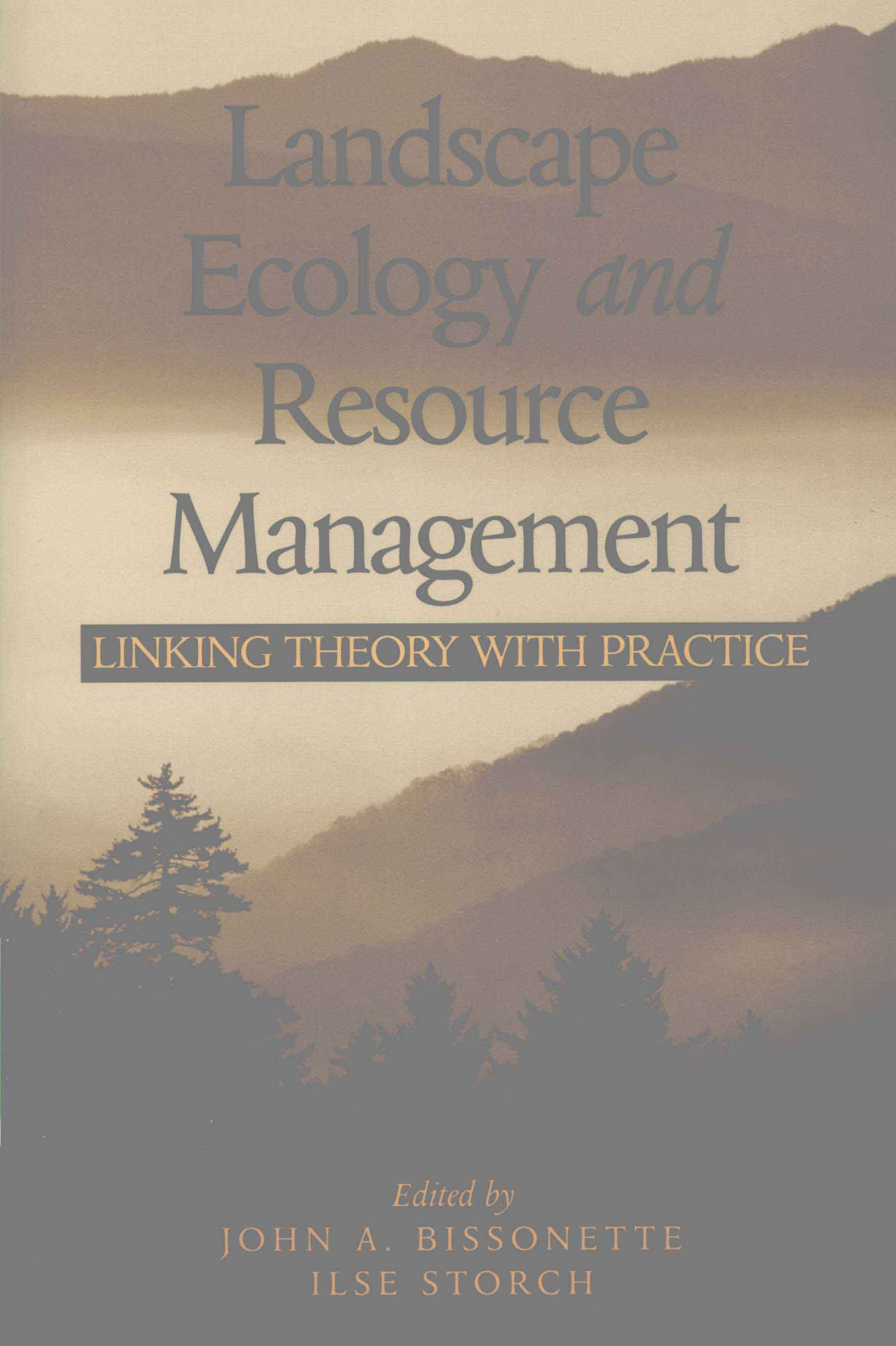

Landscape Ecology *and* Resource Management

LINKING THEORY WITH PRACTICE

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Preface

Landscape ecology as a discipline is growing rapidly; however, its incorporation into practice is proceeding more slowly. It was a well-established discipline in Europe by the time of its first recognition in North America in the early 1980s, and by 2001 the number of journal articles that mentioned landscapes, scale, and fragmentation had grown exponentially (Schneider 2001). Agencies and organizations worldwide have embraced large-scale ideas such as ecosystem management, gap analysis, and metapopulation conservation and have tried to put some of these concepts into practice. What practitioners have lacked is a conceptual foundation of applicable and operational theory, with examples of successful case studies to guide their efforts. As is the case in many developing disciplines, theory has been borrowed and cobbled together from related fields and provides an incomplete framework for application. Eventually, the conceptual basis increasingly appears to be inadequately confirmed by data. Use of the framework in management further exposes the problem of inadequate theory. What often is missing in developing disciplines is the linkage between theory and practice. This drives the need to devise a more realistic and relevant conceptual basis for guiding management. We believe this is the current state of landscape ecology and its application by wildlife and fishery biologists and resource managers. A cohesive theory of landscape ecology is not yet possible. Rather, several developments have begun to provide elements of a framework. This book was developed specifically to provide insights into some of the applicable theory that underlies resource management and to provide examples of successful case studies to help guide future efforts.

This book began as an idea after the publication of *Wildlife and Landscape Ecology: Effects of Pattern and Scale* (1997), edited by John Bissonette. After its appearance, we discussed the observation that much of the effort in landscape ecology was on theory development, with not enough attention to application, at least in North America. In Europe, and North America, and other parts of the world, we observed that despite obvious progress in landscape ecological awareness among scientists, little of that appeared to enter practitioners' discussions or actions. We asked, "How can the manager or biologist working for a resource agency or conservation organization put the powerful ideas and concepts that stem from landscape ecology into practice?" The field is expanding so rapidly that it is difficult to keep up with new developments, to say nothing of synthesizing the ideas into a workable framework. We decided to address this concern directly. In 1999 we organized a plenary session at the Second International Wildlife Management Congress held in Gödöllõ, Hungary, titled "Landscape Linkages: Ecosystem Science and Management" and a symposium titled "Scaling in Conservation Biology: Is There a Mismatch between Theory and Practice?" where we began to address this idea. This edited volume was envisioned to help further link landscape theory and resource management practice in the field. Because the application of science to management tasks is always influenced by the nature of the problem and therefore by its cultural and sociopolitical settings, we made an effort to assemble authors and studies from different parts of the world to provide examples from a wide range of problems, approaches, and biogeographic regions.

We organized the resulting 17 chapters into three sections. Part 1, "Conceptual and Quantitative Linkages," contains seven chapters intended to address fundamental aspects of landscape ecology. Part 2, "Linking People, Land Use, and Landscape Values," contains five chapters that address the links between people and the landscape. Part 3, "Linking Theory and Application: Case Studies," includes five chapters that present case studies to make the links between theory and management real.

We are especially grateful to Barbara Dean, Barbara Youngblood, Laura Carrithers, Donica Collier, Chace Caven, Carol Peschke, and all at Island Press for their continuing support and help in putting this book together. We are also grateful to the authors for promptly responding to our many requests and to all colleagues who read parts of the manuscript. Each chapter in this volume was peer reviewed by at least two scientists, and the final form of each chapter was influenced by reviewer and editor comments, and changes suggested by the authors themselves. We are thankful for a grant from the Deutsche Forschungsgemeinschaft to Ilse Storch and for a distinguished lectureship sponsored by DAAK (Stiftung Deutsch-Amerikanisches Konzil), the University of Munich, and the Munich Wildlife Society to John Bissonette that allowed us to develop our ideas further.

This book is meant to be heuristic and to provide ideas that may advance landscape ecology as a science. It is also intended to provide links between theory and practice. It is evident that there is a significant gap between current scientific understanding and its application. We hope that this book will help bridge that gap. We encourage those who develop the science to think about and try to elucidate how the ideas may be used in practice. We ask those who are charged with resource management and conservation practice to try to incorporate relevant landscape ecological ideas into their efforts. If this happens, then theory and practice can effectively be linked.

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Contents

Introduction

> The great obstacle to discovering the shape of the earth, the continents, and the oceans was not ignorance, but the illusion of knowledge.
>
> *The Discoverers,* Daniel J. Boorstin, 1983

The greatest obstacle in conducting effective conservation is not ignorance; we now know a great deal about the scope and extent of conservation problems around the world. Rather, there are two obstacles: the purview of science and human will. We have had the illusion that large landscapes could be restored and managed without grounding in adequate theory to guide efforts. Absolute habitat loss, coupled with fragmentation, has resulted in a pattern of ever smaller and more isolated parcels of intact habitat that are becoming increasingly inadequate to support viable populations of species and intact communities across the world. Anthropogenic influences are largely responsible. Another part of our illusion has been the tacit assumption that understanding the science alone would result in successful conservation efforts, without considering that the priorities of society must be modified if we are to maintain biodiversity. We now know differently. We no longer believe that complex conservation problems and conflicts can be solved quickly or without significant cross-disciplinary efforts. We also know that it will take great effort to raise conservation issues to a level where they are considered of primary importance. We are fortunate to have a developing foundation of landscape ecology and wildlife and conservation biology that can provide the scientific basis for guiding natural resource management and correcting land abuse. Modification of human behavior will remain a challenge, given the influence of culture, economics, and politics.

Land Use and Land Abuse

> With the disappearance of the forest, all is changed. . . . The earth, stripped of its vegetable glebe, grows less and less productive, and, consequently, less able to protect itself . . . and thus the earth is rendered no longer fit for the habitation of man.
>
> *Man and Nature,* George Perkins Marsh, 1864

Man and Nature, written at a time when forest cutting had radically changed the face of New England and especially Vermont, was recognized internationally within a decade of its publication (Meyer and Turner 1992). As Americans moved west, similar scenarios were played out as uncontrolled wood harvesting changed forest cover, structure, and composition; unsustainable overgrazing by domestic livestock and the historic loss of native herbivores in grasslands and arid rangelands resulted in desertification and permanent changes in grass, brush, and succulent (cacti) vegetation (Dyer et al. 1982; McNaughton 1985; Janzen 1986); and uncontrolled draining and development drastically reduced wetlands (Noss and Cooperrider 1994), changing the face of the landscape. In the first three decades of the twentieth century, *Man and Nature* was all but forgotten, but it gained a new following in the 1930s as Americans became aware of growing and persistent environmental problems. From 1900 to 1930, the political cartoons of J. Ding Darling (Lendt 1979) did much to raise environmental consciousness. During this period, Aldo Leopold (1933) put forth principles of management that would provide a conceptual foundation for the restoration of wildlife species. Although his focus was on vertebrate biota, Leopold recognized that habitat was the key to abundant and viable wildlife populations.

Squandered Resources

Before the industrial revolution and the subsequent explosion in human population density, the limitations of natural resources and wildlife habitats across the world were not a concern. Although much of Europe and Asia had been depleted of forest by the end of the Middle Ages, few were concerned about wildlife habitat in the early years of settlement in the United States. Resources were abundant, and little thought was given to conservation. However, things were to change. Between the mid-1600s and about 1920, almost one third of U.S. forests were cut. By 1920, a large percentage of land once forested in the United States was covered by second-growth forest (Miller and

Tangley 1991). Currently, about 33 percent or 302.3 million ha (about 747 million acres) of the United States is forested (Forestinformation.com 2002). Logging continued throughout the twentieth century and was accompanied by the construction of many thousands of miles of roads to provide access to the wood supply. In recent years, recreational use of forests and wildlands has increased greatly, and roads that once had only limited use have been rediscovered, further fragmenting the landscape. Although gaining an exact value is difficult, best estimates suggest that there are more than 600,300 km (about 373,000 miles) of roads in U.S. national forests alone (Williams 1998; The Lands Council 1998), and an additional 96,560 km (about 60,000 miles) of ghost roads not included in the government's inventory. For perspective, the entire U.S. interstate highway system includes 73,230 km (~45,500 miles) of roads, or about 10.5 percent of the length of all forest roads (Forman et al. 2002). If placed end to end, U.S. forest roads would circle the equator about 17 times. Increasingly recognized as a major threat to biodiversity and the integrity of forest, grassland, and desert ecosystems, concern for roads prompted 10 scientists to petition the U.S. president to support a strong roadless area conservation rule (Gould et al. 2001).

Concern for the effects of forest harvesting has not been limited to the North American continent. Although published figures vary widely, about 30 percent of the terrestrial surface of the earth (roughly 3.9 billion ha or about 9.8 billion acres; Forestinformation.com 2002; Coble et al. 1987) is covered by forest, and half of these are tropical forests (Miller and Tangley 1991). Much has been written about the destruction of tropical rainforests. Meyers (1986) reported that approximately 19 million ha (about 46.9 million acres) of tropical rainforests were destroyed annually. That harvest may have increased in the past decade and a half. Concerns about species extinctions (Meyers 1986) and climate change (Wolf 1987) have driven part of the concern about forest loss (Vaughan 1990). More than 50 percent of the earth's species live in tropical forests (World Resources Institute 1998), and tropical forests contain about 70 percent of the world's vascular plants, about 30 percent of all bird species, and about 90 percent of all invertebrates (Canadian International Development Agency 1998).

Assessing the bottom line for forest biodiversity globally is difficult at best. The World Resources Institute (2001, p. 99) wrote, "Forests have the highest species diversity and endemism of any ecosystem. Pressure on this diversity is immense, as judged from forest loss and fragmentation, but direct information about conditions is more limited. What evidence exists suggests that the number of threatened forest species is significant and growing. . . .

The capacity of remaining forests to maintain biodiversity appears to be significantly diminished."

Forest ecosystems are not the only landscapes that have been affected. Grasslands and savannas are among the most endangered terrestrial ecosystems in the world. In the United States, overgrazing, invasion of exotic species, large-scale agricultural activities, and fire suppression have been documented as major causes for their decline (Noss and Cooperrider 1994). For example, sagebrush steppe is a major vegetation type in Utah and the intermountain West and once covered more than 51.8 million ha (about 128 million acres; Rickard et al. 1988). Almost all (99 percent) of the sagebrush steppe type has been grazed by livestock, and the structure and composition of about 30 percent have been changed significantly by heavy grazing (Noss et al. 1995; West 1993, 1999). Similarly, at one time tallgrass prairie covered about 101.2 million ha (about 250 million acres) of mid–North America; today only scattered remnants of intact prairie exist.

Perhaps most affected ecosystems are wetlands. Dahl (1990) reported that over a period of 200 years, from the 1780s to the 1980s, an estimated 53 percent of all wetlands, which in the United States originally totaled 85.3 to 87.8 million ha (about 211–217 million acres) not including Hawaii or Alaska, were lost to draining and development. Significantly, a large proportion of the loss has been attributed to agriculture. A 1997 survey by the U.S. Fish and Wildlife Service (Dahl 1997) estimated that more than 23,470 ha (about 58,000 acres) of wetlands continue to be destroyed annually in the United States. At least one half of all animal species and about one third of all plant species listed under the Endangered Species Act depend on wetlands (Noss and Cooperrider 1994). Additionally, Dahl (1990) argued that so much wetland habitat had been lost that ground water supply, water quality, shoreline erosion, floodwater storage, trapping of sediments, and climatic changes were seriously threatened.

Clearly, use and abuse of land has had profound effects on the biota, but other parts of the world have been affected as profoundly. For example, "nowhere else is forest loss occurring faster in absolute terms" than in the Brazilian Amazon, which contains 40 percent of the remaining tropical forests in the world (Peres 2001). In the late 1990s, deforestation rates averaged 1.9 million ha (about 4.7 million acres) per year (Peres 2001, p. 217). This is especially troublesome because biological diversity was initially so rich. Of the 3,507 vertebrate species in the world listed as critically endangered, endangered, or vulnerable, 236 are in Brazil, 315 are in North America, and 648 are in Europe (IUCN 2000). Of the 3,331 plants so listed, Brazil accounts for 338 endangered plants, and North America and Europe have 310 and 88, respectively (IUCN 2000).

It is clear that conservation problems span the world and are large in scale. Therefore, they necessitate the linking of small- and larger-scale science to understand context, constraint, and causality and thereby inform management. Linking theory, data collection and interpretation, and application to management objectives in meaningful ways remains the challenge for conservationists and resource managers.

Linking Theory, Data, and Practice in Conservation

Although the cumulative effects of widespread, unsustainable resource use were recognized more than 150 years ago, the rudiments of a large-scale science on which to base consistent and effective management did not exist. Until recently, we assumed that smaller-scale studies, using small sampling units, could be scaled to provide answers. In the past two decades we have realized that scaling across hierarchical levels and landscape extents often results in qualitatively different patterns, making meaningful interpretation of data difficult or impossible (O'Neill et al. 1985). Even at smaller scales, a close matching of theory with data is difficult. Fagerström (1987) and Haila (1988) argued that even the simplest ecological statements include more than can be concluded by observation alone. Additionally, indirect effects, such as the presence of trophic cascades (Wootton 1994; but see Strong 1992 and Chase 2000 for counterarguments), and pulsed resources (Ostfeld and Keesing 2000), that is, the availability of much higher than normal resources for short periods of time (mast crops), seriously complicate our understanding of species interactions, even when larger-scale environmental constraints (the spatial explicitness of landscape pattern) and extreme stochastic weather events and other natural and anthropogenic disturbances are not considered. An exact match between theory and practice at any scale may be impossible, but an effective linking of relevant theory with management practice is not only possible but essential if management is to be based on sound ecological principles. However, both philosophical and technical problems must be addressed.

Technical Difficulties and Normative Paradigms

Linking theory to management at the landscape level is a worthy goal but one not easily achieved. There are at least two main difficulties. One rests with the nature of what conservation (the practice) means, what it includes, and how its concepts are interpreted; the other rests with the complex nature of larger-scale ecology (the science).

Difficulties with Normative Paradigms

The conservation literature is rife with multimeaning concepts that are used to guide conservation efforts. For example, the normative concept of ecosystem management; that is, managing for "ecosystem health with commodity extraction as an ancillary goal" (Callicott et al. 1999, p. 28; Grumbine 1997), was institutionalized by the U.S. Forest Service in 1992 (Forest Ecosystem Management Assessment Team 1993), but there has been controversy over its definition (Stanley 1995; Grumbine 1994, 1997). To provide clarification, Callicott et al. (1999) organized "normative" or "umbrella" (Noss 1995) conservation concepts into two philosophical camps based on whether *Homo sapiens* was included as part of nature (functionalism) or not (compositionalism). They argued that compositionalism included the conservation concepts of biological diversity (Wilson 1992), biological integrity (Angermeier and Karr 1994), and ecological restoration (Society for Ecological Restoration 1997), clearly concepts in which *Homo sapiens* is not considered a part of nature but rather an intrusion. Functionalism included normative concepts such as ecological services (Constanza 1991; Daily et al. 2000), ecological rehabilitation (Meffe 1995), ecological sustainability (Callicott and Mumford 1997), ecosystem health (Constanza et al. 1992), ecosystem management (Grumbine 1994, 1997), and adaptive management (Walters 1986), concepts that attempt to harmonize anthropogenic influence and disturbance with the natural world. Callicott et al. (1999) emphasized that these were extremes on a continuum and were presented for the sake of clarification. Willers (2000) and Hunter (2000) criticized aspects of the dichotomy that Callicott et al. (1999) presented, but it seems apparent that precise, clear, and standardized definitions of conservation concepts are helpful. When concepts are used loosely, much of their power is lost. Unless clear definitions are developed and used, conservation concepts become pseudocognates; that is, each person who uses the term feels that everyone else shares her or his definition (Bissonette 1997), when upon closer evaluation it is evident that is not the case. A finer grasp of meaning and context is imperative. Furthermore, a closer examination suggests that some concepts, as currently defined, cannot be made operational. For example, effective monitoring of biological diversity over space and time entails attention to the "what," "why," and "how" of data collection (Yoccoz et al. 2001). Therefore, measurable state variables are needed. Nonquantitative state variables, such as "ecosystem health" (Yoccoz et al. 2001) are difficult or impossible to measure and hence monitor. Callicott et al. (1999) have provided context and a framework that places anthropogenic disturbances and influences as the defining distinction between the two philosophical camps. This appears to be useful when addressing conservation conflicts and problems.

Difficulties with the Science

There has been much development in landscape theory in the past two decades and much discussion about how to deal with scale problems. We know what most of the relevant problems with the science are; we are only now learning how to solve them. Briefly, the science is multicausal (Bissonette 1997), nonlinear dynamics predominate (Kawata 1995), thresholds seem to exist everywhere (Levin 1992, 1999), and scaling from one hierarchical level to another often leads to qualitatively different results (O'Neill et al. 1985). These characteristics result in such complexity of causal influences and constraints at multiple hierarchical levels and with contingent feedbacks that many consider ecological systems to behave as complex adaptive systems (Levin 1999). Understanding ecological complexity and applying that knowledge to solve pressing problems in conservation is the challenge. We have had limited success. Much remains to be done. A quest for understanding complexity remains the focus of much of the discipline of landscape ecology. The attempt to link knowledge gained from research to its management application is the reason the chapters in this book have been written.

Goal

In this volume, we have assembled 17 chapters that address some of the relevant underlying theory and how landscape ecologists have tried to deal with the links to effective practice. We think that many of the approaches illustrated by these chapters are innovative and provide solid advances on which to base resource management. The coverage is by no means complete; no book of this size could provide complete coverage of the emerging field of landscape ecology or its application. However, we hope that there is sufficient heuristic content to stimulate fertile minds to strive to improve our understanding of large-scale ecology put to practice. It will be the work of others to put theory and data-based management on the ground.

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