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

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(*a*)

(*b*)

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

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(a)

(b)

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

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(a)

(b)

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

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FIGURE 1.7 Wet meadows. (*a*) Sand spit (Long Point, Lake Ontario, Canada; courtesy A. Reznicek). (*b*) Gravel lakeshore (Tusket River, Canada; courtesy A. Payne).

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FIGURE 1.8 Shallow water. (*a*) Bay (Lake Erie, Canada; courtesy A. Reznicek). (*b*) Pond (interdunal pools on Sable Island, Canada).

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FIGURE 2.1 Flooding is a natural process in landscapes. When humans build cities in or adjacent to wetlands, flooding can be expected. This example shows Cedar Rapids in the United States in 2008 (*The Gazette*), but incidences of flood damage to cities go far back in history to early cities such as Nineveh mentioned in *The Epic of Gilgamesh* (Sanders 1972).

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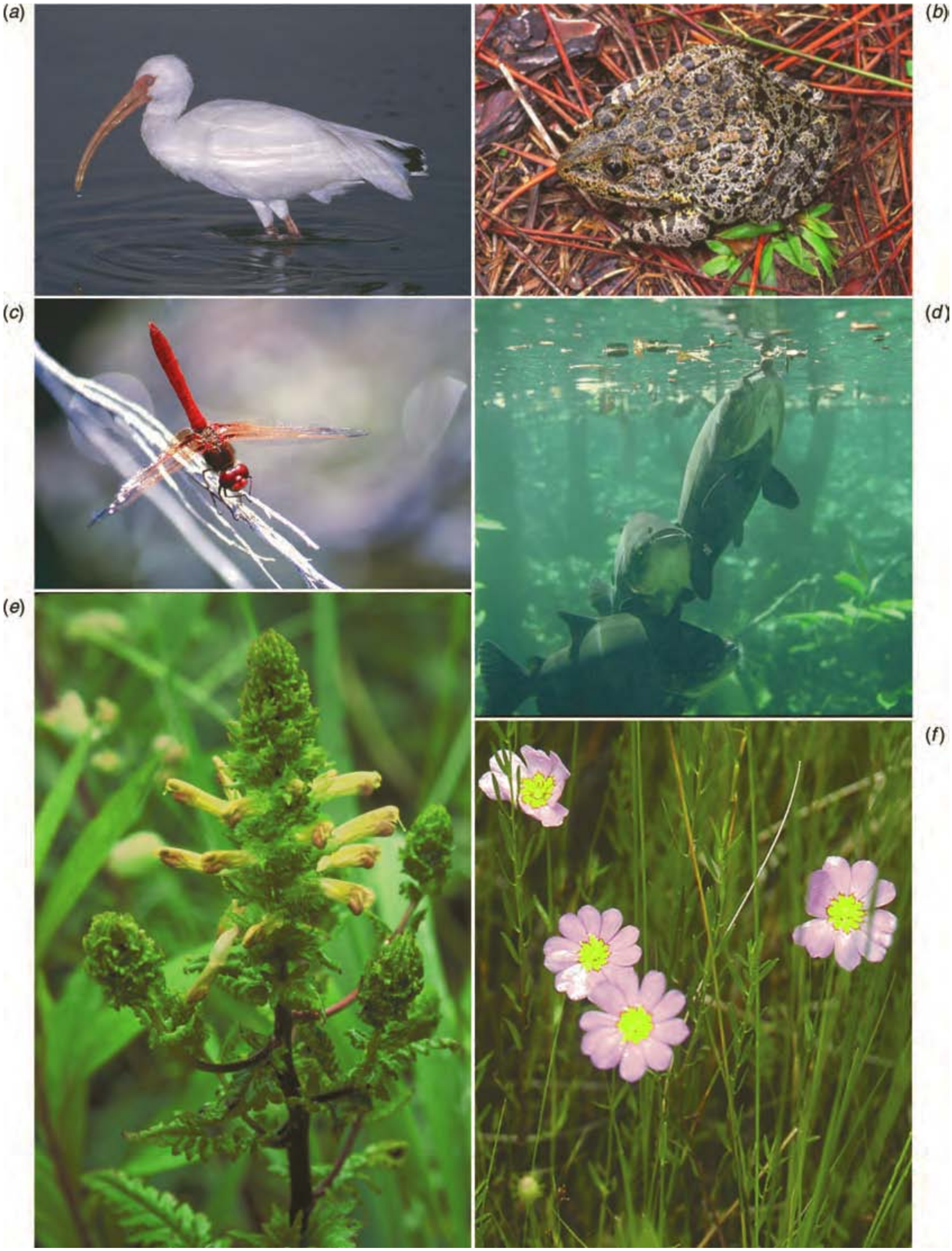

FIGURE 2.5 Many wetland organisms are dependent upon annual flood pulses. Animals discussed here include (*a*) white ibis (U.S. Fish and Wildlife Service), (*b*) Mississippi gopher frog (courtesy M. Redmer), (*c*) dragonfly (courtesy C. Rubec), and (*d*) tambaqui (courtesy M. Goulding). Plants discussed here include (*e*) furbish lousewort (bottom left; U.S. Fish and Wildlife Service) and (*f*) Plymouth gentian.

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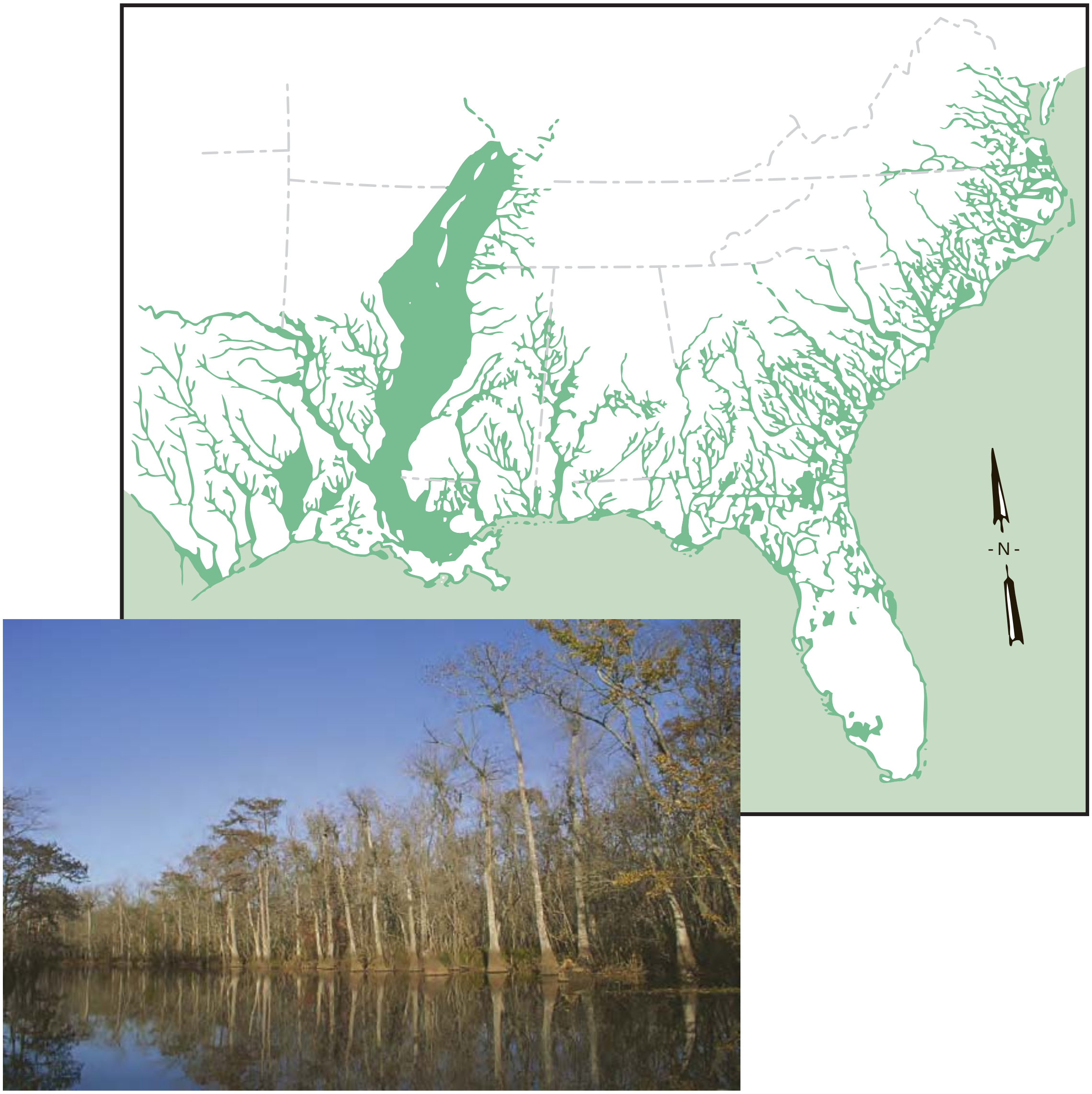

FIGURE 2.10 Spring floods produce the extensive bottomland forests that accompany many large rivers, such as those of the southeastern United States of America. (Map from Mitsch and Gosselink 1986.)

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FIGURE 2.16 During a low water year in Lake Erie there was dense regeneration of *Scirpus* and *Sagittaria* plants in Metzger Marsh. (Courtesy D. Wilcox.)

FIGURE 2.21 Dams built by humans, such as the Three Gorges Dam recently constructed on the Yangtze River, increasingly disrupt natural flood pulses in the world's great rivers. (Courtesy ChinaFotoPress/Li Ming.)

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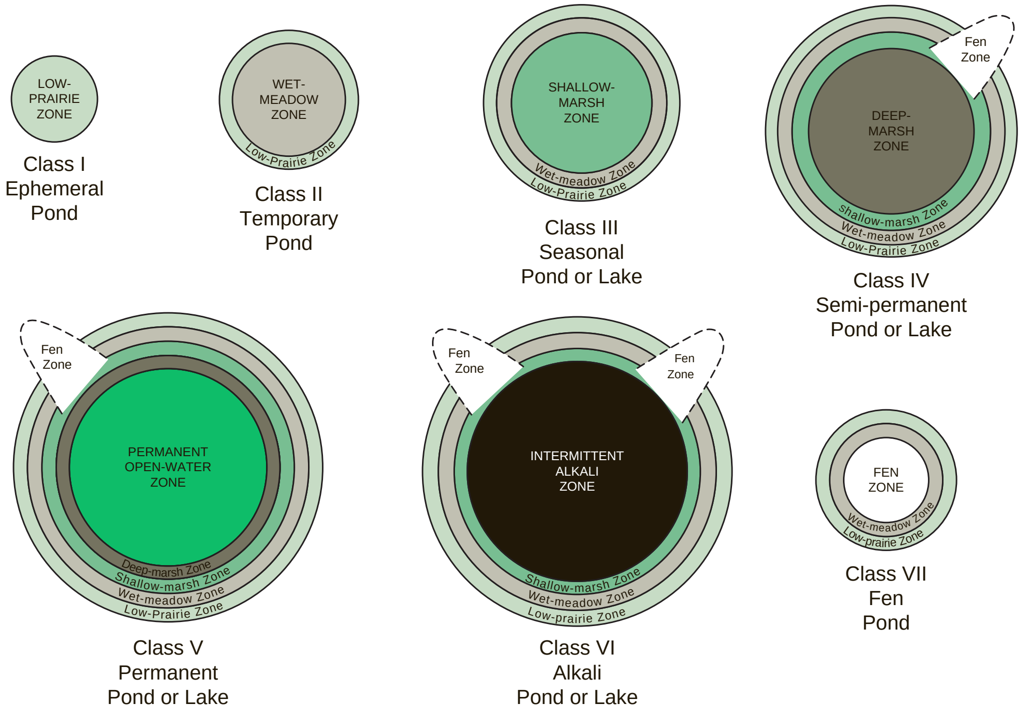

FIGURE 2.20 The vegetation patterns in prairie potholes are controlled by flooding. Here is a classification system showing vegetation zones for seven types of prairie potholes (from Stewart and Kantrud 1971 in van der Valk 1989) and an aerial view of potholes of differing classes near Minnedosa, Manitoba (Courtesy C. Rubec).

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FIGURE 3.3 Many wetlands have low fertility. Examples include peat bogs (*a*, Algonquin Provincial Park, Ontario), the Everglades (*b*), shorelines in sand plains (*c*, Axe Lake, Ontario; courtesy M. Sharp), and wet savannas with old soils (*d*, Buttercup Flats, De Soto National Forest, Mississippi).

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FIGURE 4.1 Fire removes biomass from wetlands during droughts. It also alters fertility by volatilizing nitrogen and recycling phosphorus. If the fire is sufficiently intense to burn the organic soil, pools of water can form in the depressions. (Courtesy C. Rubec.)

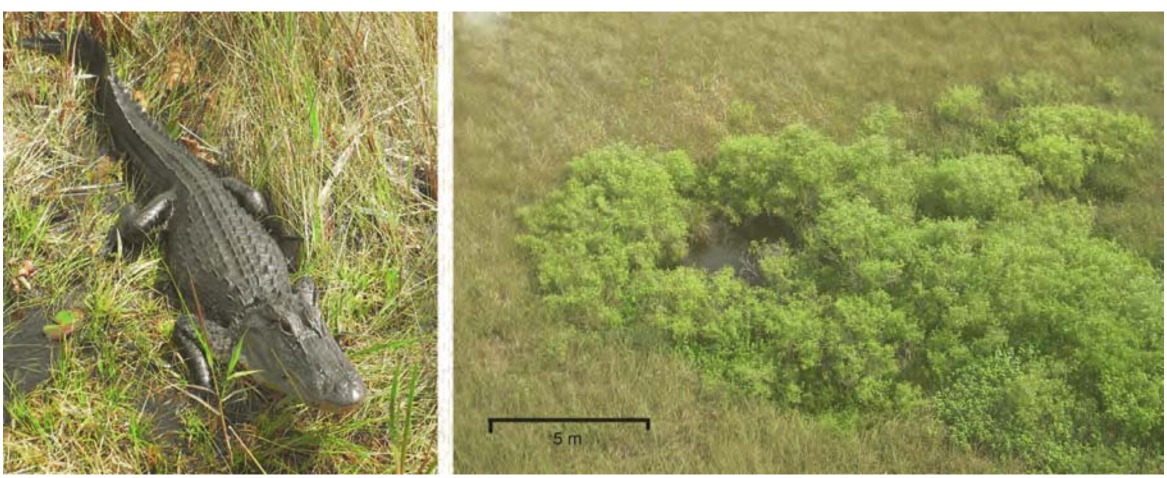

FIGURE 4.12 A gator hole in the Everglades along with its creator and occupant (not to scale). The alligator excavates a hole, which supports aquatic plants and animals, and the earth mound around the edge of the hole develops its own characteristic plant community. Large expanses of wetland can be dotted by such holes and mounds.

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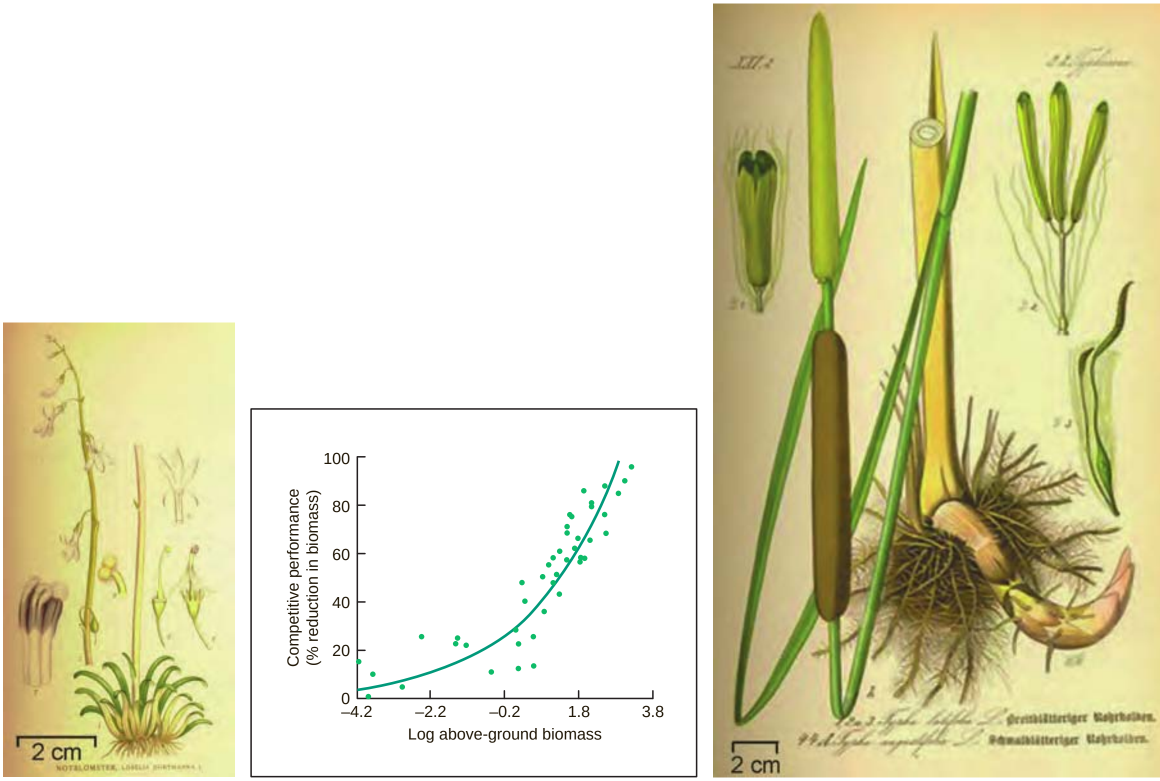

FIGURE 5.7 Competitive performance increased with plant size across an array of 44 wetland species. Small rosette species (e.g. *Lobelia dortmanna*) occur on the left side of the figure, while large leafy species (e.g. *Typha latifolia*) occur on the right. Competitive performance was measured as the percent reduction in biomass of a common test species. (After Gaudet and Keddy 1988.)

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FIGURE 5.13 Animals may also depend upon peripheral habitats. The bog turtle (*Clemmys muhlenbergii*), North America's smallest turtle (9 cm, 115 g), occurs in wet meadows. (Photo courtesy R.G. Tucker, Jr., U.S. Fish and Wildlife Service; map, U.S. Fish and Wildlife Service.)

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FIGURE 6.1 Sometimes grazing animals, such as nutria, can almost eliminate wetlands plants – as illustrated by this experimental fenced plot (exclosure) in a Louisiana marsh. (Courtesy Louisiana Department of Wildlife and Fisheries.)

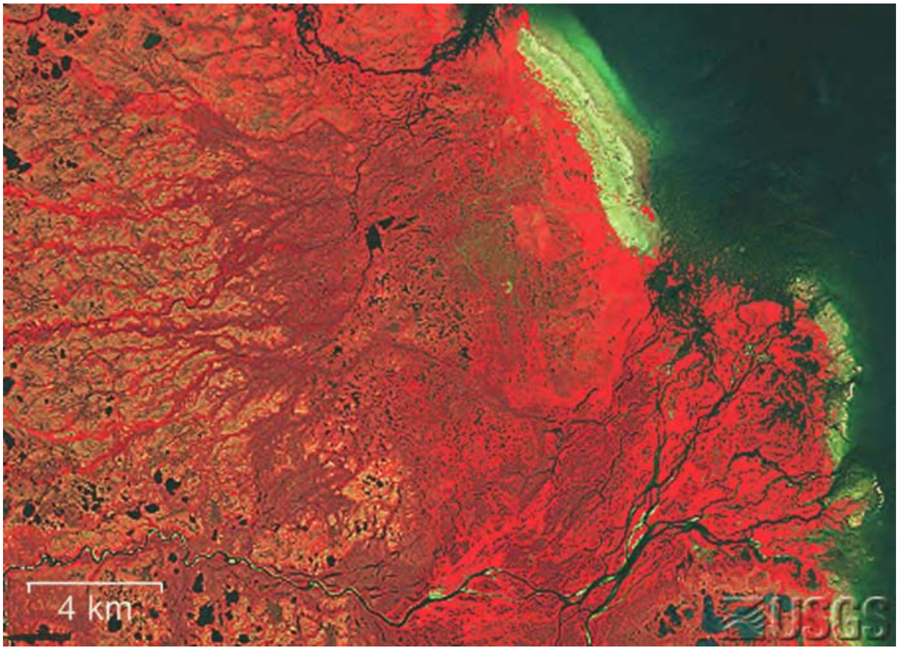

FIGURE 6.2 Geese are grazing coastal wetlands along the shore of Hudson Bay so intensely that some areas of marsh have been converted to mud flats, as shown in this July 18 satellite image of the Knife River delta in Manitoba, Canada. The mud flats are indicated by the bright strip of land. (U.S. Geological Survey 1996.)

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FIGURE 6.5 Large herbivores remain important in African wetlands, and their impacts affect many other wetland species. (From Dugan 2005.)

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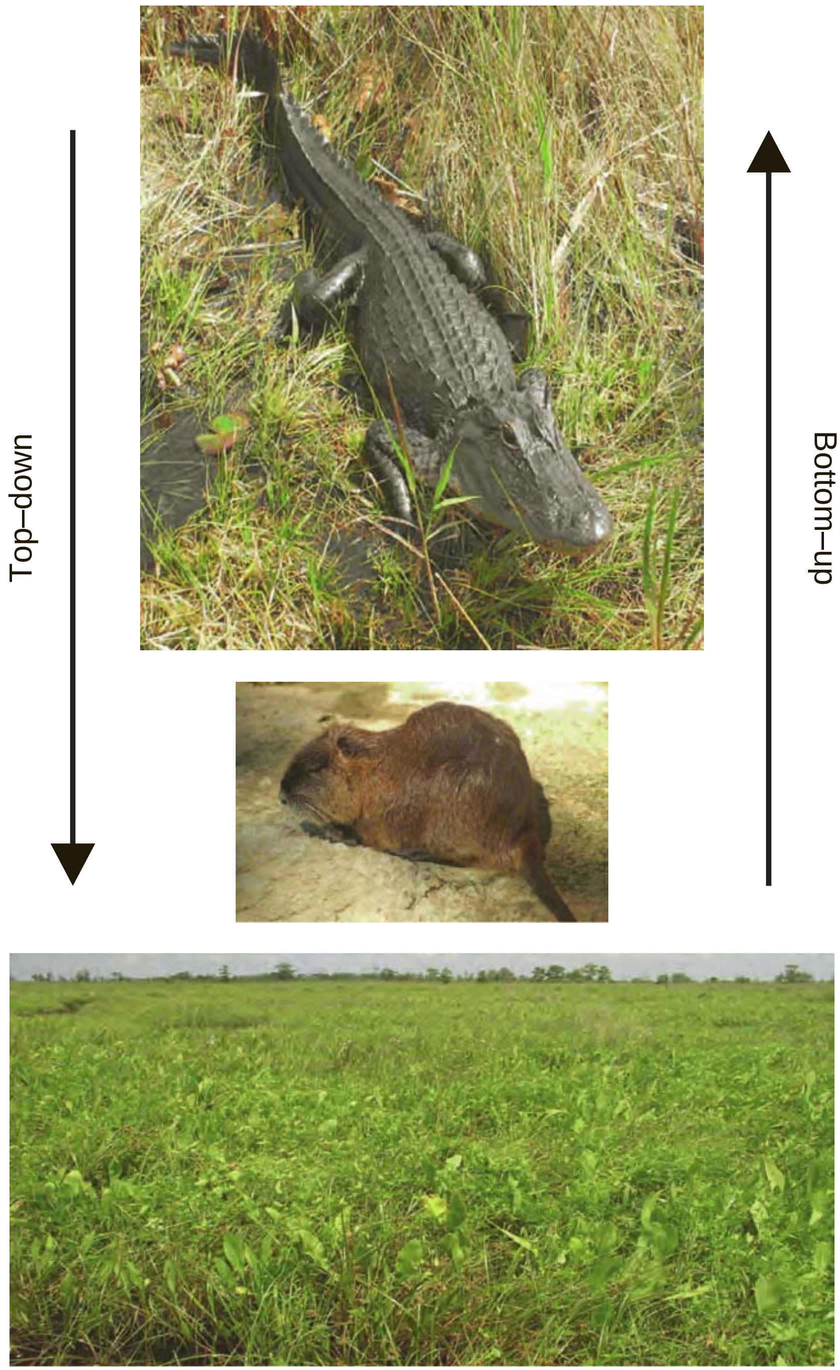

FIGURE 6.15 Does the amount of vegetation control the abundance of nutria, and hence the number of alligators? Or does the number of alligators control the abundance of nutria, and hence the amount of vegetation? The first is termed bottom–up control, and the second is termed top–down control. It is by no means clear which is the correct view, or whether both are happening simultaneously.

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FIGURE 8.1 Salinity changes the species composition of wetlands from mangrove swamp (left, Florida Keys, USA; courtesy G. Ludwing, U.S. Fish and Wildlife Service) to salt marsh (bottom right, El Yali, Chile; courtesy M. Bertness) to oligohaline marsh (top right, Gulf of Mexico, Louisiana).

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FIGURE 8.10 The flamingoes of the Camargue wetland on the Mediterranean coast depend upon invertebrates for food. (Courtesy A. Waterkeyn.)

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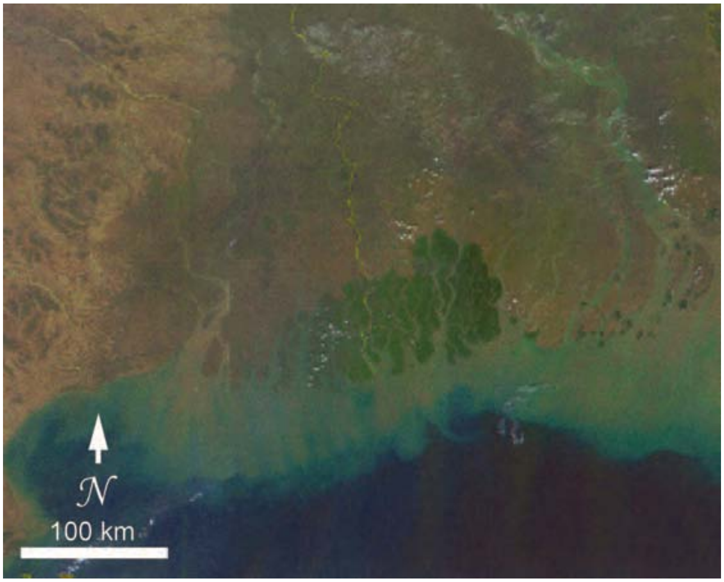

FIGURE 8.18 The Sundarbans, the world's largest mangrove swamp, occur largely in one of the most densely populated areas in the world, Bangladesh. Note the abrupt boundary where the wetland is not protected from exploitation, and note the sediment plumes coming out of the Ganges River. (From Earth Observing System, NASA.)

FIGURE 9.4 Differences in elevation produce much of the diversity found in wetlands, as illustrated by this example of zonation.

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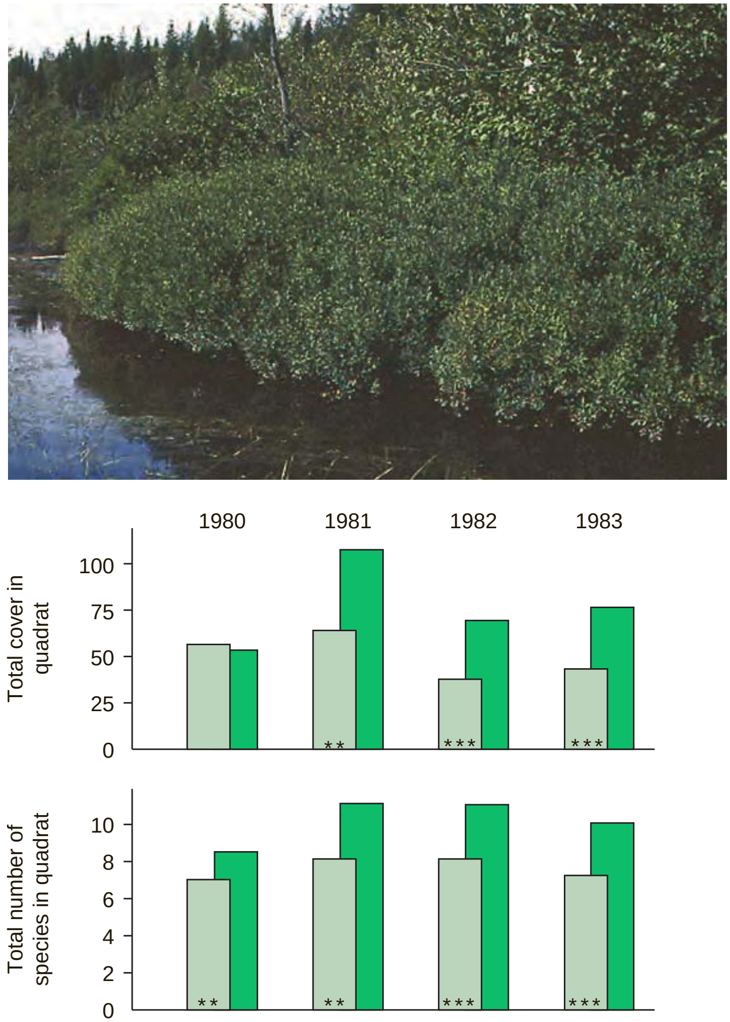

FIGURE 10.7 Shrubs occupy higher elevations in many wetlands (top). Experimentally removing the shrubs increases the cover and number of species of herbaceous wetland plants (bottom). (From Keddy 1989b.)

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FIGURE 11.6 Coal was produced in vast wetlands such as this Carboniferous coal swamp. (© The Field Museum, #GE085637c.) When coal is burned, the stored carbon returns to the atmosphere as carbon dioxide. Stored nutrients such as nitrogen are also released.

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FIGURE 13.2 Four stages of restoration in one of the author's wetlands: former wetland dried out by drainage ditches (upper left), replacing old beaver dam and filling ditches with earth (upper right), first year (lower left), second year (lower right). The wetland is now a breeding site for wood frogs, leopard frogs, mink frogs, spring peepers, American toads, gray tree frogs, green frogs, and bullfrogs.

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1 Everglade kite, *Rostrhamus sociabilis*
2 Pileated woodpecker, *Phloeceastes pileatus*
3 Prothonotary warbler, *Protonotaria citrea*
4 Rough green snake, *Opheodrys aestivus*
5 Limpikin, *Aramus guarauna*
6 Raccoon, *Procyon lotor*
7 Flamingo, *Phoenicopterus ruber*
8 Mississippi alligator, *Alligator mississippiensis*
9 Roseate spoonbill, *Ajaia ajaja*
10 Eastern fox squirrel, *Sciurus niger*
11 Snail, *Isognomon melina alata*
12 Green tree frog, *Hyla cinerea*
13 Green anolis, *Anolis carolinensis*
14 Zebra butterfly, *Heliconius charitonius*
15 Purple gallinule, *Porphyrula martinica*
16 Snail, *Pomacea flagellata*
17 Swamp rabbit, *Sylvilagus* sp.
18 Oxeye tarpon, *Megalops cyprinoides*
19 Cottonmouth moccasin, *Ancistrodon piscivorus*

FIGURE 13.3 A scene from the Everglades. The Comprehensive Everglades Restoration Plan aims to protect and restore the conditions that maintain the native biota of the Everglades. (From Dugan 2005.)

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FIGURE 13.4 Enormous canals have altered the natural hydrology of the Everglades, and provided a conduit for nutrient enriched water to enter the wetlands.

FIGURE 13.5 Removing artificial levees will also restore wetlands. (left) Prior to dike removal. (right) After removing some 6 km of dikes, natural flood regimes were restored and in 2004 the Danube River flowed freely over Tataru Island. (Courtesy World Wildlife Fund.)

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FIGURE 13.8 The Yangtze River is the third longest river in the world. It begins in the highlands of Tibet, amidst some of the world's largest high-altitude peatlands (Ruoergai peatland, bottom left; courtesy Wetlands International). Here it also flows through mountains which comprise one of the world's biodiversity hotspots, the mountains of Southwest China (star, top left). Further east it passes through large lakes such as Dongting Lake (lower right; from www.hbj.hunan.gov.cn/dongT1/default.aspx). Where it enters the sea there are large deltaic wetlands (top right; courtesy M. Zhijun). The world's largest dam, the Three Gorges Dam (Fig. 2.21), is indicated by the black dot (top left).

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FIGURE 13.10 The Caernarvon Diversion structure on the Mississippi River allows floodwaters to pass through an artificial levee and enter the wetlands of Breton Sound in the distance. (Courtesy J. Day.)

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FIGURE 13.12 Invasive aquatic plants, like water hyacinth (*Eichhornia crassipes*, bottom; courtesy Center for Aquatic and Invasive Plants, University of Florida), are notorious for their ability to invade and to dominate wet places (top; W. Durden, U.S. Department of Agriculture, Agricultural Research Service). They can reduce both biological diversity and ecological services. Such invasives pose a significant risk to restored wetlands as well as to natural wetlands.

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FIGURE 14.1 The Mesopotamian marshes (top; © Nature Iraq) have been affected by humans for thousands of years, most recently by drainage, dam construction, and warfare (bottom; from Lawler 2005). *Phragmites* reeds are the mainstay of marsh culture, being used as housing material, woven into mats, and fed to water buffalo.

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FIGURE 14.13 The fens of eastern England have been drained at least since the reign of Charles I in the early 1600s. Over 99% have been lost. The Great Fen Project plans to restore 3000 hectares around two core remnants, Holme Fen and Woodwalton Fen (top). (Courtesy The Wildlife Trust, Cambridge.)

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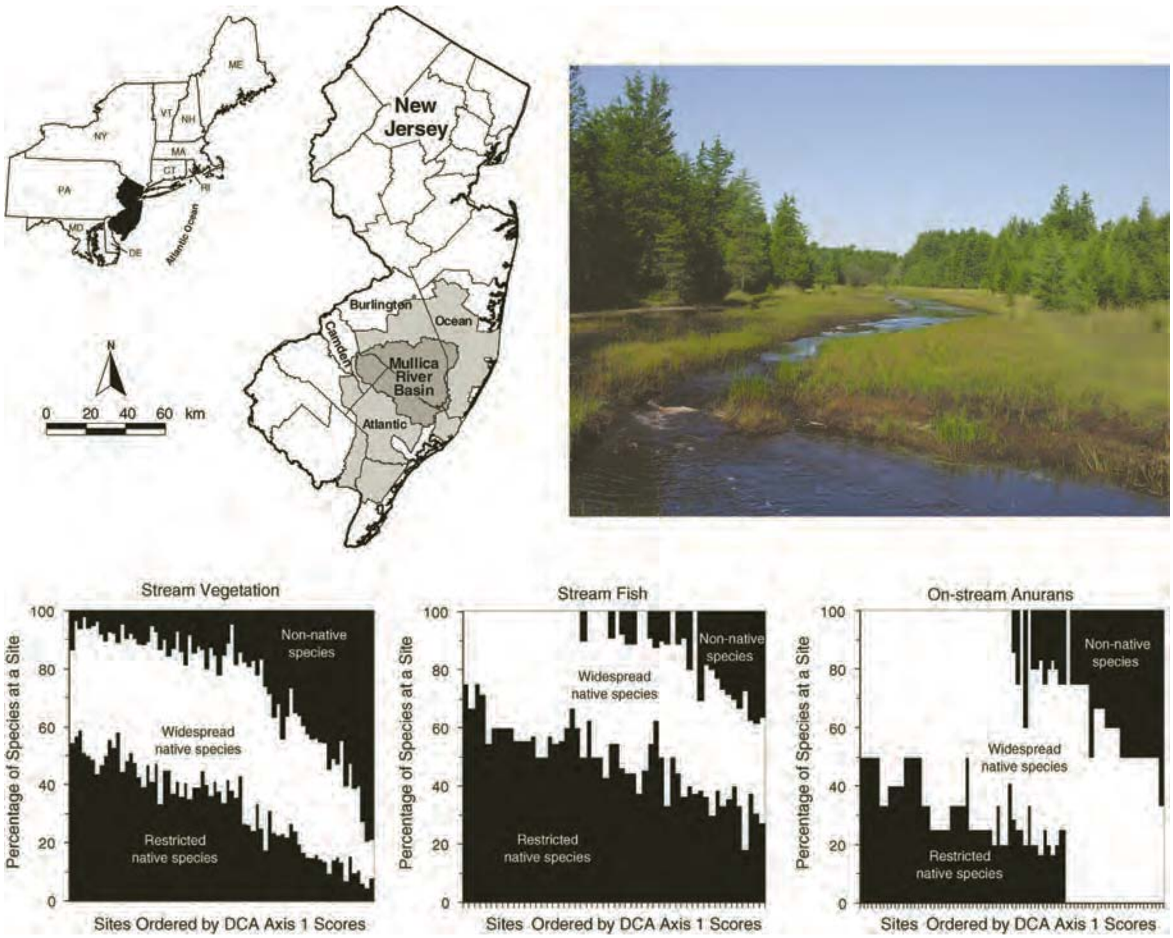

FIGURE 14.17 The composition of plants, stream fish, and frogs/toads changes along a gradient of human impact. These 88 sites from the Mullica River basin in New Jersey are ordered by scores obtained from detrended correspondence analysis (DCA) from least impacted by humans (left) to most impacted by humans (right). (From Zampella *et al.* 2006; photo of Tulpehocken Creek courtesy J. F. Bunnell.)

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