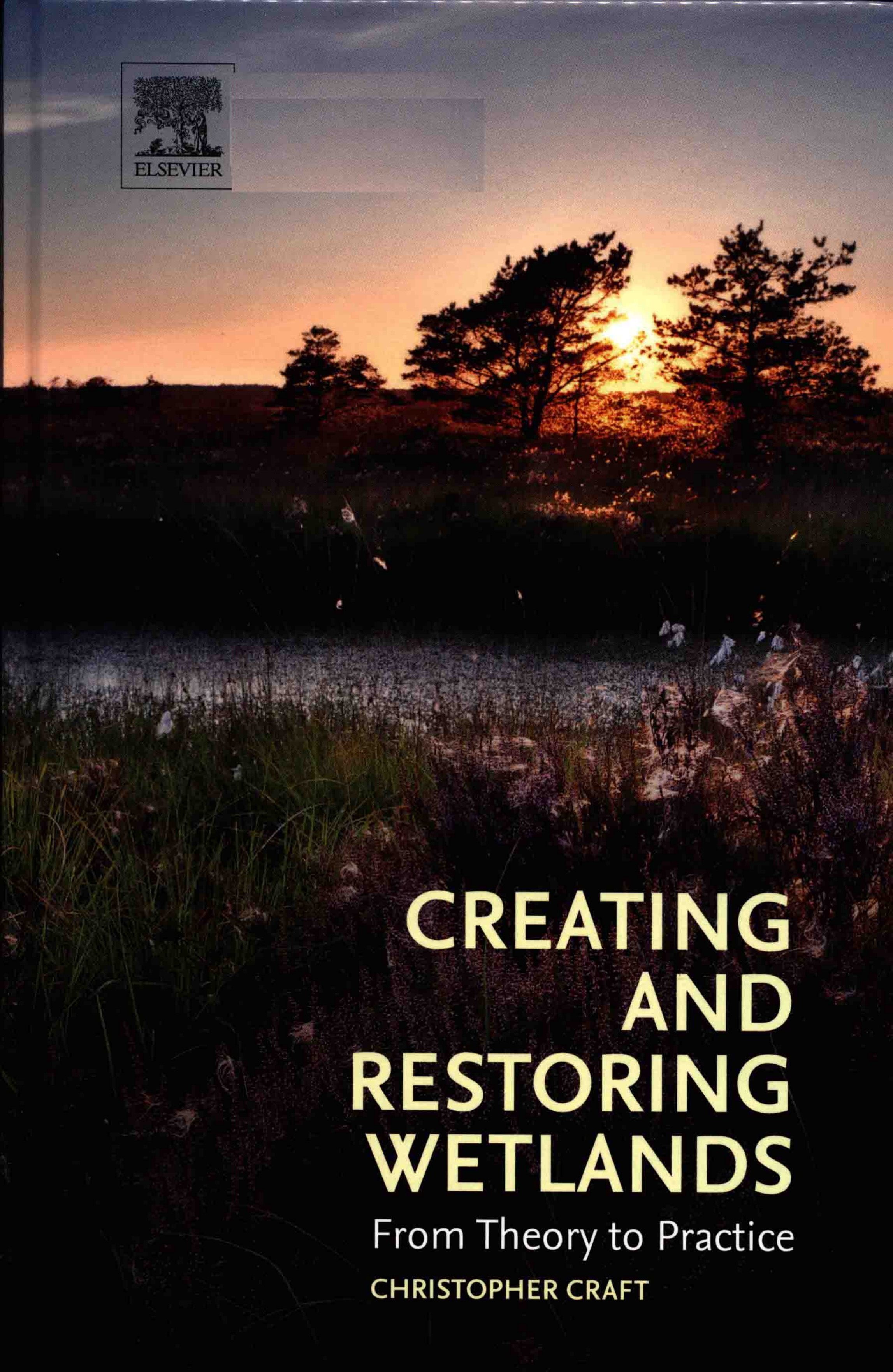

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CREATING AND RESTORING WETLANDS

From Theory to Practice

CHRISTOPHER CRAFT

Creating and Restoring Wetlands

From Theory to Practice

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Part One

Foundations

Introduction

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Chapter Outline

Wetlands, where water and land meet, have a unique place in the development of civilization. Rice, a wetland plant, feeds 3.5 billion people worldwide (Seck et al., 2012). Fish, associated with aquatic littoral zones and wetlands, is the primary source of protein for 2.9 billion people (Smith et al., 2010). Rice (*Oryza sativa*) was first cultivated in India, Southeast Asia, and China (Chang, 1976), and fish were raised among the rice paddies, providing needed protein (Kangmin, 1988). Along the Nile River, early societies were sustained by fish caught from the floodplains and coastal lagoons of the delta (Sahrhage, 2008). Civilization prospered along rivers and deltas of the Yangtze and Yellow Rivers, China; the Irrawaddy, Ganges, and Indus of India; the Nile of Egypt, and the Mesopotamian marshes of Iraq. Later, cities were established where land and water meet, on rivers, lakes, and at the sea's edge, where they were hubs of transport and commerce. As cities grew, it was convenient to drain or fill the low, wet, swampy, and marshy areas, the wetlands, to expand.

With the Industrial Revolution in the eighteenth century and its mechanization of farming and abiotic synthesis of nitrogen fertilizer, large-scale agriculture became feasible. The inevitable result of population growth and the Industrial Revolution was the widespread drainage of freshwater wetlands to grow food crops. Extensive wetlands in regions such as the Midwest US Corn Belt and the interior valleys of California were drained and farmed. Later, large-scale aquaculture, especially shrimp farms, was carved from the extensive mangrove forests of the tropics. During the twentieth century, loss of coastal and freshwater wetlands in temperate regions such as the US, Europe, and China, was extensive. Developing regions of the tropics were not far behind with widespread conversion of mangroves and other wetlands to forest plantations and aquaculture ponds later in the century.

Today, the cumulative loss of wetlands in the US, including Alaska, since European settlement is greater than 30% with much greater losses in the Midwest and California

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where more than 80% of the original acreage has been lost (Dahl, 1990). Worldwide, loss of mangroves, tropical coastal wetlands, is on the order of 20–50% (Valiela et al., 2001; FAO, 2007). In the past 35 years, more than 30% of coastal wetlands and 25% of freshwater swamps in China, where development has been rapid, have been lost (An et al., 2007; He et al., 2014). Delta regions are particularly susceptible to wetland loss as large areas are converted to agriculture (Coleman et al., 2008). Even peatlands are not immune as extractive industries such as peat harvesting and fossil fuel extraction, including oil sands of Canada and fossil fuel extraction in Siberia, *eat* away at the natural resource.

By the 1970s, increasing recognition of the alarming rate of wetland loss led to laws such as the Clean Water Act of 1972 in the US, created to protect the nation's aquatic resources, including wetlands. A key component of the law was the restoration of degraded wetlands or creation of entirely new ones to compensate for their loss. Today, government programs such as the Wetlands Reserve and Conservation Reserve Programs of the U.S. Department of Agriculture offer financial incentives to restore wetlands. In the Glaciated Interior Plains of the American Midwest, more than 110,000 ha of wetland and riparian buffers were restored between 2000 and 2007 (Fennessy and Craft, 2011). Restoration of freshwater wetlands on former agricultural land has been implemented in Europe and elsewhere to improve water quality and increase landscape diversity (Comin et al., 2001). Wetlands also are created and restored to compensate for their loss from developmental activities such as road building and urban/suburban construction. Globally, while not legally binding, the Ramsar convention encourages protection and restoration of wetlands of international importance (see Chapter 2, Definitions).

Whereas the science of wetland restoration is relatively new, people have been restoring for years. The earliest restoration projects were reforestation schemes, planting mangroves for fuel and timber. In Indochina, large-scale mangrove afforestation dates to the late 1800s or earlier (Chowdhury and Ahmed, 1994). Nearly 100 years ago, salt marsh vegetation was planted in Western Europe, the US, Australia, and New Zealand to reclaim land from the sea and to slow coastal erosion (Ranwell, 1967; Knutson et al., 1981; Chung, 2006). At the same time, freshwater wetlands were being reflooded to provide waterfowl habitat (Weller, 1994). This was done by government agencies such as the U.S. Fish and Wildlife Service and by nongovernmental organizations like Ducks Unlimited. These early restoration activities—reforestation, shoreline protection, waterfowl habitat—focused on restoring a particular function such as productivity. Restoration today consists of reestablishing a variety of ecological attributes including community structure (species diversity and habitat) and ecosystem processes (energy flow and nutrient cycling), and the broad spectrum of goods and services delivered by healthy, functioning wetlands.

Webster's Dictionary (http://www.merriam-webster.com) defines restoration as *the act or process of returning something to its original condition.* In the book, *Restoration of Aquatic Ecosystems* (1992), the U.S. National Research Council (NRC) defines restoration as *the act of bringing an ecosystem back into, as nearly as possible, its original condition.* In this book, I expand on the NRC definition to define restoration as *the act of bringing an ecosystem back into, as nearly as possible, its* *original condition* ***faster than nature does it on its own***. This definition contains two key points. Restoration aims to accelerate succession and ecosystem development by deliberate means, spreading propagules, seeds, seedlings, and transplants, and amending the soil with essential nutrients (N) and, sometimes, organic matter. The second point, from the NRC definition, recognizes that often it is not possible to restore a wetland to its original, pre-disturbance condition because stressors that degrade the system cannot be completely eliminated. Many stressors that affect aquatic ecosystems and wetlands, such as flow mistiming, nutrient enrichment, salinity, and other soluble materials (Palmer et al., 2010), originate off-site and propagate downhill and downstream where they cause damage. Other stressors, many related to hydrology, occur on-site and are easier to ameliorate. These include levees, ditches, or placement of spoil atop the site that can be breached, filled, and removed, respectively.

This book introduces the science and practice of restoring wetlands: freshwater marshes, floodplain forests, peatlands, tidal marshes, and mangroves. Globally, wetland restoration is driven by policies such as the Ramsar convention on wetlands of international importance, the Clean Water Act of the US, the Water Framework Directive of the European Union, and others. Arguably, the science of wetland restoration, using ecological theory to guide the process, lags behind practice. Wetland restoration, historically, was more of a *cut and fit* process, applying well-developed techniques used by agronomy and forestry. These techniques were initially employed on surface-mined terrestrial lands where the goal was to reclaim the land for forestry, rangeland, or wildlife habitat. In these mostly terrestrial ecosystems, lack of freshwater often slowed the restoration process and so the idea of flooded or saturated soil hydrology was seldom considered. From a scientific perspective, ecological concepts such as disturbance, succession, and ecosystem development provide a framework to understand what is needed (or not needed) to successfully restore wetlands and other ecosystems. An understanding of ecosystem dynamics, energy flow and nutrient cycling, and the natural history of wetland plants and animals also is critical. Last but not least, one cannot understate the role that humans, through activities that disturb and degrade natural systems and their efforts to repair the damage, play in restoring wetlands.

Why Restore Wetlands?

Why the interest in restoring wetlands? There are two reasons. (1) There has been dramatic and widespread decline in wetland area as noted above. Nearly all of the losses are caused by human activities, drainage, placement of fill, nutrient overenrichment, and other waterborne pollutants. Extractive activities such as peat harvesting and mining of sand and other construction materials also contribute to the loss. There is an old saying that you do not appreciate something until it's gone, and with wetlands there is truth to that. (2) The benefits that wetlands provide to society (Table 1.1). Mostly unappreciated in the past, it is widely recognized that wetlands provide valuable services such as high levels of biological productivity, both fisheries and waterfowl, disturbance regulation including shoreline protection and floodwater storage,

Table 1.1 Ecological Functions and Services of Various Types of Wetlands

Floodplain/riparian	Water quality improvement (sediment trapping, denitrification) Biological productivity (including C export to aquatic ecosystems) Floodwater storage Biological dispersal corridors Biodiversity
Freshwater marshes	Biological productivity (waterfowl) Biodiversity
Peatlands	Carbon sequestration Biodiversity
Tidal marshes	Shoreline protection Biological productivity (finfish and shellfish, outwelling of nutrients) Water quality improvement
Mangroves	Shoreline protection Biological productivity (finfish, shellfish, outwelling) Water quality improvement

water quality improvement through sediment trapping and denitrification, and habitat and biodiversity.

It is recognized that different types of wetlands provide different kinds and levels of ecosystem services. Wetlands with strong connections to aquatic ecosystems such as floodplains, tidal marshes, and mangroves maintain and enhance water quality by filtering pollutants. They also regulate natural disturbances and perturbations by storing floodwaters, dissipating wave energy, and protecting shorelines. Some wetlands possess high levels of biological productivity that support commercial and recreation finfish populations, shellfish harvesting, and breeding waterfowl populations. Freshwater marshes of the prairie pothole region in the north central US and Canada are critical breeding habitat for North American ducks (Batt et al., 1989). Wetlands of the far north in Canada and Siberia are essential to breeding populations of cranes (Kanai et al., 2002; Chavez-Ramirez and Wehtje, 2012). Coastal wetlands, saline tidal marshes, and mangroves, contribute to aquatic food webs by serving as habitat for fish and crustaceans and by outwelling or exporting organic matter that supports heterotrophic food webs. Forested wetlands, riparian areas, and floodplain forests, support food webs of aquatic ecosystems, including streams and rivers. Wetlands that lack strong surface water connections such as peatlands sequester large amounts of carbon and support high levels of plant biodiversity.

Wetland restoration projects vary in their goals, scope, and costs. It is difficult to evaluate costs versus benefits of wetland restoration projects because it is hard to assess the economic value of various ecosystem services (see Chapter 2, Definitions). Bernhardt et al. (2005) reviewed the number and cost of various aquatic ecosystems