1 Wetland overview

1.1 Introduction

Wetland. The name summons immediate images or experiences to most people – from the endless sand beach of Padre Island, Texas (Fig. 1-1), to wildlife in the Okavango Delta of Botswana (Fig. 1-2), to the deadly Great Grimpen Mire, as described in the Sherlock Holmes tale, *The Hound of the Baskervilles* by Sir Arthur Conan Doyle:

> Rank weeds and lush, slimy water plants send an odour of decay and a heavy miasmatic vapor into our faces, while a false step plunged us more than once thigh-deep into the dark, quivering mire, which shook for yards in soft undulations around our feet.

Whether real or fictional, wetlands have conspicuous roles in the physical, biological and cultural geography of the world. Wetlands are places where the ground is generally saturated or flooded for extended periods during the growing season such that distinctive soils form and specialized vegetation grows under conditions in which oxygen is depleted or absent. Such environments include marshes, fens, bogs, and swamps (see chapter 2). Wetlands occur at the confluence of unique terrestrial, hydrological and climatic conditions that give rise to some of the most biodiverse regions of the world. They also play a vital role in the cycling and storage of key nutrients, materials and energy through the Earth's system. Wetland components include water, soil, vegetation, and wildlife. Since the first human hunter-gatherers camped by springs and shores, people have utilized, modified, exploited or impacted wetlands in various ways. Moreover, the early establishment of human settlements and subsequent expansion were based on irrigated agriculture along major river floodplain valleys – Nile (Fig. 1-3), Tigris–Euphrates, Niger, Indus, Mekong, etc.

Wetlands continue to be essential for modern human society; they represent the primary sources of fresh water for people in most places around the world. Wetlands minimize flooding and storm damage, nourish fisheries (Fig. 1-4), produce fur-bearing animals, sustain irrigated agriculture, support herding and grazing (Fig. 1-5), recharge aquifers, provide shipping waterways (Fig. 1-6), supply hydropower, grow timber, yield fossil fuels (Fig. 1-7), are incubators for gemstones, and provide many other resources. These functions are clearly evident, as they influence the daily lives of people living in and deriving economic benefits from wetlands.

In spite of local recognition of wetland functions and values, however, the larger regional and global significance of wetlands is more difficult for many people to fathom. What is economically beneficial in upper portions of drainage basins – irrigation, timber harvesting, hydroelectric power, recreation and other human uses – is often deleterious for downstream inhabitants of wetlands and coastal

Wetland Environments: A Global Perspective, First Edition. James Sandusky Aber, Firooza Pavri, and Susan Ward Aber.

Figure 1-1. Padre Island National Seashore, southern Texas, United States. View northward showing Padre Island (left) and the Gulf of Mexico (right). More than 70 miles (110 km) of island and beach are protected. Note person standing at bottom for scale. Kite aerial photo by J.S. Aber and S.W. Aber.

Figure 1-2. Hippopotamus (*Hippopotamus amphibius*) displays its formidable jaws and teeth in a marsh of the Okavango Delta, Botswana, southern Africa. Photo courtesy of M. Storm.

regions. Upstream manipulations and exploitation of wetland water resources have resulted in serious degradation or dramatic changes lower in drainage basins (Fig. 1-8). In contrast, some exploitations of wetlands, for example pearl farming, actually add marine life and provide protected areas that are free from dynamite and cyanide fishing. It is safe to say, though, that few, if any, major wetland systems of the world have not been altered or changed in substantial or subtle ways by human activities.

Wetlands are situated at the transitions between dry uplands and deep-water lake and marine environments (Fig. 1-9). Wetlands, thus, may be viewed as the links that bind together all other habitats at the Earth's surface, and they play key roles in the overall environmental system through transfer and storage of materials and energy. Numerous feedback relationships exist between wetlands and their surroundings.

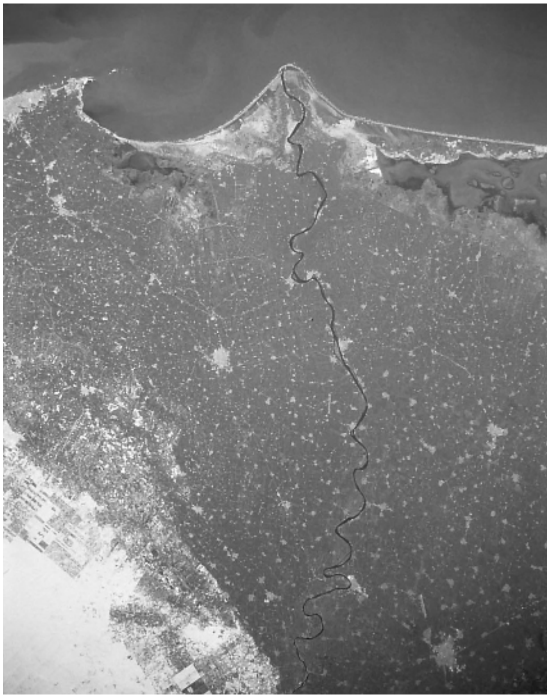

Figure 1-3. Near-vertical view of the River Nile and Mediterranean coast in the vicinity of Alexandria, Egypt. The Nile supported one of the earliest agricultural civilizations. Linhof large-format film camera, March 1990, STS36-151-101; image adapted from NASA Johnson Space Center.

Figure 1-4. Fishing nets and boats on the shore of Võrtsjärv, a large freshwater lake surrounded by marsh in southern Estonia. Photo by J.S. Aber.

Wetlands are, for example, significant sinks for carbon stored in their organic soil and sediment. They are likewise important sources for carbon dioxide (CO_2) and methane (CH_4), both greenhouse gases, released from the stored organic mass. Thus, wetlands are critical components of

Figure 1-5. Cattle grazing in the páramo (alpine) grassland-shrub vegetation in the Andes Mountains of Venezuela. The páramo zone is almost constantly in the clouds, rain or fog, as shown in the background. Photo by J.S. Aber.

Figure 1-6. Barges on the River Rhine at Andernach, Germany. Two loaded barges are moving upstream. The control house and living quarters are located at the stern of the barge. Photo by J.S. Aber.

Figure 1-7. Traditional hand cutting of peat in Ireland. After drying, the peat is used for home heating and cooking. Photo by J.S. Aber.

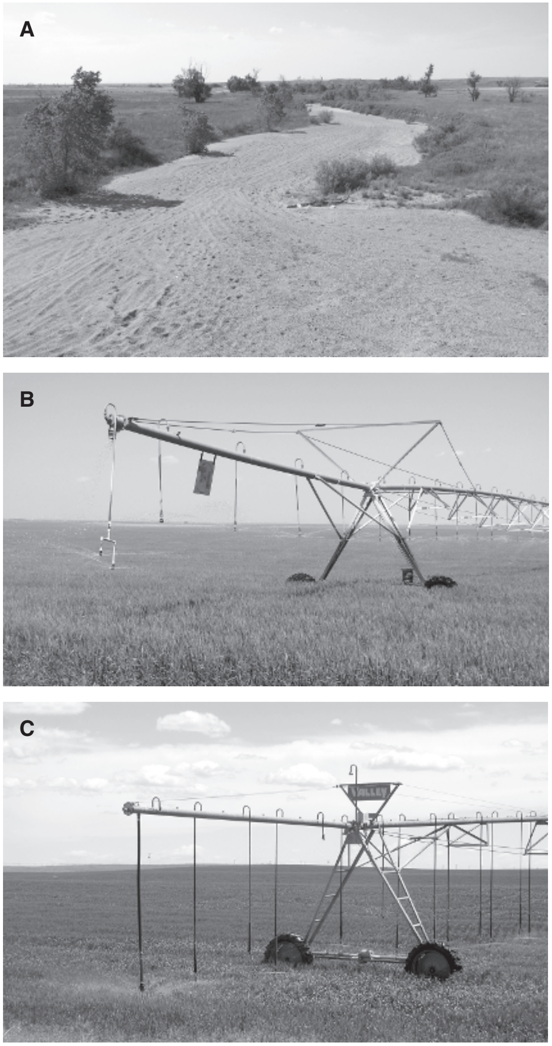

Figure 1-8. Impact of water diversions in the High Plains of the central United States. A. Dry channel of the Arkansas River at Ingalls, southwestern Kansas. Upstream reservoirs and extraction of water for irrigation have dried up the river, even in the spring of a wet year when this picture was taken. B. Center-pivot irrigation system. The sprayers are set too high for the winter wheat crop, so that considerable water is lost to wind drift and evaporation. C. Center-pivot irrigation system with the sprayers set just above the winter wheat crop to minimize evaporative loss. Photos by J.S. Aber.

the carbon cycle, which has significant implications for global climate.

The economic benefits and ecological functions of wetlands are numerous and varied, as noted above. For many people, nonetheless, wildlife is the most obvious and perhaps important aspect of wetlands. In some American and African wetlands, for example, millions upon millions of waterfowl and shorebirds visit briefly or remain seasonally during annual migrations. Such dramatic concentrations of wildlife have attracted hunters since prehistoric times, and hunting continues to be a major use of wetlands (Fig. 1-10). Wetlands are, in fact, among the most productive ecosystems in the world (Niering 1985).

Wetlands also harbor some of the greatest biodiversity found on the planet. Many aquatic animals are endemic to isolated wetlands, such as the hundreds of fish species found in the lakes of eastern Africa (Dugan 2005). In other cases, wetlands represent the last refuges of animals forced out of other habitats by human development – the Bengal tiger in the Sundarbans of India and Bangladesh and the jaguar in wetlands of South and Central America. Endangered species, such as the whooping crane (*Grus americana*), are often foremost in the public eye as symbols for the need to preserve wetland habitats (Fig. 1-11).

Costanza et al. (1997) attempted to estimate the economic value of ecosystem services for major biomes of the world. They identified 17 ecosystem services (Table 1-1), many of which are connected to or interact with wetland environments, particularly those involving water, soil, gases, nutrients and climate. The value of these services was determined using market and non-market means, such as the willingness-to-pay method (see chapter 11). They found that wetlands in general and estuaries, seagrass/algae beds, coral reefs, tidal marsh/mangroves, and swamps/floodplains in particular have the highest values for providing a broad array of ecosystem services. Wetland values are considerably greater, in fact, than tropical forest or other biomes.

1.2 How much and where

The total coverage of existing wetlands is estimated to range from at least 7 million km^2 to about 10 million km^2, or 5–8 percent of the land

Figure 1-9. Presque Isle is a sandy spit that extends from the mainland into Lake Erie in northwestern Pennsylvania, United States (see Color Plate 1-9). The transition from sandy shore, to shallow water, to deep lake is depicted in this panoramic view looking toward the northeast. Kite aerial photo by J.S. Aber and S.W. Aber.

Figure 1-10. Hunters in a camouflaged "duck boat" return from a venture in the marsh at Cheyenne Bottoms, central Kansas, United States. Photo by J.S. Aber.

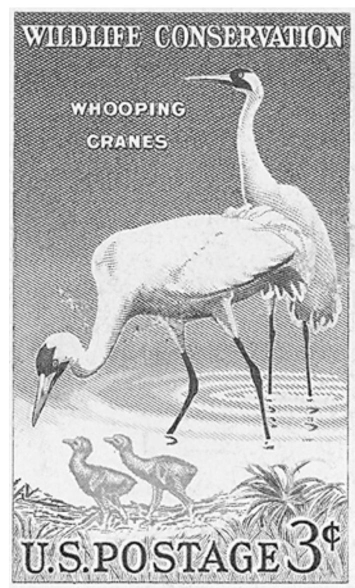

Figure 1-11. U.S. postage stamp issued in 1957 depicts a family of whooping cranes. Original stamp printed in blue, brown, and green colors. From the collection of J. Vancura.

surface of the world, depending upon the definition for what is included (Mitsch and Gosselink 2007). Bog, swamp, marsh, fen, muskeg, and similar habitats are represented in this total. The broader definition of Ramsar (see chapter 2) includes lakes, rivers, and coastal marine water bodies (up to 6 m deep), which pushes the wetland coverage to more than 12 million km^2. Peatland (mire) includes those types of wetlands that accumulate peat at least one foot (30 cm) in thickness (Fig. 1-12), which may happen in swamp, bog, muskeg, and fen environments. Peatlands cover approximately 4 million km^2 worldwide (Dugan 2005).

Wetlands of diverse types are found in all land and coastal regions of the world; however, the distribution of wetlands is certainly not uniform (Fig. 1-13). The greatest concentration of wetlands is found in boreal and subboreal

Table 1-1. Ecosystem services and functions used for estimating the value of major biomes of the world. Based on Costanza et al. (1997, Table 1).

Ecosystem services	Ecosystem functions	Examples
Gas regulation	Atmospheric chemical composition	Oxygen, ozone, sulfur oxides, UV protection
Climate regulation	Global, regional and local weather and climate	Greenhouse gases, cloud formation
Disturbance regulation	Absorbing and damping ecosystem responses	Storm protection, flood control, drought recovery
Water regulation	Hydrological flows	Irrigation, transportation, industrial applications
Water supply	Storage and retention	Soil moisture, aquifers, streams and reservoirs
Erosion and sedimentation	Retention of soil and sediment	Prevention of soil loss, siltation in lakes
Soil formation	Soil-forming processes	Rock weathering, organic matter accumulation
Nutrient cycling	Storage, processing and transfer of nutrients	Nitrogen fixation, K and P cycles
Waste treatment	Nutrient recovery, removal of harmful substances	Pollution control detoxification
Pollination	Movement of floral gametes	Pollinators for plant reproduction
Biological control	Regulation of populations	Predator control of prey
Refugia	Habitat for resident and migratory populations	Nurseries, regional habitats, migratory routes
Food production	Gross primary production for food	Crops, fish, game, fruits and nuts, livestock
Raw materials	Gross primary production for materials	Timber, fiber, fuel, fodder, minerals and ores
Genetic resources	Unique biological materials and products	Medicines, plant and animal varieties, ornamental species
Recreation	Recreational opportunities	Ecotourism, sport fishing and hunting, bird watching
Cultural	Non-commercial uses	Artistic, aesthetic, spiritual, religious, or scientific values

Figure 1-12. Layer of postglacial peat (*) ~1 m thick resting on glacial till in western Poland. Photo by J.S. Aber.

regions of high to middle northern latitudes, namely from about 50–70 degrees north (Matthews and Fung 1987; Matthews 1993; Mitsch and Gosselink 2007). Most of the wetlands north of 60° latitude are affected by permafrost (U.S. Department of Agriculture (USDA) 1996). This includes large areas in Alaska, Canada, Scandinavia, and Russia. A second concentration in wetland distribution is found in the tropics (±15° latitude) with a peak abundance just south of the Equator. Central Africa, northern South America, northern Australia, Indochina, and Indonesia possess substantial tropical wetland regions. Significant temperate wetlands are situated in middle latitudes (30–50°) in eastern China, the eastern United States, and central Europe (USDA 1996).

This global pattern of wetland distribution occurs at the confluence of local terrestrial and hydrological conditions and general climatic circulation. Influential climatic conditions include heavy precipitation and evapotranspiration in the tropics and moderate precipitation with limited evapotranspiration at middle to high latitudes. The results in both cases are surplus surface waters. Parts of the subtropical zone (~15–30° latitude), in contrast, are characterized by scarce precipitation and high rates of evapotranspiration, which lead to well-known deserts – Sahara, Kalahari, Gobi, southwestern United States, western Australia, etc. Still, major wetlands such as the marshes of southern Iraq

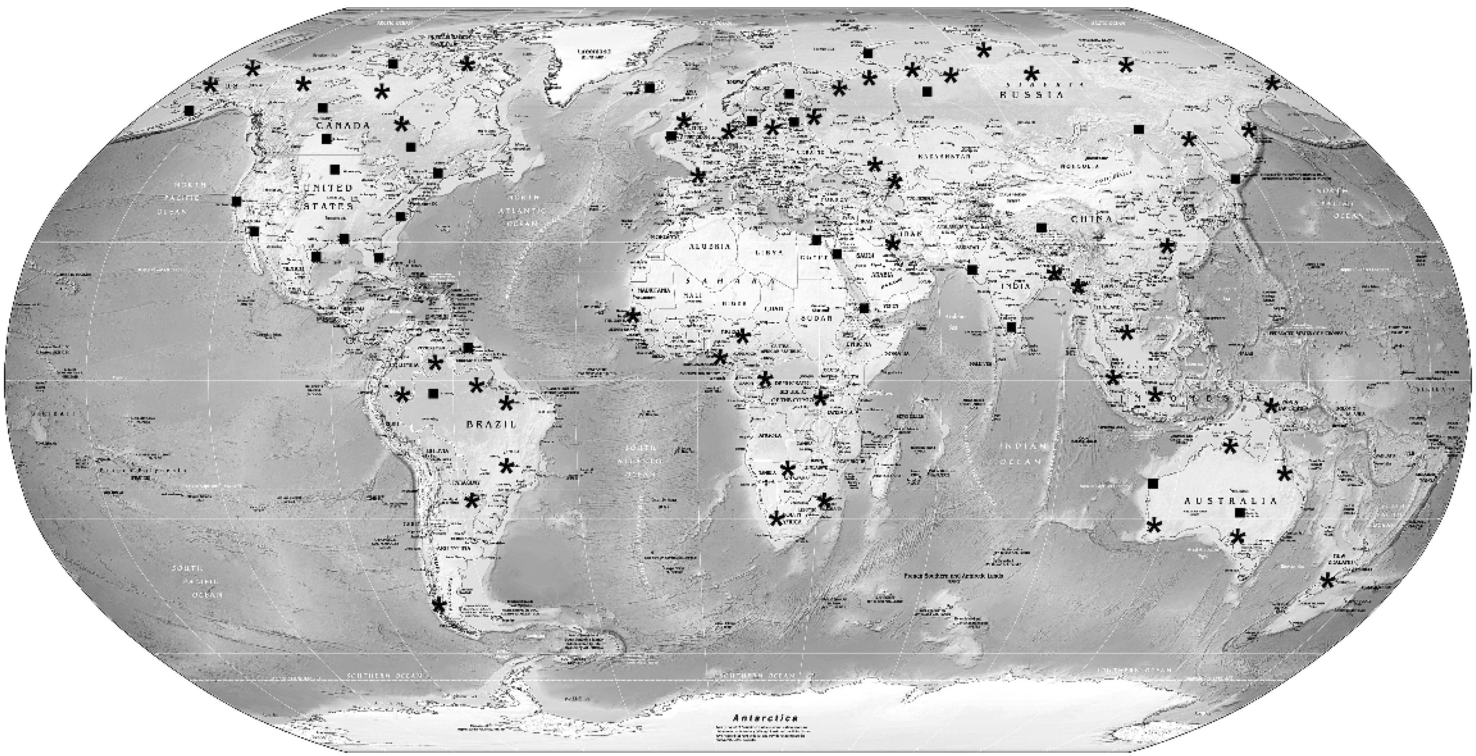

Figure 1-13. General distribution of wetlands around the world. Major wetlands (asterisk) and abundant wetlands (square). Based on Mitsch and Gosselink (2007) and other sources. Map adapted from *CIA World Factbook*, version of June 2009.

are found in the subtropical zone, where the configuration of terrestrial, hydrological and local climatic conditions gives rise to wetland habitats. Many of these subtropical wetlands are affected by high salinity, especially in the Middle East, central Asia, and Australia (U.S. Department of Agriculture (USDA) 1996).

The general climatic pattern and distribution of wetlands are influenced substantially by the positions of continents, flow of ocean currents, prevailing winds, mountains, and other major geographic features. For example, the largest mangrove swamp in the world, the Sundarbans covering 6000 km^2 (Dugan 2005), is located in the subtropics of Bangladesh and eastern India, where monsoons and runoff from the Himalaya combine to create a vast floodplain and delta complex (see chapter 15).

1.3 Wetland trends

Humans have modified and exploited wetlands in many ways, most of which have led to loss of wetland habitats and their conversion to other land uses and covers. Draining wetlands is observed globally and for various purposes – agriculture, forestry, grazing, peat mining, etc. Water supply to wetlands may be reduced by levees, canals and dams as well as by extraction of ground water. Filling is another common means of converting wetlands for building construction, urban expansion, and industrial development (Fig. 1-14). Acid rain, shoreline erosion, and pollution (Fig. 1-15) are further factors for wetland loss. Such human development began with the advent of agriculture in the Neolithic, particularly once early civilizations arose, and the pace of wetland loss has

Figure 1-14. Overview of Port Bienville, an industrial park built on the Pearl River delta in southwestern Mississippi, United States. A dredged canal provides a connection via the Pearl River to the Intracoastal Waterway along the Gulf of Mexico coast. Kite aerial photo by S.W. Aber, J.S. Aber, and M. Giardino.

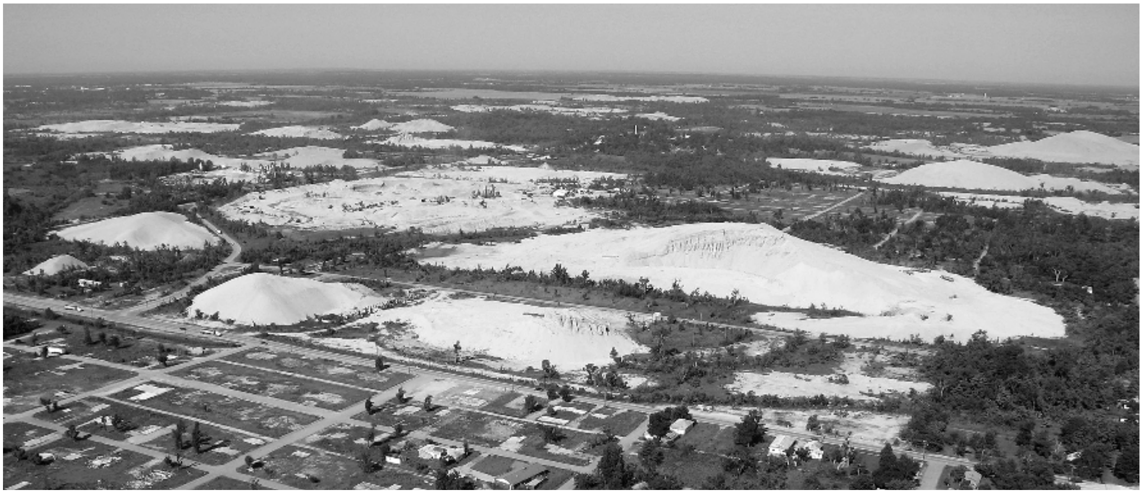

Figure 1-15. Huge chat piles are a legacy of lead-and-zinc mining at Picher, Oklahoma. Considered among the most seriously degraded sites in the United States, the landscape is essentially destroyed; toxic pollution of ground and surface water extends many kilometers downstream with severe impacts on human health and wetland habitats. View toward the southwest; blimp airphoto by J.S. Aber and S.W. Aber.

accelerated since the Industrial Revolution in the eighteenth century.

Dugan (2005) emphasized the distinction between "hydraulic" and "aquatic" civilizations in terms of how they utilized wetland resources. Hydraulic civilizations usually developed in upstream or inland settings in which water resources were seasonal or limited. Storage and distribution of water were controlled via engineering structures such as dams, levees, reservoirs and canals for irrigating farm land, all of which degrade or eliminate wetlands. Aquatic civilizations, in contrast, were situated in downstream or coastal settings where water was generally abundant. These civilizations utilized the annual flood cycle to farm deltas and alluvial plains, which had lesser impacts on wetlands. During the European period of exploration and colonization, beginning in the late fifteenth century, the hydraulic approach ruled at home and was exported throughout the world.

It is generally agreed that worldwide at least half of all pre-development wetlands have been lost to human activities (Mitsch and Gosselink 2007). This global loss of wetland habitats may be attributed primarily to the hydraulic emphasis of the past five centuries (Dugan 2005). The same holds true for the coterminous United States since the birth of the country. The 20 northeastern states are representative of this trend (Table 1-2). In general, the relatively rocky New England states (Maine, New Hampshire, Vermont, Massachusetts) had lower losses, whereas the Midwestern corn belt (Ohio, Indiana, Illinois, Iowa, Missouri) had the greatest conversions of wetland along with the Atlantic states of Connecticut and Maryland. The western Great Lakes and Appalachian states experienced intermediate reductions in wetlands. The distribution of wetland losses from state to state reflects primarily the extent of agriculture and amount of urban development.

Elsewhere around the world, similar wetland losses range from over 90 percent in New Zealand (Dugan 2005) to minimal impacts in remote and little-developed regions (Table 1-3). However, oil-and-gas and diamond exploration and extraction threaten once pristine wetlands in the circumarctic region, and human encroachment on wetlands continues apace throughout the developing tropical world, both inland and offshore. The 2010 BP Deepwater Horizon oil spill in the Gulf of Mexico demonstrates that further degradation of wetland habitat may take place even in places

Table 1-2. Wetland losses in the 20 northeastern states of the United States from *c.* 1780 to 1980. Areas given in hectares; based on Dahl (1990).

State	1780	1980	% loss
Maine	2584	2080	19
New Hampshire	88	80	9
Vermont	136	88	35
Massachusetts	328	236	28
Rhode Island	42	26	37
Connecticut	268	70	74
New York	1025	410	60
Pennsylvania	450	200	56
New Jersey	600	366	39
Delaware	192	90	54
Maryland	660	176	73
West Virginia	54	40	24
Ohio	2000	194	90
Michigan	4480	2234	50
Indiana	2240	300	87
Wisconsin	3920	2132	46
Illinois	3285	502	85
Minnesota	6030	3480	42
Iowa	1600	170	89
Missouri	1938	258	87

Table 1-3. Estimated wetland losses for selected regions of the world. Adapted from Mitsch and Gosselink (2007, Table 3.2).

Region		% loss
United States		53
Canada	Atlantic tidal/salt marshes	65
	Lower Great Lakes/St. Lawrence	71
	Prairie pothole region	71
	Pacific coastal estuaries	80
Australia	Swan Coastal Plain	75
	Coastal New South Wales	75
	Victoria	33
	River Murray basin	35
New Zealand		>90
Philippine mangrove swamps		67
China		60
Europe		60

already heavily affected by intensive human exploitation.

1.4 Wetland preservation and protection

Recognition of the importance of wetlands emerged gradually during the twentieth century, and now wetland conservation is a cause with considerable public support around the world. Early efforts focused on wildlife. As long ago as 1916 the United States and United Kingdom agreed to what became the Migratory Bird Treaty Act (1918), which protected birds migrating between the U.S. and Canada (Fig. 1-16). Specifically this act made it illegal for people to take migratory birds, their eggs, feathers or nests (U.S. Fish and Wildlife Service 2010a). Similar bilateral treaties were established by the United States with Mexico (1936), Japan (1972) and the Soviet Union (1976).

Another early and quite successful program was the U.S. Migratory Bird Hunting and Conservation Stamp, commonly known as "duck stamps," which began in the 1930s as a means to raise money for preservation of duck and goose habitat (Fig. 1-17). As of 2008, sales of duck stamps had generated US$700 million, which was used to purchase more than two million hectares (>5 million acres) of wetland habitat for the National Wildlife Refuge system.

As wildlife protection efforts in North America spread to other parts of the world, an international consensus emerged for the preservation of wetlands. Negotiations between various countries and non-governmental agencies in the 1960s culminated with a treaty adopted in the Iranian city of Ramsar in 1971. This treaty, which came into force in 1975, dealt with conserving wetland habitats necessary for migratory waterbirds. The number of contracting parties (countries) has reached 160, representing all parts of the world, and nearly 1900 sites have been listed as wetlands of international importance covering more than 185 million hectares (Ramsar 2010a).

Wetlands are a high priority also for many science-based and non-governmental

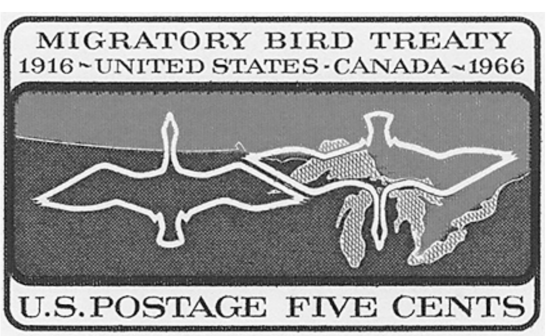

Figure 1-16. U.S. postage stamp marking the 50th anniversary of the convention on U.S.–Canada migratory birds. Original stamp printed in red, blue and black. From the collection of J. Vancura.

Figure 1-17. U.S. Migratory Bird Hunting and Conservation Stamp. Above: First U.S. "duck stamp" issued in 1934. The original stamp was flat-plate printed in blue monotone and depicted two mallards. For valid use, the stamp had to be signed; original signature can be seen faintly across the top of this example. Below: U.S. postage stamp issued to recognize the 50th anniversary of the duck stamp program, in the same blue monotone. From the collection of J. Vancura.

organizations (NGOs), such as Ducks Unlimited, Audubon, the Nature Conservancy in North America, the Wildfowl and Wetland Trust in the United Kingdom, and WetlandCare Australia, among others. As this list suggests, interested parties fall into two general categories – hunters and wildlife enthusiasts, again with wildlife conservation and sustainable management as the main themes. Such organizations have much in common; they strive in various ways to maintain, restore and protect native habitats for wildlife populations, so that future generations may enjoy the benefits of diverse wild animals thriving under natural conditions. In the case of migrating shorebirds and waterfowl, this means wetlands in summer and winter grounds as well as along the flyways during spring and autumn migrations.

These NGOs often work in close cooperation with local and national governmental agencies in order to complement or enhance efforts for wetland preservation. In the United States, the Environmental Protection Agency (EPA), Fish and Wildlife Service (FWS), Army Corps of Engineers (ACE), and Natural Resources Conservation Service (NRCS) are major agencies involved with wetland research, protection, and regulation. North of the border, Environment Canada is the lead national agency for various aspects of wetlands.

Wetlands International (WI) is the main global NGO concerned with restoring and sustaining wetland habitats, resources, and biodiversity. Headquartered in the Netherlands, WI deals mostly with wetlands in developing countries of South America, eastern Europe, southern and eastern Asia, and Africa. As a partner of Ramsar, WI has developed the Ramsar Site Information Service, which allows users to display map and statistical information about any Ramsar site online (see http://ramsar.wetlands.org/). Some WI projects highlight difficult situations; for example, efforts to protect wetlands in western Africa contradict attempts to control mosquito-borne malaria, which is epidemic in the region and a growing problem worldwide. West African malaria is a complex issue involving natural wetlands, rice agriculture, climate change, pharmacology, economic policy, and many other aspects with no easy solutions (Gwadz 2001; Touré 2001).

Figure 1-18. Emergent wetland vegetation growing in shallow, muddy water of the Baía de Marajó, part of the Amazon Delta complex, near Belém, Brazil. Photo courtesy of K. Buchele.

As global recognition of and support for environmental issues has expanded during the past half century, so has ecotourism, supported by a growing middle class with interests ranging from whale watching to tropical wildflowers. Exotic adventures into Amazonia (Fig. 1-18) or the Okavango Delta (Fig. 1-19) have brought many more people into direct contact with natural environments and wetlands. Governments and NGOs in developing countries recognize that wetland preservation makes good economic sense in order to gain further financial support.

1.5 Wetland science

The scientific study of wetlands was traditionally considered to be part of biology, and this is still often the case. Terms such as “wetland ecology” or “mire ecology” reinforce this biological emphasis. However, wetlands are integrated systems based on water, soil, climate, vegetation and wildlife as utilized and modified by human activities. Focusing mainly on biology, thus, may overlook many other fundamental aspects of wetlands (Fig. 1-20). Mitsch and Gosselink (2007) identified four factors that are unique to wetland science.

Figure 1-19. Ecotourism camp in the Okavango Delta of Botswana. The tent structures are elevated on wooden posts to minimize surface impact, and the interior accommodations are quite comfortable. Photo courtesy of M. Storm.

- Wetlands have many special properties not adequately covered in biological specialties.
- Wetlands of disparate types do have some common properties.
- Wetland studies require an interdisciplinary approach that may involve several subdisciplines not commonly included in university academic programs.
- Strong scientific understanding of many facets is necessary for the development of policy, regulation, and management of wetlands.

Several wetland scientific societies and publications support this multidisciplinary approach. A major organization in North America is the Society of Wetland Scientists (SWS), which publishes the journal *Wetlands*. According to its own description, it is "an international journal concerned with all aspects of wetlands biology, ecology, hydrology, soils, biogeochemistry, management, laws and regulations" (SWS 2010). This description certainly highlights the many disciplines and subjects of wetland research.

The International Peat Society (IPS) was constituted in Canada and is now based in Finland. The International Mire Conservation Group (IMCG) is likewise based in Europe. Together IPS and IMCG publish *Mires and Peat*, an online journal (see http://www.mires-and-peat.net/).

Figure 1-20. S. DeGraaf prepares to place a soil-temperature logger into a water-filled hole ~½ m deep in a subalpine bog at ~3200 m elevation, Colorado, United States. Study site is part of a long-term climate investigation. Photo by J.S. Aber.

Recent articles spanned the globe from ecohydrology of mires in Tierra del Fuego, Argentina (Grootjans et al. 2010) to a carbon-fiber-composite Byelorussian peat corer (Franzén and Ljung 2009). The open-access nature of this journal illustrates the desire of some societies to make their publications freely available to everybody.

The scientific organizations noted above are large and international in character. Wetlands exist throughout the world, so many smaller scientific organizations deal with local or regional interests in more specialized ways. A good example is Suoseura, the Finnish Peatland Society. It serves as the Finnish National Committee of the IPS, organized the 12th International Peat Congress in 2004, and publishes the journal *Suo*. The society has a membership of approximately 450, clearly indicating that wetlands in general and peat in particular are major scientific issues for the small country of Finland.

1.6 Book approach and outline

In this book, we recognize that a complete study of wetland environments requires the assessment of the physical and biological attributes, properties and functions of these ecosystems, and the economic, political and social aspects that mediate their use globally. We adopt a systems approach, which emphasizes simultaneously examining component parts of a system in the context of the whole. Such an approach allows us to consider the interactions between the physical, biological and human elements of wetland ecosystems. Moreover, selected examples from across the world are used to illustrate wetland characteristics and interactions. Collectively, these provide a broad understanding of the global scope of wetlands, their contributions to natural processes and human societies.

Part I of the book provides a general overview and introduction to the study of wetlands. Chapter 2 considers the physical and social components of wetland systems, while chapter 3 discusses the methods used to study and monitor these systems. Part II focuses on the fundamental physical and biological aspects of wetlands including wetland hydrology (chapter 4), soils (chapter 5), vegetation (chapter 6) and wildlife (chapter 7). In Part III, we consider short- and long-term changes in wetland environments and their roles in environmental cycles and feedback. Autogenic and allogenic change and the influence of climate, fire, tectonic activity, sea-level fluctuation, and animal activity on wetlands are addressed in chapter 8, while chapter 9 provides a long-term record of wetland formation and development through geologic time. The important role of wetlands in biogeochemical cycles and climate regimes by acting as carbon reservoirs is addressed in chapter 10.

Part IV of the book focuses on the human use and governance of wetland environments. Topics addressed in this section of the book include wetland services, resources and methods for valuation (chapter 11), wetland conservation planning and management practices (chapter 12), wetland restoration, enhancement and creation (chapter 13), and finally global wetland governance and public policy (chapter 14). The final section of this book (Part V) provides regional case studies focusing on the unique social and physical characteristics of both large and internationally renowned as well as smaller wetland sites from the low latitudes (chapter 15), middle latitudes (chapter 16), and high altitudes and latitudes (chapter 17).

1.7 Summary

Wetlands include water, soil, vegetation and wildlife, as modified and exploited by human activities. Early civilizations arose in fertile river valleys, and wetlands continue to be essential for modern human society. Wetlands provide many resources for people who live in or derive economic benefits from them. In addition, wetlands serve important, but less tangible functions for water supplies and high levels of biological productivity and biodiversity. As major sources and sinks for carbon, wetlands play critical roles in the global carbon cycle with significant consequences for greenhouse gases and potential climate change.

In spite of these direct and indirect values, people have a difficult time balancing their own, local, economic gains with broader regional or global issues concerning wetland development. Humans modify wetlands for various purposes in many ways, most commonly by artificial draining, filling, and reducing inflow or extracting water. What may be good for upstream water users, however, often leads to undesirable effects for downstream wetland habitats, water resources, and the people who depend on them.

The total extent of existing wetlands is estimated to range from 7 to 12 million km^2, depending upon the definition for what is included. These wetlands are found primarily in two latitudinal zones – boreal and sub-boreal (50–70°N) and tropical (±15°), and many more wetlands of diverse types are found in all other parts of the world. Aquatic civilizations adapt to seasonal resources in wetlands, such as annual flood cycles, in order to practice agriculture and extract resources with lesser impacts on wetland environments. Hydraulic civilizations, in contrast, undertake intensive modifications of water supplies, which lead to degradation and loss of wetlands. The hydraulic approach has been dominant around the world for the past five centuries; as a consequence, the modern wetland total is no more than half of pre-development coverage.

Wetland conservation began about a century ago with initial emphasis on protecting habitats for migrating waterbirds. The United States undertook bilateral treaties with the United Kingdom (Canada), Mexico and other countries. Among the most successful early programs was the U.S. Migratory Bird Hunting and Conservation Stamp, commonly known as "duck stamps," which still continues today. Many federal agencies are involved in wetland research and management in the United States, and similar agencies exist in many other countries. Likewise several non-governmental wetland organizations are active in North America and other parts of the world. International efforts culminated with the Ramsar Convention on Wetlands in 1971; to date, the number of contracting parties has reached 160, and nearly 1900 sites covering more than 185 million hectares have been listed as wetlands of international importance.

Given the broad range of wetland functions, their feedback relationships with other environmental factors, and human impacts, it is not surprising that scientific investigations of wetlands have become important for many reasons. So-called wetland science involves biological, physical and cultural aspects of environments and human impacts on wetlands. Several scientific societies and publications are devoted to multidisciplinary wetland science and management. In addition, ecotourism to wetlands has emerged as a popular leisure activity, thereby exposing many more people to the beauty and values of wetlands.