dissipation. Consequently, we depend on complex manifestations of biodiversity to maintain the habitability of the planet at an acceptable level. This understanding gives us a solid pragmatic basis for conserving biodiversity. Heretofore, the argument for preserving biodiversity consisted of a value-laden ideal that was adorned with promises of a few ancillary economic benefits such as pharmaceuticals and ecotourism. The thermodynamic consequences of biodiversity justify its conservation on the basis of physics that is amenable to empirical analysis and modeling.

As humans simplify ecosystems and thereby degrade the biosphere, the planetary capacity to dissipate heat from solar radiation is imperiled. Not only do we need to restore ecosystems for their value and importance as natural capital, we must also do so concomitantly to protect Earth's climate. The fostering of ecological complexity should be a universal goal of ecological restoration. We should rededicate our restoration efforts toward augmenting species richness, developing complex community structure, and providing specialized habitats for specialized species.

An implication of this thermodynamic paradigm is that global warming may be attributable in part to anthropogenic degradation of ecosystems. Regardless of the causes of global warming—whether induced by emissions of greenhouse gases or by reductions in thermodynamic regulatory capacity—the same remedy applies: ecological restoration, which increases carbon sequestration and ecosystem complexity. The thermodynamic paradigm also forcefully suggests that "greening up" landscapes with a simple vegetation cover for purposes of carbon sequestration is insufficient. Instead, full-scale ecological restoration may be needed to assure an accelerated return of ecological complexity and its dissipative capacity.

We caution, however, that the relationship between climate and thermodynamic dissipation of solar radiation as mediated by the biosphere remains sketchy and will require more formulation and documentation before it can be advanced as a major concern for public policy. Only after climatic amelioration through restoration is substantiated by compelling evidence can we anticipate public policy interest in ecological restoration as a remedy. In the meantime, we suggest that climatic amelioration by restored ecosystems would be a relevant topic of investigation for restoration ecologists.

We propose that ecological restoration will emerge as the prevailing strategy for addressing both of the vital pragmatic issues presented here, in close association with conservation and ecosystem management policies and practices. Concomitantly, the demand for ecological restoration will rise to levels that heretofore could not have been imagined but that are inevitable if total stocks of natural capital are to be maintained at or above current levels.

Conclusion: the Unified Approach

The five rationales for ecological restoration are inadequate individually. Technocratic restoration suffers from the mediocrity of bureaucratic authoritarianism and a lack of public understanding and support. The biotic and heuristic rationales are insufficient justifications by themselves to warrant mounting full-fledged restorations of consequential size. The idealistic rationale by itself is limited to small, uncomplicated projects without much need of technical, managerial, logistical, and legal support and that require no fixed completion date. The pragmatic rationale, when widely implemented, will require the full capacity of technocratic restoration and will necessarily become an expansion of it. We contend that well conceived and executed ecological restoration requires the melding of the technocratic and idealistic rationales. To achieve this, institutions that conduct technocratic restoration must relinquish some authority and actively work in partnership with stakeholders. Conversely, stakeholders—particularly local citizenry—must be motivated to assume responsibility in a partnership and inject restoration projects with idealism and cultural meaning. The attraction in such a marriage between the technocratic and idealistic rationales consists of the societal benefits accruing from the pragmatic rationale. Citizen stakeholders will not support restoration with enthusiasm unless they clearly understand and value its economic benefits. Without wide public support and participation, governments may be unable to generate political support to undertake pragmatic restoration projects. Once underway, such projects will likely fulfill the biotic rationale, simply because restoration protocol requires it (SER

2004). The heuristic rationale can be satisfied concomitantly with any other rationale.

We cite three restoration projects that have merged the technocratic and idealistic rationales successfully. First, in Costa Rica the restoration of tropical dry forest (approximately 1200-km^2 Guanacaste Conservation Area) has benefited entire villages economically and culturally (Allen 2001; Janzen 2002). Stakeholders conducted the restoration under the direction of visionaries, including ecologist Daniel Janzen, who forged an effective although unlikely coalition of Costa Rican agencies, politicians, local landowners, and international philanthropic organizations.

Second, in South Africa the 10-year-old Working for Water program employs 20,000 people in the eradication of invasive alien woody plants, particularly deep-rooted trees that transpire soil moisture and deprive native plants and agricultural lands of water. Jobs, livelihoods, and a renewed social unity are being created while natural, native landscapes are being restored through the elimination of "water-stealing" invasive species (Van Wilgen et al. 1996, 2004; Holmes et al. 2000; Holmes 2001; Milton et al. 2003). The program has contributed significantly to nation building during the postapartheid era.

Third, in Palestine and Israel the heavily polluted Alexander River is being cleaned up, and ecosystems in its basin are in process of restoration (Brandeis 2005). Beginning in 1995, 135 separate projects were conducted by several thousand volunteers from both nations under the direction of a voluntary administrative authority that had no offices and owned no property. The project had widespread political support from 21 villages and towns along the river's course. School children were engaged in tree planting, fish stocking, and recreating and protecting safe sites for soft-backed turtle nests. Palestinians and Israelis worked side by side in this united effort and gave hope to all involved that the two warring nations could resolve their strident political differences. The Alexander River project suggests that implementation of international peace initiatives could be added as another rationale for ecological restoration.

These three projects represent the vanguard for synthesis of all rationales to restore ecosystems and landscapes through the dedication of grassroots effort and the sympathetic assistance of governments. These projects epitomize the axiom to think globally and act locally because they have environmental, economic, political, cultural, and spiritual consequences at local and global scales.

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