Wetlands

Fourth Edition

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John Wiley & Sons, Inc.

This book is printed on acid-free paper.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

Wiley Bicentennial Logo: Richard J. Pacifico

Library of Congress Cataloging-in-Publication Data:

Mitsch, William J.
Wetlands / William J. Mitsch, James G. Gosselink. -- 4th ed.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-471-69967-5 (cloth)
1. Wetland ecology--United States. 2. Wetlands--United States. 3. Wetland management--United States. I. Gosselink, James G. II. Title.
QH104.M57 2007
577.68--dc22
2007001732

Printed in the United States of America.

10 9 8 7 6 5 4 3 2 1

We dedicate this book to two important ecologists who heavily influenced wetland ecology and management—Howard T. Odum and Eugene P. Odum. Both brothers died in late summer 2002. We still see their influence on dozens of principles and concepts described in this book.

Preface

This is the fourth edition of *Wetlands*—we have done a new edition every 7 years since the first edition came out in 1986. The first important change in *Wetlands* 4th edition (referred to here as *Wetlands 4*) is that it is shorter than *Wetlands* 3rd edition—with 35 percent fewer pages and 14 chapters rather than 21. It is quite rare that a new edition of a book is smaller than its predecessor; but we had our reasons. The book was becoming encyclopedic and less of a textbook with every edition and yet we were still not covering every type of wetland in the ecosystem chapters. So we shortened the book by removing the seven wetland ecosystem chapters that were in the middle of the previous 3 editions of this book. We did so with great care and respect for the reputation that this so-called "wetland bible" has developed with its previous editions. Now, with those chapters eliminated, there will be less concern expressed by some that we left out their favorite wetland and much more opportunity to focus on the three remaining sections in *Wetlands 4*—an introduction to the extent, definitions and general features of wetlands of the world (called *Introduction*), wetland science (called *The Wetland Environment*), and the applied section called *Wetland Management*. In some cases, we moved important principles from the removed ecosystem chapters to one of the three sections in this new edition.

We added a new chapter to *Wetlands 4* on "Climate Change and Wetlands" (Chapter 10). This chapter includes new information, even up to our publishing date, from the International Panel on Climate Change's (IPCC's) 2007 reports. Since wetlands may be the linchpins of climate change, this may be the most important addition to the book in some time. Wetlands are affected by climate change probably more than any other ecosystem and they are also sources of important greenhouse gases, mainly methane and nitrous oxide. They also represent enormous storages of carbon—equivalent to 100 years or more of present-day fossil fuel emissions. Any climate drift could have major effects on those storages of carbon in the world.

Much greater international coverage is included in *Wetlands 4*. We merged the North American and "rest of the World" chapters from the previous edition to one chapter on "Wetlands of the World" (Chapter 3). We initiated or expanded coverage of the Great Plains Playas in the United States, the wetlands of Mexico and Central America, the Congolian Swamp and Sine Saloum Delta of Africa, the Western Siberian Lowlands, and a new wetland phenomenon in Asia—wetland parks such as XiXi National Wetland Park in eastern China and Gandau Nature Park in Taipai, Taiwan. Over 50 photographs of the world's wetlands are now found in Chapters 1 and 3. In addition, we have provided three new estimates of the extent of wetlands in the world and have updated our world wetland map. We have also documented the importance of coastal marshes in the Louisiana Delta after Hurricane Katrina, coastal mangroves as protective systems after the Indian Ocean tsunami of December 2004, and the Mesopotamian Marshland restoration in Iraq after its drainage in the 1990s.

Thirty-seven "boxes" or sidebars are another feature in *Wetlands 4*. These boxes include important footnote-type details in many of the chapters and case studies of wetland restoration (Chapter 12) and treatment wetlands (Chapters 13). These boxes and the shorter book should be welcome changes for college students who use this textbook for wetland ecology classes. Our students thought *Wetlands 3* was a bit much for one quarter or semester. Now it is more manageable.

The book is updated in every chapter. More than 200 new wetland publications are cited in this edition with over one hundred and seventy citations from 2000 or later to augment the classics from the last half of the 20th century. Many older citations, particularly those that would be hard to find, were eliminated. New or expanded subjects, in addition to climate change (Chapter 10) include seiches in wetlands (Chapter 4), anammox and dissimilatory nitrate reduction to ammonia (DNRA) in the wetland nitrogen cycle (Chapter 5), wetland plant hypertrophy (Chapter 6), the hydrogeomorphic wetland classification system (Chapter 8), waterfowl and wildlife management in wetlands (Chapter 9), the importance of wetlands in storm and tsunami abatement (Chapter 11), emergy analysis to quantify wetland values (Chapter 11), current status of mitigation wetlands in the United States (Chapter 12), and two important U.S. Supreme Court decisions in the 21st century related to wetland protection (Chapter 14). The status of the international Ramsar Convention on Wetlands is also brought up to date in Chapter 14.

On a personal note, we are pleased to share new wetland research results generated at the Wilma H. Schiermeier Olentangy River Wetland Research Park (ORWRP) on the campus of The Ohio State University. New findings from the experimental wetlands at the ORWRP are presented in boxes on the importance of hydrologic pulses on wetland function (Chapter 4), the importance of plant introduction in freshwater marsh succession (Chapter 7), the development of hydric soils in wetland creation (Chapter 12), and long-term water quality changes in flow-through riverine wetlands (Chapter 13).

We could not have completed this edition without help from many friends and colleagues. Anne Mischo provided dozens of new illustrations for *Wetlands 4* to

supplement her beautiful work from *Wetlands 3*. We are honored to have a wetland photo from Jimmie Campbell, Columbus Ohio, on the cover of our book; we are even more thrilled that the picture was taken at the created wetlands at the Olentangy River Wetland Research Park (ORWRP) in Ohio. Ruthmarie Mitsch provided hours of editing and referencing as this edition was being completed. Cassie Tuttle assisted with literature reviews to find some of the new material in this book. Li Zhang kept the ORWRP running and provided a great sounding board for ideas to make this book better. We also appreciate the input, illustrations, or insight provided by the following (listed in alphabetical order): Jim Aber, Azzam Alwash, Chris Anderson, Mark Brown, Jean Cowan, Jenny Davis, Frank Day, John Day, Siobhan Fennessy, Max Finlayson, Brij Gopal, Wenshan He, Maria Hernandez, Carter Johnson, Wolfgang Junk, Jean-Claude LeFeuvre, Robin Lewis, Jianjian Lu, Pierrick Marion, Ken Mavuti, Andre Mauxion, Irv Mendelssohn, Thomas Nebbia, Nancy Rabalais, Bill Resch, Clayton Rubec, Kenneth Strait, Ralph Tiner, Louis Toth, Barry Warner, and Paul Whalen.

We also appreciate the professional effort on the part of editor Jim Harper and production manager Kerstin Nasdeo of John Wiley & Sons, Inc. It has been a pleasure to work with the Wiley operation since they purchased our original publisher Van Nostrand Reinhold in the mid-1990s and switched us to the Wiley brand.

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June 2007

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Part 1

Introduction

Chapter 1

Wetlands: Human History, Use, and Science

Wetlands, landscape features found in almost all parts of the world, are known as "the kidneys of the landscape" and "ecological supermarkets" to bring attention to the important values they provide. Although many cultures have lived among and even depended on wetlands for centuries, the modern history of wetlands is fraught with misunderstanding and fear, as described in much of our Western literature. Wetlands have been destroyed at alarming rates throughout the developed and developing worlds. Now, as their many values are being recognized, wetland conservation and protection have become the norm in many parts of the world. Wetlands have properties that are not adequately covered by present terrestrial and aquatic ecology, making a case for wetland science as a unique discipline encompassing many fields, including terrestrial and aquatic ecology, chemistry, hydrology, and engineering. Wetland management, as the applied side of wetland science, requires an understanding of the scientific aspects of wetlands balanced with legal, institutional, and economic realities. As interest in wetlands has grown, so too have professional organizations and agencies that are concerned with wetlands, as well as the amount of journals and literature on wetland science.

Wetlands are among the most important ecosystems on Earth. In the great scheme of things, the swampy environment of the Carboniferous period produced and preserved many of the fossil fuels on which our society now depends. In more recent biological and human time periods, wetlands have been valuable as sources, sinks, and transformers of a multitude of chemical, biological, and genetic materials. Although the value of wetlands for fish and wildlife protection has been known for a century, some of the other benefits have been identified more recently.

Wetlands are sometimes described as "the kidneys of the landscape" because they function as the downstream receivers of water and waste from both natural and human sources. They stabilize water supplies, thus ameliorating both floods and drought. They have been found to cleanse polluted waters, protect shorelines, and recharge groundwater aquifers.

Wetlands also have been called "ecological supermarkets" because of the extensive food chain and rich biodiversity that they support. They play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna. Now that we have become concerned about the health of our entire planet, wetlands are being described by some as important carbon sinks and climate stabilizers on a global scale.

These values of wetlands are now recognized worldwide and have led to wetland conservation, protection laws, regulations, and management plans. But our history with wetlands had been to drain, ditch, and fill them, never as quickly or as effectively as was undertaken in countries such as the United States beginning in the mid-1800s.

Wetlands have become the *cause célèbre* for conservation-minded people and organizations throughout the world, in part because they have become symptoms of our systematic dismantling of our water resources and in part because their disappearance represents an easily recognizable loss of natural areas to economic "progress." Scientists, engineers, lawyers, and regulators are now finding it both useful and necessary to become specialists in wetland ecology and wetland management in order to understand, preserve, and even reconstruct these fragile ecosystems. This book is for these aspiring wetland specialists, as well as for those who would like to know more about the structure and function of these unique ecosystems. It is a book about wetlands—how they work and how we manage them.

Human History and Wetlands

There is no way to estimate the impact humans have had on the global extent of wetlands except to observe that, in developed and heavily populated regions of the world, the impact has ranged from significant to total. The importance of wetland environments to the development and sustenance of cultures throughout human history, however, is unmistakable. Since early civilization, many cultures have learned to live in harmony with wetlands and have benefited economically from surrounding wetlands, whereas other cultures quickly drained the landscape. The ancient Babylonians, Egyptians, and the Aztec in what is now Mexico developed specialized systems of water delivery involving wetlands. Major cities of the world, such as Chicago and Washington, D.C., in the United States, Christchurch, New Zealand, and Paris, France, stand on sites that were once part wetlands. Many of the large airports (in Boston, New Orleans, and J. F. Kennedy in New York, to name a few) are situated on former wetlands.

While global generalizations are sometimes misleading, there was and is a propensity in Eastern cultures not to drain valuable wetlands entirely, as has been done in the West, but to work within the aquatic landscape, albeit in a heavily managed way. Dugan (1993) makes the interesting comparison between *hydraulic civilizations*

(European in origin) that controlled water flow through the use of dikes, dams, pumps, and drainage tile, partially because water was only seasonally plentiful, and *aquatic civilizations* (Asian in origin) that better adapted to their surroundings of water-abundant floodplains and deltas and took advantage of nature's pulses such as flooding. It is because the former approach of controlling nature rather than working with it is so dominant today that we find such high losses of wetlands worldwide.

Wetlands have been and continue to be part of many human cultures in the world. Coles and Coles (1989) referred to the people who live in proximity to wetlands and whose culture is linked to them as *wetlanders*. Some of these cultures and users of wetlands are illustrated in eighteen photographs in this chapter (Figures 1.1 through 1.18). Figures 1.1 through 1.7 show human cultures or settings around the world that have depended on wetlands, sometimes for centuries. Figures 1.8 through 1.11 show some of the many food products that are harvested from wetlands while Figures 1.12 through 1.16 illustrate the use of wetlands as sources of fuel, building materials, and even household goods. Most recently, wetlands have become the foci for ecotourism in many developing and developed parts of the world (Figure 1.17 through 1.18).

Sustainable Cultures in Wetlands

The Camarguais of southern France (Fig. 1.1), the Cajuns of Louisiana (Fig. 1.2), the Marsh Arabs of southern Iraq (Fig. 1.3), many Far Eastern cultures (Fig. 1.4), and the Native Americans in North America (Figs. 1.5 and 1.6) have lived in harmony with wetlands for hundreds if not thousands of years. These are the true wetlanders. For example, the Sokaogon Chippewa in Wisconsin have, for centuries, harvested and reseeded wild rice (*Zizania aquatica*) along the littoral zone of lakes and streams. They have a saying that "wild rice is like money in the bank." Wetlands were often used as places of cultural solitude and reverence, as with the Mont St. Michel, a Benedictine monastery, built between the 11th and 16th centuries in northern France (Fig. 1.7).

Food from Wetlands

Domestic wetlands such as rice paddies feed an estimated half of the world's population (Fig. 1.8). Countless other plant and animal products are harvested from wetlands throughout the world. Many aquatic plants besides rice such as Manchurian wild rice (*Zizania latifolia*) are harvested as vegetables in China (Fig. 1.9). Cranberries are harvested from bogs, and the industry continues to thrive today in North America (Fig. 1.10). Coastal marshes in northern Europe, the British Isles, and New England were used for centuries and are still used today for grazing of animals and hay production.

Wetlands can be an important source of protein. The production of fish in shallow ponds or rice paddies developed several thousands of years ago in China and Southeast Asia, and crayfish harvesting is still practiced in the wetlands of Louisiana and the Philippines. Shallow lakes and wetlands are an important provider of protein in many parts of sub-Saharan Africa (Fig. 1.11).

Figure 1.1 The Camargue region of southern France in the Rhone River delta is an historically important wetland region in Europe where Camarguais have lived since the Middle Ages. *(Photograph by Tom Nebbia, Horseshoe, North Carolina, reprinted by permission.)*

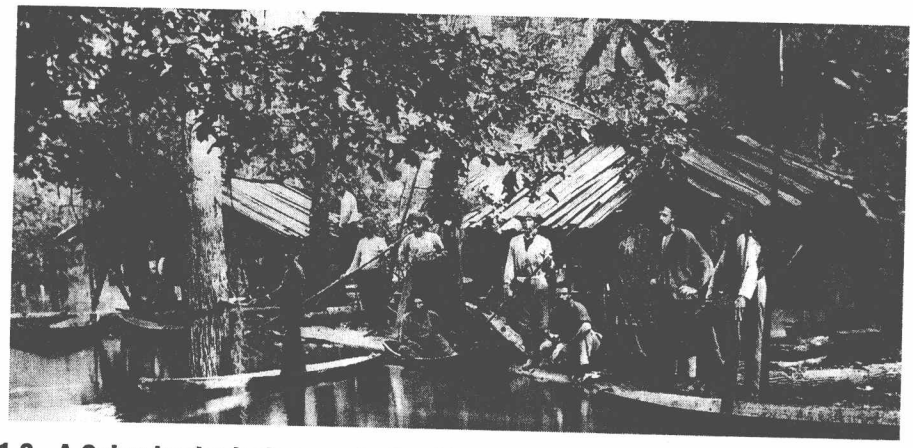

Figure 1.2 A Cajun lumberjack camp in the Atchafalaya Swamp of coastal Louisiana. American Cajuns are descendants of the French colonists of Acadia (present-day Nova Scotia, Canada), who were forced out of Nova Scotia by the English and moved to the Louisiana delta in the last half of the 18th century. Their society and culture flourished within the bayou wetlands. *(Photograph courtesy of the Louisiana Collection, Tulane University Library, New Orleans, reprinted by permission.)*

Peat and Building Materials

The Russians, Finns, Estonians, and Irish, among other cultures, have mined their peatlands for centuries, using peat as a source of energy on small-scale production (Fig. 1.12) and in large-scale extraction processes (Fig. 1.13). *Sphagnum* peat is now harvested for horticultural purposes throughout the world. In southwestern New Zealand, for example, surface *Sphagnum* has been harvested since the 1970s for export as a potting medium (Fig. 1.14). Reeds and even the mud from coastal and

Figure 1.3 The Marsh Arabs of southern Iraq lived for centuries on artificial islands in marshes at the confluence of the Tigris and Euphrates rivers. The marshes were mostly drained by Saddam Hussein in the 1990s and are now being restored (see Chapter 12).

Figure 1.4 Interior wetlands in Weishan County, Shandong Province, China, where approximately 60,000 people live amid wetland-canal systems and harvest aquatic plants for food and fiber. *(Photograph by W. J. Mitsch.)*

inland marshes have been used for thatching for roofs in Europe, Iraq, Japan, and China, as well as wall construction, fence material, lamps, and other household goods (Figs. 1.15 and 1.16). Coastal mangroves are harvested for timber, food, and tannin in many countries throughout Indo-Malaysia, East Africa, and Central and South America.

Figure 1.5 Native American "ricers" from the Sokaogon Chippewa Reservation poling and "knocking" wild rice (*Zizania aquatica*) as they have for hundreds of years on Rice Lake in Forest County, Wisconsin. *(Photograph by R. P. Gough, reprinted by permission.)*

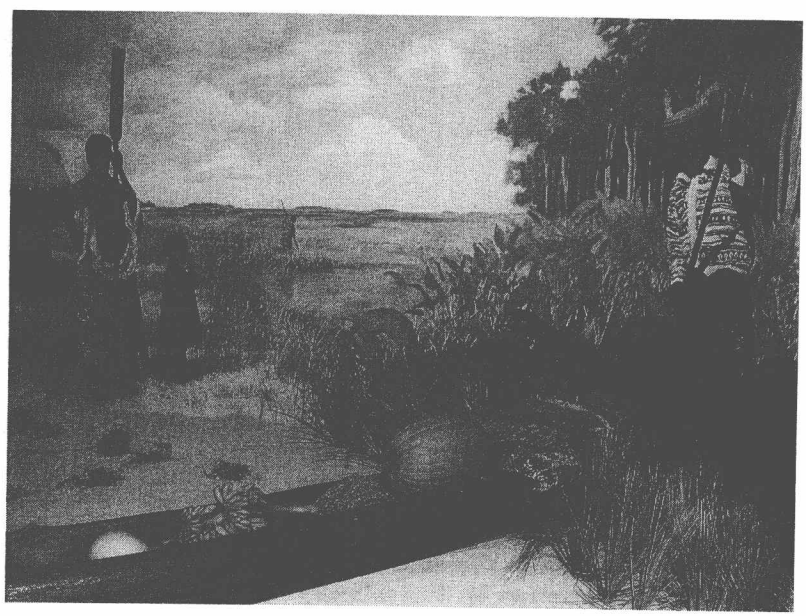

Figure 1.6 Several Native American tribes have lived in and around the wetlands of southern Florida, including the Florida Everglades. These include the Calusa Indians, who disappeared as a result of imported European disease, and later the Seminole (Miccosukee) tribe that moved south to the Everglades in the 19th century while being pursued by the U.S. Army during the Seminole Indian wars. They never surrendered. The Miccosukee adapted to living in hammock-style camps spread throughout the Everglades and relied on fishing, hunting, and harvesting of native fruits from the hammocks. *(Photograph by W. J. Mitsch, panorama at Miccosukee Indian Village, Florida Everglades.)*

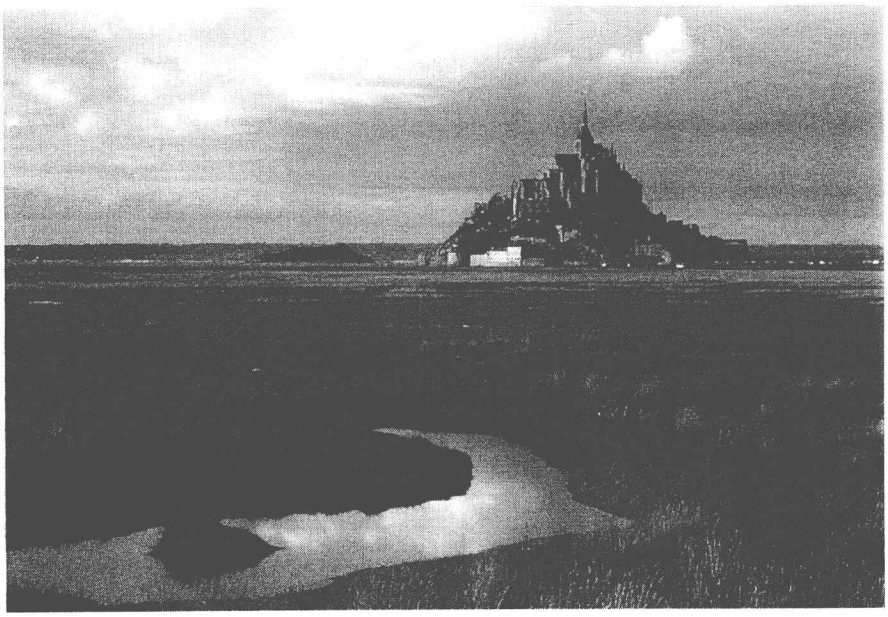

Figure 1.7 Mont St. Michel, a Benedictine monastery, built between the 11th and 16th centuries, sits amid the coastal mudflats and salt marshes between Normandy and Brittany in northwestern France. Entry to the island, now a UNESCO World Heritage site, is through a land bridge that crosses the wetlands. ***(Photograph by A. Mauxion, reprinted by permission.)***

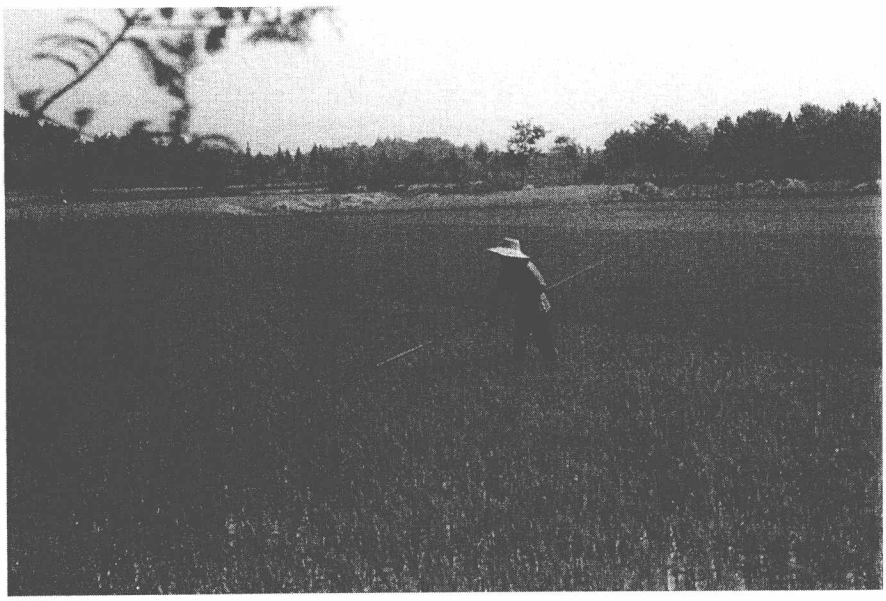

Figure 1.8 Rice production occurs in "managed" wetlands throughout Asia and other parts of the world. Half of the world's population is fed by rice paddy systems. ***(Photograph by W. J. Mitsch.)***