Wetland Environments

A Global Perspective

James Sandusky Aber / Firooza Pavri / Susan Ward Aber

free companion website

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Wetland environments: A global perspective

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with Figures and Tables from the book

DEDICATION

In memory of Kiira Aaviksoo (1955–2011), who pursued her passion for wetlands, stimulated a generation of students, and inspired our interest in Estonian bogs.

Preface

Why wetlands?

This question is often asked of the authors. Swamp, marsh, tundra, bog – these are places that are rarely visited and as such, perceptions prevail over observations so that people cannot visualize how wetlands might figure into their everyday lives. Wetlands simply do not appeal to most people from a practical or aesthetic point of view. Among the large urban and rural human populations of today, few are familiar with wetlands and fewer still have an active interest in understanding, enjoying, or protecting wetlands. In fact, for most people wetlands are wastelands – in other words, places to be converted, drained, filled, or exploited for industrial and economic uses.

For us, however, wetlands are intrinsically beautiful environments where one may see the natural and essential values in the interaction of water, soil, vegetation, wildlife, and humans (Fig. 1). Furthermore, individual wetlands are small pieces within the Earth's complex environment, a system that sustains us as well as all other life. At the transition from drylands to deep-water bodies, wetlands provide key links for the flux and temporary storage of energy and materials as well as crucial habitats for many plant and animal species. In addition to their modern environmental roles, wetlands also preserve in their sediments and fossils proxy records of past environments and climatic conditions, which help us to know how the present came to be and how the future might be. We are drawn to wetlands to observe and study their critical past and present environmental roles as well as to describe and enjoy their unique beauty.

The wetland-as-wasteland point of view may have been acceptable in the past, when human population was small and environmental effects were less understood and perceived to be insignificant. But this is no longer the case. Human population has surged from around one billion two centuries ago to seven billion today and will continue to grow rapidly in the near future. Population has more than doubled in the past half century, during which time global food and fresh-water consumption have more than tripled and use of fossil fuels has increased fourfold. Humans now co-opt at least one-third to as much as half of global photosynthesis (Foley 2010). In short, our exploitation of planetary resources has surpassed our quickly expanding population.

All aspects of the Earth's environmental system are impacted by this human assault on the planet, which includes vast conversions of land use, massive extraction of mineral resources and fossil fuels, heavy use of surface and ground water, and uncontrolled exploitation of many other non-renewable land and marine resources. The natural flows of energy and materials within the environment have been altered or disrupted as a result of modern human development.

Rockström et al. (2009a and 2009b) identified key processes for maintaining a sustainable global environment (Table 1). The boundaries set for these factors represent "tipping points" beyond which uncertain or irreversible consequences may take place. Three processes have

Figure 1. Aerial overview of the Rachel Carson National Wildlife Refuge along the Atlantic coast of southeastern Maine, United States (see Color Plate 1). The salt marsh, pools and tidal channels intervene between the beach front (right) and mainland (left), both of which have dense residential development. The human presence here has strong influence on the wetland water supply, vegetation and wildlife. View toward north; blimp airphoto by J.S. Aber, S.W. Aber and V. Valentine.

already exceeded their boundaries – biodiversity loss, nitrogen pollution, and atmospheric CO_2 increase – and other factors are approaching their limits (Foley 2010).

Of these critical processes, fresh-water use is most directly related to the subject of this book, namely wetlands. Several others are tied directly or indirectly to wetland environments as well – biodiversity loss, carbon cycle, nitrogen and phosphorus cycles, land use, ocean acidification, and chemical pollution. Wetlands are not only unique as individual environments, they also form critical connections between drylands and deep-water bodies with complex interactions and feedback relationships involving the atmosphere, hydrosphere, biosphere and lithosphere.

Why wetlands? We hope this book will foster a greater awareness and appreciation of wetlands, promote a culture of conservation and wise management, and spread the knowledge that wetlands are important, indeed crucial, elements of the global environment. Our attempts to understand, manage and enhance wetlands in the twenty-first century are parts of the larger effort to maintain a sustainable Earth for all people.

Table 1. Critical environmental processes, their boundaries, potential consequences, and possible solutions. * process that has exceeded its boundary value; based primarily on Foley (2010).

Process	Measurable rate or quantity: Pre-industrial	Current	Boundary	Consequences	Solutions
Biodiversity loss*	Extinction rate (species per million per year) 0.1 to 1.0	>100	10	Land and marine ecosystems fail	Slow land clearing and development; pay for ecosystem services
Carbon cycle*	Atmospheric CO_2 concentration (ppm) 280	387	350	Ice sheets, glaciers, sea ice and permafrost melt; global rise in sea level; regional climatic shifts	Switch to low-carbon fuels and renewable energy; pay for carbon emissions
Nitrogen cycle*	Removal from atmosphere (million tons per year) 0	133	39	Fresh-water and marine dead zones expand	Reduce fertilizer use; process animal waste; switch to hybrid vehicles
Phosphorus cycle	Removal from atmosphere (million tons per year) 1	10	12	Marine food chains disrupted	Reduce fertilizer use; process animal and human waste better
Land use	Percentage converted to cropland Negligible	11.7	15	Ecosystems fail; CO_2 escapes	Limit urban sprawl; improve farm efficiency; pay for ecosystem services
Ocean acidification	Aragonite saturation in surface water (Omega units) 3.44	2.90	2.75	Coral reefs and microorganisms die; carbon sink reduced	Switch to low-carbon fuels and renewable energy; reduce fertilizer runoff
Fresh-water use	Rate of human consumption (km^3 per year) 415	2600	4000	Aquatic ecosystems fail; water supplies disappear	Improve irrigation efficiency; install low-flow applicances
Ozone depletion	Stratospheric ozone concentration (Dobson units) 290	283	276	Radiation harms humans, plants and animals	Phase out hydrochlorofluorocarbons; test effects of new chemicals
Aerosol loading	Particulate concentration in atmosphere (values to be detemined)			Regional climatic shifts; variable and unpredicable	Reduce atmospheric emissions from power plants and vehicles
Chemical pollution	Amount emitted to or concentrated in environment (values to be detemined)			Toxic contamination; variable and unpredictable	Reduce all chemical emissions to the air, water, and ground

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Cover image: Panorama of Russell Lakes State Wildlife Area with the Sangre de Cristo Range in the far background; south-central Colorado, United States. Saline lakes and marshes occupy hollows between low, mesquite-covered dunes. Blimp aerial photo by James Aber and Susan Aber.
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Plate 1. Aerial overview of the Rachel Carson National Wildlife Refuge along the Atlantic coast of southeastern Maine, United States. The salt marsh, pools and tidal channels intervene between the beach front (right) and mainland (left), both of which have dense residential development. The human presence here has strong influence on the wetland water supply, vegetation and wildlife. View toward north; blimp airphoto by J.S. Aber, S.W. Aber and V. Valentine.

Plate 1-9. Presque Isle is a sandy spit that extends from the mainland into Lake Erie in northwestern Pennsylvania, United States. 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.

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Plate 2-2A. Water is the primary ingredient for wetlands. Nigula Bog, southwestern Estonia. Water fills numerous shallow pools of irregular size and shape. *Sphagnum* moss (reddish brown) surrounds each pool, and in between the pools, low hummocks are covered with heather and dwarf pines. A wooden walkway about half a meter wide is laid directly on the bog surface and runs across the bottom and right sides of the scene. Kite aerial photo (Aber et al. 2002).

Plate 2-10. Sangre de Cristo Formation exposed near Cuchara in south-central Colorado, United States. Several thousand meters of red sandstone, shale and conglomerate accumulated as alluvial fans during the Permian when the Ancestral Rocky Mountains were uplifted. The red color indicates oxidizing conditions in the depositional environment. These strata were tilted upward later, when the modern Rocky Mountains were deformed in the Eocene. Photo by J.S. Aber.

Plate 2-5A. Bimini Islands and Cat Cays, Bahamas. Shoals of carbonate sediment show distinctly as pale blue through the shallow, clear water of Grand Bahama Bank. False-color Landsat image in which vegetation on islands appears in red. Field of view ~75 km across; image courtesy of NASA Goddard Space Flight Center.

Plate 2-12. Watercress (*Rorippa nasturium-aquaticum*), an emergent wetland plant. A member of the mustard family (Cruciferae), it is a succulent, long-stemmed plant growing in tangled masses or low mounds up to ~30 cm (1 foot). The leaves have a strong peppery taste; watercress is highly valued for food flavoring and medicinal uses (Tilford 1997). Watercress absolutely requires clear, flowing water with temperatures <18 °C (65 °F), which means it favors spring-fed streams. Flint Hills of east-central Kansas, United States; photo by J.S. Aber.

Plate 2-16. Salt marsh and swamp at the Wells National Estuarine Research Reserve. Panorama looking toward the southwest along the Atlantic coast of southeastern Maine, United States. A bridge on Drakes Island Road (*) is part of a water-control structure that limits tidal flow between the marine lagoon in the background and marsh in the foreground. Notice the distinct vegetation zones, which reflect variations in water depth and salinity. Blimp airphoto by J.S. Aber, S.W. Aber and V. Valentine.

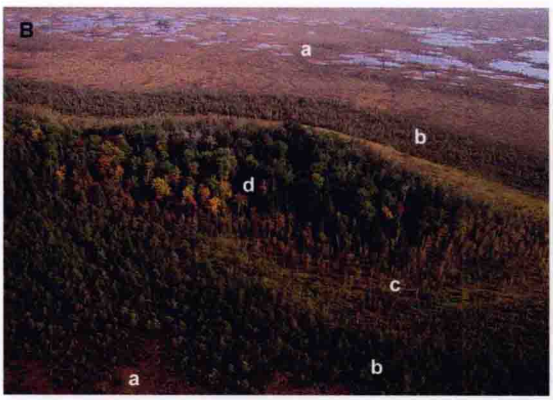

Plate 2-25B. Close-up view of tree-covered mineral island developed on a drumlin. Note distinct vegetation zones: (a) *Sphagnum* moss, (b) pine, (c) birch (partly bare), and (d) ash, elm, maple and other deciduous hardwoods, some of which display fall colors. Kite aerial photo; Aber et al. (2002).

Plate 3-4. The man-made pond in the foreground trapped recent runoff and has a high content of yellowish-brown suspended sediment. The next pond downstream did not receive this sediment and has a clean, dark blue appearance. Central Kansas, United States. Kite aerial photo by J.S. Aber and S.W. Aber.

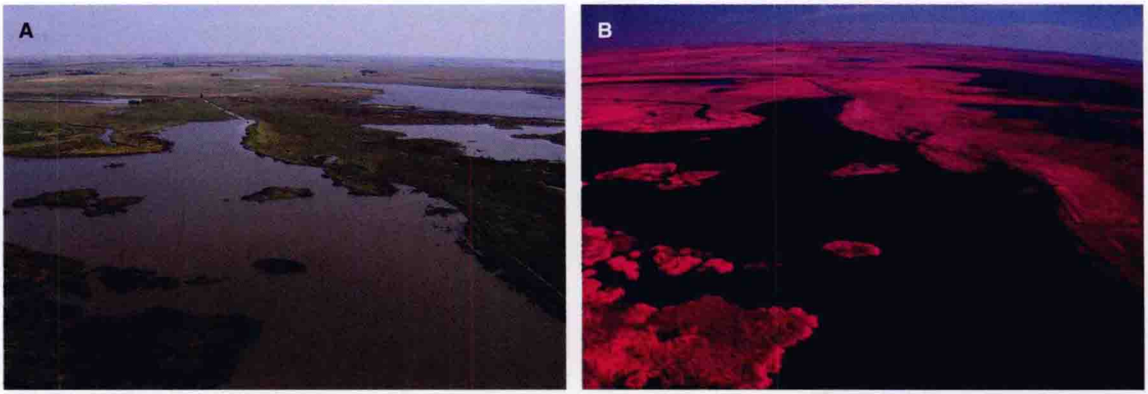

Plate 3-8. Color-visible (A) and color-infrared (B) digital images of marsh at the Nature Conservancy, Cheyenne Bottoms, central Kansas, United States. Active vegetation appears in bright red-pink colors in the latter. Kite aerial photographs from Aber et al. (2009, Fig. 5).

Plate 3-9. Close-up view of marsh and shore at Luck Lake, Saskatchewan, Canada. Distinctive vegetation zones are revealed by differences in plant texture, pattern, and color. The maroon plant is red samphire (*Salacornia rubra*), which grows on saline mudflats. Kite aerial photo by J.S. Aber and S.W. Aber.

Plate 3-10. Vertical kite aerial photograph in visible light showing water pools and vegetated hummocks in the central portion of Männikjärve Bog, Estonia. *Sphagnum* moss species display distinctive green, gold, and red autumn colors along with pale green dwarf pine trees on hummocks. These dramatic colors are not displayed so clearly at other times of the year. Field of view ~60 m across. Based on Aber et al. (2002, Fig. 2).

Plate 3-11. Red Hills in Barber County, southern Kansas, United States. Alluvial sediment accumulated in an ancient desert floodplain environment and is now eroding in a badlands topography. Bright red color indicates oxidizing conditions of deposition. Kite airphoto by S.W. Aber.

Plate 3-12. Exposed mudflat on the shore of Luck Lake, Saskatchewan, Canada. Color analysis of this photograph gives light gray to pale blue-green colors for the mud, indicating reducing conditions in the sediment. Kite aerial photo by J.S. Aber and S.W. Aber.

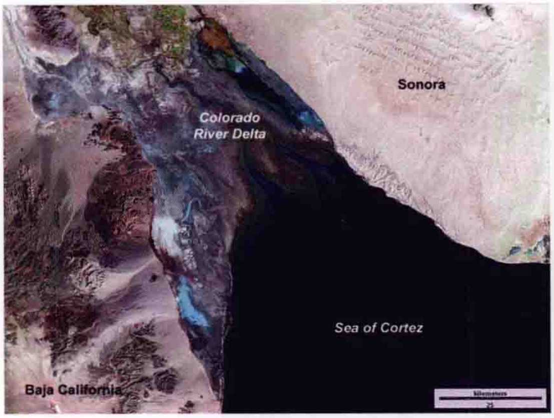

Plate 3-14. False-color composite Landsat TM image of the Colorado River delta in the Sea of Cortez, Mexico. Bands 3 (red), 4 (near-infrared) and 5 (mid-infrared) color coded as blue, green and red. Irrigated crops are bright yellow-green; dry mud/salt flats are bright cyan; sand dunes are near white. Landsat 5, March 2004. Image from NASA; processing by J.S. Aber.

Plate 3-17. Ikonos false-color composite of Fort Leavenworth, northeastern Kansas, United States. Green, near-infrared and red bands color coded as blue, green and red; active vegetation appears dark green to yellow-green colors. Dataset acquired August 2000; compare with Figure 3-16. Image from NASA; processing by J.S. Aber.

Plate 3-23. Playa basins on the nearly flat, featureless High Plains in west-central Kansas, United States. Ephemeral lake in a playa depression during a wet period. Water fills a shallow basin in a fallow field with green winter wheat fields in the background. Kite aerial photograph; after Aber and Aber (2009, Fig. 17).

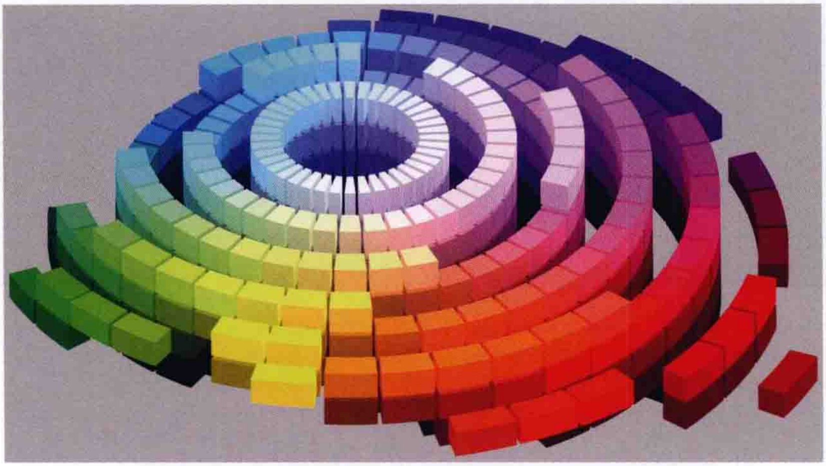

Plate 3-28. Schematic illustration of the Munsell Color system. Hue is the spectral color (circumference); chroma is the intensity of color (radius); value is the brightness (vertical axis). Modified from original illustration by SharkD; obtained from Wikimedia Commons <http://commons.wikimedia.org/>.

Plate 3-29. Distinctive colors are displayed in this wetland soil. Dark gray/brown indicates a high content of organic matter, and orange mottles show oxidized iron. Taken from Vasilas, Hurt and Noble (2010, Fig. 7).

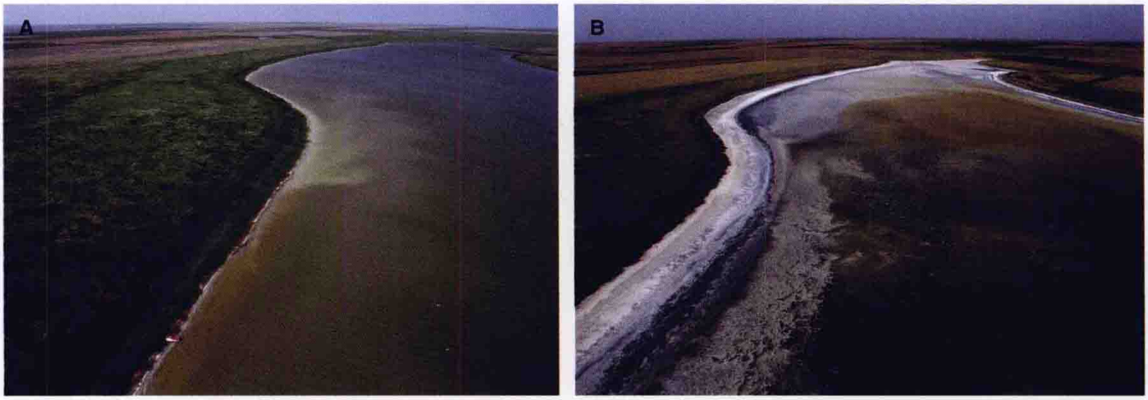

Plate 4-3. Overview of Dry Lake, an ephemeral lake at the terminal point of an enclosed basin on the High Plains in west-central Kansas, United States. A. May 2007, a wet year with the lake full of water; note small overturned row boat in lower left corner for scale. B. May 2008 displays a wet mudflat surrounded by salty soil. Similar views toward the southwest; kite airphotos by S.W. Aber and J.S. Aber.

Plate 4-6. Marsh-pond complex in the Sand Hills near Lakeside in western Nebraska, United States. Bright maroon and golden-orange colors in this pond are presumably caused by carotenoid pigments of invertebrates, such as brine shrimp, brine flies and rotifers, in the hyperalkaline water typical of the western Sand Hills region (Bleed and Ginsberg 1990). Kite airphoto by S.W. Aber and J.S. Aber.

Plate 4-12A. Finney Wildlife Area in southwestern Kansas, United States. Originally designed for a much larger lake, upstream ground-water pumping has reduced spring flows, and diversion of surface water has rendered this artificial "lake" into a wetland wildlife area. During rare wet years, a tiny puddle of water is held behind this dam. Asterisk indicates position of the outlet tower. Kite airphoto by J.S. Aber.