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Protected Land

Disturbance, Stress, and American Ecosystem Management

Springer

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ISSN 0172-6161
ISBN 978-1-4419-6812-8 e-ISBN 978-1-4419-6813-5
DOI 10.1007/978-1-4419-6813-5
Springer New York Dordrecht Heidelberg London

Library of Congress Control Number: 2010933785

Cover photograph: J.C. Hidalgo / Fotolia.com.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

By many measures, Earth's ecosystems are stressed. Actually, it may be more accurate to say that Earth's *remaining* ecosystems are stressed. The fact is that most of the planet's biomes support only a fraction of the biological communities they once did, primarily because humans have converted large areas of land to alternate uses. More than two-thirds of the global temperate forests, half of the grasslands, even a third of desert ecosystems have been conscripted for human uses like agriculture, construction, harvest and extraction. Cultivation alone covers a quarter of the habitable terrestrial surface. Aquatic ecosystems have not fared any better. An estimated half of the world's wetlands are gone, particularly those of coastal regions or on arable land. About a fifth of the coral reefs and a third of the mangrove swamps of a century ago have been lost in just the last few decades. The volume of water impounded by dams quadrupled over the same period – it now far exceeds the volume of water in unimpeded rivers (Millennium Ecosystem Assessment 2005; Mitsch and Gosselink 2007).

So any assessment of ecosystem status is necessarily an analysis of fragments and remnants, and many of these are degraded by one or more anthropogenic stressors. Agriculture and development have resulted in erosion and soil impoverishment; fertilizer use and waste disposal have lead to eutrophication of aquatic ecosystems; irrigation and overgrazing have rendered land barren. The list goes on. These stressors coupled with overharvest and habitat loss have contributed to an estimated 1,000-fold increase in Earth's baseline extinction rate (Millennium Ecosystem Assessment 2005). Invasive species have responded explosively to this displacement, and their introduction and expansion have altered the rules of competition. Truly, the ecological picture is bleak. This is all the more alarming because ecological systems provide many services on which humans depend. Food, fiber, and fuel, access to clean water and air, regulation of environmental processes, and even our sense of cultural legacy and wellness are dependent directly or indirectly on ecosystems.

In the relatively brief existence of the United States, ecosystem conversion and degradation have been acute. The ecological crisis may have reached a boiling point in the 1960s, but dismay over the detrimental effects of expansion and industrialization on the nation's ecosystems was evident long before. Marjory Stoneman Douglas brought the splendor and crisis of the Everglades to the world's attention in the 1940s, about the same time that Aldo Leopold taught us to think like a mountain.

Before them, John Muir did for the ecosystems of the American west what George Perkins Marsh and Henry David Thoreau had done for the nature preservation movement in the mid-nineteenth century. And yet, the dominant attitude for much of America's history was one of contempt for wilderness, accompanied by rampant development and exploitation that was at best tempered with a Gifford Pinchot-inspired conservation ethic. But attitudes shifted rather abruptly in the mid-twentieth century, precipitating a mandate for ecosystem protection. Of course, ecosystem protection was not a new idea. The first American forest protection measures were established in 1626; the first community forest reserve in 1710; the first national timberland in 1799; the first national park in 1872; the first state park and first state forest in 1885; and the first land trust in 1891 (Jensen and Guthrie 2005). But since the environmental revolution of the 1960s, federally protected acreage has increased tenfold, state-protected parks, natural areas, and forests have increased by a third, and land protected by private organizations has grown by an astonishing factor of 60 (Brewer 2003; Jensen and Guthrie 2005; Vale 2005). This land-protection renaissance has occurred largely in the spirit of preserving the ecosystems we still have and restoring those that we have lost.

Over the last century or so – while the nation has been trying to decide whether it loathes or loves its ecosystems – ecologists have been debating the mechanisms by which ecological systems assemble and function. At the heart of the debate is the question of whether ecosystems exist and develop as discrete, holistic units or whether they are simply coincidental and temporary associations of individual species. On one level this is purely an academic issue. But it also has important practical ramifications, particularly given the state of ecological degradation in which we find ourselves. It is a question that is relevant to our recent enthusiasm for ecosystem protection. Here is the dilemma: If ecosystems occur naturally as stable units with characteristic structure and function, then our efforts to protect critical ecological services must be aimed at the preservation of ecosystems in their natural state. On the other hand, if ecosystems have no stable state or characteristic composition, if instead they are ephemeral in space and time, then our ecosystem management must give priority to shifting populations and variable function.

Prevailing opinion on the nature of the ecosystem has evolved over the years in a way that is reminiscent of our vacillating national opinion on the value of wilderness. Due in part to early European influence, conservationists and preservationists in the United States have long been partial to the holistic view of the ecosystem as a unit. Various analogies have been used to describe this mindset: the ecosystem as a superorganism; the climax state; the self-regulating machine; the homeostatic entity; the self-maintained domain of attraction. In general, they all portray the ecosystem as a biological community with the ability to persist in a stable state by virtue of regulatory internal feedback mechanisms. Ecological disturbances, like flood, fire, or storm might disrupt the stable state, but in the holistic view a healthy ecosystem is *resilient*, meaning that it will return to a stable, optimal equilibrium if given the chance. An unhealthy ecosystem – one without characteristic species in appropriate abundances, for example – may gravitate toward an undesirable alternate state. To preserve ecosystem services, the holist suggests, such an alternate state is something that the ecosystem manager must guard against.

The individualistic view, historically the minority opinion in the American conservation movement, has recently gained evidence and support as a non-equilibrium concept of the ecosystem. Species, according to this view, respond individually to fluctuating environmental conditions. They occur in a shifting mosaic of successional patches that have little to do with the boundaries or labels we place upon the greater ecosystem. Stability, balance, the climax community, the domain of attraction – all are human perceptions of pattern in the noise of nature. The idea of ecosystem preservation loses some meaning in nonequilibrium ecology, for the structure, composition and function of each system are by their nature subject to change. Indeed, it casts doubt on our national effort to preserve ecosystems in form and function. How are we to maintain threatened species, vital ecological services, and our ecological legacy in a coherent state if ecosystems are not coherent? In the words of leading holist E.P. Odum, if you believe that nature is a continually shifting quilt of patches, "then there's no order, and why bother about conservation?" (Chaffin 1998).

This book is about ecological protection and management in the face of our changing concept of the ecosystem. In the first two chapters I place current examples of ecosystem protection in juxtaposition with historical ecosystem concepts, particularly the holistic and individualistic views. After this background, the first half of the book is devoted to the holistic and individualistic ways in which we conceptualize the ecosystem – including ecological integrity, health, stability, and resilience amidst disturbance, stress, and invasion. I then turn to ecosystem management in practice. In particular, I use examples of microbial, forest, grassland, freshwater, and saltwater ecosystems to evaluate the application of theory. My purpose is to clarify the disparate academic views on the ecosystem and to reconcile those views with applied ecosystem management.

If our long history of ecological destruction and degradation can teach us anything, it is that we are dependent upon the individual and collective function of other species on this planet. We now understand many things about the ways in which species associate and respond to stress and disturbance. Given our reliance on Earth's greater biological community, it would behoove us to apply our best understanding to the ways in which we protect these things we call ecosystems.

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Acknowledgments

This work was made possible by a Robert C. Good Faculty Fellowship awarded by Denison University in 2009. I am honored to have been granted this fellowship and grateful for the opportunity it has provided. I thank the many colleagues, friends and family who have offered advice, encouragement and support, and I particularly appreciate the constructive criticism of a number of anonymous reviewers throughout the course of the project. I thank the editors of the Springer Series on Environmental Management for their thoughtful consideration and general assistance. I thank the Denison University Librarians for assisting me with anything and everything. And, most importantly, I thank Beth, Jackie and Adam for being a constant source of inspiration, encouragement, and love.

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Four Ecosystems, Four Questions

Oak Openings, Ohio

In the sandy savannas around the Great Lakes there lives a tiny butterfly called the Karner blue. It is a delicate beauty, but to see it you have to know where and when to look. The life of an adult is short – less than 2 weeks – and there aren't as many as there used to be. In the past few decades the Karner blue population has dropped by 99%, and they are now found only in tiny remnants of their former range (Grundel et al. 1998). In part, the precipitous decline of this species is related to its feeding habits. The larvae of the Karner blue feed only on one plant, the wild lupine, and only in the northern portion of the wild lupine's range. The butterfly is also preferential to grasslands with partial tree canopy, and this sensitivity to mixed sun and shade further limits its available habitat.

Just southwest of Lake Erie is an area called the oak openings where such habitat was once relatively common. The unique characteristics of the oak openings begin with the soil; the region is underlain partially by impervious clay and partially by porous sand. The result is ideal for the Karner blue: a flood-prone woodland fringed by comparatively dry, sparse grassland. But suburban sprawl, agriculture, and other land uses have reduced the oak openings to small remnants scattered around the northeastern and upper midwestern United States (Brewer and Vankat 2006). And even the remnants aren't pristine. Fragmentation and pollution are ecologically stressful, and disturbances that maintain the savanna, particularly fire and grazing, have historically been suppressed by humans. Without these periodic disruptions, successional woody species out-compete the wild lupine and threaten the Karner blue. In 1988, this small butterfly of Ohio's oak openings was driven to local extinction (Tolson et al. 1999).

Ohio's oak openings originated with the glaciers that departed from the Great Lakes region about 14,000 years ago. Long before these sand dunes fringed the hardwood forest, the region was a great lake itself – really an extension of present day Lake Erie, but much larger. By one estimate it was 230 ft deeper than Lake Erie is today (Goldthwait 1959). The glacial meltwater that fed the lake was prevented from draining eastward to the Atlantic by massive ice dams, and so the lake grew in volume until it found an outlet in the Mississippi River basin to the west.

D.J. Spieles, *Protected Land*, Springer Series on Environmental Management,
DOI 10.1007/978-1-4419-6813-5_1,

At its peak the glacial lake covered much of today's northwest Ohio, southeast Michigan, and northeast Indiana. The constant stream of meltwater from the retreating glaciers eroded the surrounding landscape, and millions of tons of sediments entered the glacial lake and eventually settled on the lakebed, which would one day be the basis for a flat, impermeable landscape fringed by sandy beaches.

The glacial lake was no fleeting feature of the landscape – it existed for nearly a thousand years and became a thriving ecosystem in its own right. At first, it was a barren pool of cold, muddy water, but living things were quickly claiming environments that the glaciers surrendered. The first colonizers to arrive in the lake likely included microorganisms and seeds that were blown by the wind or transported by birds, landing by chance in the cold, turbid water. Surrounding the lake was glacial tundra, with shallow pools of meltwater and sparse vegetation stunted by permafrost and glacial winds. Over centuries of harsh conditions the diversity of living things in and around the lake gradually increased, and soon the lake teemed with fish, while mammoth, musk oxen, and caribou browsed along its shore. Through both life and death these organisms added a rain of organic detritus to the settling silt, contributing to the thick muck that would one day make this an imposing landscape for human settlers (Teller 1987).

After a thousand years of colonization and development, the glacial lake suddenly and catastrophically disappeared. The retreating glacier exposed an eastern outlet that was a great deal lower in elevation than the glacial lake. The lake lost 90% of its volume in little more than a century, reduced to a small puddle in the footprint of today's Lake Erie (Teller 1987). All that remained of the glacial lake were the remnant beaches and the basin floor. As the lake bed dried and warmed there was a rush for colonization by terrestrial plants and animals. The odds-on favorites for invasion were plants in the poll position: those that had been established along the former shoreline, which could most easily distribute seed into the drained lake basin. Sedges and grasses quickly invaded, but the real winners of this ecological lottery were cone-bearing trees that had been migrating northward, stalking the glacier in its retreat. Thus the former lake rapidly became a coniferous swamp. But this had happened before. In fact, the forest and glacier had been playing this game of cat-and-mouse for a geologic age. Prior to this most recent glaciation, and perhaps during many interglacial periods, this region had been a coniferous forest; after each establishment, advancing glaciers once again plowed through the trees and devastated the ecosystem. Ancient spruce logs have been found in present-day layers of glacial till, evidence of forests that matured and perished as dictated by the glaciers (Goldthwait 1959). And now, for a time, the spruce forest had returned.

But the ice was not finished. After five centuries of forest growth, the glaciers re-advanced and cut off the drainage routes to the east. Lake levels rose again as quickly as they had once fallen, and the forest was drowned. The region was once again a lake, this time for about 600 years. It was an ecologically chaotic time. On the southern shore, with dogged persistence, was the coniferous forest, while glacial tundra existed to the north. The tundra communities of mammoth, caribou and bison were thus in close proximity with the mastodon, stag moose, and giant sloth of the forest.

Wolves played no favorites and ranged throughout both environments. To make matters even more intriguing, the lake that now existed had been open, in alternating fashion, with both the Atlantic and Mississippi outlets. This allowed for aquatic migration from both directions, making the glacial lake an ecological melting pot in which species from the eastern seaboard co-existed alongside fish from the Mississippi River basin. Eventually, as the ice finally retreated northward and Lake Erie reached its modern level, the trees reclaimed the mud (Pielou 1991).

The ecosystem that would become known as the oak openings thus came about in what can only be described as a series of ecological convulsions – ice advance and retreat, colonization, extinction, and re-colonization; flood, permafrost, and rivers reversing flow direction. The ultimate factors governing the development of the oak openings include the glacial ice and the rock and sediment that it eroded and carried, the climate and wind patterns that deposited organisms, the regional topography, and the periodic drainage and flooding. Living things also played a key role in this ecological development – from microorganisms to megaherbivores, living things altered the soil and water conditions and contributed their biomass to the ecosystem. But there was no single ecosystem. In its first 2,000 years since glacial retreat the region had in fact been many unique ecosystems, each with distinct limitations, opportunities, and residents.

Even after the convulsions of glacial advance and retreat had finally ended, there was still tremendous ecological change. As the climate warmed over the centuries, plant and animal species migrated northward. The spruce swamp became a pine swamp, and then a willow-poplar or elm-ash-maple or oak-hickory forest, depending on location (Sampson 1930). On the sandy beaches of the glacial lakes, which were slightly higher and drier than the old lake bed, oak woodland communities assembled. Dry years and indigenous humans encouraged fires on the ridges, effectively converting the sandy uplands to prairies and oak savannas. Animal communities were also transient over the centuries. The mastodon, the stag moose, and the giant sloth all migrated away from or were hunted out of the area and eventually became extinct, replaced by black bear, deer, elk and bison. These, too were extirpated by the late nineteenth century amid massive human clearing, drainage and development that would eventually consume nearly every trace of the glacial lake and its sandy ridges (Mayfield 1962).

No one knows exactly when the Karner blue came to reside in Ohio's oak openings. But we do know that ecological change and anthropogenic stress eventually rendered its habitat unsuitable. In 1992, a partnership of conservation organizations began working to reintroduce the Karner blue to Ohio (Tolson et al. 1999). The focal point for this restoration was a small patch of oak openings that looked as they might have prior to European contact: the 750 acre Kitty Todd Preserve. Actually, the preserve might be thought of as a collection of habitats. There are grasslands here, including wet prairies that would soak your boots if you walked through them in the spring. In other places there are oak savannas that transition into forests and then, with only a few centimeters change in elevation, to treeless sand dunes. Just off the dunes you'll find patches of swamp forest, shadows of those that once made the region almost impassible and uninhabitable for humans. So there is diversity of