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Restoration ecology and conservation biology

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Abstract

Restoration ecology is undergoing rapid growth as an academic discipline, similar to that experienced by conservation biology over the last 15 years. Restoration ecology and conservation biology share many underlying biodiversity goals, but differ in striking ways. Using data from published literature in these two fields, I document that conservation biology has been more zoological, more descriptive and theoretical, and more focused on population and genetic studies than restoration ecology, which has been more botanical, more experimental, and more focused on population, community and ecosystem studies. I also use documented trends in population, land use, and biodiversity awareness to suggest that in the future ecological restoration will play an increasing role in biodiversity conservation. The conservation mind set is one of loss on a relatively short time horizon, whereas the restoration mind set is one of long-term recovery. I suggest that a restoration mind set can provide useful insights into problems of conservation today, illustrated with examples examining edge effects and integrated conservation and development projects.

Keywords: Restoration; Conservation; Controlled experiments; Edge effects; ICDP

1. Introduction and apologia

Restore v. to make almost as good as new; to give back.
(two different* New York Times *Crosswords)

As we enter the new century, restoration ecology is undergoing dramatic growth as an academic discipline (Fig. 1a). A decade ago, the field of conservation biology experienced similar explosive growth. Both of these "new" academic fields build upon many years of earlier work by applied scientists in wildlife biology, forest and range management, and even horticulture and landscape architecture. Each found its renaissance through the attentions of academic biologists, whose research interests were molded to fit the new and critical needs of biodiversity conservation and restoration (Soule 1986; Jordan et al., 1987). Although there are many parallels and shared goals between conservation biology and restoration ecology, there are also important differences. In this overview, I will (a) quantify some of the differences between conservation biology and restoration ecology, both operationally and philosophically, (b) suggest a long-term ascendancy of restoration ecology, and (c) give examples of how a restoration mind set can illuminate conservation today.

Any discussion of ecological restoration in the context of conservation biology must begin with two resounding caveats:

1. Although restoration can enhance conservation efforts, restoration is always a poor second to the preservation of original habitats.
2. The use of ex situ 'restoration' (mitigation) as an equal replacement for habitat and population destruction or degradation ('take') is at best often unsupported by hard evidence, and is at worst an irresponsible degradative force in its own right.

However, the fact that ecological restoration can be misused to the detriment of biodiversity conservation need not blind us to its tremendous potential to achieve laudable conservation goals when implemented appropriately (Falk et al., 1996; Zedler, 1996a,b).

Although this paper will suggest a long-term ascendancy of restoration ecology, it is not my intention to suggest this implies that the current biodiversity crisis is anything less than the most important challenge of our generation, nor to suggest that the potential of ecological

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restoration somehow gets us 'off the hook' in our obligation to minimize the current extinction spasm through the aggressive application of political pressure, human and financial resources, and modern principles of conservation biology.

Also, I do not wish to suggest a simple dichotomy between restoration ecology and conservation biology. Indeed, I consider restoration to be a subset of conservation. The comparison I make below is between conservation biology as it is practised in the 1990s and the newly emerging academic field of restoration ecology.

1.1. Conservation, the science of habitat and biodiversity loss: stemming the flow

In his insightful paper, 'Directions in conservation biology', Graehme Caughley (1994) identified two major paradigms in conservation biology. The *declining population paradigm* emphasizes the forces that cause populations to decline, and focuses operationally on ways to lessen those forces and reverse declines. The declining population paradigm in many ways anticipates restoration ecology, and has been the primary approach of wildlife and fisheries professionals who for many decades were at the forefront of what we now call conservation biology. The *small population paradigm* emphasizes the unique risks of populations that have already been driven to dangerously small sizes, and focuses operationally on means to maintain population viability and minimize extinction in small populations. The small population paradigm has been the emphasis of the new generation of academic conservation biologists. Were I to add an additional (overarching) theme to these two, it would be that of fragmentation: fragmented populations and fragmented landscapes (Harris, 1984; Quammen, 1996; Laurance and Bierregaard, 1997; Schwartz 1997).

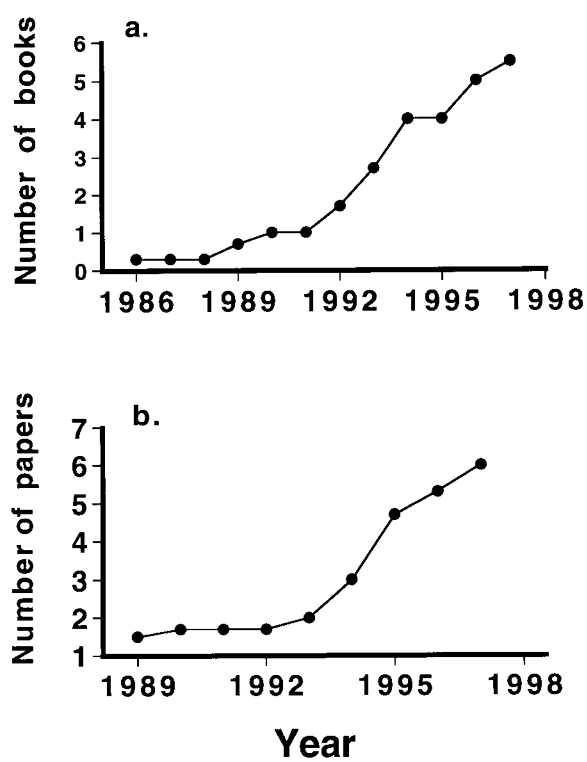

Fig. 1. (a) Three-year running mean of the number of books appearing in a key word search ('restoration ecology') of the University of California Melvyl© library database, 1986–1998. (b) Three-year running mean of the number of papers with the title words 'land abandon#' appearing in the Current Contents© journal database for the years 1989–1998. # is a truncation symbol.

1.2. Restoration, the science of habitat and biodiversity recovery

Restoration ecology has at its core the assumption that many degradative forces are temporary, and that some proportion of habitat loss and population decline is recoverable. Of course, extinctions are forever and many habitat losses are not likely to be recovered. Such losses are increasingly preventable and inexcusable. Conservation biology deserves center stage as it seeks to minimize these permanent losses. Restoration ecology, thus far playing a secondary role, seeks to repair what can be repaired, and to ensure the future fate of surviving habitats and populations, regardless of whether they were previously threatened.

2. A statistical comparison of conservation biology and restoration ecology

There are several ways in which conservation biology and restoration ecology differ, at least in their current forms (Table 1). Some are due to historical biases; others are more deeply imbedded. These differences can be quantified. I examined all issues published in the journals '*Conservation Biology*', '*Biological Conservation*',

Table 1
Conservation biology and restoration ecology constrasted

Trait	Conservation biology	Restoration ecology
Mind set	(Threats of) permanent losses	Long-term recovery
Dominant organizational levels	Genetic, population	Community, ecosystem
Dominant taxon	Vertebrate animals	Plants
Dominant conceptual theme	Population viability and dynamics	Succession and assembly
Dominant mode of inquiry	Decriptive and modeling	Experimental

'*Restoration Ecology*', and '*Restoration and Management Notes*' for the last three years (1996–1998). Each research article was characterized with respect to organizational approach, focal taxa, mode of inquiry, and geographic region (Table 2).

2.1. Organizational level

In the journal survey, genetic/ecophysiological/population approaches out-numbered community/ecosystem/landscape approaches by more than two to one in the conservation journals, whereas the latter outnumbered the former by 50% in the restoration biology journals ($X^2 = 6$, d.f. $= 3$, $p < 0.001$) (Table 2).

Conservation biology has been rooted in population biology. This is true both of historical wildlife management and the emergence of conservation biology as an academic discipline. Both conservation genetics and viability analyses are essentially population biology. Note that the common word in Caughley's two paradigms is 'population'. Most conservationists understand that this emphasis is at least partly misplaced and would agree that habitat loss is the greatest threat to biodiversity today. Nonetheless, it is populations of endangered species that have attracted the most scientific, public, and legislative interest. In addition, many populations are (a) superficially amenable to explicit modeling, and (b) subject to (genetic) laboratory and short-term field studies, both of which have encouraged an emphasis in the scientific literature in favor of population approaches to conservation. And of course, extinction occurs one population at a time.

In contrast, recent research in restoration ecology is more broadly rooted in community and ecosystem

Table 2
Analysis of four journals devoted to conservation biology and ecological restoration. BC, *Biological Conservation*; CB, *Conservation Biology*; RE, *Restoration Ecology*; RMN, *Restoration and Management Notes*[a]

Topic	Conservation biology			Restoration ecology		
Journal	BC	CB	Total	RE	RMN	Total
Organizational level						
Genetic/molecular	19	63	82 (12%)	4	0	4 (2%)
Population	218	172	390 (57%)	37	34	71 (38%)
Community	80	43	123 (18%)	44	35	79 (42%)
Ecosystem/landscape	44	42	86 (13%)	31	4	35 (18%)
Target taxon						
Plants	103	70	173 (26%)	74	72	146 (72%)
Animals	244	236	480 (72%)	24	8	31 (16%)
Other kingdoms	3	2	5 (0.7%)	5	0	5 (2.5%)
(Soil and water)	9	2	11 (2%)	10	9	19 (9%)
Mode of inquiry						
Controlled experiments	24	16	40 (6%)	44	22	66 (34%)
Uncontrolled experiments	40	41	81 (12%)	29	37	66 (34%)
Descriptive	227	194	421 (64%)	25	17	42 (22%)
Theoretical/modeling	32	52	84 (13%)	5	3	8 (4%)
Reviews	22	14	36 (5%)	9	1	10 (5%)
Geographical region						
Temperate, Boreal, and Polar						
US and Canada (less Arctic)	45	136	181	67	87	154
Europe	123	22	145	11	2	13
Australia, New Zealand	59	19	78	13	1	14
Temperate and Boreal Asia	21	7	28	2	0	2
Other temperate (Africa and South Africa)	26	20	46	2	0	2
Polar	3	0	3	1	0	1
Total	277	204	481 (77%)	96	90	186 (96%)
Subtropical and tropical						
Americas	21	35	56	4	3	7
Africa	20	28	48	0	0	0
Asia	12	19	31	0	0	0
Other	5	2	7	0	0	0
Total	58	84	142 (23%)	4	3	7 (3.6%)

[a] Journal dates surveyed from January 1996 to October 1998. Numbers represent the numbers of articles found that had the targeted characteristics; percentages are in parentheses. Multiple entries per article within topic classes were allowed, and some articles were not attributable (e.g. to a particular geographical area). 'Population' also includes distributional, behavioral and ecophysiological studies (autecology). 'Uncontrolled experiments' are assessments of uncontrolled or unreplicated manipulations by humans, as well as natural experiments.

ecology as well as population ecology (Table 2). Clearly, one cannot restore individual bits of biodiversity unless appropriate habitat (and soil) exist. There are of course population restoration projects that overlay functional ecosystems, and many of these lie at the interface between conservation and restoration (Bowles and Whelan 1994, and see below). Nonetheless, it is in the restoration of complex communities that restoration ecology finds its greatest challenges and opportunities, and its fullest expression.

2.2. Dominant focal taxa

The journal survey also revealed that conservation biology has been far more *zoological* (by nearly 3 to 1), and restoration ecology has been far more *botanical* (by more than 4 to 1, see Table 2, $X^2 = 207$, d.f. = 1, $p < 0.001$). These biases were less in '*Biological Conservation*' and in '*Restoration Ecology*' than in '*Conservation Biology*' and '*Restoration and Management Notes*'. Articles in the restoration ecology journals were also more than three times as likely to be directed toward other kingdoms (soil bacteria and fungi) than were articles in conservation journals, although this was not statistically significant (Table 2, $X^2 = 2.73$, d.f. = 1, $p < 0.10$).

The zoological emphasis in conservation biology is rooted more in history than in genuine need. Several factors combine to create this bias: decades of wildlife and fisheries interest in conservation, the early involvement of zoos, and the zoological bias implicit in our own taxonomic position (as expressed in public interest, nature films, endangered species listings, and whaling and ivory bans that are unaccompanied by bans on trade in tropical hardwood and old growth timber). A more detailed analysis of conservation biology articles suggests that among animal studies, there is a bias toward vertebrates as target taxa, in particular birds and mammals (invertebrates, 14%; fishes, 8%, amphibians, 3%, reptiles, 9%, birds, 34%, mammals, 30%). This parallels a similar bias in funding by conservation organizations, but not in the public opinion of species values, which is more evenly distributed among taxa, including plants (Czech et al., 1998).

Restoration ecology has been primarily a botanical science, and this is likely to continue. There has been criticism of this emphasis (Morrison, 1998) and an apologia (Allen, 1998), but I suggest that there is little need to be apologetic. We typically define ecosystems by their botanical components, e.g. oak-hickory forest, tall grass prairie. Plants comprise the vast majority of all terrestrial ecosystems' biomass, and anchor the base of trophic pyramids. Ecological restoration is justly botanically biased. For similar reasons, restoration ecology has a stronger soils component than conservation biology. Most restoration projects concentrate on establishing a basic suite of plant species, and often (less than ideally) let the animals and 'minor' plant species fend for themselves (Dobson et al., 1997a,b).

Nonetheless, restoration ecology could include more zoological science. The restoration of species of all taxa is an important restoration activity (Bowles and Whelan, 1994; Allen, 1998), and many restoration and mitigation projects have as their underlying objective the re-establishment of an animal population (Strum and Southwick, 1986; Kleiman et al., 1991). Most restoration projects, even when they are primarily botanical, would benefit from more explicit zoological consideration (Morrison, 1995; Neal, 1998). Zoological studies can be directly supportive of the botanical aspect of restoration when grazers, seed dispersers, and pollinators are central to the success of restoration efforts. Although less bias against zoological papers may be appropriate, it is likely that ecological restoration will continue to be primarily a botanical science, at least in terrestrial ecosystems.

2.3. Mode of inquiry

Controlled, replicated, manipulative experiments are considered a hallmark of good science, and they are increasingly the standard in ecology. In many conservation research projects, however, they are difficult to carry out, especially in the context of rare or threatened species. This is somewhat less the case in wildlife management, the antecedent for conservation biology. We are still in the early stages of discovering and quantifying what the problems are in biodiversity conservation, a process that is largely descriptive. One way that conservation biology has sought alternative rigor is through theoretical modeling of populations and gene pools (With, 1997), an approach less explored by restoration ecologists. Research in conservation biology is, therefore, more often descriptive and theoretical.

In contrast, ecological restoration is by definition a manipulative activity, and the majority of research is explicitly experimental. Again, the journal survey supports these differences. Articles in restoration ecology were more than five times as likely to include controlled, replicated experiments as were articles in conservation biology (34 vs 6%, Table 2, $X^2 = 210$, d.f. = 3, $p < 0.001$). Perhaps tellingly, botanical articles in conservation journals were more than three times as likely to include controlled, replicated experiments as were zoological articles (10 vs 3%).

The 'uncontrolled experiments' in conservation journals were mostly taking as much statistical advantage as possible of situations that were largely beyond the control of the researcher. In contrast, many of the 'uncontrolled experiments' reported in the restoration journals were in fact controlled manipulations by the researcher, but without replication. Too often, we lose opportunities to turn the experiments of restoration projects into more powerful scientific research (Michener, 1997).

2.4. Geographical region

Although all four journals had a strong temperate (U.S. and European) bias, articles in the conservation biology journals were six times more likely to address tropical biomes than those in restoration ecology journals (23 vs 3.6%, $X^2 = 36$, d.f. = 1, $p < 0.001$, Table 2). Conservation biology rightly recognizes that the biodiversity crisis is most profound in the tropics, and makes conscious efforts to report tropical research. In contrast, the paucity of tropical research by restoration ecologists represents a large void, and opportunity (see Parrotta and Turnbull, 1997; Lugo, 1998). Both of the surveyed restoration journals are published in the United States, and are even more parochial, with fully 79% of their articles referent to temperate North America, and all seven of their tropical papers from the Americas.

2.5. Conceptual bases

There has been considerable energy expended in defining the conceptual bases for conservation biology and restoration ecology (Hobbs and Norton, 1996; With, 1997; Allen et al., 1997). While this is a laudable activity, it also reflects our roots as academics who honor basic over applied research. I think we need to clearly distinguish between the genuine value of having deep conceptual roots, and the reality that we have a monumental operational task ahead of us in which huge (and intellectually challenging) research strides have been made and will continue to be made that are referent to these conceptual bases, but need not test them directly. A more balanced approach in which applied research is a full partner of research into the conceptual basis of problems is pursued at the United States Department of Agriculture, National Institutes of Health, and Environmental Protection Agency. A similar balance is reflected in journal articles and actual research by both conservation biologists and restoration ecologists, but only sporadically in the funding decisions of NSF or the committee rooms of doctoral and masters candidates.

On average, the conceptual bases of conservation biology have been strongly flavored by its population and zoological emphases, and those of restoration have been flavored by its community and botanical emphases. Out of several strong candidates, I would suggest population dynamics and population viability as the core concepts in conservation biology (Norton, 1995; Beissinger and Westphal, 1998), and succession and assembly as the core concepts in restoration ecology (Luken, 1990; Packard, 1994; Hobbs and Norton, 1996; Lockwood, 1997; Pritchett, 1997).

On a more operational level, restoration projects are more likely to be grass-roots initiated or implemented by people living in the local community. Conservation projects, which are more likely to occur far from human settlement, are more often 'top-down' activities, initiated and implemented by government agencies and national or regional conservation organizations.

3. The future of conservation and restoration

> Here is the means to end the great extinction spasm. The next century will, I believe, be the era of restoration in ecology
>
> E.O. Wilson (1992)

While my previous observations are well supported by evidence from the literature, I now explore an aspect of restoration and conservation that is more speculative. I would like to suggest that within the next several decades, there will be a shift in emphasis in conservation science away from the topics central in current conservation biology toward an emphasis on ecological restoration. In short, that the long-term future of conservation biology is restoration ecology.

At the heart of this argument is the realization that we are in a unique biodiversity crisis. The core activities and paradigms of conservation biology are absolutely essential for the long-term conservation of biodiversity. I will address the possibility that this crisis is resulting from a temporary and devastating bottleneck, but it is clear that what we save will be dependent on the diameter of that bottleneck, and conservation is the main means we have for *widening* it. Ecological restoration offers the promise of *shortening* bottlenecks.

It is my belief that 50 years from now, the majority of the world's habitats and species will either be destroyed or on their way to recovery from a degraded state. When conservation biologists meet, they will be concerned less with how to conserve remnants of small populations and how to prevent further habitat degradation, and more with how to consolidate and restore the remnants of the crisis. Some are doing this even now.

What world trends lead me to suggest this change in emphasis? First, the down side: I believe that most of the biodiversity that will be lost to humans will be lost in the next fifty years. But I also believe that population stabilization, land abandonment, and biodiversity awareness provide a window of opportunity (Waggoner et al., 1996) for shaping a world in which future losses will not only become less likely in the latter half of the next century, but will begin to be reversed.

3.1. Population stabilization

For the first time since such statistics were kept, population growth rates are becoming less positive on all continents of the globe. The United Nations has been making global population projections for many years, and their recent 'most likely' projections are that world population will essentially stabilize by the middle of the 21st century, to more than 90% of the eventual maximum world population. In March of 1998, they lowered their best guess of the maximum number from 11.5 billion to 10.8 billion, and then yet again in October of 1998 lowered the 2050 estimate by another half billion, based mostly on faster than expected reductions in birth rates (United Nations, 1998a,b). Most conservation biologists would reasonably argue that ten billion people is still far too many, and the rising economic expectations of these people is likely to present a far greater threat to the environment than just their numbers. Nonetheless, a stable or even (in many countries) declining population within the next century may allow the survival of considerable biodiversity. Forty percent of the world's population live in countries where natality is already below replacement, and some European countries are projected to decline in population appreciably in the next 50 years.

3.2. Land abandonment

Of equal or greater importance to biodiversity is where these billions are choosing to live. Thus far, the greatest biodiversity losses have occurred through habitat loss. Conversely, the greatest opportunities for ecological restoration occur through land abandonment. Worldwide, there is a continuing movement of people from rural areas to cities and suburbia (O'Meara, 1999). These cities are often environmental, employment, and logistical nightmares, but they do represent *demographic abandonment* of the land, especially lands of marginal agricultural value (e.g. Popper and Popper, 1994; Licht, 1997).

Demographic abandonment is often followed by *land use abandonment*, in which less productive land is taken out of production and allowed to revert to a (degraded) 'natural' state. A survey of Current Contents© in June 1998 revealed exponential growth in the numbers of research articles with the title words 'Land abandon#' (Fig. 1b), and most of these articles were concerned with ecological restoration. A large number of restoration sites throughout North America and Europe are the results of agricultural abandonment.

The resurgence of regenerating temperate forests of the United States (and elsewhere) is perhaps the most dramatic example of land use abandonment (Williams, 1989; Wernick et al., 1997; Moffat, 1998), but this is increasingly a tropical phenomenon as well. The famous Biological Dynamics of Forest Fragments experiment in the Amazon has recently been plagued by the regeneration of (early successional) forest on abandoned land between the habitat islands (R. Bierregaard, pers. commun.). This is part of a worldwide trend in which the abandonment of tropical lands previously converted from forest to agriculture is occurring on a scale similar to and even exceeding deforestation itself (Houghton, 1994; Lamb et al., 1997). This is still happening, of course, in the context of catastrophic net losses of primary tropical forest habitat (Laurance and Bierregaard, 1997; Laurance, 1998).

In the semi-arid Laikipia ecosystem where I work in Kenya, decades of land subdivision and agricultural conversion are now being reversed, with land ownership consolidating and land use reverting to non-farming uses (livestock production and wildlife tourism). Although the world is likely to need vast areas of prime agricultural land for the foreseeable future (Brown, 1999), the dissemination of agricultural technologies that are increasingly efficient and environmentally sustainable may allow vast amounts of land under the plow to revert, even with modest population growth (Waggoner et al., 1996). The amount of land under the plow in the United States has declined throughout the 20th Century even as the population has more than doubled and food exports continue to exceed imports (Table 3). This abandoned land represents a golden opportunity for restoration ecology, and therefore for conservation (Dobson et al., 1997a,b).

The regenerating ecosystems on these abandoned lands do not replace the ecosystems that were lost, at least on the scale of many decades, and it would be far better to not lose the original habitats (Vitousek, 1994). It is becoming increasingly clear that much of this devastating habitat degradation, whether it is by subsistence farmers or by large logging or ranching concerns, contributes little to national economic development (Gullison and Lossos, 1993). The sooner we recognize both the minimal gains and the temporary nature of alternative land uses, the more likely we are to conserve these habitats intact (Young 1993).

Although there will continue to be abandonment of marginal agricultural land as people move to the cities, it is clear that riparian, wetland, and coastal ecosystems will feel the brunt of this demographic movement. These ecosystems will become increasingly threatened even as pressure on more terrestrial and inland ecosystems starts to ease.

3.3. Biodiversity awareness

We live in an age of unique biodiversity awareness. Conservative politicians call themselves 'green', entire

Table 3
Twentieth century patterns of population and land under cultivation in the United States (most values from United States Department of Commerce 1975, 1997; the 1997 'Acres in cropland' was calculated from USDA, 1998)

Year	1920	1950	1970	1997
Population ($\times 10^6$)	106	151	203	268
Acres of cropland ($\times 10^6$)	413	409	384	356
Acres cultivated per capita	3.9	2.7	1.9	1.3
Farm population ($\times 10^6$)	32	23	10	3.7 (1995)

cable channels are dominated by nature programming, international boycotts and treaties enforce conservation practices, and young people worldwide understand both practical and esthetic values of biodiversity. Perhaps the most dramatic conservation trend in the latter half of the twentieth century has been the increase in sympathy for biodiversity that cuts across ages, political views, income levels, and levels of national development (Newmark et al., 1993; Young, 1993; Czech et al., 1998). Progress has not been monotonic, and some feel we are living in an era of retrenchment. (Certainly the trend of international conservation organizations being bought out by development dollars is not encouraging.) However, there is every reason to believe that aggressive education campaigns will continue to win the hearts and minds of increasing numbers in future generations. If we are to pass through the conservation bottleneck into the restoration era, we will need the broad-based support of these generations.

3.4. Caveats

Of course, the above analysis is simplistic as well as optimistic. We may yet destroy the world's biodiversity with global warming, ozone depletion, wasteful land use, and unbridled population and consumptive growth (Vitousek, 1994). Cities are no panacea. They must be made attractive, livable, efficient, and sustainable (Mangel et al., 1996; O'Meara, 1999). Modern methods of food production have not yet proven that they can be maintained in the long run, although the trends are encouraging (Waggoner et al., 1996; Rasmussen et al., 1998). I offer here not a definitive solution, but the outlines of a ray of hope for the future, a future in which ecological restoration can move to the fore.

Restoration may become the dominant conservation activity in the latter part of the coming century (and thereafter), but it will only be able to work with what we manage to salvage in the interim. ***Conservation biology and implementation as they are practised today are nothing less than the most important human activities in the history of the planet.*** It is my optimistic hope that one day they can take a back seat to the great restoration opportunities that are already being seized, and that will increase dramatically in the future. In addition, I believe that a restoration mind set can also enhance current conservation theory and practice.

4. Implications of the differences between conservation and restoration, or how a restoration mind set can illuminate conservation biology

Independent of my suggestion that ecological restoration will come to dominate conservation in coming decades, I would like to suggest that a restoration mind set can illuminate conservation research and policy even as they are practised today. The conservation mind set is one of more or less permanent loss; the implicit assumption is that all trends are down, and that our goal is to slow or stop degradation (declining population paradigm) or to maintain the remnants as small fragments of the original (small population paradigm). Delisting endangered species is met with (justified?) suspicion.

The restoration mind set is one of recovery after temporary loss. Conservation problems are viewed in the context of this future recovery. When restoration ecologists hear a statement like, 'This endangered population of 250 individuals has a 50% chance of extinction over the next 100 years', they think, 'Why would we let this population languish at 250 individuals for so long? Let's restore it!'

One may even say that restoration ecologists tend to be *optimistic*, and conservation biologists *pessimistic*. This has led to conflicting interpretation of trends (Richter, 1997; Dobson et al., 1997b). I would argue that both contain elements of truth.

The following are three specific examples of applying a restoration mind set in a conservation biology setting:

4.1. Species recovery plans and captive breeding/gene banks

In fact, several major activities of conservation biologists are fully in the restoration mind set. Reintroduction projects and research (Strum and Southwick, 1986; Stanley-Price, 1989; Kleiman et al., 1991; Bowles and Whelan, 1994; Ostro et al., 1999) are about single species restorations, although rarely coupled with an overall community restoration project (Falk et al., 1996). Although limited in species richness, captive breeding and gene bank programs often have as one of their main assumptions the future restoration of functional ecosystems.

4.2. Edges and fragmentation

One of the consequences of habitat fragmentation is increased edge-to-interior ratio, especially in the context of a mosaic of degraded and intact habitat (Fig. 2). Conservation biologists have richly documented the negative consequences of these edges (e.g., Alverson et al., 1994; Murcia, 1995; Wester and Young, 1997; Russo and Young, 1997; Viana et al., 1997; Hartley and Hunter, 1998; Stevens and Husband, 1998). In particular, edges favor weedy species at the expense of more specialized and often rarer interior species.

On the other hand, there is increasing evidence that habitat regeneration on degraded land is limited by distance to the nearest intact edge. Numerous studies have documented declines in woody plant recruitment or seed rain as one moves away from the edge of intact forest into surrounding degraded land (Gorchov et al., 1993; Robinson and Handel, 1993; Guariguata et al., 1995;

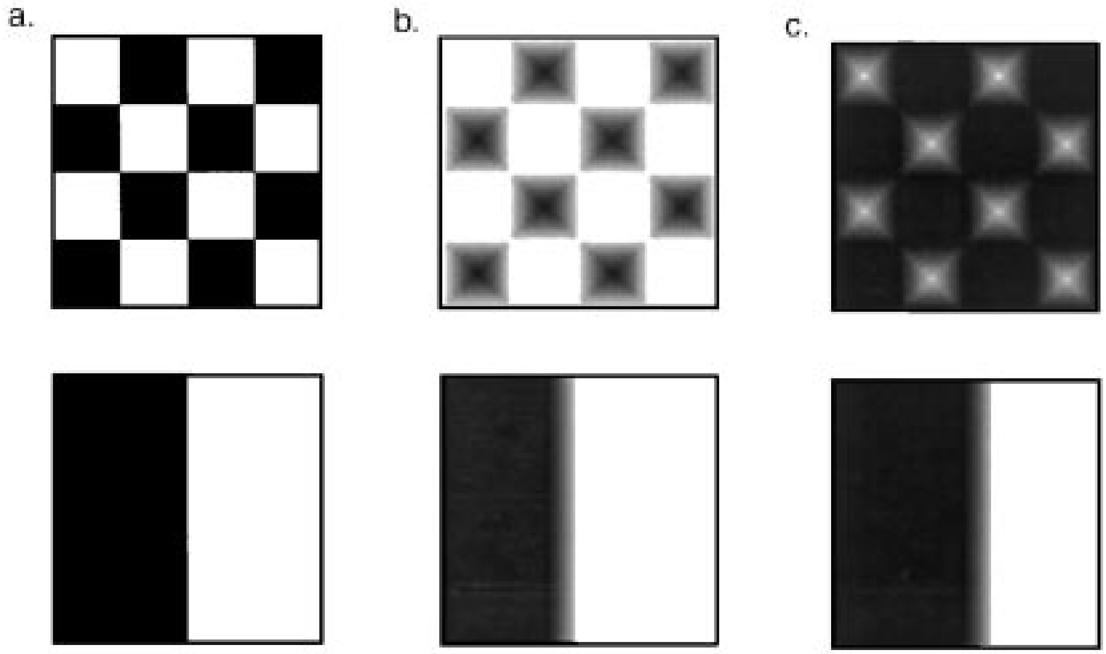

Fig. 2. The effects of different fragmentation patterns on an ecosystem. Dark areas represent healthy habitat, and light areas represent degraded habitat. (a) In both patterns half the original habitat is destroyed, leaving either small patches with high edge-to-interior ratios (top) or large patches with low edge-to-interior ratios (bottom). (b) Negative edge effects are more degradative when the habitat is broken into smaller fragments. Conservation biologists generally consider this scenario when recommending small edge to interior ratios. (c) Positive edge effects, such as the arrival of regeneration propagules, may be maximized in a degraded landscape with more embedded fragments.

Bakker et al., 1996; Wunderle, 1997; Keenan et al., 1997; Lamb et al., 1997; Parrotta et al., 1997; Clark et al., 1998). In addition, exposed canopy edges produce more seeds than shaded interior canopies (Young, 1995).

If we think of habitat fragmentations as essentially permanent (conservation biology mind set), then the negative aspects of high edge-to-interior dominate our thinking. If we think of these fragmentations as transitory (restoration ecology mind set), then the regenerative aspects of edge to interior ratio become a factor. Traditional landscape analysis in conservation recommends low edge-to-interior ratios, based on the negative influences of edge (Fig. 2b). Such analysis suggests that leaving a few large areas intact with most of their land far from degradative edges (Fig. 2b, below) is better than leaving many small areas with exposed edges (Fig. 2b, above). This analysis is particularly applicable in mosaics of protected reserves and (permanent) alternative land uses that are incompatible with biodiversity.

In a regenerating mosaic, however, increased edge potentially can confer a benefit, especially when edges are a critical source of regeneration propagules (Fig. 2c). In such situations, leaving many small areas intact and therefore leaving more degraded land near intact habitat (Fig. 2c, above; see Liu and Ashton, 1999) may be preferable to leaving a few large areas intact, but isolating much of the degraded habitat from sources of regenerative propagules (Fig. 2c, below; see also Davis and Cantlon, 1969).

Of course, this example is not intended as a full analysis of negative and positive aspects of fragmentation, of which edge effects are only a part (see Harris, 1984; Alverson et al., 1994; Laurence and Bierrregaard, 1997; Schwartz, 1997). Indeed, evidence suggests that uncritical application of the "checkerboard" pattern by the United States Forest Service in the past was more detrimental to old growth coniferous forests than it was beneficial to forest regeneration (Wallin, 1993). This example is offered instead to illustrate how a restoration mind set could, in the right circumstances, provide a new and potentially valuable tool in making land management decisions, and one that has not been fully examined as a research question in conservation biology.

4.3. *Rural development*

One of the keystones of modern biodiversity conservation in the tropics is the widespread uncritical acceptance of the concept of integrated conservation and development projects (ICDPs and their relatives). These projects have at their heart the untested assumption that economically assisting rural populations in the vicinity of biodiversity will enhance the viability of that biodiversity. Although some of these projects have been relatively successful as small scale economic development, there is little scientific evidence of their success as conservation projects (Kiss, 1998; Inamdar et al., 1999) other than via their enforcement and education components. In fact, there is increasing evidence that they may exacerbate threats to biodiversity by increasing population pressure in sensitive areas (Branden and Wells, 1992; Oates, 1995; Barrett and Arcese, 1995; Noss, 1997). More fundamentally, ICDPs are also based on the conservationist's mind set of fixed land losses and fixed demographic and land use patterns.

There are three human groups concerned about poor rural populations in biodiversity areas. Most of the slash and burn subsistence agriculturists themselves do not want to be there. They would rather have good jobs in the city. The governments may use these rural areas as population pressure valves, but in the long run would rather have the development of urban manufacturing and service industries that would fill the people's economic needs. Most conservationists (although a shrinking number of conservation organizations) clearly recognize that the ideal would be to have far fewer people in the rural landscape (Terborgh, 1989; Caro et al., 1998). Yet these three groups produce plans (ICDPs) that have as their main effects the delay or reversal of the movement off of the land that all three would prefer, and that would be the best conservation strategy of all. This is not strictly a tropical phenomenon. Similar government policies have similar retarding effects on land abandonment in the Great Plains of the United States (Licht, 1997), and in other agricultural ecosystems of Europe and North America.

I am not suggesting that we stop short-term rural development, but rather that we recognize the reality of demographic and land use abandonment, and work with rather than against this natural force. This is primarily a restorationist's mind set of temporary habitat loss. If we recognize that habitat losses to subsistence and marginal agriculture (and extractive industries) are temporary phenomena, we can work to increase the rate of the subsequent land abandonment (and to actively prevent losses in the first place) and to ensure that in the interim, local habitat losses are in the context of a mosaic of land use that maximizes the probability of successful natural regeneration and active restoration that will follow.

5. Conclusion

The divergent approaches documented here have impeded a fuller integration of biodiversity conservation and restoration. Perhaps by recognizing these differences explicitly, these two fields can take more conscious steps toward fruitful collaboration. The biodiversity crisis represents the greatest challenge humans have ever faced. To the extent that *this generation* will continue to fail, it will represent our greatest failure as a species, and the one for which we are least likely to be forgiven by the generations to come. To the extent that we at least partly succeed (in spite of ourselves), it will represent our species' greatest achievement. Conservation biology in the short-term and restoration ecology in the long-term are the complementary activities that will form the basis of our belated (but not hopeless) attempt to salvage the disaster.

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