Wetlands – Then and Now

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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, Richard O'Hara and Anna VanDeWalle 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 – Then and Now Module Description

This instructional guide is designed to provide instructors with lecture materials and resources that describe the various ways that wetlands are classified, their current status and a historical perspective on wetlands. Trajectories and drivers of wetland loss and degradation in the United States are emphasized. Current wetland issues including the loss of mangrove wetlands and the impacts of the 2010 Gulf of Mexico oil spill are also examined. Student objectives, a general lecture outline and a more detailed *PowerPoint* presentation with instructor notes are provided. 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. Describe the various classification schemes used to categorize wetland types
2. Describe changes in the human perception of wetlands
3. Describe historical trends in the loss and degradation of wetlands with an emphasis on those in the United States
4. Describe the primary drivers of wetland loss
5. Evaluate the loss of mangrove wetlands and the impact of oil spills as examples of short-term and long-term impacts on wetlands

Wetlands – Then and Now - General Lecture Outline

I. Wetland Distribution
  A. Global
  B. United States
II. Wetland Classification
  A. Cowardin Wetland Classification System
    1. Marine (subtidal and intertidal)
    2. Estuarine
    3. Riverine
    4. Lacustrine (Limnetic or Littoral)
    5. Palustrine
  B. Other Classification Systems
    1. Shaw and Fredine (1956)
    2. Mitsch and Gosseline (1986)
    3. General
    4. Hydrogeomorphic Approach (HGM)
  C. Internationally important wetlands – The Ramsar Convention
III. Historical Perspective
  A. Historical views on wetlands
  B. Boston, Massachusetts as an example project
IV. The Status of Wetlands
  A. Current status
  B. Historical status
  C. Causes of wetland loss
    1. Indirect – population growth and economic development
    2. Direct
      a) Infrastructure development
      b) Land conversion
      c) Eutrophication and pollution
      d) Overharvesting and exploitation
      e) Introduction of invasive alien species
    3. Mississippi River Basin as an example
    4. Mangrove forests as an example
    5. Effects of 2010 Gulf oil spill on wetlands
V. Summary

PowerPoint Presentation with Instructor Notes

Wetlands - Then and Now

By Wynn W. Cudmore, Ph.D.

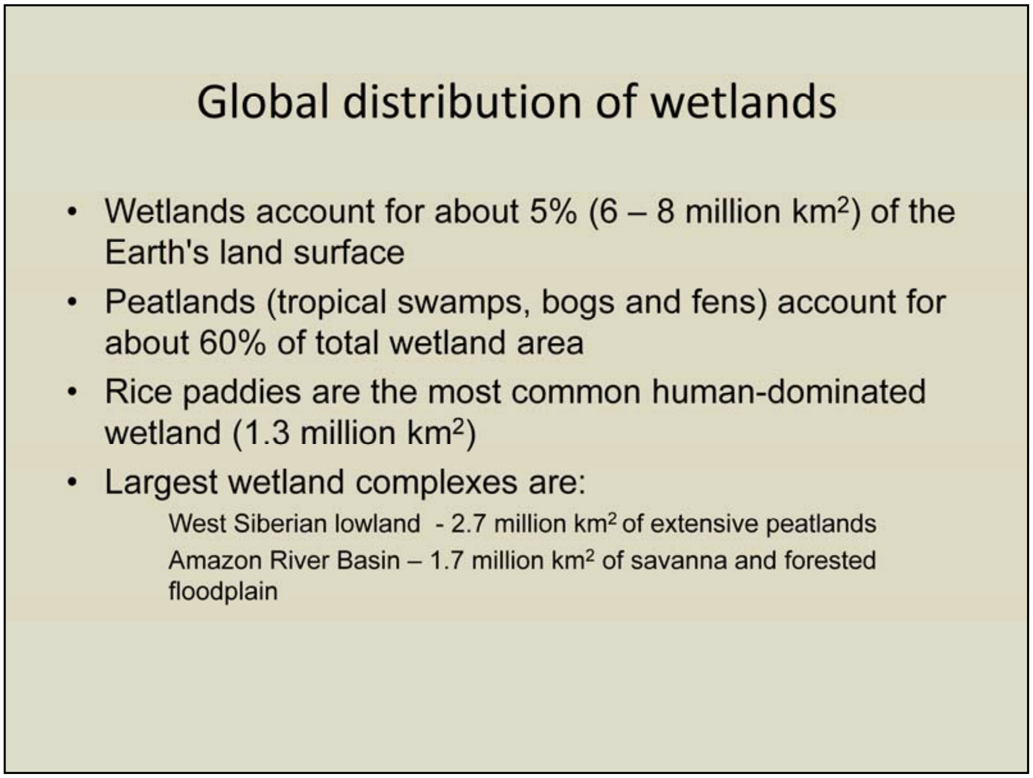
Northwest **C**enter for **S**ustainable **R**esources

DUE # 0757239

This project supported in part by the National Science Foundation. Opinions expressed are those of the authors and not necessarily those of the Foundation.

This module will describe the various ways that wetlands are classified, their current status and a historical perspective on wetlands. Current wetlands issues will also be discussed.

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



Wetlands are found on every continent except Antarctica. Global estimates for the area of wetlands range from 6 – 8 million km^2, depending on the definition of "wetland" used. If the lower end of the range is accepted, wetlands account for about 5% of the Earth's land surface, somewhat smaller than all 50 of U.S. states considered together including Hawaii and Alaska.

More than half is in the tropics and subtropics (rainforests, river deltas, coastal swamps) and most of the remainder is in northern boreal peat lands. Peatlands (tropical swamps, bogs and fens) account for the largest area, covering about 4 million km^2 or about 60% of total wetland area. Rice paddies are the main human-dominated wetland accounting for about 1.3 million km^2. The largest wetland complexes in the world are the West Siberian lowland (a 2,745,000 km^2 area of extensive bogs and fens) and the Amazon River Basin (a 1,738,000 km^2 area of savanna and forested floodplain).

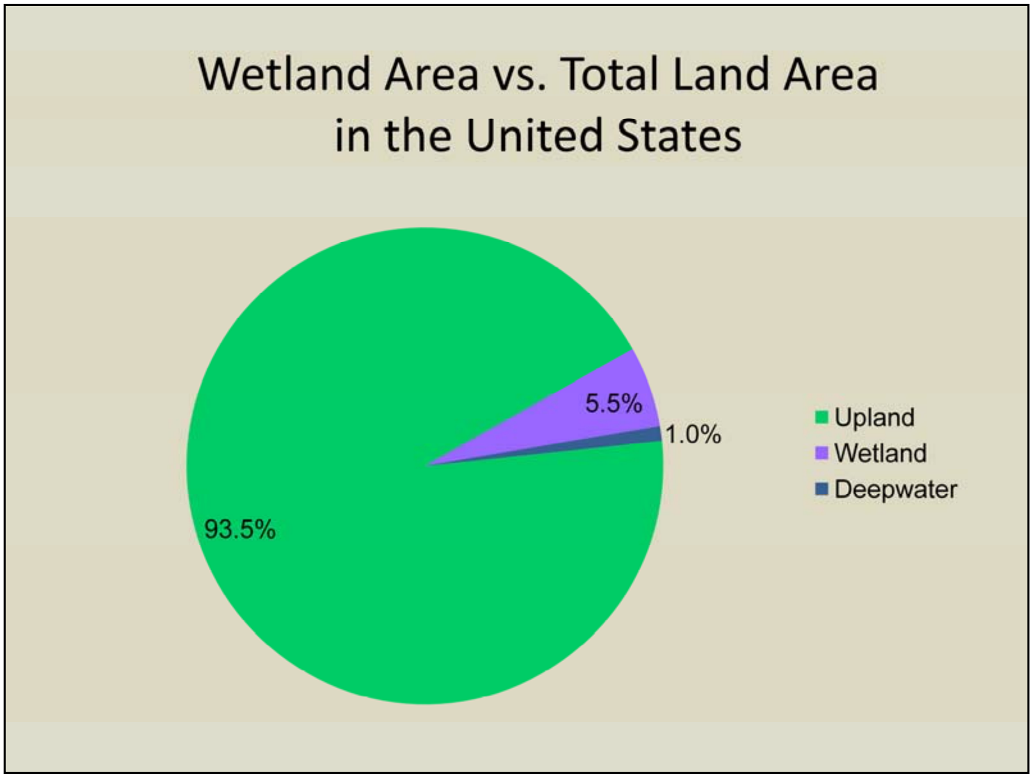
NOTE: The most widely used definition of "wetland" is as follows:

"….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."

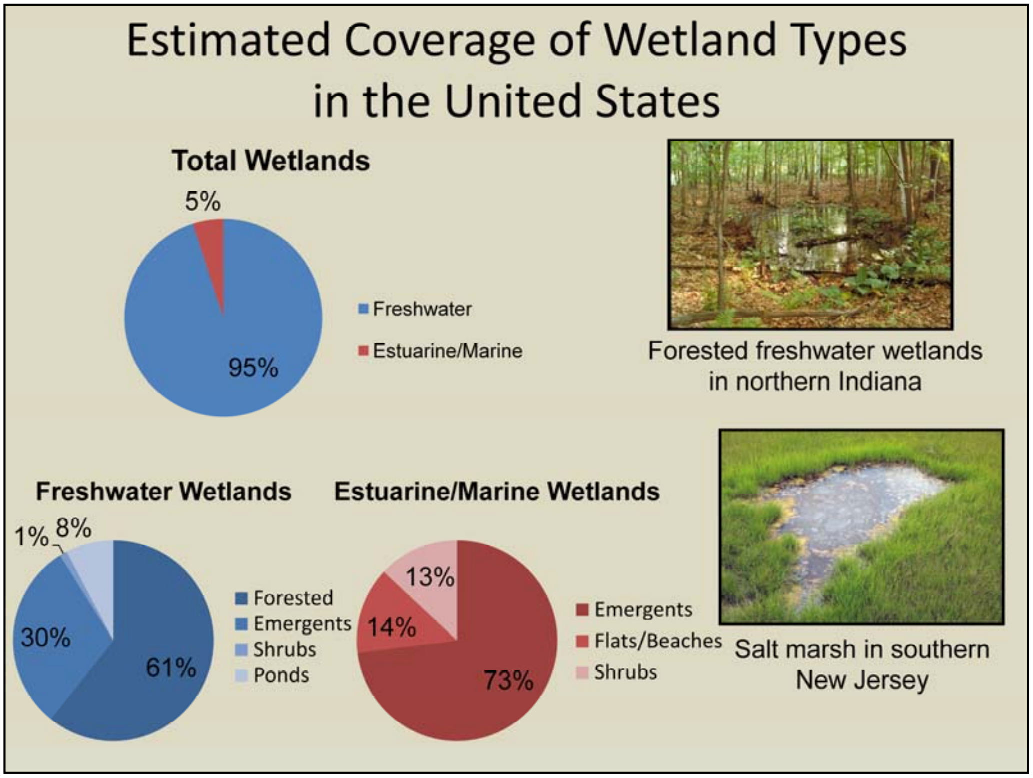
Army Corps of Engineers/Environmental Protection Agency (1984)

There are, however, several others. A detailed discussion of wetland definitions is included in the NCSR module entitled, *Wetlands – An Introduction*.

Peat is a generic term for a relatively un-decomposed organic soil. Thus, in peat soils more than two-thirds of the plant fibers can be identified. For most northern peatlands the botanical origin of the organic portion of this soil is Sphagnum moss.



The most recent national assessment of wetlands (Dahl 2006) estimates that there are 107.7 million acres(43.6 million ha) of wetlands in the conterminous (lower 48 states) United States, comprising 5.5% of U.S. land area. (NOTE: The deepwater estimate excludes the Great Lakes)



The vast majority of U.S. wetlands are freshwater (95%) with the remaining 5% represented by various marine and estuarine wetland types. Forested wetlands account for about half (51%) of freshwater wetlands, while emergent wetlands (25.5%), shrub wetlands (17%) and shallow ponds make up the remainder. Among marine and estuarine wetlands, emergent wetlands (salt marshes) account for the majority (73%). Estuarine shrub wetlands (including mangroves) (13%) and un-vegetated wetlands such as sandbars, mudflats and beaches make up the remainder.

See Dahl (2006) for details.

Photo Credits:

Top - David Riecks, Illinois-Indiana Sea Grant, USEPA
Bottom – Jane Thomas, IAN Image Library (ian.umces.edu/imagelibrary/)

The Cowardin Wetland Classification System

Marine	Open coastlines subject to waves and currents; salinity >30 ppt (parts per thousand)
Estuarine	Mouths of rivers where they flow into oceans, tidal influenced, salinity 0.5-30 ppt
Riverine	River and stream-related wetlands
Lacustrine	Lake-related wetlands in topographical depressions; > 8 ha in area without woody and persistent herbaceous vegetation
Palustrine	Shallow water wetlands dominated by vegetation (< 8 ha of open water, or <2 m at low water), usually non-tidal or with salinity <0.5 ppt

See notes slide 6 (page 16)

Notes Slide 6 (page 16)

The Cowardin Classification System (USFWS 1979) is commonly used in the United States and establishes 5 major categories of wetland with a hierarchy of taxonomic-like groupings of 11 subsystems and 55 classes based on either dominant vegetation or underlying substrate:

I. Marine – open coastlines subject to waves and currents; salinity >30 ppt (shallow coastal bays, coral reefs, rocky shoreline cliffs, sandy shorelines without significant freshwater influence)

A. Subtidal – below mean low tide

B. Intertidal – between mean low tide and mean high tide

II. Estuarine – mouths of rivers where they flow into oceans, protected from high energy waves and ocean currents; influenced by tides and water is frequently diluted by freshwater; salinity 0.5-30 ppt (tidal salt marshes, shrub wetlands, mangrove swamps in subtropical and tropical environments). Estuarine wetlands are among the most productive ecosystems on earth due to:

- Nutrient transport from both rivers and the ocean
- Tidal action that promotes mixing
- Sunlight promotes algal growth in shallow water
- Plant abundance provides lots of surface area for photosynthesis and plant stems and roots trap decaying organic material (detritus) supporting a broad detritus-based food web

III. Riverine – River and stream-related systems (floodplains, bottomlands, riparian zones, delta marshes) – classification further divided into where in the river system wetland occurs (tidal, lower perennial portions of stream network, upper perennial or intermittent)

IV. Lacustrine – Lake-related wetlands in topographical depressions; over 8 ha in area without woody or persistent herbaceous vegetation (freshwater marsh, shrub wetlands, forest wetlands). Further classified as:

A. Limnetic – open water habitats

B. Littoral – lake margin habitats

V. Palustrine – majority of wetlands fall into this category; dominated by vegetation; water depth is shallow (less than 8 ha of open water or <2 m at low water); usually non-tidal or at least with low salinity <0.5 ppt); includes bogs, fens, freshwater marshes and swamps, other forested wetlands, peatlands, scrub-shrub wetlands, ephemeral ponds, moss-lichen wetlands, emergent wetlands, pocosins

“ppt” = parts per thousand

“ha” = hectare

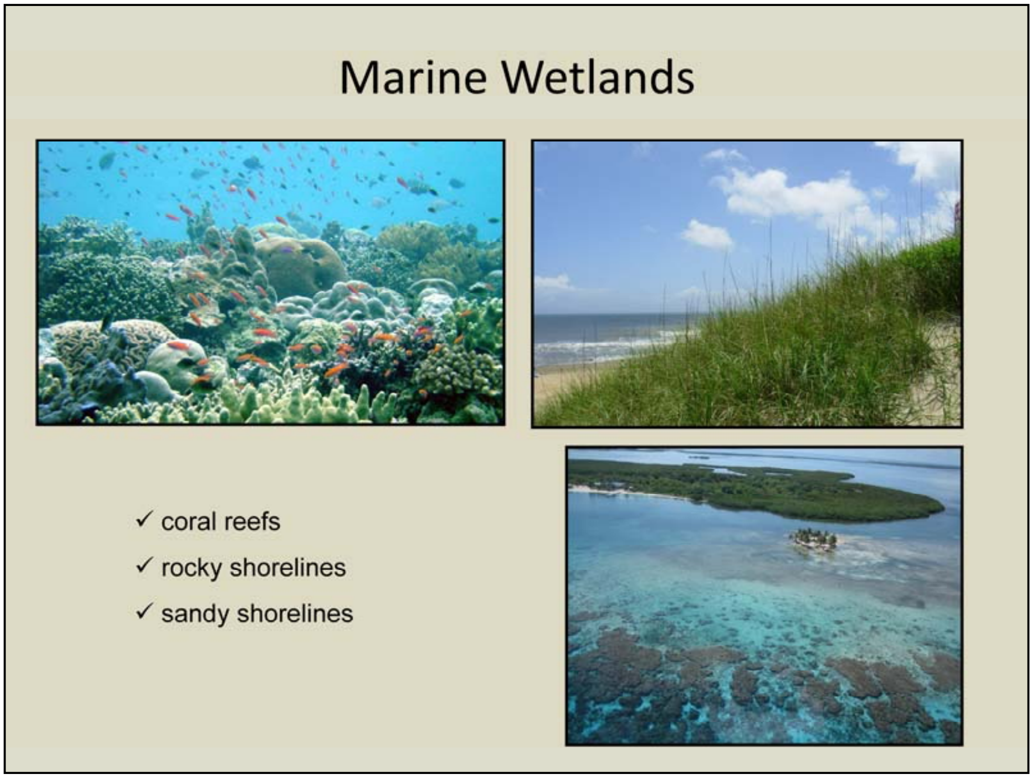


Photo credits:

Left – ARC Centre of Excellence for Coral Reef Studies
Top right – James Shelton/Marine Photobank
Bottom right – Jason Valdez/Marine Photobank

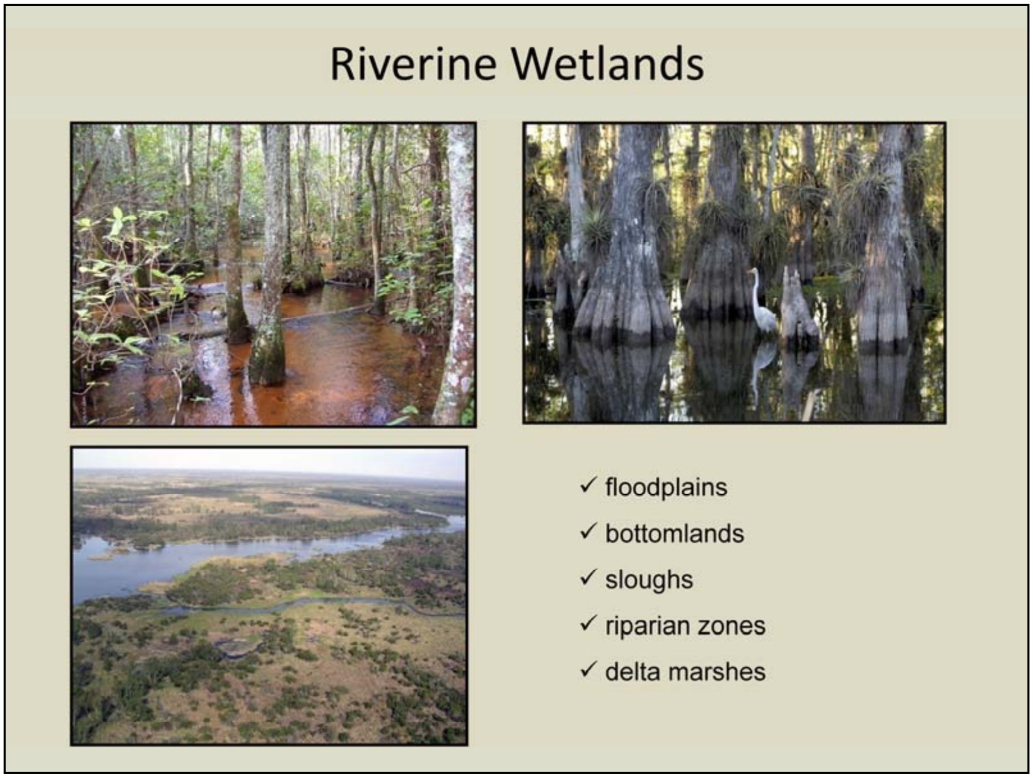
Tidal salt marshes – estuarine wetlands dominated by herbaceous vegetation

Mangrove swamps - marine or estuarine wetlands dominated by salt-tolerant woody vegetation (e.g., red mangrove)

Shrub wetlands – estuarine wetlands dominated by small (< 5 m high) scrubby bushes and trees that are tolerant of salt water

Photo credits:

Left – (tidal salt marsh): Tom Blagden Jr., USEPA
Top right – (shrub wetland): NOAA/Department of Commerce
Bottom right – mangrove swamps: Ralph F. Kresge, NOAA



Floodplains – overflow areas subject to inundation when rivers escape their banks

Bottomland – a type of riparian forested wetland dominated by hardwoods; associated with lakes, streams and rivers; typically inundated only during winter and early spring except during flood conditions

Slough – marshes associated with rivers; typically form in depressions that may be remnants of an old river channel that becomes associated with the main river only at high flows

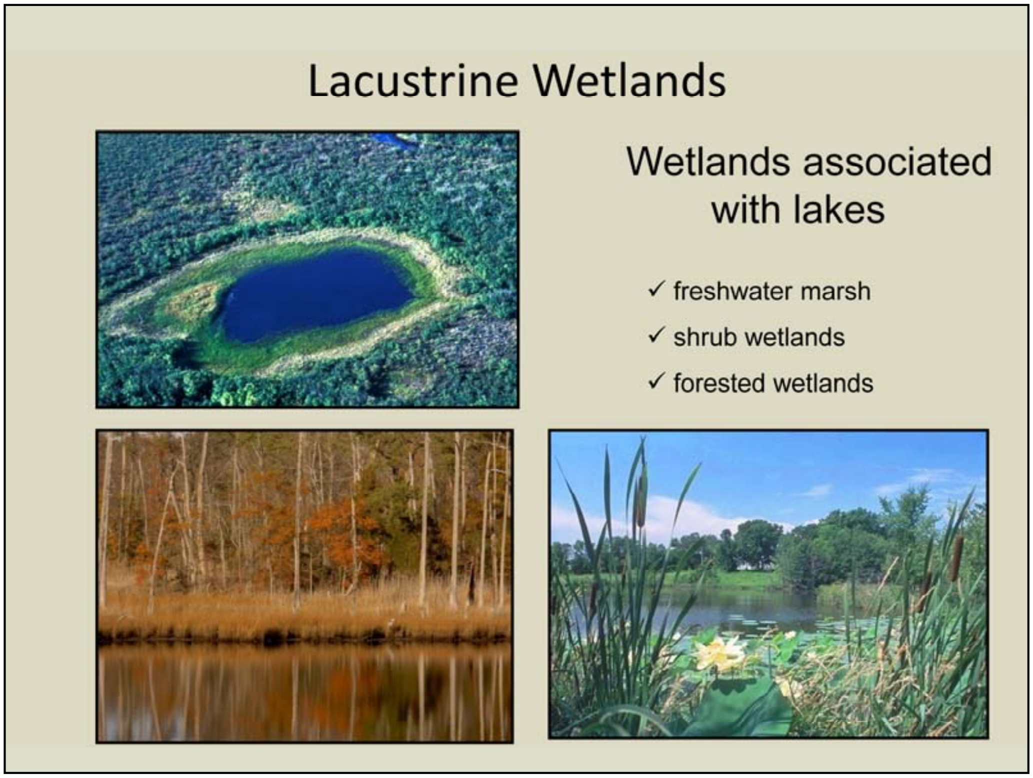
Riparian zones – vegetation associated with creeks and rivers; not <u>necessarily</u> wetlands

Delta marshes – wetlands that form at the lower end of rivers before the rivers enter the ocean, estuary or lake

Swamp – a general term for a variety of wetland types, all dominated by woody vegetation

Photo credits:

Top left (Georgia forested wetland) – Pete Pattavina, U.S. Fish and Wildlife Service, Georgia Ecological Services Field Office
Top right (Cypress and great egret) – National Park Service
Bottom left – Tim Carruthers, IAN Image Library (ian.umces.edu/imagelibrary/)

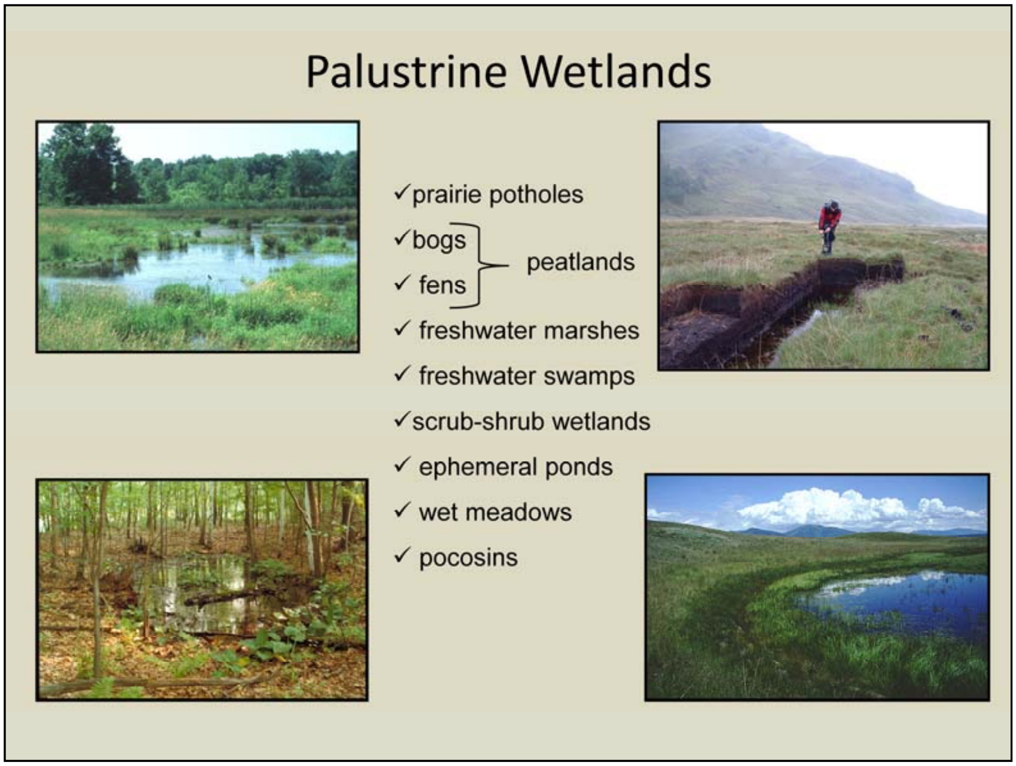


Marsh – shallow water wetlands with little to no peat accumulation; dominated by emergent herbaceous vegetation (e.g., sedges, rushes, cattails) and floating aquatic plants (duckweed and water lilies); a broad category of highly productive wetlands usually at close to neutral pH ("lacustrine" when associated with lakes)

Playa lake – marsh-like ponds in the arid southern Great Plains (Texas, New Mexico, Kansas, Oklahoma, and Colorado) – top left photo

Photo credits:

Top – U.S. Fish and Wildlife Service
Bottom left – James Shelton/Marine Photobank
Bottom right – New York, USDA NRCS



See notes slide 11 (page 22)

Photo credits:

Top left - New York, USDA NRCS
Top right: - Natural Resource Conservation Service. Peat soils in Richland County, Wisconsin. Ho Chunk Nation of the Winnebago Tribe of Wisconsin
Bottom left: David Riecks, Illinois-Indiana Sea Grant, USEPA
Bottom right: U.S. Army Corp of Engineers

Notes slide 11 (page 22)

If deepwater habitats are eliminated from consideration (i.e., oceans, lakes and rivers), 94% of all U.S. wetlands are classified by USFWS as palustrine wetlands.

Prairie potholes – small shallow ponds called potholes that formed when glacial ice melted at the end of the last Ice Age (12,000-25,000 years ago). Except during floods individual basins are usually isolated from each other. In the northern plains of North America (Dakotas, Iowa and prairie provinces of southern Canada). Potholes are filled in the spring with runoff from snowmelt or rain, or from elevated ground water tables that saturate porous lowland soils and provide a relatively constant source of water through the summer.

Bog – waterlogged peatlands in old lake basins or depressions; peat accumulation exceeds decomposition; productivity is typically low; vegetation is dominated by Sphagnum moss, which during its growth takes up cations (Ca^{2+} and Mg^{2+}) and can exchange hydrogen ions creating acidic conditions; peat also releases organic acids; unique plants are adapted to low nutrient, highly acidic (pH 3.0-4.0) conditions (e.g., sundew and carnivorous pitcher plant)

Fen – peat-accumulating wetlands dominated by herbaceous vegetation; they receive their water from groundwater and are found at low points in the landscape or near slopes where groundwater intercepts the surface; found in glaciated regions of the northern U.S.; not as acidic as bogs

Peatlands – a collective term for bogs and fens

Muskeg – a type of bog found in arctic and boreal regions dominated by sphagnum moss and sometimes small shrubs and stunted black spruce trees

Swamp – a general term for a variety of wetland types, all dominated by woody vegetation

Scrub-shrub wetlands – wetlands dominated by woody vegetation less than 5 m in height

Vernal pool (Ephemeral pond) – small shallow flooded depressions in grasslands or forests; soils are usually saturated only in winter and early spring; may be dry for up to several years

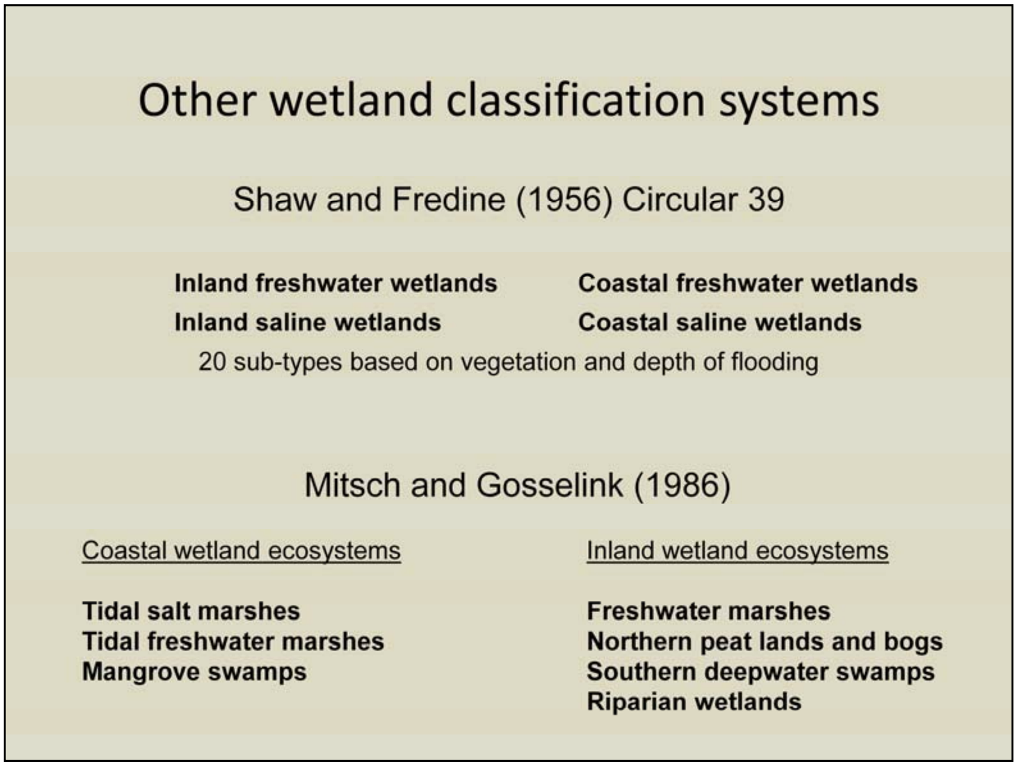
Wet meadow – grasslands with waterlogged soils after heavy precipitation

Pocosins – a type of bog (nutrient poor, acidic) found in the southeastern U.S. (most are in North Carolina); dominated by evergreen shrubs; name is derived from a Native American word meaning “swamp on a hill” as they are typically found in flat areas perched at higher elevations

- Hudson Bay lowlands (bogs, fens swamps and marshes) – 374,000 km^2
- Mackenzie River basin (bogs, fens swamps and marshes) – 166,000 km^2
- Mississippi River Delta / Louisiana (bottomland hardwood forests, swamps, marshes) – 108,000 km^2
- Prairie Pothole Region (marshes, meadows) – 63,000 km^2
- Chesapeake Bay (estuarine wetlands) – America's largest estuary – 11,603 km^2
- Everglades of South Florida (marshes) – "river of grass" – 34,000 km^2

Although not as expansive as some of the others listed here, wetlands of San Francisco Bay and the Sacramento River Delta in California illustrate biologically diverse ecosystems, ongoing restoration efforts and contentious issues regarding development and agriculture.

Photo credit: Adapted from Free pictures online



See notes slide 13 (page 25)

Notes slide 13 (page 25)

The Cowardin System is difficult to apply in the field, and many wetland managers and wetland legislation use earlier terminology originally presented as **Circular 39** (Shaw and Fredine 1956). Four main areas (inland fresh, inland saline, coastal fresh and coastal saline) are further subdivided into 20 types by life forms of vegetation and depth of flooding.

Mitsch and Gosselink (1986) divide North American wetlands into 7 types:

<u>Coastal wetland ecosystems:</u>

Tidal salt marshes – tidal influence possibly in addition to inflow from freshwater sources; supports vegetation that can tolerate salinity (halophytes); highest productivity of all wetland systems due to nutrient and organic input from upstream and alternating aerobic and anaerobic conditions created by tidal action

Tidal freshwater marshes – found upstream of estuaries; still under the influence of tides but fresh water dominates; highly productive ecosystems due to input of nutrients from upstream sources

Mangrove swamps – marine or estuarine wetlands dominated by salt tolerant woody vegetation (e.g., red mangrove)

<u>Inland wetland ecosystems;</u>

Freshwater marshes

Northern peat lands and bogs

Southern deepwater swamps – riparian forested wetlands with standing water most of the year (e.g., cypress swamps)

Riparian wetlands – other wetlands associated with river systems

Wetlands may also be categorized more generally as:

Emergent wetlands – e.g., saltmarshes or cattail marshes

Submergent wetlands – shallow water wetlands where plants are beneath the water’s surface

Shrub/Scrub wetlands – dominated by short woody vegetation

Forested wetlands – dominated by trees; commonly referred to as swamps

This system is most commonly used when aerial photographs are used to identify and categorize wetlands.

The Hydrogeomorphic (HGM) Approach

A 7-class classification system based on the hydrologic regime and geomorphic position of a wetland

Depressional	Tidal fringe
Riverine	Lacustrine fringe
Mineral flats	Slopes
Organic flats	

The HGM approach:

- is also used to evaluate wetland functions
- assesses wetlands based on their structural components (hydrology, soils, plants and animals) and the processes (physical, biological and chemical) that link them
- is based on a comparison of measured and estimated values of these functions between the study wetland and reference standard sites
- assigns an index from 0.0 to 1.0 to represent the level of wetland condition for each function

See notes slide 14 (page 27)

Notes slide 14 (page 27)

Originally developed as a new scheme for the classification of wetlands, the hydrogeomorphic approach is based on classifying wetlands using the hydrologic regime and geomorphic position. Seven wetland types are recognized in this system (see links below and Brinson 1993):

Depressional Riverine Mineral flats

Organic flats Tidal fringe Lacustrine fringe Slopes

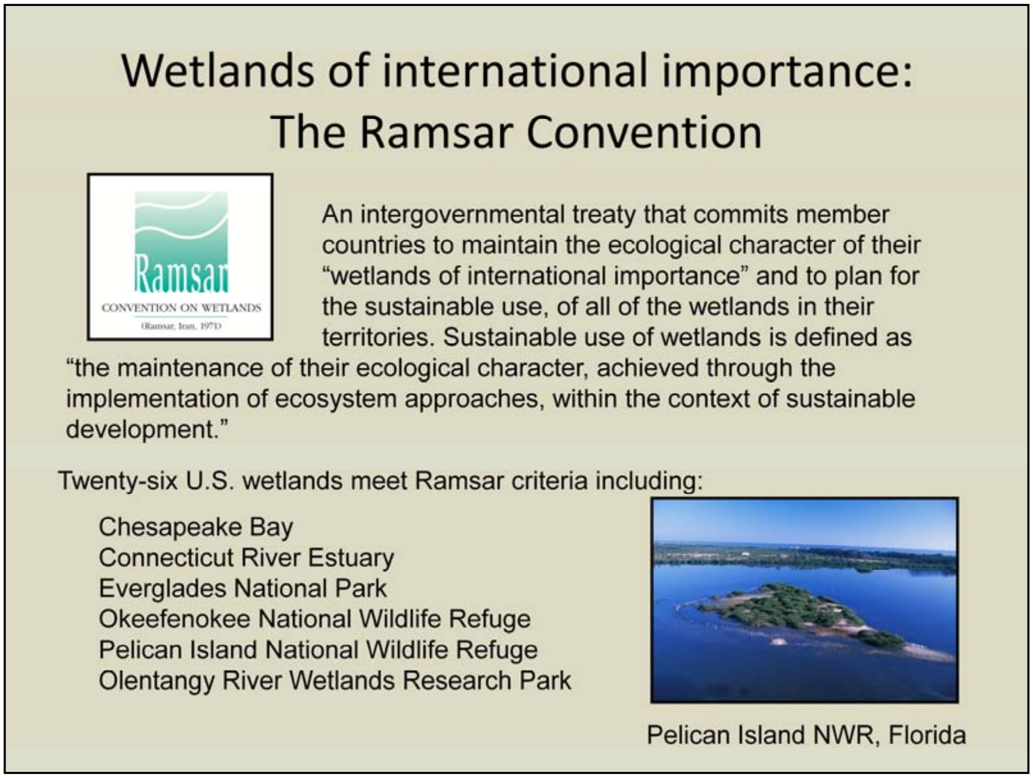
More recently, the HGM approach has been used as a way to evaluate wetland functions. It is designed to assess wetlands based on their structural components (hydrology, soils and plants and animals), and the processes (physical, biological and chemical) that link these components. Understanding the interactions of the structural components of the wetlands ecosystem with the surrounding landscape is the basis of the HGM approach. As discussed elsewhere, wetlands perform a number of ecological functions (e.g., coastal protection, flood mitigation, water purification, wildlife habitat, etc.). However, not all wetlands perform the same functions, nor do wetlands of the same type perform the same functions at the same level of performance. The HGM approach is based on a comparison of measured and estimated values of these functions between the study wetland and reference standard sites. It provides an index from 0.0 to 1.0 to represent the level of wetland condition for each function. Rather than using direct measurement of ecosystem function, the method uses indicators of ecosystem structure and process as indirect measures of functionality.

Some examples of HGM indicators used for slope or flats wetlands in Oregon along with the ecosystem function(s) they indicate:

Indicator	Function(s)
Presence of logs or boulders that extend above surface of permanent water	Amphibian and turtle habitat
Percent of site that is mowed or grazed at least annually	Sediment stabilization, phosphorus retention, support of wetland vegetation
Percent of soil mottling	Nitrogen removal
Distance to nearest busy road	Breeding waterbird support, amphibian and turtle habitat, songbird habitat support

A number of national and regional HGM Guidebooks have been published by the U.S. Army Corps of Engineers to give some guidance to practitioners on the application of this approach. Citations to representative HGM guidebooks are given in the *Resources* section of this module.

Note that both the Mitsch and Gosselink (1986) and the HGM method divide wetlands into 7 types. The difference is that the former is based primarily on vegetation characteristics, while the latter is based on geomorphic position and hydrology.



See notes slide 15 (page 29)

Photo credit: George Gentry, USFWS

Notes slide 15 (page 29)

The Ramsar Convention on Wetlands of International Importance (usually called the “Ramsar Convention” since it was convened in Ramsar, Iran in 1971) is an intergovernmental treaty that commits its member countries to maintain the ecological character of their “Wetlands of International Importance” and to plan for the “wise use,” or sustainable use, of all of the wetlands in their territories. The wise use of wetlands is defined as “the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development.”

Unlike the other global environmental conventions, Ramsar is not affiliated with the United Nations. It is the only global environmental treaty that deals with a particular ecosystem, and the Convention's member countries cover all geographic regions of the planet. The Convention's mission is “the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.”

The Ramsar Convention provides for the development and maintenance of a “List of Wetlands of International Importance.” The chief objective is to “develop and maintain an international network of wetlands which are important for the conservation of global biological diversity and for sustaining human life through the maintenance of their ecosystem components, processes and benefits/services.” Globally, this list includes 1896 wetlands of international importance covering about 185.5 million hectares. As of January 2010, the United States had 26 of these sites covering about 1.5 million hectares. Included among these are some of the most recognizable natural features in the U.S.:

Chesapeake Bay and associated estuaries

Connecticut River Estuary

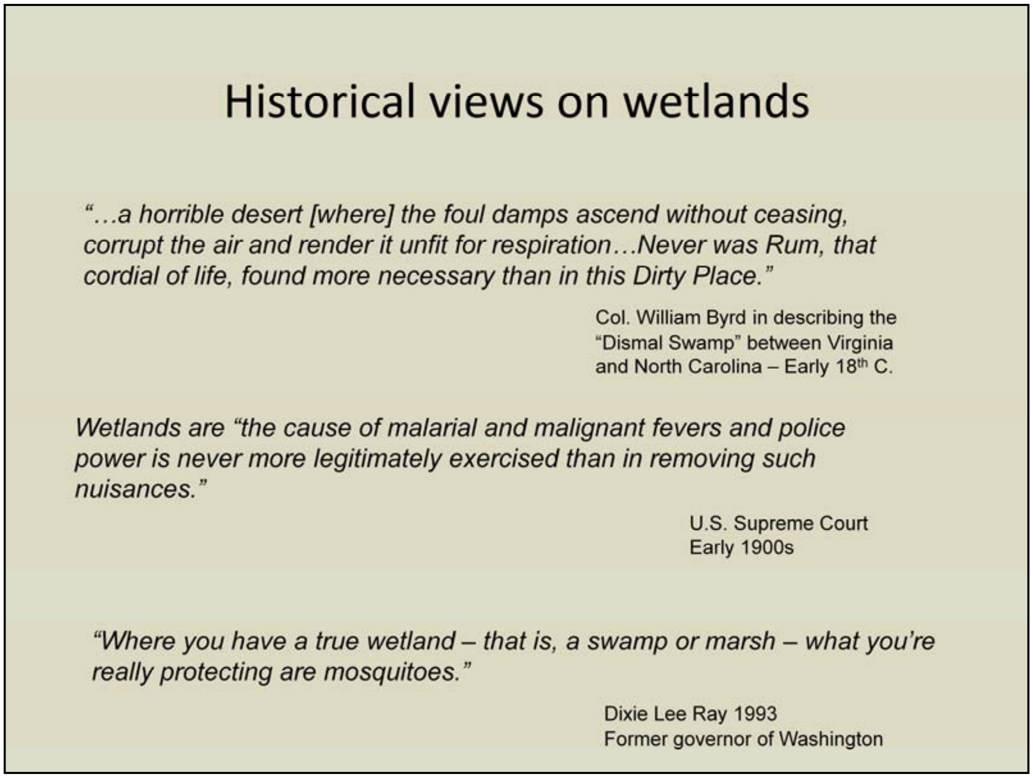
Everglades National Park

Okeefenokee National Wildlife Refuge (Georgia/Florida)

Pelican Island National Wildlife Refuge (Florida)

Olentangy River Wetlands Research Park (Ohio)

A 4-minute *Youtube* video is available that introduces Ramsar and describes the value of wetlands.



Col. William Byrd (an early 18th Century surveyor) described the area between Virginia and North Carolina as the "Dismal Swamp" – "a horrible desert [where] the foul damps ascend without ceasing, corrupt the air and render it unfit for respiration…Never was Rum, that cordial of life, found more necessary than in this Dirty Place."

In the early 1900s the U.S. Supreme Court proclaimed that wetlands were "the cause of malarial and malignant fevers" and that "the police power is never more legitimately exercised than in removing such nuisances."

Dixie Lee Ray, the former governor of Washington and the chair of the Atomic Energy Commission, in a 1993 radio address described wetlands this way:

"Where you have a true wetland – that is, a swamp or marsh – what you're really protecting are mosquitoes."

These quotes provide evidence of how wetlands were generally perceived during the European settlement of the U.S. In some segments of our society this perception of wetlands as "useless or wasted land" is still prevalent.

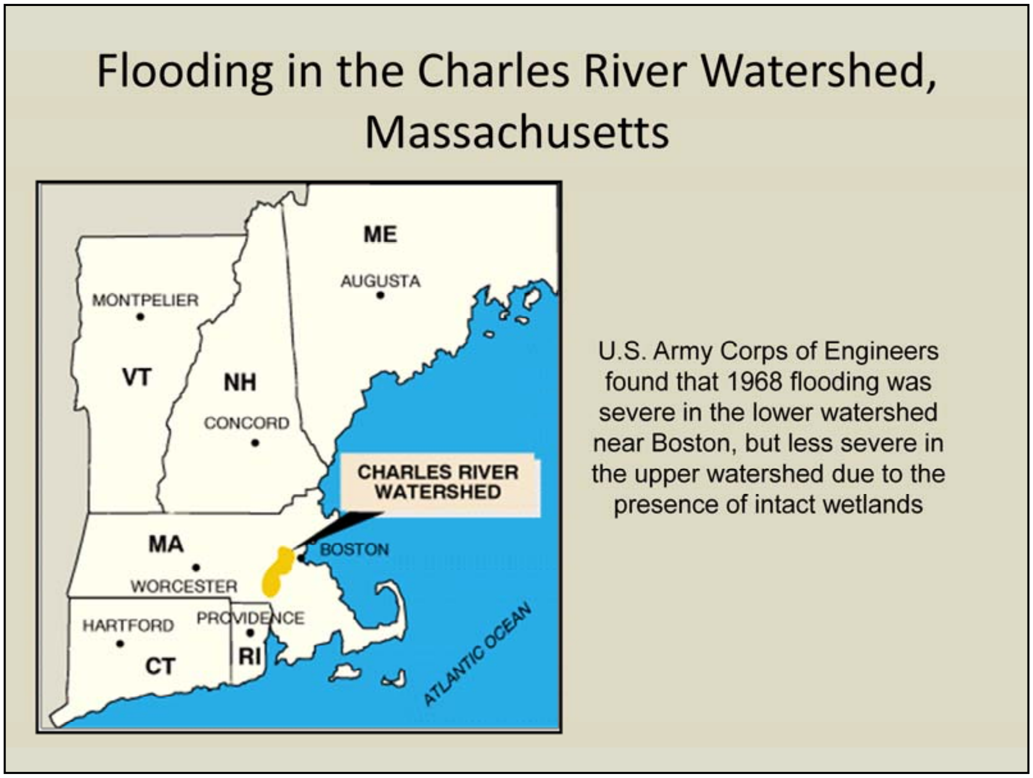
The development of many cities and towns in the U.S. took place on wetlands, which were flat areas and thought to be otherwise useless. The city of Boston is one such example.

Prior to European settlement, most of the New England coastline was occupied by wetlands. Native Americans relied on the resources provided by the extensive salt marshes, estuaries and fens. Spring spawning runs of salmon, herring and alewife provided a reliable food source and local estuaries and tidal mudflats provided abundant fish (smelt, tomcod, flounder and sturgeon) and shellfish (clams, crabs, oysters). Early settlers also found uses for the abundant vegetation in wetlands as grazing sites for livestock, harvest of salt hay and cord grass for thatch roofs.

The city of Boston, Massachusetts, in particular, was once dominated by wetlands. As early as the late 1700s however, the area was remarkably transformed. Filling in the mudflats of Boston Harbor and the marshy fens of the Back Bay area began in 1790. In the early 1800s, dams raceways and basins were built to tap into the power of the tides and rivers to grind corn, mill flour and produce iron and textiles. Driven by fears of the Back Bay as a reservoir for diseases such as cholera and diphtheria and the demand for land, the filling of the Back Bay began in earnest in 1858 and continued over the next 50 years. The work was primarily conducted by the state and the land was sold to developers. Among the Back Bay developments that eventually arose from the wetlands were Logan International Airport and historic Fenway Park, home to the Boston Redsox, which derives its name from the once-present wetlands there.

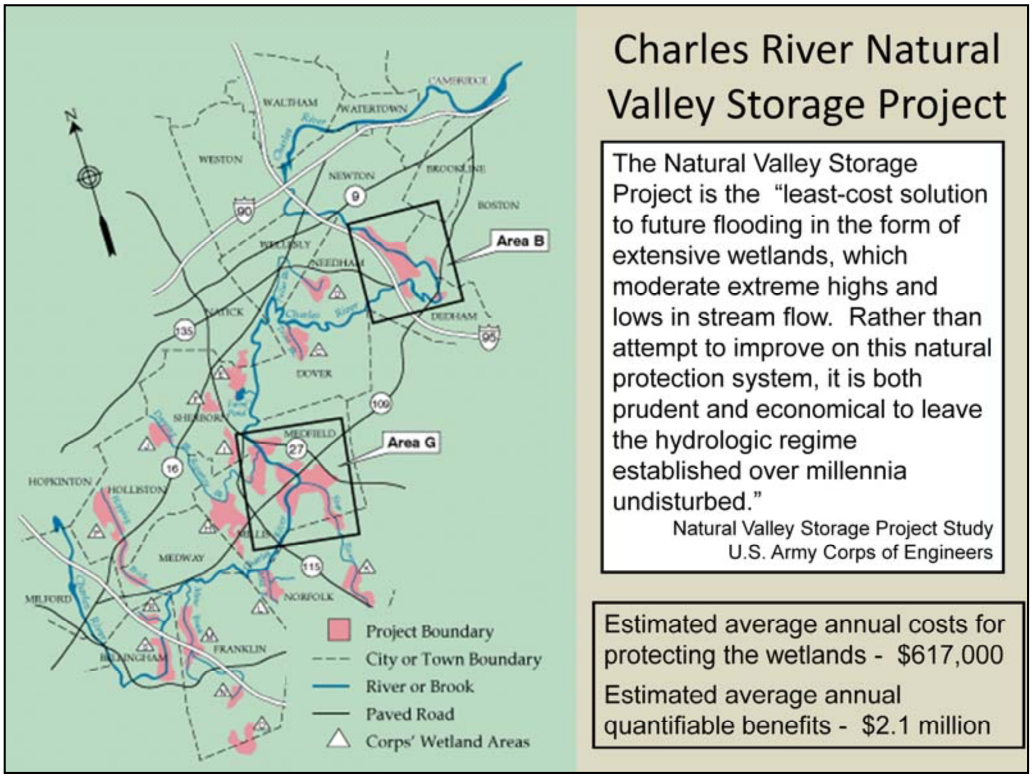
Similar examples of the conversion of wetlands to developed areas can be seen throughout the U.S.

Photo credit: Google Earth



However, there <u>are</u> 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 classic rain-on-snow event 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 includes 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 <u>upper</u> part of the watershed (south and west of Boston) 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. (Recall that much of Boston is, in fact, built on drained wetlands). The natural wetlands had "absorbed" the flood waters and effectively "controlled the flood."

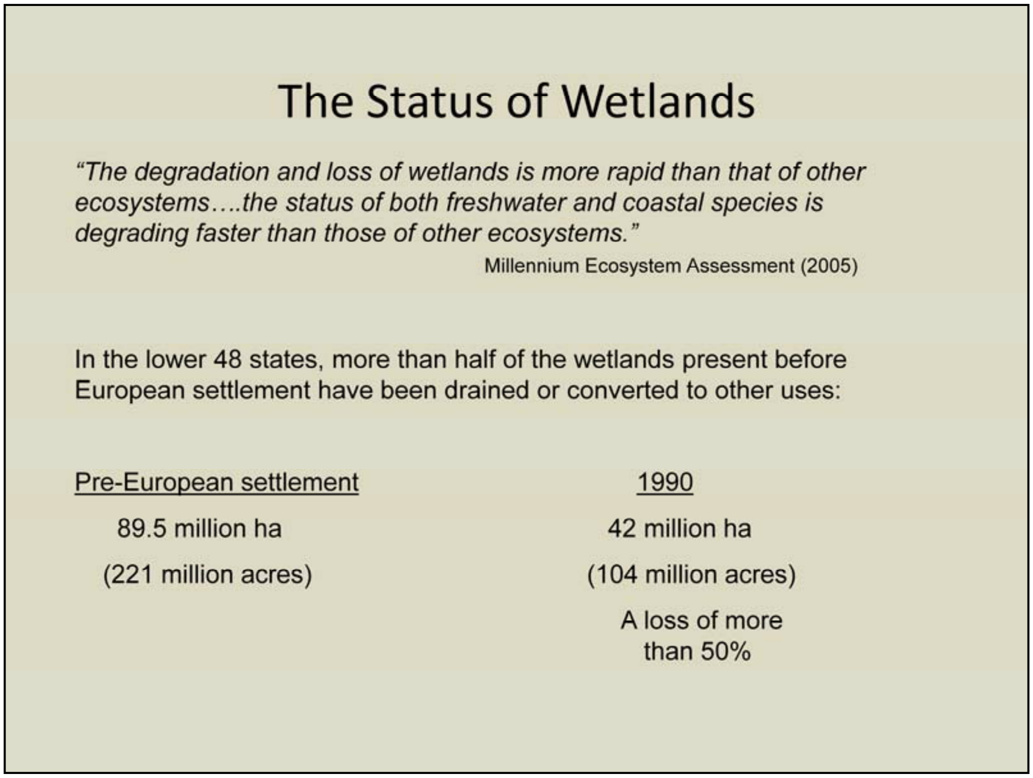
Image credit: U.S. Army Corps of Engineers



Four years later (1972), when a large development project was being proposed in the watershed, the Army Corps of Engineers 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).

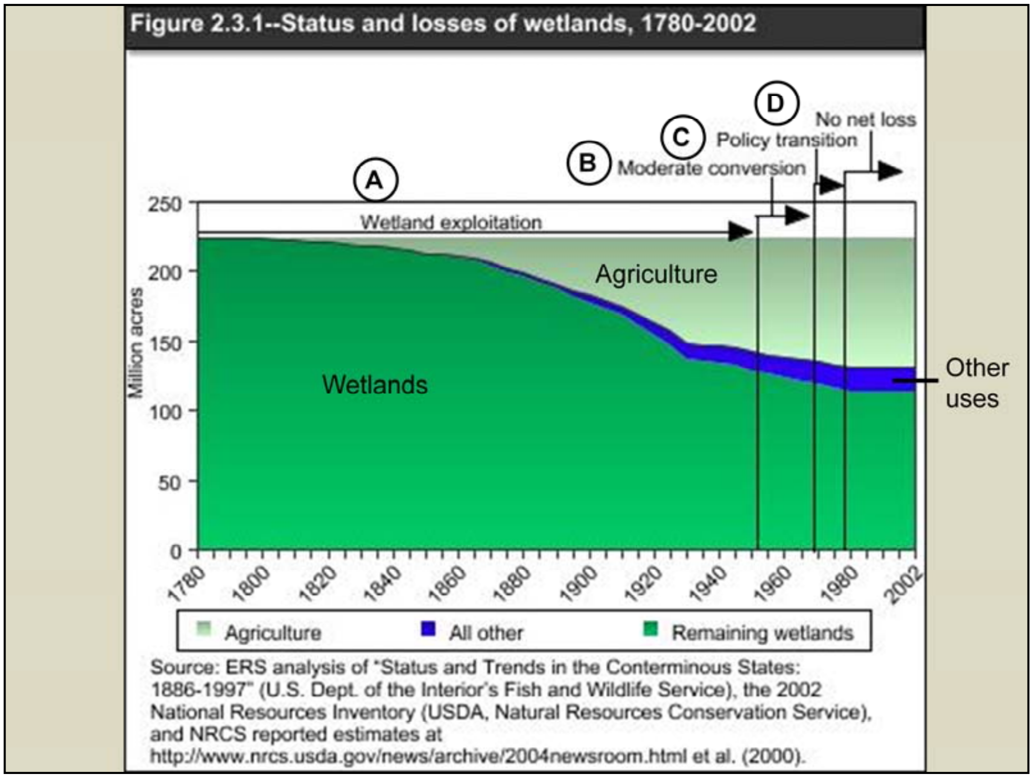
In 1974 Congress authorized the acquisition and permanent protection of 17 wetland areas in the middle and upper watershed. Estimated annual costs for protecting the wetlands through purchase and conservation easements have averaged $617,000, while annual quantifiable benefits have averaged $2.1 million. This map of the Charles River Natural Valley Storage Project illustrates wetland areas (in pink) that have been set aside for flood control. Areas "B" and "G" on the map indicate the location of two of the larger complexes that provide both flood control and recreational functions (e.g., wildlife viewing, canoeing, fishing). Area B (Cutler Park in Newton, Dedham and Boston) encompasses 700 acres of wetlands. Area G includes 1100 acres of wetland owned by the Corps and 1000 acres with flood easements, which the Corps is allowed to inundate during flood events to minimize damage to more populated areas downstream.

Image credit: Adapted from U.S. Army Corps of Engineers



The loss and degradation of wetlands in North America since European settlement has been substantial. In the lower 48 states, more than half of the wetlands have been drained and converted to other uses. The original (1780s) amount of wetlands in the U.S. (including Alaska) is estimated at approximately 158 million hectares. The 1980s, National Wetland Inventory estimates that approximately 30% of this area has been lost (converted to non-wetland). However, the large contribution by Alaska skews the national picture as the original acreage of wetlands in that state is estimated to be nearly 69 million hectares. Only 0.1% of original Alaskan wetlands have been lost. An examination of the lower 48 states provides a more realistic picture of the status of U.S. wetlands. At the time of European settlement the lower 48 contained about 89.5 million ha (221 million acres) of wetlands = about 2X the size of California. More than 50% has been lost (converted to non-wetland). About 42 million hectares (104 million acres) remain as measured by the National Wetlands Inventory conducted in the mid-1980s (Dahl 1990).

See Mitsch appendix A for table of estimated losses.



See notes slide 21 (page 36)

Image credit: U.S. Department of Agriculture Economic Research Service

Notes slide 21 (page 36)

In the U.S. (lower 48) about 2/3 (66%) of total wetland losses (24.2 million acres) between 1954 and 2002 were due to the conversion of wetlands to agricultural lands. For this reason, future gains in wetland area will likely draw from agricultural lands and also because restoration of agricultural lands to wetlands is less costly than conversion of other land uses (e.g., urban). This figure illustrates changes in U.S. land use in areas that were originally wetlands from 1780-2002. Wetlands are represented in dark green, agriculture in light green and all other land uses (urban, commercial, residential, etc.) in blue.

Pre-European settlement wetland acreage in the lower 48 = 221-224 million acres (Midwest 27%, Southeast 24% and Delta and Gulf States 24%). As settlement increased and drainage methods and technology improved, wetlands were converted to other land uses.

The following periods are indicated on the figure:

A. Wetland Exploitation (1700s to 1954)

During this time period wetland conversion was supported and encouraged by large federal programs and local cooperative efforts. From 40-44% of original wetlands were converted during this time period with most occurring after 1885. Conversion rates from 1885-1954 are estimated at approximately 814,000 – 887,000 acres per year.

B. Moderate Wetlands Conversion (1954-1974)

Wetland conversion continued during this time but at about half the rate of previous 50 years (about 458,000 acres per year). Conversion to agriculture was the primary driver of wetland loss, which outpaced wetland gain (mostly due to abandonment of agricultural land) by a ratio of 3 to 1.

C. Wetland Policy Transition (1974-1982)

Growing public concern about wetland loss resulted in policy changes and new legislation that provided some protection to wetlands (e.g., Clean Water Act 1972 Section 404 which regulated the discharge of dredge and fill material into waters of the U.S. including wetlands and Executive Order 11990 signed by President Carter in 1977, which directed federal agencies to minimize the loss and degradation of wetlands and to improve wetland health). These policies resulted in a slowing of wetland conversion and losses.

D. No Net Loss (1982-2002)

A national goal of "no net loss" was first established by the H.W. Bush administration. This goal means that wetlands should be conserved whenever possible, and that acres of wetlands converted to other uses must be offset by restoration or creation of wetlands, thus maintaining or eventually increasing the wetlands resource base. Several federal programs and legislation supported the policy including Swampbuster provisions of the Food Security Act (1985), Wetland Reserve Program (1990) and more rigorous enforcement of Section 404 permitting under the CWA. As indicated in the figure, since initiation of "no net loss," wetland acreage has stabilized at about 134 million acres.

Summary of rates of U.S. wetland loss

Time period	Average annual net loss (-) or gain (+) in acres
1950s – 1970s	-458,000
1970s – 1980s	-290,000
1980s – 1990s	- 58,550
1998 – 2004	+ 32,000

Net increases in wetland acreage do not necessarily ensure increased wetland functions

Slowing trend of wetlands loss is due to:

Wetland protection measures

Removal of incentives to drain wetlands

Improved public education

Wetland restoration efforts

Federal wetland mitigation requirements

See notes slide 22 (page 38)

Notes slide 22 (page 38)

Summary of Rates of U.S. Wetland Loss

From the previous slide it is apparent that the U.S lost most of its wetlands before 1950. Since that time the overall trend has been a slowing of the rate of wetland loss and, in recent years, a net gain of wetlands. The slowing trend of wetlands loss is due to wetland protection measures and the removal of incentives to drain wetlands for development, improved public education and wetland restoration efforts, and federal wetland mitigation requirements. Despite these actions, several wetland types in the U.S. are still being lost and degraded due to human activities, primarily land use conversion and pollution.

Not long ago, wetlands were regarded as wastelands in need of conversion to dry land ("reclamation"). Public opinion has radically changed in a relatively short period of time. As public attitudes towards wetlands changed, more legislation was passed to protect them. In the U.S. a national policy of "no net loss" of wetlands was adopted in the 1980s. Projects that eliminated wetlands were required to give high priority to avoidance or minimization of impacts to compensate by replacement with other wetlands of similar value (see *Wetland Mitigation* module for details).

Prior to 1970s era legislation, loss rates were about 1% per year in the U.S. (lower 48) or about 458,000 acres (185,400 hectares) per year. This reflects the absence of any wetland protection during this time.

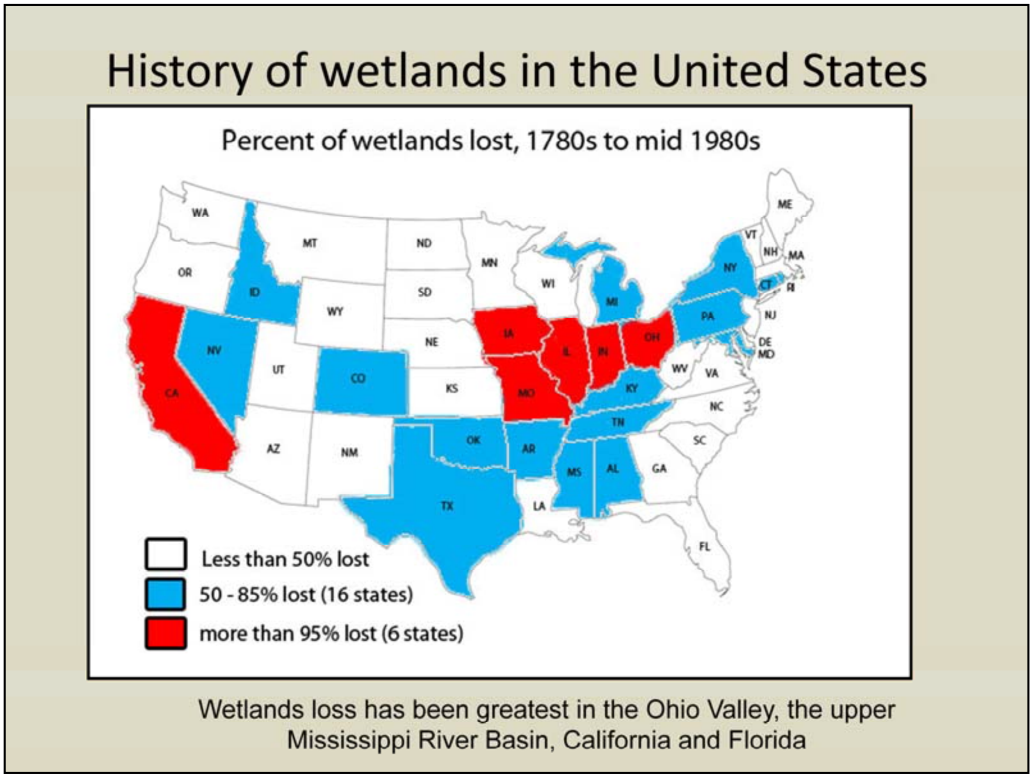
1970s - 1980s – Loss of 290,000 acres (117,400 hectares) per year

1980s -1990s - Loss of 58,500 acres (23,700 hectares) per year

1998-2004 – U.S. had a net gain of about 32,000 acres (12,900 ha) per year. However, continued losses of swamp and marsh wetlands were offset by a gain of small ponds and shallow open water wetlands such as prairie potholes which are easily constructed and provide good waterfowl habitat ("duck donuts"). Net increases in wetland acreage do not necessarily ensure increased wetland functions. For example, the loss of 10 acres of a mature forested wetland compensated by a constructed wetland of similar size dominated by open water. Also, this evaluation takes only wetland acreage into account, not wetland quality. Almost all gains in wetland acreage have occurred in freshwater wetland types; saltwater/estuarine wetlands continue to experience net loss.

Dahl, T.E. 1990. Wetlands losses in the United States, 1780s to 1980s. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C. 21 pp.

Dahl, T.E. 2006. Status and trends of wetlands in the coterminous United States: 1998 2004. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.



The extent of wetland loss has varied across the United States.

At the time of European settlement there were approximately 221 million acres of wetlands in the lower 48 states.

As a whole, the lower 48 states had lost just over 50% (103 million acres) of their wetlands by the mid-1980s. Six states, however, had lost >85% of their wetlands and 22 states had lost >50%. The states highlighted in red (the Ohio Valley, the upper Mississippi River Basin and California) have experienced notable loss of their wetlands. Although wetlands loss in Florida (46%) is less than 50%, by area, it has lost more wetlands than any other state. Of the 8.2 million hectares of wetland that existed in 1780, only 4.5 million hectares remained by the mid-1980s.

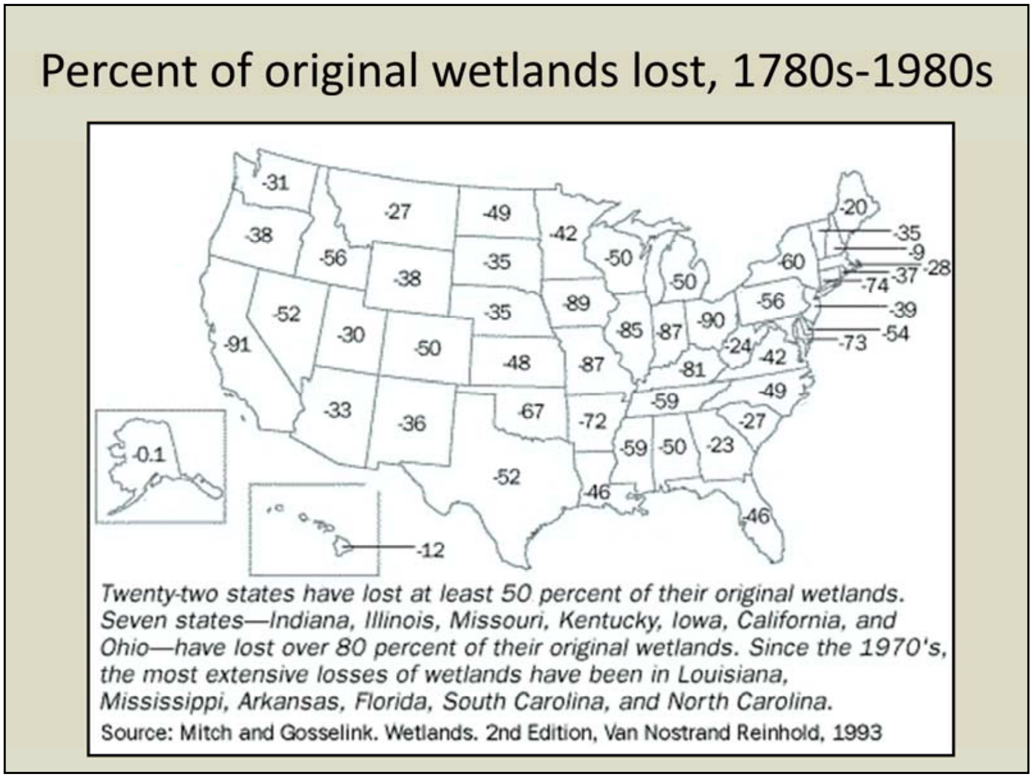
Consequences of this loss have not been fully realized.

Why did this loss occur? What impacts of the loss are understood? What impacts are we still realizing?

Societal views on wetlands have changed considerably in the last half century. Our interest in the restoration and preservation of wetlands has increased as our understanding of the value of wetlands has become more fully understood.

The history of wetlands will be described in broad increments of U.S. history. The historical backdrop will be described including the thinking at the time that allowed wetlands to be replaced with other land uses. Those who implement restoration and preservation efforts must fully understand past conditions as well as the reasons for degradation.

Image credit: adapted from U.S. Geological Survey



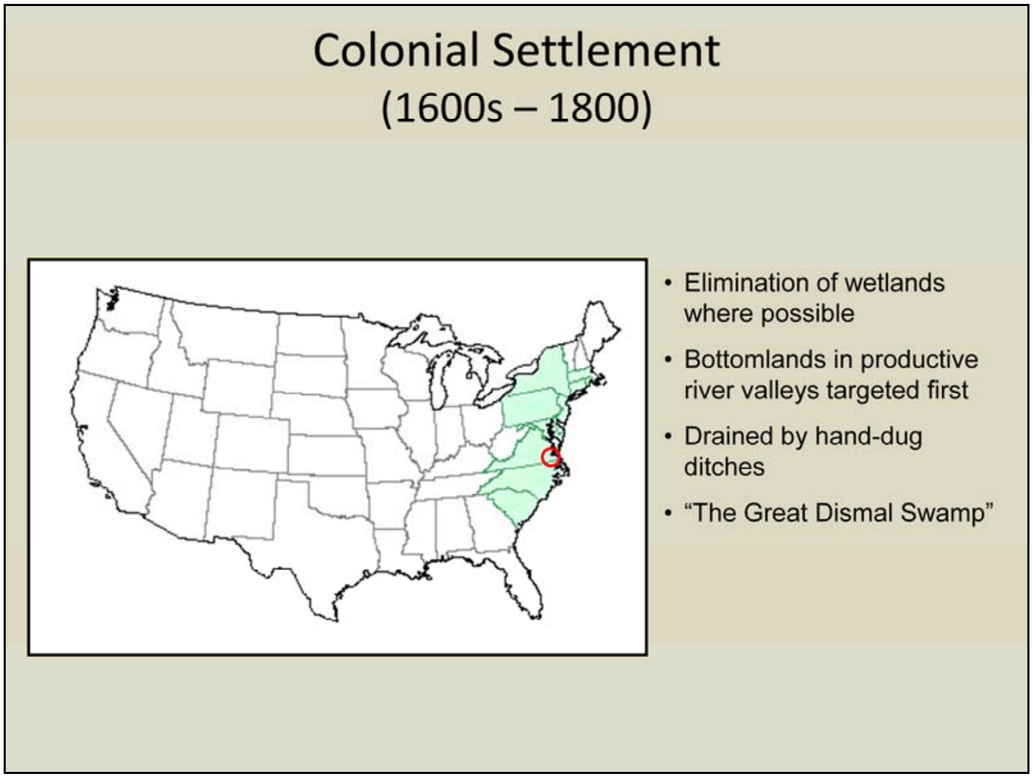
Ten states (Arkansas, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri, and Ohio) have lost 70 percent or more of their original wetland acreage.

Some notable U.S. examples include:

- Iowa has lost 99% of pre-settlement wetlands
- California has lost 90% of the extensive marshes and deltas that once occupied the Central Valley
- Southeastern U.S. – wooded swamps and floodplain forests have been widely impacted by logging and conversion to farmland
- Gulf Coast wetlands have been impacted by cutting channels for oil and gas exploration and navigation through wetlands (see NCSR Module *Wetlands and Hurricanes* for more detail on this)

Wetland loss depends on wetland type – mangrove swamps, for example, have been lost due to coastal development, logging and aquaculture – especially shrimp farms in South America and Southeast Asia. In the U.S., the most easily drained wetlands, those receiving only temporary flooding, have been nearly eliminated from agricultural regions.

Image credit: U.S. Environmental Protection Agency



Note: Colored states indicate those with substantial wetland loss during this time period.

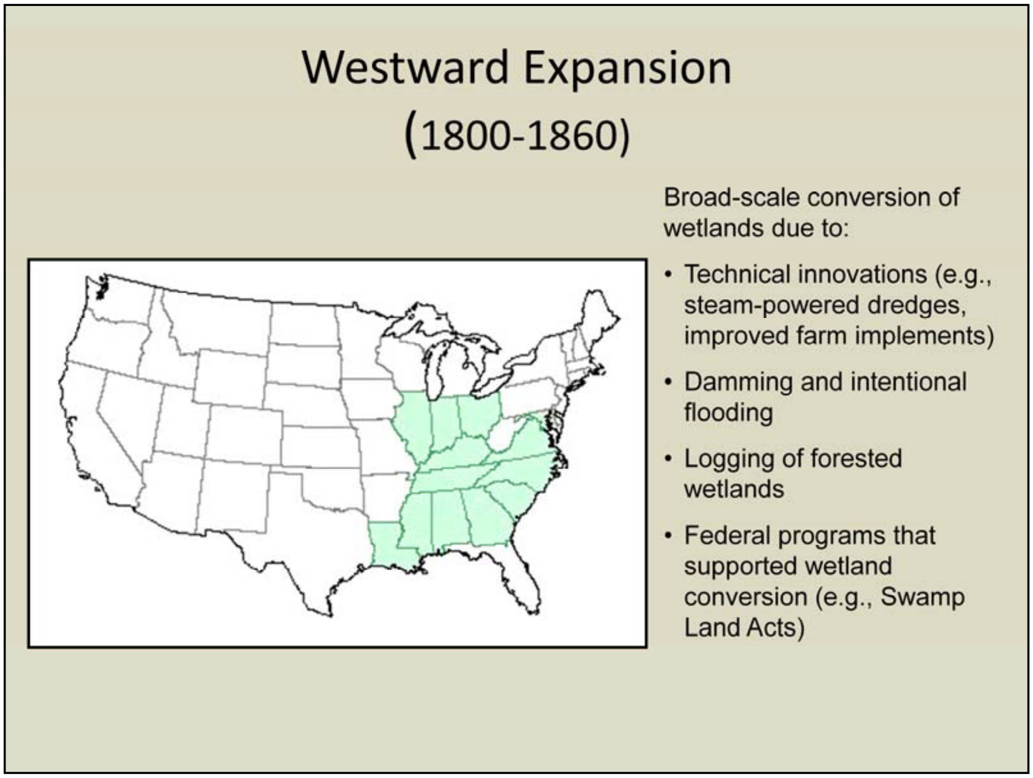
COLONIAL SETTLEMENT – 1600s – 1800

Source of information on early land use comes from the U.S. Public Land Survey established in 1785 by the Land Ordinance Act. Surveys were required to partition land for settlement.

Wetlands were considered to be dangerous swampy lands that fostered disease, impeded travel and prevented agriculture. Thus, the emphasis was on the elimination of wetlands where possible. Bottomlands in the most productive river valleys were targeted first and drained by ditches dug by hand. Initially these “new farmlands” were used for subsistence farming, but soon their high productivity led to farming for a profit. Drainage of wetlands was particularly prevalent in the mid-1700s in South Carolina, North Carolina and Virginia, where the Great Dismal Swamp was targeted for conversion to agricultural land.

In instances where resources were being extracted from wetlands, they were seen by pioneers as inexhaustible. Ducks, geese, mink and muskrats, for example, were all taken from wetlands in large quantities.

Image credit: adapted from U.S. Geological Survey



Note: Colored states indicate those with substantial wetland loss during this time period.

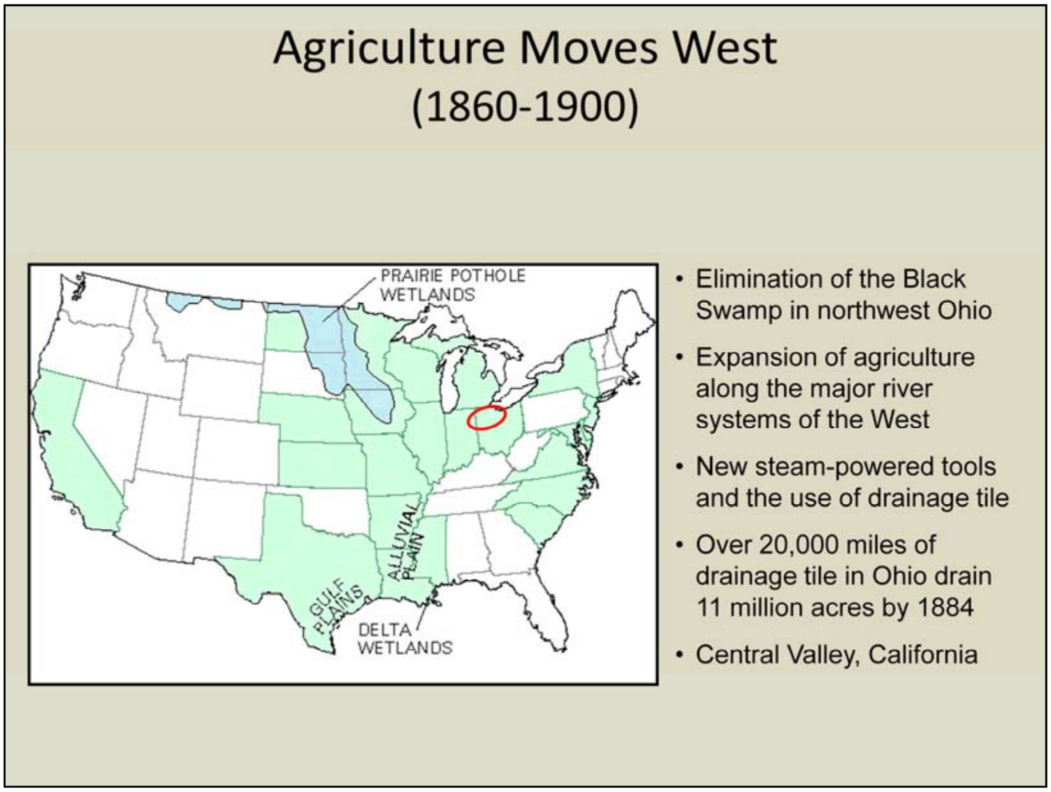
WESTWARD EXPANSION – 1800-1860

This period of rapid expansion of the territories of the U.S. was characterized by large land acquisitions such as the Louisiana Purchase, the annexation of Texas and the Oregon Compromise. Settlers moved westward into the Ohio and Mississippi River Valleys, both of which contained large acreages of wetlands. Broad-scale conversions of wetlands began to have impacts. Technical innovations such as the steam-powered dredge facilitated the channelization of small waterways, often eliminating their associated wetlands. New farm implements also allowed cultivation of ground that had not previously been farmed as the process of draining, clearing and plowing played out over large acreages.

Wetlands were also impacted in this time period by intentional flooding of wetlands and damming of waterways. Forested wetlands were also targeted for their valuable timber. The harvest of birch, ash, elm, oak, cottonwood, hickory and maple supplied wood for construction and fuel as the Midwest was settled.

We also see the first large scale federal programs that promoted the drainage of wetlands during this time period. The Swamp Land Acts granted all “swamp and overflow lands” to the states for drainage and reclamation. For the next 100 years government policy to “reclaim” wetlands persisted.

Image credit: adapted from U.S. Geological Survey



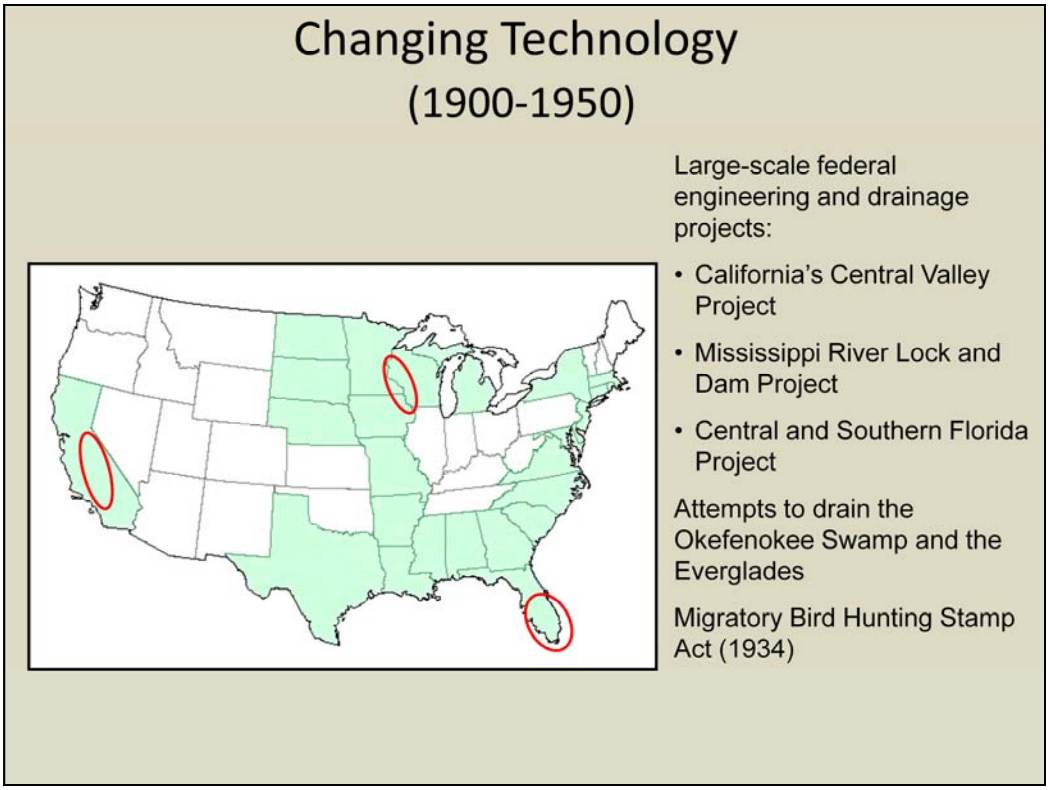
Note: Colored states indicate those with substantial wetland loss during this time period.

AGRICULTURE MOVES WEST – 1860-1900

During the American Civil War the movement of heavy equipment and troops was impeded by natural wetlands. As a result, a network of routes around and through wetlands was required. Detailed maps were produced that give us a glimpse of the status of wetlands at this time. The Black Swamp, a huge forested wetland in northwest Ohio, occupied an area nearly the size of Connecticut. As a result of an enthusiastic campaign of logging and draining, by the end of the 19th century the Black Swamp no longer existed.

Meanwhile, agriculture expanded along the major river systems of the West. Wetlands in the path of this expansion were rapidly converted. Wetlands of the prairie pothole region of north central states, the delta wetlands of Mississippi and Louisiana and the bottomlands of the lower Mississippi River were all transformed to agricultural lands. The drainage of wetlands was facilitated by the development of new technologies including the use of steam powered devices for digging and the manufacture of drainage tiles. By 1884, in Ohio alone over 20,000 miles of drainage tiles had been installed draining 11 million acres of land. The Central Valley of California also began in the mid-1800s as farmers drained and diked floodplain areas.

Image credit: adapted from U.S. Geological Survey



See notes slide 28 (page 45)

Image credit: adapted from U.S. Geological Survey

Notes slide 28 (page 45)

Note: Colored states indicate those with substantial wetland loss during this time period.

CHANGING TECHNOLOGY – 1900-1950

This period is marked by large-scale engineering and drainage projects, mostly as part of ambitious federal programs. Three examples:

1. California's Central Valley Project – levees, drainage projects, water diversion projects, flood control projects, water control structures were built on most of the tributaries on rivers entering the valley. Today there are more than 100 dams in the project and thousands of miles of canals. Only 14% of the original wetlands remain.

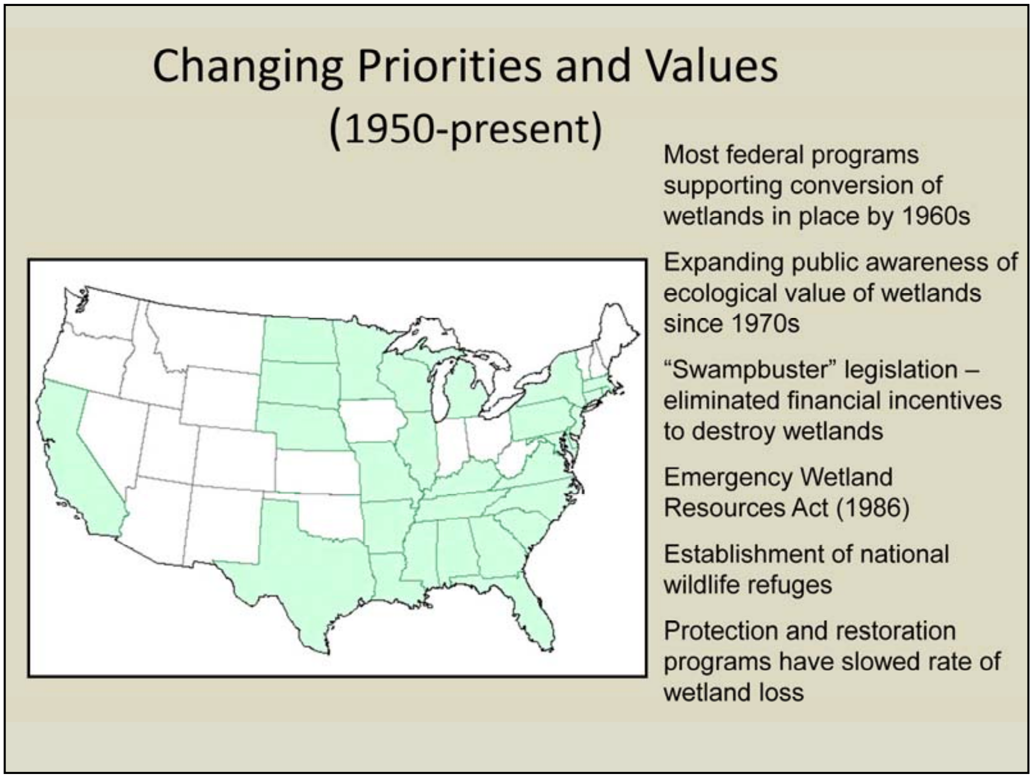
2. Mississippi River Lock and Dam Project – transformed the complex river channel of the Mississippi River with its associated forested wetlands, islands and sloughs to a permanent navigable waterway. This was accomplished by constructing a series of dams along the length of the Mississippi River.

3. Central and Southern Florida Project – a huge flood control project constructed by the Army Corps of Engineers to reduce flooding in much of Florida. The system included construction of levees, water storage areas, channelization of rivers, and huge mechanical pumps. This massive change in the hydrology of this part of the state severely impacted the vast wetlands in the region.

Other large scale projects of this time period included:

Attempts to drain Horicon Marsh (Wisconsin), the Okefenokee Swamp (Georgia), Lake Mattamuskeet (North Carolina's largest natural lake), the vast peatlands north of Red Lake, Minnesota, and the Everglades (Florida). As sugarcane became an important commercial crop in southern Florida, additional wetlands were drained to put into production of this crop.

Despite active federal support of draining wetlands during this time there was a growing recognition of the importance of wetlands as bird habitat. In 1934, the Migratory Bird Hunting Stamp Act was signed into law. This was the first piece of federal legislation that recognized wetlands as something that should be acquired and even restored.



Note: Colored states indicate those with substantial wetland loss during this time period.

CHANGING PRIORITIES AND VALUES – 1950-present

By the 1960s, most federal programs supporting the conversion of wetlands were in place. Most were implemented to create more agricultural lands or to enhance flood control projects. Tile and open ditch drainage systems, for example, were considered “conservation practices” by federal agriculture support programs. For example, from 1955-1975 the Agriculture Conservation Program alone drove the loss of 550,000 acres of wetlands per year.

Expanded public awareness of the ecological value of the nation’s wetlands has occurred since the 1970s. Consequently, several pieces of federal legislation have attempted to protect and restore wetlands in an effort to reverse some of the losses earlier in our history. Some examples include:

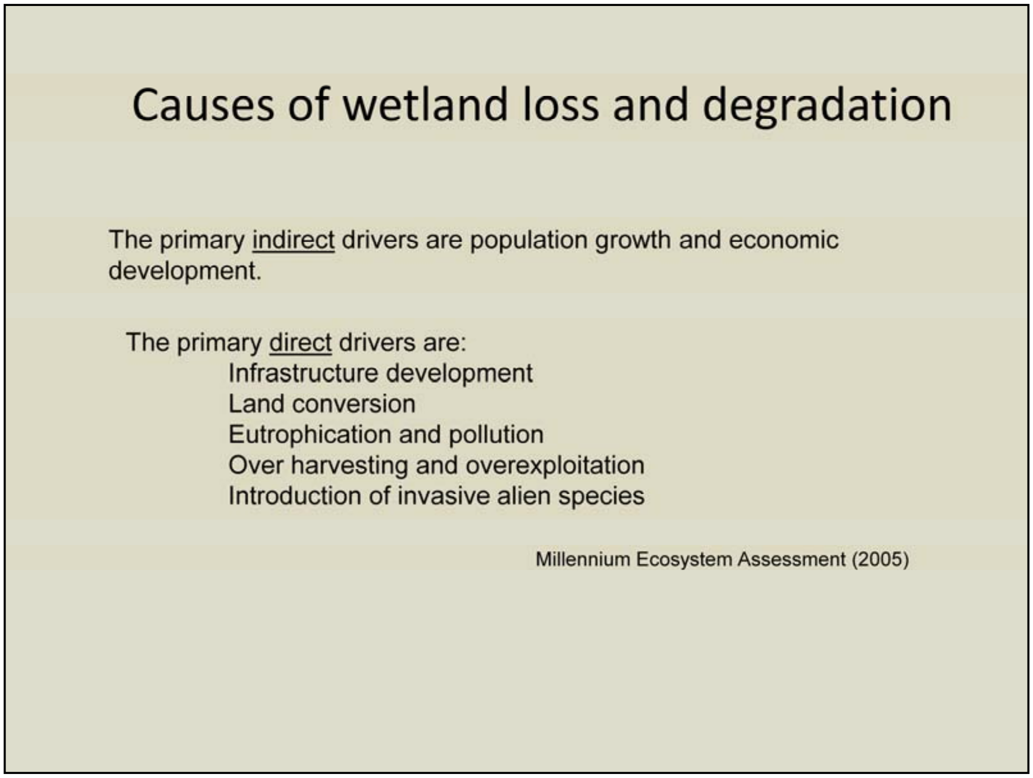
- “Swampbuster” legislation – eliminated financial incentives to destroy wetlands
- Emergency Wetland Resources Act (1986)

This act authorized the purchase of wetlands by the federal government for conservation purposes using monies from the Land and Water Conservation Fund. It also required the development of a National Wetlands Conservation Plan and mandated states to include wetlands in their Comprehensive Outdoor Recreation Plans.

- Establishment of national wildlife refuges on public wetlands

Although the rate of wetlands loss has slowed since the 1970s, wetland loss has not stopped despite a federal policy of no net loss of wetlands since the 1980s. Restoration of wetlands is now commonplace including some large-scale projects (e.g., Everglades).

Image credit: adapted from U.S. Geological Survey



"The primary indirect drivers of degradation and loss of inland and coastal wetlands have been population growth and increasing economic development. The primary direct drivers of degradation and loss include:

Infrastructure development

Land conversion

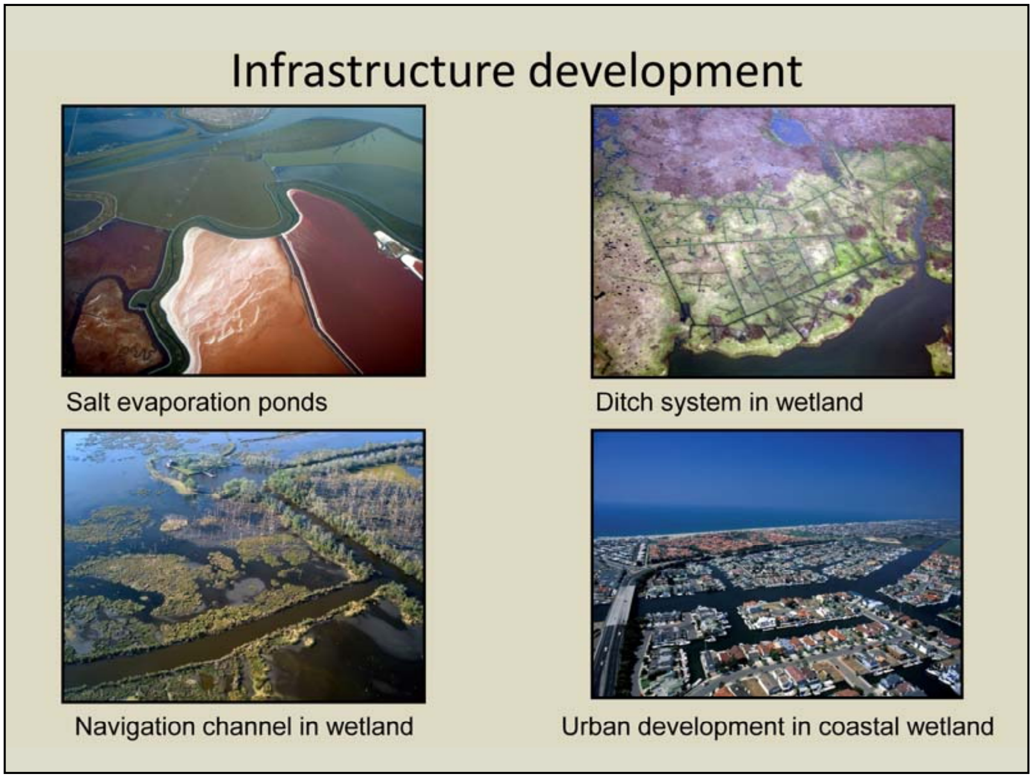
Eutrophication and pollution

Over harvesting and overexploitation

Introduction of invasive alien species"

Millennium Ecosystem Assessment (2005)

Examples of each of these direct drivers of wetlands loss will be shown on the following slides.



See notes slide 31 (page 49)

Photo credits:

Top left (salt evaporation ponds) - Gerick Bergsma 2009/Marine Photobank
Top right (ditch system in wetland) - Ben Fertig, IAN Image Library (ian.umces.edu/imagelibrary/)
Bottom left (navigation channel in wetland) - Tim Carruthers, IAN Image Library (ian.umces.edu/imagelibrary/)
Bottom right (urban development in coastal wetland) - (c) Wolcott Henry 2005/Marine Photobank

Notes slide 31 (page 49)

Infrastructure development has resulted in the loss and degradation of wetlands. Specific examples include dredging for navigation, channelization, construction of dams, dikes and sea walls for flood control, filling for solid waste disposal, road building and residential industrial development. Several examples are illustrated in these photos.

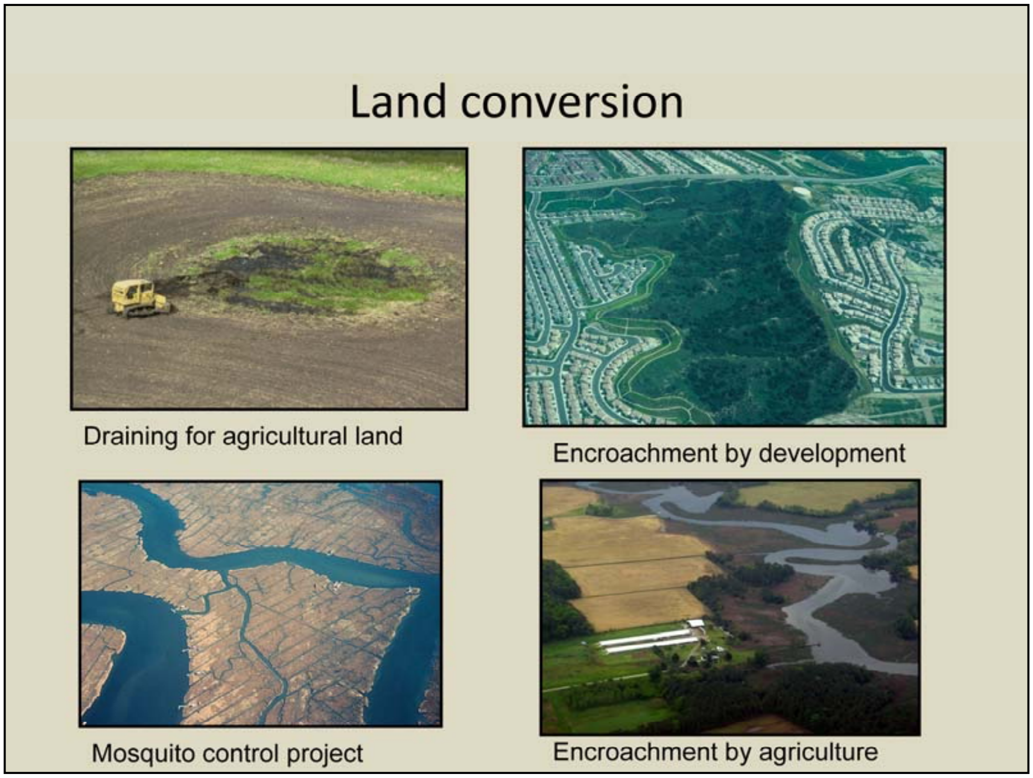
Photos:

1. Salt evaporation ponds used to extract salt from seawater replace tidal salt marshes along the southern end of San Francisco Bay, California. The different colors arise from blooms of microorganisms that are able to tolerate the highly saline water. The State of California and the federal government has recently purchased 15,000 acres of salt ponds that are now being restored back to wetland habitat.

2. Ditch system in wetland for increasing the rate of freshwater runoff on Chesapeake Bay National Estuarine Research Reserve, Somerset County, Maryland

3. Navigation channel resulting in eroding wetlands in coastal Louisiana, southeast of Houma.

Development has altered the coastal landscape and wetland ecosystems in southern California. Urban development creates impervious surfaces and road and bridges can alter hydrology and affect the salinity of coastal wetlands. Large-scale facilities such as airports and wastewater treatment plants are frequently built in wetlands. Shore stabilization projects, especially in coastal areas, cut off upland areas that serve as “wetland retreats” as sea levels rise. Since more than half of the U.S. population is found in coastal counties, threats to coastal wetlands are particularly severe.



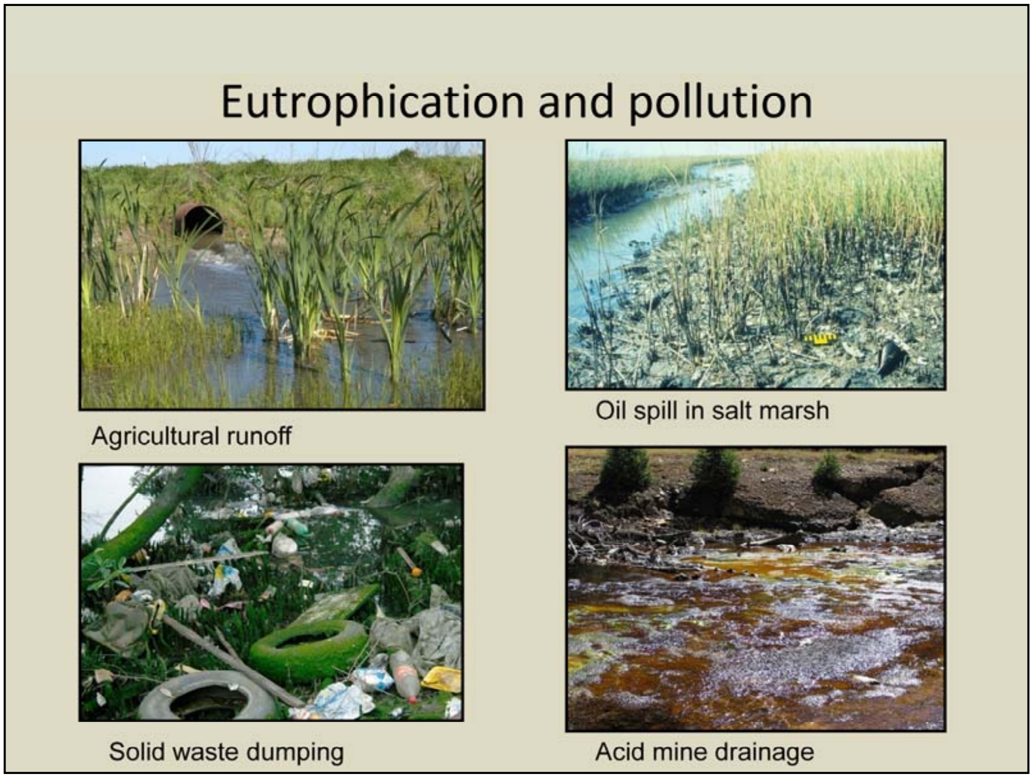
Photos:

1. Draining for agricultural land - Bulldozer being used to cut channels and drain a wetland for agriculture.
2. Encroachment by development - A forested wetland surrounded by and being encroached upon by residential development.
3. Mosquito control project - Ditching and draining of wetlands in an effort to control mosquitoes.
4. Encroachment by agriculture - Chicken farm and agricultural fields border wetlands on a creek off the Wicomico River, Maryland.

In the U.S. most wetlands loss since 1950 has been due to the conversion of wetlands into farmland.

Photo credits:

Top left (draining for agricultural land) - U.S. Fish and Wildlife Service
Top right (encroachment by development) - U.S. Fish and Wildlife Service, Claire Dobert
Bottom left (mosquito control project) - U.S. Fish and Wildlife Service
Bottom right (encroachment by agriculture) - Emily Nauman, IAN Image Library (ian.umces.edu/imagelibrary/)

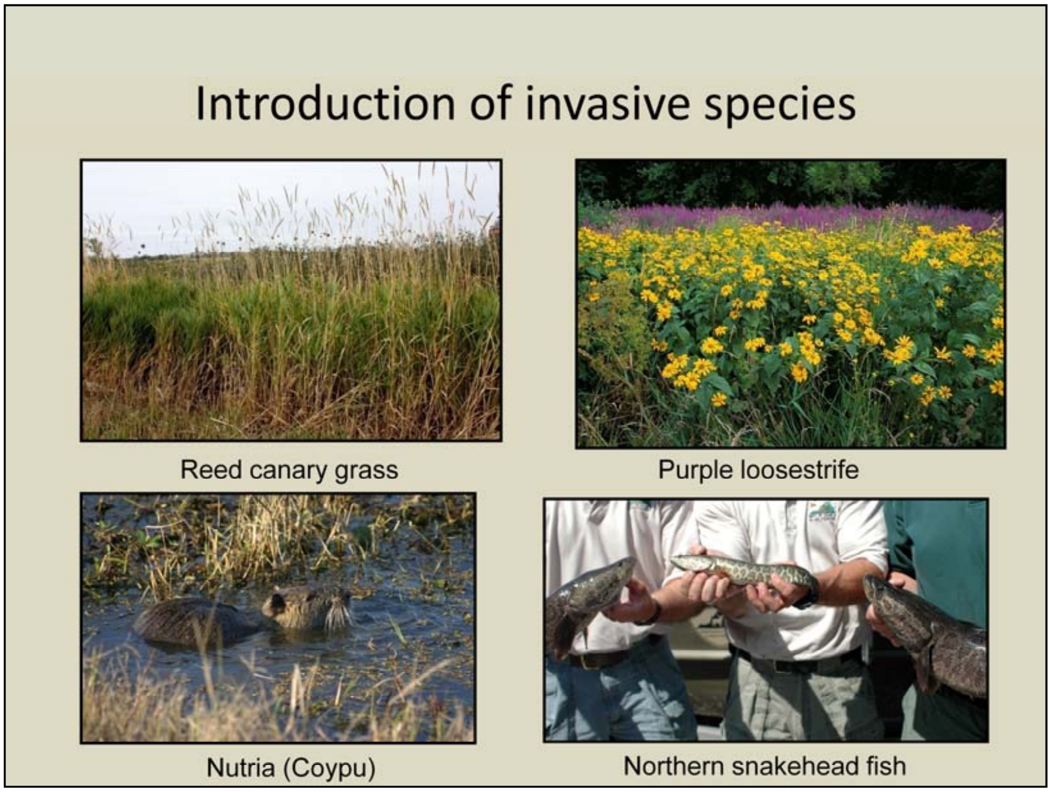


Photos:

1. Runoff in an agricultural area in Missouri
2. Oil spill impacts in a *Spartina alterniflora* salt marsh on East Timbalier Island, Louisiana.
3. Solid waste dumping in a wetland in Brazil.
4. Acid mine drainage - iron-rich wetland resulting from weathering of sulfide minerals from a hard rock mine near Silverton, Colorado.

Photo credits:

Top left (agricultural runoff) - Missouri USDA NRCS
Top right (oil spill in salt marsh) - NOAA Restoration Center
Bottom left (solid waste dumping) - Marcelo Bicudo/Marine Photobank
Bottom right (acid mine drainage) - Mark R. Stanton, USGS



See notes slide 34 (page 53)

Photo credits:

Top left (reed canary grass) - Becca Cudmore
Top right (purple loostrife) - U.S. Fish and Wildlife Service, Karen and John Hollingsworth
Bottom left (nutria) - USFWS, Steve Hillebrand
Bottom right (northern snakehead fish) - USFWS, Brett Billings

Notes slide 34 (page 53)

A number of plants have become invasive in wetland habitats, out-competing native species.

1. Reed canary grass, for example, forms nearly pure stands in a variety of wetland types in the Pacific Northwest. It tolerates a wide range of soil types and levels of saturation and has proven resistant to most control methods such as burning, grazing, mechanical removal and herbicides. Phragmites (reed grass) poses a similar problem in the mid-Atlantic states.

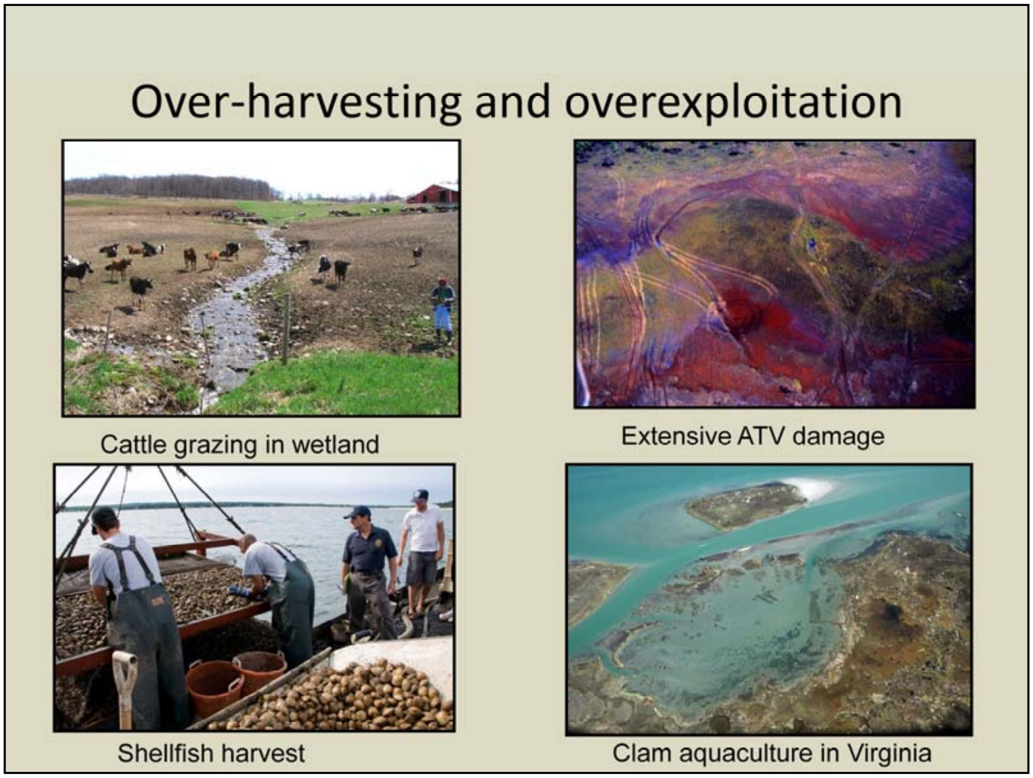
NOTE: Reed canary grass does have some native ecotypes, but the European ecotype is more aggressive and has hybridized, creating many ecotypes that grow under a wide range of conditions.

2. Purple loosestrife (purple flower in background) was introduced from Eurasia as an ornamental and, possibly, unintentionally in ship's ballast. It is now found in almost all 50 states (except those in the extreme southeast) and in all of southern Canada. Where established, it crowds out native plant species.

A few animals have also become invasives in wetland habitats:

3. Nutria, or coypu, (*Myocastor coypus*)) were first introduced into the U.S. in 1899 in California to develop a new fur-production industry. Intentional introductions, intentional releases after the collapse of the industry and unintentional escapes have resulted in feral populations in at least 15 states. A prolific herbivore that is able to occupy a wide range of wetland habitat types, nutria have become a threat to wetlands by creating "eat-outs" – areas that are devoid of vegetation due to nutria grazing. In Louisiana alone, an estimated 100,000 acres of coastal wetland are affected. The species is contributing to the conversion of coastal wetlands into open water. Nutria cut off wetland plants at their base and dig for roots and rhizomes in the winter. When population levels and grazing intensity are high there is little time for recovery of wetland plants. Nutria have also impeded restoration efforts by uprooting and eating baldcypress seedlings. Ironically, nutria were intentionally introduced into Louisiana to control the water hyacinth (*Eichhornia crassipes*), another invasive species.

4. The Northern snakehead fish is native to China and a relatively recent arrival to the United States. A voracious predator of native fish and frogs, it was first discovered in Maryland in 2002 and became permanently established in the Potomac River in about 2004. Since then it has been reported in a number of states from Florida to California and is likely to spread further. Snakehead fish can breathe air and can survive for up to four days on land if it is wet. They can make their way across wet land to other bodies of water, and thus are a threat to native species in a variety of wetland types.



Cattle grazing in wetland (New York) destroys native vegetation and increases sedimentation and contamination of waters by animal waste.

Extensive all-terrain vehicle (ATV) damage and trail system in Grand Bay National Estuarine Research Reserve, Mississippi. Wetland habitat is slash pine flatwoods and savanna.

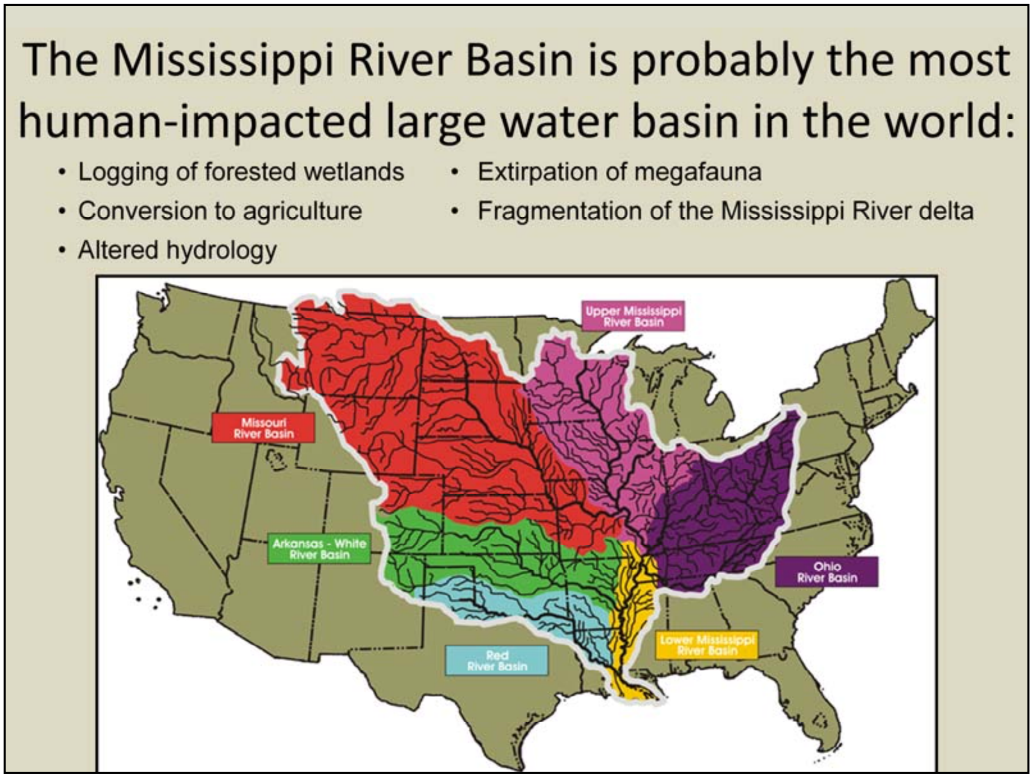
New York clam harvest and preparation for market.

A clam aquaculture operation in Virginia.

If not done properly, shellfish harvest and aquaculture operations can impact water quality and destroy natural wetlands.

Photo credits:

Top left (cattle grazing in wetland) - New York, USDA NRCS
Top right (extensive ATV damage) – P.R. Hoar, NOAA/NESDIS/NCDDC
Bottom left (shellfish harvest) - U.S. Food and Drug Administration
Bottom right (clam aquaculture) - Jane Thomas, IAN Image Library (ian.umces.edu/imagelibrary/)



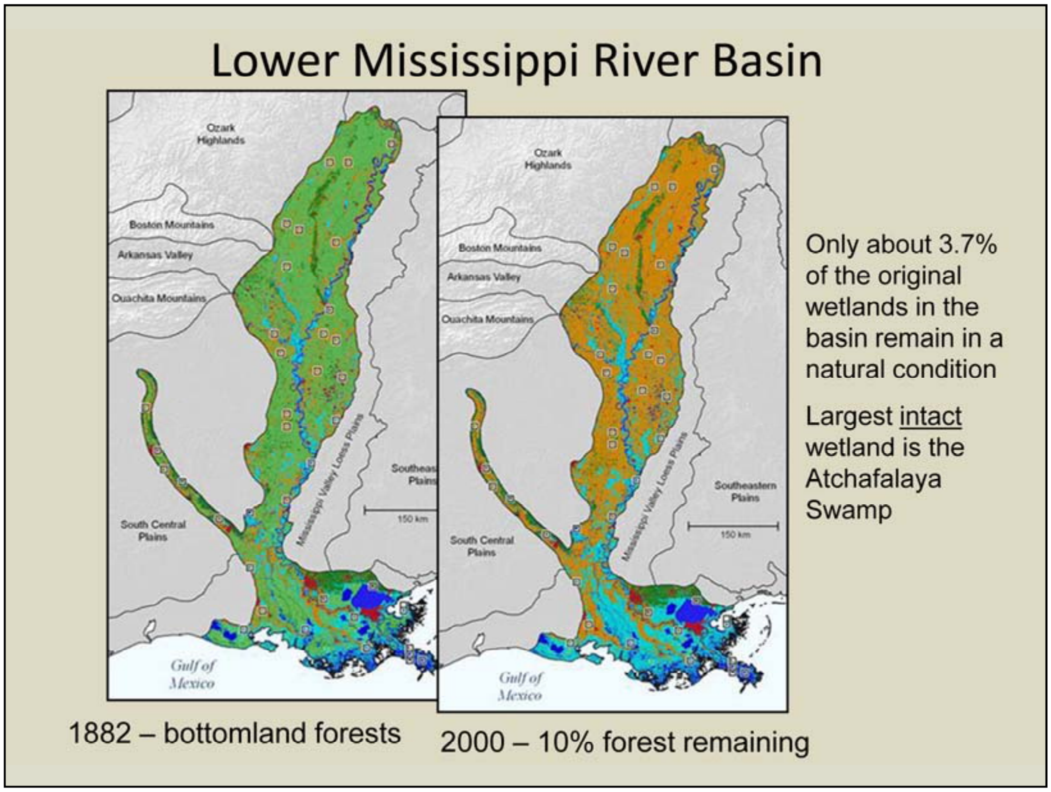
The Mississippi River Basin as a specific example:

Among the largest wetlands of the world (approximately 40% of the area of the lower 48 states), those associated with the vast Mississippi River Basin are probably also the most disturbed by humans. Primary causes for loss and degradation include:

- logging and clearing of forested wetlands
- land conversion to agriculture – resulting habitat loss and agricultural runoff, particularly nitrate-based fertilizers, which have been shown to contribute to the hypoxic “Dead Zone” in the Gulf of Mexico
- altered hydrology as a result of massive engineering projects and elaborate systems of levees, canals, reservoirs, etc. This significantly reduced sediment flow to wetlands in the lower basin
- extirpation of megafauna – e.g., bison, panthers, red wolves, black bear
- fragmentation of the Mississippi River delta by channels cut for cypress logging, navigation and, most recently, for the oil and gas industry. Allows saltwater intrusion.

Wetland deterioration in the lower Mississippi river basin makes the region more vulnerable to the effects of hurricanes.

Photo credit: U.S. Army Corps of Engineers, Mississippi River Commission



Of the original wetlands in the Lower Mississippi River Basin, only about 4000 km^2 (3.7%) remain in a somewhat natural condition. The largest relatively intact (though still impacted by all of the above to some degree) wetland in the Mississippi River Basin is the Atchafalaya Swamp, which lies to the west of the Mississippi River in southern Louisiana.

The first map shows the bottomland forests as they existed (green) in the Lower Mississippi River Basin in 1882. The second map shows the extent of remaining bottomland forests of the Lower Mississippi River Basin in 2000.

Image credit: Adapted from USGS

Specific threats to mangroves

Prop roots of red mangrove

Red mangrove seedling in a shallow lagoon in the Bahamas

Mangrove forests are found in tropical and subtropical marine environments where they create a barrier between land and sea, filtering sediment from coastal runoff and protecting the coastline from storms and tsunamis. In the U.S., mangrove wetlands are nearly pure stands of red mangrove. Their extensive prop roots (left) form an extensive maze that serves as vital nursery habitat for a wide variety of marine organisms.

In the U.S., mangrove forests reach their greatest development along the southern Florida coast. Mangroves and surrounding waters support over 220 fish species, 24 reptiles and amphibians and 181 bird species.

Globally, less than half of the original mangrove forest remains and much of what remains is in a degraded condition. A 2010 analysis of Landsat satellite imagery by the U.S. Geological Survey estimated the global coverage of mangrove forests at 138,000 km^2, only 6.9% of which is protected. Indonesia (22.6%), Australia (7.1%), Brazil (7.0%) and Mexico (5.4%) account for the largest percent of the total coverage.

Causes for decline and current threats include:

1. Conversion of mangrove forests to aquaculture, agriculture, tourism and urban land uses
2. Overexploitation of resources, especially harvest of mangrove trees for fuel
3. Sea level rise – some estimate that if current trends persist, mangrove forests will disappear in the next 100 years. (Giri, et al. 2010)

Photo at right shows a Red mangrove seedling in a shallow lagoon in the Bahamas. A backhoe can be seen in the background dredging a large sand spit across the lagoon.

Photo credit (both photos): Matthew D Potenski, MDP Photography/Marine Photobank

Shrimp aquaculture operation in Thailand replaces mangrove forest

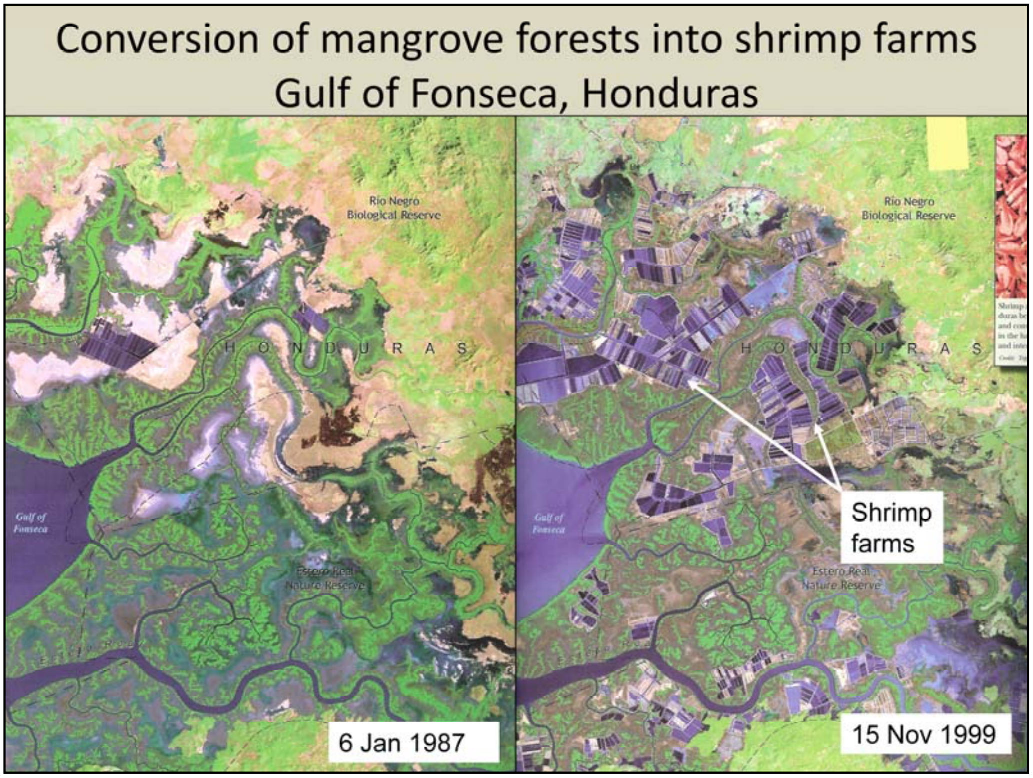
A large-scale shrimp aquaculture facility in Thailand (2001). This facility was developed on once-pristine mangrove forest impacting coastal ecosystems. Mangrove forests are cleared and then dredged to form ponds in which water levels are controlled by a sophisticated system of canals and pumps. Post-larval shrimp are raised in other hatcheries and then reared in these ponds. Shrimp are fed a high protein pelletized feed that is derived from bycatch (“trash fish”) that would otherwise be discarded from commercial fishing operations. Antibiotics are commonly used to treat or prevent diseases and marine waters are used as a water source for the facility. Most shrimp produced here are exported to the U.S. and Europe.

Photo credit: Ellen Hines/Marine PhotoBank

Prawn aquaculture facility in Australia
in an area of former mangroves

Concentrated aquaculture operations such as these in coastal zones have serious environmental impacts. In addition to the loss of wetlands, shrimp aquaculture creates tremendous amounts of organic waste that can reduce water quality and deplete oxygen levels in coastal waters. Shrimp aquaculture has also been linked to the decline of commercial fisheries in areas where this activity is concentrated.

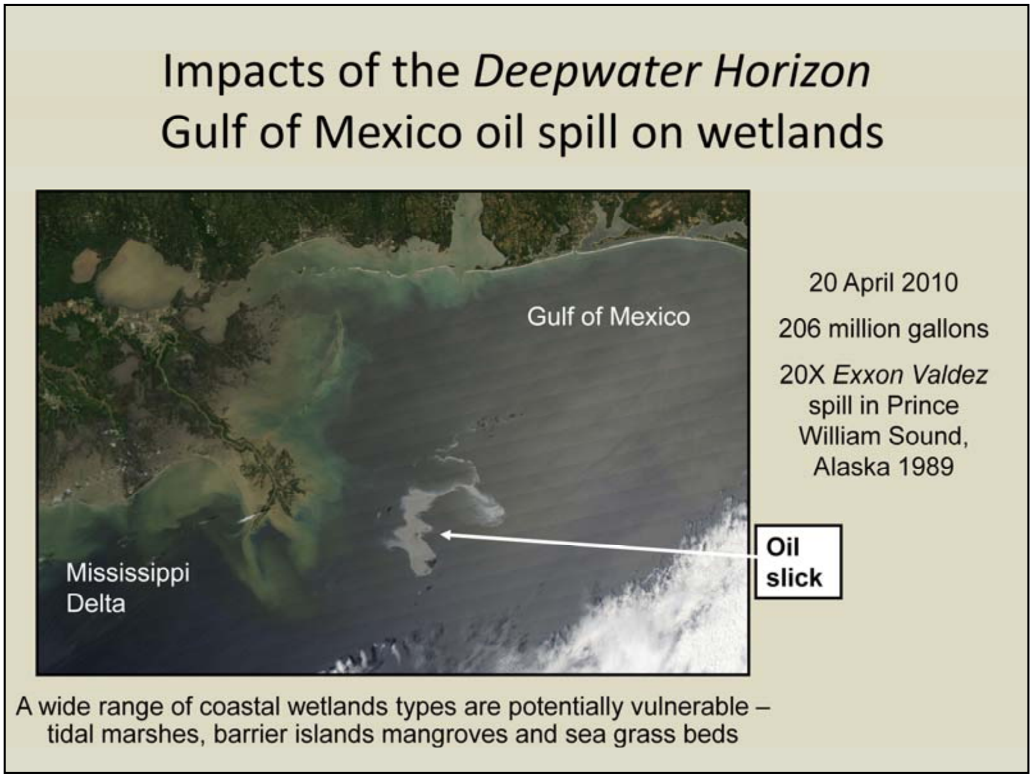
Photo credit: Adrian Jones, IAN Image Library (ian.umces.edu/imagelibrary/)



This image illustrates the rapid development (over only 12 years) of shrimp farming in the delta of the Gulf of Fonesca, Honduras. Large areas have been converted from natural mangrove forests and estuaries of the delta into shrimp farms (shrimp aquaculture). Shrimp aquaculture began in the 1970s and continued in the 1980s with the support of international financial organizations and the Honduran government. By the 1990s shrimp aquaculture was one of the country's top grossing industries. The rapid growth of the industry has resulted in both social and environmental impacts.

Photo source:

UNEP. 2005. One Planet Many People: Atlas of Our Changing Environment. Division of Early Warning and Assessment. United Nations Environment Programme, Nairobi, Kenya. 320 pp.

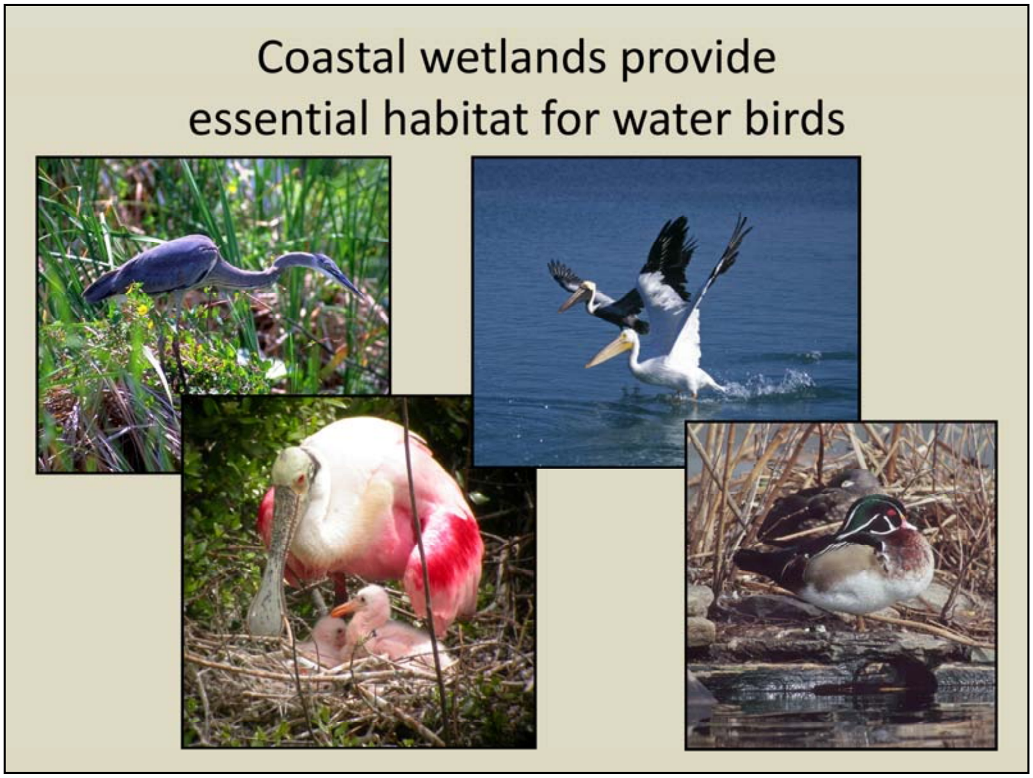


Impacts of Gulf oil spill on wetlands

Pollution, including oil spills, account for some wetland loss. On April 20, 2010 a deepwater oil drilling platform in the Gulf of Mexico operated by the international oil company *BP*, exploded. The *Deepwater Horizon* disaster immediately resulted in the death of 11 oil workers, the loss of the drilling platform and ultimately, an oil spill that was estimated to be approximately 206 million gallons, nearly 20 times the amount spilled by the *Exxon Valdez* in Prince William Sound, Alaska in 1989. The well was finally capped on July 15, 2010, but by that time the economic impacts to the region's commercial fishing and tourism industries were significant. The ecological impacts of the spill to coastal wetlands and the Gulf itself are largely unknown. However, as impact studies are completed, we can use what we have learned from other spill events to predict the nature and extent of impacts.

The photo is NASA satellite imagery showing an oil sheen from the *Deepwater Horizon* spill as it appeared on April 26, 2010. The Mississippi Delta can be seen in the left portion of the image as well as the oil slick in the center of the image, which is approximately 600 miles in circumference at this point.

Photo credit: NASA Earth Observatory/Marine Photobank

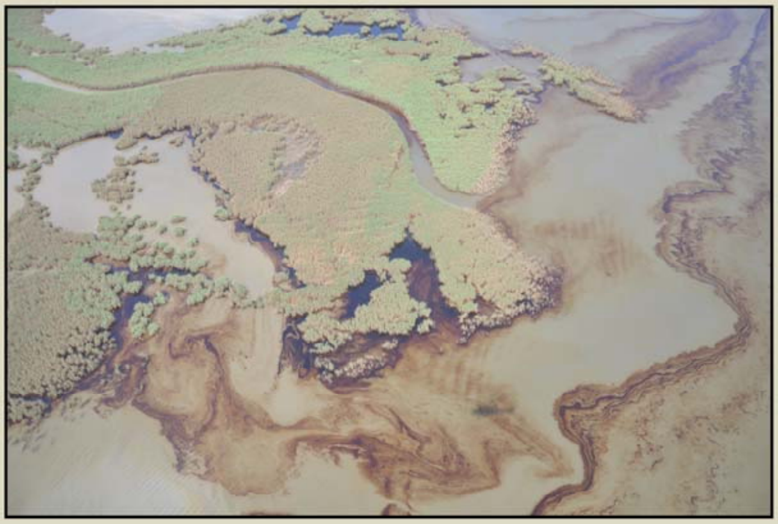


Wading birds, seabirds and waterfowl are abundant and diverse in the gulf region and particularly susceptible to the effects of oil. Barrier island beaches provide important nesting sites for seabirds, resting stops for migrating shorebirds and feeding areas for shorebirds. Tidal marshes and bays provide critical wintering habitat for waterfowl and feeding areas for wading birds.

Wading birds (herons, egrets, spoonbills)
Sea birds (petrels, shearwaters, terns, pelicans, gulls)
Waterfowl (ducks, geese, loons)

Photo credits:
Top left (heron) - courtesy http://philip.greenspun.com
Top right (pelicans) – USFWS
Bottom left (spoonbills) - Brennan Mulrooney, National Park Service
Bottom right (Wood duck) – Tim McCabe, USDA Natural Resources Conservation Service

Gulf Oil Spill – May 2010



Oil from *Deep Horizon* spill moves into coastal Louisiana wetlands

Coastal wetlands are known to be critical components of healthy and productive fisheries. This connection is well-established in the Gulf of Mexico where Louisiana alone accounts for 30% of domestic seafood production and for 40% of the total wetlands in the lower 48 states. The loss of wetlands in the Gulf has the potential for great economic and environmental harm. The oil spill, the dispersants used during the event and clean-up efforts themselves all have the potential to affect wetland ecosystems. Emergent plants and wetland animals, particularly those that are found in the substrate (e.g., clams and oysters) and zooplankton suspended in the water column are of particular concern. A wide range of coastal wetlands types are potentially vulnerable to the effects of the spill – from the tidal marshes of Louisiana to mangroves in Florida, Texas and Mexico to seagrass beds.

Photo credit: Connely Keiffer

Gulf Oil Spill – May 2010

Booms deployed to protect coastal Louisiana wetlands

Oil booms such as those seen in this photograph are the primary defense against oil washing ashore. Miles of boom were deployed by BP, the U.S. Coast Guard, state agencies and private contractors to protect Gulf Coast wetlands.

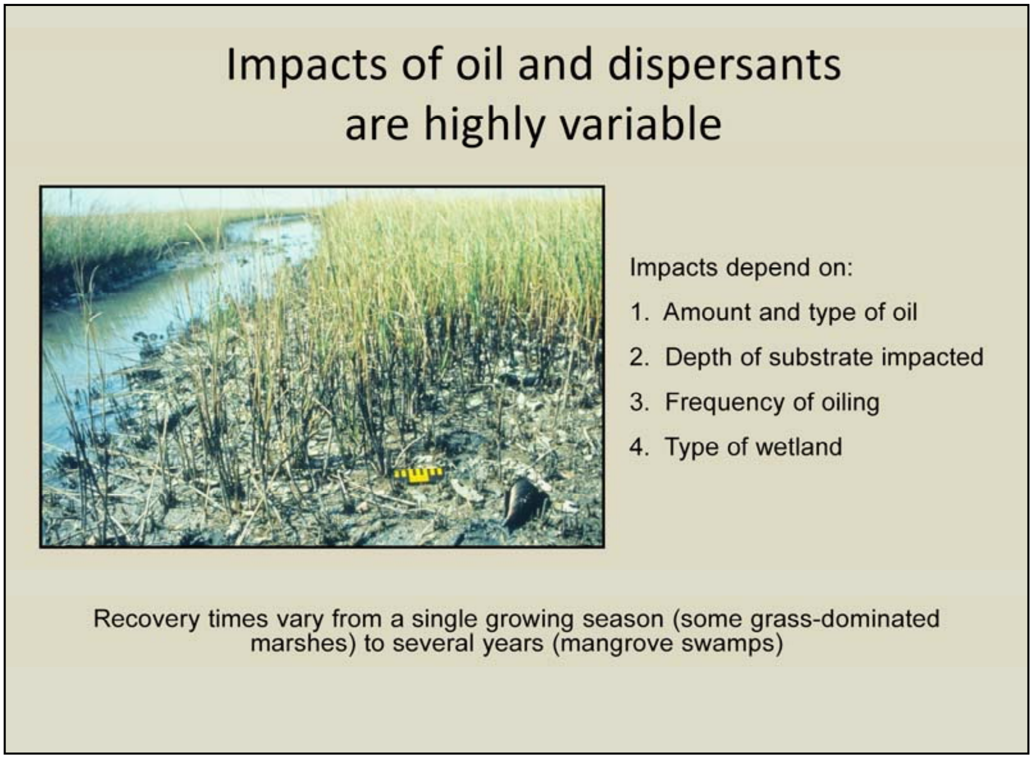
Photo credit: Connely Keiffer

Gulf Oil Spill – May 2010

Oil boom and cleanup operation on a barrier island beach

However, these booms are designed for flat water and are effective only when winds are calm. When winds picked up, booms were frequently blown ashore on barrier islands and tidal marshes where they became ineffective. Dispersants may have also reduced the effectiveness of the booms. In some areas the dispersed oil sank beneath the surface and washed ashore under the boom. Photo shows cleanup operation on a barrier island beach.

Photo credit: Connely Keiffer



The impacts of oil on wetlands have been studied around the world using both experimental and monitoring studies in areas where previous spills have occurred. The degree of impact on wetlands is highly variable and dependent upon a number of factors including the type of vegetation, the extent of weathering of the oil, the geographic location of the wetland, etc. Previous studies indicate that tropical and sub-tropical mangrove wetlands and tidal marshes, such as those found in the Gulf are particularly sensitive to oil. However, recovery times can vary from a single growing season (e.g., some grass-dominated marshes) to several years (e.g., mangrove swamps).

The following is based in part on an interview with Dr. Irving Mendelssohn, an ecology professor at Louisiana State University:

The impact of oil on wetlands is determined by the amount and type of oil, the depth of substrate impacted and the frequency of oiling. If the oil affects only the stems and leaves, wetland plants may die back, but will regenerate the next growing season by growing from rhizomes and roots. This is how most wetland plants regenerate after any disturbance.

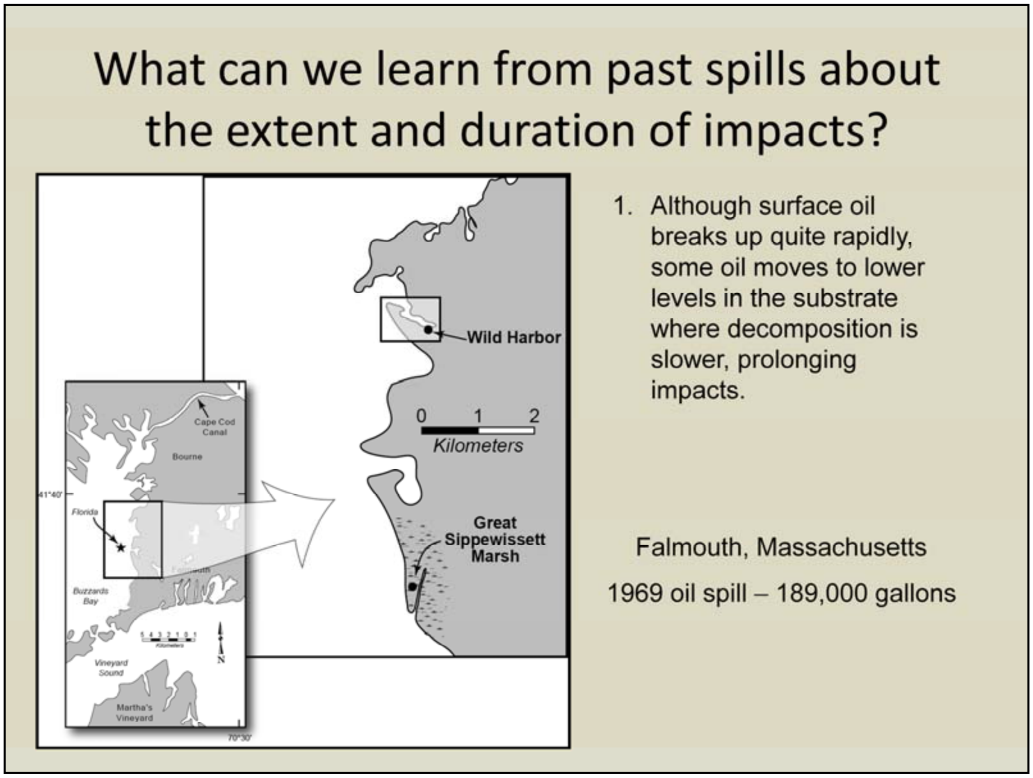
If, however, the oil penetrates the soil layer, shoots, leaves, roots and rhizomes are all affected, plants die and soil collapses resulting in accelerated subsidence. The soil may then erode creating open water and preventing plant re-establishment.

A single, low-level exposure is not likely to penetrate the soil and have the effect described above. But, repeated exposures can cause multiple diebacks of vegetative structures and plants use up available energy and may die as a result. Below-ground reserves become depleted and eventually the plants cannot recover.

What is the effect of using dispersants?

Previously used dispersants were extremely toxic to wetland animals. The new ones are less toxic. Tests have been conducted on coastal wetland plants with little effect on plants, but tests on animals are preliminary.

Photo credit: NOAA Restoration Center



What can we learn from past spills about the extent and duration of the impacts?

Until about 20 years ago, the conventional wisdom was that oils spills did most of their damage in the first several weeks after the spill – wildlife, fisheries and wetland impacts were well-documented. But, every oil spill is different and we have since learned that some impacts play out over several years and perhaps decades. Monitoring after such infamous spills as the *Exxon Valdez* in 1989, the *Ixtoc 1* in Mexico in 1979 and two major spills off Cape Cod, Massachusetts in the 1969 and 1974 have helped scientists appreciate the complexity of the impacts of a spill. Their findings include the following:

1. Although surface oil on shore and on the water breaks up quite rapidly (this may be particularly true in the Gulf where temperature and nutrient conditions promote the growth and activity of bacteria that can use oil as a nutrient source), some of the oil moves to lower levels in the substrate where oxygen levels are low and thus decomposition of oil is slower. As a result, impacts may be prolonged.

Studies of saltmarshes along the elbow of Cape Cod, Massachusetts impacted by an oil spill several decades ago provide some evidence. In 1969, the barge *Florida* ran aground off the coast of Cape Cod, spilling 189,000 gallons of fuel. Prevailing winds pushed the oil into Wild Harbor in Falmouth, but left the Great Sippewissett Marsh, just a few miles to the south, unscathed.

Image credit: Jack Cook, Woods Hole Oceanographic Institution

Sediment analysis in spill-affected saltmarsh

Analysis of Wild Harbor sediment in 2001 indicated that:

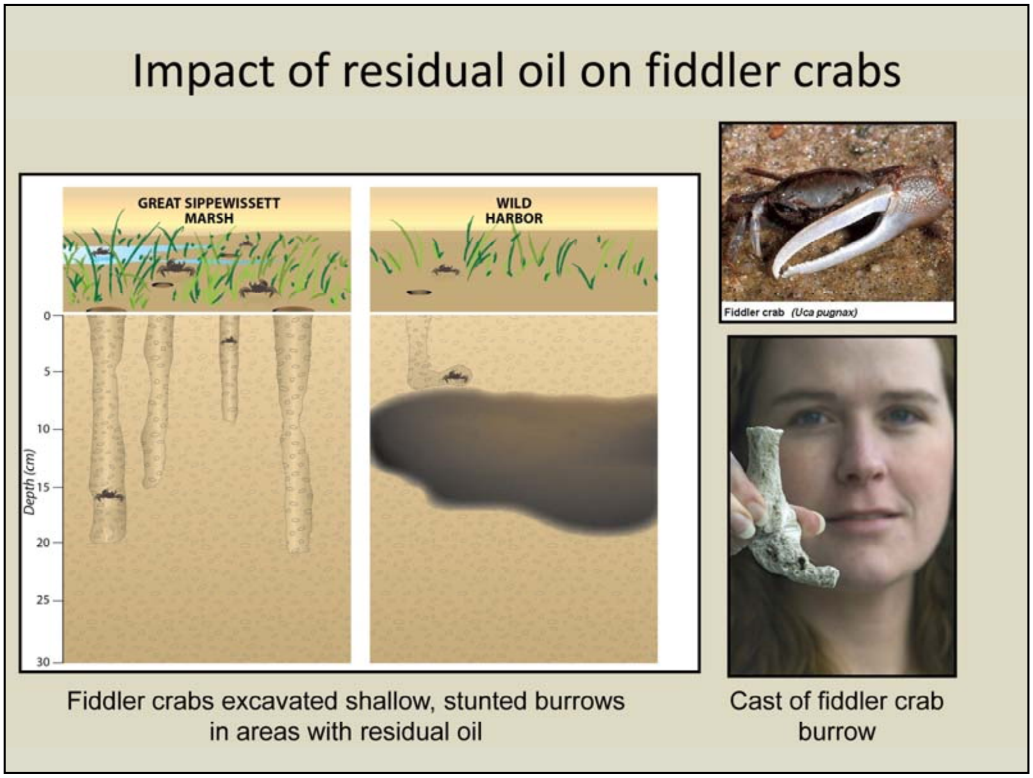
1. Toxic components of original spill remained
2. Bacteria were no longer decomposing oil

Core sampling in Wild Harbor sediment

Analysis of Wild Harbor marsh sediments in 2000-01 using gas chromatography indicated that while oil in the water and on beaches had disappeared soon after the spill, oil remained in marsh sediments. In fact, its chemical composition had not changed much since the mid-1970s when initial studies were conducted. Toxic compounds found in oil (polycyclic aromatic hydrocarbons – PAHs) were detected in the sediment and suspected of having negative impacts on the saltmarsh ecosystem. Further analysis suggested that although bacterial decomposition of oil occurred soon after the spill, that activity had apparently stopped by 2001.

Helen White, a graduate student in the MIT/WHOI Joint Program, takes a core of sediment in Wild Harbor to analyze how bacteria decomposed oil from the 1969 spill.

Photo credit: Tom Kleindinst, Woods Hole Oceanographic Institution



Comparative studies of fiddler crab behavior in Wild Harbor (affected by oil spill) and nearby Great Sippewissett Marsh (unaffected by spill) confirmed that oil in the sediment was having an effect on saltmarsh organisms. Fiddler crabs showed some behavioral abnormalities and burrow horizontally rather than vertically to avoid a layer of oil that persists in the substrate only a few inches from the surface. Concerns about this species are elevated because their burrowing activities normally aerate wetland soils increasing the level of oxygen available to the roots of wetland plants and other organisms. Scientists made plaster of Paris casts of fiddler crab burrows in each study area. Crabs from the Sippewissett area excavated burrows that were straight, with average depths of 14.8 centimeters. Burrows in Wild Harbor averaged only 6.8 centimeters in depth and were stunted. The crabs appear to turn back when they encounter residual oil.

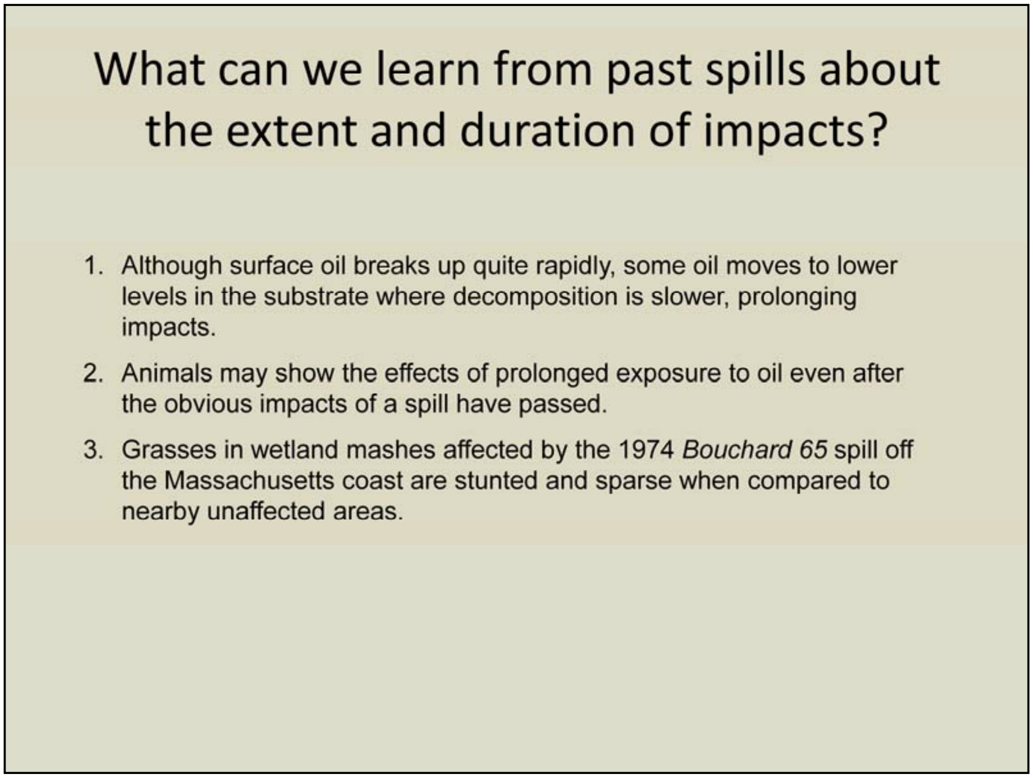
Boston University graduate student Jennifer Culbertson used plaster of Paris casts of fiddler crab burrows to demonstrate fiddler crab burrowing behavior. Crabs turned back when they came in contact with buried residual oil.

Image credits:
Left - E. Paul Oberlander, Woods Hole Oceanographic Institution
Top right (fiddler crab) - NOAA
Bottom Right (cast of fiddler crab)- Tom Kleindinst, Woods Hole Oceanographic Institution

Plaster of Paris casts of fiddler crab burrows from
healthy marshes (left) and marshes with residual oil (right)

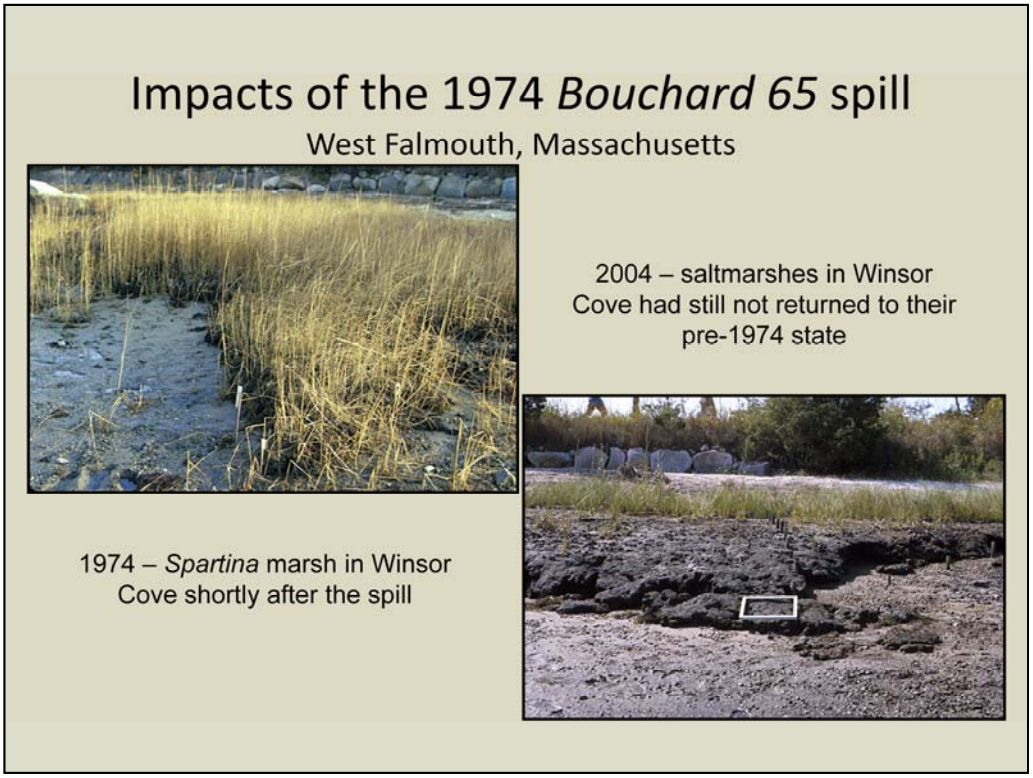
Plaster of Paris casts of fiddler crab burrows illustrate the impact of residual oil in saltmarsh sediments. Burrows from healthy marshes (Great Sippewissett Marsh) are deep and straight (left). Burrows from marshes with buried, residual oil from the 1969 oil spill (Wild Harbor) excavate shallow and erratic burrows.

Photo credit: Tom Kleindinst, Woods Hole Oceanographic Institution



2. Animals in spill areas may show the effects of prolonged exposure to oil even after the obvious impacts of a spill have passed. Liver tests in sea otters and ducks, for example, in Alaska showed evidence of exposure to hydrocarbons in the late 1990s and populations of several species of animals (including sea otters) have not fully recovered since the 1989 spill. Herring populations have still not recovered.

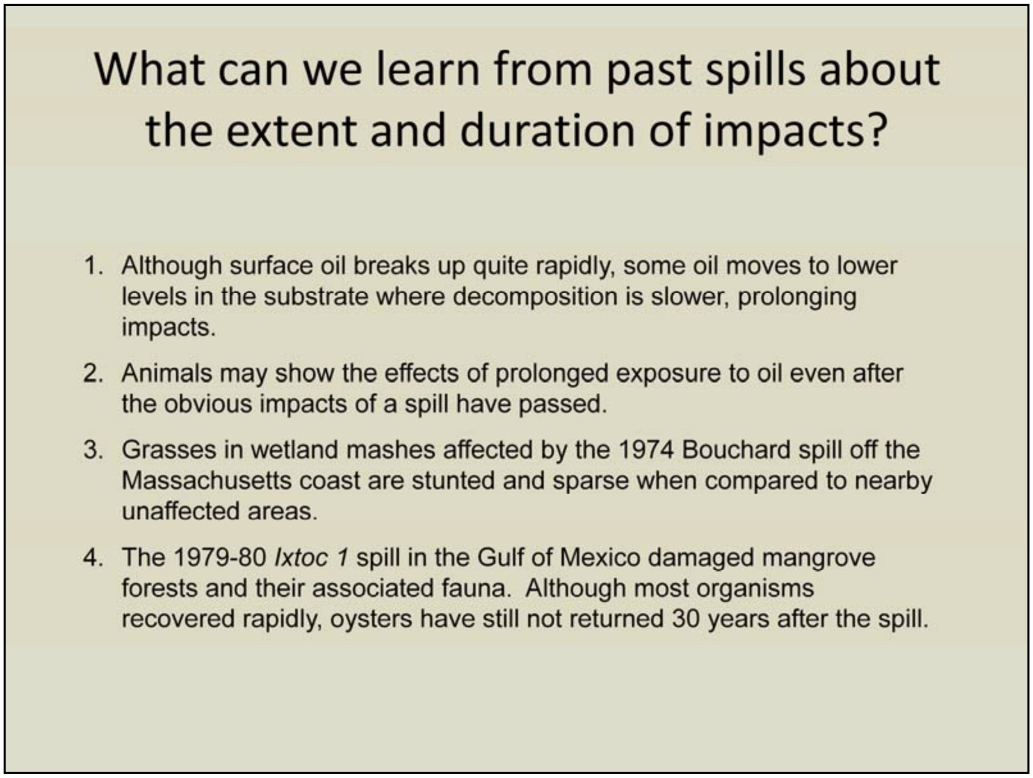
3. Grasses in wetland mashes affected by the 1974 Bouchard spill off the Massachusetts coast are stunted and sparse when compared to nearby unaffected areas. Razor clam populations and *Spartina* marshes were affected immediately, but severe erosion played out over a period of several months and years after the spill. Grasses in some areas are only now beginning to re-establish.



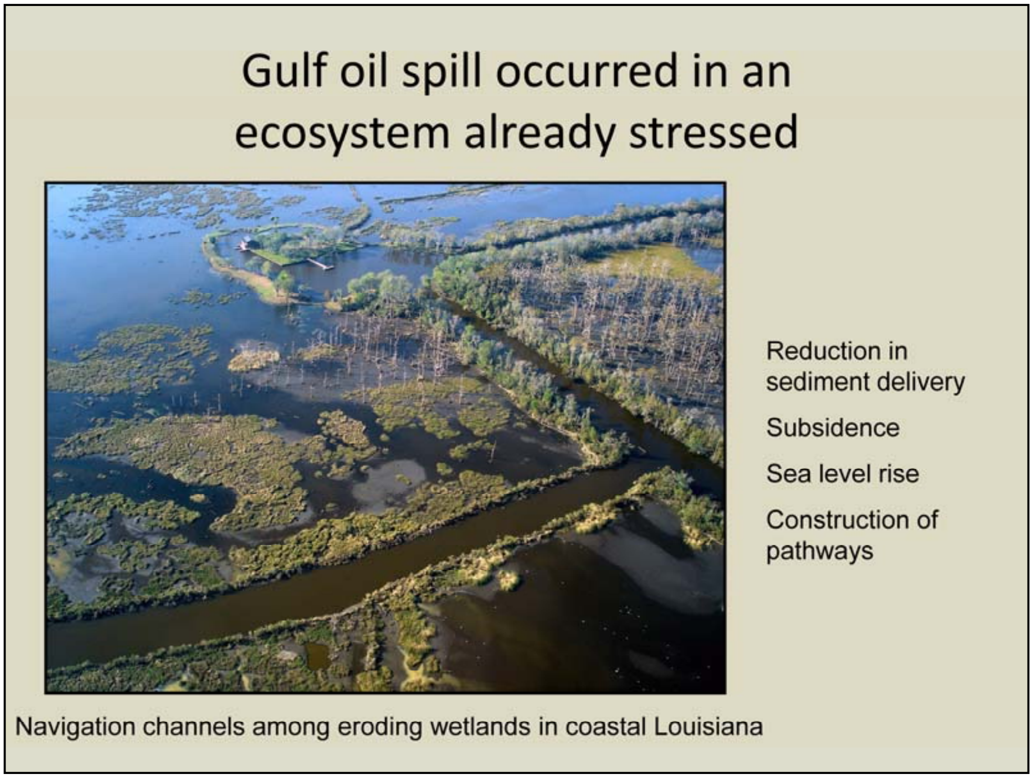
Saltmarshes of Winsor Cove in West Falmouth, Massachusetts were severely impacted by the *Bouchard 65* spill in 1974. Saltmarsh grasses (*Spartina*) were not visibly coated with oil immediately after the spill. However, sufficient amounts of toxic chemical compounds from the oil settled into the underlying peat and sediments to prevent vegetation from returning for decades afterward.

Thirty years later, saltmarsh grasses had not returned to their pre-1974 state. Recent studies at the site reveal that petroleum hydrocarbons continue to persist in the marsh.

Image credits: George Hampson, Woods Hole Oceanographic Institution



4. In 1979-80 the *Ixtoc 1* well in the Gulf of Mexico spilled millions of gallons of oil and its impacts may be the best approximation of what might be expected from the *BP* spill. Wetlands in this area along the Texas coast are dominated by mangroves, which support a rich diversity of marine life. The mangroves, as well as their associated fauna are perhaps the best indicators of a lingering effect . In some areas mangroves are less dense than before the spill. Oysters, once found in abundance attached to the fibrous roots of mangroves, have not returned after the spill even though 30 years have passed. On the other hand, most organisms that had been wiped out by the spill repopulated areas that had been affected within a few years after the spill.



Navigation channels among eroding wetlands in coastal Louisiana

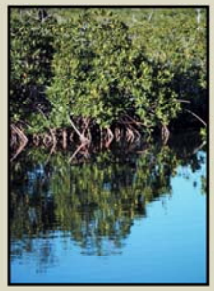
Which, if any of these impacts are applicable to the vast wetlands of the Louisiana coast remain to be seen. These are some of the most productive marshes in the world providing critical habitat for shrimp, oysters, wetland birds and fish. It is important to recognize that these wetlands were already under stress from other human impacts. The reduction of sediment delivered to the wetlands due to dams and diversions in the Mississippi River Basin and subsidence, sea level rise due to global climate change, the construction of pathways through existing marshes all have contributed to the degradation of these wetlands. Louisiana's rate of wetlands loss has been estimated at between 16,000 and 25,000 acres per year. The oil spill must be seen as another stressor that adds to the cumulative impact of all of these. Restoration will require that all of these stressors be addressed in a broad ecosystem-based approach. Possible funding sources for Gulf Coast restoration efforts include:

1. Fines paid to U.S. Government by BP
2. A portion of a new per-barrel oil tax
3. Revenues from offshore oil and gas leasing

Photo credit: Tim Carruthers, IAN Image Library (ian.umces.edu/imagelibrary/)

What rehabilitation activities are likely to be most effective?

- Best option may be no action
- Any physical or chemical presence during cleanup activities may worsen the situation
- *In-situ* burning may be appropriate for some grass-dominated wetlands
- Nutrient addition (biostimulation) is probably not appropriate for the Gulf spill



See notes slide 56 (page 76)

Photo credit:
Left: Katie Fuller 2009/Marine Photobank
Right: Ralph F. Kresge, NOAA

Notes slide 56 (page 76)

What rehabilitation activities can be used to accelerate the recovery of oiled marshes?

Any physical or chemical presence during cleanup activities have the potential to worsen the situation. The best option may be no action – marshes will recover on their own and cleanup efforts may do more harm than good.

Clean up efforts after a major spill off the northwest France coast illustrates the problem. When the *Amoco Cadiz* tanker spilled 67 million gallons of crude oil off the coast of France in 1978, marshes were hard hit as oil sank deep into wetland soils. Authorities decided to use bulldozers to remove nearly 20 inches of oiled soil from the affected wetlands. However, marsh plants, were soon found to be highly sensitive to sediment depth. Over 30 years after the event bulldozed areas are still missing 40% of their vegetation, while areas that were not bulldozed have returned to pre-spill conditions.

In the case of the *Exxon Valdez* spill high pressure hot water sprayers were used to clean oiled beaches. Later monitoring illustrated that this cleanup effort delayed recovery, killing many intertidal organisms especially those that live in the sediment such as clams.

Cleanup must be tailored for the individual situation – all oil spills are different. *In situ* burning may be appropriate in some grass-dominated wetlands, while nutrient addition may be appropriate in some well-drained high elevation wetlands.

Does "in situ burning" (on-site burning) have an impact on wetlands?

Even a thin layer of water will protect below-ground structures. Burning in the absence of water increases the risk of damage to below-ground plant structures.

Should nutrient addition (biostimulation) be used to stimulate the growth of bacteria and fungi that accelerate the breakdown of oil?

In the Gulf, nutrient levels are already high. Therefore, biostimulation is probably not a good idea. In the Gulf, oxygen levels are limiting except in higher elevation wetlands.

Summary

- Wetlands are most commonly classified as marine, estuarine, lacustrine, riverine or palustrine
- Wetlands have historically been seen as “wastelands”
- More than half of pre-European settlement wetlands in the lower 48 have been drained or converted to other uses
- The degradation and loss of wetlands is more rapid than that of other ecosystems
- U.S. wetland loss has been greatest in the Ohio Valley, the upper Mississippi River Basin, and in California and Florida
- The primary drivers of wetland loss are infrastructure development, land conversion, pollution, overexploitation and invasive species
- Mangrove wetlands have been particularly impacted by the development of aquaculture in coastal areas
- The 2010 Gulf of Mexico oil spill has the potential for short-term and long-term impacts on a variety of wetland types

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- Marine Photobank: Ellen Hines, Emily Nauman, Gerick Bergsma 2009 , (c) Wolcott Henry 2005, James Shelton, Jason Valdez, Katie Fuller 2009, Marcelo Bicudo, Matthew D Potenski, MDP Photography
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- National Park Service: Brennan Mulrooney,
- Natural Resource Conservation Service. Peat soils in Richland County, Wisconsin. Ho Chunk Nation of the Winnebago Tribe of Wisconsin
- NOAA: Department of Commerce, Ralph F. Kresge, Restoration Center
- NOAA/NESDIS/NCDDC, P.R. Hoar
- http://philip.greenspun.com
- UNEP. 2005. One Planet Many People: Atlas of Our Changing Environment.

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- U.S. Environmental Protection Agency: Tom Blagden Jr., David Riecks, Illinois-Indiana Sea Grant
- U.S. Food and Drug Administration
- U.S. Fish and Wildlife Service : Brett Billings, Claire Dobert , George Gentry, Pete Pattavina,, Georgia Ecological Services Field Office, Karen and John Hollingsworth, Steve Hillebrand
- USDA Natural Resources Conservation Service: Missouri, New York, Tim McCabe
- Woods Hole Oceanographic Institution: George Hampson, Jack Cook, Paul Oberlander, Tom Kleindinst,

Catherine Carmichael (undergraduate from Trinity College) and Emily Peacock (guest graduate student from Boston University) measuring the density of salt marsh grasses at Winsor Cove. (Summer 2006) (Tom Kleindinst)
Photo credit: Tom Kleindinst, Woods Hole Oceanographic Institution

(EXTRA PHOTO)

Wetlands –Then and Now - Resources

Wetland Status and Trends

NOTE: There are many documents that examine wetlands status and trends on a regional or state basis. Only national publications have been included here. Instructors may wish to consult documents that are more specific to their region. Wetland status and trends reports for most states and regions can be found at:
http://www.fws.gov/wetlands/StatusAndTrends/index.html

Council on Environmental Quality. 2005. Conserving America's wetlands: Implementing the President's goal. Exec. Office of the President, Washington, D.C. 37 pp.

Dahl, T.E. 1990. Report to Congress wetlands losses in the United States 1780s to 1980s. U.S. Department of the Interior, Washington, D.C. 21 pp.
http://www.npwrc.usgs.gov/resource/wetlands/wetloss/

Dahl, T.E. and C.E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, Mid-1970s to mid-1980s. U.S. Fish and Wildlife Service, Washington, D.C. 28 pp.
http://www.fws.gov/wetlands/_documents/gSandT/NationalReports/WetlandsStatusTrendsConterminousUS1970sto1980s.pdf

Dahl, T.E. 2000. Status and trends of wetlands in the conterminous United States 1986-1997. U.S. Fish and Wildlife Service, Washington, D.C.
http://library.fws.gov/Pubs9/wetlands86-97_lowres.pdf

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/_documents/gSandT/NationalReports/StatusTrendsWetlandsConterminousUS1998to2004.pdf

Giri, C., et al. 2010. Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecology and Biogeography 2010:1-6.
http://onlinelibrary.wiley.com/doi/10.1111/j.1466-8238.2010.00584.x/abstract

Tiner, R.W. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish and Wildlife Service, National Wetlands Inventory. 59 pp.
http://www.archive.org/details/wetlandsofunited00nati

Tiner, R.W., et al. 2002. Geographically isolated wetlands: A preliminary assessment of their characteristics and status in selected areas of the United States. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA.
http://www.fws.gov/wetlands/_documents/gOther/GeographicallyIsolatedWetlandsFS.pdf

Tiner, R.W. 2003. Geographically isolated wetlands of the United States. Wetlands 23(3):494-516.

Tiner, R.W. 2003. Estimated extent of geographically isolated wetlands in selected areas of the United States. Wetlands 23(3):636-652.

U.S. Geological Survey. 1998. Status and trends of the Nation's biological resources. 2 Vols. U.S. Geological Survey, Washington, D.C. 964 pp.
www.nwrc.usgs.gov/sandt/

Hydrogeomorphic (HGM) Approach for Assessing Wetlands Functions

Brinson, M.M. 1993. A hydrogeomorphic classification for wetlands. WRP-DE-4. Vicksburg, MS: U.S. Army Corps of Engineer Waterways Experiment Station.

This is the original description of the HGM approach for wetlands.

U.S. Army Corps of Engineers
http://el.erdc.usace.army.mil/wetlands/overview.html

This 2-page document provides an overview of the HGM approach. Originally developed as a new scheme for the classification of wetlands, the hydrogeomorphic approach is based on classifying wetlands based on hydrologic regime and geomorphic position. More recently, the HGM approach has been used as a way to evaluate wetland functions. It is designed to assess wetlands based on their structural components (hydrology, soils and plants and animals), and the processes (physical, biological and chemical) that link these components.

A number of national and regional HGM Guidebooks have been published by the U.S. Army Corps of Engineers to give some guidance to practitioners on the application of this approach. Citations to three representative HGM guidebooks are given below; others are available on the Army Corps of Engineers web site.

Brinson, M. M., et al. 1995. A guidebook for application of hydrogeomorphic assessments to riverine wetlands. Technical Report WRP-DE-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A308 365.
www.el.erdc.usace.army.mil/wetlands/pdfs/wrpde11.pdf

Shafer, D. J., and D.J. Yozzo. 1998. National guidebook for application of hydrogeomorphic assessment of tidal fringe wetlands. Technical Report WRP-DE-16, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
www.el.erdc.usace.army.mil/wetlands/pdfs/wrpde16.pdf

Shafer, D. J., et al. 2002. Regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of northwest Gulf of Mexico tidal fringe wetlands. ERDC/EL TR-02-5, U.S. Army Engineer Research and Development Center, Vicksburg, MS.
www.el.erdc.usace.army.mil/wetlands/pdfs/trel02-5.pdf

Wetlands and the Gulf Oil Spill

The Ohio State University Buckeye Swamp Blog.
http://swamp.osu.edu/Gulf_oil_spill_2010/

This site maintained by the Olentangy River Wetland Research Park has a number of links to sites that describe the wetlands-oil spill connection.

Whigham, D.F. 2010. The *Deepwater Horizon* and wetlands – Statement from the Environmental Concerns Committee - Society of Wetland Scientists.
www.sws.org

Wetland types

Blaustein, R. 2008. Biodiversity hotspot: The Florida panhandle. BioScience 58:784-790.

Colburn, E.A. 2004. Vernal pools: Natural history and conservation. McDonald and Woodward Publishing Co., Blacksburg, VA. 426 pp.

A synthesis of our understanding of the habitat characteristics of vernal pools in glaciated southeastern Canada and northeastern U.S., their biodiversity and factors that govern the interactions between pool organisms and their environment.

DeWeerdt, S. 2004. Reflections on the pond. Conservation in Practice 5:20-27.

Koellner, T. and O.J. Schmitz. 2006. A global crisis for seagrass ecosystems. BioScience 56: 987-996.

Hornberg, G., et al. 1998. Boreal forest swamps. BioScience 48:795-802.

Lodge, T.E. 2010. The Everglades handbook. CRC Press. Boca Raton, Florida. 380 pp.
www.crcpress.com

This text is a comprehensive examination of one of the most significant wetlands in the U.S. The ecosystems of the Everglades region are fully described along with their characteristic plant and animal species. Historical changes to the Everglades and restoration strategies to re-establish ecological functions are also addressed.

Martin, J.F. 2002. Landscape modeling of the Mississippi Delta. BioScience 52:357-365.

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

This text describes the structure and function of wetland ecosystems found in North America.

Turner, R.E. and N.N. Rabalais. 2003. Linking landscape and water quality in the Mississippi River Basin for 200 years. BioScience 53:563-572.

Valiela, I. et al. 2001. Mangrove forests: One of the world's most threatened major tropical environments. BioScience 51: 807-815.

Wetlands – Then and Now – Video Resources

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 on wetland types and causes for wetland loss and degradation. They are intended for a general audience, but are of high quality and appropriate to enhance lectures.*

Episode #407. Pond Turtles. 2007. 15 min.

Declines of western pond turtle populations in Oregon are due to habitat loss, bullfrog predation (an invasive species) and illegal collecting. A captive breeding program at the Oregon Zoo in Portland attempts to grow turtles to sufficient size ("head starting") and then releases them into suitable habitat. This species has declined by over 90% as compared to historic levels. Hatchlings and eggs are collected from nests in the wild and then brought to the zoo for rearing. Survivability in captivity is about 95%. Nesting habitat requirements include short grass, sun exposure, some slope and no rocks. The goal of the program is to get self sustaining populations that do not require "head starting."

Episode #414 – Klamath Basin. 1993. 15 min.

Klamath Lake and surrounding wetlands have an ongoing complex of problems related to water: low water levels in lake, decreased crop production due to lack of irrigation water, endangered sucker fish, declining migratory wetland birds. Beginning in 1904, the Bureau of Reclamation drained marshlands for agricultural lands and homesteaders. Water was diverted for irrigation from Klamath Lake. Now there is not enough irrigation water to go around. Farmers blame the Endangered Species Act – "We can't overcome the tentacles of the Endangered Species Act." Water quality is also an issue. The lake suffers from eutrophication and excess blue-green algae due to farming, ranching and irrigation withdrawals which speed up the eutrophication process. Wetland removal has caused a loss of the water storage/filtration function of wetlands. The conversion of ranchland back to marshland raises concerns among ranchers. "Was reclamation a mistake?" – Different people have different views.

Episode #606 – Klamath River Special. 1995. 30 min.

This 30 minute special program examines contentious issues over water and wetlands in the Klamath Basin in southern Oregon. The video is not yet available on line.

Episode #808 Bullfrogs. 1997. 15 min.

At William F. Finley National Wildlife Refuge in western Oregon, invasive species heavily impact native pond turtle, red-legged frog, spotted frog and Oregon chub populations (Bruce Coblentz of Oregon State University). Bullfrogs were introduced into the state in 1930 for the frog leg market. Each female bullfrog can produce tens of thousands of eggs. A food habits study being conducted Ridgefield National Wildlife Refuge in Washington indicates that bullfrogs have a varied diet including insects, frogs, salamanders and fish. Bullfrog control methods include reducing water temperatures (since cool water temperatures favor native species over bullfrogs) and drawing down water levels to dry ponds, which should kill bullfrog tadpoles (which, unlike native frogs over winter as tadpoles). Long term monitoring is required to see if bullfrog removal (especially breeding females) has an impact.

Vernal Pools – Episode #1004. 1999. 15 min.

Vernal pools are unique wetlands that appear in spring and dry up during the summer. In southern Oregon near Medford, vernal pools occur among pastures slated for development. The pools harbor two rare plant species and the federally-protected, fairy shrimp. An impervious rock or soil layer beneath the surface prevents water from seeping into the soil and thus, water sits on the surface during spring. This creates a "mounded prairie" landscape that is valued for cattle pasture, hay production and development after leveling. Past development has resulted in only 20% of the mounded prairie landscape remaining. Some exotics occupy vernal pools, but the majority are native species specially adapted to this unique habitat – ostracods, copepods, flatworms, Daphnia, fairy shrimp and dyticid beetles. Ponds are too short-lived for vertebrate predators such as fish. Unusual or endangered plant species include mousetail, coyote thistle, Lomatium and meadowfoam. Loss of vernal pools to development is permanent. Some landowners have sued to de-list species and allow further development.

Mendelssohn, I. 2010. Impacts of Gulf oil spill on wetlands
www.youtube.com/watch?v=syGM13egoc0
www.youtube.com (search for "Impacts of Gulf oil spill on wetlands – Mendelssohn Louisiana State University")

This 10-minute interview with Dr. Irving Mendelssohn, an ecology professor at Louisiana State University, describes the potential impact of the Gulf oil spill on wetlands.

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.