Chapter 1

Wetlands: Human Use and Science

Wetlands are found in almost all parts of the world. They are sometimes referred to as "kidneys of the landscape" and "nature's supermarkets" to bring attention to the important ecosystem services and habitat values that they provide. Although many cultures have lived among and even depended on wetlands for centuries, the modern history of wetlands until the 1970s 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 benefits are being recognized, wetland conservation has become the norm. In many parts of the world, wetlands are now revered, protected, and restored; in other parts, they are still being drained for human development.

Because wetlands have properties that are not adequately covered by current terrestrial and aquatic ecology paradigms, a case can be made 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 awareness of the ecosystem services of wetlands has grown, so too have public interest for wetland protection, wetland science programs in universities, and publications about wetlands in scientific journals.

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 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 mitigating both floods and drought. They have been found to cleanse polluted waters, protect shorelines, and recharge groundwater aquifers.

Wetlands also have been called nature's 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 before current times 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. In some regions of the world that destruction of wetlands continues.

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, DC, 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, in part 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.*

Sustainable Cultures in Wetlands

Some of the original wetlander cultures are described here. The Marsh Arabs of southern Iraq (Fig. 1.1) and the Camarguais of southern France's Rhone River Delta (Fig. 1.2) are two examples of ancient cultures that have lived in harmony and sustainably with their wetland environments for centuries. In North America, the Cajuns of Louisiana and several Native Americans tribes have lived in harmony with wetlands for hundreds of years. The Louisiana Cajuns, descendants of the French colonists of Acadia (present-day Nova Scotia, Canada), were forced out of Nova Scotia by the English and moved to the Louisiana delta in the last half of the

Figure 1.1 The Marsh Arabs of present-day southern Iraq lived for centuries on artificial islands in marshes at the confluence of the Tigris and Euphrates rivers in Mesopotamia. The marshes were mostly drained by Saddam Hussein in the 1990s and are now being restored.

Figure 1.2 The Camargue region of southern France in the Rhone River Delta is a historically important wetland region in Europe where Camarguais have lived since the Middle Ages. (Photo by Tom Nebbia, reprinted with permission)

Figure 1.3 A Cajun lumberjack camp in the Atchafalaya Swamp of coastal Louisiana. (Photo courtesy of the Louisiana Collection, Tulane University Library, reprinted with permission)

eighteenth century. Their society and culture flourished within the bayou wetlands (Fig. 1.3). The Chippewa in Wisconsin and Minnesota have harvested and reseeded wild rice (*Zizania aquatica*) along the littoral zone of lakes and streams for centuries (Fig. 1.4). They have a saying: "Wild rice is like money in the bank."

Likewise, several Native American tribes lived and even thrived in large-scale wetlands, such as the Florida Everglades. These include the ancient Calusa, a culture that based its economy on estuarine fisheries rather than agriculture. The Calusa disappeared primarily as a result of imported European disease. In the nineteenth century, the Seminoles and especially one of its tribes, the Miccosukee, moved south to the Everglades 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

Figure 1.4 "Ricer" poling and "knocking" wild rice (*Zizania aquatica*) into canoes as Anishinaabe (Chippewa, Ojibwe) tribes and others have done for hundreds of years on Rice Lake in Crow Wing County, Minnesota. (Photo by John Overland, reprinted with permission)

spread throughout the Everglades and relied on fishing, hunting, and harvesting of native fruits from the hammocks (Fig. 1.5). A recent quote in a Florida newspaper by Miccosukee tribal member Michael Frank is poignant yet hopeful about living sustainably in the Florida Everglades:

> We were taught to never, ever leave the Everglades. If you leave the Everglades you will lose your culture, you lose your language, you lose your way of life.
>
> —**Michael Frank, as quoted by William E. Gibson, "Pollution Is Killing Everglades, Miccosukee Warn,"** ***South Florida Sun Sentinel*****, August 10, 2013**

Literary References to Wetlands

With all of these important cultures vitally depending on wetlands, not to mention the aesthetics of a landscape in which water and land often provide a striking panorama, one might expect wetlands to be more respected by humanity; this has certainly not always been the case. Wetlands have been depicted as sinister and forbidding and as having little economic value throughout most of Western literature and history. For example, in the *Divine Comedy*, Dante describes a marsh of the Styx in Upper Hell as the final resting place for the wrathful:

> Thus we pursued our path round a wide arc of that ghast pool,
> Between the soggy marsh and arid shore,
> Still eyeing those who gulp the marish [marsh] foul.

Figure 1.5 The Miccosukee Native Americans adapted to life in the Florida Everglades in hammock-style camps. They relied on fishing, hunting, and harvesting of native fruits from the hammocks. (Photo by W. J. Mitsch of panorama at Miccosukee Indian Village, Florida Everglades)

Centuries later, Carl Linnaeus, crossing the Lapland peatlands in 1732, compared that region to that same Styx of Hell:

> Shortly afterwards began the muskegs, which mostly stood under water; these we had to cross for miles; think with what misery, every step up to our knees. The whole of this land of the Lapps was mostly muskeg, hinc vocavi Styx. Never can the priest so describe hell, because it is no worse. Never have poets been able to picture Styx so foul, since that is no fouler.

In the eighteenth century, an Englishman who surveyed the Great Dismal Swamp on the Virginia–North Carolina border and is credited with naming it described the wetland as

> [a] horrible desert, the foul damps ascend without ceasing, corrupt the air and render it unfit for respiration . . . . Never was Rum, that cordial of Life, found more necessary than in this Dirty Place.
>
> **—Colonel William Byrd III, "Historie of the Dividing Line Betwixt Virginia and North Carolina," in *The Westover Manuscripts*, written 1728–1736 (Petersburg, VA: E. and J. C. Ruffin, printers, 1841)**

Even those who study and have been associated with wetlands have been belittled in literature:

> Hardy went down to botanise in the swamp, while Meredith climbed towards the sun. Meredith became, at his best, a sort of daintily dressed Walt Whitman: Hardy

> became a sort of village atheist brooding and blaspheming over the village idiot.
>
> —**G. K. Chesterton, Chapter 12 in *The Victorian Age in Literature* (New York, NY: Henry Holt and Company, 1913)**

The English language is filled with words that suggest negative images of wetlands. We get *bogged down* in detail; we are *swamped* with work. Even the mythical *bogeyman*, the character featured in stories that frighten children in many countries, may be associated with European bogs. Grendel, the mythical monster in *Beowulf*, one of the oldest surviving pieces of Old English literature and Germanic epic, comes from the peatlands of present-day northern Europe:

> Grendel, the famous stalker through waste places, who held the rolling marshes in his sway, his fen and his stronghold. A man cut off from joy, he had ruled the domain of his huge misshapen kind a long time, since God had condemned him in condemning the race of Cain.
>
> —***Beowulf*, translated by William Alfred, *Medieval Epics* (New York, NY: The Modern Library, 1993)**

Hollywood has continued the depiction of the sinister and foreboding nature of wetlands and their inhabitants, in the tradition of Grendel, with movies such as the classic *Creature from the Black Lagoon* (1954), a comic-book-turned-cult-movie *Swamp Thing* (1982), and its sequel *Return of the Swamp Thing* (1989). Even Swamp Thing, the man/monster depicted in Figure 1.6, evolved in the 1980s from a feared creature to a protector of wetlands, biodiversity, and the environment. A more modern approach to scaring and entertaining the public with megafauna from the swamps is a science fiction movie *Mega Python vs. Gatoroid* (2011) that is set in the Florida Everglades (Fig. 1.7). The movie exaggerates much of the current dynamics about the Florida Everglades including conservation, invasive species, genetically altered organisms, fund-raising by conservationists, and conflicts among hunters, conservation agencies, and environmentalists. In some respects, current life in the Everglades imitates art. Big snakes and alligators from wetlands continue to strike fear.

As long as wetlands remain more difficult to stroll through than a forest and more difficult to cross by boat than a lake, they will remain misunderstood by the general public unless a continued effort of education takes place.

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. Cranberries are harvested from bogs, and the industry continues to thrive today in North America (Fig. 1.9). 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 production of salt hay. Salt marsh coastlines of Europe are still used for the production of salt.

Figure 1.6 The sinister image of wetlands, especially swamps, has often been promoted in popular media such as Hollywood movies and comic books. Shown here are four examples: (a) Swamp Thing movie poster; (b) Swamp Thing: Dark Genesis cover; (c) Saga of Swamp Thing #26; and (d) Swamp Thing #9. All ™ and © DC Comics.

Wetlands can be important sources 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. 1.10).

Peat and Building Materials

Russians, Finns, Estonians, and Irish, among other cultures, have mined their peatlands for centuries, using peat as a source of energy in small-scale production

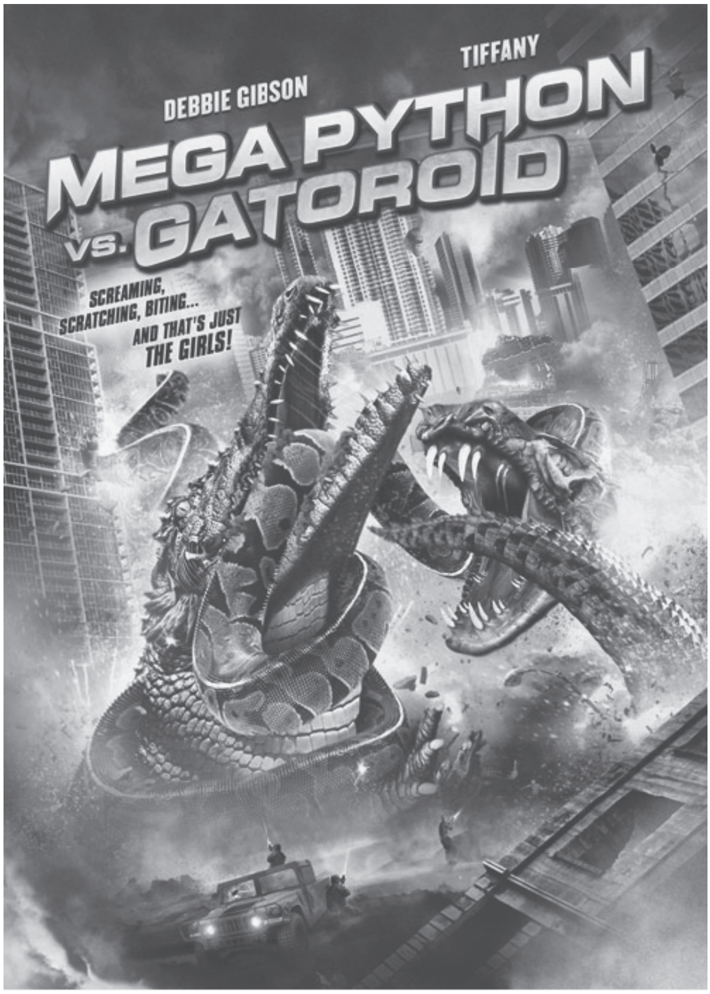

Figure 1.7 The playbill for the *Mega Python vs. Gatoroid* science fiction movie published by The Asylum in 2011 (http://www.theasylum.cc). (Permission from David Latt, President, The Asylum, Burbank, CA)

(Fig. 1.11) and in large-scale extraction processes (Fig. 1.12). *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. Reeds and even the mud from coastal and inland marshes have been used for thatching for roofs in Europe, Iraq, Japan, and China as well as in wall construction, as fence material, and for lamps and other household goods (Fig. 1.13). Coastal mangroves are harvested for timber, food, and tannin in many countries throughout Indo-Malaysia, East Africa, and Central and South America.

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. (Photo by W. J. Mitsch)

Figure 1.9 Cranberry wet harvesting is accomplished by flooding bogs in several regions of North America. The cranberry plant (*Vaccinium macrocarpon*) is native to the bogs and marshes of North America and was first cultivated in Massachusetts. It is now also an important fruit crop in Wisconsin, New Jersey, Washington, Oregon, and parts of Canada. (Photo courtesy of Ocean Spray Cranberries, Inc.)

Figure 1.10 Humans use the wetlands of sub-Saharan Africa for sustenance, as with this man fishing for lungfish (*Proptopterus aethiopicus*) in Lake Kanyaboli, western Kenya. (Photo by M. K. Mavuti, reprinted with permission)

Figure 1.11 Harvesting of peat, or "turf," as a fuel has been a tradition in several parts of the world, as shown by this scene of turf carts in Ireland.

Wetlands and Ecotourism

Ecotourism is a modern version of wetland use. Wetlands have been the focus of attempts by several countries to increase tourist flow into their countries. The Okavango Delta in Botswana is one of the natural resource jewels of Africa, and protection of this wetland for tourists and hunters has been a priority in that country since the

Figure 1.12 Large-scale peat mining in Estonia. (Photo by W. J. Mitsch)

Figure 1.13 A wetland house in the Ebro River Delta region on the Mediterranean Sea, Spain. The walls are made from wetland mud, and the roof is thatched with reed grass and other wetland vegetation. (Photo by W. J. Mitsch)

1960s. Local tribes provide manpower for boat tours (in dugout canoes called *mokoros*) through the basin and assist with wildlife tours on the uplands as well (Fig. 1.14). In Senegal, West Africa, there is keen interest in attracting European birder tourists to the mangrove swamps along the Atlantic coastline. For many people, ecotourism in the wetlands is all about the wildlife and especially the birds (Fig. 1.15). It has been reported that bird-watching, or "birding," is a $32 billion per year industry in the United States alone.

Figure 1.14 The vast seasonally flooded Okavango Delta of northern Botswana in southern Africa is a mecca for ecotourism. The wetlands attract tourists, as shown in this illustration, and also wildlife hunting. In addition, the wetlands provides basic sustenance to these communities. (Photo by W. J. Mitsch)

(a) (b)

Figure 1.15 Intense ecotourism interest in the wetlands in Asia is shown by (a) crowds that surround Lake Biwa in Shiga Prefecture, Japan, at a winter 2006 international wetlands forum, and (b) press coverage at the Ramsar Convention held in Changwon, Korea, in 2008. (Photos by W. J. Mitsch)

The advantage of ecotourism as a management strategy is obvious—it provides income to the country where the wetland is found without requiring or even allowing resource harvest from the area. The potential disadvantage is that if the site becomes too popular, human pressures will begin to deteriorate the landscape and the very ecosystem that initially drew the tourism.

Wetland Conservation

Prior to the mid-1970s, drainage and destruction of wetlands were accepted practices around the world and were even encouraged by specific government policies. Wetlands were replaced by agricultural fields and by commercial and residential development. Had those trends continued, wetlands would have been in danger of extinction in some parts of the world decades ago. Some countries and states, such as New Zealand and California and Ohio in the United States, reported 90 percent loss of their wetlands. Only through the combined activities of hunters and anglers, scientists and engineers, and lawyers and conservationists has the case been made for wetlands as a valuable resource whose destruction has serious economic as well as ecological and aesthetic consequences for the nations of the world. This increased level of respect was reflected in activities such as the sale of federal “duck stamps” to waterfowl hunters that began in 1934 in the United States (Fig. 1.16); other countries, such as New

Figure 1.16 Federal Migratory Bird Hunting and Conservation Stamps are more commonly known as duck stamps. They are produced by the U.S. Postal Service for the U.S. Fish & Wildlife Service and are not valid for postage. Originally created in 1934 as the federal licenses required for hunting migratory waterfowl, today income derived from their sale is used to purchase or lease wetlands. *Top*; First duck stamp from 1934 (mallards); *Bottom*; 2013 duck stamp (wood duck).

Zealand, have followed suit. Approximately 2.4 million hectares (ha) of wetlands have been purchased or leased as waterfowl habitat by the U.S. duck stamp program alone since 1934.

The U.S. government now supports a variety of other wetland protection programs through at least a dozen federal agencies; individual states have also enacted wetland protection laws or have used existing statutes to preserve these valuable resources. On an international scale, the Convention of Wetlands of International Importance, or the Ramsar Convention, a multinational agreement for the conservation of wetlands, has formally registered as "Wetlands of International Importance" 210 million ha of wetlands in 168 contracting parties. The Ramsar Convention is the only global international treaty specific to the conservation and wise management of a specific ecosystem.

Wetland Science and Wetland Scientists

A specialization in the study of wetlands is often termed *wetland science* or *wetland ecology*, and those who carry out such investigations are called *wetland scientists* or *wetland ecologists*. The term *mire ecologist* has also been used. Some have suggested that the study of all wetlands be called *telmatology* (*telma* being Greek for "bog"), a term originally coined to mean "bog science" (Zobel and Masing, 1987). No matter what the field is called, it is apparent that there are four good reasons for treating wetland ecology as a distinct field of ecological study:

1. Wetlands have unique properties that are not adequately covered by present ecological paradigms and by fields such as limnology, estuarine ecology, and terrestrial ecology.
2. Wetland studies have begun to identify some common properties of seemingly disparate wetland types.
3. Wetland investigations require a multidisciplinary approach or training in several fields not routinely combined in university academic programs.
4. There is a great deal of interest in formulating sound policy for the regulation and management of wetlands. These regulations and management approaches need a strong scientific underpinning integrated as wetland ecology.

A growing body of evidence suggests that the unique characteristics of wetlands—standing water or waterlogged soils, anoxic conditions, and plant and animal adaptations—may provide some common ground for study that is neither terrestrial ecology nor aquatic ecology. Wetlands provide opportunities for testing "universal" ecological theories and principles involving succession and energy flow, theories that were developed for aquatic or terrestrial ecosystems. For example, wetlands provided the setting for the establishment of the current system used for lake trophic status (e.g., oligotrophic, eutrophic [Weber, 1907]), the successional theories of Clements (1916), and the energy flow approaches of Lindeman (1942).

They also provide an excellent laboratory for the study of principles related to transition zones, ecological interfaces, and ecotones.

Our knowledge of different wetland types such as those discussed in this book is often isolated in distinctive literatures and scientific circles. One set of literature deals with coastal wetlands, another with forested wetlands and freshwater marshes, and still another with peatlands. Very few investigators have analyzed the properties and functions common to all wetlands. This is probably one of the most exciting areas for wetland research because there is so much to be learned. Comparisons of wetland types have shown, for example, the importance of hydrologic flow-through for the maintenance and productivity of these ecosystems. The anoxic biochemical processes that are common to all wetlands provide another area for comparative research and pose many questions: What are the roles of different wetland types in local and global biochemical cycles? How do the activities of humans influence these cycles in various wetlands? What are the synergistic effects of hydrology, chemical inputs, and climatic conditions on wetland biological productivity? How can plant and animal adaptations to anoxic stress be compared in various wetland types?

The true wetland ecologist must be an ecological generalist because of the number of sciences that bear on those ecosystems. Knowledge of wetland flora and fauna, which are often uniquely adapted to a substrate that may vary from submerged to dry, is necessary. Emergent wetland plant species support both aquatic animals and terrestrial insects. Because hydrologic conditions are so important in determining the structure and function of the wetland ecosystems, a wetland scientist should be well versed in surface and groundwater hydrology. The shallow-water environment means that chemistry—particularly for water, sediments, soils, and water–sediment interactions—is an important science. Similarly, questions about wetlands as sources, sinks, or transformers of chemicals require investigators to be versed in many biological and chemical techniques. While the identification of wetland vegetation and animals requires botanical and zoological skills, backgrounds in microbial biochemistry and soil science contribute significantly to the understanding of the anoxic environment. Understanding adaptations of wetland biota to the flooded environment requires both biochemistry and physiology. If wetland scientists are to become more involved in the management of wetlands, some engineering techniques, particularly for wetland hydrologic control or wetland creation, need to be learned.

Wetlands are seldom, if ever, isolated systems. Rather, they interact strongly with adjacent terrestrial and aquatic ecosystems. Hence, a holistic view of these complex landscapes can be achieved only through an understanding of the principles of ecology, especially those that are part of ecosystem and landscape ecology and systems analysis. Finally, if wetland management involves the implementation of wetland policy, then training in the legal and policy-making aspects of wetlands is warranted.

Thousands of scientists and engineers are now studying and managing wetlands. Only a relatively few pioneers, however, investigated these systems in any detail prior to the 1960s. Most of the early scientific studies dealt with classical botanical surveys or investigations of peat structure. Several early scientific studies of peatland hydrology were produced, particularly in Europe and Russia. Later, investigators such

Table 1.1 Pioneer researchers in wetland ecology and representative citations for their work

Wetland Type and Researcher	Country	Representative Citations
Coastal Marshes/Mangroves		
Valentine J. Chapman	New Zealand	Chapman (1938, 1940)
John Henry Davis	USA	Davis (1940, 1943)
John M. Teal	USA	Teal (1958, 1962); Teal and Teal (1969)
Howard T. Odum	USA	H. T. Odum et al. (1974)
D. S. Ranwell	UK	D. S. Ranwell (1972)
Peatlands/Freshwater Wetlands		
C. A. Weber	Germany	Weber (1907)
Herman Kurz	USA	Kurz (1928)
A. P. Dachnowski-Stokes	USA	Dachnowski-Stokes (1935)
R. L. Lindeman	USA	Lindeman (1941, 1942)
Eville Gorham	UK/USA	Gorham (1956, 1961)
Hugo Sjörs	Sweden	Sjörs (1948, 1950)
G. Einar Du Rietz	Sweden	Du Rietz (1949, 1954)
P. D. Moore/D. J. Bellamy	UK	Moore and Bellamy (1974)
S. Kulczynski	Poland	Kulczynski (1949)
Paul R. Errington	USA	Errington (1957)
R. S. Clymo	UK	Clymo (1963, 1965)
Milton Weller	USA	Weller (1981)
William H. Patrick	USA	Patrick and Delaune (1972)

as Chapman, Teal, Sjörs, Gorham, Eugene and H. T. Odum, Weller, Patrick, and their colleagues and students began to use modern ecosystem and biogeochemical approaches in wetland studies (Table 1.1). Currently active research centers devoted to the study of wetlands include the School of Coast and Environment at Louisiana State University; the H. T. Odum Center for Wetlands at the University of Florida; the Duke Wetland Center at Duke University; Florida Gulf Coast University's Everglades Wetland Research Park in Naples, Florida; the Harry Oppenheimer Okavango Research Centre (HOORC) in Botswana, Africa: and the Institute for Land, Water, and Society at Charles Stuart University in Australia.

In addition, a professional society now exists, the Society of Wetland Scientists, which has among its goals to provide a forum for the exchange of ideas within wetland science and to develop wetland science as a distinct discipline. The Association of State Wetland Managers (ASWM) is an organization based primarily in the USA as a place for state, federal, and local managers and consultants to meet and discuss wetland management issues. They currently sponsor popular webinars on subjects related to wetlands. The International Association of Ecology (INTECOL) has sponsored a major international wetland conference every four years somewhere in the world since 1980. Table 1.2 lists the locations around the world where the INTECOL Wetland conference has been held and each meeting's theme, attendance, and resulting publications.

Table 1.2 INTECOL wetland conferences, 1980 to 2012, indicating year, location, theme, approximate attendance, chair/organizer, and resulting publications

Year	Location	Theme	Attendance	Organizer	Key Publication(s)
1980	New Delhi, India		90	B. Gopal	Gopal et al., 1982a,b
1984	Trebon, Czechoslovakia		210	J. Kvet/J. Pokorny	Pokorny et al., 1987; Mitsch et al., 1988; Bernard, 1988; Whigham et al., 1990, 1993
1988	Rennes, France	Conservation and Development: The Sustainable Use of Wetland Resources	400	J. C. Lefeuvre	Lefeuvre, 1989, 1990; Maltby et al., 1992
1992	Columbus, USA	Global Wetlands: Old World and New	905	W. J. Mitsch	Mitsch, 1993, 1994; Wetzel et al., 1994; Finlayson and van der Valk, 1995; Gopal and Mitsch, 1995; Jørgensen, 1995
1996	Perth, Australia	Wetlands for the Future	550	A. J. McComb; J. A. Davis	McComb and Davis, 1998; Tanner et al., 1999; Zedler and Rhea, 1998
2000	Quebec City, Canada	Quebec 2000: Wetlands at the Millennium*	2160	C. Rubec, B. Belangér, and G. Hood	11 books/special reports; 6 special journal issues; 8 International Peat Society Proceedings
2004	Utrecht, Netherlands		787	J. T. A. Verhoeven	Vymazal, 2005; Bobbink et al., 2006; Junk 2006; van Diggelen et al., 2006; Verhoeven et al., 2006; Davidson and Finlayson, 2007; Whitehouse and Bunting, 2008
2008	Cuiaba, Brazil	Big Wetlands, Big Concerns	700	P. Teixeira de Sousa Jr.; C. Nunes da Cunha	Vymazal, 2011; Junk, 2013
2012	Orlando, USA	Wetlands in a Complex World**	1240	R. Best/ K.R. Reddy	

*INTECOL met with three additional societies in 2000: International Peat Society; International Mire Conservation Group; Society of Wetland Scientists.
**INTECOL met with Society of Wetland Scientists in 2012.

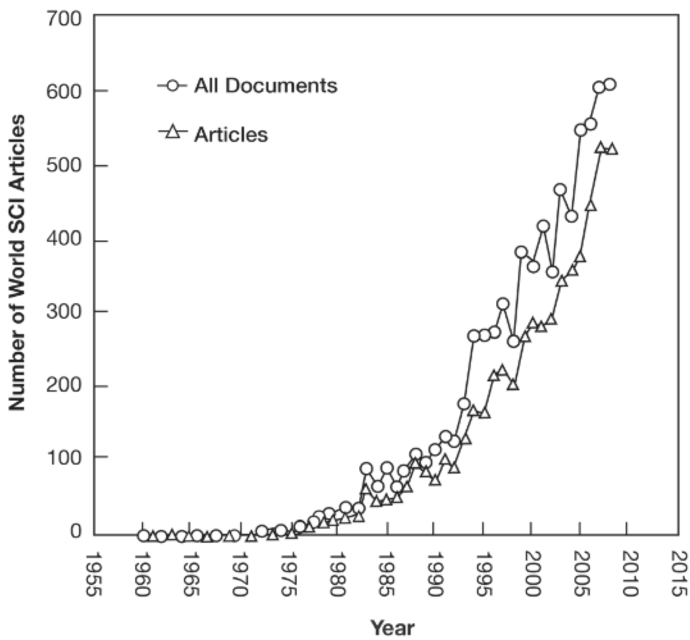

Figure 1.17 Science Citation Index (SCI) listed scientific articles that included "wetland" in their title or in keywords during the period 1960 to 2010 (From Zhang et al., 2010).

The increasing interest and emphasis on wetland science and management has been demonstrated by a veritable flood of books, reports, scientific journal articles, and conference proceedings, most in the last two decades of the twentieth century and the first decade of the twenty-first century. From 1991 to 2008, the annual number of wetland research journal articles published and the number of wetland articles cited increased six- and nine-fold, respectively (Fig. 1.17). The journal citations in this book are only the tip of the iceberg of the literature on wetlands. Two journals specific to wetlands—*Wetlands* and *Wetlands Ecology and Management*—are now published to disseminate scientific and management papers on wetlands, and several other scholarly journals frequently publish papers on the topic. Dozens of wetland meeting proceedings and journal special issues have been published from conferences on wetlands held throughout the world.

Wetland Managers and Wetland Management

Just as there are wetland scientists who are uncovering the processes that determine wetland functions and values, so too there are those who are involved, by choice or by vocation, in some of the many aspects of wetland management. These individuals, whom we call *wetland managers*, are engaged in activities that range from waterfowl production to wastewater treatment. They must be able to balance the scientific aspects of wetlands with myriad legal, institutional, and economic constraints to provide optimum wetland management. The management of wetlands has become increasingly important in many countries because government policy and wetland regulation seek to reverse historic wetland losses in the face of continuing draining or encroachment by agricultural enterprises and urban expansion. The simple act of being able to identify the boundaries of wetlands has become an important skill for a new type of wetland technician in the United States called a *wetland delineator*.

Private organizations, such as Ducks Unlimited, Inc. and The Nature Conservancy have protected wetlands by purchasing thousands of hectares of wetlands throughout North America. Through the Ramsar Convention and an agreement jointly signed by the United States and Canada in 1986 called the North American Waterfowl Management Plan, wetlands are now being protected primarily for their waterfowl value on an international scale. In 1988, a federally sponsored National Wetlands Policy Forum (1988) in the United States raised public and political awareness of wetland loss and recommended a policy of "no net loss" of wetlands. This recommendation has stimulated widespread interest in wetland restoration and creation to replace lost wetlands, and "no net loss" has remained the policy of wetland protection in the United States since the late 1980s.

Subsequently, a National Research Council (NRC) report in the United States (NRC, 1992) called for the fulfillment of an ambitious goal of gaining 4 million ha of wetlands by the year 2010, largely through the reconversion of crop- and pastureland. That goal was not met. Wetland creation for specific functions remains an exciting new area of wetland management that needs trained specialists and may eventually stem the tide of loss and lead to an increase in this important resource. Another NRC report (1995) reviewed the scientific basis for wetland delineation and classification, particularly as it related to the regulation of wetlands in the United States at that time, and yet another NRC (2001) study investigated the effectiveness of the national policy of mitigation of wetland loss in the United States.

Wetland management organizations, such as the Association of State Wetland Managers (ASWM) and the Society of Wetland Scientists (SWS), focus on disseminating information on wetlands, particularly in North America. The International Union for the Conservation of Nature and Natural Resources (IUCN) and the Ramsar Convention, both based in Switzerland, have developed a series of publications on wetlands of the world. Wetlands International (www.wetlands.org) is the world's leading nonprofit organization concerned with the conservation of wetlands and wetland species. It comprises a global network of governmental and nongovernmental experts working on wetlands. Activities are undertaken in more than 120 countries worldwide. The head office is located in Wageningen, Netherlands.

Recommended Readings

Beautifully illustrated popular books and articles, many with color photographs, were developed on wetlands by many authors in years past. Here are some of our timeless favorites.

Dugan, P. 1993. *Wetlands in Danger*. London: Oxford University Press.

Finlayson, M., and M. Moser, eds. 1991. *Wetlands*. Oxford, UK: Facts On File.

Kusler, J., W. J. Mitsch, and J. S. Larson. 1994. Wetlands. *Scientific American* 270(1): 64–70.

Littlehales, B., and W. A. Niering. 1991. *Wetlands of North America*. Charlottesville, VA: Thomasson-Grant.

Lockwood, C. C., and R. Gary. 2005. *Marsh Mission: Capturing the Vanishing Wetlands*. Baton Rouge: Louisiana State University Press.

McComb, A. J., and P. S. Lake. 1990. *Australian Wetlands*. London: Angus and Robertson.

Mendelsohn, J., and S. el Obeid. 2004. *Okavango River: The Flow of a Lifeline*. Cape Town, South Africa: Struik.

Mitchell, J. G., R. Gehman, and J. Richardson. 1992. Our Disappearing Wetlands. *National Geographic* 182(4): 3–45.

Niering, W. A. 1985. *Wetlands*. New York: Knopf.

Rezendes, P., and P. Roy. 1996. *Wetlands: The Web of Life*. San Francisco: Sierra Club Books.

References

Bernard, J. M., ed. 1998, *Carex*. Special Issue of *Aquatic Botany* 30: 1–168.

Bobbink R., B. Beltman, J. T. A. Verhoeven, and D. F. Whigham, eds. 2006. Wetlands: Functioning, Biodiversity, Conservation and Restoration. *Ecological Studies* 191, Springer, Berlin, 315 pp.

Chapman, V. J. 1938. Studies in salt marsh ecology. I-III. *Journal of Ecology* 26: 144–221.

Chapman, V. J. 1940. Studies in salt marsh ecology. VI-VII. *Journal of Ecology* 28: 118–179.

Clements, F. E. 1916. *Plant Succession*. Publication 242. Carnegie Institution of Washington. 512 pp.

Clymo, R. S. 1963. Ion exchange in *Sphagnum* and its relation to bog ecology. *Annals of Botany (London) New Series* 27: 309–324.

Clymo, R. S. 1965. Experiments on breakdown of *Sphagnum* in two bogs. *Journal of Ecology* 53: 747–758.

Coles, B., and J. Coles. 1989. *People of the Wetlands, Bogs, Bodies and Lake-Dwellers.* Thames & Hudson, New York. 215 pp.

Dachnowski-Stokes, A. P. 1935. Peat land as a conserver of rainfall and water supplies. *Ecology* 16: 173–177.

Davidson, N. C., and M. Finlayson, eds. 2007. Satellite-based radar - Developing tools for wetlands management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 17(3): 219–329.

Davis, J. H. 1940. The ecology and geologic role of mangroves in Florida. Publication 517. Carnegie Institution of Washington, pp. 303–412.

Davis, J. H. 1943. The natural features of southern Florida, especially the vegetation and the Everglades. *Florida Geological Survey Bulletin* 25. 311 pp.

Dugan, P. 1993. *Wetlands in Danger*. Michael Beasley, Reed International Books, London. 192 pp.

Du Rietz, G. E. 1949. Huvudenheter och huvudgränser i Svensk myrvegetation. *Svensk Botanisk Tidkrift* 43: 274–309.

Du Rietz, G. E. 1954. Die Mineralbodenwasserzeigergrenze als Grundlage Einer Natürlichen Zweigleiderung der Nord-und Mitteleuropäischen Moore. *Vegetatio* 5– 6: 571–585.

Errington, P. L. 1957. *Of Men and Marshes*. The Iowa State University Press, Ames, IA.

Finlayson, C. M. and A. G. van der Valk. 1995. Classification and inventory of the world's wetlands. *Special Issue Vegetatio* 118: 1–192.

Gopal, B., R. E. Turner, R. G. Wetzel, and D. F. Whigham, eds. 1982a. Wetlands: Ecology and Management. International Scientific Publications, Jaipur, India. Vol. 1, 514 pp.

Gopal, B., R. E. Turner, R. G. Wetzel, and D. F. Whigham, eds. 1982b. Wetlands: Ecology and Management. International Scientific Publications, Jaipur, India. Vol. 2, 156 pp.

Gopal, B., and W. J. Mitsch, eds. 1995. The role of vegetation in created and restored wetlands. *Special Issue Ecological Engineering* 5:1–121.

Gorham, E. 1956. The ionic composition of some bogs and fen waters in the English lake district. *Journal of Ecology* 44: 142–152.

Gorham, E. 1961. Factors influencing supply of major ions to inland waters, with special references to the atmosphere. *Geological Society of America Bulletin* 72: 795–840.

Jørgensen, S. E., ed. 1995. Wetlands: Interactions with watersheds, lakes, and riparian zones. *Special issue Wetlands Ecology and Management* 3:79–137.

Junk, W., ed. 2006. The comparative biodiversity of seven globally important wetlands. *Special Issue of Aquatic Sciences* 68(3): 239–414.

Junk, W., ed. 2013. The world's wetlands and their future under global climate change. *Special Issue of Aquatic Sciences* 75(1): 1–167.

Kulczynski, S. 1949. Peat bogs of Polesie. *Acad. Pol. Sci. Mem.*, Ser. B, No.15. 356 pp.

Kurz, H. 1928. Influence of Sphagnum and other mosses on bog reactions. *Ecology* 9: 56–69.

Lefeuvre J. C., ed .1989. Conservation et développement : gestion intégrée des zones humides. Troisième conférence internationale sur les zones humides, Rennes, 19-23 Septembre 1988. Ed. Muséum National d'Histoire Naturelle, Laboratoire d'Evolution des Systèmes Naturels et Modifiés, Paris. 371 pp.

Lefeuvre J. C. 1990. INTECOL's Third International Wetlands Conference. Rennes, 1988. *Bull. Ecol.*, 21(3), 80 pp.

Lindeman, R. L. 1941. The developmental history of Cedar Creek Lake, Minnesota. *American Midland Naturalist* 25: 101–112.

Lindeman, R. L. 1942. The trophic-dynamic aspect of ecology. *Ecology* 23: 399–418.

Maltby E., P. J. Dugan, and J. C. Lefeuvre, eds. 1992. Conservation and Development: The Sustainable Use of Wetland Resources. Proceedings of the Third International Wetlands Conference. IUCN, Gland, Switzerland. 219 pp.

McComb, A. J. and J. A. Davis, eds. 1998. Wetlands for the Future - Contributions from INTECOL's V International Wetlands Conference. Gleneagles Press, Adelaide, Australia, 750 pp.

Mitsch, W. J. 1993. INTECOL's IV International Wetlands Conference: A report. *International Journal of Ecology and Environmental Sciences* 19:129–134.

Mitsch, W. J., ed. 1994. *Global Wetlands: Old World and New*. Elsevier, Amsterdam. 967+ xxiv pp.

Mitsch, W. J., and J. G. Gosselink. 1986. *Wetlands*, Van Nostrand Reinhold, New York. 539 pp.

Mitsch, W. J., M. Straskraba, and S.E. Jørgensen, eds. 1988. Wetland Modelling. Elsevier, Amsterdam, 227 pp.

Mitsch, W. J., and J. G. Gosselink. 1993. *Wetlands*, 2nd ed. Van Nostrand Reinhold and John Wiley & Sons, New York. 722 pp.

Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands*, 3rd ed. John Wiley & Sons, New York. 920 pp.

Mitsch, W. J., and J. G. Gosselink. 2007. *Wetlands*, 4th ed. John Wiley & Sons, Hoboken, NJ. 582 pp.

Moore, P. D., and D. J. Bellamy. 1974. *Peatlands*. Springer-Verlag, New York. 221 pp.

National Research Council (NRC). 1992. *Restoration of Aquatic Ecosystems*. National Academy Press, Washington, DC. 552 pp.

National Research Council (NRC). 1995. *Wetlands: Characteristics and Boundaries*. National Academy Press, Washington, DC. 306 pp.

National Research Council (NRC). 2001. *Compensating for Wetland Losses under the Clean Water Act*. National Academy Press, Washington, DC, 158 pp.

National Wetlands Policy Forum. 1988. *Protecting America's Wetlands: An Action Agenda*. Conservation Foundation, Washington, DC. 69 pp.

Odum, H. T., B. J. Copeland, and E. A. McMahan, eds. 1974. *Coastal Ecological Systems of the United States*. Conservation Foundation, Washington, DC. 4 vols.

Patrick, W. H., Jr., and R. D. Delaune. 1972. Characterization of the oxidized and reduced zones in flooded soil. *Proceedings of the Soil Science Society of America* 36: 573–576.

Pokorny, J., O. Lhotsky, P. Denny, and R. E. Turner, eds. 1987. Waterplants and wetland processes. Special issue of *Archiv Fur Hydrobiologie* 27: I-VIII and 1–265.

Ranwell, D. S. 1972. *Ecology of Salt Marshes and Sand Dunes*. Chapman & Hall, London. 258 pp.

Sjörs, H. 1948. Myrvegetation i bergslagen. *Acta Phytogeographica Suecica* 21: 1–299.

Sjörs, H. 1950. On the relationship between vegetation and electrolytes in North Swedish mire waters. *Oikos* 2: 239–258.

Tanner, C. C., G. Raisin, G. Ho, and W. J. Mitsch, eds. 1999. Constructed and Natural Wetlands for Pollution Control. *Special Issue of Ecological Engineering* 12: 1–170.

Teal, J. M. 1958. Distribution of fiddler crabs in Georgia salt marshes. *Ecology* 39: 18–19.

Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. *Ecology* 43: 614–624.

Teal, J. M., and M. Teal. 1969. *Life and Death of the Salt Marsh*. Little, Brown, Boston. 278 pp.

van Diggelen, R., Middleton, B., Bakker, J.P., Grootjans, A.P., Wassen, M.J. (eds.) 2006. Fens and floodplains of the temperate zone: Present status, threats, conservation and restoration. *Special Issue of Applied Vegetation Science* 9(2): 157–316.

Verhoeven J. T. A., B. Beltman, R. Bobbink, and D. F. Whigham, eds. 2006. Wetlands and Natural Resource Management. Ecological Studies 190, Springer, Berlin, 347 pp.

Vymazal, J., ed. 2005. Constructed wetlands for wastewater treatment. *Special Issue of Ecological Engineering* 25: 475–621.

Vymazal, J., ed. 2011. Enhancing ecosystem services on the landscape with created, constructed and restored wetlands. *Special Issue of Ecological Engineering* 37(1): 1–98.

Weber, C. A. 1907. Autbau und Vegetation der Moore Norddutschlands. *Beibl. Bot. Jahrb.* 90: 19–34.

Weller, M. W. 1981. *Freshwater Marshes*. University of Minnesota Press, Minneapolis. 146 pp.

Wetzel, R. G., A. van der Valk, R. E. Turner, W. J. Mitsch and B. Gopal, eds. 1994. Recent studies on ecology and management of wetlands. *Special Issue of International Journal of Ecology and Environmental Sciences* 20(1-2): 1–254.

Whigham, D. F., R. E. Good, and J. Květ, eds. 1990. Wetland Ecology and Management: Case Studies, Tasks for Vegetation Science 23, Kluwer Academic Publishers, Dordrecht, 180 pp.

Whigham, D. F., D. Dykyjová, and S. Hejný, eds. 1993. Wetlands of the World: Inventory, Ecology and Management. Volume 1. Africa, Australia, Canada and Greenland, Mediterranean, Mexico, Papua New Guinea, South Asia, Tropical South America, United States. Kluwer Academic Publishers, Dordrecht, 768 pp.

Whitehouse, N. J., and M.J. Bunting, eds. 2008. Palaeoecology and long-term wetland function dynamics: A tool for wetland conservation and management. *Special Issue of Biodiversity and Conservation* 17(9): 2051–2304.

Zedler, J., and N. Rhea, eds. 1998. Ecology and management of wetland plant invasions. *Special issue of Wetlands Ecology and Management* 5(3): 159–242.

Zhang. L., M. H. Wang, J. Hu, and Y.-S. Ho. 2010. A review of published wetland research, 1991–2008: Ecological engineering and ecosystem restoration. *Ecological Engineering* 36: 973–980.

Zobel, M., and V. Masing. 1987. Bog changing in time and space. *Archiv für Hydrobiologie, Beiheft: Ergebnisse der Limnologie* 27: 41–55.