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Excerpt
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1 Wetlands: an overview

All life contains water. From distant space, Earth appears as a mosaic of blue and green, blue for water, green for plants. This book is about the ecological communities that occur where green meets blue: wetlands. Wetlands are intimately associated with water. They are one of the most productive habitats on Earth, and they support many kinds of life. This book explores the general principles that control the distribution and composition of wetlands around the world. The cover (Figure 1.1, artwork by Howard Coneybeare) illustrates a typical temperate zone wetland. Common wetland plants shown include floating-leaved water lilies (*Nymphaea odorata*), emergent pickerelweed (*Pontederia cordata*), and shoreline reed canary grass (*Phalaris arundinacea*). The food web is largely composed of invertebrates that feed upon decaying plants. Near the top of the food web are vertebrates such as fish (yellow perch), reptiles (snapping turtle), and birds (great egret). The surrounding forests interact with the wetland. Amphibians, such as tree frogs, over-winter in the forest, while nutrients and runoff from the forest enter the wetland.

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Wetlands have always influenced humans. Early civilizations first arose along the edges of rivers in the fertile soils of floodplains. Wetlands continue to produce many benefits for humans – along with fertile soils for agriculture, they provide food such as fish and waterbirds. Additionally, wetlands have other vital roles that are less obvious – they produce oxygen, store carbon, and process nitrogen. Of course, wetlands have also been a cause of human suffering, such as providing habitat for mosquitoes that carry malaria. And, for thousands of years, human cities in low areas have flooded during periods of high water. Philosophers and theologians may enquire how it is that one system can be both life-giving and death-dealing. Our more confined task as scientists is

- to explore the basic patterns that occur in wetlands,
- to uncover the causes of these patterns, and
- to guide society in wise coexistence with wetlands.

I intend to take you through these three steps in this book. Along the way, we will encounter not only hard science, but some entertaining natural history – fish that breathe air, mosses that drown trees, plants that eat insects, and frogs that climb trees. We shall also meet the world's largest wetlands, wetlands that perch on hillsides, wetlands that burn, and of course, wetlands that flood.

1.1 Definitions and distribution

Wetlands form at the interface of terrestrial and aquatic ecosystems and have features of both. While they may be highly variable in appearance and species composition, inundation by water is a shared characteristic that is, in turn, reflected in soil processes and adaptations of the biota. Thus wetlands are found where there is water, from saline coastal areas to continental interiors, but most are associated with fresh water.

FIGURE 1.1

1.1.1 Definition of wetlands

A wetland is an ecosystem that arises when inundation by water produces soils dominated by anaerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding.

This broad definition includes everything from tropical mangrove swamps to subarctic peatlands. This single sentence of definition has a complex structure: there is a cause (inundation by water), a proximate effect (reduction of oxygen levels in the soil), and a secondary effect (the biota must tolerate both the direct effects of flooding and the secondary effects of anaerobic conditions). It is not the only definition, and maybe not even the best, but it shall get us started. Since many biologists and lawyers or agencies and organizations have attempted to define wetlands, we shall start with this simple idea. We shall explore other definitions in Section 1.8.1.

Since wetlands require water, the obvious place to begin is the distribution of water on Earth. Table 1.1 shows that a majority of the Earth's available water is in the oceans. A much smaller amount is present as fresh water. Heat from the sun drives a distillery, removing water vapor from the oceans and returning it to the land as precipitation. Some wetlands form along the edges of oceans; these tend to be mangrove swamps in equatorial regions and salt marshes at higher latitudes. A majority of wetlands are, however, freshwater ecosystems. They occur where rainwater accumulates on its way back to the ocean. Some people regard the distinction between freshwater and saltwater wetlands as critical, and you will often run into many documents that refer to "interior wetlands" and "coastal wetlands." Certainly salinity is very important in determining which kinds of plants and animals occur, but in this book we shall do our best to think about wetlands as one group of ecosystems.

Since life began in the oceans, most life, including freshwater life, has a chemical composition more like the ocean than fresh water (Table 1.2). Yet it appears that most life found in fresh water today did not originate in fresh water, but first adapted to land, and then adapted to fresh water. Fish, were, of course, an exception. The bodily fluids of freshwater aquatic animals still show a strong similarity to oceans. Indeed, many studies

Table 1.1 **Mass of water in different forms on Earth**

Form	Mass ($\times 10^{17}$ kg)
Chemically bound in rocks[a]	
Crystalline rocks	250 000
Sedimentary rocks	2100
Free water[b]	
Oceans	13 200
Ice caps and glaciers	292
Ground water to a depth of 4000 m	83.5
Freshwater lakes	1.25
Saline lakes and inland seas	1.04
Soil moisture	0.67
Atmospheric water vapor	0.13
Rivers	0.013

[a] Does not cycle.
[b] Part of hydrological cycle.
Source: From Clapham (1973).

Table 1.2 **Concentrations of some common ions in animals, sea water, and fresh water (concentrations are given as mM/kg water)**

Ions	Standard sea water	Fresh water (soft)	Fresh water (hard)	Crab (*Maia*) blood	Frog (*Rana esculenta*) blood	Crayfish (*Astacus fluviatilis*) blood (mM/l blood)	Rat (*Rattus rattus*) blood
Na^+	478.3	0.24	2.22	487.90	109	212	140
K^+	10.13	0.005	1.46	11.32	2.6	4.1	6.4
Ca^{2+}	10.48	0.067	3.98	13.61	2.1	15.8	3.4
Mg^{2+}	54.5	0.043	1.67	44.14	1.3	1.5	1.6
Cl^-	558.4	0.226	2.54	552.4	78	199	119
SO_4^{2-}	28.77	0.045	3.95	14.38	–	–	–
HCO_3^{2-}	–	–	2.02	–	26.6	15	24.3

Source: Modified from Wilson (1972).

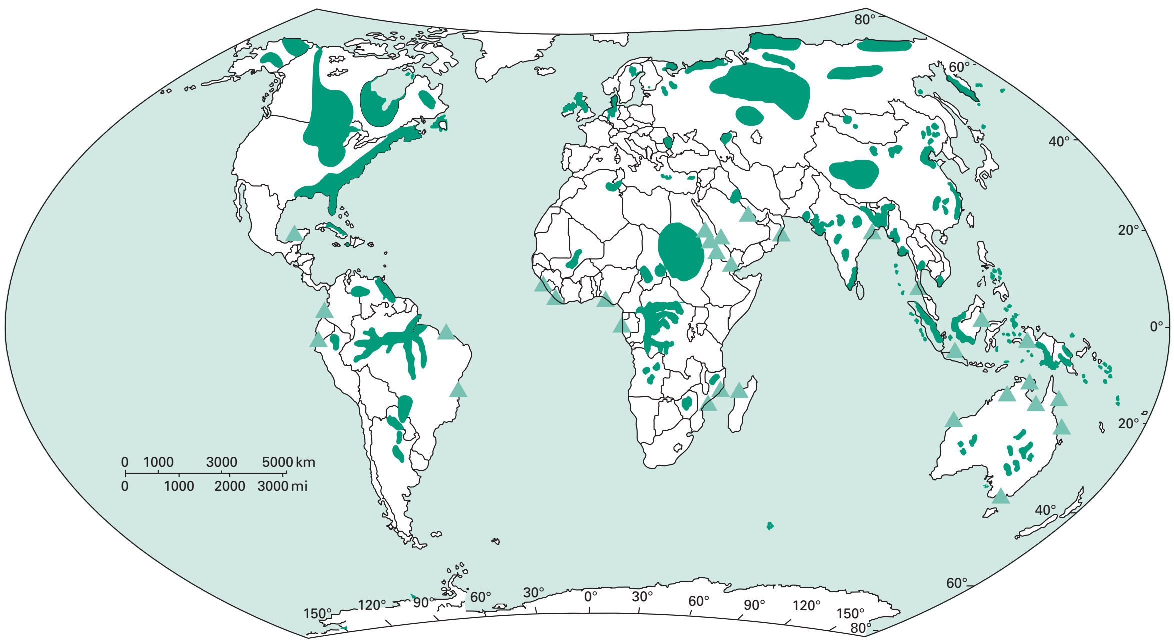

FIGURE 1.2 The major wetland areas on Earth. Mangrove swamps are shown as triangles. (Compiled from Dugan 1993 and Groombridge 1992.)

of ion balance in freshwater organisms show that fish, amphibians, and invertebrates attempt to maintain an inner ocean in spite of surrounding fresh water. They also show that, as with plants, access to oxygen becomes limiting once a site is flooded.

Wetlands have soil, so they are not truly aquatic like planktonic and pelagic communities. But they have standing water, so neither are they truly terrestrial. As a consequence, they are often overlooked. Terrestrial ecologists often assume they will be studied by limnologists, while limnologists may assume the reverse. We will therefore feel free to borrow from both terrestrial ecologists and limnologists in studying wetlands.

1.1.2 Distributions

Figure 1.2 presents an approximate distribution of global wetlands. Such a map has many limitations. It is difficult to map wetlands at the global scale for at least three reasons. Firstly, wetlands are frequently a relatively small proportion of the landscape. Secondly, they are distributed in small patches or strips throughout biomes, and therefore cannot be mapped at a scale suitable for reproducing in a textbook. Thirdly, they are very variable, and one biome can therefore contain a wide array of wetland types. Table 1.3 lists the largest wetland areas in the world. These set an important priority list for research and conservation.

1.2 Wetland classification

Now that we have a definition, and some idea of where wetlands occur, the next step is to sort them into similar types. Each type can be visualized as a particular set of plant and animal associations that recur. This recurrence probably means that the same causal factors are at work. Unfortunately, the

Table 1.3 **The world's largest wetlands (areas rounded to the nearest 1000 km^2)**

Rank	Continent	Wetland	Description	Area (km^2)
1	Eurasia	West Siberian Lowland	Bogs, mires, fens	2 745 000
2	South America	Amazon River basin	Floodplain forest and savanna, marshes, mangal	1 738 000
3	North America	Hudson Bay Lowland	Bogs, fens, swamps, marshes	374 000
4	Africa	Congo River basin	Swamps, riverine forest, wet prairie	189 000
5	North America	Mackenzie River basin	Bogs, fens, swamps, marshes	166 000
6	South America	Pantanal	Savannas, grasslands, riverine forest	138 000
7	North America	Mississippi River basin	Bottomland hardwood forest, swamps, marshes	108 000
8	Africa	Lake Chad basin	Grass and shrub savanna, marshes	106 000
9	Africa	River Nile basin	Swamps, marshes	92 000
10	North America	Prairie potholes	Marshes, meadows	63 000
11	South America	Magellanic moorland	Bogs	44 000

Source: From Fraser and Keddy (2005).

terminology for describing wetlands varies both among human societies, and among their scientific communities. Thus one finds an abundance of words used to describe wetlands – bog, bayou, carr, fen, flark, hochmoore, lagg, marsh, mire, muskeg, swamp, pocosin, pothole, quagmire, savanna, slob, slough, swale, turlough, yazoo – in the English language alone. Many of these words can be traced back centuries to Old Norse, Old Teutonic, or Gaelic origins (Gorham 1953). Now add in other world languages, and the problem is compounded.

Given the global distribution, it is not surprising to find that abundant wetland classification schemes have been developed. They vary, for example, by geographic region, the intended use of the classification results, and the scale at which classification is undertaken. We will start with a simple classification system that distinguishes six wetland types largely on the basis of location and hydrology. After learning more about the environmental factors that control the development of wetlands and their communities, we will return to wetland definition and classification (Section 1.8).

1.2.1 The six basic types

To keep the terminology simple, we will begin with four types of wetland, and then add two to extend the list to six. One of the simplest classification systems recognizes only four types: swamps, marshes, fens, and bogs.

Swamp

A wetland that is dominated by trees that are rooted in hydric soils, but not in peat. Examples would include the tropical mangrove swamps (mangal) of Bangladesh and bottomland forests in floodplains of the Mississippi River valley in the United States (Figure 1.3).

Marsh

A wetland that is dominated by herbaceous plants that are usually emergent through water and rooted in hydric soils, but not in peat. Examples would include cattail (*Typha angustifolia*) marshes around the Great Lakes and reed (*Phragmites australis*) beds around the Baltic Sea (Figure 1.4).

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(a) (b)

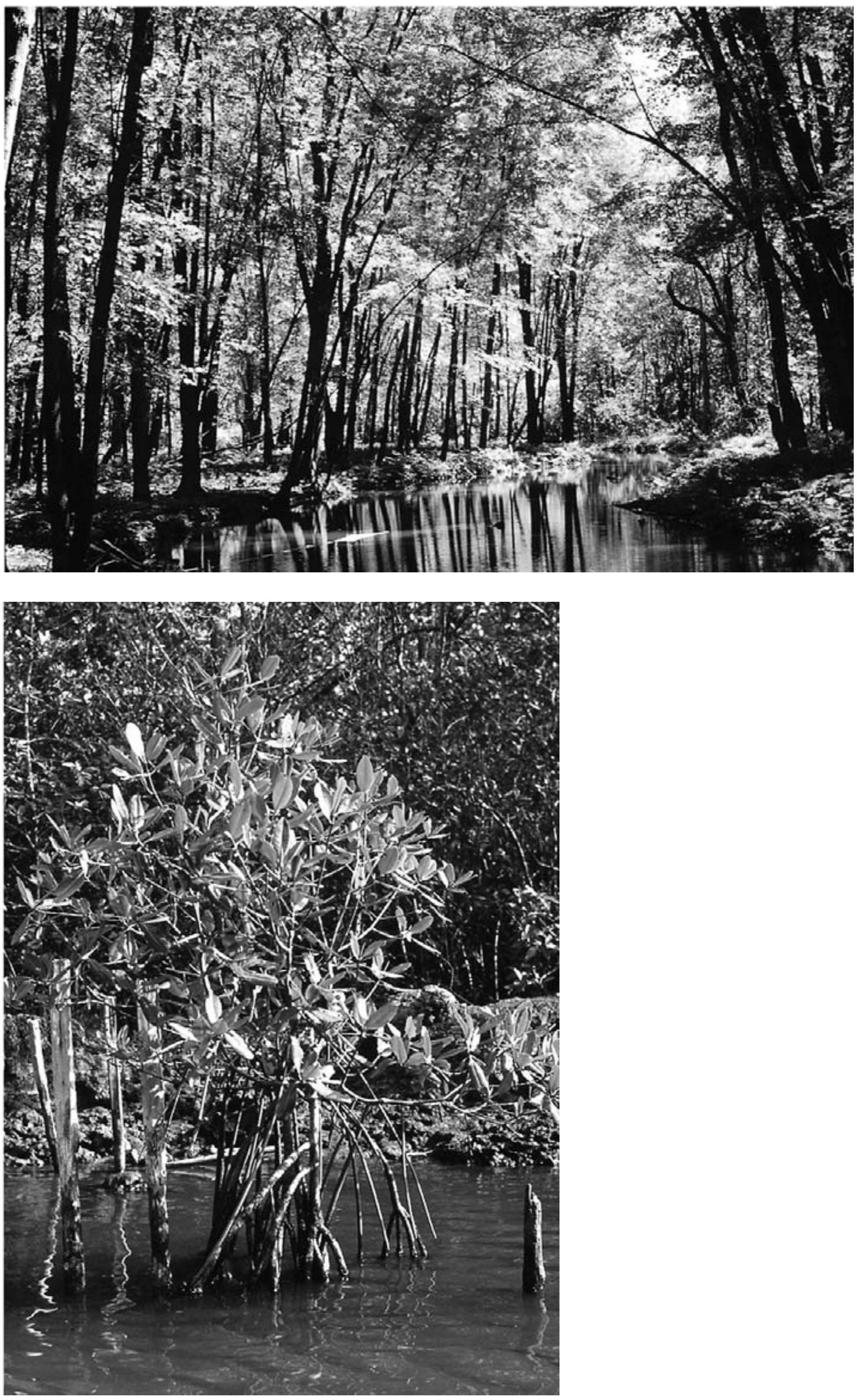


FIGURE 1.3 Swamps. (*a*) Floodplain swamp (Ottawa River, Canada). (*b*) Mangrove swamp (Caroni wetland, Trinidad). (See also color plate.)

(a)

(b)

FIGURE 1.4 Marshes. (*a*) Riverine marsh (Ottawa River, Canada; courtesy B. Shipley). (*b*) Salt marsh (Petpeswick Inlet, Canada). (See also color plate.)

Bog

A wetland dominated by *Sphagnum* moss, sedges, ericaceous shrubs, or evergreen trees rooted in deep peat with a pH less than 5. Examples would include the blanket bogs which carpet mountainsides in northern Europe, and the vast peatland of the West Siberian Lowland in central Russia (Figure 1.5).

Fen

A wetland that is usually dominated by sedges and grasses rooted in shallow peat, often with considerable groundwater movement, and with pH greater than 6. Many occur on calcareous rocks, and most have brown mosses, in genera including *Scorpidium* or *Drepanocladus*. Examples can be found within the extensive peatlands of northern Canada and Russia, as well as in smaller seepage areas throughout the temperate zone (Figure 1.6).

Other wetland types could be added to these four. Two important ones are the following.

Wet meadow

A wetland dominated by herbaceous plants rooted in occasionally flooded soils. Temporary flooding excludes terrestrial plants and swamp plants, but drier growing seasons then produce plant communities typical of moist soils. Examples would include wet prairies along river floodplains, or herbaceous meadows on the shorelines of large lakes. These wetlands are produced by periodic flooding and may be overlooked if visited during a dry period (Figure 1.7).

Shallow water

A wetland community dominated by truly aquatic plants growing in and covered by at least 25 cm of water. Examples include the littoral zones of lakes, bays in rivers, and the more permanently flooded areas of prairie potholes (Figure 1.8).

Any attempt to sort the diversity of nature into only six categories will have its limitations. The Everglades, for example, have a peat substrate, moving water, and many reeds. So is it a fen or a marsh or wet prairie, a mixture of several of these, or something completely unique? Rather than worry further about this, we should probably admit that wetlands show great variation, and agree to not get stalled or diverted by debates over terminology. As Cowardin and Golet (1995) observe “no single system can accurately portray the diversity of wetland conditions world-wide. Some important ecological information inevitably will be lost through classification.”

1.2.2 Some other classification systems

The system I present above has the advantage of simplicity and generality. You should be aware that there are more elaborate systems, and that these vary around the world. Each wetland classification system tries to summarize the major types of wetland vegetation, and then relate them to environmental conditions. Here are a few examples. We shall add several more near the end of the chapter.

A global summary

Figure 1.9 provides a summary that ties different classification systems into a unified whole. It begins with “water regime,” from permanently waterlogged on the left to permanent shallow water on the right. Combining these three hydrological regimes with “nutrient supply,” one obtains peatlands on the left, swamps in the middle, and lakes on the right. Further, the scheme then goes on to address the main plant forms that will occur. (One other system has been presented by Gopal *et al.* [1990] to summarize world wetland types. It again has two principal axes, hydrology and fertility, but it will be introduced at the end of Chapter 3 after these two factors have been explored in more depth.)

Hydrogeomorphic classifications

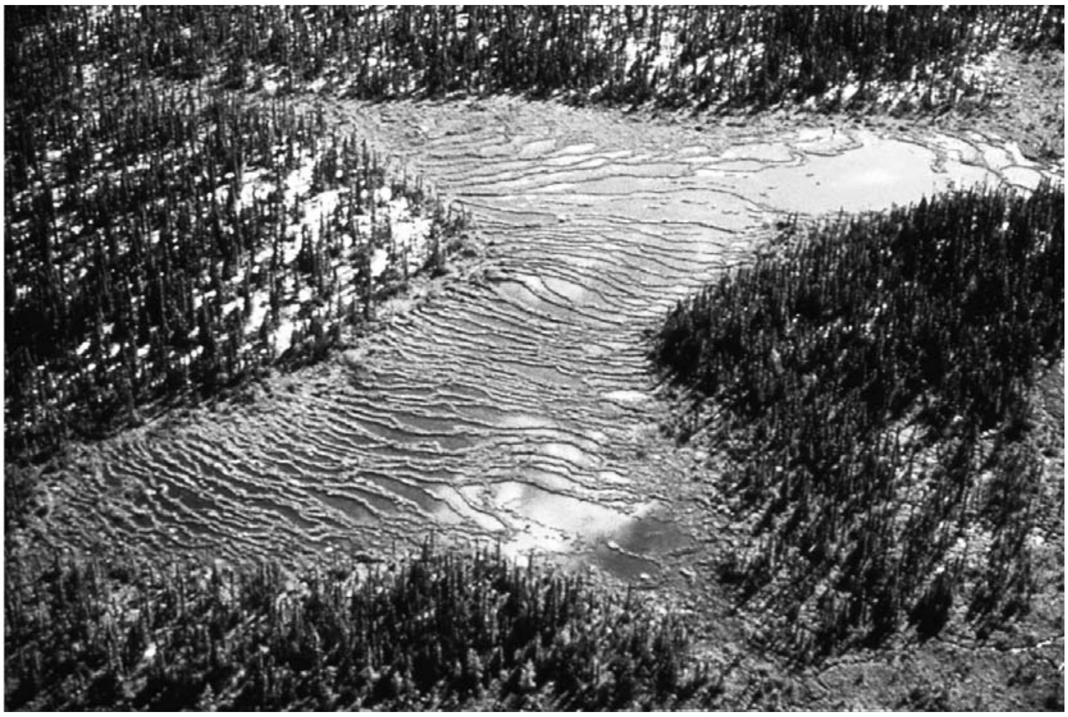
The location or setting of a wetland often has important consequences for duration of flooding and water quality. Hence, there are classification systems that emphasize the landscape setting of the wetland, such as the widely used Cowardin classification system (Table 1.4). Setting may be particularly

(a)

(b)

FIGURE 1.5 Bogs. (*a*) Lowland continental bog (Algonquin Park, Canada). (*b*) Upland coastal bog (Cape Breton Island, Canada). (See also color plate.)

(a)



(b)

FIGURE 1.6 Fens. (*a*) Patterned fen (northern Canada; courtesy C. Rubec). (*b*) Shoreline fen (Lake Ontario, Canada). (See also color plate.)