MODULE 2: AN INTRODUCTION TO WETLAND FUNCTIONS AND VALUES

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OVERVIEW

Wetlands provide many ecosystem services that benefit people economically. Improvements in water quality and protection from flood damage are the most valuable services provided, and tidal coastal wetlands, estuaries and floodplains are types of wetlands that are particularly important to contributing those services. The biodiversity in wetlands provides many values to people, including recreation, food supplies, and cultural values. Historical wetland losses have been extensive in many parts of the world, both from agricultural and urban development. Climate change will likely exacerbate wetland destruction as hotter and drier conditions and rising sea levels threaten wetlands. Increased decomposition rates in tundra peatlands from increasing temperatures is a major concern as a positive feedback to global warming because it will release more of the greenhouse gases that contribute to climate change.

ECONOMIC VALUATION OF WETLANDS

Wetlands are among the most valuable habitats on earth. Costanza et al. (1997, 2014) quantified the values of the ecosystem services that the world's different habitats provide. Ecosystem services are attributes of natural habitats that provide humans with things of economic value, that otherwise people would have to pay for. For example, some wetlands are locations for ecotourism, where visitors contribute money to the local economy, while other wetlands help purify water, reducing costs of making water potable for human consumption. For an individual, one might consider the costs and benefits of developing a wetland (e.g., turning it into a cornfield) versus how much they would save or accrue by conserving it. The analyses by Costanza et al. found that, after coral reefs, the four most valuable natural habitats on the globe (on a per hectare basis) were wetlands, specifically tidal saltmarsh/mangrove wetlands, estuarine wetlands, coastal sea-grass/algae beds, and swamp/floodplain wetlands.

Habitat Type	Value (2007 US $/hectare/yr)
1. Coral Reefs	352,249
2. Tidal Marshes/mangroves	193,843
3. Estuaries	28,916
4. Coastal sea-grass/algae beds	28,916
5. Swamps/floodplains	25,661
6. Lakes/rivers	12,512
7. Tropical Forests	5,382
8. Grasslands	4,166
9. Temperate/boreal forests	3,137
10. Continental shelf	2,222
Other Notable Habitats:	
Open Oceans	660
Urban Land	6,661
Cropland	5,567

Table 1. Ten most valuable natural habitat types on earth, on a per hectare basis

Source: Costanza et al. 2014

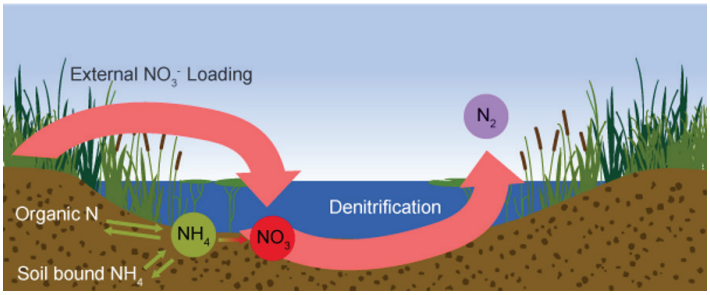
These wetland habitats benefit humans by providing substantial services that otherwise would be very costly to implement. Below we outline the most important ecosystem services that wetlands provide.

WETLANDS REGULATE WATER QUALITY AND QUANTITY

Wetlands are low spots on the landscape and water tends to flow towards them, often laden with sediments and pollutants. Deep waterbodies like rivers, lakes, and oceans often have margins of wetland habitat on their peripheries that mitigate the impacts of pollutants. Wetlands possess several characteristics that naturally enable them to purify water. When wetlands are inundated, the water tends to be shallow and thus the water column interacts extensively with the substrate. Plants and debris on the substrate will physically filter sediments from the water, cleaning it.

Additionally, flooded wetland soils frequently become anoxic (i.e., no oxygen present) due to microbial activity using up available oxygen. The microbial communities must then turn to alternative ways to "respire," and many wetland microbes use molecules other than oxygen to survive. Nitrate is a preferred option for microbial respiration in anoxic conditions.

Nitrate is a common pollutant from fertilizer use and is also a major pollutant in wastewater (Bijay-Singh & Craswell 2021). Nitrate is problematic in rivers, lakes, and oceans because it causes eutrophication, sometimes leading to algal blooms. For example, a "dead zone" exists in the Gulf of Mexico where most marine life cannot live. It is caused by nitrates flowing into the ocean from the Mississippi River (Rabalais et al. 2002), which induce algal blooms. The decomposition of the algae uses up much of the oxygen in the water, leading to the dead zone. When nitrate laden water flows into wetlands, however, the nitrate is rapidly converted by microbes to harmless nitrogen gas (which naturally makes up most of the atmosphere) through a process called denitrification (see diagram below; Keddy 2000). In this way, wetlands purify the water and protect connected deep-water bodies.



Pathways of nitrogen in wetlands. (Courtesy of Iowa State University Extension Service)

Natural wetlands provide an enormous value towards cleaning water at no cost. Sometimes, municipalities intentionally create wetlands as a low-cost way to treat wastewater to take advantage of their ability to filter out solids and to eliminate nitrate from water. Costanza et al. (1997) placed a value of >$20,000/hectare/year (ha/yr) for estuaries and almost $10,000/ha/yr for floodplains in terms of services associated with improving water quality. More generally, cycling of multiple nutrients (especially nitrogen, phosphorus, and carbon) is a valuable function of most wetlands. These processes are explained in more detail in a supplemental PowerPoint presentation available at https://www.sws.org/.

Another major service provided by wetlands is flood protection. Many wetlands function like "sponges" on the landscape, absorbing excessive water from flood events and then slowly releasing the water to rivers and streams, oceans, or groundwater aquifers. Efforts to break the connection between rivers and their adjacent floodplain wetlands by channelization (cutting a straight path through a winding river), or constructing levees to prevent flooding of fields or houses that have been built on the floodplain, greatly reduce the capacity of the floodplains to absorb water. Ultimately, these river modifications have disastrous consequences for people living downstream, because the river floodplains can no longer absorb rising waters after a heavy rain event, leading to massive flooding downstream. With extreme rain events becoming more common (https://www.ipcc.ch/ar6-syr/), conserving or restoring wetlands could provide a useful mechanism to make landscapes more resistant to floods, thereby protecting humans. Moreover, allowing floodplain habitats converted into agricultural use to be periodically flooded may enhance their productivity, reducing the need for costly artificial fertilization. In a similar way, coastal wetlands such as mangroves and salt marshes provide developed seashore areas with protection from storm surges and tsunami waves. Coastlines are often highly developed, such that the flood protection service provided by coastal wetlands is very valuable; this is the main reason coastal tidal wetlands have extremely high values (see Table 1; Costanza et al. 2014).

Floodplain wetlands absorb excess water from large floods, reducing how high the water rises, and protecting people's property. Croplands on floodplains are enriched by the flooding, and those lands can become especially productive for crops after the floods subside. (Photo: © Chris Boyer, kestrelaerial.com)

WETLANDS SUPPORT SUBSTANTIAL BIODIVERSITY (MICROBES, PLANTS AND ANIMALS)

A host of organisms are adapted specifically to live in wetlands and occur nowhere else. Because of these wetland "specialists," wetlands contribute greatly to the overall biodiversity of many regions. The

biodiversity of wetlands is of significant non-monetary value. But much of this biodiversity also enhances human life. Wetlands are favorite locations for people to view birds, other wildlife, and unique plants, and ecotourism to prominent wetlands can be important to the local economy. For example, over 1 million people per year visit Everglades National Park, and all expect to see alligators. The Okavango Delta in Botswana and the Amazon basin are major birding and wildlife ecotourism destinations. In China, cranes are important birds to the national culture, and many wetlands there have been specifically preserved as habitat for these iconic birds. Wetlands associated with oceans, estuaries, river floodplains, and lake margins can be valuable nursery habitats for fish and shellfish, and in this way support many fisheries, both commercial and recreational (Schultz et al. 2020). Hunters and trappers harvest ducks and select mammals from wetlands, and in some areas, such as the Prairie Pothole Region of North America, this activity is of major economic importance. Wetland forests can be sustainably harvested to provide wood and fiber for human use. Many animals in adjacent uplands and rivers/lakes/oceans benefit from wetlands by using them as refugia or foraging areas, so the benefits of wetlands to biodiversity extends beyond their boundaries. As mentioned above, the anaerobic microbes that prevail in wetlands are important to water purification. Overall, the plants, animals, and microbes of wetlands provide a range of economic benefits to people. Costanza et al. (1997) placed a value of up to $1000/ha/yr for wetland services associated with recreation and food supplies, which mostly revolve around biodiversity. Because of the ongoing loss of wetland habitats, wetland plants and animals are at risk and are prominent components of many threatened and endangered species lists.

Wetlands support plants found nowhere else such as these cypress and tupelo trees. (Photo: Darold Batzer)

A wide range of birds, such as these Florida sandhill cranes in the Okefenokee Swamp, use wetlands as habitats. (Photo: Okefenokee National Wildlife Refuge)

Wetlands are homes for a diversity of frog and salamander species such as these ornate chorus frogs. (Photo: Kevin M. Enge, Florida Fish and Wildlife Conservation Commission)

WETLANDS PROVIDE RECREATIONAL AND CULTURAL VALUES TO PEOPLE

We have already mentioned that ecotourism, fishing, and hunting result in some wetlands being major sources of economic activity. Boating and canoeing are additional important recreational activities associated with wetlands.

The benefits of wetlands to human societies are not new. Many "cradles of civilization" are associated with wetlands, such as the marshes of the Fertile Crescent along the Tigris and Euphrates Rivers (https://en.wikipedia.org/wiki/Marsh_Arabs) and the Nile River

Many aquatic insects, such as this dragonfly, inhabit wetlands. (Photo: Clesson Higashi, University of Georgia, Graduate Student)

Delta and floodplain. In these areas, wetlands provided fish as protein, and annual flooding produced fertile agricultural fields. In North America, certain wetlands such as the Okefenokee Swamp, the Florida Everglades, many saltmarshes, and wildrice lakes have long had special importance to native peoples. Today, nature centers occur in many urban areas, where residents can go to experience natural environments; many are located in association with wetlands, especially river corridors. Costanza et al. (1997) placed a value of up to $2000/ha/yr for the cultural values of some wetlands.

Reed houses, Iraq marshes. (Photo by Paul Dober, WikiCommons)

WETLANDS ARE IMPORTANT TO REGULATING CLIMATE CHANGE

Climate change is caused primarily by increasing levels of carbon dioxide and other greenhouse gases in the atmosphere. One service that wetlands provide to humanity is slowing the rate of global warming, as well as ocean acidification, by taking carbon out of circulation. Plants take CO2 out of the atmosphere by photosynthesis and use it to build their own tissues. The physical structure of plants also traps particles of organic matter that otherwise would decompose into CO_2. To the extent that this carbon is stored for a long time, either as wood or buried in sediments, it no longer contributes to global warming and ocean acidification.

In some wetlands, more carbon is fixed or trapped each year than is decomposed, and peat can develop (peat is partially decomposed plant matter). This is a unique feature of wetlands because the anaerobic nature of their soils slows decomposition, allowing organic matter to accumulate. Over long periods of time, vast deposits of peat have developed in some wetlands (Bridgham et al. 2006), especially in the northern peatlands of Canada, Russia, and other Arctic countries. At the same time, peatlands also release significant amounts of methane each year (Bridgham et al. 2006). Methane, produced by anaerobic decomposition, is a potent greenhouse gas. Thus, in terms of climate change, peatlands provide a benefit by sequestering carbon dioxide but that benefit is counteracted by the release of methane (although fortunately methane breaks down quickly in the atmosphere). This example illustrates that assessing how wetlands affect concentrations of greenhouse gases in the atmosphere is complicated. However, should temperatures rise in regions where peat is abundant (such as the tundra), and decomposition rates there increase, peatlands may become an important source of new greenhouse gases to the atmosphere, exacerbating climate warming (Bridgham et al. 2006). Thus, the fate of peatlands is a major concern in terms of future climate change.

Northern peatland, Alaska. (Photo courtesy of NOAA)

Almost all natural communities trap carbon to some extent, but coastal wetlands are particularly good at it. Plant productivity in coastal wetlands is often high, due to abundant water and nutrients. At the same time, because sea level is rising several millimeters per year, large amounts of sediment tend to accumulate on the surface of coastal wetlands each year. This sediment is a combination of dead plant material produced within the wetland and particulate material settling out of the tidal water. In either case, the result is that large amounts of carbon are buried in anoxic sediments where it is slow to decompose. At the same time, coastal wetlands produce little methane compared to freshwater wetlands. For all these reasons, coastal wetlands can store carbon (called "blue carbon," because it is marine) at much higher rates per hectare than freshwater wetlands or terrestrial habitats. This ability of coastal wetlands to store carbon at high rates suggests that coastal wetlands should be an important part of the portfolio of nature-based solutions to climate change and provides an important argument for their protection and wise management.

Coastal saltmarsh in Georgia, USA. (Photo by Steven Pennings)

WETLAND LOSSES THREATEN THE BENEFITS WETLANDS PROVIDE TO PEOPLE

Many wetlands occur, or previously occurred, in places desirable for human development. For example, humans tend to live near water bodies, such as rivers and oceans, and wetlands naturally occur there. Due to development pressures, many coastal wetlands have been converted to ports, marinas, and housing developments (see photos below). Other coastal wetlands have been converted into aquaculture ponds for raising shrimp and crabs. Further inland, people discovered that drained freshwater wetlands can be converted to productive croplands. The shallow nature of wetlands makes them relatively easy for humans to develop (although difficult to maintain due to flooding and subsidence). Historically, agricultural development was the primary reason for wetland destruction. For example, the plains of Iowa and the Central Valley of California, USA, both major agricultural regions, have lost over 90% of their wetlands (Dahl 2000). In northeast China, vast areas of wetland have been converted to rice agriculture (Song et al. 2014). In recent decades, losses of wetlands due to agriculture have slowed, but losses due to urban development have increased (Brinson and Malvárez 2002). Intact wetlands tend to remain in places that are not desirable cropland (e.g., tundra) or in places difficult to drain such as deep-water wetlands. Despite the knowledge that wetlands are valuable, threats to wetlands persist to this day. Isolated wetlands—those not directly associated with rivers, lakes, or oceans—have recently lost some of the legal protections in the US that formerly existed, and those kinds of wetlands are particularly vulnerable to draining or filling for agricultural or urban development. The global area of floodplain wetlands has been dramatically reduced even in this century (https://eos.org/articles/natural-floodplains-are-quickly-vanishing).

Top: A natural estuarine wetland of coastal Washington State, USA. Bottom: A similar nearby estuarine wetland area that was drained and filled for commercial proposes. (Photos by Michelle Ryder [top] and Ashley Christensen [bottom])

Most wetlands that have already been destroyed are in areas considered valuable to humans, and thus restoring them back to a natural condition would come at a high economic cost. This is why it is so important to realize that wetlands have economic values in and of themselves. Wetland restoration can provide useful economic benefits to society, even when expensive (e.g., Schultz et al. 2020). Conserving wetlands that still exist also provides economic value.

Wetlands and the services that they provide are considered particularly vulnerable to climate change compared to other habitat types (Poff et al. 2002). Because they are shallow, many freshwater wetlands may dry up and disappear should temperatures increase or rainfall decrease. Coastal wetlands may become inundated by rising sea levels, and because terrestrial habitat adjacent to many coastal wetlands is developed, many coastal wetlands cannot expand inland as water levels rise—a phenomenon termed "coastal squeeze." Even where wetlands persist, climate change may reduce many of the valuable ecosystem services that wetlands provide (e.g., wetlands that dry or are flooded briefly may no longer effectively process nitrate pollutants or provide habitat for valuable wetland plants or animals). Because wetlands are valuable, but also at high risk of loss, there is considerable interest in managing the wetlands that remain, restoring degraded wetlands, and creating new wetlands to replace those that have been lost.

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REFERENCES CITED

Bijay-Singh and E. Craswell. 2021. Fertilizers and nitrate pollution of surface and ground water: an increasingly pervasive global problem. *SN Applied Sciences* 3(4), 518. https://doi.org/10.1007/s42452-021-04521-8

Bridgham, S. D., J. P. Megonigal, J. K. Keller, N. B. Bliss, and C. Trettin. 2006. The carbon balance of North American wetlands. *Wetlands* 26: 889-916.

Brinson, M. M. and A. I. Malvárez. 2002. Temperate freshwater wetlands: types, status, and threats. *Environmental Conservation* 29: 115-133.

Costanza, R., d'Arge, R., De Groot, R., Farber, S., et al. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387(6630): 253-260.

Costanza, R., R. De Groot, P. Sutton, S. Van der Ploeg, et al. 2014. Changes in the global value of ecosystem services. *Global Environmental Change* 26: 152-158.

Dahl, T. E. 2000. Status and trends of wetlands in the conterminous United States 1986 to 1997. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Keddy, P. A. 2010. *Wetland Ecology: Principles and Conservation.* Cambridge University Press.

Poff, N. L., M. M. Brinson, and J. W. Day. 2002. Aquatic Ecosystems and Global Climate Change. Pew Center on Global Climate Change, Arlington, VA, 44:1-36.

Rabalais, N. N., R. E. Turner, and W. J. Wiseman Jr. 2002. Gulf of Mexico hypoxia, aka "The dead zone." *Annual Review of Ecology and Systematics* 33: 235-263.

Schulz, K., P. W. Stevens, J. E. Hill, A. A. Trotter, et al. 2020. Coastal wetland restoration improves habitat for juvenile sportfish in Tampa Bay, Florida, USA. *Restoration Ecology* 28: 1283-1295.

Song, K., Z. Wang, J. Du, L. Liu, L. Zeng, and C. Ren. 2014. Wetland degradation: its driving forces and environmental impacts in the Sanjiang Plain, China. *Environmental Management* 54: 255-271.

OTHER SUGGESTED READINGS

Batzer, D.P. and A.H. Baldwin (eds.). 2012. *Wetland Habitats of North America: Ecology and Conservation Concerns.* University of California Press, Berkeley, CA.

Mitsch, W.J., B. Bernal, and M.E. Hernandez. 2015. Ecosystem services of wetlands. *International Journal of Biodiversity Science, Ecosystem Services & Management* 11: 1-4.

Mitsch, W.J. and J.G. Gosselink. 2015. *Wetlands*. 5th Edition. John Wiley & Sons, Hoboken, NJ.

National Research Council, Committee on Characterization of Wetlands. 1995. *Wetlands: Characteristics and Boundaries.* National Academy Press, Washington, DC.

Tiner, R.W. 2005. *In Search of Swampland: A Wetland Sourcebook and Field Guide*. 2nd Edition. Rutgers University Press, New Brunswick, NJ.

Tiner, R.W. 2013. *Tidal Wetlands Primer: An Introduction to Their Ecology, Natural History, Status, and Conservation.* University of Massachusetts Press, Amherst, MA.

Xu, X., M. Chen, G. Yang, B. Jiang, and J. Zhang. 2020. Wetland ecosystem services research: A critical review. *Global Ecology and Conservation* 22, e01027.

Zedler, J. B. and S. Kercher. 2005. Wetland resources: status, trends, ecosystem services, and restorability. *Annual Review of Environmental Resources* 30: 39-74.