

Handbook of Ecological Restoration

The two volumes of this handbook provide a comprehensive account of the rapidly emerging and vibrant science of the ecological restoration of both habitats and species.

Habitat restoration aims to achieve complete structural and functional, self-maintaining biological integrity following disturbance. In practice, any theoretical model is modified by a number of economic, social and ecological constraints. Consequently, material that might be considered as rehabilitation, enhancement, reconstruction, or re-creation is also included. Re-establishment and maintenance of viable, self-sustaining wild populations are the aims of species-centred restoration.

Restoration in Practice details the state of the science in a range of biomes within terrestrial and aquatic (marine, coastal and freshwater) ecosystems. Policy and legislative issues on all continents are also outlined and discussed. The accompanying volume, *Principles of Restoration*, defines the underlying principles of restoration ecology in relation to manipulations and management of the biological, geophysical and chemical framework.

The Handbook of Ecological Restoration will be an invaluable resource to anyone concerned with the restoration, rehabilitation, enhancement or creation of habitats in aquatic or terrestrial systems, throughout the world.

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Handbook of Ecological Restoration

Volume 2 Restoration in Practice

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This book is dedicated to Morgan, Rowan and Bryony, in the hope that theirs and future generations are able to enjoy and live in harmony with all life on earth

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Foreword

Ecosystem disturbance has been defined as an event or a series of events that changes the relationships between organisms and their habitats from their natural states, both spatially and temporally.¹ These changes may range from small to large, temporary to permanent, and slight to severe. The causative agents that lead to ecosystem degradation are many, but a recent United Nations report attributed the bulk of disturbance worldwide to five primary causes (with percentage of disturbance for each): overgrazing (35), deforestation (29), agricultural activity (28), overexploited vegetation (7), and industrial activity (1).² Acting in concert with extensive habitat loss (see below), the worldwide loss of biological diversity is under way.

The causative agents outlined function through at least seven major activities of disturbance: extensive clearing of natural vegetation for agriculture, abandonment of unproductive land, selective harvesting of desirable species and introduction of alien ones, mining, draining of wetlands, introduction of chemicals in the environment, and the impact of war.³ Other activities, such as extensive urban expansion, can also be added to this list. The scales of these disturbances are often seen as local or regional, but, as Harlan Cleveland noted, 'Private decisions are partly public; domestic affairs are partly international; local issues are partly global.'⁴

Though estimates abound, the exact extent of land that is now disturbed or degraded by human activities is not known. Nonetheless, such estimates make it clear that ecosystem disturbance is a widespread phenomenon. Ecologists estimate that between one-third and one-half of the earth's land surface has been transformed by human action.⁵ Recent studies calculate global ecosystem disturbance at well over 5000 million ha,⁶ with nearly 550 000 ha degraded per day (an area larger than New York City), and approximately 200 million ha per year (an area larger than Poland).⁷ Such staggering figures are corroborated by scientists separately

studying agricultural, dryland and tropical ecosystems. Regardless of the exact figure for the area of disturbance, there is little doubt that many productive ecosystems are already seriously degraded.

The impact of human-induced global change looms large on the environmental horizon, which may make ecosystem restoration even more difficult than it is now. Most experts agree that climate change is occurring at a pace unprecedented in geological history. Changes, both in the physical nature of the earth (such as temperature regimes and melting of glaciers) and in its biota (such as changes in the phenology of animals and plants and the loss of coral reefs), provide compelling evidence that temperature changes afoot will have detrimental, unpredictable and unintended consequences. The effects of changing climate on the ecological amplitudes of biotic populations and species along environmental gradients will be crucial for restoration.

During the past three decades or so, a vast body of impressive scientific investigation has addressed the problems, practices and strategies for the rehabilitation and restoration of ecosystems from diverse regions of the world. Among these, ecological studies of drastic disturbances (such as mining) stand out. From diverse ecosystems, these have included such investigations as the nature of newly excavated geological materials and their weathering, lack of nutrients, mobilisation of toxic elements, patterns and processes of vegetation colonisation of new habitats, the diversity and stability of newly formed ecosystems, ecological succession, and ecosystem modelling. Our knowledge base has advanced enough, I believe, that we should be able to make predictions, with reasonable accuracy, on the course of establishing biological productivity for most ecosystems in the world.

However, our success in conveying the results of these investigations to policy makers, never so critical as now, has been much poorer than desirable. Granted that the scientists and decision-makers operate in disparate settings with vastly

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different traditions and *modus operandi*, both must work together more effectively. For while finding solutions to problems lies within the purview of scientists, mandating applications from the findings of science lies with the policy-makers and legislators; thus, science becomes a social enterprise. The art of true governing and leadership, in my view, rests on three basic attributes: communication, persuasion, and action. Active participation in all three on the part of the scientific community – ecologists in particular – is crucial in making such public policy.

Although gaps in ecological knowledge exist, these should not be viewed as a serious limitation to the development and implementation of appropriate restoration, rehabilitation, or reclamation strategies. Indeed, a new applied field of science – Restoration Ecology – has already emerged. It endeavors to examine the nature and extent of environmental disturbances and provide solutions for both preventing and mitigating the harmful effects of human activities on land and water resources.

This Handbook documents the state-of-the-science of restoration ecology. It presents the underlying *Principles of Restoration* (Volume 1) and in this Volume 2, *Restoration in Practice*, pointing to the direction of future efforts. Besides bearing testimony to the hard work and unswerving persistence of their editors, the volumes may prove to be a landmark with which future efforts are judged and, more importantly, may enhance the efficacy and speed of restoration.

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Preface

Few would deny the need for ecological restoration in a world that sees the continued impoverishment of our natural resources and habitats, coupled with the extinction of our fellow life-forms: earth's biodiversity. Inevitably, we are all driven by short-term goals in our daily lives, irrespective of whether these are for basic needs such as food, water and shelter or whether they are something rather more materialistic in nature. Particularly in more developed societies, however, we have little excuse for forgetting our responsibilities towards the planet and its other inhabitants. Despite the admirable efforts of the many environmental and ecological activists who seek to secure the future of the planet's habitats and biodiversity, and the advances made by recent international agreements, notably at the Earth Summit in Rio in 1992, future generations still face the prospect of ecological impoverishment.

Periodic crises, such as wars and other conflicts, and unwillingness to deviate from selfish short-term goals, perhaps for economic or political gain (for example the US avoidance of the Kyoto protocol) should not be allowed to obscure our vision. When crises have past and policies have been reversed, even though many things may have changed, the longer-term ecological problems and trends will remain to be faced. Scientists could fairly be accused of not doing enough. Thorough scientific investigation of complex issues rarely proceeds fast enough for the needs of practitioners faced with immediate problems. Nor have researchers always been as effective as they could have been at communicating the practical value of their findings. A number of recent events have highlighted the need for scientists to earn and justify the trust of society at large. However, restoration ecology has broken away from its early and ultimately sterile preoccupation with definitions of change and 'original' state. We recognise that change is continual and an integral part of the backdrop of our activities. The realities of global climate change and the increasing intervention in the genetic make-up of crops, amongst

many other things, ensure that we cannot go back to some fixed, utopian state. Our efforts will be best directed forwards, armed with scientific knowledge of the interactions between taxa, trophic levels and the wider environment, a holistic understanding of what has happened in the past and a keen desire for improvement.

Perhaps for the first time an approach or philosophy has emerged that cuts across the disciplines, uniting peoples from a wide variety of backgrounds – a look at the delegate list of any Society of Ecological Restoration (SER) conference will verify this – under a common banner of trying to make things better. Restoration ecology embodies that movement and SER is doing a fine job in promoting the message.

This handbook, organised in two volumes, aims to produce a comprehensive account of the burgeoning and vibrant science of restoration ecology. Although it largely documents science, the book is intended to present the science in practical terms for those who may describe themselves primarily as practitioners, engineers or conservationists and includes a wealth of information on planning and legislative tools for planners or managers. Rather presumptuously, we have sought to inspire all concerned with restoration. Even the most hardened reductionists – the 'watchmakers' or more accurately 'watchdismantlers' – must have been inspired by Tony Bradshaw's words: 'the acid test of our understanding is not whether we can take ecosystems to bits on pieces of paper, however scientifically, but whether we can put them together in practice and make them work'.

Practice is the essence of this second volume. The first part, Part 6 in the work as a whole, outlines restoration policy and infrastructure across continents, using the Americas, Europe, Africa, Asia and Oceania as divisions. Cultural and political attitudes to restoration, the institutional and legal framework for restoration and application (successful or not) of such a framework to the restoration

of particular biomes are the central themes discussed. The breadth of this subject matter could easily warrant a book on each region with contributions from many authors. Expecting a complete treatise on each aspect from a single or a few authors, given the constraints on space, is clearly inappropriate. Moreover, the resource base for applying policy and legislative instruments is highly variable in different parts of the world, as is the underpinning cultural attitude. At the very least, an increased understanding of how restoration may be applied in different regions has emerged. The illustration of the strengths and weaknesses of the different political and legislative frameworks in which restoration is undertaken has produced a fascinating mix of principles and potential models that could be applied in a wealth of circumstances.

The second Part of the volume (Part 7 of the work) outlines state-of-the science practice in the restoration of a broad range of biomes in 19 chapters. These inevitably focus on systems in which practical restoration and associated research have been most active. The first series of six chapters deals with systems in or associated with the sea ('Marine and coastal ecosystems'; 'Seagrasses'; 'Coral reefs'; 'Beaches'; 'Coastal dunes'; and 'Salt-marshes'). The aquatic motif continues with chapters on 'Rivers and streams', 'Lakes' and 'Freshwater wetlands'. The main contributions on lake restoration have been on shallow lakes and the chapter reflects this. Cold biomes are represented by chapters on 'Polar tundra' and 'High-elevation ecosystems'. Another series of chapters covers terrestrial biomes more or less limited by water supply and grazing ('Atlantic heathlands'; 'Calcareous grasslands'; 'Prairies'; 'Semi-arid woodlands and desert fringes'; and the particularly distinctive 'Australian semi-arid lands and savannas'). The final three chapters tackle the special challenges of restoring forest systems ('Temperate woodlands'; 'Tropical moist forest'; and 'Tropical dry forest').

The themes of each chapter are essentially the same with: (i) the distinctive features and processes of the biome concerned outlined in an introduction; (ii) the rationale for restoration determined by the interplay between the value (in ecological, sociological and economic terms) of the biome and the

nature and extent of previous degradation; (iii) description and application of the principle strategies, techniques and tools for restoration, amply illustrated by case studies; and (iv) concluding remarks outlining what has worked or not worked and the direction of future efforts. The only notable deviation from this structure is the final chapter where the long-running and important restoration of Area de Conservación Guanacaste, a tropical dry forest in northwestern Costa Rica is documented. Differences in the nature and extent of the problem, the level of understanding of ecosystem functioning and the nature of the works required mean there are, inevitably, differences in the balance between the chapters. Constraining our authors in a structural strait-jacket would have been inappropriate.

What has also become clear is the difference in the depth, efficacy and predictability and style of restoration practice. In some habitats, restoration may be focused upon physical manipulation, removing constraints and encouraging natural recovery processes. Utilising flow and sediment dynamics in the restoration of rivers, vegetation succession in the restoration of forests and colonisation of invertebrates in the restoration of coral reefs all spring to mind. Other restorations require the prevention of similar processes, for example setting back or restriction of succession in the restoration of heathland. The manipulation of the biota within food webs may also be necessary. Nowhere is this more advanced than in lake ecosystems, where it is centred upon the biomanipulation of fish communities to initiate cascading trophic responses. The state-of-the-science is clearly far more advanced in some systems than others, with consequences for predictability of outcome that ultimately affect opportunities for restoration, because those holding the purse-strings like some guarantee of success. We hope that readers will take heart from experiences in other systems outside of their own and that there will be cross-fertilisation of ideas, principles and techniques.

Recording experiences in all possible habitats was clearly beyond the scope of even such a substantial handbook. We have striven to be as complete as possible and to make a statement about current knowledge and practice. We have also aimed to point the

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way forward, so that restoration can continue to learn from mistakes born of a lack of understanding. Consequently, we have tried to incorporate a range of habitats, concentrating on broad types, but including more specific, limited – in geographical terms – habitats where considerable effort has been made (e.g. calcareous grassland and Atlantic heathland). We hope that readers who do not find an account of the system they are concerned with will find relevant experiences in other systems, and be able to apply them.

Our contributors provide the strengths in the book. Any weaknesses in its structure and scope are ours. We are deeply indebted to all those that have contributed their time and efforts in what has proved to be a massive undertaking. It has been an honour to have Tony Bradshaw, John Cairns Jr. and

Erik Jeppesen on the editorial board and we are grateful for their unfaltering support throughout the project's long history. We are grateful to CUP for taking up the challenge when we needed a new publisher, and particularly to Alan Crowden, who made the transition seamless. Shana Coates provided editorial assistance from the press. We are also grateful for the skilled copy-editing of Anna Hodson and for the essential support and hard work of Mark Tomlinson of ECON in the preparation of manuscripts. We thank the reviewers, many of whom were also authors, for generously sharing their insights and suggesting improvements to chapters. This book was born out of what was a difficult time in both our lives; perhaps nothing worthwhile is ever easy. We hope it will inspire current and future restorers.

Martin Perrow and Tony Davy