Wetlands – An Introduction

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NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are designed to facilitate adaptation in a variety of settings. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section, and when appropriate, *PowerPoint* slides. The modules also contain other sections which contain additional supporting information such as assessment strategies and suggested resources.

Acknowledgements

We thank Mike Graybill of South Slough National Estuarine Research Reserve, Jan Hodder of The Oregon Institute of Marine Biology, and David Lonsdale of Chemeketa Community College for their thoughtful reviews. Their comments and suggestions greatly improved the quality of this module. We thank NCSR administrative assistant, Liz Traver, for the review, graphic design and layout of this module. Carla Cudmore located appropriate photographs and figures for this module and obtained permission for their use.

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NCSR *Wetland Ecology and Management Series* Introduction

Wetlands are among the most productive ecosystems on earth, and as such, provide countless ecological and economic benefits to humans. Management of this valuable resource is complex and represents an opportunity to approach the nature and management of a natural resource from several different perspectives in natural resource or environmental science programs. The NCSR *Wetland Ecology and Management Series* is designed to support the instruction of wetlands topics at the undergraduate level. It is modular in nature and instructors can pick and choose some topics for coverage and de-emphasize or ignore others. Thus, these curriculum materials are designed to meet a variety of instructional needs and strategies. The NCSR *Wetland Ecology and Management Series* is comprised of the following modules:

- ***Wetlands – An Introduction***

This module characterizes the wetlands resource and introduces students to wetlands as ecosystems and to the rationale for wetlands management. Wetland functions and values are also described.

- ***Wetlands – Then and Now***

This module describes the current status of wetlands and compares that to their place in history. Wetland types, classification schemes and causes for wetland loss and degradation are also discussed.

- ***Wetlands Management I – Determination and Delineation***

This module introduces wetlands management and describes wetland determination and delineation as first steps in wetland management projects. A field activity is included that engages students in the essential elements of wetland determination and delineation.

- ***Wetlands Management II – Compensatory Mitigation***

This module introduces the concept of compensatory mitigation and evaluates its effectiveness as a strategy for managing the wetland resource. A wetland mitigation field activity is included that describes how instructors can identify appropriate local wetland mitigation sites and how to organize a mitigation tour.

- ***Wetlands and Climate Change***

This module describes the complex relationship between wetlands and climate change.

- ***Wetlands and Hurricanes***

This module examines the impact of hurricanes on wetlands as well as the role of wetlands in the protection of coastal areas.

- ***Wetland Restoration in the Everglades***

This module uses restoration efforts in south Florida as a case study of wetland restoration.

Each module includes a lecture outline, *PowerPoint* presentation and detailed instructor notes. Modules with field-based activities also include student handouts, detailed procedures, data sheets and notes to instructors. In addition to the presentations and field activities described above, complete citations and brief summaries of relevant web, print and video resources are provided that can be used to:

- Enhance existing lecture topics
- Develop lectures on new topics
- Develop geographically relevant case studies
- Update wetlands statistics
- Select articles for student reading
- Access video and photos for presentation purposes

Intended audience

The NCSR *Wetland Ecology and Management Series* is intended to provide instructional support for undergraduate education at the freshman/sophomore level. Technical programs that include wetlands topics such as Wetlands Management, Civil Engineering and Biological Technician programs will find the modules to be a useful introduction to wetlands science and management. The materials are not designed to provide the training that is required by individuals to become certified wetland delineators or other types of wetlands technicians, as these curriculum materials and mechanisms for their delivery are available elsewhere. Also, NCSR wetlands materials are not designed for K-12 as a number of efforts have addressed wetlands for this level. In addition to providing background for those who will work with wetlands in their profession, NCSR materials also provide the background and context for students in other undergraduate programs. The materials may generate interest in some to pursue wetlands management as a career, but more importantly will result in an informed citizenry on wetlands issues. It is hoped that a more informed public will gather support for wetland conservation efforts as they occur in their local communities and help build a greater understanding of their importance.

The need for an undergraduate wetlands curriculum

Recent interest in wetlands as a valuable and dwindling resource has resulted in a large and growing volume of wetlands-related curriculum. However, the vast majority of these wetlands education resources target audiences other than first- and second-year college students. The K-12 audience, for example, has been well-served by efforts such as Project WET (Slattery and Kesselheim, 2003). The demand for training of wetlands delineators and those with expertise in wetland mitigation has driven the development of a number of continuing education classes that teach this material. The intended audience is those who are in the wetlands profession who seek the proper certification to conduct these activities. Examples include:

The Ohio State University
Olentangy River Wetland Research Park
www.swamp.osu.edu

North Carolina State University
Forestry and Environmental Outreach Program (FEOP)
http://www.ces.ncsu.edu/nreos/forest/feop/

Portland State University
Environmental Professional Program
http://epp.esr.pdx.edu/

The Swamp School
www.swampschool.org

Some degree programs at 4-year colleges and universities include courses in wetland ecology and management. However, the majority are taught at the graduate level and curriculum materials are not widely available for use outside of those institutions.

Thus, there appears to be a lack of classroom-ready materials and resources available for **undergraduate courses** that include some coverage of wetlands topics and form a bridge between the various wetlands curriculum materials described above. The NCSR *Wetland Ecology and Management Series* is designed to fill that void.

Guidelines for use

The manner in which instructors use the modules in this series will depend upon:

- The course in which the module will be used

The wetland mitigation modules are most appropriate for inclusion in undergraduate courses such as *Environmental Science*, *Introduction to Natural Resources*, *Wetlands Ecology* and *Introduction to Wetlands Management*. Parts of the modules may also have application in courses with a broader scope such as *General Ecology* and *General Biology*.

- The background of the students

The wetland mitigation modules assume some basic understanding of basic ecology including populations, communities and ecosystem structure and function. The treatment of ecology in either a college- or high school-level general biology course should be sufficient. Instructors may need to provide additional background to students who are not familiar with this material.

- The time that will be dedicated to the study of wetlands

There is sufficient information and resources in the wetlands mitigation modules to present anything from a single one-hour lecture to a significant portion of a full semester-long or quarter-long course. Instructors may select from the various components depending on course objectives and the amount of time allocated for wetlands topics.

A note on wetland field and laboratory experiences

The NCSR *Wetland Ecology and Management Series* emphasizes lecture support for instructors who are looking for wetlands material to insert into their courses. Although classroom lectures and discussions are a necessary element of a course that deals with wetlands issues, field and laboratory experiences enhance the learning experience and allow the instructor to explore topic areas that are not easily covered in the classroom. Additionally, students are more likely to become engaged in the topic when they can experience it firsthand.

Field activities may include a wide variety of experiences ranging from "tours" of various wetland types and restoration or mitigation projects to investigative experiences where students are actively engaged in the "scientific process."

Types of field activities (adapted from Baldwin, 2001):

- Field identification of wetland plants
- Preparation of plant collections using standard herbarium techniques
- Field identification of wetland animals
- Estimates of animal diversity and abundance (e.g., collection of invertebrates in soil litter samples, mammal livetrapping, amphibian surveys)
- Vegetation sampling methods (e.g., qualitative, line-intercept, transect, quadrat sampling)
- Analysis of wetland plant diversity and abundance
- Determination of hydric soils indicators
- Determination of site hydrology

Details of these methods are beyond the scope of this series and have been well-documented elsewhere in field and laboratory manuals designed for college-level courses. See resources below for some examples.

RESOURCES

Baldwin, A.H. 2001. Got mud? Field-based learning in wetland ecology. Journal of College Science Teaching 31:94-100.

O'Neal, L.H. 1995. Using wetlands to teach ecology and environmental awareness in general biology. American Biology Teacher 57:135-139.

Slattery, B.E. and A.S. Kesselheim. 2003. WOW! The wonders of wetlands: An educator's guide. Environmental Concern, Inc., St. Michaels, MD and The Project WET International Foundation, Bozeman, MT. 348 pp.

Wetlands – An Introduction

Module Description

This instructional guide is designed to provide instructors with lecture materials and resources that introduce wetlands as ecosystems. Student objectives, a general lecture outline and a more detailed *PowerPoint* presentation with instructor notes are provided. Wetland definitions and their importance are discussed as well as the criteria that are used to distinguish wetlands from uplands. The structural and physiological adaptations of wetland plants, wetland functions and the economic value of ecological services provided by wetlands are also presented. Instructors who are looking for videos or additional print and web-based resources on the topics covered here should consult the resources list provided at the end of this module where these resources are summarized and cited.

Objectives

Upon successful completion of this module students should be able to:

1. Distinguish between wetlands and uplands using soils, hydrological and vegetation criteria
2. Describe the structural and physiological adaptations of wetland plants
3. Describe the various ecosystem functions that are provided by wetlands
4. Evaluate the economic value of ecological services provided by wetlands

Wetlands – An Introduction –

General Lecture Outline

I. Introduction and Context
   A. The wetlands industry
   B. The value of wetlands
   C. Wetlands as ecosystems
   D. Loss and degradation of wetlands
   E. Wetland definitions - history
   F. Regulated activities
   G. Change in perception of wetlands
   H. Jurisdictional wetlands
II. Wetland Identification Criteria
   A. Wetland (hydric) soils
      1. Water saturation extended time during growing season
      2. Anaerobic conditions result
      3. Biological and chemical effects
   B. Hydrology – hydrological regime
      1. Sources of water
      2. Hydroperiod
   C. Vegetation – wetland plants
      1. Structural and physiological adaptations of wetland plants
      2. Hydrophytic plants as wetland indicators
III. Wetland functions
   A. Hydrologic processes
      1. Flood control
      2. Protection against storms and tsunamis
      3. Groundwater recharge
      4. Storage of surface water
      5. Erosion control
   B. Water quality improvement
      1. Removal of pollutants
      2. Protection of drinking water
      3. Wastewater treatment
   C. Wildlife habitat
      1. High net productivity
      2. Habitat for endangered species
      3. Habitat for marine species
      4. Vernal pools and isolated wetlands
IV. Wetland values
   A. Comparisons with other ecosystems
   B. Estimates of economic value

PowerPoint Presentation with Instructor Notes

Wetlands - An Introduction

By Wynn W. Cudmore, Ph.D.

Northwest **C**enter for **S**ustainable **R**esources

DUE # 0757239

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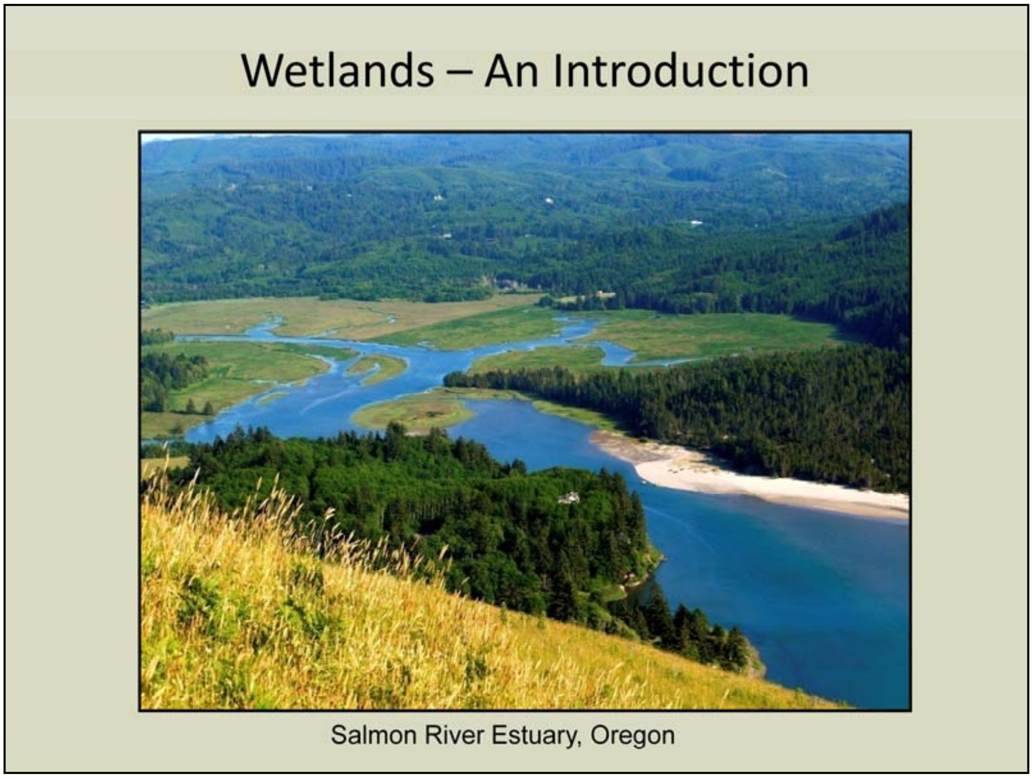


Salmon River Estuary, Oregon

This presentation is designed to introduce wetlands as ecosystems. Wetland definitions and their importance are discussed as well as the criteria that are used to distinguish wetland from non-wetland habitats.

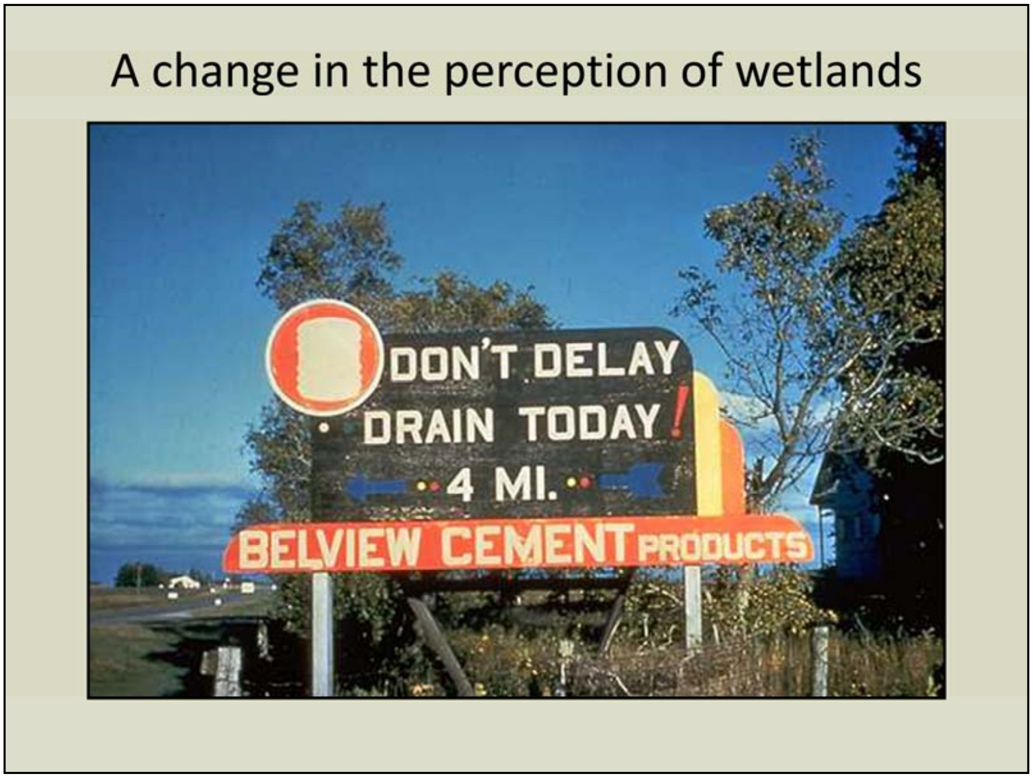
This photograph of the Salmon River Estuary on the central Oregon coast illustrates the beauty and interconnectedness of a tidal wetland. Above - and below – surface runoff flows from the forested upland in the background through the wetland in the center of the photo and ultimately into the estuary. Tidal flow brings salt water from the ocean into the wetland twice a day to further inundate this wetland. Note also the stark contrast between the emergent wetland vegetation dominating most of the photo with the open water habitat in the lower right and the tree-dominated vegetation of upland in the top of the photo.

Photo credit: Becca Cudmore

In September 2010, the Port of Tacoma in Washington was ordered by the Environmental Protection Agency to restore wetlands it had destroyed in 2006 and 2008. The EPA claimed that the port had filled in 5 acres of wetland without a permit, a violation of federal law. The port claims that it cleared and graded wetlands at Hylebos Marsh in Tacoma at the direction of federal and state agencies to eliminate an invasive snail outbreak. The Washington Department of Agriculture (WDA) claims that it provided technical advice to the port that included removing low-lying vegetation and small trees that would impede spraying a snail pesticide. Large trees could remain. After the decision was made to clear and grade the site, the Port of Tacoma informed the WDA and the U.S. Department of Agriculture of their decision. The outcome remains uncertain.

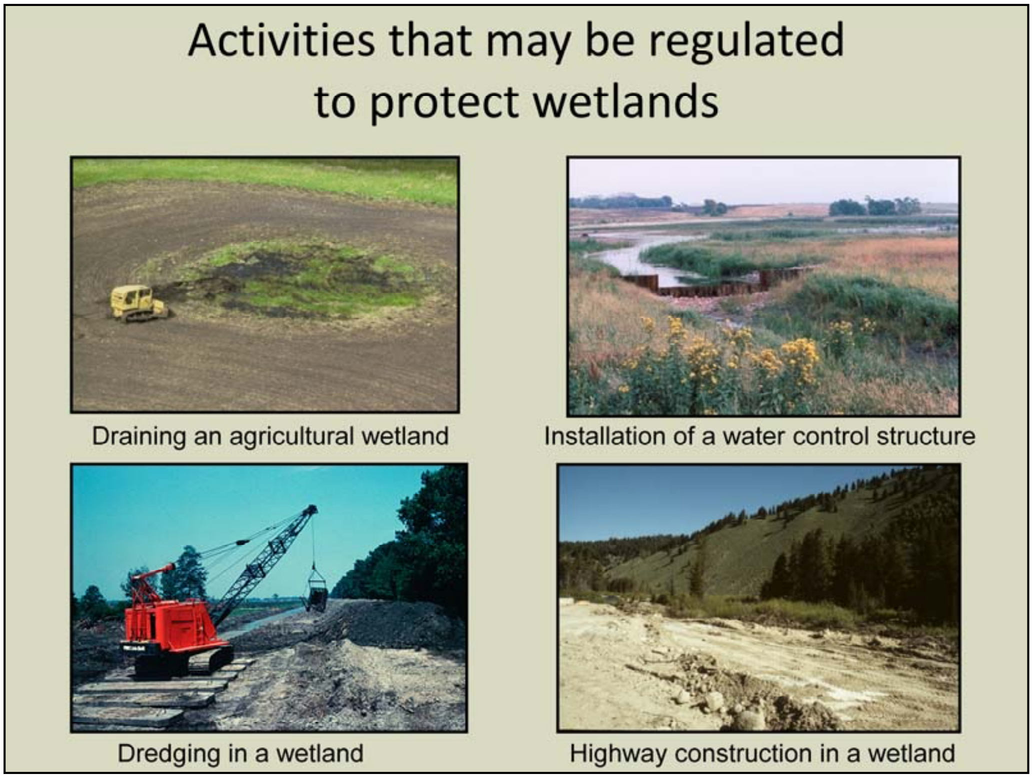
This is the world of wetlands management – conflict, scientific uncertainty, political posturing – while the general public remains largely uninformed of the context of the debate. What are wetlands? Why are they protected? What government agencies are responsible for their management? In recent years, we have come to recognize the need to regulate the destructive development of wetland areas. We have developed complicated permitting processes involving several agencies. At times, one agency's requirements are counter to another and communication among agencies can be poor. Contention and confusion may reign as developers attempt to navigate the system. The general public sees glimpses of the debate as reports of conflicts between developers and conservationists, impacts of oil spills on wetlands, and debates in Congress over funding for wetlands programs appear in the popular press. This series of modules is designed to shed some light on these questions and to provide the background required by citizens to make informed decisions concerning this natural resource.

Photo credit: Port of Tacoma



Historically, wetlands were considered "wastelands," suitable only for mosquitoes and draining. Until recently, wetland habitats were being destroyed at the rate of a half million acres per year. In recent times, wetlands have become recognized as important not only to wildlife, but also to humans. They filter out pollutants from water, provide a dependable water supply and serve as a natural means of flood and erosion control. The wetlands that remain are now recognized as a valuable natural resource.

Photo credit : U.S. Fish and Wildlife Service, National Conservation Training Center



With laws that were passed in the 1970s to protect wetlands (in particular, “dredge and fill” permit requirements under Section 404 of the Clean Water Act), it became necessary to define, identify and delineate wetlands. This section of the Clean Water Act (CWA) requires that authorization be obtained from the Army Corps of Engineers to deposit dredged or fill material into “waters of the United States, including wetlands.” The following activities, for example, are likely to require a permit if they are conducted in a wetland – placement of fill material, ditching activities, levee and dike construction, land leveling, road construction, and dam construction.

Photo credits:

Top left (draining) - U.S. Fish and Wildlife Service
Top right (water control structure) - U.S. Fish and Wildlife Service
Bottom left (dredging in wetland) - U.S. Fish and Wildlife Service, Gary Heet
Bottom right (highway construction) - NMFS/Northwest Fisheries Science Center; Pacific Northwest Collection

With the designation of wetlands as "waters of the United States" under Section 404 of the Clean Water Act of 1972, wetlands gained status as a protected entity under the laws of the United States. Consequently, a "wetlands industry" has emerged comprised of regulators, environmental lawyers, wetland engineers, and wetland consultants who are engaged in various aspects of wetlands management and conservation. These individuals are involved in the identification and delineation of wetlands, the design of mitigation projects to compensate for their loss and the development and enforcement of wetland regulations and policy. Ecosystem science generated by wetlands scientists and the emerging field of ecological restoration inform their activities. Educators at all levels have taken on the responsibility of conveying our new understanding of wetlands to students of all types and ages.

Photo credits:

Top left (girl with net) – U.S. Fish and Wildlife Service, Steve Hillebrand
Top right (person with orange vest) - Becca Cudmore
Bottom left – USDA, Brian Prechtel
Bottom right – U.S. Fish and Wildlife Service, Pedro Ramirez, Jr.

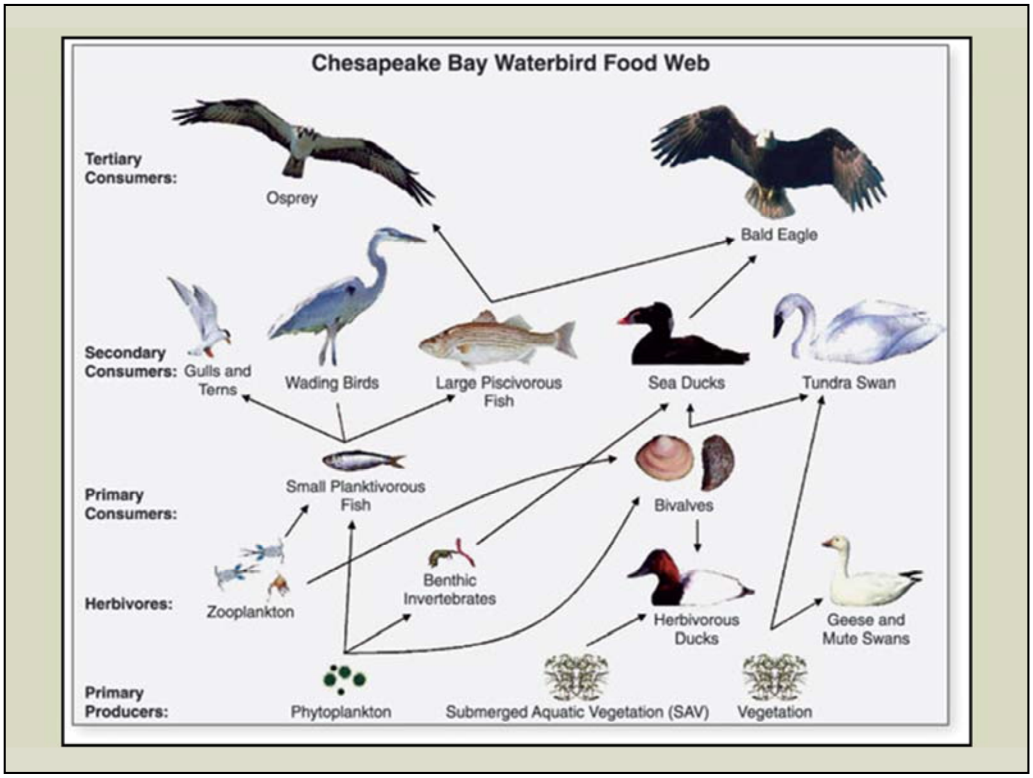
The Value of Wetlands

- High net productivity
- Abundant and diverse wildlife
- Water quality improvement
- Flood and storm protection

Wetlands bordering the Wicomico River, a tributary of Chesapeake Bay on Maryland's eastern shore

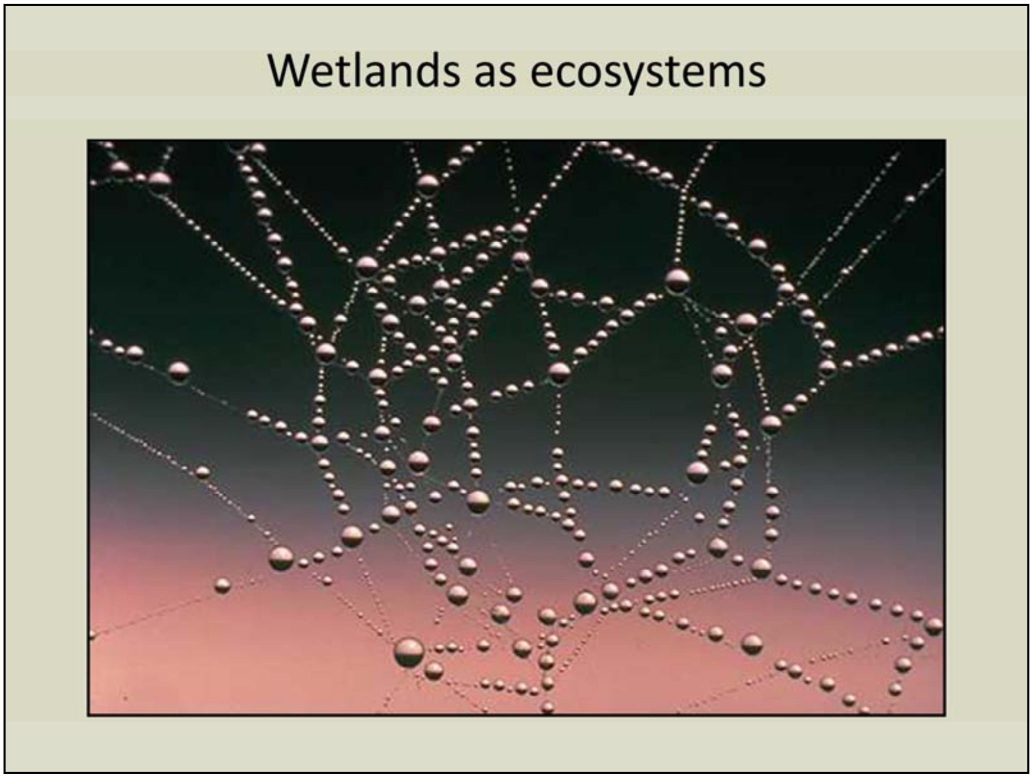
Wetlands are among the most important and productive ecosystems on earth. Measures of productivity rival those of tropical rainforests and coral reefs. The high net productivity of wetlands is the result of rapid recycling of nutrients that occurs with changing water levels and the breakdown of organic material catalyzed by wet conditions. Dead plant material, rapidly broken down in water by microorganisms, which in turn is fed upon by aquatic invertebrates, is the basis for food webs that support the abundance and diversity of wetland-associated wildlife. Although their importance as wildlife habitat has been known since the early 1900s, other functions, such as trapping sediment and pollutants, retaining rainwater, making rivers less prone to flooding and providing protection to coastal areas from storms, have only recently become known.

Photo credit: IAN Image Library (ian.umces.edu/imagelibrary/), Emily Nauman



This simplified food web for the Chesapeake Bay and associated wetlands illustrates energy flow in this ecosystem. Note that in this food web, large birds occupy several different trophic levels. Some ducks and geese are primary consumers; sea ducks, wading birds and tundra swans are secondary consumers; and, ospreys and eagles are tertiary consumers.

Photo credit: USGS, modified from Perry and others, 2005

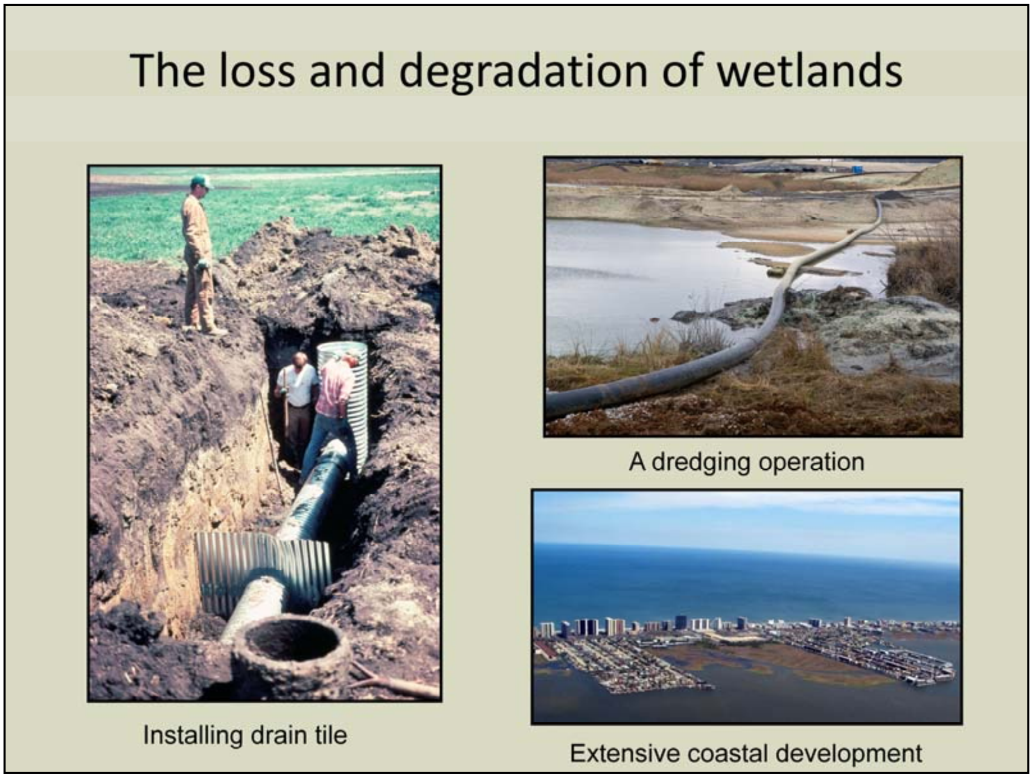


Wetlands, like all ecosystems, are comprised of an interconnected web of the living and the non-living. Plants, soil, bacteria, water, birds, and myriads of other ecosystem components are connected in ways that we are only now beginning to understand. Although we lack complete understanding of the intricate connections that exist in these ecosystems, it is important that we apply the knowledge that we do have and incorporate new findings as they are revealed through scientific research. The more we know about the natural systems that we manage, the better our management will be and the less likely that we will make costly mistakes.

Wetlands should be understood in the broader context in which they occur. Wetlands are but one component of watersheds, where they influence <u>and</u> are influenced by other components. Consider, for example, those areas where some of the most contentious wetlands issues in the United Sates occur – the Mississippi River Basin, the San Joaquin River Delta in California, the Klamath Basin in Oregon, the Chesapeake Bay in Maryland and Virginia, and the Everglades in Florida. Each of these areas contains wetlands that are degraded to various degrees and have lost some of their ecological and economic value. However, in addition to wetlands, other ecosystem types are represented within the watershed, each with its own human influence and degree of degradation. The quality of a wetland may, therefore, be influenced by events and conditions some distance away. Agricultural practices, urban development, forest harvest, oil extraction, and mining, for example, may all have direct or indirect impacts on what at first appears to be an isolated wetland.

Consequently, solutions to contentious wetlands issues require broad-based, comprehensive approaches that consider all ecosystem components.

Photo credit: U.S. Fish and Wildlife Service, National Conservation Training Center



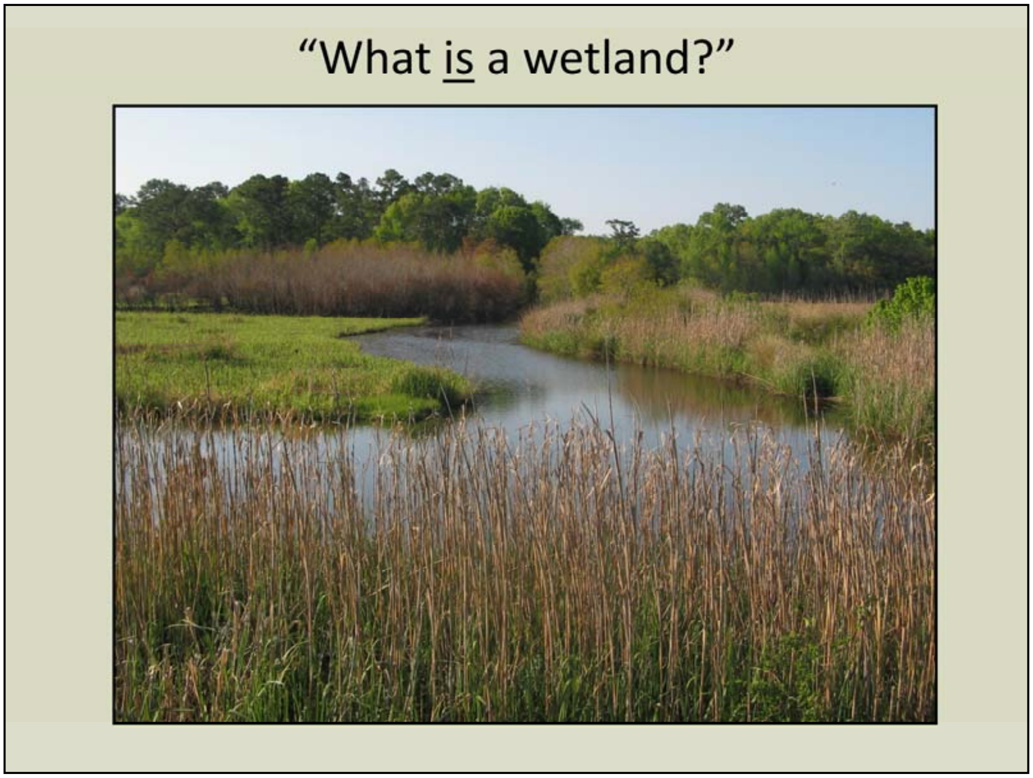
Despite their ecological and economic importance, wetlands are among the most commonly altered habitats in the human landscape. Millions of acres have been converted to agricultural land and residential development. Others have been isolated from their water source or polluted beyond recognition. As a result, many areas in the U.S. and elsewhere are left with only a small percentage of their historic wetlands. Consequently, wetland conservation has been demanded by society and has become the battle cry of a number of environmental organizations. In many areas of the world, wetlands conservation and restoration have become commonplace as society attempts to reverse earlier attempts to eradicate wetlands in favor of “more productive” lands.

These photos illustrate the types of activities that result in the loss or degradation of wetlands:

- Installing drain tile to remove water from an agricultural field
- A dredging operation in a wetland
- Extensive coastal development and eroding wetlands

Photo credits:

Left (drain tile) - U.S. Fish and Wildlife Service, Division of Public Affairs
Top right (dredging operation) - Tennessee Valley Authority
Bottom right (coastal development) - IAN Image Library (ian.umces.edu/imagelibrary/), J. Woerner

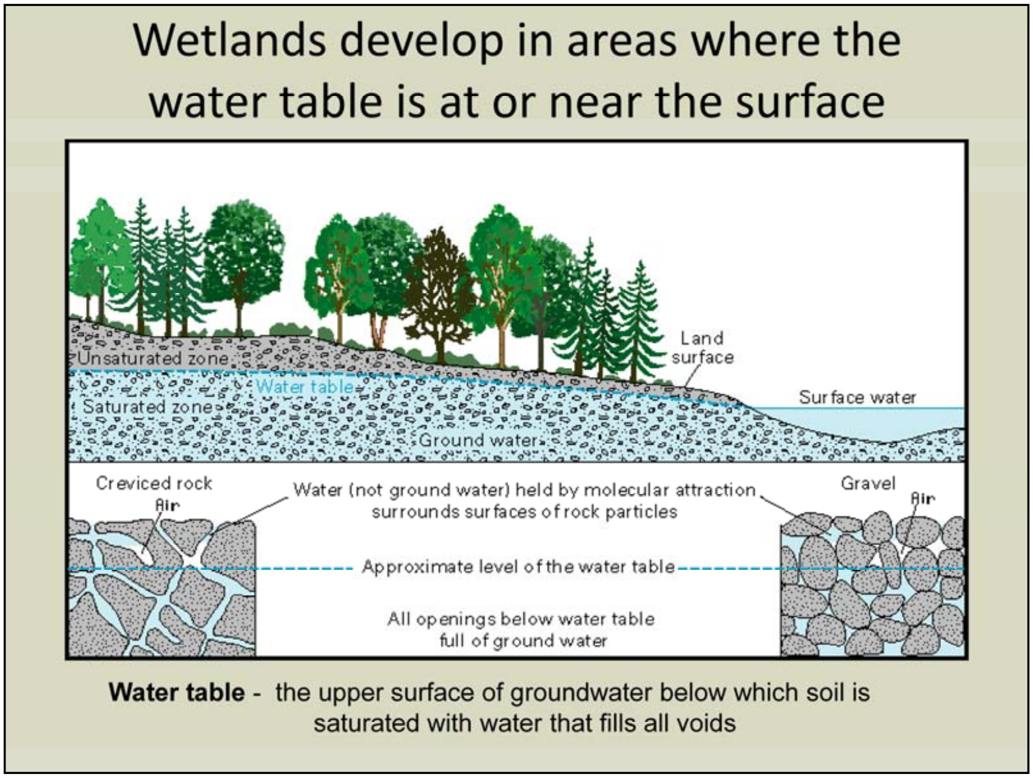


When most people envision a "wetland," images of dark, misty swamps or waving marsh grasses probably come to mind. Although these certainly qualify as wetlands, we have learned that a number of habitats that are not quite so "stereotypical wetland" also serve important wetland functions and as a result are now identified as "wetlands."

Photo credit: IAN Image Library (ian.umces.edu/imagelibrary/), Ben Fertig

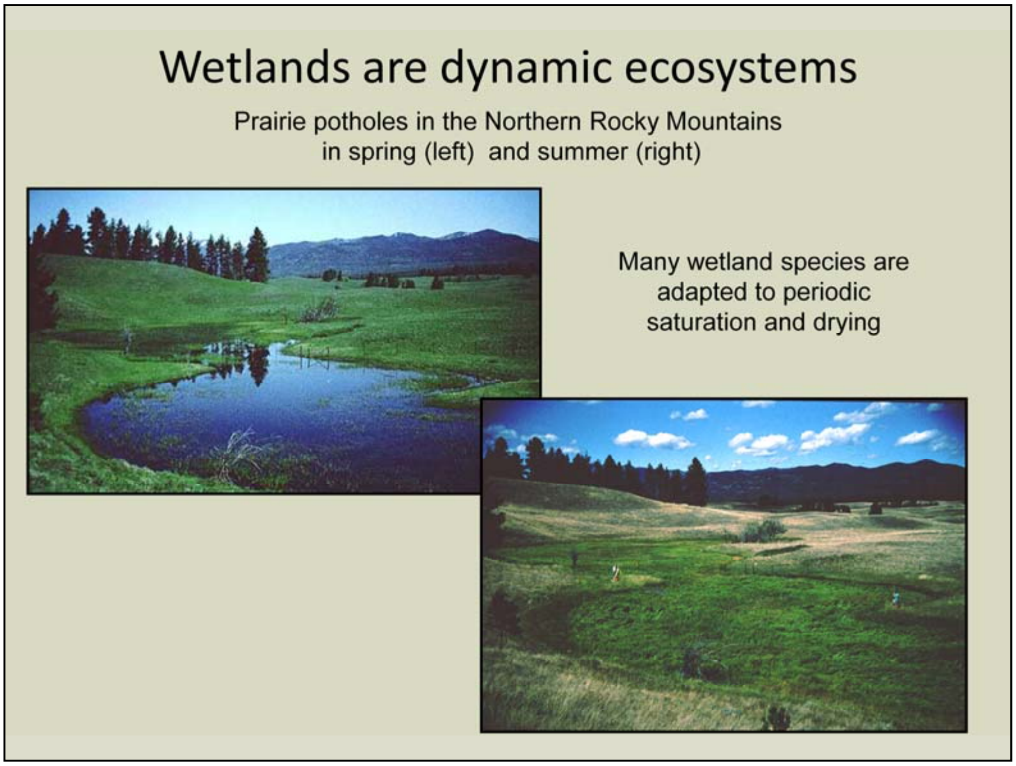
Wetlands usually occupy a transitional zone between well-drained uplands and permanently flooded deepwater habitats; examples include swamps, salt marshes and bogs. Many wetlands are permanently or intermittently flooded with shallow water; others are characterized by water tables that are at or near the surface. Most wetlands, however are not permanently inundated with water.

Photo credit: New York, USDA NRCS



Groundwater lies beneath the soil surface in geological deposits called **aquifers** (areas of permeable rock, clay and sand) as illustrated in this image. The **water table** is defined as the upper surface of groundwater below which soil is saturated with water that fills all voids (see details in lower portion of diagram). Wetlands develop in areas where the water table is at or near the surface. Therefore, wetlands that appear to be separated from one another may actually be linked through underground aquifers. Although not <u>necessary</u> for the development of a wetland, such areas may be periodically covered with shallow water.

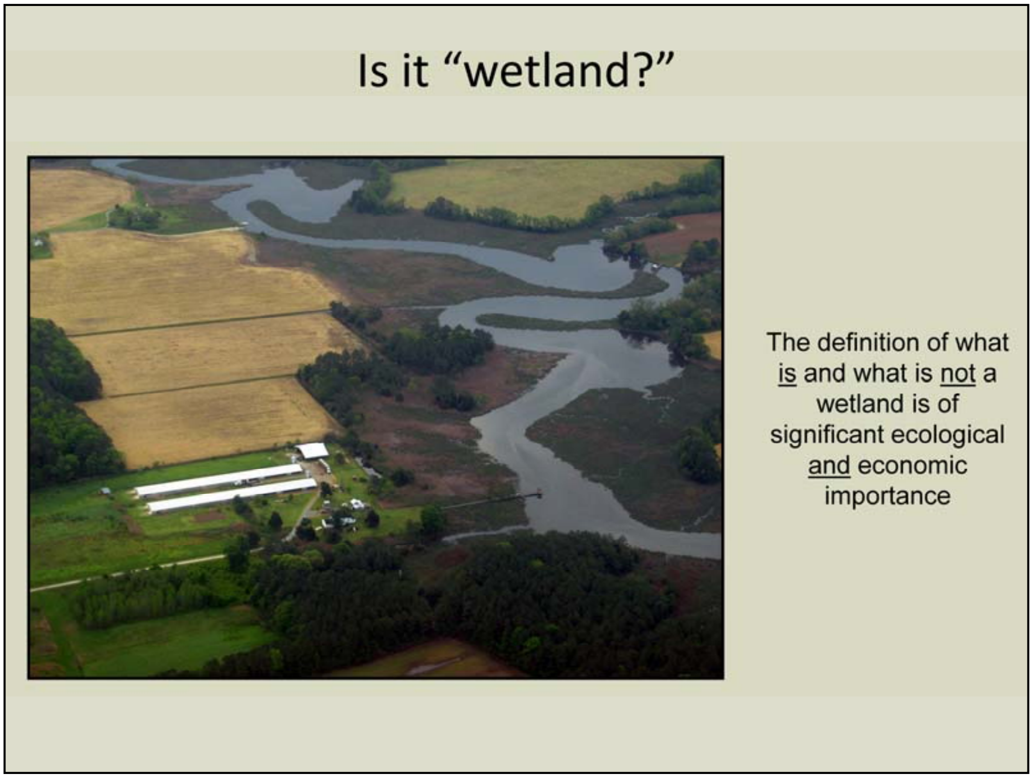
Image credit: USGS



Wetlands are dynamic; they change seasonally with changes in annual precipitation. Wetlands with static water levels tend to become more pond-like and lose some of their ecological value. Many wetland plants and animals are adapted to the periodic saturation and drying that occurs and small changes in flood/dry patterns can drastically change plant and animal species composition.

Prairie pothole wetlands, for example, are characterized by freshwater marshes that develop in shallow, often seasonal ponds that fill with rain and snowmelt in spring. Some dry out in summer and fall, while others retain some open water throughout the year. In these permanent, shallow ponds, concentric rings of vegetation result with submerged and floating aquatic plants dominating deeper water in the middle of the depression, bullrushes and cattails closer to shore and sedges and rushes adjacent to the upland.

Photo credit (both images): U.S. Army Corps of Engineers



The definition of what is and what is not a wetland is not simply an academic exercise. Landowners who plan to develop wetlands must meet requirements set forth in state and federal law, and in most cases, must compensate for those wetlands that are lost due to the development. This may come at great financial expense to the landowner.

Photo credit : IAN Image Library (ian.umces.edu/imagelibrary), Emily Nauman

The evolution of formal wetland definitions

Year	Definition	Source
1956	"…. lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, and river-overflow lands."	Circular 39 Definition from Shaw and Fredine 1956

Formal definitions of wetlands have been proposed since the 1950s. This early U.S. Fish and Wildlife Service definition is still used by wetlands scientists and managers in part because it is simpler than those that came later.

"…. lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, and river-overflow lands. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but the permanent waters of streams, reservoirs, and deep lakes are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist-soil vegetation."

Note that this early definition is quite general, emphasizes wetland vegetation and relies on providing <u>examples</u> of wetland types.

Circular 39 Definition (definition quoted from Shaw and Fredine 1956, p. 3)

The evolution of formal wetland definitions

Year	Definition	Source
1956	"…. lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, and river-overflow lands."	Circular 39 Definition from Shaw and Fredine 1956
1979	"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…. Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes, 2) the substrate is predominantly undrained hydric soil, and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year."	U.S. Fish and Wildlife Service (Cowardin, et al. 1979)

U.S. Fish and Wildlife Service wetland definition in Classification of Wetlands and Deepwater Habitats of the United States (Quoted from Cowardin, et al. 1979, p.3)

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…. Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes, 2) the substrate is predominantly undrained hydric soil, and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Note that this definition addresses both vegetation characteristics and physical attributes of wetlands. It also includes the three features of wetlands that are widely used today – hydrology, wetland soils and wetland vegetation.

The evolution of formal wetland definitions

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1984	"….those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."	Army Corps of Engineers/ Environmental Protection Agency (1984)

ACOE/EPA early 1980s definition: (Quoted from 33 CFR323.2c; 1984)

Wetlands are "….those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."

Note that this definition is still rather vague and, again, is based on vegetation types.

In an attempt to devise an objective, science-based and comprehensive definition of wetlands, a panel of government scientists established such a definition in 1989. Farmers and real-estate developers responded saying that the definition was too inclusive and saw it as an economic threat to property values. During the 1990s there were several attempts to narrow the definition (primarily in response to these complaints). The narrower definition removed "marginal wetlands" from the definition that were not as wet as the more readily recognized swamps and marshes. As a result, nearly half of lands in the U.S. that were designated as wetlands were removed from wetland protection.

The evolution of formal wetland definitions

Year	Definition	Source
1956	"…. lowlands covered with shallow and sometimes temporary or intermittent waters. They are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, and river-overflow lands."	Circular 39 Definition from Shaw and Fredine 1956
1979	"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water…. Wetlands must have one or more of the following three attributes: 1) at least periodically, the land supports predominantly hydrophytes, 2) the substrate is predominantly undrained hydric soil, and 3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year."	U.S. Fish and Wildlife Service (Cowardin, et al. 1979)
1984	"….those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas."	Army Corps of Engineers/ Environmental Protection Agency (1984)
2000	"Wetlands are ecosystems that arise when inundation by water produces soils dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding."	Keddy, P.A. (2000)

Note that this definition is the first that defines wetlands in the context of ecosystems.

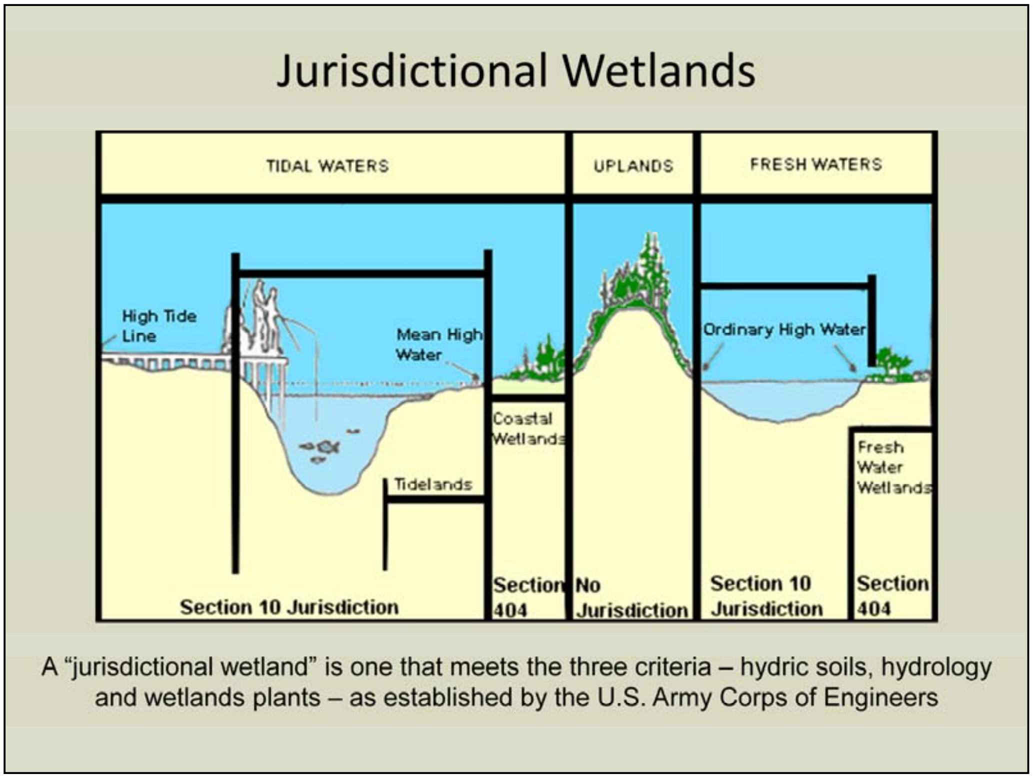
Vernal pool wetland in northern California

Therefore, wetlands are areas that are covered by water or at least have waterlogged soils for significant periods of time during the growing season. Wetland plants have the ability to live in saturated soils for at least part of the growing season. Although some wetlands such as marshes or swamps are usually easily identifiable as wetlands, those that are dry during most of the year such as some wet meadows, bottomland forests, pocosins and prairie potholes may not appear to be “wetlands” to the casual observer.

Pocosin – a type of bog (nutrient poor and acidic) dominated by evergreen shrubs found on the coastal Atlantic plain

Prairie pothole – small, shallow ponds formed when glacial ice melted at the end of the last Ice Age.

Photo credit: USDA Natural Resources Conservation District, Gary Kramer



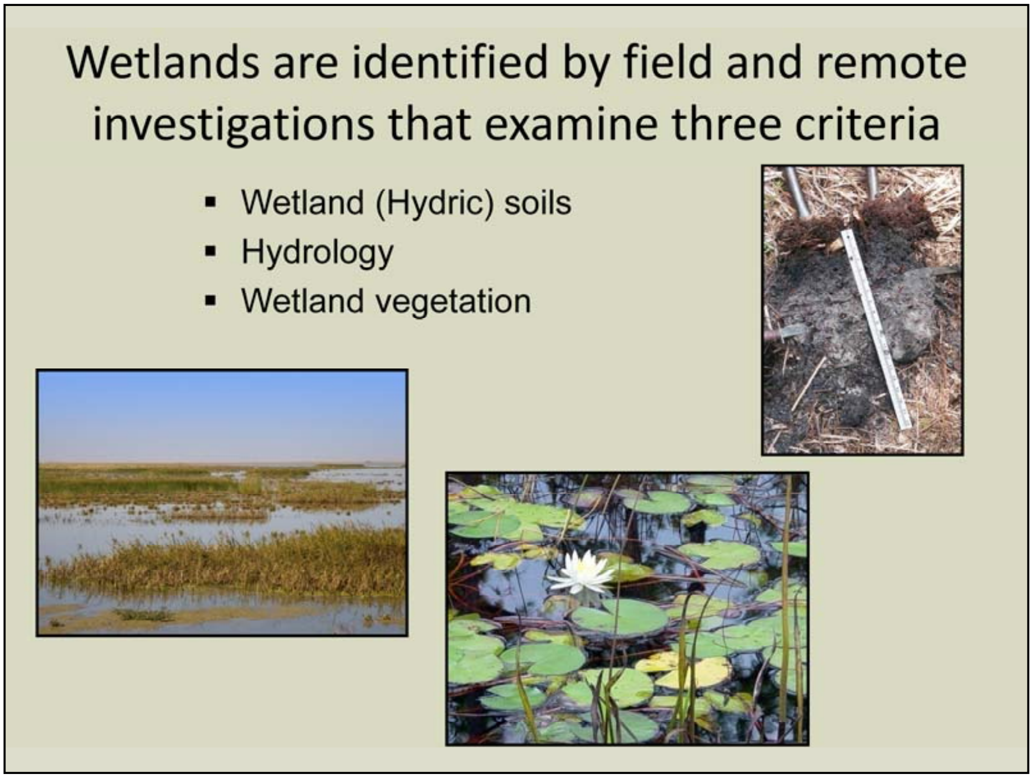
The choice of <u>which</u> definition to apply is in part determined by the reason for wetland identification. An area is considered to be a "jurisdictional wetland" if criteria are met (as established by the Army Corps of Engineers Manual) for all three wetlands characteristics – hydric soils, hydrology, wetlands plants. Property that fails to meet one or more of these criteria are not considered to be jurisdictional wetlands and thus do not fall within those regulations that are wetlands specific (even though they <u>may</u> be providing wetlands functions to various degrees).

Disturbed wetlands (e.g., a wetland that was filled before it became illegal to do so) may be evaluated in a similar manner, but it is possible that only one or two of the criteria may be used in the determination.

This diagram illustrates the various wetland types that come under the jurisdiction of the Army Corps of Engineers under Section 404 of the Clean Water Act – both coastal and freshwater wetlands are included.

"Section 10 jurisdiction" situations are also shown. These waters fall under Section 10 of the Rivers and Harbors Act of 1899, which prohibits the obstruction or alteration of navigable waters of the U.S. It covers any work that affects the course, location, condition or capacity of navigable waters (e.g., piers, wharfs, breakwaters, jetties, weirs, etc.).

Photo credit: U.S. Army Corps of Engineers



Wetland identification criteria

Note that although the details of formal definitions of wetlands differ, nearly all identify the same three characteristics. Wetland identification and delineation is now determined by field and remote investigations that allow a professional to identify the presence of certain characteristics of the 3 main components of wetlands that are included in the definitions above:

- Wetland (Hydric) soils
- Hydrology (the distribution and movement of water)
- Wetland vegetation

Each of these will be discussed in detail.

Photo credits:

Left (hydrology) - USDA Natural Resources Conservation Service
Top right (soils) - USDA Natural Resources Conservation Service
Bottom (vegetation) - Ben Fertig, IAN Image Library (ian.umces.edu/imagelibrary/)

Wetland (Hydric) Soils

- Soils that are water saturated for extended periods of time during the growing season
- Soil oxygen is rapidly depleted due to chemical and biological oxygen demands
- Anaerobic conditions result
- Lack of oxygen has a number of effects on biological and chemical processes in soil

Mottling is a wetland soil characteristic

Hydric soils are defined as soils that are water saturated for extended periods of time during the growing season. Soils that are "waterlogged" will often demonstrate characteristics that distinguish them from non-hydric soils. In non-hydric soils, oxygen is trapped in the many spaces between soil particles. This oxygen is used by plants to carry out respiration – the metabolism of sugars to obtain energy. In hydric soils however, this soil oxygen is rapidly depleted due to chemical and biological oxygen demands and anaerobic conditions result. This lack of oxygen has a number of effects on the biological and chemical processes in soil.

For example, since plants require oxygen in the soil to carry out respiration, if anaerobic conditions persist for just a few weeks during the growing season, most upland plants will perish. As discussed later, wetland plants have special adaptations that provide them with an advantage over most other plants in low oxygen conditions.

This photo illustrates one characteristic of wetland (hydric) soils. Mottling refers to the presence of different zones of color and texture within a soil sample caused by periods of saturation. Indicators of hydric soils are more fully discussed in the *Wetlands Management I - Determination and Delineation* module.

Photo credit: Becca Cudmore

Hydrology – hydrological regime

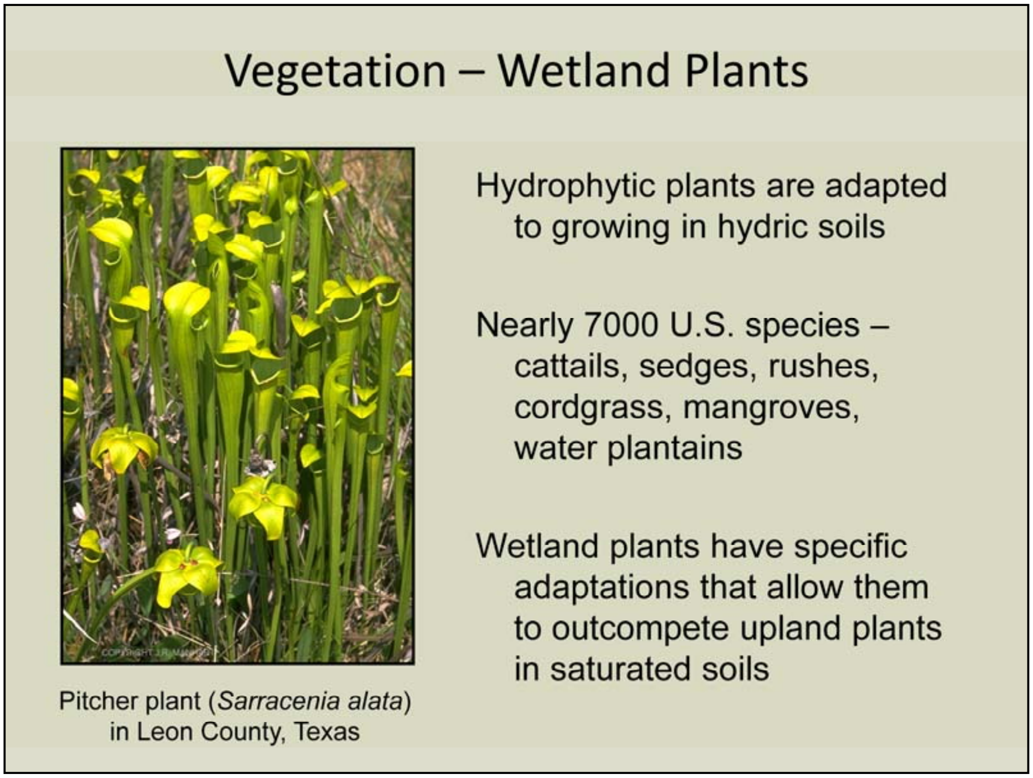
Possible sources of water:

- Tidal flow
- Precipitation
- Groundwater seeps
- Periodic flooding

Hydroperiod - the temporal pattern of water's fluctuation (regular or sporadic)

The hydroperiod strongly influences the type of wetland that is supported.

The amount and pattern of water presence determines a wetland. Water is often at or just below the surface creating saturated conditions that favor wetlands plants. Sources of water may vary with time of day (e.g., tides), season and from year to year and may include ebb and flow of tides, precipitation, ground water seeps, or periodic flooding. In many wetland types, water accumulates above a poorly drained soil layer. Many wetlands are seasonal in nature and are dry during one or more seasons every year. The hydroperiod is the pattern in time of water's fluctuation and may be regular (as in tides or the onset of a predictable rainy season) or sporadic (as in flooding). The hydroperiod has a strong influence on the type of wetland that is supported. Different wetland plants and animals have different adaptations to slight differences in hydroperiod.



In addition to the criteria described above, wetlands are distinguished from uplands by having an abundance of plants adapted to growing in wet soils. Wetland plants are hydrophytic and have adaptations that allow them to occupy saturated, anaerobic soils. There are nearly 7000 plant species (6728 on “1988 National List” published by U.S. Fish and Wildlife Service) in the United States that may occur in wetlands – cattails, sedges, rushes, cordgrass, willows, mangroves and water plantains are common examples. While non-wetland plants take in oxygen through the roots and distribute it to the stems and leaves, in saturated soils wetland plants must use other strategies. Having these adaptations affords a great adaptive advantage to wetland plants over non-wetland plants in these environments. As a result, wetland plants outcompete other plants in these environments.

Insectivorous plants such as the pitcher plant shown here are particularly common in some wetlands because acidic conditions limit the availability of nitrogen. The ability to trap and digest insects provides a supplemental nitrogen source and an advantage over those plants that do not have this adaptation.

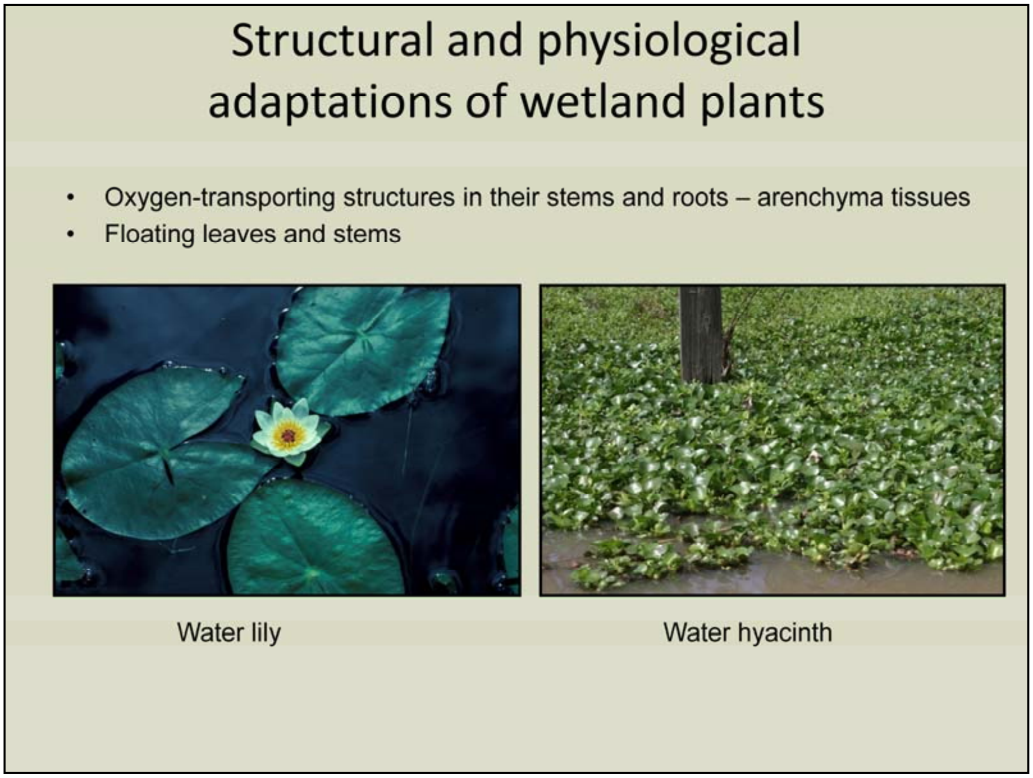
Photo credit: Photo Courtesy of James R. Manhart, Texas A&M University

Structural and physiological adaptations that allow hydrophytic plants to occupy wetland habitats include the following:

- Oxygen-transporting structures in their stems and roots (reeds, cattails, sedges and rushes) – arenchyma tissues

Arenchyma tissues are characterized by large air-filled cavities that allow for the exchange of gases between plant tissues above and below water.

Photo credit: Becca Cudmore

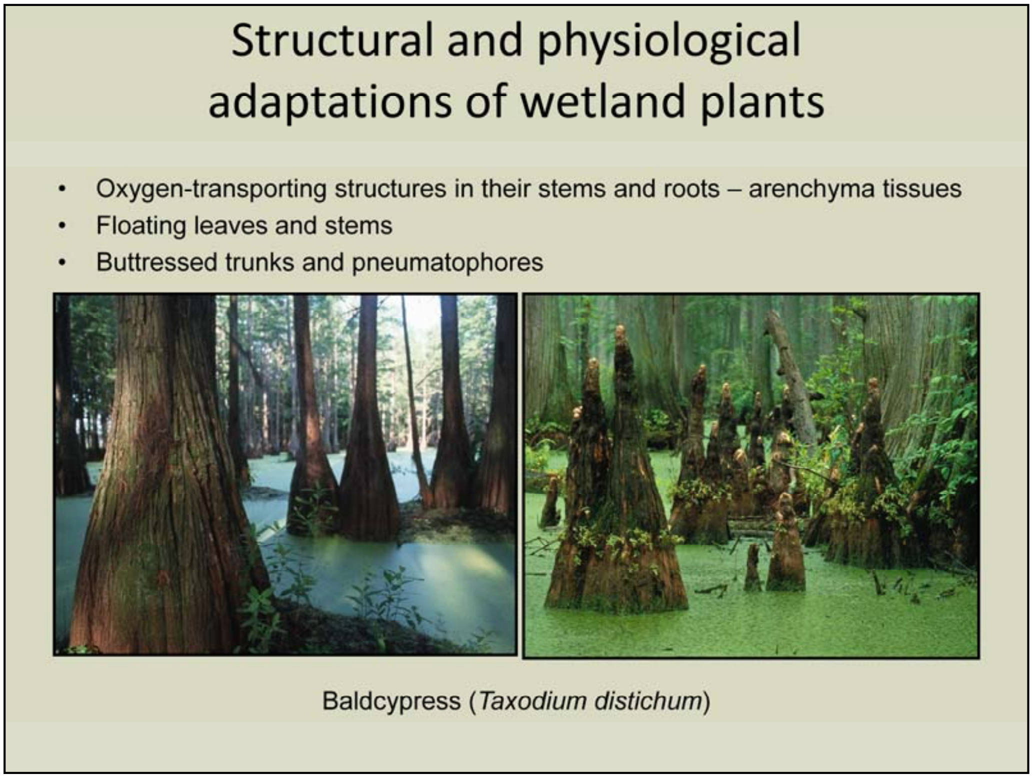


Structural and physiological adaptations that allow hydrophytic plants to occupy wetland habitats include the following:

- The ability of leaves (e.g., water lilies) or entire plants (e.g. water hyacinth and duckweed) to float on shallow water. Floating leaves allow for free gas exchange and better exposure to sunlight particularly in environments with fluctuating water levels.

Photo credits:

Left (water lily) - U.S. Fish and Wildlife Service
Right (water hyacinth) - U.S. Fish and Wildlife Service, Steve, Hillebrand

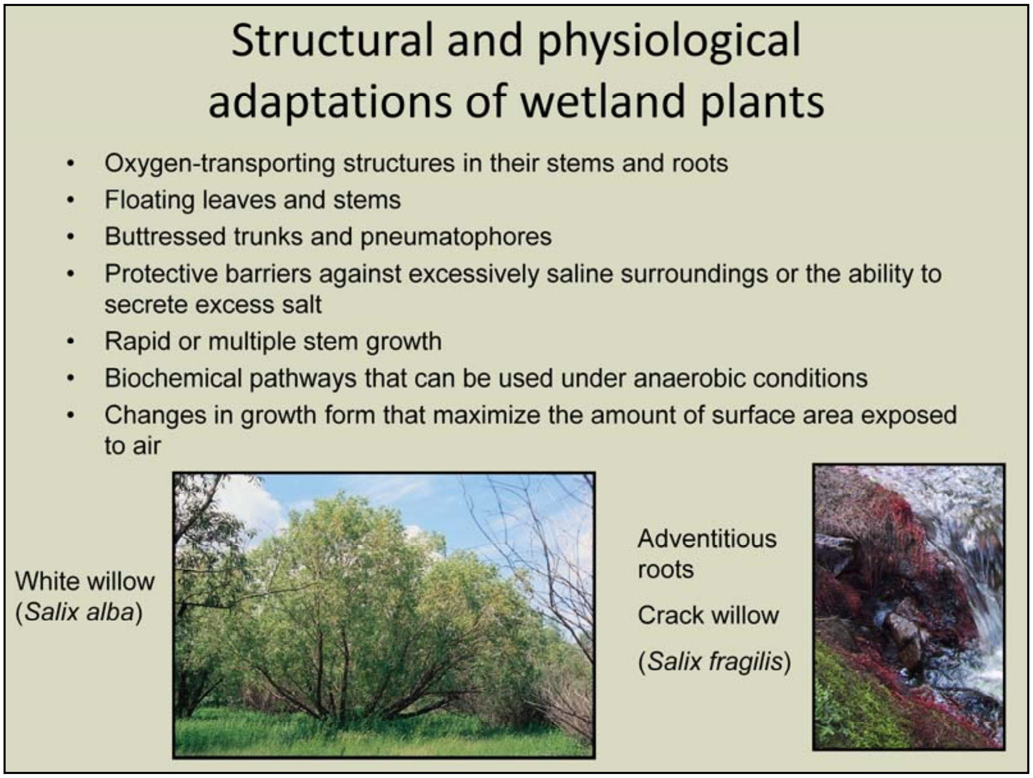


Structural and physiological adaptations that allow hydrophytic plants to occupy wetland habitats include the following:

- Buttressed trunks and pneumatophores (e.g., cypress "knees") that extend above the high water mark where, at least in some species (e.g., black mangrove), they are thought to transport oxygen and carbon dioxide to other tissues in the tree. They also serve a support function in a flood- and hurricane-prone part of the country (e.g., water tupelo, sweet blackgum, red mangrove, baldcypress)

Photo credits:

Left - USDA Natural Resources Conservation Service, Dot Paul
Right - U.S. Fish and Wildlife Service, Ned Trovillion



Structural and physiological adaptations that allow hydrophytic plants to occupy wetland habitats include the following:

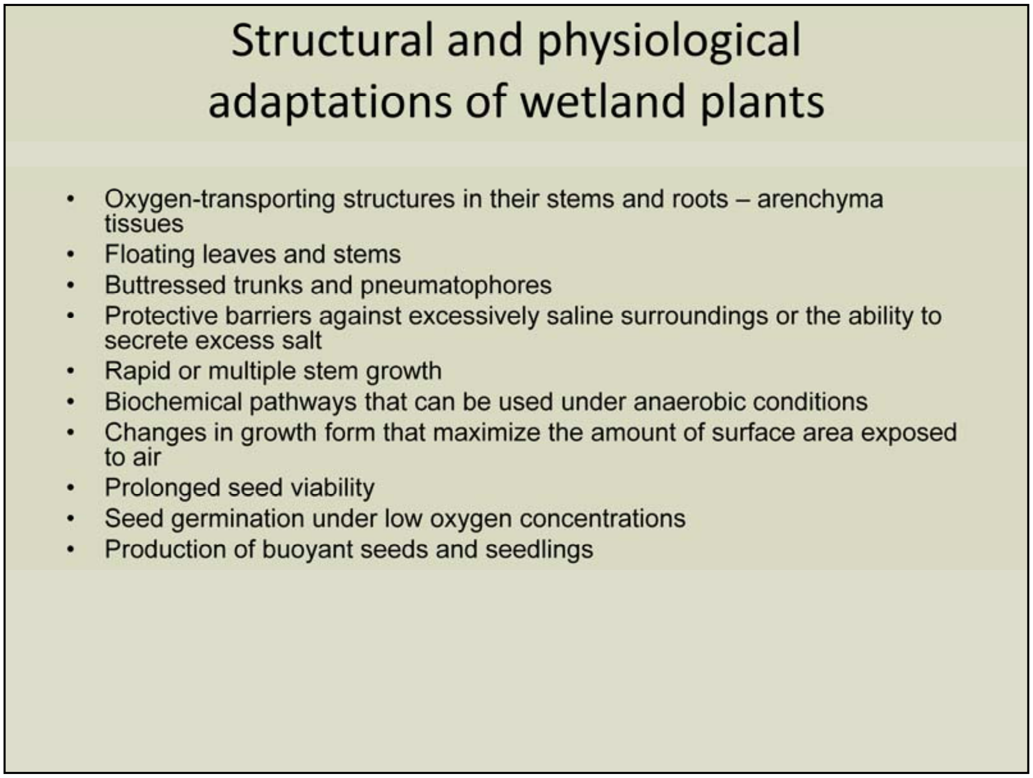
- Protective barriers against excessively saline surroundings or the ability to secrete excess salt (e.g., some marsh grasses)
- Rapid or multiple stem growth that allows plants to keep leaves and stems above water during floods
- Biochemical pathways in plant cells that can be used under anaerobic conditions
- Changes in growth form that maximize the amount of surface area exposed to air - adventitious roots, shallow roots, multiple stems, roots close to the surface (Boxelder, black cottonwood, willows)

Adventitious roots of Crack willow (in red) can be seen in photo at right.

Photo credits:

White willow - USDA-NRCS PLANTS Database / Herman, D.E., et al. 1996. *North Dakota tree handbook*. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck.

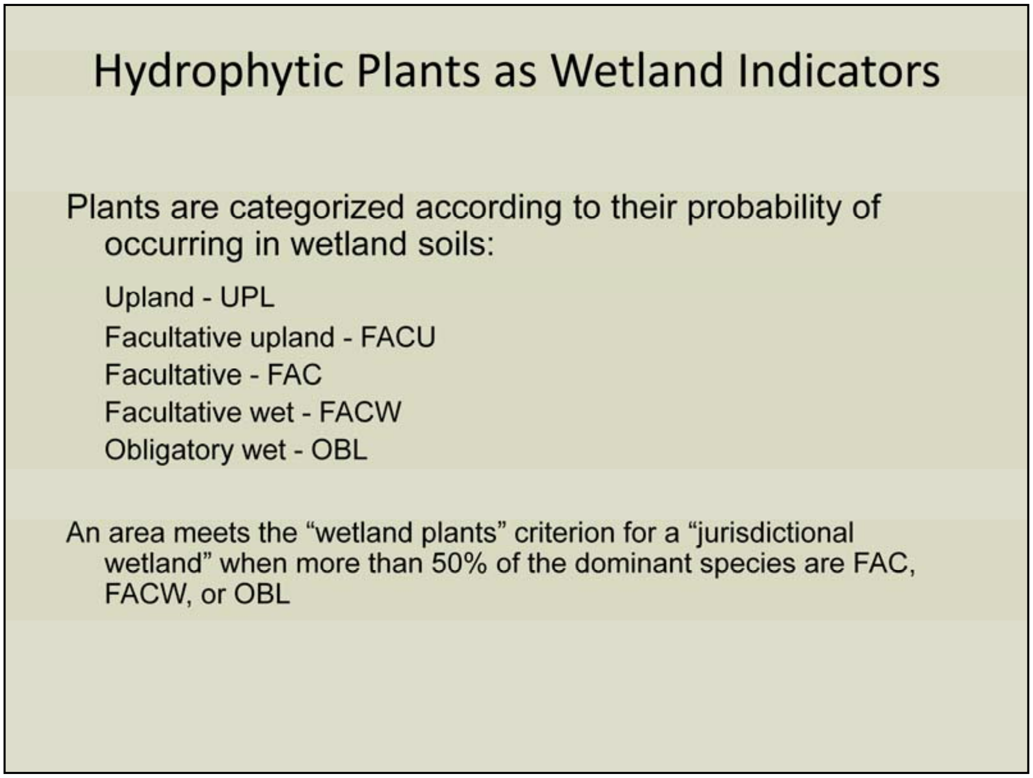
Crack willow roots (right) – David Lonsdale



Structural and physiological adaptations that allow hydrophytic plants to occupy wetland habitats include the following:

- Prolonged seed viability – some wetland plants have seeds that remain viable for over 20 years creating a persistent seed bank that germinates when conditions are appropriate.
- Seed germination under low oxygen concentrations
- Production of buoyant seeds and seedlings

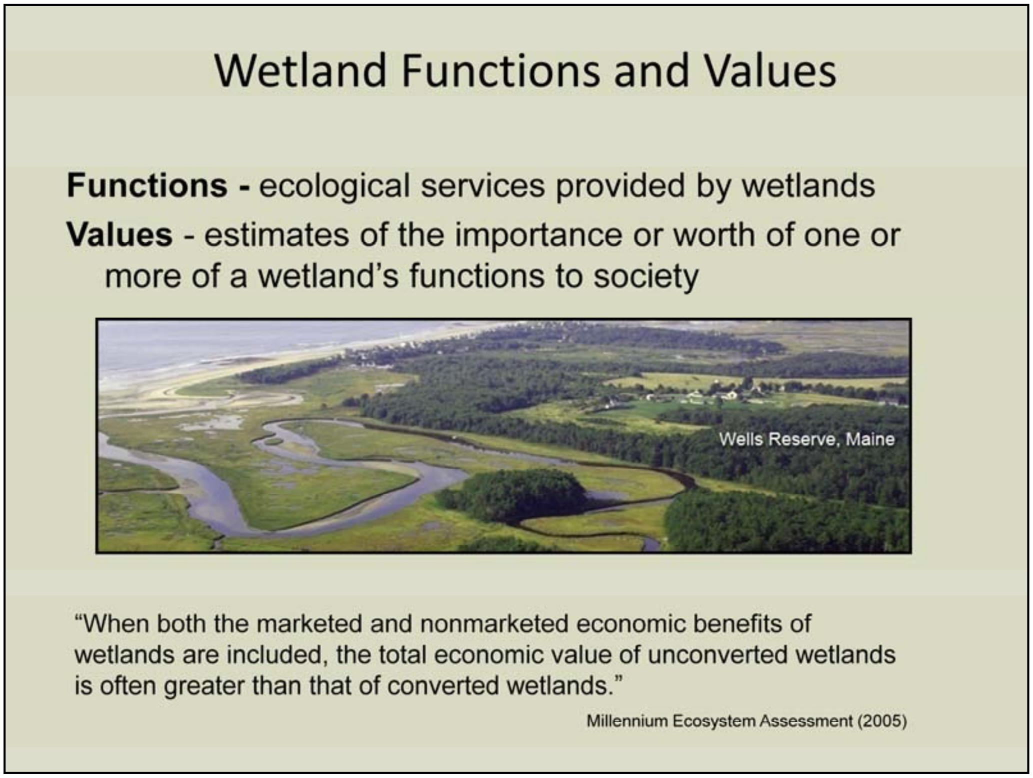
Red Mangrove provides an interesting example. Their large (4-6” long) seeds begin germination on the tree and then drop into the water while still attached to the fruit. A 40-day obligate flotation period assures dispersal from the parental tree. Seeds may float at sea for up to one year. When the seeds encounter suitable habitat, they change density making the root tip heavier. The seed becomes vertical in orientation and roots into the substrate.



For the purposes of wetland identification, plants are categorized according to their probability of occurring in wetland soils. Five widely-used categories have been developed that are described in the *Wetland Determination and Delineation* module. An area is considered to be a jurisdictional wetland when more than 50% of the dominant species are “wetland plants” – facultative, facultative wet, or obligatory wetland plants (see*Wetland Determination and Delineation* module for details).

Facultative – optional or discretionary; in this context, plants that are “facultative” (FAC) are those that have about an equal probability of appearing in wetlands and uplands. FACU plants can survive in either, but are more likely to be in uplands. FACW plants are more likely to be in wetlands.

Obligatory – required; in this context, plants that are OBL are found <u>only</u> in wetlands.



For most of the 20th century, wetlands were viewed as "wastelands" or as areas that provided little benefit beyond waterfowl habitat. As the American public became aware of ecosystem services provided by wetlands, they recognized that past policies had resulted in both ecological and economic costs. This growing concern prompted governments at all levels to enact legislation that would protect remaining wetlands and attempt to restore some lost wetlands.

Functions are ecological services provided by wetlands and may be categorized in a number of different ways (see below for one way).

Values are estimates of the importance or worth of one or more of a wetland's functions to society.

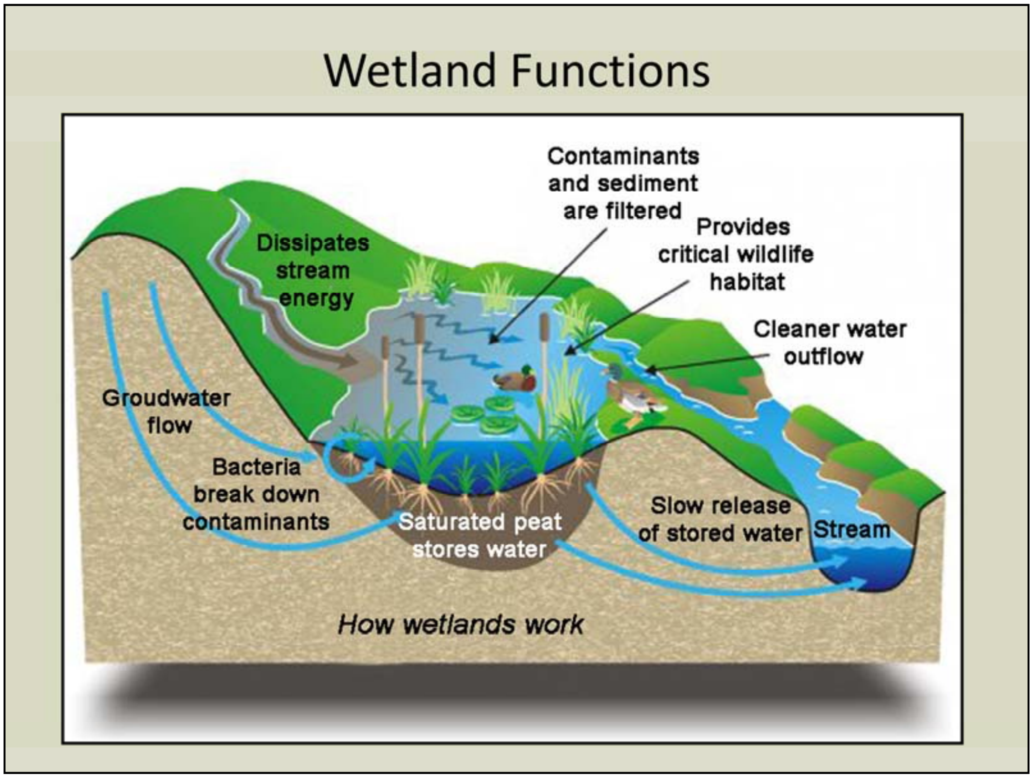
Humans may assign value to wetlands as a result of their location in the landscape, the wide variety of functions they perform or the uniqueness of their plant and animal communities. Individuals may also value wetlands for their aesthetic qualities, as sites for education and scientific research, as locations of historical or archaeological significance or as repositories for water during floods.

Estimates of "value" can be determined in a number of different ways. For example:

- the revenue generated by the sale of fish and shellfish that depend on wetlands for part of their life cycle
- the tourist dollars that are associated with a wetland
- measures of public support for protecting fish and wildlife

Assigning values to aesthetic and ecological services is inherently difficult due to individual differences in value systems.

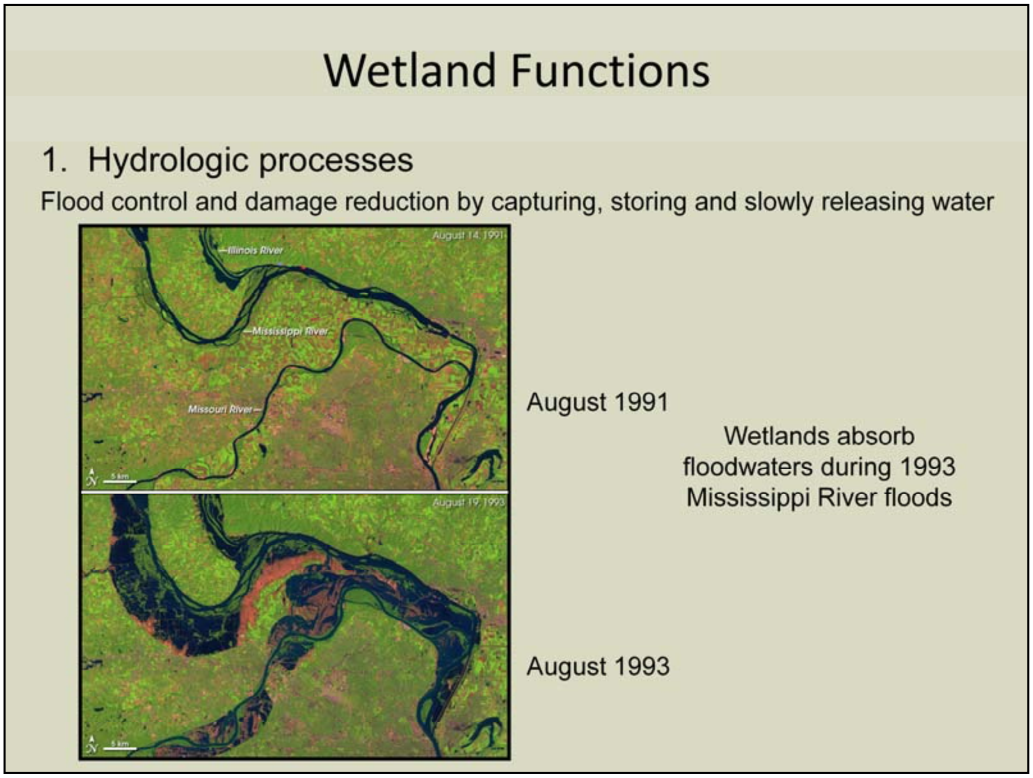
Photo credit: National Estuarine Reserve Research System, National Oceanic and Atmospheric Administration/Department of Commerce



Wetland functions are illustrated in this diagram. They fall into three categories – hydrological processes, water quality improvement and fish and wildlife habitat. Each is discussed in detail in the slides that follow.

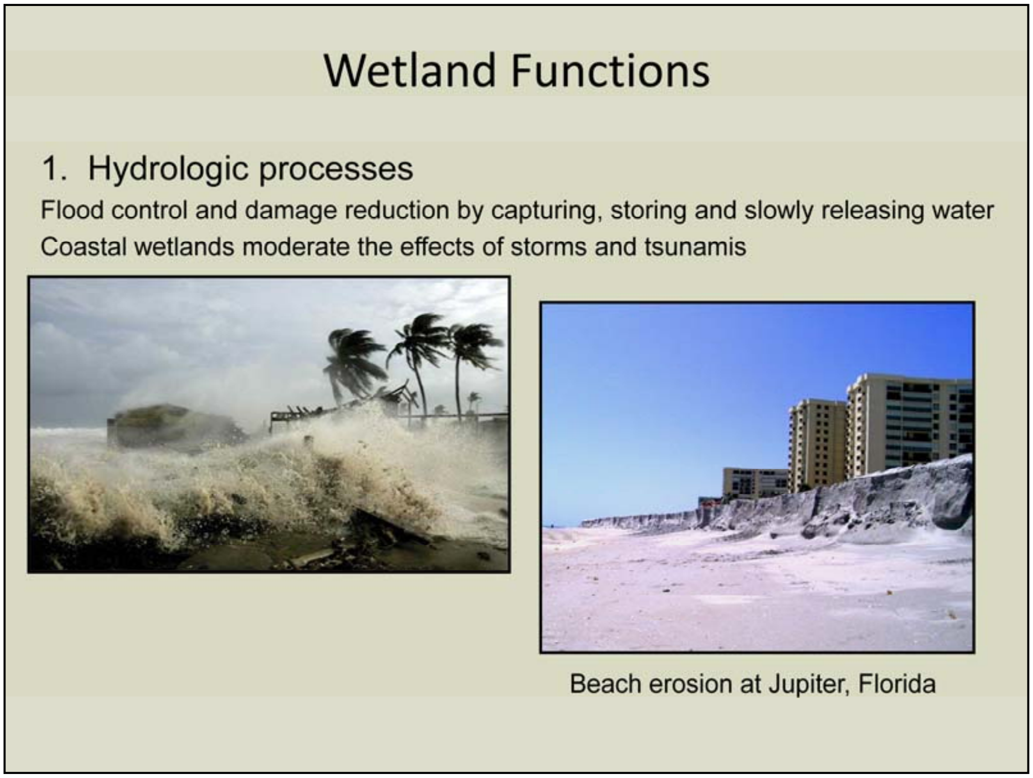
Wetlands also serve as a carbon sink. This function is discussed in more detail in the NCSR *Wetlands and Climate Change* module.

Photo Credit: Natural Resources Canada



Wetlands associated with river systems absorb floodwaters during periods of heavy rainfall or snowmelt. Conversion of these wetlands to agricultural, industrial or residential land uses reduce the water storage capacity of the landscape and may increase the risk of downstream flooding.

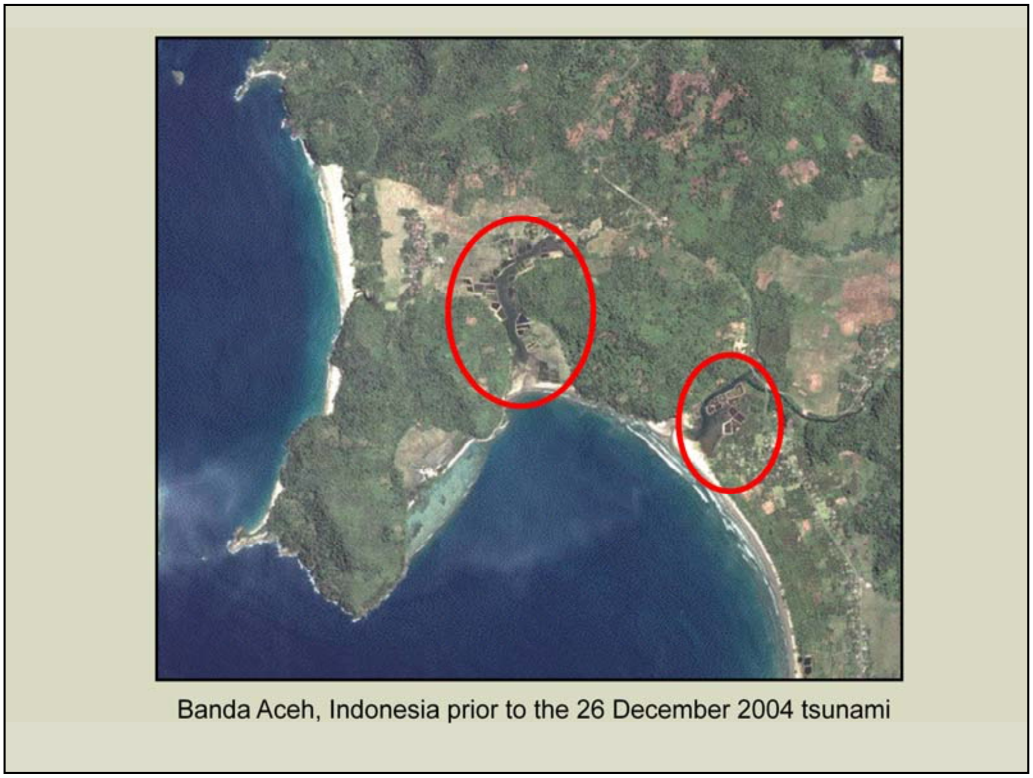
Image Credit: NASA Earth Observatory



Wetlands serve as buffers to storm surges generated by hurricanes. Quantifying the reduction of storm surges by wetlands has proven to be complex. A commonly cited reduction of "one foot for every 2.7 miles (measured inland from shoreline) of wetlands" is based on a 1963 U.S. Army Corps of Engineers report, which examined the penetration of storm surges from seven southern Louisiana storms from 1909-1957.

Photo credit:

Right - William Djubin, EarthRehab/Marine Photobank



This is an aerial view of Banda Aceh, Indonesia prior to the 26 December 2004 tsunami that devastated the region. The image shows areas that were cleared of mangrove wetlands for shrimp farms, a growing industry in the region.

Photo credit: Marine Photobank

Shrimp farms can be clearly seen in this enlarged image.

Photo credit: Marine Photobank

Banda Aceh, Indonesia after the 26 December 2004 tsunami

Coastal damage was found to be more extensive in areas that were cleared of mangroves (primarily for shrimp aquaculture) than those left intact, illustrating the protective function of coastal wetlands.

Danielsen, F., et al. 2005. The Asian tsunami: A protective role for coastal vegetation. Science 310:643.

Photo credit: Marine Photobank

Wetland Functions

1. Hydrologic processes
   - Flood control and damage reduction by capturing, storing and slowly releasing water
   - Coastal wetlands moderate the effects of storms and tsunamis
   - Recharge groundwater
   - Store surface water serving as natural reservoirs
   - Control erosion by serving as sediment traps and by stabilizing soils
2. Water quality improvement
   - Trap, retain and process pollutants in flooded soil - “kidneys of the landscape”
   - Protect drinking water supplies
   - Treat wastewater – “treatment wetlands”

Constructed wetlands can be used to treat wastewater

Constructed wetlands in Boulder City, Nevada

In recent years, constructed wetlands have been used to augment or, in some instances, replace more conventional wastewater treatment plants. Examples include the system shown here in Boulder City, Nevada and others in Avondale, Arizona and Arcata, California. A number of physical, chemical and biological processes occur in wetlands that improve water quality:

Physical processes – filtration, evaporation, sedimentation (gravitational settling of solids)

Chemical processes – precipitation (formation of insoluble compounds), chemical decomposition (hydrolysis, breakdown by UV)

Biological processes – bacterial metabolism, uptake and utilization by plants, shading by plants

Photo credit: Lynn Betts, USDA Natural Resources Conservation Service

Wetland Functions

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   - Store surface water serving as natural reservoirs
   - Control erosion by serving as sediment traps and by stabilizing soils
2. Water quality improvement
   - Trap, retain and process pollutants in flooded soil - “kidneys of the landscape”
   - Protect drinking water supplies
   - Treat wastewater – “treatment wetlands”
3. Wildlife habitat
   - High net productivity, but often low plant diversity

This photo shows Alaska brown bears feasting on sedges in Hallow Bay, Katmai National Park and Refuge, Alaska.

Even at northern latitudes wetlands maintain a high level of net productivity.

Commercially important species are also grown in wetlands including wild rice, blackberries, cranberries, blueberries and peat moss.

Coastal Native American tribes relied heavily on tidal wetlands for shellfish (oysters, clams and mussels) and these species continue to be harvested both commercially and recreationally today. Both coastal and inland tribes also used wetland plants (tule rush and bullrush, in particular) for house construction, basket weaving and even boat building.

Photo credit: National Park Service

Wetland Functions

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3. Wildlife habitat
   - High net productivity
   - Habitat for threatened and endangered species

Wetlands as habitat for threatened and endangered species

Wood stork (*Mycteria americana*) – an endangered species

Wetlands cover less than 5% of the U.S. land surface, but the U.S. Fish and Wildlife Service estimates that one-third of all endangered species spend at least part of their lives in wetlands. Nearly 50% of all threatened and endangered freshwater fish, 30% of all threatened and endangered birds and 16% of all threatened and endangered mammals require wetland habitats.

Wetlands serve as essential habitat for a number of threatened and endangered species, represented by this wood stork (*Mycteria americana*). The wood stork is native to wetlands of southeastern U.S. and has been listed as an endangered species since 1984. It is a highly colonial species and nests in large cypress or mangrove trees on islands. The species declined from an estimated population in the 1930s of about 40,000 birds to a low of about 10,000 in the late 1970s. The current population is approximately 16,000 birds. The primary causes for decline are thought to be a decline in the species' food base (small fish) driven by the loss of wetland habitat and changes in water hydroperiods. Throughout most of its range, wetlands have been drained and water regimes have been changed due to construction of extensive systems of levees, canals and water control structures.

Photo credit: U.S. Fish and Wildlife Service, Steve Hillebrand

Wetland Functions

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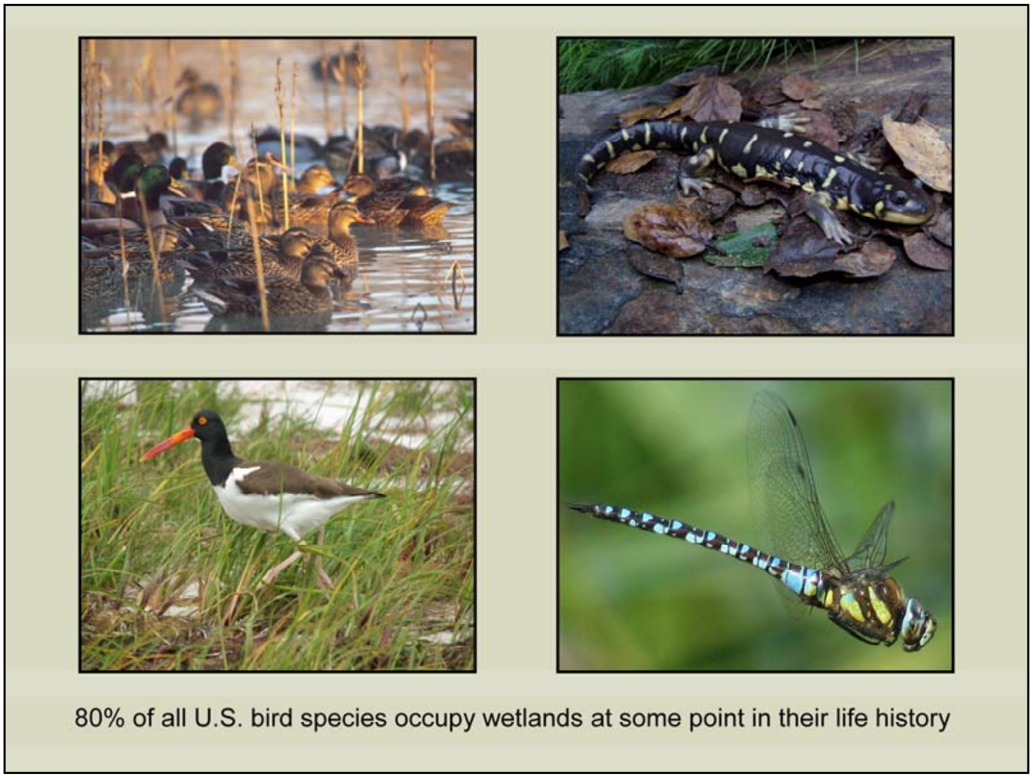
3. Wildlife habitat
   - High net productivity
   - Habitat for threatened and endangered species
   - Wetlands are especially important habitat for waterfowl, songbirds, shorebirds, wading birds, reptiles, amphibians, and many invertebrates



Wetlands support a disproportionate percentage of native biodiversity – 80% of all breeding bird populations in U.S. and >50% of migratory bird species occupy wetlands at some point in their life histories. The Prairie Pothole region in the Midwest, for example, is thought to produce 50-75% of the total continental duck production (mallards, gadwall, blue-winged teal, shoveler and pintails) in the United States and is the single most productive habitat for waterfowl in the world. These shallow wetlands thaw early in the spring producing abundant food for migratory birds at a time when it is most needed.

Wetlands also support a diversity of amphibian and aquatic insect species.

Photos:

Mallard ducks
Oystercatcher
California tiger salamander *(Ambystoma californiense)*
Dragonfly

Photo credits:

Top left – ducks: New York, USDA NRCS
Top right – salamander: Copyright, 2006, William Flaxington
Bottom left – Oystercatcher: Thomas M. Carlton/Marine Photobank
Bottom right – dragonfly: James Martin (www.martin-james.net/contact.html)

Wetland Functions

1. Hydrologic processes
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   - Wetlands are especially important habitat for waterfowl, songbirds, shorebirds, wading birds, reptiles, amphibians, and many invertebrates
   - Nurseries for marine fish and shellfish

Native oysters attached to prop roots of red mangrove
Sanibel Island, Florida

Many commercially important fish and shellfish species spend at least part of their life cycle in wetlands. This photo shows native oysters attached to the prop roots of red mangrove on Sanibel Island, Florida.

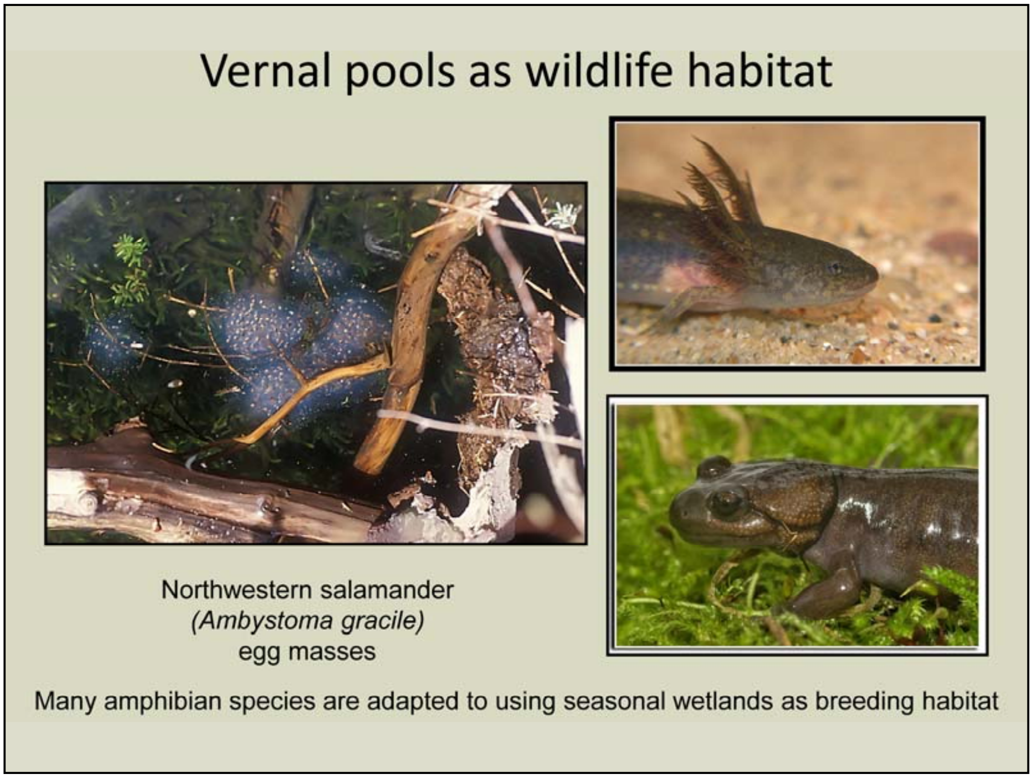
Estuary and wetland-dependent fish and shellfish species account for about 75% of the total annual seafood harvest in the U.S. and about 90% of the recreational catch. In the Gulf of Mexico alone, coastal waters attract millions of sports fishermen and beach users and tourism contributes billions of dollars to the economy of Gulf coast states. This relationship between wetlands, fish populations and the fisheries they support cannot be overemphasized. Wetlands provide essential habitat, clean water, food production, spawning and nursery areas and refuges from predators, floods and storms for fish and shellfish. While past efforts have emphasized over-harvesting as the primary cause for fish declines, the loss of wetlands and a re-evaluation of their role, must be added to fish recovery efforts.

Photo credit: Bruce Neill, Sanibel Sea School/Marine Photobank

This image shows a geoduck (pronounced “gooey-duck”) farm on an intertidal mudflat in Puget Sound, Washington. Geoducks (*Panopea abrupta*) are a highly prized mollusk species native to the Pacific Coast and grown commercially in coastal wetlands. The PVC tubes shown in the image each house 3 or 4 geoducks and are installed to reduce predation. Geoducks are the world’s largest burrowing clam and can live up to 160 years. They are typically grown for 4 to 6 years and then harvested using hydraulic water jets. Most are sold to a highly lucrative Asian sushi market.

Photo credits:

Mudflat - Kathryn Townsend/Marine Photobank
Geoducks - Washington State Department of Natural Resources

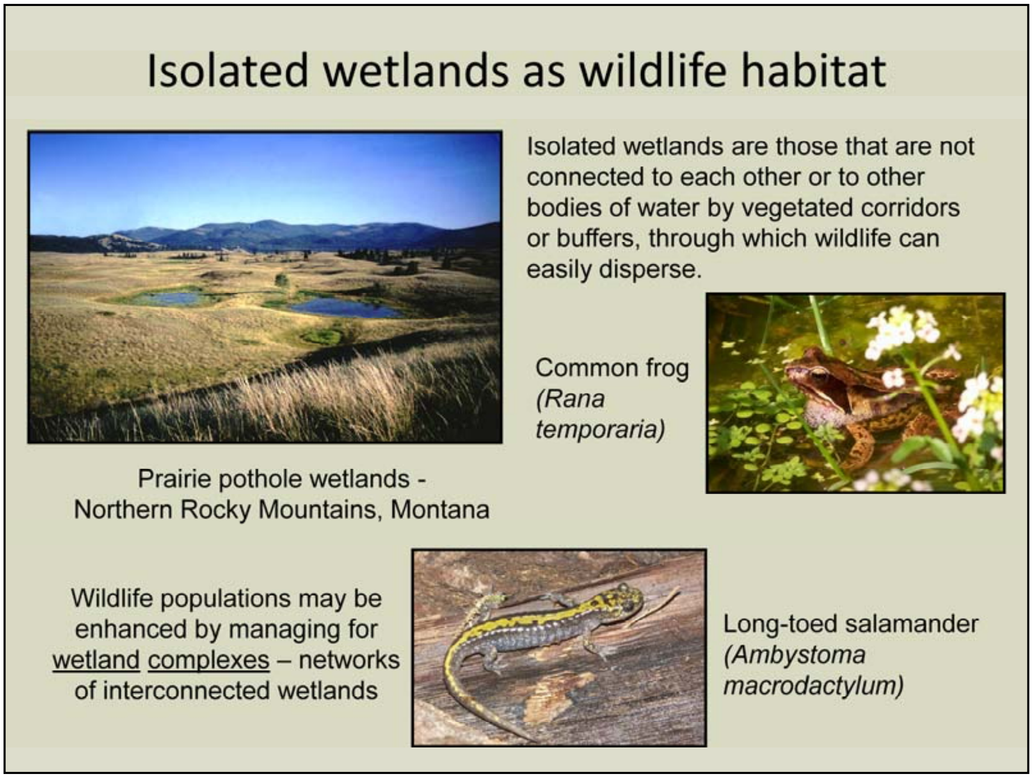


Even wetlands that appear dry during parts of the year provide important habitat for some wildlife. A number of amphibian species, for example lay their eggs in the spring when wetlands contain lots of water due to snowmelt and spring rains. Larvae develop in an aquatic environment that is relatively warm, well-stocked with insect larvae for food and lacking aquatic predators. Since these ponds dry out later in the summer they do not support fish – common predators of amphibians in more permanent waters. Fully developed, amphibians emerge in summer and migrate to surrounding aquatic, riparian, or upland habitat to forage or over-winter. Many invertebrates also thrive in the fish-free aquatic environments of temporary wetlands.

Vernal pools – shallow bodies of water that fill up in spring and typically dry out later in the summer

Photo credits:

Northwestern salamander egg masses – Copyright 2004 Henk Wallays
Spotted salamander (*Ambystoma opacum*) larva - Copyright 2005 Henk Wallays
Northwestern salamander adult - Copyright 2007 Henk Wallays
Used with written permission from the photographer



See notes slide 51 (page 61)

Photo credits:

Left: U.S. Army Corps of Engineers
Middle right (*Rana temporaria* Common frog) – Copyright 2004 Henk Wallays
Bottom right (*Ambystoma macrodactylum* Long-toed salamander) - Copyright 2003 Henk Wallays
Used with written permission of the photographer

Notes Slide 51 (page 61)

In addition to the loss and degradation of wetland acreage, remaining wetlands have become increasingly disconnected (ecologically isolated) from surrounding wetlands. Much like the distribution of old growth forests in the Pacific Northwest and tropical rainforests in Brazil, this has resulted in a loss of critical habitat for a wide variety of wildlife species.

Wetlands may be isolated from each other geographically, hydrologically, or ecologically. Although each of these has consequences for wildlife, most wildlife research has focused on the consequences for wildlife in a landscape that has ecologically isolated habitats. Ecologically isolated wetlands are those that are not connected to each other or to other bodies of water by vegetated corridors or buffers, through which wildlife can easily disperse.

Ecological isolation is species-specific – what may be seen as "isolated" by an amphibian species, for example, with limited dispersal abilities, may not be seen as "isolated" by waterfowl, which are able to cover longer distances. Wetlands may be isolated from one another by natural features or, increasingly, by human activities, particularly urban and agricultural development. Wetlands that are ecologically connected to one another form wetland complexes, which create a mosaic of habitat for wildlife. Many wildlife species do best when a variety of wetland types exist in the landscape and when they are able to move freely among diverse habitats to meet their complex life history needs (e.g., feeding, rearing of young, nesting, thermal cover). Although many wildlife species inhabit isolated wetlands, their long-term survival may be impaired by isolation. Healthy populations of many wildlife species depend on a landscape that consists of a variety of wetlands connected with vegetated corridors or smaller creeks and streams. Maintaining a high diversity and abundance of interconnected smaller wetlands is given high priority by managers responsible for maintaining native wildlife populations. In many cases, wetland complexes comprised of a number of smaller wetlands of different types may be more valuable to wildlife than a few larger wetlands of the same type.

Wetland Values

Value may be assigned to wetlands as a result of:

- their location in the landscape
- the functions they perform
- the uniqueness of their plant and animal communities
- their aesthetic qualities
- as sites for education and scientific research
- as locations of historical or archaeological significance
- as repositories for water during floods

A number of different criteria may be used to assign values to wetlands.

Estimated value ($ per hectare) of ecosystem services for different ecosystem types

Ecosystem Service	Eastern Temperate forests	Great Plains	Deserts	West Coast coastal forests	Western mountain forests	Wetlands
Gas regulation	104	7	-----	31	64	265
Disturbance regulation	6	7	2	3	11	31,736
Water supply	79	28	85	46	21	2954
Nutrient cycling	1508	22	60	2431	159	15,985
Soil erosion control	241	241	237	241	241	-----
Commodities	710	3853	-----	4	1	6029
Biodiversity	6	46	-----	6	6	384
Recreation	1874	1003	16	1874	1874	3617

("----" indicates "unable to estimate value, data not available")

Data from Dodds, et al (2008)

See notes slide 53 (page 64)

Notes Slide 53 (Page 64)

There have been a number of attempts to assign a dollar value to ecosystems that take into account the ecosystem services they provide. Most of these ecosystem services do not make it into the accounting system that we currently use to assign value. For example, see Kahn (1995), Costanza, et al. (1997). In general, wetlands show high value in these studies when compared to other ecosystem types.

More recently, Dodds, et al. (2008) attempt to compare goods and services across eight different ecosystems and for both native and restored lands in the lower 48 states. They found that restored lands in general provide 31-93% of native land benefits within a decade after restoration, with wetlands providing the most economic value and deserts the least. Restored wetlands recovered about 90% of their economic value within 10 years after restoration. They suggest that although conservation of native lands should be a priority, restored lands (especially wetlands) can have substantial value. However, policies such as “no net loss” of wetlands need to recognize that restored wetlands do not necessarily provide the same economic or ecological benefits as native lands.

What are these “ecosystem services?”

Gas regulation – carbon and methane sequestration

Disturbance regulation – storm protection, flood control, drought recovery

Water supply – storage and retention of water

Nutrient cycling - storage, cycling processing of nutrients (especially N and P)

Soil erosion control

Commodities – production of wood fiber, minerals, materials, crops, fish and game

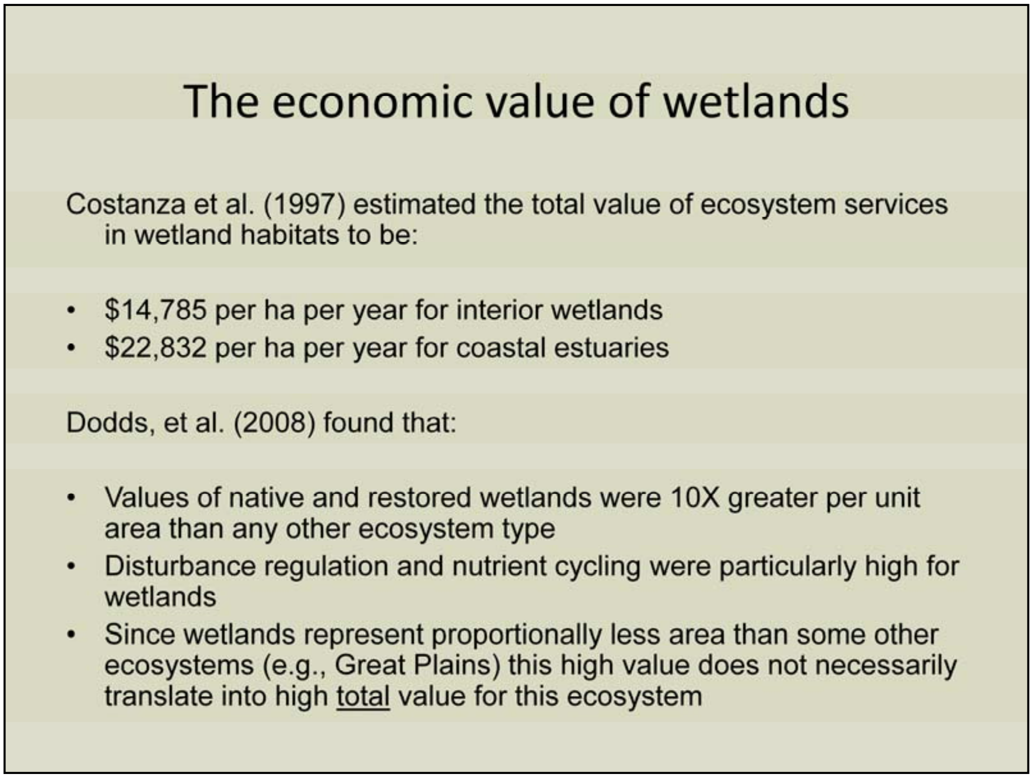
Commercial and recreational fisheries, for example, support an industry that contributes $111 billion annually to the national economy, employing nearly 2 million people.

Biodiversity – e.g., genetic resources, pollination, refuges for desirable species

Recreation – hunting, fishing, hiking, wildlife viewing, etc.

Specific methods used for assigning value to these ecosystem services are discussed in the original article.

Dodds, W.K. 2008. Comparing ecosystem goods and services provided by restored and native lands. BioScience 58:837-845.



Wetland Values

Costanza et al. 1997 estimate the total value of ecosystem services in wetland habitats to be:

$14,785 per ha per yr for interior wetlands

$22,832 per ha per yr for coastal estuaries

Somewhat less than values shown for Dobbs, et al. probably due to methods, updated information and scope (global vs. U.S.)

Dodds, et al. (2008) main points:

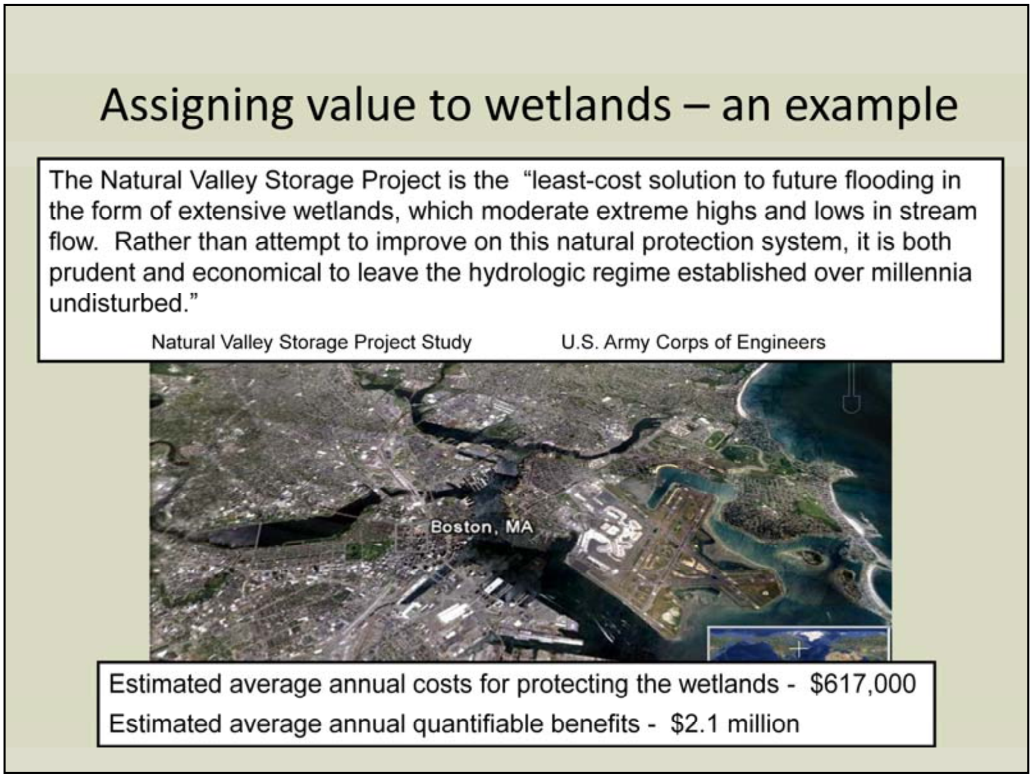
1. Values of native and restored wetlands were 10X greater per unit area than any other ecosystem type. Validates high economic value of wetlands.
2. Disturbance regulation and nutrient cycling were particularly high for wetlands as compared to other ecosystems. This is due to the well-documented capabilities for wetlands to provide flood control, storm protection and nutrient processing functions.
3. Since wetlands represent a proportionally less area than some other ecosystems (e.g., Great Plains) this high value does not necessarily translate into high total value for this ecosystem

Economic Values of Services Provided by the World's Ecosystems

Ecosystem type	Value ($/hectare/year)
Estuaries	22,832
Swamps/floodplains	19,580
Coastal seagrass/algae beds	19,004
Tidal marsh/mangroves	9,990
Lakes/rivers	8,498
Coral reefs	6,075
Tropical forests	2,007
Coastal continental shelf	1,610
Temperate/boreal forests	302
Open ocean	252

Data from Costanza, et al. 1997

These data are from an earlier and more inclusive examination of the relative value of services provided by the world's ecosystems. Note that wetlands of various types score high value when compared to other ecosystem types. The relatively high value of wetlands to people is primarily due to their role in nutrient cycling, water supplies, flood regulation and waste treatment. Additional value is provided as a result of recreation, food production and cultural (e.g., esthetic, spiritual, scientific) values.



However, there are examples in our not so distant past when the true value of wetlands has been appreciated and assigned significant value. In March of 1968, a series of major storms in the Boston area resulted in extensive flooding in the city. A major snowmelt and 7 inches of rain in two days hit the Charles River watershed, a 307-square mile area that included the city of Boston. When personnel from the Army Corps of Engineer's New England Division flew over the affected area, they noticed that while Boston itself had experienced serious flooding, the upper part of the watershed was nearly unaffected. They determined that the difference was the presence of relatively intact wetlands in the upper watershed, while the wetlands in the lower watershed in the Boston area had long since been filled in and drained. (Much of Boston is in fact built on wetlands). The natural wetlands had "absorbed" the flood waters and effectively "controlled the flood."

Four years later, when a large development project was being proposed in the watershed, the Army Corps surprised developers and environmentalists alike by not supporting the development and proposing instead permanent protection of 8500 acres of upstream wetlands. The so-called, Natural Valley Storage Project was thought by the Corps to be the "least-cost solution to future flooding in the form of extensive wetlands, which moderate extreme highs and lows in stream flow. Rather than attempt to improve on this natural protection system, it is both prudent and economical to leave the hydrologic regime established over millennia undisturbed." (Quoted from final draft of Army Corps of Engineers Natural Valley Storage Project study). Estimated annual costs for protecting the wetlands through purchase and conservation easements have averaged $617,000, while annual quantifiable benefits have averaged $2.1 million.

Photo credit: Google Earth

Summary

- Wetlands occupy transitional zones between upland and deepwater habitats
- Jurisdictional wetlands are defined by three criteria – hydric soils, hydrology and wetland plants
- Wetland plants have a variety of structural and physiological adaptations that allow them to occupy saturated soils
- Wetland functions include hydrologic processes, water quality improvement and wildlife habitat
- The economic value of ecological services ($/ha) provided by wetlands exceeds that of other ecosystems

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- USDA-NRCS PLANTS Database / Herman, D.E., et al. 1996. *North Dakota tree handbook*. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck.
- U.S. Geological Survey
- Washington State Department of Natural Resources
- William Flaxington

Wetlands – An Introduction - Resources

Wetland Definitions, Classification and Identification

Cowardin, L. M., et al. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online.

http://www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm (Version 04DEC1998).

Keddy, P.A. 2000. Wetland ecology. Principles and conservation. Cambridge University Press, Cambridge, UK.

Tiner, R. 1997. NWI maps – Basic information on the Nation's wetlands. BioScience. May 1997.

Tiner, R.W. 1999. Wetland indicators: A guide to wetland identification, delineation, classification and mapping. CC Press LLC, Boca Raton, FL.
www.crcpress.com

Shaw, S.P. and C.G. Fredine. 1956. Wetlands of the United States – their extent and their value to waterfowl and other wildlife. Circular 39. U.S. Department of the Interior, Washington, D.C.

Wetland Functions and Values

Costanza, R., et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Danielsen, F. et al. 2005. The Asian tsunami: A protective role for coastal vegetation. Science 310:643.

Dodds, W.K. 2008. Comparing ecosystem goods and services provided by restored and native lands. BioScience 58:837-845.

Fletcher, R. 2003. Loss of wetlands: How are bird communities affected?
www.actionbioscience.org/environment/fletcher.html

This Action BioScience educational module describes the evidence for the relationship between wetland loss and bird communities

Gibbons, J.W. 2003. Terrestrial habitat: a vital component for herpetofauna of isolated wetlands. Wetlands 23: 630-635.

Kahn, J.R. 1995. The economic approach to environmental and natural resources. Harcourt Brace, Inc., Orlando, Florida.

Lehtinen, R.M., S.M. Galatowitsch, and J.R. Tester. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands 19:1-12.

Leibowitz, S.G. 2003. Isolated wetlands and their functions: an ecological perspective. Wetlands 23: 517-531.

Schuyt, K. and L. Brander. 2004. The economic values of the world's wetlands. World Wildlife Fund. Gland, Amsterdam. 32 pp.

Williams, T. 1996. What good is a wetland? Audubon 98:43-53.

Wetlands – An Introduction - Video Resources

Crash: A tale of two species. Public Broadcasting Service. NATURE . DVD - 55 min. www.shopPBS.org

This PBS video examines the ecological role and economic importance of the horseshoe crab, a marine species that has remained essentially unchanged for 350 million years. The timing of reproductive behavior of the species is intricately connected to the migration and survival of coastal wading birds. This relationship serves as a good example of interconnectedness in coastal wetlands.

Oregon Field Guide – Wetlands Videos

Oregon Public Broadcasting
7140 Macadam Avenue
Portland, OR 97219
www.opb.org/programs/ofg/episodes/browse

All of the following Oregon Field Guide *episodes are available on-line. The titles listed and described below are brief segments that address some aspect of the biological diversity of wetlands. They are intended for a general audience, but are of high quality and appropriate to enhance lectures.*

Episode #209. Darlingtonia. 1991. 3 min.

This brief segment describes the natural history of the pitcher plant (or cobra lily) - Darlingtonia californica*. This carnivorous wetland plant has a characteristic thin-walled hood that attracts insects and strategically placed slick surfaces, directional hairs and digestive enzymes that trap and digest insects.*

Episode #406. Disappearing Frogs. 15 min. 1993

Amphibians are important environmental bioindicators ("canaries in the cold mine"). Research is being conducted by Andy Blaustein of Oregon State University, who studies the effects of ultraviolet radiation on Pacific treefrogs and western toad populations at Lost Lake in the Oregon Cascades. Portland State University researcher, Mark Hayes, is compiling historical records for declining amphibian species such as the western spotted frog. Decline of this species to near extinction is due to habitat alteration (draining of wetlands for agriculture and development) and the introduction of exotic species such as bullfrogs, sunfish and largemouth bass. Grazing practices in the 1960s and 1970s in particular damaged the best habitat and only red-legged frogs occur there, and their populations are also declining. The rough-skinned newt, by contrast, is an amphibian species whose numbers appear to be healthy. Some amphibian declines have occurred in what appear to be pristine conditions.

Episode #801 Salamander Pond. 1997. 15 min.

Mark Hayes of Portland Community College finds that rough-skinned newts are abundant (20,000-80,000 individuals) in small manmade ponds. Aquatic stages are smooth and with keeled tails. Females lay single eggs in vegetation. Long-toed salamanders, garter snakes, bullfrogs and great blue herons are also common. Red-legged frogs and Pacific treefrogs also lay eggs in the shallow water of the pond. Physid snails, dyticid beetle larva and wolf spiders also inhabit these ponds.

Episode #903 Estuary Seine. 1998. 15 min.

Salmon smolt populations are monitored in coastal Oregon estuaries using a seining sampling technique. Wild and hatchery salmon and steelhead are counted in the Siletz, Yaquina and Alsea Rivers. Other fish are also sampled – e.g., starry flounder, pipefish, surf perch. Seal scat is sampled to determine the role of predators on salmon populations. The removal of large woody debris from estuaries has resulted in a loss of structure and perhaps contributed to salmon declines.

Episode #1510 Yellow Rails. 2004. 15 min.

The Yellow rail is a rare and little-known marsh bird found in shallow wetlands of southern Oregon. This video shows biologists using live capture and banding methods to monitor bird populations. This species was "missing" for 30 years until it was detected in the Klamath marsh in the 1980s. Approximately 85% of its preferred habitat has been drained and half of the known population occurs in this marsh. For this reason, the species must be closely monitored.

Wetlands International
www.wetlands.org

This international wetlands conservation organization produces a number of short videos that are available for download from their web site. The following titles provide some interesting perspectives on the relationship between wetlands and climate change:

1. Adapting to climate change: Mangrove forests (5 min.)
2. Palm oil production, peatland loss and carbon dioxide emissions (5 min.)
3. Tierra Del Fuego peatlands and climate change (10 min.)

General and Comprehensive Resources

The following resources cover a broad range of wetlands-related topics. Several are comprehensive web sites that contain a variety of information on wetlands that may be relevant to instructors. More detailed descriptions of the content of these web sites are provided in a separate section entitled "Detailed Descriptions of Comprehensive Resources" that follows. These resources have been identified with an asterisk (*) in the list below. More specific resources that cover one or few aspects of wetlands are provided in the module that is most relevant to those topics.

Association of State Wetland Managers (*)
www.aswm.org

The Association of State Wetland Managers is a nonprofit membership organization established to promote and enhance protection and management of wetland resources, to promote application of sound science to wetland management and to provide wetland training and education.

Batzer, D.P. and R.R. Sharitz. 2007. Ecology of freshwater and estuarine wetlands. Univ. of Calif. Press. 581 pp.
www.ucpress.edu

This is a comprehensive undergraduate text in wetland ecology. It is appropriate for a course devoted entirely or primarily to wetlands. Otherwise, it would be a useful reference for instructors who incorporate wetlands topics into a broader course in ecology.

Dahl, T.E. 2006. Status and trends of wetlands in the conterminous United States 1998-2004. U.S. Fish and Wildlife Service, Washington, D.C. 112 pp.
http://www.fws.gov/wetlands/StatusAndTrends/

Environmental Protection Agency (*)
www.epa.gov/wetlands

The EPA wetlands site provides some good introductory information on wetlands. Wetlands definitions, types, status and trends, functions and values and wetlands management (including mitigation) and protection are all covered.

Hammer, D.A., ed. 1989. Constructed wetlands for wastewater treatment. Lewis Publishers, Inc., Chelsea, MI . 831 pp.

Kusler, J.A. and T. Opheim. 1996. Our national wetland heritage: A protection guide, 2nd ed. Environmental Law Institute, Washington, D.C. 149 pp.

This is a comprehensive guide to the protection and restoration of wetlands by local governments, private citizens, conservation organizations and landowners.

Maltby, E. and T. Barker (eds.). 2009. The wetlands handbook. Wiley-Blackwell, Inc. San Francisco, CA. 800 pp.
www.wiley.com

At $300 this text is probably only for the most serious wetlands instructors. It is a comprehensive analysis of ecosystem-based approaches to wetlands management. The emphasis is on maintaining/restoring ecological functions in freshwater wetlands.

Marks, R. 2006. Ecologically isolated wetlands. Natural Resources Conservation Service and Wildlife Habitat Council. Fish and Wildlife Habitat Management Leaflet #38. 8 pp.

This brief document is an excellent introduction to wetlands and is suitable to assign for student reading. Wetland processes and functions, ecological and economic benefits and issues associated with wetland loss and degradation are covered. As the title suggests, management issues emphasize what can be done to reduce the effects of wetland isolation.

Millennium Ecosystem Assessment. 2005. Ecosystems and human wellbeing: Wetlands and water – Synthesis. World Resources Institute, Washington, D.C.
www.millenniumassessment.org/documents/document.358.aspx.pdf

http://www.maweb.org/documents/document.358.aspx.pdf

This is a global assessment of wetlands resources with recommendations for future management.

Mitsch, W.J. and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Co., Inc. New York, NY. 539 pp.

Mitsch, W.J. and J.G. Gosselink. 2007. Wetlands. 4th ed. John Wiley and Sons, Inc., Hoboken, NJ.

A potential choice for a textbook for a course on wetlands, but designed for junior/senior level students and for those with some background in ecology.

Mitsch, W.J., et al. 2009. Wetland ecosystems. John Wiley and Sons, Inc., Hoboken, NJ. 285 pp.

Earlier editions of the Mitsch and Gosselink Wetlands *classic wetlands text (described above) included seven "ecosystem" chapters that described the structure and function of wetland ecosystems found in North America. In the interest of reducing the size of this text, the authors decided in the most recent edition to pull out these chapters and develop a separate text.* Wetland Ecosystems *is the result of that effort.*

National Research Council (NRC). 1995. Wetlands: Characteristics and boundaries. National Academy Press, Washington, D.C. 306 pp.

National Research Council (NRC). 2001. Compensating for wetlands losses under the Clean Water Act. National Academy Press, Washington, D.C. 158 pp.

Oregon Wetlands Explorer (*)
www.oregonexplorer.info/wetlands/

This joint project of Oregon State University, The Wetlands Conservancy and Oregon Division of State Lands is primarily designed for wetlands professionals, but educators (especially those in Oregon) will find some useful information here.

Payne, N.F. 1992. Techniques for wildlife habitat management of wetlands. McGraw-Hill, Inc., New York, NY. 549 pp.

Ramsar Convention on Wetlands
www.ramsar.org

The Ramsar site is most useful for international wetlands information. The Ramsar Convention is an intergovernmental treaty that commits its member countries to maintain the ecological character of "wetlands of international importance." The site provides digital photos and other media for instructor use including a 4-minute introductory You-tube video that introduces Ramsar and describes the value of wetlands.

Society of Wetland Scientists (*)
www.sws.org

The Society of Wetland Scientists (SWS) is the premier professional organization for wetland scientists and other professionals in the field. SWS publishes, Wetlands, *the leading journal on wetlands science and issues. Their web site has a number of resources that educators will find useful.*

Tiner, R.W. 2005. In search of swampland: A wetland sourcebook and field guide. Rutgers University Press, New Brunswick, NJ
http://rutgerspress.rutgers.edu

This resource is an excellent introduction to wetlands issues written for the "average citizen."

U.S. Army Corps of Engineers (*)
www.usace.army.mil/CECW/Pages/techbio.aspx

The Army Corps of Engineers has primary responsibility for waterways in the U.S. and is the primary agency that regulates wetlands at the federal level. As a focal point for federal wetlands management, this site has links to lots of wetlands resources with an emphasis on wetland delineation and classification, wetland functions and values, mitigation banking, and wetland plants and soils.

U.S. Fish and Wildlife Service - National Wetland Inventory (*)
www.fws.gov/wetlands

This site, maintained by the U.S. Fish and Wildlife Service, provides a wealth of useful information and tools including wetland status reports (national and regional), Google Earth with wetlands maps overlay and digitized wetlands maps.

U.S. Geological Survey – National Wetlands Research Center
www.nwrc.usgs.gov

Wetlands International
www.wetlands.org

The mission of this international conservation organization is "to sustain and restore wetlands, their resources and biodiversity for future generations." The organization uses science-based information to promote the protection and restoration of wetlands. Instructors looking for an international perspective on wetlands issues, especially those related to climate change and wetland bird conservation, will find Wetland International publications to be useful resources. The organization also produces a number of short (5-15 min.) videos available for download on their web site. Topics include the impacts of climate change on mangrove forests, wetland restoration and carbon dioxide storage in peatland forests.

Details on Comprehensive Web Sites (*)

Association of State Wetland Managers
www.aswm.org

The Association of State Wetland Managers is a nonprofit membership organization established to promote and enhance protection and management of wetland resources, to promote application of sound science to wetland management and to provide wetland training and education. Their web site has lots of resources related to all wetlands topics including:

A wetlands glossary:
http://www.aswm.org/watersheds/wetlands-and-watershed-protection-toolkit/887-wetlands-and-watershed-protection-toolkit?start=15

An excellent collection of publications that examine the relationship between wetlands and climate change:
www.aswm.org/science/climate_change/climate_change.htm

A collection of publications that examine the Gulf Oil Spill and its impact on wetlands. Includes coverage of wetland legal issues such as the Rapanos decision, "navigability," landmark legal cases,"takings." Instructors may also want to subscribe to "Wetland Breaking News" a newsletter on up-to-date wetlands issues and new publications.
http://aswm.org/wetland-science/2010-gulf-oil-spill

Environmental Protection Agency
www.epa.gov/wetlands
http://water.epa.gov/type/wetlands/index.cfm

The EPA wetlands site provides some good introductory information on wetlands. Wetlands definitions, types, status and trends, functions and values, wetlands management (including mitigation) and protection are all covered. The "Fact Sheets" are concise, 1-2 page summaries of various wetlands topics. Specific EPA sites of interest to instructors include:

This EPA wetlands module outlines the various values assigned to wetlands and describes how they are measured.
www.epa.gov/watertrain/wetlands/index.htm

This is an EPA site dedicated to wetland mitigation.
www.epa.gov/wetlandsmitigation

This EPA fact sheet is an excellent introduction to wetland mitigation banking.
www.epa.gov/owowwtr1/wetlands/facts/fact16.html

This is a short (approx 15 min.) video designed for a general audience that emphasizes the importance of providing outdoor, nearby nature, experiences for children – emphasis is on wetlands and includes interviews with wetlands scientists and environmentalists. Web site has directions for saving/ downloading video.
www.epa.gov/wetlands/education/wetlandsvideo/

A series of wetlands fact sheets on most aspects including an overview of wetland types, functions and values, threats, restoration, and monitoring and assessment.
www.epa.gov/owow/wetlands

The EPA wetlands helpline
http://water.epa.gov/type/wetlands/wetline.cfm

U.S. Fish and Wildlife Service – National Wetlands Inventory
www.fws.gov/wetlands

The U.S. Fish and Wildlife Service is the principal federal agency that provides information to the public on the extent and status of the nation's wetlands. This site provides a wealth of useful information and tools including wetland status reports (national and regional), Google Earth *with wetlands maps overlay and digitized wetlands maps. Perhaps the most useful tool is the "Wetlands Mapper," which visually displays the results of the national wetlands inventory, based primarily on an analysis of aerial photographs. Wetlands are identified, mapped and then superimposed on topographic maps. The inventory does not identify all wetlands in an area, but probably the most significant ones. The "Wetlands Mapper" allows viewing of identified wetlands either on-line or hard copy maps can be ordered for every state (see "Hard Copy Orders"). Each map is mapped as a polygon with an imbedded code that indicates the specific wetland type and other information related to this site.*

The WetlandsMapper shows the location of wetlands identified on National Wetlands Inventory (NWI) maps and integrates digital map data with other resource information. The following links provide a useful introduction to this feature:

- Wetlands Mapper Documentation and Instructions Manual (www.fws.gov/wetlands/_documents/gData/WetlandsMapperInstructionsManual.pdf)
- Frequently Asked Questions: Wetlands Mapper (www.fws.gov/wetlands/_documents/gData/QuestionsAnswersAboutNewMapper.pdf)
- Frequently Asked Questions web page (www.fws.gov/wetlands/FAQs.html)

NWI wetlands data can also be viewed with Google Earth. Instructions and a link to do so are included at the NWI web site.

This U.S. Fish and Wildlife site also includes Wetlands Status and Trends Reports, *which provide long-term trend information about specific changes and places and the overall status of wetlands in the United States. The historical database provides photographic evidence of land use and wetlands extent dating back to the 1950s. This provides an accurate record to assist in future restoration efforts.*

Status and Trends Reports available on the web site include:

- NOAA/USFWS joint report on Coastal Wetland Trends 1998-2004 (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsCoastalWatershedsEasternUS1998to2004.pdf)

- Status and Trends of Wetlands in the Conterminous United States 1998 to 2004 (Dahl, 2006) (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsConterminousUS1998to2004.pdf)
- Status and Trends of Wetlands in the Conterminous United States 1986 to 1997 (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsConterminousUS1986to1997.pdf)
- Wetlands Status and Trends in the Conterminous United States, Mid-1970's to Mid-1980's (www.fws.gov/wetlands/_documents/gSandT/NationalReports/WetlandsStatusTrendsConterminousUS1970sto1980s.pdf)
- Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States 1950's to 1970's (www.fws.gov/wetlands/_documents/gSandT/NationalReports/StatusTrendsWetlandsDeepwaterHabitatsConterminousUS1950sto1970s.pdf)

Links to other resources such as the National Wetlands Plant List and an EPA evaluation of the impact of climate change on coastal wetlands are also available.

Oregon Wetlands Explorer
www.oregonexplorer.info/wetlands/

This joint project of Oregon State University, The Wetlands Conservancy and Oregon Division of State Lands was first launched in 2009 as "a useful tool for anyone doing wetland work in Oregon." It is primarily designed for wetlands professionals, but educators (especially those in Oregon) will find some useful information here. The following are included:

1. *Statewide database of wetlands maps, hydric soils, FEMA flood zones, Wetland Reserve Program (WRP) sites, wetland mitigation banks. Local wetland inventories and recommended priority sites for conservation*
2. *A tool for rapid assessment for wetlands*
3. *Oregon-related information on various wetland topics*
4. *Wetland GIS and vegetation plot data*

Society of Wetland Scientists
www.sws.org/

The Society of Wetland Scientists (SWS) is the premier professional organization for wetland scientists and other professionals in the field. SWS publishes, Wetlands*, the leading journal on wetlands science and issues. Their web site has a number of resources that educators will find useful. Several are described below:*

This newly developed web page was designed to document the impact of the Deepwater Horizon oil spill in the Gulf of Mexico on wetlands. It includes insights from wetland scientists, links top pertinent resources and digital photographs.
www.sws.org/oilspill/

This page lists links to specific short courses in wetlands training – delineation, hydric soils, plant identification, restoration, mitigation, and constructed wetlands.
www.sws.org/training/

This is a directory of wetland-related academic programs at U.S. colleges and universities.
www.sws.org/colleges/

These "position papers" on various wetlands topics are designed to "increase public understanding of wetlands issues and to promote sound public policy." They are written by experts in the field and are based on the best available science. Topics include oil effects on wetlands, mosquito control, mitigation banking, performance standards for wetland restoration and creation, and definitions of wetland restoration. The papers are brief, well-referenced and provide excellent background for educators with a particular interest in specific wetland issues. They are also suitable to assign as student reading to provide a basis for discussions on wetland issues.
www.sws.org/wetland_concerns/

The SWS also publishes the "SWS Research Brief," which helps translate wetland research results for a non-technical audience. The research of selected wetlands scientists is highlighted in each brief. These make excellent student reading and serve to familiarize students with the process of science – how scientists formulate questions, collect data, present their findings and draw conclusions from them.
www.sws.org/ResearchBrief/

Some topics include:

Restoration of mangroves
Invasive plants in wetlands
Impact of elevated CO_2 levels on wetlands
Impact of hurricane Katrina on wetlands
Relationship between marshes, mosquitoes and malaria

The SWS education page is designed with the college educator in mind and is intended "to facilitate sharing of techniques, skills, tools and ideas on and about wetlands education." See for educational resources including labs, field activities, courses, links to other web sites, etc. The Society of Wetlands Scientists also maintains a list of colleges and universities that offer courses or programs in wetland science or ecology.
www.sws.org/education/

Here are some examples of materials that college instructors will find most useful:

1. *Links to general information on wetlands*
2. *Syllabi, lab exercises and exams for wetlands courses*

NOTE: Instructors with an interest in teaching wetland concepts using digital imagery and aerial photography will find the "Wetland Education Through Maps and Aerial Photography" (WETMAAP) site to be particularly useful.

3. *Digital images collection for wetlands education*

U.S. Army Corps of Engineers
www.usace.army.mil/CECW/Pages/techbio.aspx

The Army Corps of Engineers has primary responsibility for waterways in the United States and is the primary agency that regulates wetlands at the federal level. As a focal point for federal wetlands management, this site has links to lots of wetlands resources. Those that are most relevant to this series of modules include the following:

Wetlands delineation and classification
- Corps Wetlands Delineation Manual (www.el.erdc.usace.army.mil/elpubs/pdf/wlman87.pdf)
- Regional Supplements to the Corps Delineation Manual (www.usace.army.mil/CECW/Pages/reg_supp.aspx)
- USFWS National Wetlands Inventory (www.fws.gov/wetlands/)
- Classification of Wetlands & Deepwater Habitats of the U.S. (www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm)
- Recognizing Wetlands - An Informational Pamphlet (www.usace.army.mil/CECW/Documents/cecwo/reg/rw_bro.pdf)

Wetlands functions and values
- Current HGM Information and Guidebooks (http://el.erdc.usace.army.mil/wetlands/hgmhp.html)
- Hydrogeomorphic Approach to Assessing Wetland Functions (http://el.erdc.usace.army.mil/wetlands/hgmhp.html)
- National Plan to Implement the Hydrogeomorphic Approach to Assessing Wetland Functions (www.usace.army.mil/CECW/Documents/cecwo/reg/hydro_geo.pdf)
- Wetland Functions & Values - A Report by the National Science Foundation, 1995 (www.usace.army.mil/CECW/Documents/cecwo/reg/wet_f_v.pdf)
- Consequences of Losing or Degrading Wetlands
- U.S. Environmental Protection Agency Wetlands Information Website http://water.epa.gov/type/wetlands

Mitigation banking
- Federal Guidance for the Establishment, Use and Operation of Mitigation Banks (http://water.epa.gov/lawsregs/guidance/wetlands/mitbankn.cfm)
- National Wetland Mitigation Banking Study: Technical and Procedural Support to Mitigation Banking Guidance, 1995 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/WMB-TP-2.pdf)
- National Wetland Mitigation Banking Study: Model Banking Instrument, 1996 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/WMB-TP-1.pdf)
- National Wetland Mitigation Banking Study: The Early Mitigation Banks: A Follow-up Review, 1998 (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/iwrreports/98-WMB-WP.pdf)

- National Wetlands Mitigation Action Plan (www.usace.army.mil/CECW/Documents/cecwo/reg/Mit_Action_Plan.pdf)
- IWR - Wetlands and Regulatory (www.iwr.usace.army.mil/index.php?option=com_content&view=category&layout=blog&id=7&Itemid=3/publications.cfm)

Plants and soils

- NRCS Soils Website (www.soils.usda.gov/)
- Field Indicators of Hydric Soils in the U.S. ftp://ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/FieldIndicators_v7.pdf
- National List of Vascular Plant Species that Occur in Wetlands:
  - 1996 (www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list96.pdf)
  - 1988 (www.usace.army.mil/CECW/Documents/cecwo/reg/plants/list88.pdf)
  - National Wetland Plant List (NWPL) https://rsgis.crrel.usace.army.mil/apex/f?p=703:1:2631898853215485
- NRCS Plants Database (www.plants.usda.gov/java/)
- Center for Aquatic and Invasive Plants - University of Florida (www.plants.ifas.ufl.edu/)
- Global Invasive Species Database (www.issg.org/database/welcome/)
- Interactive Key to Wetland Monocots of the U.S. (www.npdc.usda.gov/technical/plantid_wetland_mono.html)

Sources for Digital Images

Barras, J.A. 2007. Satellite images and aerial photographs of the effects of Hurricanes Katrina and Rita on coastal Louisiana. U.S. Geological Survey Data Series 281.
www.pubs.usgs.gov/ds/2007/281

Bureau of Land Management Image Library
www.blm.gov/wo/st/en/bpd.html

Most of the images in this web site are "public domain" and can be used without further authorization from the BLM.

The Integration and Application Network (IAN)
www.ian.umces.edu/imagelibrary/

The Integration and Application Network (IAN) is an initiative of the University of Maryland Center for Environmental Science. IAN emphasizes environmental problems in the Chesapeake Bay and its watershed. Although registration is required, there is no cost to download images.

The Natural Resources Conservation Service Photo Gallery
www.photogallery.nrcs.usda.gov

The Natural Resources Conservation Service Photo Gallery provides a comprehensive collection of natural resources and conservation-related photos from around the U.S. They are available for non-commercial use, free-of-charge with proper acknowledgement (described on web site).

NBII Life – Library of Images From the Environment
www.life.nbii.gov/dml/home.do

The National Biological Information Infrastructure (NBII) Library, Images from the Environment (LIFE), provides high-quality environmental images that are freely available for educational use. The collection includes images of plants, animals, fungi, microorganisms, habitats, wildlife management, environmental topics, and biological study/fieldwork. Images are annotated with background information(context, scientific names, location, habitat classifications, etc.), greatly improving their use as educational materials.

NOAA Photo Library/NERR Collection
http://www.photolib.noaa.gov/nerr/index.html
This collection includes images of estuaries in the National Estuarine Research Reserve System. Collection contains more than 1000 photos with images of landscapes, habitats, and individual specimens with descriptions.

U.S. Department of Agriculture PLANTS Database
www.plants.usda.gov

Plant images may be used for non-commercial use although copyrighted images require notification of the copyright holder.

The Society of Wetland Scientists
www.sws.org/regional/pacificNW/photo.html

The Ramsar Convention on Wetlands
www.ramsar.org/cda/en/ramsar-media-photos/main/ramsar/1-25-126_4000_0__

Has a good collection of photos from sites that have met Ramsar criteria.

U.S. Environmental Protection Agency Image Gallery
www.epa.gov/newsroom/pictures.htm

EPA maintains several collections of photographs and other images available for use by the public. Please note that while photographs and graphic materials produced by the federal government are not subject to copyright restriction, some photographs included in these collections may be copyrighted. Please observe carefully all rights and permissions information.

U.S. Fish and Wildlife National Digital Library
www.fws.gov/digitalmedia/

The U.S. Fish and Wildlife Service's National Digital Library is a searchable collection of public domain images, audio/video clips and publications. Permission is not required for use; however you are asked to give credit to the photographer or creator and the U.S. Fish and Wildlife Service.

U.S. Forest Service
www.fs.fed.us/photovideo/

USDA Forest Service's "Find-a-Photo" site allows access to thousands of copyright-free wildlife, fish, wildflower and environmental education photographs, donated by Forest Service employees, their partners and volunteers.