Proceedings of the 15th Annual British Columbia Mine Reclamation Symposium in Kamloops, BC, 1991.
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ECOSYSTEM RESTORATION VERSUS RECLAMATION: THE VALUE OF MANAGING FOR BIODIVERSITY

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ABSTRACT

Recent public demands for the preservation of biological diversity are often using this concept as a surrogate for the value of rare species, nature preserves, and wilderness. But diversity *per se* can have value in intensively managed and artificial ecosystems as well, suggesting that maybe we should practice ecosystem "restoration" more than just land reclamation". If a plant community is to be long-lived or self-sustaining, then natural diversity and processes provide a useful model to follow.

Information on the value of biodiversity can be divided into utilitarian, ecological and ethical/aesthetic categories. All arguments must consider issues of sampling and management scales, the separate richness and equitability components of diversity, and natural trends in diversity.

Utilitarian arguments center on the fact that we cannot now identify which individual species are critical to ecosystem sustainabiliry, nor which individual species may be useful to humans in the future. Additional ecological values of diversity stem from the unsuspected complexity of ecosystems. Many individual species hold "keystone" roles in defining overall system behaviour, affecting both stability and productivity. Additional human-centered and biocentric concerns also argue for the preservation and enhancement of biological diversity in managed as well as natural landscapes. Efforts to restore biological diversity provide a useful means of experimenting with the factors controlling ecosystem struture and function.

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La restauration d'ecosystemes versus la rehabilitation de sites; l'importance de la gestion pour la biodiversite

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De recentes exigences de la population, en matiere de preservation de la diversite biologique, utilisent ce concept comme substitut a la valorisation des especes rares, des reserves naturelles et des espaces sauvages. Mais en soi, la diversite peut avoir de la valeur au sein d'ecosystemes artificiels et geres de facon intensive, ce qui suggere que nous devrions peut-etre preferer la restauration d'ecosystemes a une simple rehabilitation de sites. Si une communaute vegetale doit se maintenir et vivre longtemps, la diversite naturelle et ses processus fournissent alors un modele utile a suivre.

L'information portant sur la valeur de la biodiversite peut se diviser en categories utilitaires, ecologiques et ethico-esthetiques. Tous les arguments doivent prendre en consideration des facteurs tels que le probleme de dimension, les categories ou taxons, les echelles de gestion et d'echantillonnage, les composantes de richesse et d'equite de la diversite, pris separement, ainsi que ses tendances naturelles.

Les arguments utilitaires se fondent sur le fait que nous ne sommes pas en mesure d'identifier les especes qui sont d'importance primordiale pour la survie d'un ecosysteme ni celles qui pourraient etre utiles a l'humanite dans l'avenir. Un grand nombre d'especes sauvages sont ou peuvent etre une source utile de produits naturels et peuvent servir comme indicateurs biologiques (de la sante d'un ecosysteme donne ou des mesures requises pour ameliorer la gestion). Il existe une certaine incertitude concernant les changements climatiques et les valeurs socio-economiques futures. Il serait done prudent de maximiser la flexibility en orientant la gestion dans un contexte le plus diversifie possible en ce qui a trait aux especes et aux produits potentiels.

D'autres valeurs de diversite ecologique decoulent de la complexite insoupconnee des ecosystemes. Plusieurs especes individuelles exercent un role determinant dans la definition du comportement general d'un systeme parce qu'elles influencent sa stabilite et sa productivite. De plus, il est evident que la diversite represente un moyen de reduire la probabilite, ainsi que la dissemination des insectes parasitaires et des maladies. La diversite peut egalement augmenter la capacite de recuperation d'un systeme soumis a des pertubations. D'autres arguments d'un point de vue humain et biocentrique militent aussi en faveur de la preservation et de l'amelioration de la diversite biologique dans des environnements geres ou naturels.

INTRODUCTION

Land reclamation is typically undertaken for a number of practical purposes: to stabilize land surfaces, to control pollution, for visual improvement, and to facilitate further land use. The goal of ecological restoration, however, is to assemble a stable ecosystem that is compositionally and functionally similar to that which existed prior to human disturbance. Its aims of enhancing species diversity, attaining a "natural" composition of species, and establishing sustainable ecosystem functions are considered ambitious and somewhat superfluous to most land reclamation objectives. I propose that, on the contrary, the restoration of biological diversity, in its many forms, Is an important and practical tool for ensuring reclamation success.

Biological diversity or "biodiversity" refers to the variety of life forms (especially species) in a general sense. Depending on context and scale, biodiversity can refer to the range of alleles or genotypes within a population, to the variety of species or growth forms in a biotic community, or to the variety of vegetation types across a landscape. Biodiversity can encompass both compositional and structural attributes. It has two quantifiable components: the number of elements (e.g., species), which is referred to as richness, and the evenness of those elements, referred to as *equitability*. Biological diversity is thus a measurable attribute of populations, communities, ecosystems and landscapes. Diversity can be measured at the plot or stand level (*alpha diversity),* where it indicates the range of species which may interact with each other. It can also be measured as the rate of species turnover across the landscape *(beta diversity),* indicative of the range in habitats or successional stages. Caution must always be exercised in explicitly stating the area over which compositional data were obtained for the calculation of diversity statistics ... it is meaningless to compare diversity levels if sampling effort is not identical.

Demands for the preservation of biodiversity often confound a number of different concepts. In particular, biodiversity is often equated with individual rare or endangered species, old-growth forests, nature preserves or wilderness areas. It is true that rare species are more likely to be represented in diverse communities, and the need for ecological reserves of all sizes is a corollary of the need for preserving biological diversity (Rowe 1989). Such "preservation values" are usually best served on lands that have not been severely disturbed by man, if suitably representative ecosystems still exist. While protecting indigenous biodiversity often means excluding the hand of man, the restoration and utilization of biodiversity can be usefully practiced by land managers in general.

RESTORATION ECOLOGY

In seeking to reassemble a drastically disturbed ecosystem, ecological restoration undertakes two fundamental activities: it is managing for some pre-disturbance level of biodiversity, and it is combining species in an essentially experimental manner. In some cases, restoration may merely mimic the composition of a pre-existing ecosystem. More commonly, considerable effort is placed on preparing the site, selecting some appropriate set of species or an appropriate "inoculum" of native propagules, and instituting a management regime that will facilitate the re-establishment of ecosystem processes that had once prevailed there before. In so doing, the exercise of restoration provides an "acid test" of our understanding of ecological systems, and a vital proving ground for many theories of ecosystem dynamics (Bradshaw 1983, Jordon et al 1987).

Why should the use of native species and natural processes provide a model for the rehabilitation of disturbed land? Firstly, the fact that it had prevailed in the past means that, by definition, the natural ecosystem was in some manner successfully adapted to the local site and climate, and is capable of persistence there. Secondly, the effort to re-establish all species presumes less about our knowledge of mechanisms underlying the maintenance of these ecosystems. In making a full complement of species available, we can let *nature* do the sorting and screening ... and we will learn something in the process. While we may never succeed at precisely recreating a natural system, the attempt is likely to pay off with some sort of self-sustaining community, and a better understanding of the factors controlling its development. The management of renewable natural resources benefits in many ways from the consideration and promotion of biodiversity.

THE VALUE OF BIOLOGICAL DIVERSITY

The following discussion is a brief review of some of the reasons why biological diversity is worth preserving and enhancing whenever possible. Wilson (1986) provides a comprehensive overview of the need, at a global level, to conserve our rich heritage of biological resources. Basically, biodiversity is often essential to ecosystem recovery from severe disturbance; it serves to buffer "future shock", acting as insurance against unforeseen catastrophes and changing values; it keeps options open as we strive to develop resources in a sustainable manner. From a number of ethical and aesthetic perspectives, the promotion of rich assemblages of plant and animal life is simply "the right thing to do."

Important Natural Products From Wild Species

Throughout the world, a large number of wild species are currently used for food, fiber and medicine in subsistence economies, and for sale to the market economy. Any issue of the journal, "Economic Botany", cites a rich variety of traditional and industrial uses for many plant species. Some of these species (e.g., saskatoon berry, *Amelanchier alnifolia)* are currently being domesticated. Wild relatives of domestic species frequently carry genes that are valuable for their ability to confer enhanced stress- or pest-resistance. The screening of natural products for pharmaceutical potential is far from complete, and promising discoveries are found even in our local flora (e.g., the anti-carcinogenic properties of taxol, derived from the bark of western yew, *Taxus brevifolia).*

Some scientists suggest that the genetic resources of wild populations can be adequately protected in seed banks, botanical gardens and zoos. Such efforts may be essential where populations are faced with extinction. This strategy is ultimately untenable for the preservation of most species because of phenomena such as genetic drift, inbreeding disorders, higher-order genetic complexes, and the dynamic nature of gene frequencies over space and time. Natural biological systems are not merely static gene "warehouses," but are also natural "research and development laboratories" in which selective pressure from harsh environments continues to generate products which we find useful.

These features argue for the protection of rare populations wherever they are found, especially at the peripheries of their range (where selective forces can be expected to be especially active). The protection of regional biotic richness is thus an appropriate consideration in any resource development project. Furthermore, habitat restoration (i.e., the reconstruction of an appropriate abiotic and biotic milieu) may be required for the stewardship of endangered species if their natural habitat has itself become rare (e.g., the native tallgrass prairies of Manitoba and the mid-western states; Burton et al. 1988). Habitat restoration, not just for rare species but also for exploitable wildlife species, is bound to be a growing focus of activity for reclamation planners, scientists and technicians (e.g., the active wetland restoration program of Ducks Unlimited).

<u>The Utility of Indicator Species</u>

Many "minor" species can serve a useful role as ecological indicators, integrating environmental conditions more effectively than human programs of spot sampling. The presence, vigour, abundance, and tissue composition of different species, varying in their environmental sensitivities, can serve as inexpensive "meters" of ecosystem functioning and health, like the proverbial "canary in a coal mine."

Plants are often the best indicators of abiotic site conditions, while animals are often good indicators of pollution (being higher in the food chain). Range management has long used plants classified as "increasers" and "decreasers" as principal indicators of deteriorating or improving grassland condition, respectively (Dyksterhuis 1949). Repeated monitoring of their relative abundance thereby allows grazing regimes to be adjusted accordingly for the maintenance of productivity. Replacement of diverse native grassland communities (especially the decreaser species) with depauperate mixtures of a few exotic species hence reduces the sensitivity of rangeland monitoring programs.

<u>Insurance Against Future Uncertainty</u>

It is prudent to retain a diverse array of alternative resources in the face of an uncertain future. Not only are future economic and social values uncertain, but so are climatic conditions. While not so constraining as in forestry (where crops are planted several decades before they can be harvested; see Burton et al. *in review),* changes in land use values or in the environment can rapidly make reclamation and mitigation plans quite unsuitable. Alpha diversity can be a hedge against environmental change, and beta diversity can be used as a hedge against socioeconomic change. In conjunction with ongoing monitoring and the reformulation of management plans, this conscious promotion of biodiversity is a key tool to the "adaptive management" of land resources (Walters 1986).

The use of species mixtures has long been accepted as an effective means of promoting successful reclamation. Over variable terrain, it is likely that at least one species (in a well-designed plant mixture) will thrive where others won't, so that at any one place in a stand, some vegetation is likely to establish. Likewise, a variety of species, representing a range of ecological behaviour, is more likely to maintain a presence in the face of severe or unusual growing seasons. Whether unusually hot and dry, or unusually cool and wet, a well-designed species mixture should always have some species establishing and surviving successfully. Such environmental aberrations may be essentially random, or directional (in the context of climate change as a result of the greenhouse effect). In either case, it is difficult to anticipate the exact nature of these changes; unusual years occur unpredictably, and climate change simulations do not agree on the magnitude, direction or location of changes in soil moisture availability (Dickinson 1989). The incorporation of biological diversity can often save a reclamation program.

Ecosystem Productivity and Stability

The agricultural model of reclamation involves major inputs of energy to shape the site (by contouring, ripping, etc.), plant it to rapidly growing species, and fertilize it to accelerate revegetation. This approach can certainly be effective, if one is prepared to invest this energy and to intermittently repeat some procedures. This approach does not always work, as some difficult sites may defy revegetation, and some pioneer species can be overly persistent (Wagner et al. 1978). Furthermore, it is desirable for long-lived communities of perennial plants to be self-sustaining, requiring minimal inputs of active management. Incomplete reclamation success is often due to the absence of seemingly unimportant species. Because of their role in facilitating subsequent recruitment and stand development, key plant species may be needed to initiate successional pathways by means of providing shade, nitrogen, and litter, or by trapping snow and seeds (MacMahon 1987).

One of the best examples of the importance of biodiversity to ecosystem recovery and sustained productivity is the role of mycorrhizae and soil bacteria. Many revegetation attempts have been frustrated because the proper complements of soil organisms were not available. Use of fresh inoculum (usually just small packets of soil from healthy ecosystems) have proven tremendously effective in facilitating the establishment of perennial grasses and shrubs (Allen 1988) as well as trees (Perry et al. 1989). Great variation in sensitivity to substrate conditions dictates that a diversity of fungal and bacterial species or strains may be needed to insure vascular plant establishment across a landscape. Much of the effectiveness of topsoil dressings on minespoils is due to their role in providing a healthy and diverse microflora, as evidenced by their loss of potency if stored for prolonged periods of time. It can be argued that specific consumer organisms are also required to maintain sustainable ecosystem functions; these species can also be actively introduced, or their immigration from surrounding lands can facilitated through the use of migration corridors and the provision of appropriate habitat.

Some species exhibit an effect on overall ecosystem functioning that is disproportionate to their abundance. These species, such as nitrogen-fixing microorganisms or their vascular hosts, or "starvation food sources" for consumers, may set the carrying capacity for many other species. These "keystone species" are often minor components of an ecosystem, and their role may not be apparent without extensive study spanning periods of stressful conditions.

There has been considerable debate as to whether biological diversity actually confers some degree of stability to an ecosystem. In general, alpha diversity can contribute to ecosystem resistance to displacement as well as to its resilience following disturbance, simply by increasing the probability that *some* species will survive or re-establish. Beta diversity is partially responsible for the more equilibrial behaviour we observe over broader scales; system stability is generally seen to increase with areal extent (Barbour et al. 1987). In many cases, it now appears that the functional attributes of key species may be more important than diversity *per se* in conferring stand-level stability (Leps et al. 1982). One area where the stabilizing role of biodiversity is unambiguous is in the spread of pests and diseases: multi-species stands have repeatedly demonstrated greater ability to resist insect and disease outbreaks than have monocultures. Since many herbivores and pathogens exhibit some degree of host-specificity, the dispersion of "non-food" plants amid suitable "food" plants serves to greatly constrain their outbreak and spread.

Biological diversity need not be expressed at the level of species or growth-form in order to confer these advantages. High genetic diversity, both within and among populations, provides the raw material for survival and adaptation in the face of strong selective pressure and novel threats. This has been convincingly demonstrated by the micro-evolutionary development of metal-tolerant grass populations on mining wastes (Bradshaw 1983). Especially in reclamation, it is prudent to harness the potential of this genetic diversity, rather than replacing it with plant lines selected merely for broad adaptability or high productivity.

Aesthetic and Ethical Considerations

A number of non-monetary and ethical reasons exist for the preserving species and maintaining natural ecosystem processes. These arguments apply less to questions of reconstructing degraded land than they do to the conversion or harvesting of natural ecosystems. These factors can be strong motivating forces for some individuals, and (as evidenced by the increasing politicization of environmental issues) for the collective will.

While some individuals prefer to see order, uniformity and efficiency imposed upon the land, many people simply *like* biological diversity! Aesthetics are (by their personal nature) very subjective, yet there is an appreciation of natural beauty in all cultures. A great many people are thrilled when they experience a meadow with a profusion of wildflowers, or a view with a variety of landforms, textures and vegetation covers. In addition, many people subscribe to an environmental ethic that prescribes the restoration of ecosystem after they are disturbed, and the honouring of the right of all other life forms to exist (Regan 1981). These factors must be considered when reclaiming land for human use (especially in an area of recreational use), even when commodity production remains a goal.

THE CASE FOR EXPERIMENTATION

These examples demonstrate that it is extremely near-sighted to identify any species or population as "unimportant" to mankind or to overall ecosystem functioning. As stated by Aldo Leopold (1949), one of the fathers of restoration ecology, "To keep every cog and wheel is the first precaution of intelligent tinkering." This philosophy of "using all the pieces" remains central to the holistic philosophy of restoration science, in contrast to the minimalist or reductionist philosophy of reclamation science. The choice of which approach to follow often reduces to a matter of land use designation and personal preference, as the cost and effectiveness of both approaches may be comparable. When some form of natural vegetation is desired for aesthetic or wildlife habitat purposes, very inexpensive restoration methods utilizing soil seed bank dynamics and natural succession may be most appropriate (Burton et al. 1983). In other cases, particularly when the land is slated for agricultural production, standard agronomic inputs and manipulations may be more appropriate. The choice of approach may, itself, be guided by considerations of beta diversity: landscape diversity can be maximized by a combination of approaches, or by promoting the land use that Is currently least abundant.

Despite its utility in achieving reclamation goals, Diamond (1987) argues that restoration can never actually re-establish "natural" ecosystems, that it is always incomplete. First of all, there is the problem of extinct and extirpated species that can no longer be included In a reconstructed ecosystem. Conversely, exotic weeds are pervasive and cannot be excluded at a reasonable Thirdly, most restoration projects are conducted at such a small scale, iten disjunct from other natural ecosystems, so that many natural landscape processes (such as dispersal, migration, and disturbances such as wildfire) are As a result, species composition and dynamics are bound to be quite different than in the original ecosystem. Restoration is likely to be most effective (both biologically and cost-wise), therefore. In areas where the above factors are minimal, e.g., the revegetation of small disturbances In otherwise intact natural forest. Finally, the effort and dedication required for good restoration suggest that, if the goal is biological conservation, energy is better spent in ensuring the preservation of virgin ecosystems unless they have already been destroyed.

Given the fact that restoration is always incomplete anyway, departures from the "natural" model are inevitable. I therefore suggest that each restoration or reclamation effort be considered an experiment in "synthetic ecology". Working only within the constraint of using species native to the region, restoration projects offer the opportunity to explore the importance of biodiversity. While these activities may be undertaken within an Industrial or regulatory setting, they should still be considered experimental, and, as such, they should include designated controls and replicates. It has been argued that *all* forms of renewable resource management remain experimental In nature (McNab 1983). For example, in western North America we have rarely harvested a crop of trees which was planted by man and tended for an entire rotation, so it is appropriate to consider silviculture in this part of the world to be experimental. Based on the above arguments, all disciplines of resource management which follow the agronomic model but aim for sustalnability, from reclamation and silviculture to range management and agriculture itself, may benefit from following restoration ecology as a model instead (Pilarskl *in press,* Burton et al. *in review).*

Every technique of site preparation or soil replacement, every change in the species included or omitted, all permutations of the order of species introductions, and all subsequent management regimes can be considered experimental treatments worthy of replication and quantitative monitoring. Even if you do not have the resources to do the monitoring, the conscious identification (and mapping) of pre-disturbance and untreated controls, and of "leave strips" in the application of all subsequent treatments will do much to facilitate any future analysis of your project/experiment. In this manner the efficacy of particular techniques can be established, and we can also learn some basic things about the roles of particular species. Restoration experiments allow us to answer such questions as:

- Which is more important to ecosystem development (on a particular substrate, in a particular biogeoclimatic zone), initial floristic composition or the site-modifying effects of relay floristics? That is, can succession be bypassed altogether, or can "mature" ecosystems be restored only after serai phases have prepared the site?

- Which species are particularly important in determining successional trajectories?
- Are diverse species mixtures or particular combinations of species, (e.g. the fewest number of species which most fully occupy the "environmental space, as hypothesized by Burton et al. 1988) necessarily more resistant to weed invasion and climatic aberrations?

These sorts of questions are central to the scientific understanding of ecosystem dynamics, but are also crucial to the management of forests, range, and all disturbed lands. We know that a diverse array of species plays an important role in ecosystem productivity and stability, but we have yet to identify all the mechanisms involved. Conserving natural biodiversity and tinkering with combinations and permutations of the native flora and fauna provide useful models for effective land reclamation, and for the testing of ecological theory.

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