A STUDY ON WETLAND ECOLOGY

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ABSTRACT

Wetlands are a critical part of our natural environment. They protect our shores from wave action, reduce the impacts of floods, absorb pollutants and improve water quality. They provide habitat for animals and plants and many contain a wide diversity of life, supporting plants and animals that are found nowhere else. Wetlands provide an important range of environmental, social and economic services. Many wetlands are areas of great natural beauty and many are important to Aboriginal people. Wetlands also provide important benefits for industry. For example, they form nurseries for fish and other freshwater and marine life and are critical to Australia's commercial and recreational fishing industries. Wetlands are the vital link between land and water. However, the present study has conducted to explore wetland ecology, to assess the types, characteristics and uses of wetland ecology. The study was documentary analysis type. Data and information were collected from secondary sources. Data were collected from Books, Research Reports, Journal, Thesis, Food and Agricultural Organization (FAO), United Nation Development Program (UNDP), Different Annual Reports. From the study it was found that wetland ecology is essential for human being, animals for forests, flora, fauna, environment, and ecosystem. Wetland ecology is needed for conservation of biodiversity. It is also important for climate change. From the wetland ecology, human being becomes benefitted in different ways. So, man should make different wetlands for their own interest and should take care the existing wetland ecology to protect the ecosystem and environment.

Key words: *Wetland, Ecology, Water purification, Biodiversity, Climate Change, Environment, Human activity, Flora, Fauna.*

INTRODUCTION

A wetland is typically an area of land that is completely saturated with water, whether all throughout the year or only during certain seasons. Because these areas of land are covered in water as well as a variety of different land and water dwelling plant life, they are well known to have rich and distinct ecosystems from, for instance, waterways or the dry land. As a direct result of this rich ecosystem, wetlands are especially important to the world because they are the homes of some of the most endangered wildlife and plant life in the world. Wetlands are important to us as they remove pollution, recharge groundwater supplies, control floods, and provide home for variety of plants and animals. Wetlands are important to fish and wildlife populations and that roughly 96 percent of commercially important species of fish are wetlands-dependent. A 1989 study by the American Fisheries Society's Endangered Species Committee found nearly one third of native North American freshwater fish species are endangered, threatened or of special concern. Of that number, 93 percent were adversely affected by habitat loss. In addition, one tenth of North America's freshwater mussels (such as clams) have become extinct. About three quarters of the remaining are classified as rare or imperiled. This is primarily due to habitat destruction from dam construction and pollution. Also, about 80 percent of America's bird population relies on wetlands, according to the U.S. Fish and Wildlife Service. A prime example is the wood stork, whose population has dropped from 60,000 birds in the 1930's to around 10,000 by 1984. This entire decline is attributed to the loss and degradation of wetlands, according to the U.S. Environmental Protection Agency's Office of Wetlands, Oceans and Watersheds. Some species of frogs, toads and salamanders depend exclusively on seasonal wetland areas as their only habitat. Seasonal wetlands are those areas that have standing water for relatively brief periods. They are temporary and often isolated, making them safe from predatory fish and other creatures, allowing the amphibians to thrive.

OBJECTIVES OF THE STUDY

The objectives of the study are as follows:
1. To explore wetland ecology.
2. To identify the types, characteristics and uses of wetland ecology.

METHODOLOGY OF THE STUDY

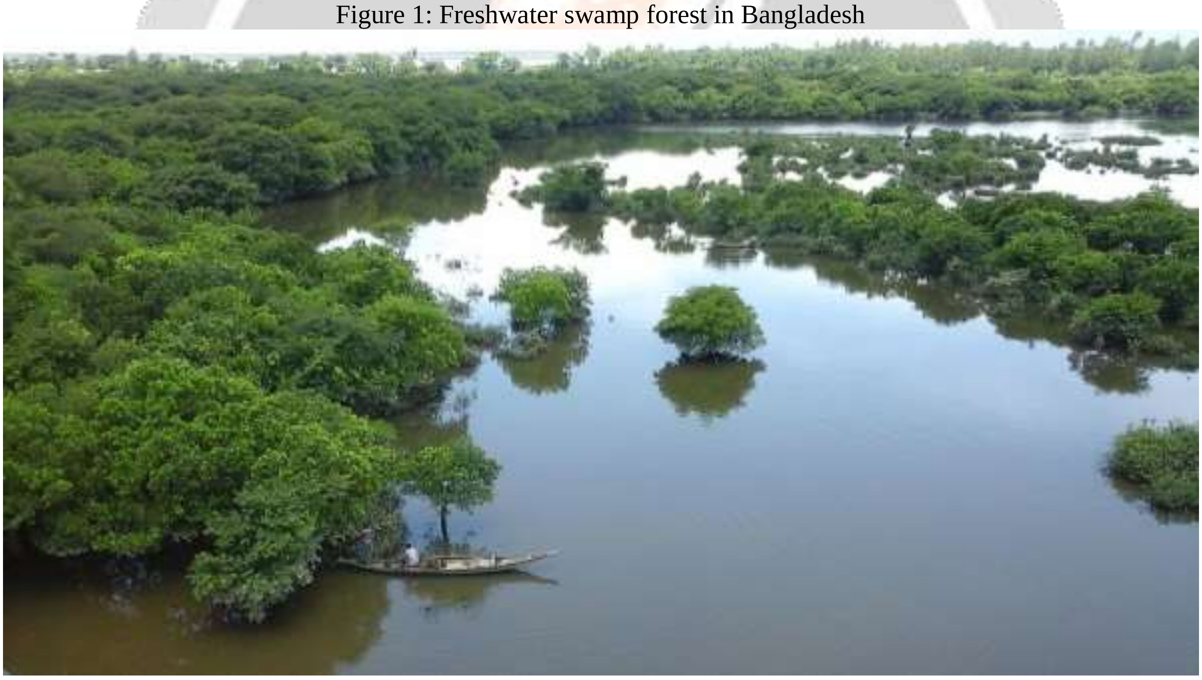
The study was documentary analysis type. Data and information were collected from secondary sources. Data were collected from Books, Research Reports, Journal, Thesis, Food and Agricultural Organization (FAO), United Nation Development Program (UNDP), Different Annual Reports.

DEFINITION OF WETLAND

Wetlands are a critical part of our natural environment. They protect our shores from wave action, reduce the impacts of floods, absorb pollutants and improve water quality. They provide habitat for animals and plants and many contain a wide diversity of life, supporting plants and animals that are found nowhere else.

A wetland is a distinct ecosystem that is inundated by water, either permanently or seasonally, where oxygen-free processes prevail.[1] The primary factor that distinguishes wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants,[2] adapted to the unique hydric soil. Wetlands play a number of functions, including water purification, water storage, processing of carbon and other nutrients, stabilization of shorelines, and support of plants and animals.[3] Wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal life. A patch of land that develops pools of water after a rain storm would not necessarily be considered a "wetland", even though the land is wet. Wetlands have unique characteristics: they are generally distinguished from other water bodies or landforms based on their water level and on the types of plants that live within them. Specifically, wetlands are characterized as having a water table that stands at or near the land surface for a long enough period each year to support aquatic plants.[4]

Figure 1: Freshwater swamp forest in Bangladesh



A more concise definition is a community composed of hydric soil and hydrophytes.[5] Wetlands have also been described as ecotones, providing a transition between dry land and water bodies.[6] Mitsch and Gosselink write that wetlands exist "...at the interface between truly terrestrial ecosystems and aquatic systems, making them

1 Keddy, P.A. (2010). Wetland ecology : principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

2 Butler, S., ed. (2010). Macquarie Concise Dictionary (5th ed.). Sydney, Australia: Macquarie Dictionary Publishers. ISBN 978-1-876429-85-0.

3 Wetlands". USDA- Natural Resource Conservation Center.

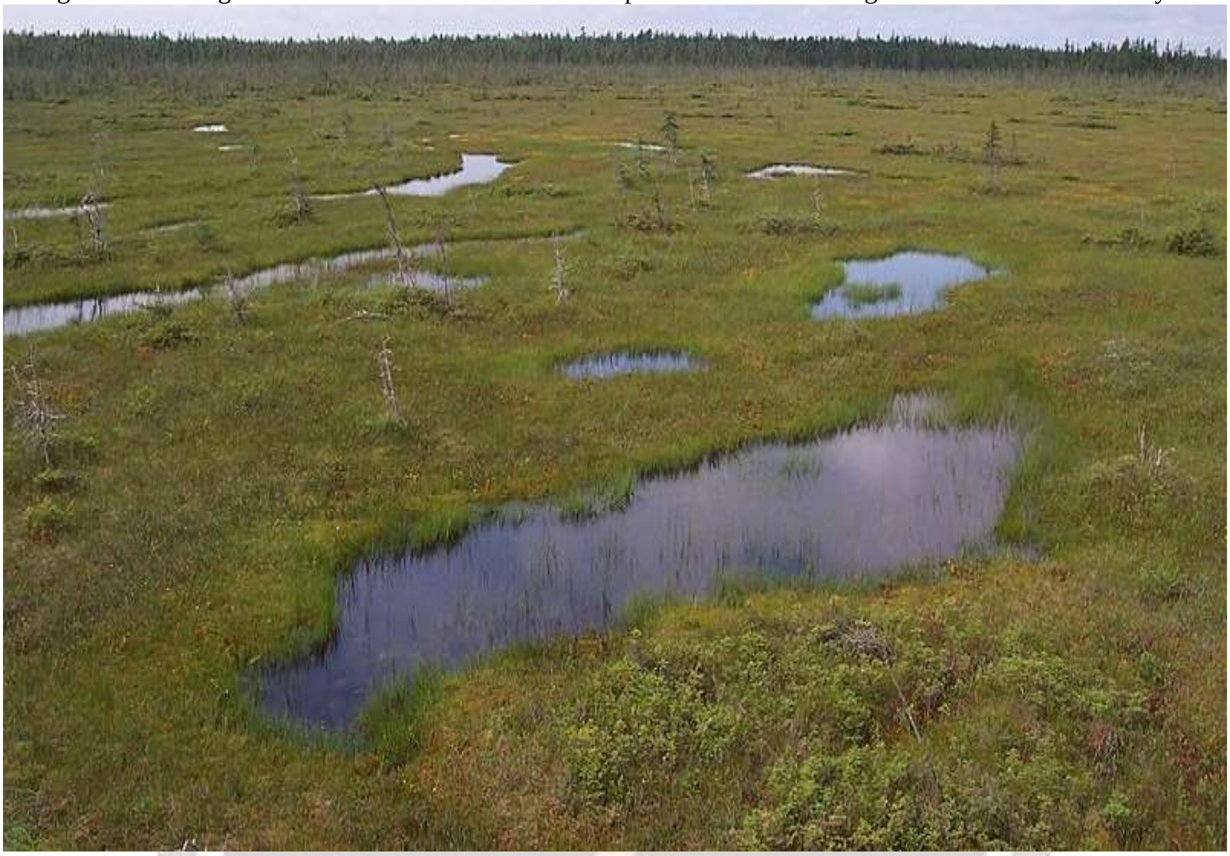
4 "Glossary of Terms". Carpinteria Valley Water District. Archived from the original on April 25, 2012. Retrieved 2012-05-23.

5 Keddy, P.A. (2010). Wetland ecology : principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

6 Glossary". Alabama Power. Archived from the original on 2012-03-21. Retrieved 2012-05-23.

inherently different from each other, yet highly dependent on both."[7] The Convention uses a broad definition of wetlands. This includes all lakes and rivers, underground aquifers, swamps and marshes, wet grasslands, peat lands, oases, estuaries, deltas and tidal flats, mangroves and other coastal areas, coral reefs, and all human-made sites such as fish ponds, rice paddies, reservoirs and salt pans.[8]

Figure 2: Peat bogs are freshwater wetlands that develop in areas with standing water and low soil fertility.



Technical definitions

A wetland is "an ecosystem that arises when inundation by water produces soils dominated by anaerobic and aerobic processes, which, in turn, forces the biota, particularly rooted plants, to adapt to flooding."[9] There are four main kinds of wetlands–marsh, swamp, bog and fen (bogs and fens being types of mires). Some experts also recognize wet meadows and aquatic ecosystems as additional wetland types.[10] The largest wetlands in the world include the swamp forests of the Amazon and the peat lands of Siberia.[11]

7 Mitsch, William J.; Gosselink, James G. (2007-08-24). Wetlands (4th ed.). New York, NY: John Wiley & Sons. ISBN 978-0-471-69967-5.

8 https://www.ramsar.org/about/the-importance-of-wetlands

9 Keddy (2010), p. 2.

10 Keddy, P.A. (2010). Wetland ecology: principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

11 Fraser, L.; Keddy, P.A., eds. (2005). The World's Largest Wetlands: Their Ecology and Conservation. Cambridge, UK: Cambridge University Press. ISBN 978-0521834049.

Figure 3: Sunrise at Viru Bog, Estonia

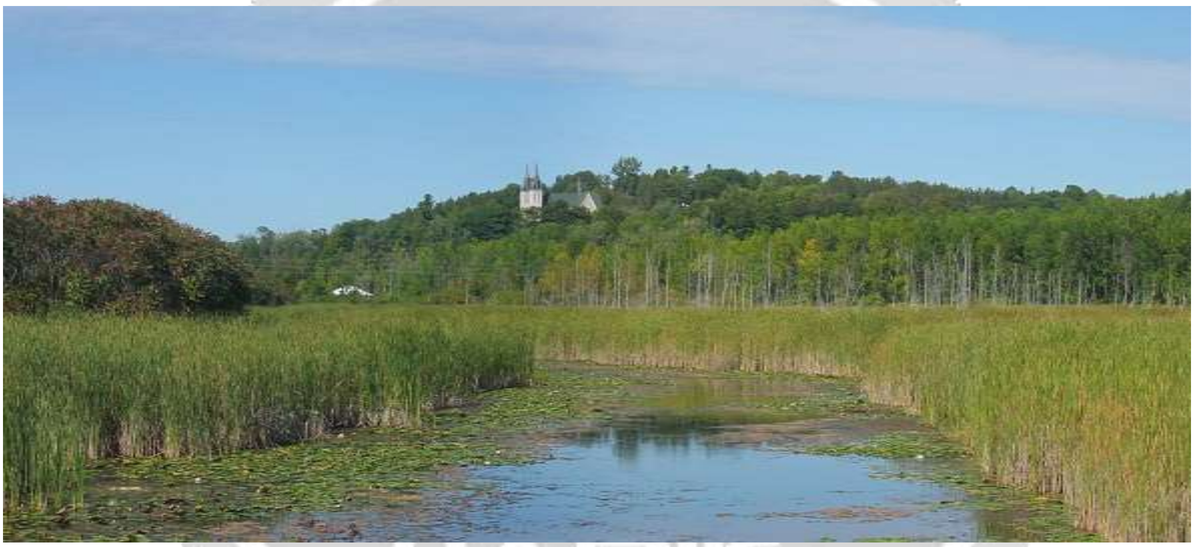


Figure 4: Marshes develop along the edges of rivers and lakes.

Ramsar Convention definition

Under the Ramsar international wetland conservation treaty, wetlands are defined as follows:[12]

Article 1.1: "...wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters."

Article 2.1: "[Wetlands] may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands."

DIFFERENT TYPES OF WETLANDS

There are a number of different types of wetlands that occur all over the globe. They are usually split into four distinct categories with further distinctions depending on location and other factors.

1. Marshes

Marshes are wetlands that are always inundated, rather than being submerged under water just during the summer or a couple of months over the year, for instance. Marshes can be freshwater or saltwater and amount of water in the marsh can change with the seasons. They boast a great variety of vegetation that has adapted

[12] The Ramsar 40th Anniversary Message for November". Ramsar. Retrieved 2011-10-10.

especially to live in saturated soil. There are a number of sub-categories of marsh, including freshwater, saltwater, inland and coastal. Each of these has their own distinct ecosystems and can be found all over the world. Marshes wildlife includes beavers, alligators, newts, shrimp and turtles.

2. Swamps

Swamps differ from marshes in that, typically, they are dominated by woody plants (rather than soft-stemmed plants). Some of these trees are often harvested by people from all over the world to make timber and to build their homes, which can affect the ecosystem drastically if too many are taken without being replaced with new saplings. Swamps are typically the home to various birds and fish as well as smaller creatures. Swamps like Everglades in Florida are found in low-lying areas near rivers or coastal areas. There are two main types of swamps: forested swamps and shrub swamps. Swamps are home to variety of animals like snakes, bobcat, alligators, beaver, and large diversity of birds.

3. Bogs

Bogs are characterized by more acidic waters and spongy peat deposits as well as a covering of sphagnum moss. Unlike marshes and swamps, bogs tend to get their wetness from precipitation rather than waterways such as streams or runoffs from rivers. These wetlands are fantastic for preventing downstream flooding since they absorb precipitation as it falls and prevents the swelling of rivers and other waterways. There are two sorts of bogs: northern bogs and pocosins.

4. Fens

Fens are, like bogs, peat-forming wetlands, although they usually get their wetness from ground water rather than precipitation, which mean that they are slightly less acidic. This means that they tend to support a greater array of wildlife, from plants to fish to birds and everything in between. Like bogs, fens are beneficial because they can help prevent the flooding of land elsewhere, since they soak up water from the ground and prevent it from seeping anywhere else.

TYPES OF WETLANDS IN BANGLADESH

a) Mangroves
b) Lagoons, salt ponds, salinas
c) Estuaries
d) Tidal creeks
e) Freshwater and brackish marshes
f) Swamp forests
g) Riverine forests
h) Palm and pine barrens
i) Coastal woodland

List of wetland types

The following list is that used within Australia to classify wetland by type:[13]

A—Marine and Coastal Zone wetlands

1) Marine waters—permanent shallow waters less than six meters deep at low tide; includes sea bays, straits
2) Subtidal aquatic beds; includes kelp beds, sea grasses, tropical marine meadows
3) Coral reefs
4) Rocky marine shores; includes rocky offshore islands, sea cliffs
5) Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets
6) Intertidal mud, sand or salt flats
7) Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
8) Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swamp forests
9) Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
10) Freshwater lagoons and marshes in the coastal zone
11) Non-tidal freshwater forested wetlands

[13] A Directory of Important Wetlands in Australia". Australian Department of the Environment. 2009-07-27. Retrieved 2012-05-23.

B—Inland wetlands

1) Permanent rivers and streams; includes waterfalls
2) Seasonal and irregular rivers and streams
3) Inland deltas (permanent)
4) Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
5) Permanent freshwater lakes (> 8 ha); includes large oxbow lakes
6) Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes
7) Permanent saline/brackish lakes
8) Seasonal/intermittent saline lakes
9) Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
10) Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes sloughs, potholes; seasonally flooded meadows, sedge marshes
11) Permanent saline/brackish marshes
12) Seasonal saline marshes
13) Shrub swamps; shrub-dominated freshwater marsh, shrub carr, alder thicket on inorganic soils
14) Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils
15) Peat lands; forest, shrub or open bogs
16) Alpine and tundra wetlands; includes alpine meadows, tundra pools, temporary waters from snow melt
17) Freshwater springs, oases and rock pools
18) Geothermal wetlands
19) Inland, subterranean karst wetlands

C—Human-made wetlands

1) Water storage areas; reservoirs, barrages, hydro-electric dams, impoundments (generally > 8 ha)
2) Ponds, including farm ponds, stock ponds, small tanks (generally < 8 ha)
3) Aquaculture ponds; fish ponds, shrimp ponds
4) Salt exploitation; salt pans, salines
5) Excavations; gravel pits, borrow pits, mining pools
6) Wastewater treatment; sewage farms, settling ponds, oxidation basins
7) Irrigated land and irrigation channels; rice fields, canals, ditches
8) Seasonally flooded arable land, farm land

Other classification systems for wetlands exist. In the US, the best known are the Cowardin classification system and the hydrogeomorphic (HGM) classification system.

Wetland names

Variations of names for wetland systems:

1. Backwater
2. Bayou
3. Marsh
   a) Brackish marsh
   b) Freshwater marsh
4. Swamp
   a) Freshwater swamp forest
   b) Coniferous swamp
   c) Peat swamp forest
   d) Mangrove swamp
5. Flooded grasslands and savannas
6. Constructed wetland
7. Riparian zone
8. Mire
   a) Fen
   b) Bog
9. Vernal pool

IMPORTANCE OF WETLANDS

Since there are a number of different types of wetlands, there are a number of benefits that each one offers. Not all of them offer the same benefits to animal life, plant life and even humans as others, but all of them are essential and it is very important to protect both them and the life that they support, some of which cannot be found anywhere else in the world.

1. Prevent Flooding

Most importantly, wetlands are best known to prevent flooding. Because the plant life and the soil in all different sorts of wetlands is used to being saturated with water, it can hold onto the water better than other areas (for instance, of forest or farmland). Water that falls as precipitation or that flows down from mountains in streams or that is present in the ground is caught and held in wetlands, which prevents other areas, perhaps further downhill, from flooding. This can have a positive impact not only on the environment as a whole, but is very useful for people who have build their settlements next to rivers or other waterways that might otherwise have been prone to flooding.

2. Release Vegetative Matter

Wetlands release water back into waterways and surrounding areas – although they do so slowly, which is why they are so good at preventing flooding. This water, after having been in areas that are so rich in various different sorts of plant life, is filled with vegetative matter that then finds its way into rivers and streams. This vegetative matter is absolutely essential for sustaining the fish that live in these waterways.

3. Rejuvenating Ecosystems

The releasing of vegetative matter also provides an essential in the amount of nutrients, seeds and other matter going into streams and rivers, not to mention other creatures. This can help to stabilize, rejuvenate or enrich ecosystems in areas around wetlands.

4. A Home for Animals

Many animals have wetlands as their homes. Birds such as herons, fish and amphibians all make their homes in these sorts of places. They offer the perfect place for animals to be safe and hidden from predators – perhaps from the air – as well as providing a great deal of diverse foodstuffs such as grasses, mosses and other plant life. Amphibians may hunt and scavenge away from the wetlands, but they always return to find a good place to mate and breed, because wetlands offer a lot more safety than other places.

5. Water Purification

As a direct result of having wetlands, the water in the surrounding areas will be a lot cleaner and purer than in other areas. This is because the water is filtered through the wetlands. Fish and other animals may eat vegetation, plants may strain out rubbish that may be in the water because of humans or things like twigs that have fallen from nearby trees, meaning that these things do not make it into streams or rivers further down the line. Wetlands decompose vegetative matter (for the most part – some of it makes its way into streams and rivers to provide food for fish) and even convert various chemicals to make the water even cleaner for the creatures that live both in the wetland and in other water systems. This makes them one of the most productive and critical natural filtering systems in the world.

6. Erosion Control

Sediment is a natural problem that usually originates in rivers. As the water flows past drier earth, it will sometimes sweep sediment away. This sediment will eventually end up in the sea, which is not hugely problematic, but erosion can be an issue. With earth disappearing, animals may find they have less space to hunt, mate or live. Wetlands act as a sort of erosion control. Emergent – plants that are firmly rooted in the ground but that have stalks that rise up out of the water into the air – grow almost exclusively in wetlands, and it is this that slows the flow of water. This means that the strength of the water is lessened and erosion occurs less powerfully in these sorts of areas, as well as in lakes and rivers where the water is slower.

ECOLOGY

The most important factor producing wetlands is flooding. The duration of flooding or prolonged soil saturation by groundwater determines whether the resulting wetland has aquatic, marsh or swamp vegetation. Other important factors include fertility, natural disturbance, competition, herbivory, burial and salinity.[14] When peat accumulates, bogs and fens arise.

CHARACTERISTICS OF WETLANDS

Wetlands vary widely due to local and regional differences in topography, hydrology, vegetation, and other factors, including human involvement. Wetlands may have following characteristics:

a) Occupy a transitional zone
b) Diversity varies according to origin, geographical location, water regime and chemistry, dominant flora and soil or sediment characteristics
c) Sustainability of wetlands depends largely on the dynamics of water supply and loss
d) The ecosystem function of a wetland is dependent on its biogeochemical processes

HYDROLOGY

Wetland hydrology is associated with the spatial and temporal dispersion, flow, and physio-chemical attributes of surface and ground water in its reservoirs. Based on hydrology, wetlands can be categorized as riverine (associated with streams), lacustrine (associated with lakes and reservoirs), and palustrine (isolated). Sources of hydrological flows into wetlands are predominantly precipitation, surface water, and groundwater. Water flows out of wetlands by evapotranspiration, surface runoff, and subsurface water outflow. Hydrodynamics (the movement of water through and from a wetland) affects hydro-periods (temporal fluctuations in water levels) by controlling the water balance and water storage within a wetland.[15] Landscape characteristics control wetland hydrology and hydrochemistry. The O_2 and CO_2 concentrations of water depend on temperature and atmospheric pressure. Hydrochemistry within wetlands is determined by the pH, salinity, nutrients, conductivity, soil composition, hardness, and the sources of water. Water chemistry of wetlands varies across landscapes and climatic regions. Wetlands are generally minerotrophic with the exception of bogs.

1. Role of salinity

Salinity has a strong influence on wetland water chemistry, particularly in wetlands along the coast[16] and in regions with large precipitation deficits. In non-riverine wetlands, natural salinity is regulated by interactions between ground and surface water, which may be influenced by human activity.[17]

2. Soil

Carbon is the major nutrient cycled within wetlands. Most nutrients, such as sulfur, phosphorus, carbon, and nitrogen are found within the soil of wetlands. Anaerobic and aerobic respiration in the soil influences the nutrient cycling of carbon, hydrogen, oxygen, and nitrogen,[18] and the solubility of phosphorus[19] thus contributing to the chemical variations in its water. Wetlands with low pH and saline conductivity may reflect the presence of acid sulfates[20] and wetlands with average salinity levels can be heavily influenced by calcium or magnesium. Biogeochemical processes in wetlands are determined by soils with low redox potential.[21] Wetland soils are identified by redoxymorphic mottles or low chroma, as determined by the Munsell Color System.

3. Biota

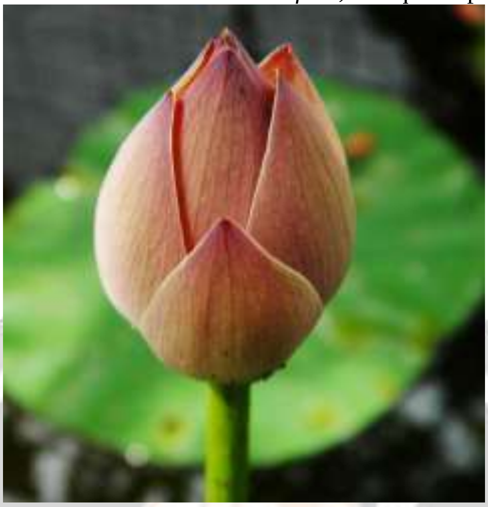
The biota of a wetland system includes its flora and fauna as described below. The most important factor affecting the biota is the duration of flooding.[22] Other important factors include fertility and salinity. In fens,

[14] Keddy, P.A. (2010). Wetland ecology : principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.
[15] Richardson, J. L.; Arndt, J. L.; Montgomery, J. A. (2001). "Hydrology of wetland and related soils". In Richardson, J. L.; Vepraskas, M. J. (eds.). Wetland Soils. Boca Raton, FL: Lewis Publishers.
[16] Silliman, B. R.; Grosholz, E. D.; Bertness, M. D., eds. (2009). Human Impacts on Salt Marshes: A Global Perspective. Berkeley, CA: University of California Press.
[17] Smith, M. J.; Schreiber, E. S. G.; Kohout, M.; Ough, K.; Lennie, R.; Turnbull, D.; Jin, C.; Clancy, T. (2007). "Wetlands as landscape units: spatial patterns in salinity and water chemistry". Wetlands, Ecology & Management. 15 (2): 95–103. doi:10.1007/s11273-006-9015-5.
[18] Ponnamperuma, F. N. (1972). The chemistry of submerged soils. Advances in Agronomy. 24. pp. 29–96. doi:10.1016/S0065-2113(08)60633-1. ISBN 9780120007240.
[19] Moore, P. A., Jr.; Reddy, K. R. (1994). "Role of Eh and pH on phosphorus geochemistry in sediments of Lake Okeechobee, Florida". Journal of Environmental Quality. 23 (5): 955–964. doi:10.2134/jeq1994.00472425002300050016x.
[20] Minh, L. Q.; Tuong, T. P.; van Mensvoort, M. E. F.; Bouma, J. (1998). "Soil and water table management effects on aluminum dynamics in an acid sulphate soil in Vietnam". Agriculture, Ecosystems & Environment. 68 (3): 255–262. doi:10.1016/s0167-8809(97)00158-8.
[21] Schlesinger, W. A. (1997). Biogeochemistry: An Analysis of Global Change (2nd ed.). San Diego, CA: Academic Press.
[22] Keddy, P.A. (2010). Wetland ecology: principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

species are highly dependent on water chemistry. The chemistry of water flowing into wetlands depends on the source of water and the geological material in which it flows through[23] as well as the nutrients discharged from organic matter in the soils and plants at higher elevations in slope wetlands.[24] Biota may vary within a wetland due to season or recent flood regimes.

a) Flora

Figure 5: Bud of *Nelumbo nucifera*, an aquatic plant



There are four main groups of hydrophytes that are found in wetland systems throughout the world.[25] Submerged wetland vegetation can grow in saline and fresh-water conditions. Some species have underwater flowers, while others have long stems to allow the flowers to reach the surface.[26] Submerged species provide a food source for native fauna, habitat for invertebrates, and also possess filtration capabilities. Examples include sea grasses and eelgrass. Floating water plants or floating vegetation is usually small, like arrow arum (Peltandra virginica). Trees and shrubs, where they comprise much of the cover in saturated soils, qualify those areas in most cases as swamps.[27] The upland boundary of swamps is determined partly by water levels. This can be affected by dams[28] some swamps can be dominated by a single species, such as silver maple swamps around the Great Lakes.[29] Others, like those of the Amazon basin, have large numbers of different tree species.[30] Examples include cypress (Taxodium) and mangrove.

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[23] Bedford, B. L. (1996). "The need to define hydrologic equivalence at the landscape scale for freshwater wetland mitigation". Ecological Applications. 6 (1): 57–68. doi:10.2307/2269552. JSTOR 2269552.

[24] Nelson, M. L.; Rhoades, C. C.; Dwire, K. A. (2011). "Influences of Bedrock Geology on Water Chemistry of Slope Wetlands and Headwaters Streams in the Southern Rocky Mountains". Wetlands. 31 (2): 251–261. doi:10.1007/s13157-011-0157-8.

[25] "Blacktown Council wetlands". Archived from the original on 2011-04-10. Retrieved 2011-09-25.

[26] Hutchinson, G. E. (1975). A Treatise on Limnology. Vol. 3: Limnological Botany. New York, NY: John Wiley.

[27] Keddy, P.A. (2010). Wetland ecology: principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

[28] Hughes, F. M. R., ed. (2003). The Flooded Forest: Guidance for policy makers and river managers in Europe on the restoration of floodplain forests. FLOBAR2, Department of Geography, University of Cambridge, Cambridge, UK.

[29] Wilcox, D. A; Thompson, T. A.; Booth, R. K.; Nicholas, J. R. (2007). Lake-level variability and water availability in the Great Lakes. USGS Circular 1311.

[30] Goulding, M. (1980). The Fishes and the Forest: Explorations in Amazonian Natural History. Berkeley, CA: University of California Press.

b) Fauna

Figure 6: Many species of frogs live in wetlands, while others visit them each year to lay eggs

Snapping turtles are one of the many kinds of turtles found in wetlands.
Fish are more dependent on wetland ecosystems than any other type of habitat. Seventy-five percent of the United States' commercial fish and shellfish stocks depend solely on estuaries to survive.[31] Tropical fish species need mangroves for critical hatchery and nursery grounds and the coral reef system for food. Amphibians such as frogs need both terrestrial and aquatic habitats in which to reproduce and feed. While tadpoles control algal populations, adult frogs forage on insects. Frogs are used as an indicator of ecosystem health due to their thin skin which absorbs both nutrient and toxins from the surrounding environment resulting in an above average extinction rate in unfavorable and polluted environmental conditions.[32]Reptiles such as alligators and crocodiles are common in wetlands of some regions. Alligators occur in fresh water along with the fresh water species of the crocodile. The Florida Everglades is the only place in the world where both crocodiles and alligators coexist.[33] The saltwater crocodile inhabits estuaries and mangroves and can be seen in the coastline bordering the Great Barrier Reef in Australia.[34] Snakes, lizards and turtles also can be seen throughout wetlands. Snapping turtles are one of the many kinds of turtles found in wetlands. Birds, particularly waterfowl and wading birds, use wetlands extensively[35]Mammals include numerous small and medium-sized species such as voles, bats, and platypus in addition to large herbivorous and apex species such as the beaver, coypu, swamp rabbit, Florida panther, and moose. Wetlands attract many mammals due to abundant seeds, berries, and other vegetation components, as well as abundant populations of prey such as invertebrates, small reptiles and amphibians. Insects and invertebrates total more than half of the 100,000 known animal species in wetlands. Insects and invertebrates can be submerged in the water or soil, on the surface, and in the atmosphere[36]

c) Algae

Algae are diverse water plants that can vary in size, color, and shape. Algae occur naturally in habitats such as inland lakes, inter-tidal zones, and damp soil and provide a dedicated food source for many animals, including some invertebrates, fish, turtles, and frogs. There are three main groups of algae:

- Planktons are algae which are microscopic, free-floating algae. This algae is so tiny that on average, if 50 of these microscopic algae were lined up end-to-end, it would only measure one millimeter. Planktons are the basis of the food web and are responsible for primary production in the ocean using photosynthesis to make food.
- Filamentous algae are long strands of algae cells that form floating mats.

[31] "Ramsar Convention Ecosystem Services Benefit Factsheets". Retrieved 2011-09-25.
[32] Frogs | Bioindicators". Savethefrogs.com. 2011. Retrieved 2014-01-21.
[33] Mazzotti, F.J.; Best, G.R.; Brandt, L.A.; Cherkiss, M.S.; Jeffery, B.M.; Rice, K.G. (2009). "Alligators and crocodiles as indicators for restoration of Everglades's ecosystems". Ecological Indicators. 9 (6): S137−S149. doi:10.1016/j.ecolind.2008.06.008.
[34] Messel, H. 1981. Surveys of tidal river systems in the Northern Territory of Australia and their crocodile populations (Vol. 1). Pergamon Press.
[35] Milton, W. (1999). Wetland birds: habitat resources and conservation implications. Cambridge: Cambridge University Press. ISBN 978-0511011368. OCLC 50984660.
[36] Invertebrates in freshwater wetlands of North America: ecology and management. Batzer, Darold P., Rader, Russell Ben., Wissinger, Scott A. New York: Wiley. 1999. ISBN 978-0471292586. OCLC 39747651.

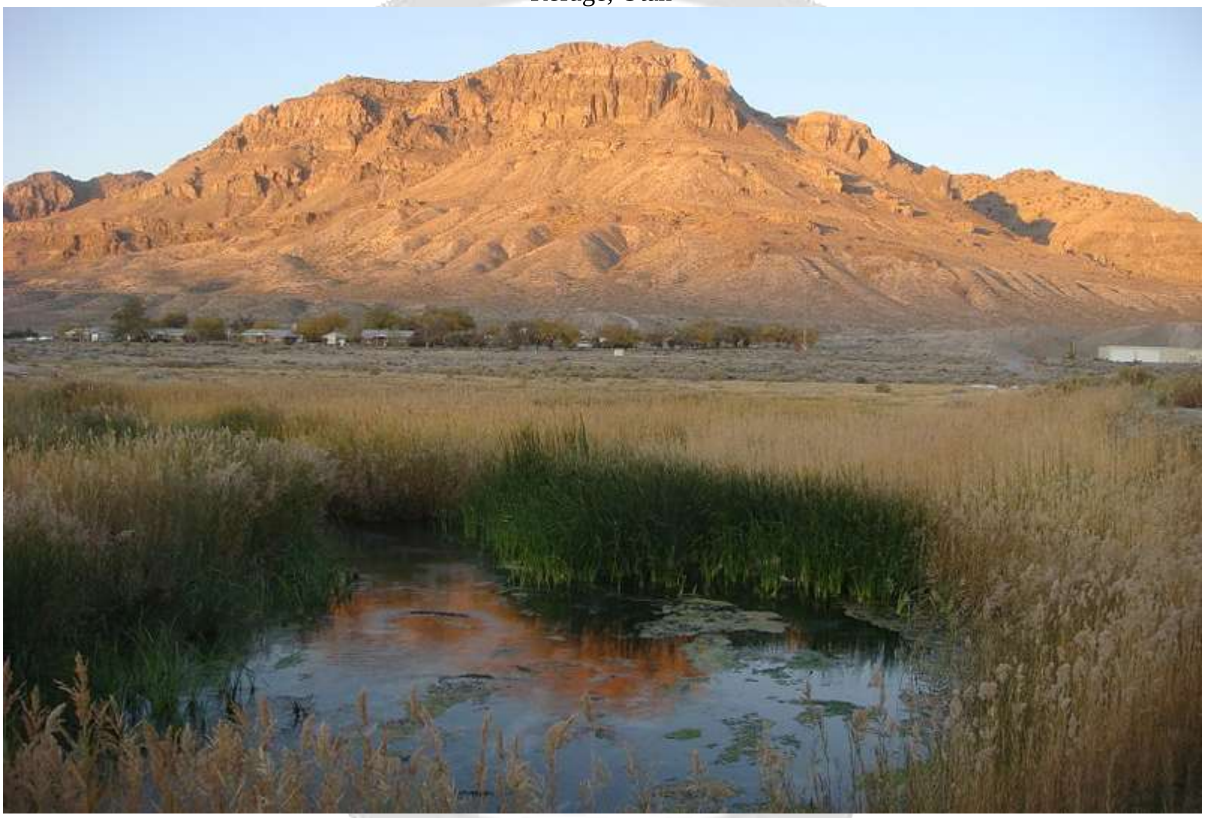
- Chara and Nitella algae are upright algae that look like a submerged plant with roots.[37]

CLIMATES

1. Temperature

Wetlands are located in every climatic zone. Temperatures vary greatly depending on the location of the wetland. Many of the world's wetlands are in temperate zones, midway between the North or South Pole and the equator. In these zones, summers are warm and winters are cold, but temperatures are not extreme. In a subtropical zone wetland, such as one along the Gulf of Mexico, a typical temperature might be 11 °C (52 °F). Wetlands in the tropics are much warmer for a larger portion of the year. Wetlands on the Arabian Peninsula can reach temperatures exceeding 50 °C (122 °F) and would therefore be subject to rapid evaporation. In northeastern Siberia, which has a polar climate, wetland temperatures can be as low as −50 °C (−58 °F). Peat lands insulate the permafrost in subarctic regions, thus delaying or preventing thawing of permafrost during summer, as well as inducing the formation of permafrost.[38]

Figure 7: Wetlands contrast the hot, arid landscape around Middle Spring, Fish Springs National Wildlife Refuge, Utah



2. Rainfall:

The amount of precipitation a wetland receives varies widely according to its area. Wetlands in Wales, Scotland, and western Ireland typically receive about 1,500 mm (59 in) per year. In some places in Southeast Asia, where heavy rains occur, they can receive up to 10,000 mm (390 in). In some drier regions, wetlands exist where as little as 180 mm (7.1 in) precipitation occurs each year. Temporal variation:[39]

- Perennial systems
- Seasonal systems
- Episodic (periodic or intermittent) system of the down
- Surface flow may occur in some segments, with subsurface flow in other segments
- Ephemeral (short-lived) systems
- Migratory species

[37] "Taken from Blacktown Council Wetland Inventory". Blacktown Council. Archived from the original on 2012-01-22. Retrieved 2012-05-23.

[38] "PEATLANDS, CLIMATE CHANGE MITIGATION AND BIODIVERSITY CONSERVATION".

[39] Ramsar Convention Technical Reports"

USES OF WETLANDS

Depending partly on a wetland's geographic and topographic location,[40] the functions it performs can support multiple ecosystem services, values, or benefits. United Nations Millennium Ecosystem Assessment and Ramsar Convention described wetlands as a whole to be of biosphere significance and societal importance in the following areas, for example:

- Water storage (flood control)
- Groundwater replenishment
- Shoreline stabilisation and storm protection
- Water purification
- Reservoirs of biodiversity
- Pollination
- Wetland products
- Cultural values
- Recreation and tourism
- Climate change mitigation and adaptation

According to the Ramsar Convention: “ The economic worth of the ecosystem services provided to society by intact, naturally functioning wetlands is frequently much greater than the perceived benefits of converting them to 'more valuable' intensive land use – particularly as the profits from unsustainable use often go to relatively few individuals or corporations, rather than being shared by society as a whole”.

1. Water storage (flood control)

Storage reservoirs and flood protection: The wetland system of floodplains is formed from major rivers downstream from their headwaters. "The floodplains of major rivers act as natural storage reservoirs, enabling excess water to spread out over a wide area, which reduces its depth and speed. Wetlands close to the headwaters of streams and rivers can slow down rainwater runoff and spring snowmelt so that it doesn't run straight off the land into water courses. This can help prevent sudden, damaging floods downstream."[41] Notable river systems that produce large spans of floodplain include the Nile River, the Niger river inland delta, [the Zambezi River flood plain], [the Okavango River inland delta], [the Kafue River flood plain][the Lake Bangweulu flood plain] (Africa), Mississippi River (USA), Amazon River (South America), Yangtze River (China), Danube River (Central Europe) and Murray-Darling River (Australia).

Human impact: Converting wetlands to upland through drainage and development forces adjoining or downstream water channels into narrower corridors. This accelerates watershed hydrologic response to storm events and this increases the need in some cases for alternative means of flood control. That is because the newly formed channels must manage the same amount of precipitation, causing flood peaks to be [higher or deeper] and floodwaters to travel faster. Water management engineering developments in the past century have degraded these wetlands through the construction of artificial embankments. These constructions may be classified as dykes, bunds, levees, weirs, barrages and dams but serve the single purpose of concentrating water into a select source or area. Wetland water sources that were once spread slowly over a large, shallow area are pooled into deep, concentrated locations. Loss of wetland floodplains results in more severe and damaging flooding. Catastrophic human impact in the Mississippi River floodplains was seen in death of several hundred individuals during a levee breach in New Orleans caused by Hurricane Katrina. Ecological catastrophic events from human-made embankments have been noticed along the Yangtze River floodplains since the middle of the river has become prone to more frequent and damaging flooding. Some of these events include the loss of riparian vegetation, a 30% loss of the vegetation cover throughout the river's basin, a doubling of the percentage of the land affected by soil erosion, and a reduction in reservoir capacity through siltation build-up in floodplain lakes.[42]

2. Groundwater replenishment

The surface water which is the water visibly seen in wetland systems only represents a portion of the overall water cycle which also includes atmospheric water and groundwater. Wetland systems are directly linked to groundwater and a crucial regulator of both the quantity and quality of water found below the ground. Wetland systems that are made of permeable sediments like limestone or occur in areas with highly variable and fluctuating water tables especially have a role in groundwater replenishment or water recharge. Sediments that are porous allow water to filter down through the soil and overlying rock into aquifers which are the source of

[40] United Nations Environment Programme (UNEP) – Home page". Retrieved 2011-12-11.
[41] Ramsar Convention Ecosystem Services Benefit Factsheets". Retrieved 2011-09-25.
[42] Ramsar Convention Ecosystem Services Benefit Factsheets". Retrieved 2011-09-25.

95% of the world's drinking water. Wetlands can also act as recharge areas when the surrounding water table is low and as a discharge zone when it is too high. Karst (cave) systems are a unique example of this system and are a connection of underground rivers influenced by rain and other forms of precipitation. These wetland systems are capable of regulating changes in the water table on upwards of 130 m (430 ft).

Human impact: Groundwater is an important source of water for drinking and irrigation of crops. Over 1 billion people in Asia and 65% of the public water sources in Europe source 100% of their water from groundwater. Irrigation is a massive use of groundwater with 80% of the world's groundwater used for agricultural production.[43] Unsustainable abstraction of groundwater has become a major concern. In the Commonwealth of Australia, water licensing is being implemented to control use of water in major agricultural regions. On a global scale, groundwater deficits and water scarcity is one of the most pressing concerns facing the 21st century.[44]

3. Shoreline stabilization and storm protection

Tidal and inter-tidal wetland systems protect and stabilize coastal zones. Coral reefs provide a protective barrier to coastal shoreline. Mangroves stabilize the coastal zone from the interior and will migrate with the shoreline to remain adjacent to the boundary of the water. The main conservation benefit these systems have against storms and storm surges is the ability to reduce the speed and height of waves and floodwaters.

Human impact: The sheer number of people who live and work near the coast is expected to grow immensely over the next fifty years. From an estimated 200 million people that currently live in low-lying coastal regions, the development of urban coastal centers is projected to increase the population by fivefold within 50 years.[45] The United Kingdom has begun the concept of managed coastal realignment. This management technique provides shoreline protection through restoration of natural wetlands rather than through applied engineering. In East Asia, reclamation of coastal wetlands has resulted in widespread transformation of the coastal zone, and up to 65% of coastal wetlands have been destroyed by coastal development.[46] One analysis using the impact of hurricanes versus storm protection provided naturally by wetlands projected the value of this service at US$33,000/hectare/year.[47]

4. Water purification

Nutrient retention: Wetlands cycle both sediments and nutrients balancing terrestrial and aquatic ecosystems. A natural function of wetland vegetation is the up-take, storage, and (for nitrate) the removal of nutrients found in runoff from the surrounding soil and water.[48] In many wetlands, nutrients are retained until plants die or are harvested by animals or humans and taken to another location, or until microbial processes convert soluble nutrients to a gas as is the case with nitrate.

Sediment and heavy metal traps: Precipitation and surface runoff induces soil erosion, transporting sediment in suspension into and through waterways. These sediments move towards larger and more sizable waterways through a natural process that moves water towards oceans. All types of sediments which may be composed of clay, sand, silt, and rock can be carried into wetland systems through this process. Wetland vegetation acts as a physical barrier to slow water flow and trap sediment for short or long periods of time. Suspended sediment often contains heavy metals that are retained when wetlands trap the sediment. In some cases, certain metals are taken up through wetland plant stems, roots, and leaves. Many floating plant species, for example, can absorb and filter heavy metals. Water hyacinth (Eichhornia crassipes), duckweed (Lemna) and water fern (Azolla) store iron and copper commonly found in wastewater. Many fast-growing plants rooted in the soils of wetlands such as cattail (Typha) and reed (Phragmites) also aid in the role of heavy metal up-take. Animals such as the oyster can filter more than 200 litres (53 US gal) of water per day while grazing for food, removing nutrients, suspended sediments, and chemical contaminants in the process. On the other hand, some types of wetlands facilitate the mobilization and bioavailability of mercury (another heavy metal), which in its methyl mercury form increases the risk of bioaccumulation in fish important to animal food webs and harvested for human consumption.

[43] Ramsar Convention Ecosystem Services Benefit Factsheets". Retrieved 2011-09-25.
[44] Ramsar Convention Ecosystem Services Benefit Factsheets". Retrieved 2011-09-25.
[45] United Nations Environment Programme (UNEP) – Home page". Retrieved 2011-12-11.
[46] MacKinnon, J.; Verkuil, Y. I.; Murray, N. J. (2012), IUCN situation analysis on East and Southeast Asian intertidal habitats, with particular reference to the Yellow Sea (including the Bohai Sea), Occasional Paper of the IUCN Species Survival Commission No. 47, Gland, Switzerland and Cambridge, UK: IUCN, p. 70, ISBN 9782831712550[permanent dead link]
[47] FAO". Archived from the original on 2007-09-09. Retrieved 2011-09-25.
[48] "Letting Nature Do the Job". Wild.org. 2008-08-01. Archived from the original on 2013-01-13. Retrieved 2012-05-23.

Capacity: The ability of wetland systems to store or remove nutrients and trap sediment and associated metals is highly efficient and effective but each system has a threshold. An overabundance of nutrient input from fertilizer run-off, sewage effluent, or non-point pollution will cause eutrophication. Upstream erosion from deforestation can overwhelm wetlands making them shrink in size and cause dramatic biodiversity loss through excessive sedimentation load. Retaining high levels of metals in sediments is problematic if the sediments become resuspended or oxygen and pH levels change at a future time. The capacity of wetland vegetation to store heavy metals depends on the particular metal, oxygen and pH status of wetland sediments and overlying water, water flow rate (detention time), wetland size, season, climate, type of plant, and other factors.

Human impact: The capacity of a wetland to store sediment, nutrients, and metals can be diminished if sediments are compacted such as by vehicles or heavy equipment, or are regularly tilled. Unnatural changes in water levels and water sources also can affect the water purification function. If water purification functions are impaired, excessive loads of nutrients enter waterways and cause eutrophication. This is of particular concern in temperate coastal systems.[49] The main sources of coastal eutrophication are industrially made nitrogen, which is used as fertilizer in agricultural practices, as well as septic waste runoff.[50] Nitrogen is the limiting nutrient for photosynthetic processes in saline systems, however in excess; it can lead to an overproduction of organic matter that then leads to hypoxic and anoxic zones within the water column.[51] Without oxygen, other organisms cannot survive, including economically important finfish and shellfish species.

Examples: An example of how a natural wetland is used to provide some degree of sewage treatment is the East Kolkata Wetlands in Kolkata, India. The wetlands cover 125 square kilometers (48 sq mi), and are used to treat Kolkata's sewage. The nutrients contained in the wastewater sustain fish farms and agriculture.

5. Constructed wetland

The function of most natural wetland systems is not to manage wastewater. However, their high potential for the filtering and the treatment of pollutants has been recognized by environmental engineers that specialize in the area of wastewater treatment. These constructed wetland systems are highly controlled environments that intend to mimic the occurrences of soil, flora, and microorganisms in natural wetlands to aid in treating wastewater effluent. Constructed wetlands can be used to treat raw sewage, storm water, agricultural and industrial effluent. They are constructed with flow regimes, micro-biotic composition, and suitable plants in order to produce the most efficient treatment process. Other advantages of constructed wetlands are the control of retention times and hydraulic channels. The most important factors of constructed wetlands are the water flow processes combined with plant growth. Constructed wetland systems can be surface flow systems with only free-floating macrophytes, floating-leaved macrophytes, or submerged macrophytes; however, typical free water surface systems are usually constructed with emergent macrophytes.[52] Subsurface flow-constructed wetlands with a vertical or a horizontal flow regime are also common and can be integrated into urban areas as they require relatively little space.[53]

[49] Valiela, I.; Collins, G.; Kremer, J.; Lajtha, K.; Geist, M.; Seely, B.; Brawley, J.; Sham, C. H. (1997). "Nitrogen loading from coastal watersheds to receiving estuaries: New method and application". Ecological Applications. 7 (2): 358–380. doi:10.2307/2269505. JSTOR 2269505.

[50] Galloway, J. (2003). "The Nitrogen Cascade". BioScience. 53 (4): 341–356. Bibcode:1985BioSc..35..499W. doi:10.1641/0006-3568(2003)053[0341:tnc]2.0.co;2.

[51] Diaz, R. J.; Rosenberg, R. (2008). "Spreading Dead Zones and Consequences for Marine Ecosystems". Science. 321 (5891): 926–929. Bibcode:2008Sci...321..926D. doi:10.1126/science.1156401. PMID 18703733.

[52] Vymazal, J.; Kröpfleova, L. (2008). "Wastewater treatment in constructed wetlands with horizontal sub-surface flow". Environmental Pollution.

[53] Hoffmann, H.; Platzer, C.; von Münch, E.; Winker, M. (2011). "Technology review of constructed wetlands – Subsurface flow constructed wetlands for greywater and domestic wastewater treatment" (PDF). Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit.

Figure 8: Constructed wetland in an ecological settlement in Flintenbreite near Lübeck, Germany

6. Reservoirs of biodiversity

Wetland systems' rich biodiversity is becoming a focal point at International Treaty Conventions and within the World Wildlife Fund organization due to the high number of species present in wetlands, the small global geographic area of wetlands, the number of species which are endemic to wetlands, and the high productivity of wetland systems. Hundreds of thousands of animal species, 20,000 of them vertebrates, are living in wetland systems. The discovery rate of fresh water fish is at 200 new species per year. The impact of maintaining biodiversity is seen at the local level through job creation, sustainability, and community productivity. A good example is the Lower Mekong basin which runs through Cambodia, Laos, and Vietnam. Supporting over 55 million people, the sustainability of the region is enhanced through wildlife tours. The U.S. state of Florida has estimated that US$1.6 billion was generated in state revenue from recreational activities associated with wildlife.

Biodiverse river basins: The Amazon holds 3,000 species of freshwater fish species within the boundaries of its basin, whose function it is to disperse the seeds of trees. One of its key species, the Piramutaba catfish, Brachyplatystoma vaillantii, migrates more than 3,300 km (2,100 mi) from its nursery grounds near the mouth of the Amazon River to its spawning grounds in Andean tributaries, 400 m (1,300 ft) above sea level, distributing plants seed along the route.

Productive intertidal zones: Intertidal mudflats have a level of productivity similar to that of some wetlands even while possessing a low number of species. The abundance of invertebrates found within the mud are a food source for migratory waterfowl.

Critical life-stage habitat: Mudflats, saltmarshes, mangroves, and sea grass beds have high levels of both species richness and productivity, and are home to important nursery areas for many commercial fish stocks.

Genetic diversity: Populations of many species are confined geographically to only one or a few wetland systems, often due to the long period of time that the wetlands have been physically isolated from other aquatic sources. For example, the number of endemic species in Lake Baikal in Russia classifies it as a hotspot for biodiversity and one of the most biodiversity wetlands in the entire world. Evidence from a research study by Mazepova et al. suggest that the number of crustacean species endemic to Baikal Lake (over 690 species and subspecies) exceeds the number of the same groups of animals inhabiting all the fresh water bodies of Eurasia together. Its 150 species of free-living Platyhelminthes alone is analogous to the entire number in all of Eastern Siberia. The 34 species and subspecies number of Baikal sculpins is more than twice the number of the analogous fauna that inhabits Eurasia. One of the most exciting discoveries was made by A. V. Shoshin who registered about 300 species of free-living nematodes using only six near-shore sampling localities in the

Southern Baikal. "If we will take into consideration, that about 60% of the animals can be found nowhere else except Baikal, it may be assumed that the lake may be the biodiversity center of the Eurasian continent."[54]

Human impact: Biodiversity loss occurs in wetland systems through land use changes, habitat destruction, pollution, exploitation of resources, and invasive species. Vulnerable, threatened, and endangered species number at 17% of waterfowl, 38% of fresh-water dependent mammals, 33% of freshwater fish, 26% of freshwater amphibians, 72% of freshwater turtles, 86% of marine turtles, 43% of crocodilians and 27% of coral reef-building species. Introduced hydrophytes in different wetland systems can have devastating results. The introduction of water hyacinth, a native plant of South America into Lake Victoria in East Africa as well as duckweed into non-native areas of Queensland, Australia, have overtaken entire wetland systems suffocating the wetlands and reducing the diversity of other plants and animals. This is largely due to their phenomenal growth rate and ability to float and grow on the surface of the water.

7. Wetland products and productivity

Wetland productivity is linked to the climate, wetland type, and nutrient availability. Low water and occasional drying of the wetland bottom during droughts (dry marsh phase) stimulate plant recruitment from a diverse seed bank and increase productivity by mobilizing nutrients. In contrast, high water during deluges (lake marsh phase) causes turnover in plant populations and creates greater interspersion of element cover and open water, but lowers overall productivity. During a cover cycle that ranges from open water to complete vegetation cover, annual net primary productivity may vary 20-fold.[55] The grasses of fertile floodplains such as the Nile produce the highest yield including plants such as *Arundo donax* (giant reed), *Cyperus papyrus* (papyrus), *Phragmites* (reed) and *Typha* (cattail, bulrush). Wetlands naturally produce an array of vegetation and other ecological products that can be harvested for personal and commercial use.[56] The most significant of these is fish which have all or parts of their life-cycle occur within a wetland system. Fresh and saltwater fish are the main source of protein for one billion people and comprise 15% of an additional two billion people's diets. In addition, fish generate a fishing industry that provides 80% of the income and employment to residents in developing countries. Another food staple found in wetland systems is rice, a popular grain that is consumed at the rate of one fifth of the total global calorie count. In Bangladesh, Cambodia and Vietnam, where rice paddies are predominant on the landscape, rice consumption reach 70%. Some native wetland plants in the Caribbean and Australia are harvested sustainably for medicinal compounds; these include the red mangrove (Rhizophora mangle) which possesses antibacterial, wound-healing, anti-ulcer effects, and antioxidant properties.[57]Food converted to sweeteners and carbohydrates include the sago palm of Asia and Africa (cooking oil), the nipa palm of Asia (sugar, vinegar, alcohol, and fodder) and honey collection from mangroves. More than supplemental dietary intake, this produce sustains entire villages. Coastal Thailand villages earn the key portion of their income from sugar production while the country of Cuba relocates more than 30,000 hives each year to track the seasonal flowering of the mangrove Avicennia. Other mangrove-derived products:

- Fuel wood
- Salt (produced by evaporating seawater)
- Animal fodder
- Traditional medicines (e.g. from mangrove bark)
- Fibers for textiles
- Dyes and tannins

Human impact: Over-fishing is the major problem for sustainable use of wetlands. Concerns are developing over certain aspects of farm fishing, which uses natural waterways to harvest fish for human consumption and pharmaceuticals. This practice has become especially popular in Asia and the South Pacific. Its impact upon much larger waterways downstream has negatively affected many small island developing states. Aquaculture is continuing to develop rapidly throughout the Asia-Pacific region specifically in China with world holdings in Asia equal to 90% of the total number of aquaculture farms and 80% of its global value.[58] Some aquaculture has eliminated massive areas of wetland through practices seen such as in the shrimp farming industry's destruction of mangroves. Even though the damaging impact of large scale shrimp farming on the coastal ecosystem in

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[54] Timoshkin, O. A., ed. (2004). Index of animal species inhabiting Lake Baikal and its catchment area. Guides and Keys to Identification of Fauna and Flora of Lake Baikal. 2. 1 (1st ed.). Novosibirsk, Nauka: John Wiley & Sons. ISBN 978-5-02-031736-9

[55] Johnson, W. C.; Millett, B. V.; Gilmanov, T.; Voldseth, R. A.; Guntenspergen, G. R.; Naugle, D. E. (2005). "Vulnerability of Northern Prairie Wetlands to Climate Change". Bio Science. 10: 863–872.

[56] Maltby, Edward (1986). Waterlogged wealth: why waste the world's wet places?. Earthscan. London: International Institute for Environment and Development. ISBN 978-0905347639. OCLC 18834448.

[57] The Ramsar Information Sheet on Wetlands of International Importance". September 18, 2009. Retrieved November 19, 2011.

[58] Bange, H. W. (2006). "Nitrous oxide and methane in European coastal waters". Estuarine, Coastal and Shelf Science. 70 (3): 361–374. Bibcode: 2006ECSS...70..361B. doi:10.1016/j.ecss.2006.05.042.

many Asian countries has been widely recognized for quite some time now, it has proved difficult to check in absence of other employment avenues for people engaged in such occupation. Also burgeoning demand for shrimps globally has provided a large and ready market for the produce. Threats to rice fields mainly stem from inappropriate water management, introduction of invasive alien species, agricultural fertilizers, pesticides, and land use changes. Industrial-scale production of palm oil threatens the biodiversity of wetland ecosystems in parts of Southeast Asia, Africa, and other developing countries. Over-exploitation of wetland products can occur at the community level as is sometimes seen throughout coastal villages of Southern Thailand where each resident may obtain for themselves every consumable of the mangrove forest (fuel wood, timber, honey, resins, crab, and shellfish) which then becomes threatened through increasing population and continual harvest.

8. Additional functions and uses of wetlands

Some types of wetlands can serve as fire breaks that help slow the spread of minor wildfires. Larger wetland systems can influence local precipitation patterns. Some boreal wetland systems in catchment headwaters may help extend the period of flow and maintain water temperature in connected downstream waters. Pollination services are supported by many wetlands which may provide the only suitable habitat for pollinating insects, birds, and mammals in highly developed areas. It is likely that wetlands have other functions whose benefits to society and other ecosystems have yet to be discovered.

WETLANDS AND CLIMATE CHANGE

Wetlands perform two important functions in relation to climate change. They have mitigation effects through their ability to sink carbon, converting a greenhouse gas (carbon dioxide) to solid plant material through the process of photosynthesis, and also through their ability to store and regulate water.[59] Wetlands store approximately 44.6 million tonnes of carbon per year globally.[60] In salt marshes and mangrove swamps in particular, the average carbon sequestration rate is 210 g CO_2 m^{-2} y^{-1} while peat lands sequester approximately 20–30 g CO_2 m^{-2} y^{-1}.[61] Coastal wetlands, such as tropical mangroves and some temperate salt marshes, are known to be sinks for carbon that otherwise contributes to climate change in its gaseous forms (carbon dioxide and methane). The ability of many tidal wetlands to store carbon and minimize methane flux from tidal sediments has led to sponsorship of blue carbon initiatives that are intended to enhance those processes.[62]However, depending on their characteristics, some wetlands are a significant source of methane emissions and some are also emitters of nitrous oxide[63] which is a greenhouse gas with a global warming potential 300 times that of carbon dioxide and is the dominant ozone-depleting substance emitted in the 21st century.[64] Excess nutrients mainly from anthropogenic sources have been shown to significantly increase the N_2O fluxes from wetland soils through denitrification and nitrification processes (see table below).[65] A study in the intertidal region of a New England salt marsh showed that excess levels of nutrients might increase N2O emissions rather than sequester them.[66]

Table 1: Nitrous oxide fluxes from different wetland soils

Wetland type	**Location**	**N_2O flux (μmol N_2O m^{-2} h^{-1})**
Mangrove	Shenzhen and Hong Kong	0.14 – 23.83
Mangrove	Muthupet, South India	0.41 – 0.77

[59] Synthesis of Adaptation Options for Coastal Areas. Climate Ready Estuaries Program, EPA 430-F-08-024. Washington, DC: US Environmental Protection Agency. 2009.

[60] Chmura, G. L. (2003). "Global carbon sequestration in tidal, saline wetland soils". Global Biogeochemical Cycles. 17 (4): 1111. Bibcode: 2003GBioC..17.1111C. doi:10.1029/2002GB001917

[61] Chmura, G. L. (2003). "Global carbon sequestration in tidal, saline wetland soils". Global Biogeochemical Cycles. 17 (4): 1111. Bibcode: 2003GBioC..17.1111C. doi:10.1029/2002GB001917

[62] "More on blue carbon and carbon sequestration

[63] Thompson, A. J.; Giannopoulos, G.; Pretty, J.; Baggs, E. M.; Richardson, D. J. (2012). "Biological sources and sinks of nitrous oxide and strategies to mitigate emissions". Philosophical Transactions of the Royal Society B. 367 (1593): 1157–1168. doi:10.1098/rstb.2011.0415. PMC 3306631. PMID 2245110

[64] Ravishankara, A. R.; Daniel, John S.; Portmann, Robert W. (2009). "Nitrous Oxide (N2O): The Dominant Ozone-Depleting Substance Emitted in the 21st Century". Science. 326 (5949): 123–125. Bibcode:2009Sci...326..123R. doi:10.1126/science.1176985. PMID 19713491

[65] Martin, Rose M.; Wigand, Cathleen; Elmstrom, Elizabeth; Lloret, Javier; Valiela, Ivan (20 April 2018). "Long-term nutrient addition increases respiration and nitrous oxide emissions in a New England salt marsh". Ecology and Evolution. 8 (10): 4958–4966. doi:10.1002/ece3.3955. ISSN 2045-7758. PMC 5980632. PMID 29876073.

[66] Moseman-Valtierra, S.; et al. (2011). "Short-term nitrogen additions can shift a coastal wetland from a sink to a source of N2O". Atmospheric Environment. 45 (26): 4390–4397. Bibcode: 2011AtmEn..45.4390M. doi:10.1016/j.atmosenv.2011.05.046.

Mangrove	Bhitarkanika, East India	0.20 – 4.73
Mangrove	Pichavaram, South India	0.89 – 1.89
Mangrove	Queensland, Australia	−0.045 – 0.32
Mangrove	South East Queensland, Australia	0.091 – 1.48
Mangrove	Southwest coast, Puerto Rico	0.12 – 7.8
Mangrove	Isla Magueyes, Puerto Rico	0.05 – 1.4
Salt marsh	Chesapeake Bay, US	0.005 – 0.12
Salt marsh	Maryland, US	0.1
Salt marsh	North East China	0.1 – 0.16
Salt marsh	Biebrza, Poland	−0.07 – 0.06
Salt marsh	Netherlands	0.82 – 1.64
Salt marsh	Baltic Sea	−0.13
Salt marsh	Massachusetts, US	−2.14 – 1.27

Source: Table adapted from Moseman-Valtierra (2012)[67] and Chen et al. (2010)[68]

Data on nitrous oxide fluxes from wetlands in the southern hemisphere are lacking, as are ecosystem-based studies including the role of dominant organisms that alter sediment biogeochemistry. Aquatic invertebrates produce ecologically-relevant nitrous oxide emissions due to ingestion of denitrifying bacteria that live within the subtidal sediment and water column[69] and thus may also be influencing nitrous oxide production within some wetlands.

WETLAND DISTURBANCE

Wetlands, the functions and services they provide as well as their flora and fauna, can be affected by several types of disturbances. The disturbances (sometimes termed stressors or alterations) can be human-associated or natural, direct or indirect, reversible or not, and isolated or cumulative. When exceeding levels or patterns normally found within wetlands of a particular class in a particular region, the predominant ones include the following[70]

1. Enrichment/Eutrophication
2. Organic Loading and Reduced Dissolved Oxygen
3. Contaminant Toxicity
4. Acidification
5. Salinization
6. Sedimentation
7. Altered Solar Input (Turbidity/Shade)
8. Vegetation Removal
9. Thermal Alteration
10. Dehydration/Aridification
11. Inundation/Flooding
12. Habitat Fragmentation
13. Other Human Presence

Disturbances can be further categorized as follows:

[67] Moseman-Valtierra, S. (2012). "Chapter 1: Reconsidering the climatic roles of marshes: Are they sinks or sources of greenhouse gases?". In Abreu, D. C.; Borbón, S. L. (eds.). *Marshes: Ecology, Management and Conservation*. New York, NY: Nova Science.

[68] Chen, G.; Tam, N.; Ye, Y. (2010). "Summer fluxes of atmospheric greenhouse gases N2O, CH4 and CO2 from mangrove soil in South China". Science of the Total Environment. 408 (13): 2761–2767. Bibcode: 2010ScTEn.408.2761C. doi:10.1016/j.scitotenv.2010.03.007. PMID 20381125

[69] Stief, P.; Poulsen, M.; Nielsen; et al. (2009). "Nitrous oxide emission by aquatic macrofauna". Proceedings of the National Academy of Sciences. 106 (11): 4296–4300. Bibcode:2009PNAS..106.4296S. doi:10.1073/pnas.0808228106. PMC 2651200. PMID 19255427

[70] Office of Research & Development. "Impacts on quality of inland wetlands of the United States: A survey of indicators, techniques, and applications of community-level biomonitoring data". cfpub.epa.gov. Retrieved 2018-07-27.

Minor disturbance
Stress that maintains ecosystem integrity.[71]
Moderate disturbance
Ecosystem integrity is damaged but can recover in time without assistance.[72]

Impairment or severe disturbance
Human intervention may be needed in order for ecosystem to recover.[73]
Just a few of the many sources of these disturbances are[74]

a) Drainage
b) Development
c) Over-grazing
d) Mining
e) Unsustainable water use

They can be manifested partly as:

a) Water scarcity
b) Impacts to Endangered species
c) Disruption of wildlife breeding grounds
d) Imbalance in sediment load and nutrient filtration

WETLAND CONSERVATION
Wetlands have historically been the victim of large draining efforts for real estate development, or flooding for use as recreational lakes or hydropower generation. Some of the world's most important agricultural areas are wetlands that have been converted to farmland.[75] Since the 1970s, more focus has been put on preserving wetlands for their natural function yet by 1993 half the world's wetlands had been drained.[76]In order to maintain wetlands and sustain their functions, alterations and disturbances that are outside the normal range of variation should be minimized.

1. Balancing wetland conservation with the needs of people
Wetlands are vital ecosystems that provide livelihoods for the millions of people who live in and around them. The Millennium Development Goals (MDGs) called for different sectors to join forces to secure wetland environments in the context of sustainable development and improving human wellbeing. A three-year project carried out by Wetlands International in partnership with the International Water Management Institute found that it is possible to conserve wetlands while improving the livelihoods of people living among them. Case studies conducted in Malawi and Zambia looked at how dambos – wet, grassy valleys or depressions where water seeps to the surface – can be farmed sustainably to improve livelihoods. Mismanaged or overused dambos often become degraded, however, using a knowledge exchange between local farmers and environmental managers, a protocol was developed using soil and water management practices. Project outcomes included a high yield of crops, development of sustainable farming techniques, and adequate water management generating enough water for use as irrigation. Before the project, there were cases where people had died from starvation due to food shortages. By the end of it, many more people had access to enough water to grow vegetables. A key achievement was that villagers had secure food supplies during long, dry months. They also benefited in other ways: nutrition was improved by growing a wider range of crops, and villagers could also invest in health and education by selling produce and saving money.[77]

2. Ramsar Convention
The Convention on Wetlands of International Importance, especially as Waterfowl Habitat, or Ramsar Convention, is an international treaty designed to address global concerns regarding wetland loss and degradation. The primary purposes of the treaty are to list wetlands of international importance and to promote their wise use, with the ultimate goal of preserving the world's wetlands. Methods include restricting access to the majority portion of wetland areas, as well as educating the public to combat the misconception that wetlands

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[71] Clewell, AF; Aronson, J (2013). Ecological restoration (2nd ed.). Washington, DC: Island Press.
[72] Clewell, AF; Aronson, J (2013). Ecological restoration (2nd ed.). Washington, DC: Island Press.
[73] Clewell, AF; Aronson, J (2013). Ecological restoration (2nd ed.). Washington, DC: Island Press.
[74] Wetlands International works to sustain and restore wetlands for people and biodiversity". Wetlands International. Retrieved 2014-01-21.
[75] Lander, Brian (2014). "State Management of River Dikes in Early China: New Sources on the Environmental History of the Central Yangzi Region". T'oung Pao. 100 (4–5): 325–362. doi:10.1163/15685322-10045p02
[76] unknown title". New Scientist (1894). 1993-10-09. p. 46.
[77] Good practices and lessons learned in integrating ecosystem conservation and poverty reduction objectives in wetlands" (PDF). The Ramsar Convention on Wetlands. 2008-12-01. Retrieved 2011-11-19.

are wastelands. The Convention works closely with five International Organization Partners. These are: Birdlife International, the IUCN, the International Water Management Institute, Wetlands International and the World Wide Fund for Nature. The partners provide technical expertise, help conduct or facilitate field studies and provide financial support. The IOPs also participate regularly as observers in all meetings of the Conference of the Parties and the Standing Committee and as full members of the Scientific and Technical Review Panel.

VALUATION

The value of a wetland to local communities, as well as the value of wetland systems generally to the earth and to humankind, is one of the most important valuations that can be conducted for sustainable development. This typically involves first mapping a region's wetlands, then assessing the functions and ecosystem services the wetlands provide individually and cumulatively, and evaluating that information to prioritize or rank individual wetlands or wetland types for conservation, management, restoration, or development. Over a longer period, it requires keeping inventories of known wetlands and monitoring a representative sample of the wetlands to determine changes due to both natural and human factors. Such a valuation process is used to educate decision-makers such as governments of the importance of particular wetlands within their jurisdiction.

1. Assessment

Rapid assessment methods are used to score, rank, rate, or categorize various functions, ecosystem services, species, communities, levels of disturbance, and/or ecological health of a wetland or group of wetlands. This is often done to prioritize particular wetlands for conservation (avoidance) or to determine the degree to which loss or alteration of wetland functions should be compensated, such as by restoring degraded wetlands elsewhere or providing additional protections to existing wetlands. Rapid assessment methods are also applied before and after a wetland has been restored or altered, to help monitor or predict the effects of those actions on various wetland functions and the services they provide. Assessments are typically considered to be "rapid" when they require only a single visit to the wetland lasting less than one day, which in some cases may include interpretation of aerial imagery and GIS analyses of existing spatial data, but not detailed post-visit laboratory analyses of water or biological samples. Due to time and cost constraints, the levels of various wetland functions or other attributes are usually not measured directly but rather are estimated relative to other assessed wetlands in a region, using observation-based variables, sometimes called "indicators", that are hypothesized or known to predict performance of the specified functions or attributes. To achieve consistency among persons doing the assessment, rapid methods present indicator variables as questions or checklists on standardized data forms, and most methods standardize the scoring or rating procedure that is used to combine question responses into estimates of the levels of specified functions relative to the levels estimated in other wetlands ("calibration sites") assessed previously in a region.[78] Rapid assessment methods, partly because they often use dozens of indicators pertaining to conditions surrounding a wetland as well as within the wetland itself, aim to provide estimates of wetland functions and services that are more accurate and repeatable than simply describing a wetland's class type.[79] A need for wetland assessments to be rapid arises mostly when government agencies set deadlines for decisions affecting a wetland, or when the number of wetlands needing information on their functions or condition is large. In North America and a few other countries, standardized rapid assessment methods for wetlands have a long history, having been developed, calibrated, tested, and applied to varying degrees in several different regions and wetland types since the 1970s. However, few rapid assessment methods have been fully validated. Done correctly, validation is a very expensive endeavor that involves comparing rankings of a series of wetlands based on results from rapid assessment methods with rankings based on less rapid and considerably more costly, multi-visit, detailed measurements of levels of the same functions or other attributes in the same series of wetlands.

2. Inventory

Although developing a global inventory of wetlands has proven to be a large and difficult undertaking, many efforts at more local scales have been successful. Current efforts are based on available data, but both classification and spatial resolution have sometimes proven to be inadequate for regional or site-specific environmental management decision-making. It is difficult to identify small, long, and narrow wetlands within the landscape. Many of today's remote sensing satellites do not have sufficient spatial and spectral resolution to monitor wetland conditions, although multispectral IKONOS and Quick Bird data may offer improved spatial resolutions once it is 4 m or higher. Majority of the pixels are just mixtures of several plant species or vegetation types and are difficult to isolate which translates into an inability to classify the vegetation that defines the wetland. Improved remote sensing information, coupled with good knowledge domain on wetlands will

[78] Adamus, P. (2016). "Manual for the Wetland Ecosystem Services Protocol (WESP)" (PDF). Oregon State University. Retrieved July 28, 2018.

[79] Dorney, J.; Savage, R.; Tiner, R.W.; Adamus, P., eds. (2018). Wetland and Stream Rapid Assessments: Development, Validation, and Application. Cambridge: Academic Press. ISBN 978-0-12-805091-0.

facilitate expanded efforts in wetland monitoring and mapping. This will also be extremely important because we expect to see major shifts in species composition due to both anthropogenic land use and natural changes in the environment caused by climate change.

3. Monitoring

A wetland needs to be monitored over time to assess whether it is functioning at an ecologically sustainable level or whether it is becoming degraded. Degraded wetlands will suffer a loss in water quality, loss of sensitive species, and aberrant functioning of soil geochemical processes.

4. Mapping

Practically, many natural wetlands are difficult to monitor from the ground as they quite often are difficult to access and may require exposure to dangerous plants and animals as well as diseases borne by insects or other invertebrates. Therefore, mapping using aerial imagery is one effective tool to monitor a wetland, especially a large wetland, and can also be used to monitor the status of numerous wetlands throughout a watershed or region. Many remote sensing methods can be used to map wetlands. Remote-sensing technology permits the acquisition of timely digital data on a repetitive basis. This repeat coverage allows wetlands, as well as the adjacent land-cover and land-use types, to be monitored seasonally and/or annually. Using digital data provides a standardized data-collection procedure and an opportunity for data integration within a geographic information system. Traditionally, Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and the SPOT 4 and 5 satellite systems have been used for this purpose. More recently, however, multispectral IKONOS and Quick Bird data, with spatial resolutions of 4 by 4 m (13 by 13 ft) and 2.44 by 2.44 m (8.0 by 8.0 ft), respectively, have been shown to be excellent sources of data when mapping and monitoring smaller wetland habitats and vegetation communities. For example, Detroit Lakes Wetland Management District assessed area wetlands in Michigan, USA, using remote sensing. Through using this technology, satellite images were taken over a large geographic area and extended period. In addition, using this technique was less costly and time-consuming compared to the older method using visual interpretation of aerial photographs. In comparison, most aerial photographs also require experienced interpreters to extract information based on structure and texture while the interpretation of remote sensing data only requires analysis of one characteristic (spectral). However, there are a number of limitations associated with this type of image acquisition. Analysis of wetlands has proved difficult because to obtain the data it is often linked to other purposes such as the analysis of land cover or land use.

5. Further improvements

Methods to develop a classification system for specific biota of interest could assist with technological advances that will allow for identification at a very high accuracy rate. The issue of the cost and expertise involved in remote sensing technology is still a factor hindering further advancements in image acquisition and data processing. Future improvements in current wetland vegetation mapping could include the use of more recent and better geospatial data when it is available.

CONCLUSION

Wetlands are vital for human survival. They are among the world’s most productive environments; cradles of biological diversity that provide the water and productivity upon which countless species of plants and animals depend for survival. Wetlands are indispensable for the countless benefits or “ecosystem services” that they provide humanity, ranging from freshwater supply, food and building materials, and biodiversity, to flood control, groundwater recharge, and climate change mitigation. Wetlands also release vegetative matter into rivers, which helps feed fish in the rivers. Wetlands help to counter balance the human effect on rivers by rejuvenating them and surrounding ecosystems. Many animals that live in other habitats use wetlands for migration or reproduction. Amphibians often forage in upland areas but return to the water to mate and reproduce. While wetlands are truly unique, they must not be thought of as isolated and independent habitat. To the contrary, wetlands are vital to the health of all other biomes and to wildlife and humans everywhere. Unlike most other habitats, wetlands directly improve other ecosystems. Because of its many cleansing benefits, wetlands have been compared to kidneys. The analogy is good one. Wetlands and kidneys both help control water flow and cleanse the system. Yet study after study demonstrates that wetland area and quality continue to decline in most regions of the world. As a result, the ecosystem services that wetlands provide to people are compromised. Managing wetlands is a global challenge and the Convention presently counts over 160 countries as Contracting Parties, which recognize the value of having one international treaty dedicated to a single ecosystem. Further mores research should be conducted to know about the wetland ecosystem and improve the growth and development of wetland ecology.