Wetland Restoration in the Everglades

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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 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 <u>not</u> 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.

Wetland Restoration in the Everglades Module Description

This instructional guide is designed to provide instructors with lecture materials and resources that describe the concepts and practice of wetland restoration using the restoration of the Everglades in South Florida as a case study. Student objectives, a general lecture outline and a more detailed *PowerPoint* presentation with instructor notes are provided. The general features of wetland restoration and some common elements are first discussed followed by an in-depth account of how these concepts are being implemented in the Everglades Ecosystem. Historical conditions in the Everglades are described as well as the primary drivers of environmental degradation in this region. The importance of broad-scale ecosystem-based approaches to restoration is emphasized.

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. This module includes a detailed transcript of a two-volume set of videos that provides excellent support for the topics covered in this module.

Objectives

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

1. Define wetland restoration
2. Describe some common elements of wetland restoration projects
3. Describe the historical degradation that has occurred in the Everglades Ecosystem of South Florida
4. Outline the goals and methods of Everglades restoration
5. Identify common characteristics of successful wetland restoration projects

Wetland Restoration in the Everglades - General Lecture Outline

I. Wetland Restoration
  A. Definition
  B. Objectives
  C. Common elements
    1. Remove physical stressors
    2. Restore hydrology
    3. Control invasive species
    4. Re-plant vegetation
    5. Captive breeding and re-establishment of animals
    6. Monitoring
    7. Vegetation management

II. The Everglades Ecosystem
  A. Wetland types
  B. Historical conditions
    1. Hydrology
    2. Vegetation
  C. Biodiversity
  D. Land use

III. Environmental Degradation in the Everglades
  A. Disturbed hydrology
  B. Increased demands for land and freshwater
  C. Oxidation of peat soils in wetlands
  D. Introduction of invasive species
  E. Poor water quality
  F. Climate change
  G. Historical changes in land use

IV. Ecological Restoration - The Comprehensive Everglades Restoration Plan
  A. Computer modeling of historical hydrology
  B. Everglades Nutrient Removal Project
  C. Reconstruction of the Kissimmee River
  D. Removal of invasive plants
  E. Aquifer storage reservoirs
  F. Purchase of agricultural lands

V. The Future of Wetland Restoration
  A. Watershed level approaches based on ecosystem management
  B. Involvement of private landowners
  C. Interconnections between wetlands, the economy and human well-being
  D. Scientific uncertainties
  E. Increasing human populations and climate change

PowerPoint Presentation with Instructor Notes

Wetland Restoration in the Everglades

By Wynn W. Cudmore, Ph.D.
Northwest **C**enter for **S**ustainable **R**esources

DUE # 0757239

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Wetland Restoration

Restoration – return of a wetland from a disturbed or altered condition to some improved condition; usually accomplished by restoring hydrology (e.g., removing dikes, levees or drainage tile)

Restoration of a riverbank damaged by cattle grazing

See notes slide 2 (page 12)

Photo credits:
Left – U.S. Fish and Wildlife Service, Division of Public Affairs, Bridgette Constanzo
Right – U.S. Fish and Wildlife Service, Division of Public Affairs

Notes slide 2 (page 12)

<u>The demand for wetland restoration and creation</u>

In the U.S., federal and state regulations implemented since the 1970s and policies such as “no net loss” of wetlands have dramatically increased demand for wetland restoration projects. As discussed elsewhere, wetland restoration and creation have become common ways to replace wetlands lost to development and agriculture. A “wetlands industry” has emerged that is involved in wetland determination, wetland delineation, wetland mitigation, and conveying the intricacies of wetland regulations to landowners. In addition, due to the amount of wetlands that have been lost, there are those (government agencies, environmental groups and some private landowners) who restore wetlands on a voluntary basis.

Some large scale wetland restoration efforts in the U.S. include:

Everglades (Florida)

Delaware Bay

Mississippi Delta (Louisiana)

Prairie Pothole Region (north central states)

Wetland management is a science-based endeavor and as such requires individuals with an understanding of related physical (hydrology, soils, chemistry, etc.) and biological (botany, ecology, etc.) science principles. For those involved in wetland design, engineering skills are also essential.

Restoration of wetlands can often be achieved simply by restoring water supplies that have been diverted. However, monitoring must occur so we have some measure of when restoration has occurred.

The “before” and “after” photos shown here illustrate the dramatic change that can occur with restoration. In this case a riverbank damaged by cattle grazing was restored by planting vegetation and fencing cattle from the area.

Wetland Restoration – some considerations:

"Restoration to what?" An ongoing discussion concerning ecological restoration in general, and wetland restoration, in particular, centers around this question: "To what benchmark should the present ecosystem be restored?" After all, ecosystems are not static and change significantly on many time scales. In general, restoration attempts to return an ecosystem to some earlier and "healthier" condition but, <u>how</u> early and <u>how</u> healthy? The further back we choose our benchmark, the less likely it will be that we know much about the conditions of an ecosystem (although the relatively new field of historical ecology is developing an impressive array of new techniques that help with this). In the United States, the benchmark of "historical conditions that existed prior to European settlement" or "conditions prior to significant anthropogenic impact" are commonly selected as a goal even though most agree that the selection of these time frames are somewhat arbitrary.

Despite the challenges of establishing a target for restoration, most wetland restorationists are able to establish some criteria against which success is to be measured (e.g., plant diversity and abundance, duration of soil saturation, persistent hydrology, etc.). Success of wetland restoration projects using these type of criteria is highly variable. Tidal restoration projects, especially when adjacent to healthy, functioning wetlands are among the most successful. Forested wetland restoration projects are at the other end of the scale, in part due to the long time required to establish appropriate vegetation structure.

Photo shows a 5000-acre freshwater marsh restoration site in California. The site has been enrolled in the Wetland Reserve Program for 16 years and was originally an agricultural field.

Photo credit: USDA Natural Resources Conservation Service

Although wetland restoration must be closely tailored to local conditions, there are some common elements to most restoration projects.

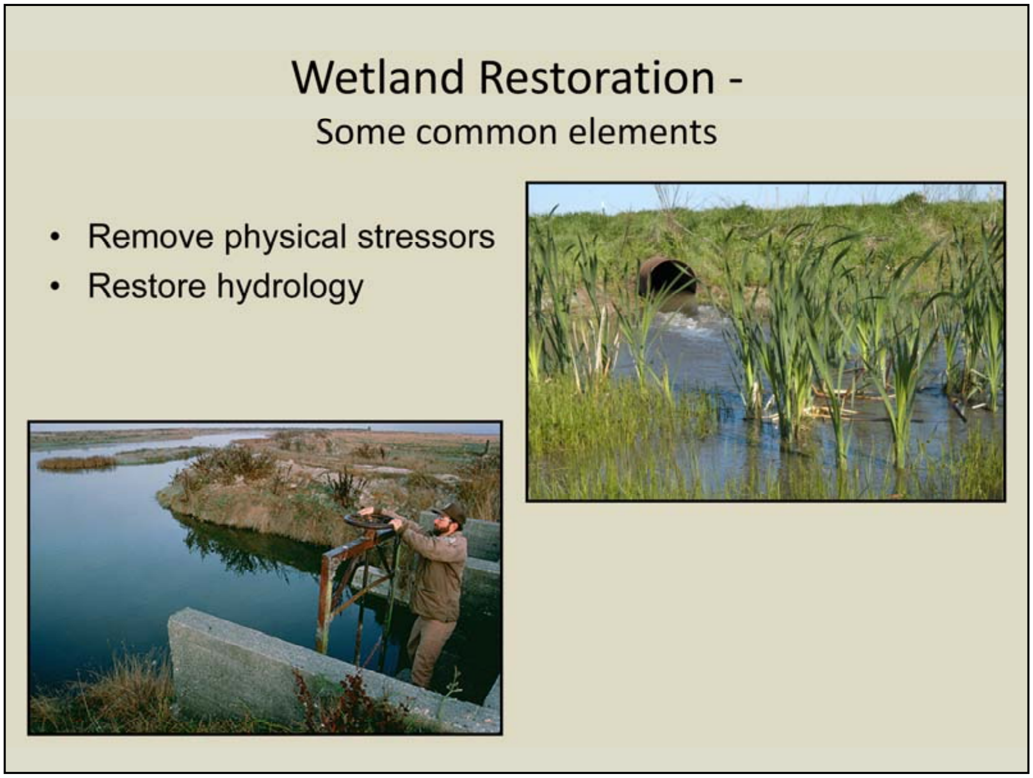
1. Remove physical stressors – “stressors” may include grazing, logging, urban development, saltwater intrusion, solid waste dumping or poor water quality due to runoff from adjacent lands. Successful restoration is likely to begin with addressing these issues first.

Top right photo – Wetland overgrazed by livestock presenting a number of environmental concerns, including sedimentation and contamination of waters by animal wastes (New York state).

Left photo – Pollution of a wetland due to acid mine drainage. This iron-rich wetland resulted from weathering of sulfide minerals from a nearby mine (Silverton, Colorado).

Bottom right photo – A wetland being used as a dump site.

Photo credit:
Left (acid mine drainage) - U.S. Geological Survey, Mark R. Stanton
Top right (cattle grazing) - New York, USDA NRCS
Bottom right (dump site) - Mark Roberts, U.S. Fish and Wildlife Service, Division of Public Affairs

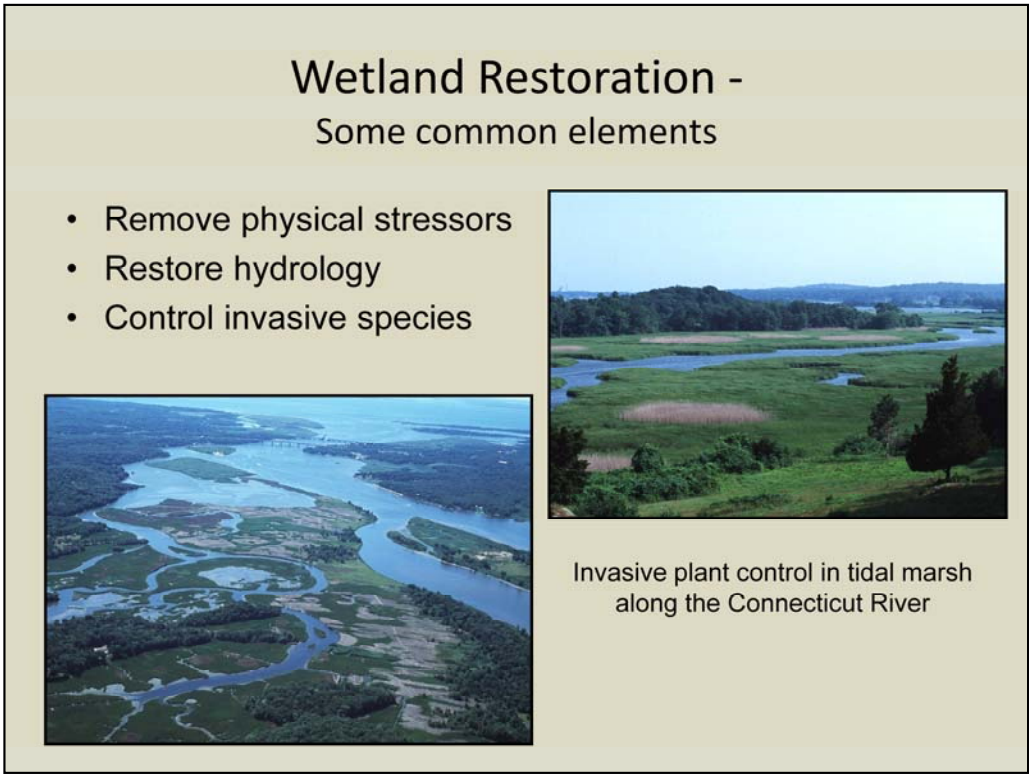


2. Restore hydrology – may include changing water flow by removing levees or dams, excavation or restoring historical river channels; improving water storage; achieving longer periods of soil saturation. Water control structures (bottom photo) and culverts (top photo) may need to be installed to divert water flow.

Bottom photo – Wildlife biologist adjusts water control structure on Humboldt Bay National Wildlife Refuge, California.

Top photo – Culvert diverts water flow to an emergent wetland in Missouri.

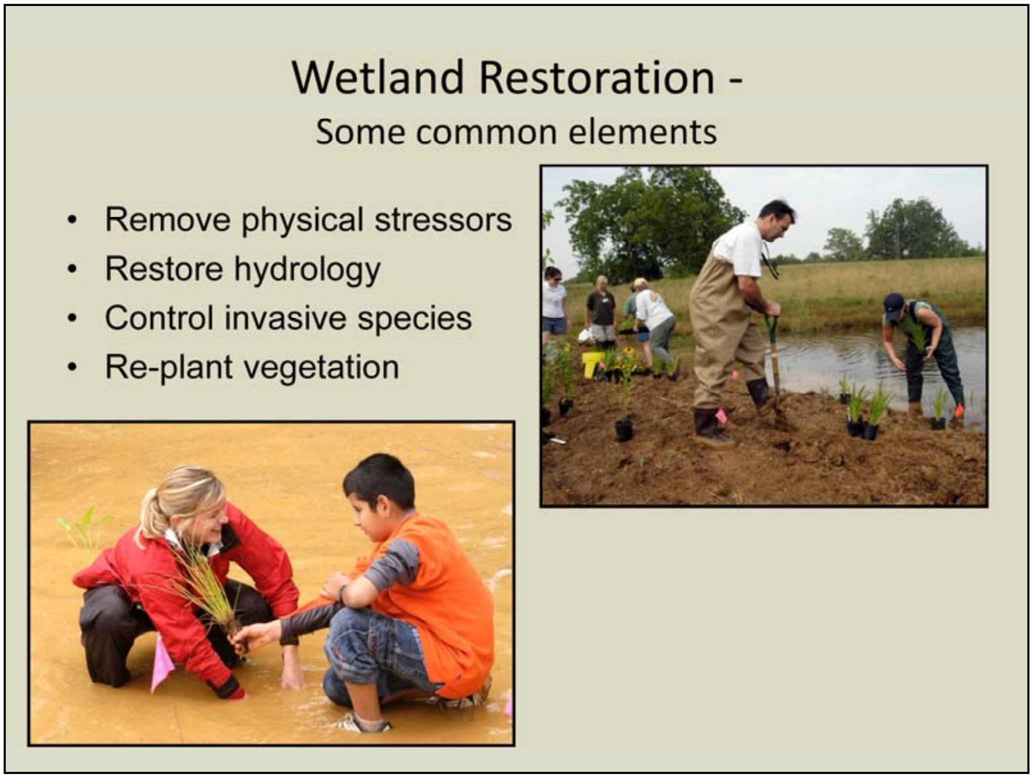
Photo credits:
Left - U.S. Fish and Wildlife Service, Division of Public Affairs, John and Karen Hollingsworth
Right - Missouri USDA NRCS



3. Control invasive species - may include physical removal, use of herbicides or pesticides, or biological control (e.g., predator introduction)

Photos show Connecticut River tideland habitat undergoing invasive plant control (light colored areas that have been sprayed with a herbicide) and native plant community restoration.

Photo credits: (Both photos)
Paul Fusco, USDA Natural Resources Conservation Service



4. Re-planting vegetation – often not necessary as seeds of many wetland plants are quite persistent and may germinate and establish once hydrology is restored; if planting is required, native species with the genetic composition best adapted to local conditions are used; may involve seed collection and/or starting some plants in greenhouses or purchasing from a native plant nursery.

Planting efforts can be used as an educational opportunity as seen in the lower photo where a teacher and her student are participating in a wetland restoration project at Harpers Ferry National Historical Park in West Virginia. In the top photo, participants in a “Wonders of Wetlands” Workshop at the National Conservation Training Center in West Virginia work to restore a pond.

Photo credits (both photos): Todd Harless, U.S. Fish and Wildlife Service

Wetland Restoration -

Some common elements

- Remove physical stressors
- Restore hydrology
- Control invasive species
- Re-plant vegetation
- Captive breeding and re-establishment of animals

Pond turtle

Bullfrog

5. Captive breeding and re-establishment of animals is less commonly used than plant re-introductions. A “head start” program for pond turtles in Oregon and Washington collects eggs in the wild and then raises the hatchlings in captivity to a sufficiently large size to avoid predation by (non-native) bullfrogs. The young turtles are then released in suitable habitat.

Photo credit:
Left: Oregon Zoo
Right (bullfrog) - © 2008 Bruce Avera Hunter, Courtesy of life.nbii.gov

6. Monitoring – water quality measurements, plant and/or animal abundance and diversity, appearance of habitat elements for endangered species, etc., may be monitored as part of an adaptive management approach to restoration. Given the amount of scientific uncertainty concerning restoration projects, most incorporate adaptive management into the planning (e.g., Coast 2050 for the Gulf Coast and the Comprehensive Everglades Restoration Plan.)

Top photo – A wetlands consultant examines soils in a restored wetland in Marion County, Oregon.

Bottom photo – An environmental specialist with the Goshute Indian Reservation and a wetlands scientist with the Natural Resource Conservation Service review wetland monitoring plans.

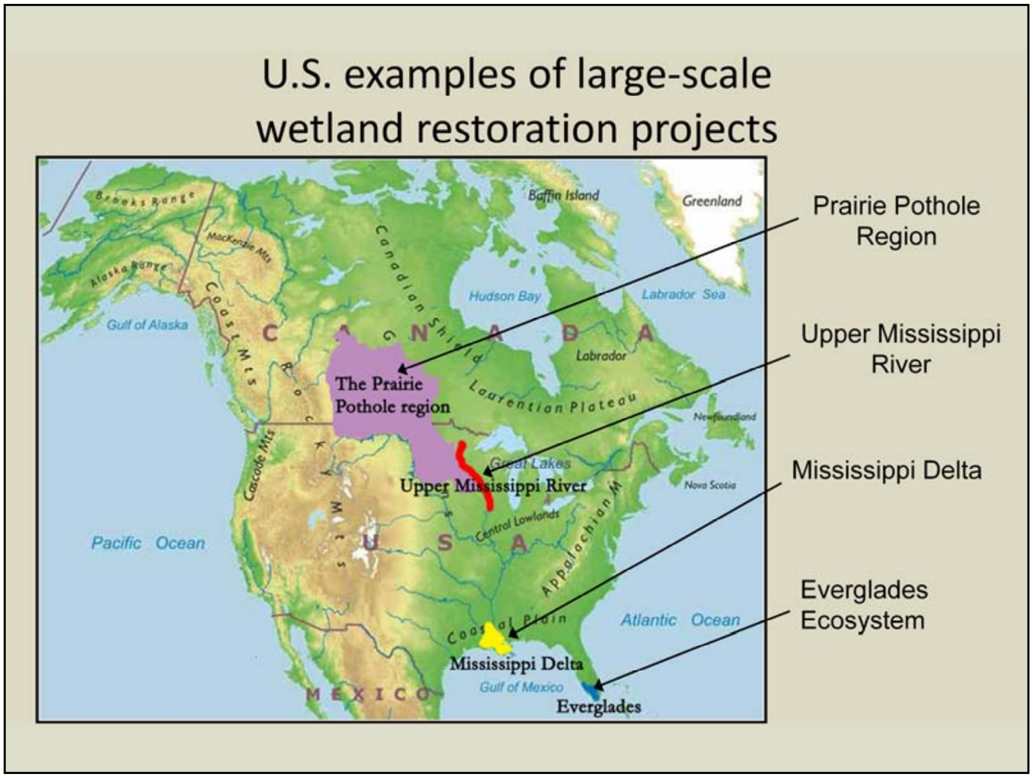
Photo credits:
Top right – Becca Cudmore
Bottom left - USDA Natural Resources Conservation Service, Ron Nichols

7. Vegetation management – mowing, herbicide spraying, prescribed burning or grazing may be used as tools to achieve plant species abundance and diversity goals. These may be required even if invasive species are not a problem. For example, cattails or an annual grass may become overly abundant and exclude other species, thereby reducing plant diversity. Burning or mowing prior to seed set can reduce reproduction of these species and favor others. Plant diversity increases as a result.

Top photo - Prescribed burn of marsh grasses on a national wildlife refuge in California as part of a wetland restoration program.

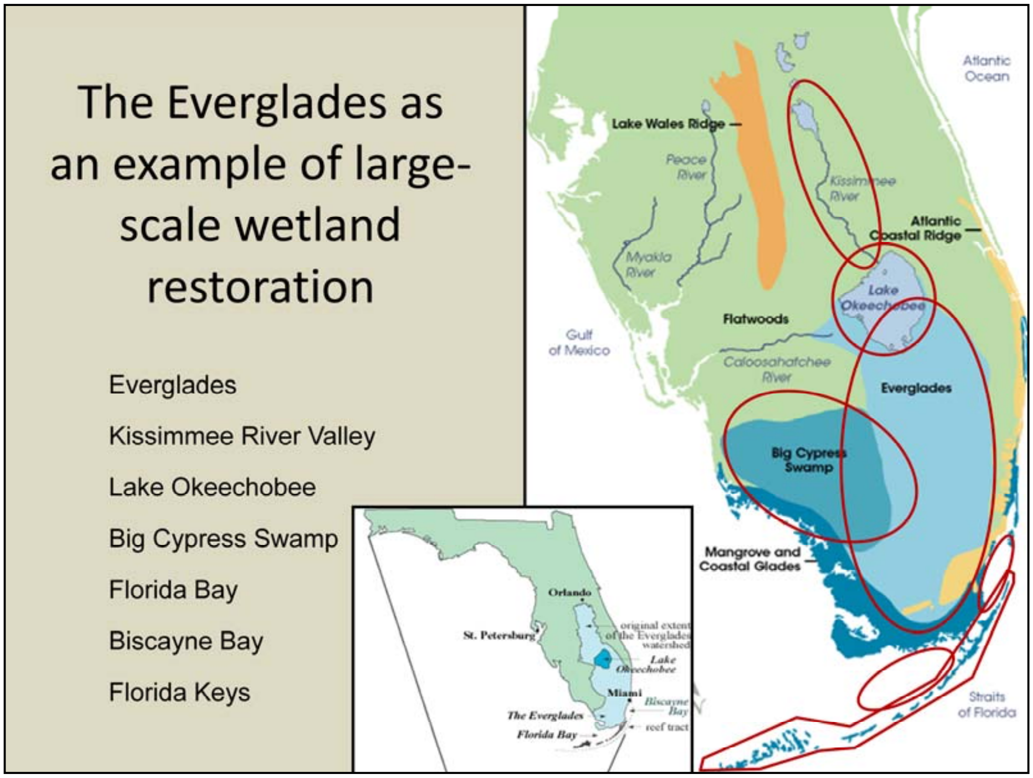
Bottom photo - Disking cattails in wetland area on a national wildlife refuge to maintain habitat (Rainwater Basin Wetland Management District, Nebraska)

Photo credits:
Top (fire) - U.S. Fish and Wildlife Service, Dave Menke
Bottom (tractor) - U.S. Fish and Wildlife Service, Phyllis Cooper



A number of large-scale wetland restoration projects are underway in the United States. Among these are the Upper Mississippi River and the Prairie Pothole Region - see Dahl (2006) for details on these projects. For a detailed description of the restoration plan for the Mississippi Delta and the Gulf Coast, see the NCSR module entitled, *Wetlands and Hurricanes*. The restoration of the Everglades Ecosystem is the focus of the remainder of this presentation.

Photo credit: Adapted from Free pictures online

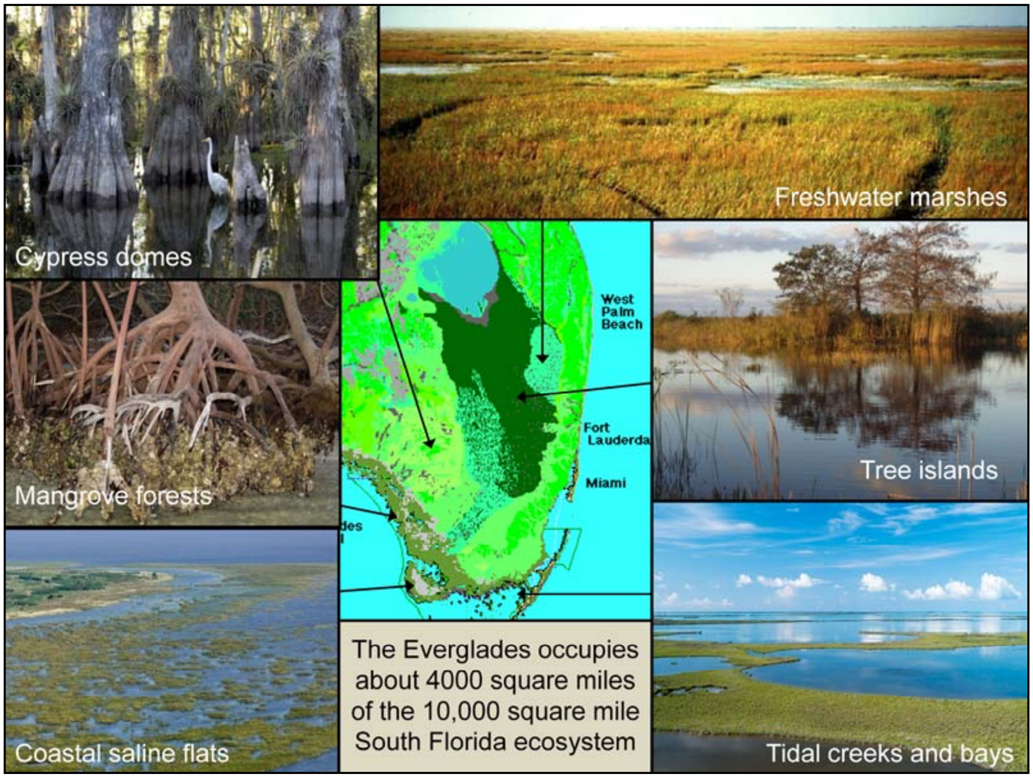


The Everglades is an expansive subtropical wetland that is centrally located in the South Florida Ecosystem, which also includes the Kissimmee River Valley, Lake Okeechobee, Big Cypress Swamp, Florida Bay, Biscayne Bay, and the Florida Keys. The Everglades occupies about 4000 square miles of the entire watershed, which is 310 miles from north to south and 62 miles from east to west (10,000 square miles). As such it is the largest wetland in the United States and one of the largest freshwater marshes in the world.

For a detailed description of the restoration plan for the Mississippi Delta and the Gulf Coast, see the NCSR module entitled, *Wetlands and Hurricanes*.

For more detail on restoration projects in the Upper Mississippi River and in the Prairie Pothole Region, see Dahl (2006).

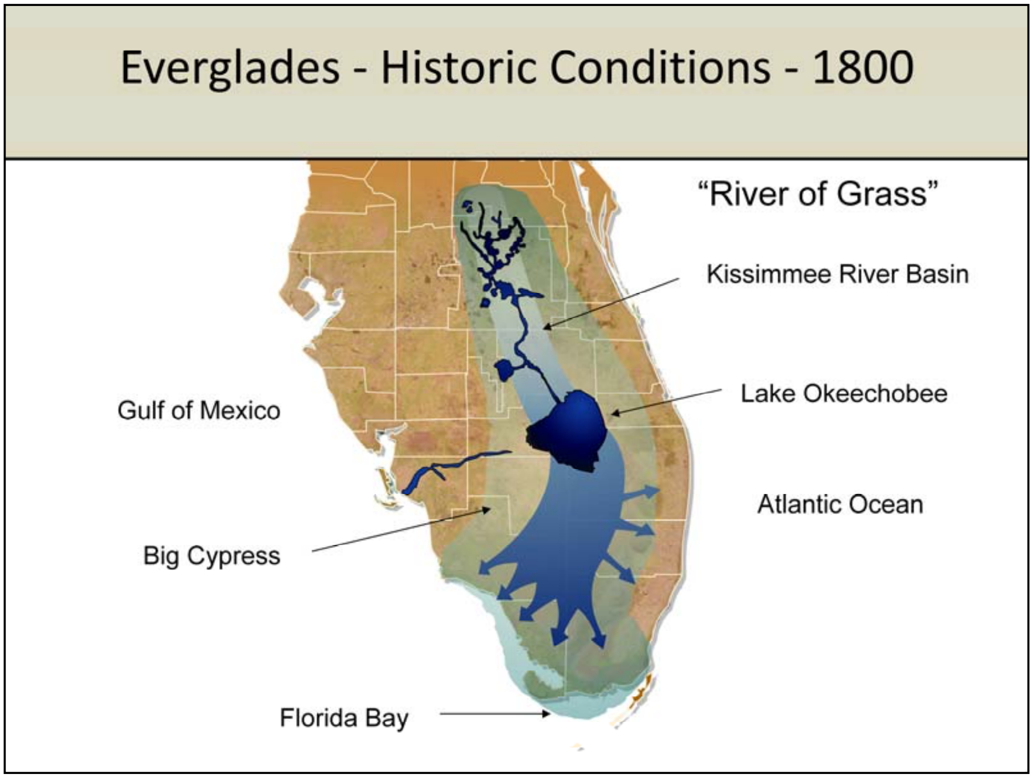
Photo credit: NASA Earth Observatory



Several wetland types are represented in the Everglades including coastal saline flats, mangrove forests, cypress domes, freshwater marshes, wetland tree islands, and tidal creeks and bays.

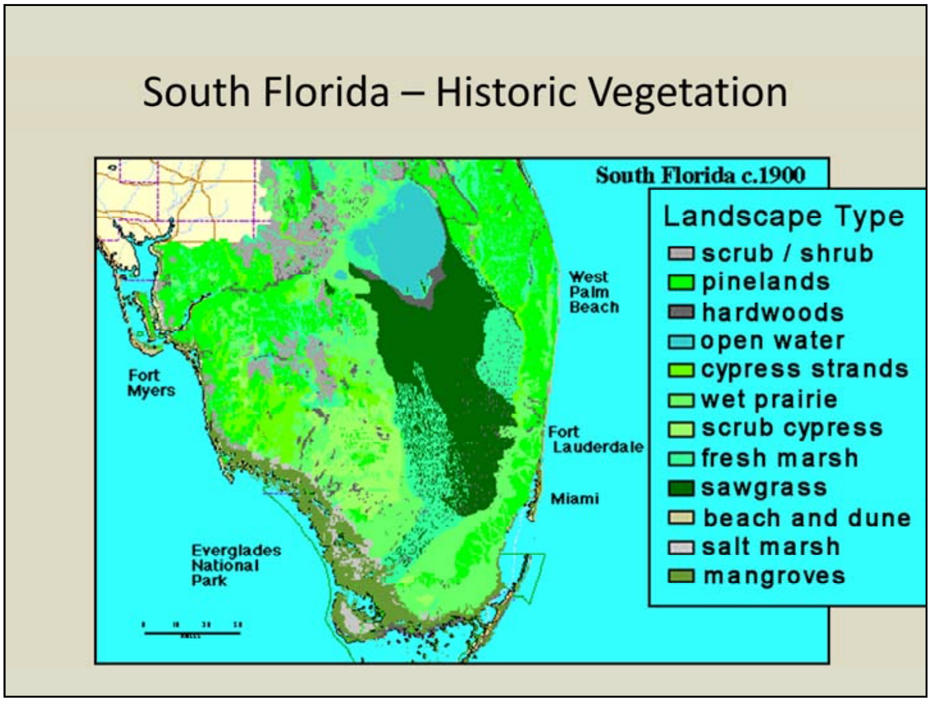
Cypress domes develop in depressions that are flooded for long periods during the rainy season. They are dominated by baldcypress (*Taxodium distichum*) and pond cypress (*T. ascendens*). The best conditions for cypress growth (long hydroperiod) are generally found near the center of the depression. Therefore, trees get progressively smaller toward the mangroves, forming the “dome.”

Photo credits:
Coastal saline flats - Southwest Florida Water Management District
Mangrove forests - Bruce Neill, Sanibel Sea School/Marine Photobank
Cypress domes – National Park Service
Freshwater marshes – U.S. Geological Survey
Tree islands – U.S. Army Corps of Engineers
Tidal creeks and bays - Southwest Florida Water Management District



Before European settlement, the South Florida landscape was a mosaic of habitats connected by the flow of fresh water from Lake Okeechobee through the Everglades and ultimately emptying into Florida Bay. The Everglades Ecosystem (in light green in diagram) is drained by a broad (as many as 60 miles wide in places), slow flowing and shallow (less than one foot deep in most places) river (in blue) that flows from the headwaters of the Kissimmee River to Florida Bay. The "Everglades proper," which includes Everglades National Park, extends from Lake Okeechobee to Florida Bay and was called the "River of Grass" by Marjorie Stoneman Douglas in her book of the same name. The historic Kissimmee River was hydrologically unique among North American river systems in that it had prolonged periods (30% of an average year) of extended floodplain inundation. The diagram represents the natural hydrology as it occurred in approximately 1800.

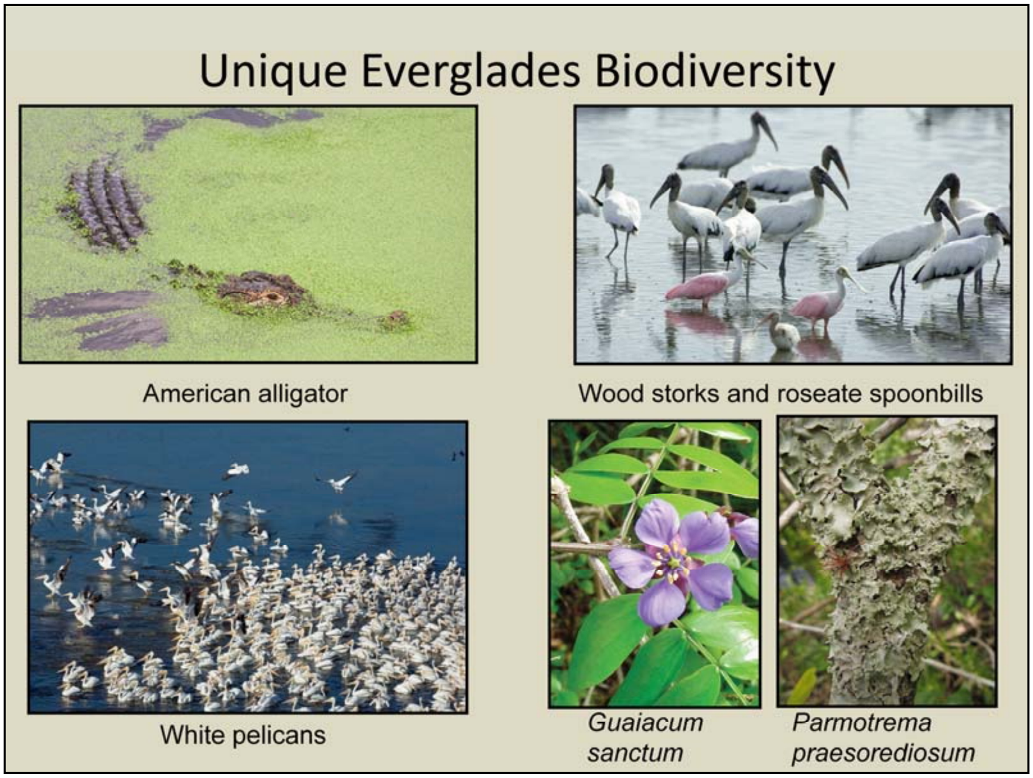
Photo credit: Comprehensive Everglades Restoration Plan (CERP)



Vegetation maps of southern Florida in approximately 1900 show that most of the area south of Lake Okeechobee was dominated by a large area of sawgrass (dark green) and other freshwater marshes (light green). Cypress swamps and forest (yellow and light green) are found in the area west of the freshwater marshes. Mangroves (dark olive) and saltmarshes (pink) dominate the southern and western coastal areas of the peninsula.

Photo credit:

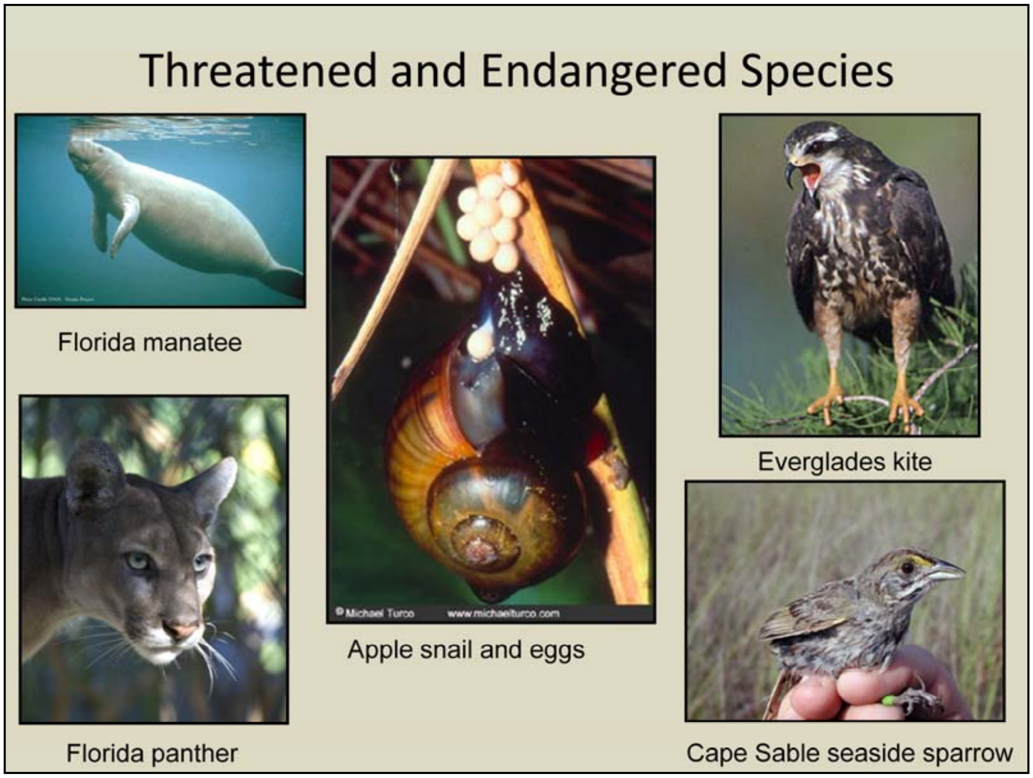
ETE is made possible through a cooperative agreement with the NASA Goddard Space Flight Center and is supported by NASA's Learning Technology Program (LTP)



The Everglades harbors an impressive biological diversity. Wading birds are particularly diverse and abundant and include sandhill cranes, white pelicans, anhingas, white ibis, black-necked stilts, roseate spoonbills and yellow-crowned night herons. The Everglades is the only place in the world where alligators and crocodiles occur in the same area – alligators in fresh water and crocodiles in brackish and salt water. *Guaiacum sanctum*, also known as the "tree of life," is one of the two species (*G. officinale*, is the other) that yield highly valued wood, lignum vitae. This wood is extremely dense and contains a thick and oily resin that makes it highly resistant to decay. The species has "treatened" status with habitat loss and over-harvest believed to be the primary causes for its decline.

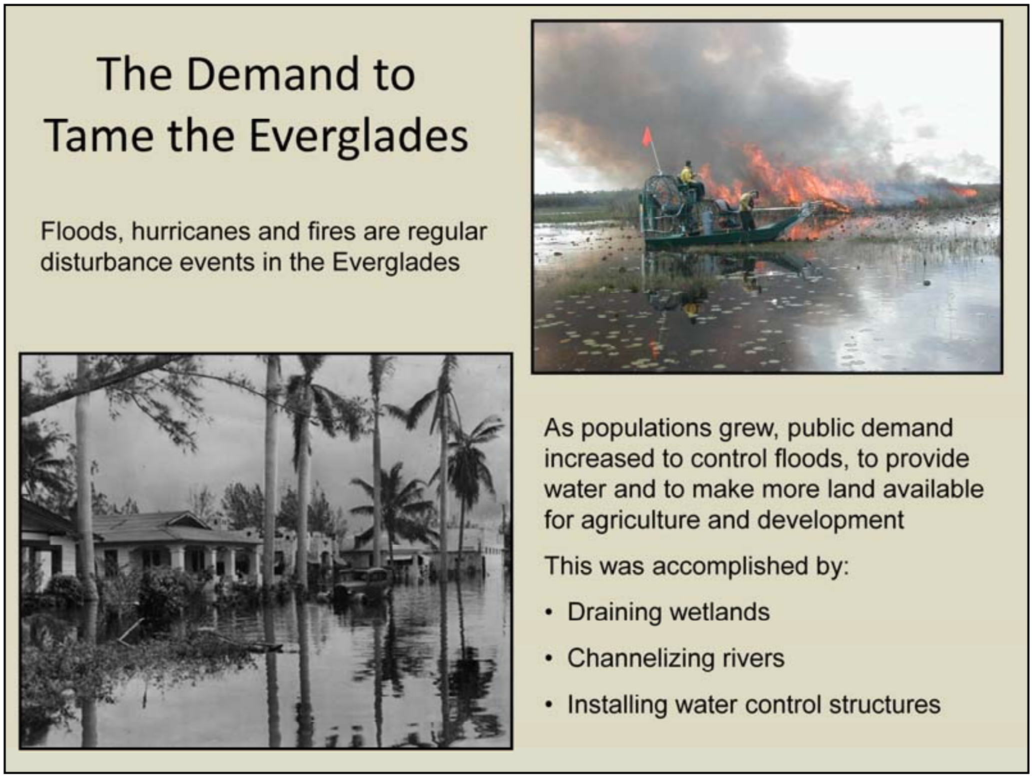
As of 2010, over 400 species of lichens have been identified in Everglades National park, 27 of which are new to North America. One species is new to science and at least 10 others have not yet been properly described and given a scientific name. Everglades National Park ranks 5th in lichen biodiversity when compared to other national protected areas in the United States.

Photo credits:
Top left (American alligator) - Southwest Florida Water Management District
Top right (Wood storks) - Southwest Florida Water Management District
Bottom left (White pelicans) - Southwest Florida Water Management District
Bottom right (*Guaiacum sanctum*) – Wikimedia commons, Derek R. Artz
Bottom right (leafy lichen) – National Park Service



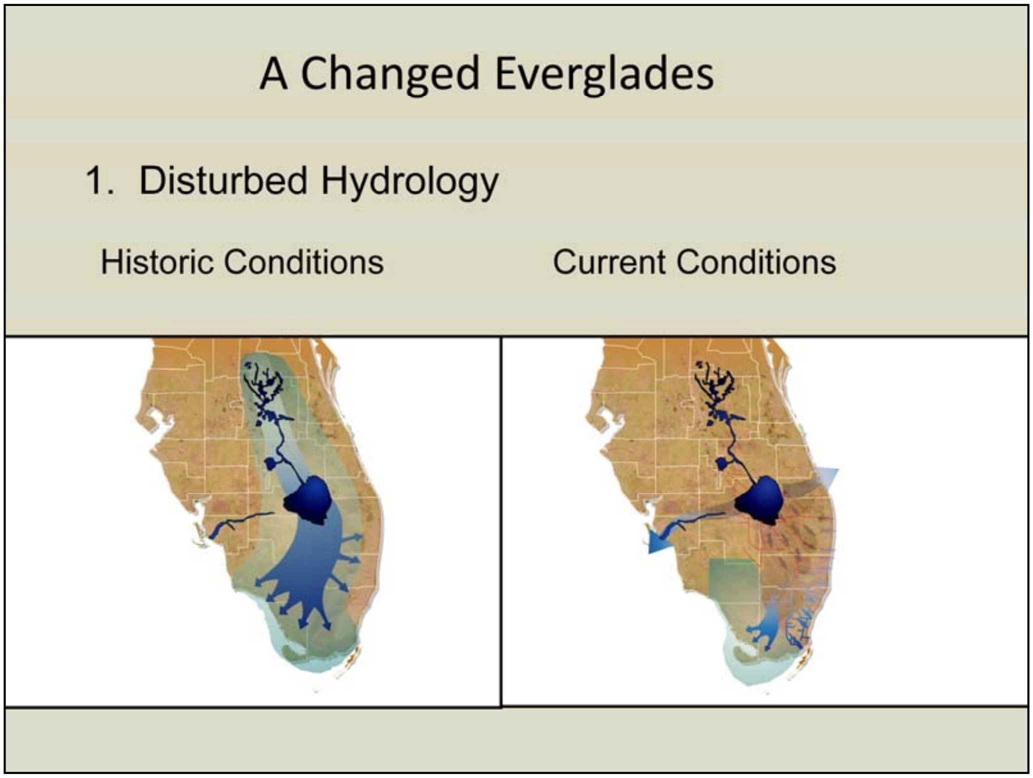
The Everglades provides habitat for at least 55 species of threatened and endangered species, including the Florida manatee, American crocodile, Cape Sable seaside sparrow and the Florida panther. The Everglades kite is a highly specialized raptor that feeds almost exclusively on Apple snails. The Everglades kite has declined from an estimated population of over 3000 in the late 1990s to less than 1000 birds in 2008.

Photo credits:
Florida manatee – U.S. Geological Survey, Sirenia Project
Florida panther – Rodney Cammauf, National Park Service
Apple snail laying eggs – © Michael Turco www.michaelturco.com
Everglades kite – U.S. Geological Survey
Cape Sable seaside sparrow – U.S. Fish and Wildlife Service



Historically, large-scale disturbances such as floods, hurricanes and fires were a regular occurrence and Everglades species were adapted to them. However, these disturbances were not conducive to the increasing human population of South Florida. Although small scale efforts to drain the Everglades began as early as the 1880s, the development of one the most extensive water management systems in the world began in earnest after hurricanes and widespread flooding in the 1920s. For the next several decades, the federal government responded to public pressure to provide flood control and more land for agriculture and development by draining wetlands, channelizing rivers and installing water control structures (canals, floodgates, pump stations and levees) that could divert and store water. The result was a dramatically changed Everglades.

Photo credits:
Fire – National Park Service
Flood - Miami News Collection, HistoryMiami,1989-011-8007



Disturbed hydrology

Although a number of types of degradation have occurred in the Everglades over the past century, none is more obvious than the changes made to the flow of water through the system – natural flow volume, timing and distribution have all been altered.

Photo credits: Comprehensive Everglades Restoration Plan (CERP)

A Changed Everglades

1. Disturbed hydrology
   - Straightening of the Kissimmee River and draining of adjacent wetlands

- In the 1960s the once-meandering, 103-mile Kissimmee River was transformed into a 56-mile canal called “C-38” and 30,000 acres of its adjacent wetlands were drained. This was all done to prevent the retention of water and to speed flood waters to the ocean.

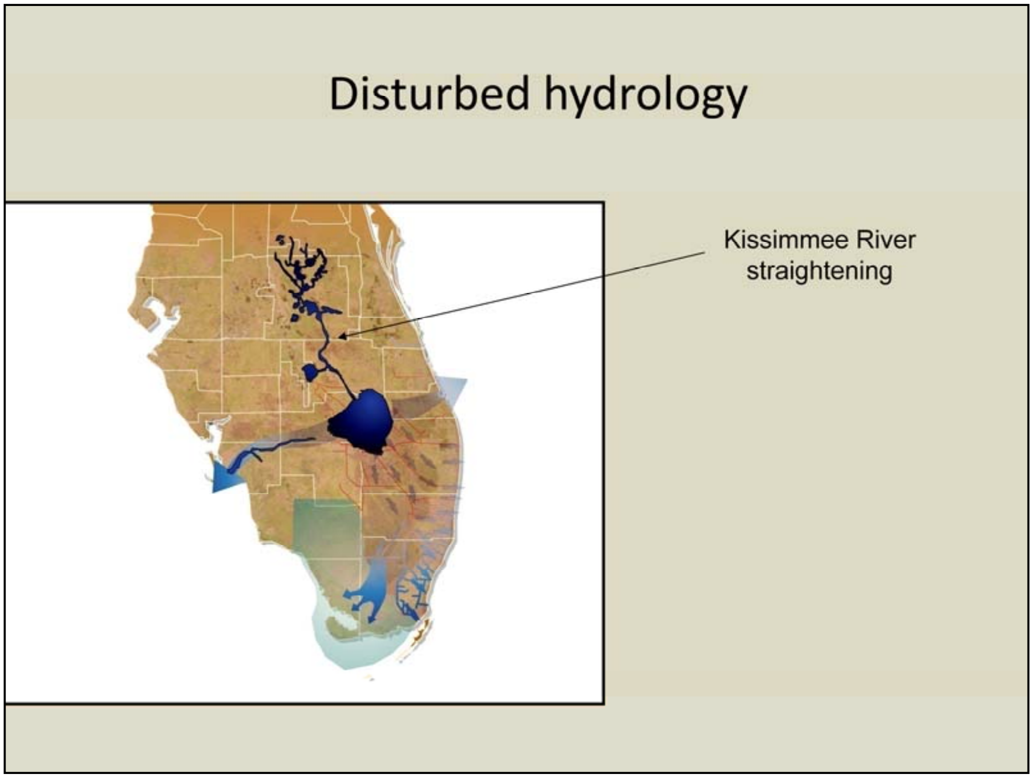
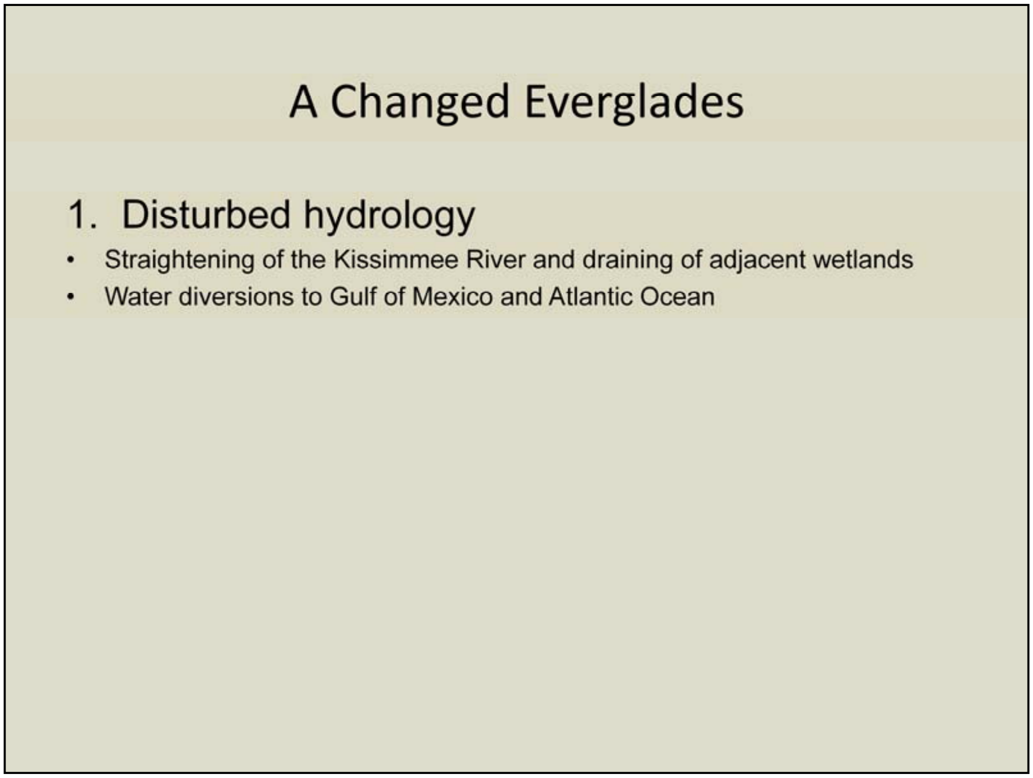


Photo credit: Comprehensive Everglades Restoration Plan (CERP)



- So-called “extra water” was diverted west to the Gulf of Mexico and east to the Atlantic Ocean to reduce water volume. Seasonally, huge volumes of freshwater on both coasts altered the salinity of estuaries and covered oyster beds with sediment.

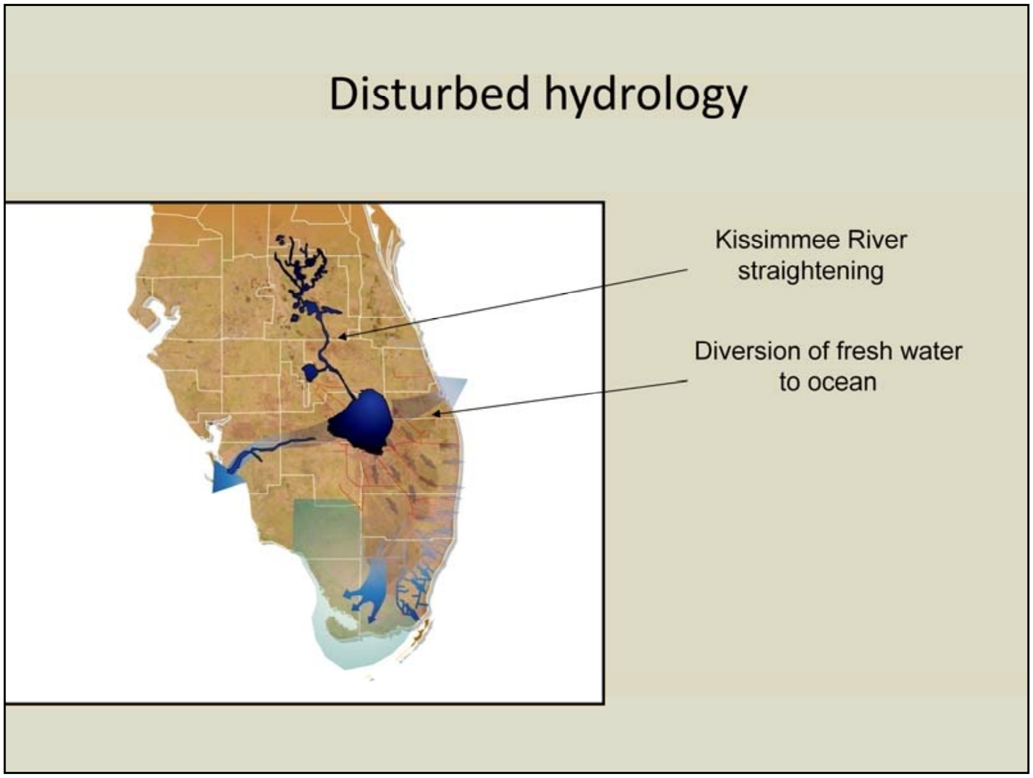


Photo credit: Comprehensive Everglades Restoration Plan (CERP)

A Changed Everglades

1. Disturbed hydrology
   - Straightening of the Kissimmee River and draining of adjacent wetlands
   - Water diversions to Gulf of Mexico and Atlantic Ocean
   - Water control structures (canals, flood gates, pump stations and levees) installed

- In the early 1970s the massive Central and Southern Florida Project was completed, redirecting the flow of water from its natural path through an elaborate system of water control structures - 1400 miles of canals, flood gates, pump stations and levees. Now, less than half of the estimated 2 million cubic kilometers of water that used to flow south from Lake Okeechobee reaches the Everglades. Due to the loss of wetlands retentive nature, the Everglades are now typically too wet in the wet season and too dry in the dry season. Transitions between dry and wet conditions are often far more rapid than they were historically.

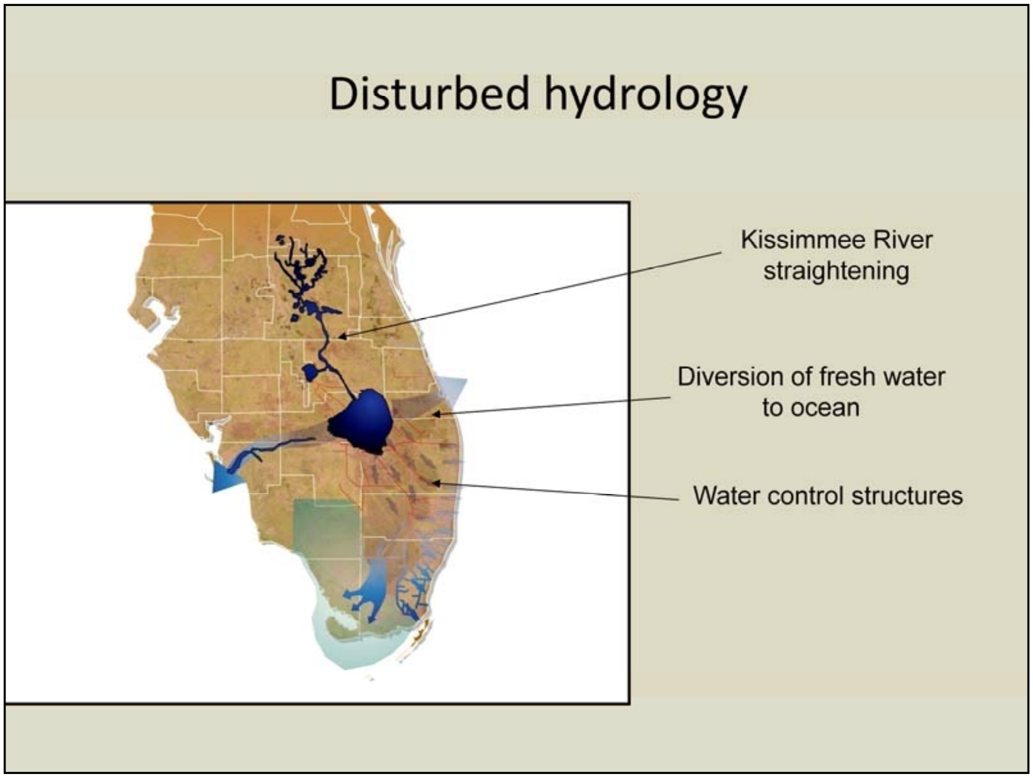
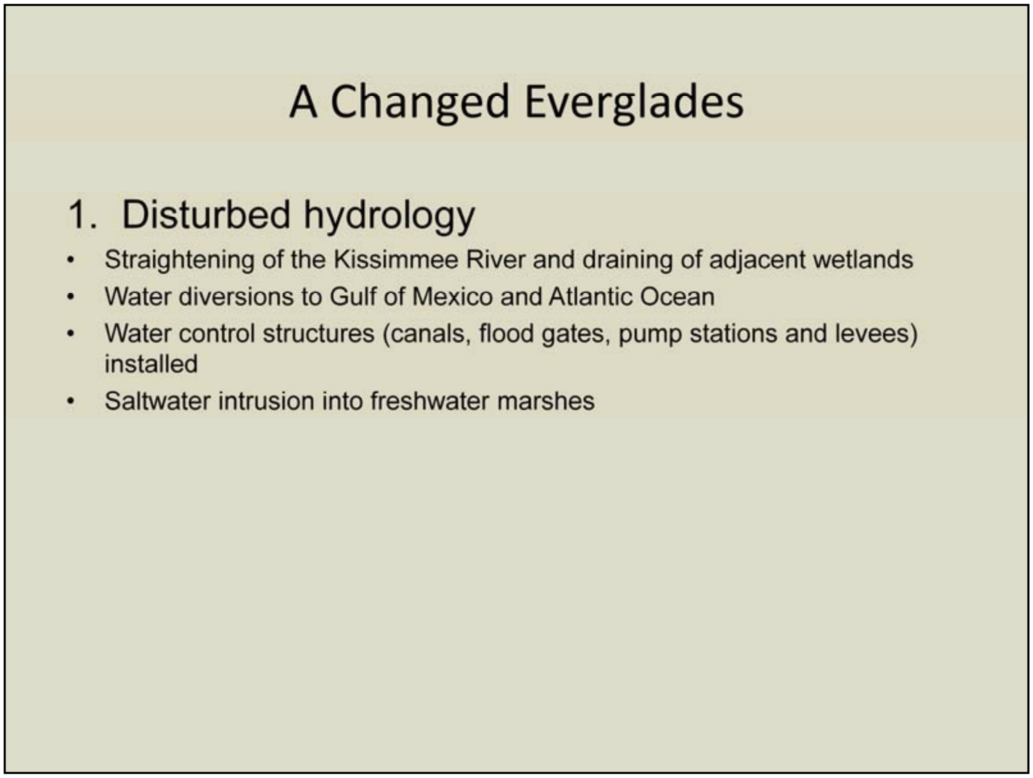


Photo credit: Comprehensive Everglades Restoration Plan (CERP)



- As freshwater volumes declined in the Everglades system, saltwater intrusion extended further north damaging freshwater wetlands and their associated species. Sea level rise due to climate change further increases saltwater intrusion. Recent paleoecological studies of pollen and seeds conducted on samples from Everglades National Park (Shark River Slough) indicate a wetter and fresher environment than previously thought. These samples contain an abundance of water lilies, which are associated with open water, greater depths and longer periods of inundation.

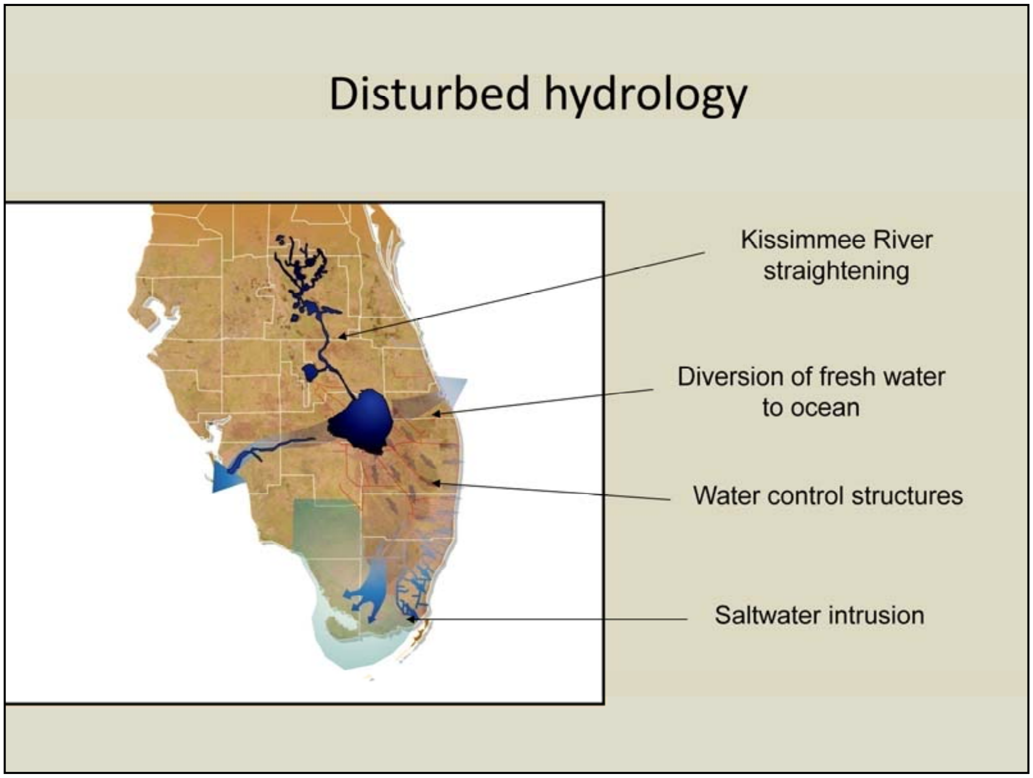
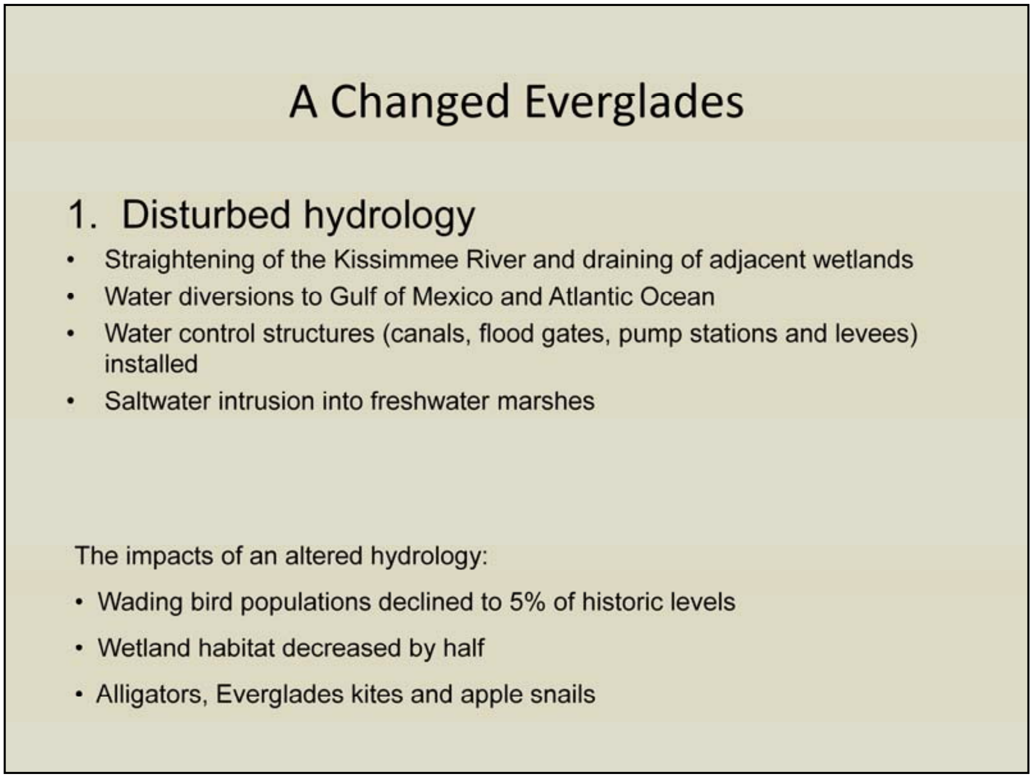
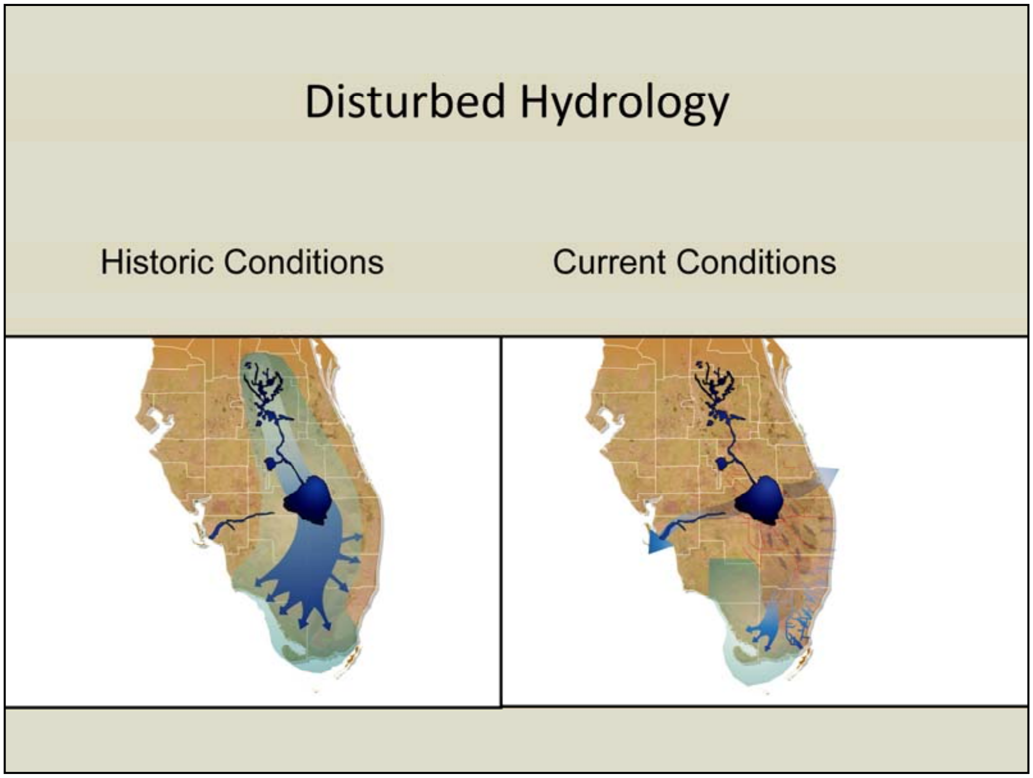


Photo credit: Comprehensive Everglades Restoration Plan (CERP)



Impacts of an altered hydrology on wildlife:

These changes in Everglades hydrology led to drastic declines in wintering waterfowl, wading bird and game fish populations, and the loss of ecosystem functions. Wading bird populations have declined to about 5% of historic levels. The combination of drainage and development has reduced the amount of wetlands by half. The timing and rate of change of water levels are critical to species found in the Everglades. Gradual changes in water levels are necessary to support foraging and reproduction of Everglades birds and alligators. Also, the reproduction of apple snails, the primary food of the Everglades kite, is highly dependent on the timing and rate that water recedes. Rapid increases in water levels can inundate and destroy snail egg masses. Rapidly receding water can cause the eggs to hatch into conditions that are too dry for the young snails.



Review disturbed hydrology:

- Central and Southern Florida Project was completed in the early 1970s
- Flow of water from the Kissimmee River, south to Florida Bay goes through an elaborate system of 1400 miles of canals, flood gates, pump stations and levees. Now, less than half of the estimated 2 million cubic kilometers of water that used to flow south from Lake Okeechobee reaches the Everglades.
- Kissimmee River was transformed into a 56-mile canal called "C-38" and 30,000 acres of its adjacent wetlands drained.
- "Extra water" was diverted west to the Gulf of Mexico and east to the Atlantic Ocean to reduce water volume. Seasonally huge volumes of freshwater on both coasts altered the salinity of estuaries and covered oyster beds with sediment.
- Saltwater intrusion extended further north damaging freshwater wetlands and their associated species. Wading bird populations have declined to about 5% of historic levels.

The combination of drainage and development has reduced the amount of wetlands by half.

Photo credits: Comprehensive Everglades Restoration Plan (CERP)

A Changed Everglades

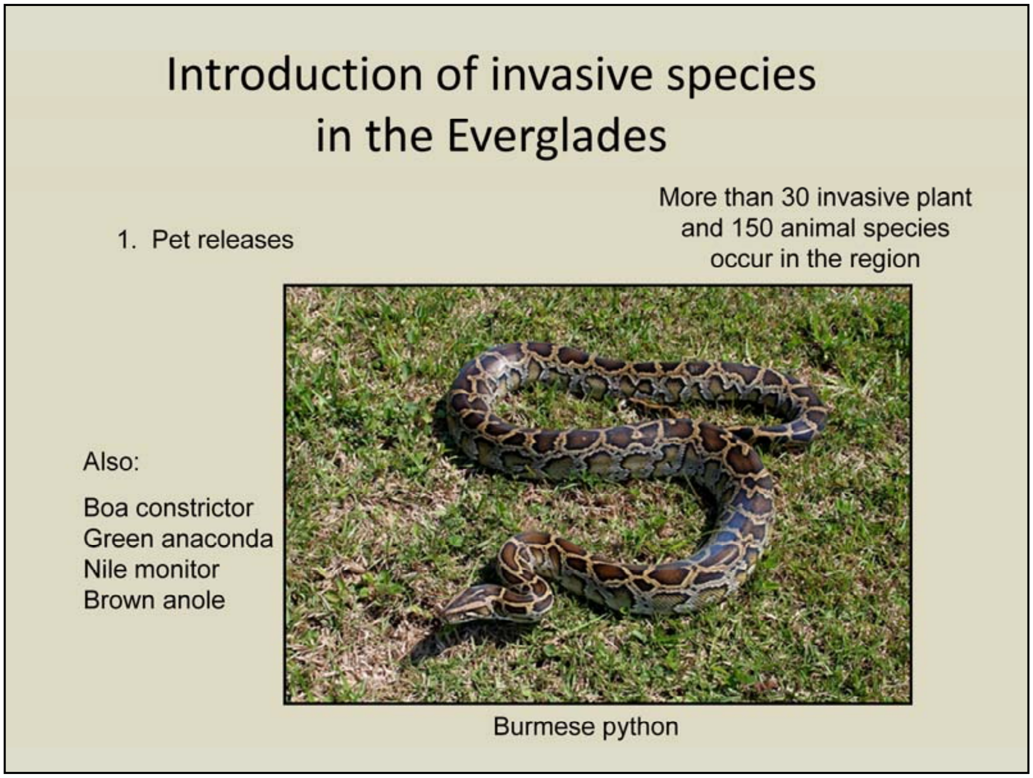
1. Disturbed hydrology
2. Increased demands for land and freshwater
3. Oxidation of peat soils in wetlands
4. Introduction of invasive species

2. Increased demands for land and freshwater due to human population growth, urban development and agriculture

Development began in the early 1900s and continues today as the peat-rich soils were drained for agriculture and development. Per capita water consumption in Florida is 123 gallons per day per person (compared to a national average of 108 gallons).

3. Oxidation of peat soils in wetlands due to draining result in soil erosion. Once Everglades soils become dry they are subject to biological oxidation (decomposition) and gradually decline in thickness. Drained peat soils are also vulnerable to wind erosion.

4. Introduction of invasive species. A number of non-native plant and animal species have become established in the Everglades. Some of these have become invasive and have out-competed native species.



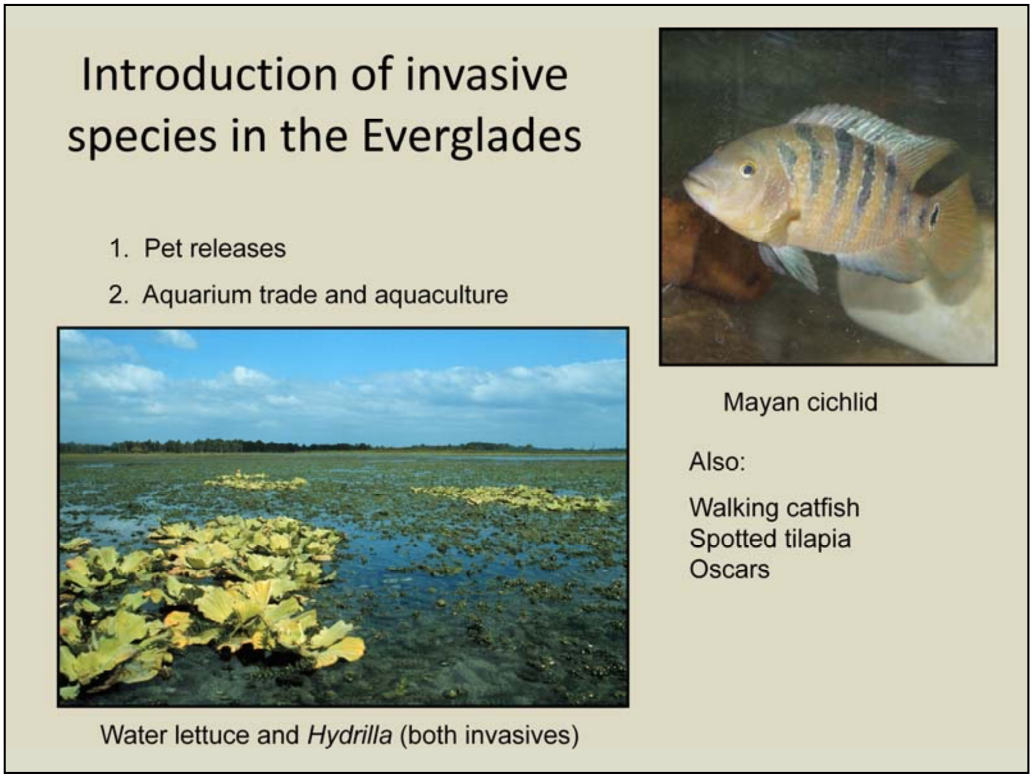
Invasive exotic species are a serious and growing threat to the Everglades ecosystem. More than 30 invasive plants and 150 invasive animals are known to occur in the region. Some examples, arranged by the mechanism of introduction include:

1. Pet releases

Burmese python – Pythons have recently become established in south Florida where they can grow to large size (20 feet and 250 pounds) and become formidable predators of native vertebrate species. Rare and endangered species (Key Largo woodrat, Round-tailed muskrat and wood stork) have been found in the stomachs of pythons. In 2005, a 13-foot Burmese python was found burst open after attempting to swallow a 6-foot alligator in Everglades National Park!

Other exotic snakes that have apparently been released by pet owners when they reach unmanageable size and have become established in the Everglades, include reticulated python, boa constrictor, and green anaconda. Other reptiles kept as pets, such as Nile monitors and brown anoles have also been released and become established.

Photo credit: National Park Service



2. Aquarium trade and aquaculture

Hydrilla (*Hydrilla verticillata*) – A submerged aquatic plant from Sri Lanka that arrived in the 1950s and crowds out other plants and clogs waterways. This photo illustrates how completely invasive species (*Hydrilla*, in this case) can overwhelm an area. Water lettuce (mostly in lower left of photo) is a native wetland plant.

Over 50 nonnative fish species can now be found in south Florida, including many believed to have been released or escaped from the aquarium trade and aquaculture operations:

Water lettuce (*Pistia stratiotes*) is also an introduced invasive plant.

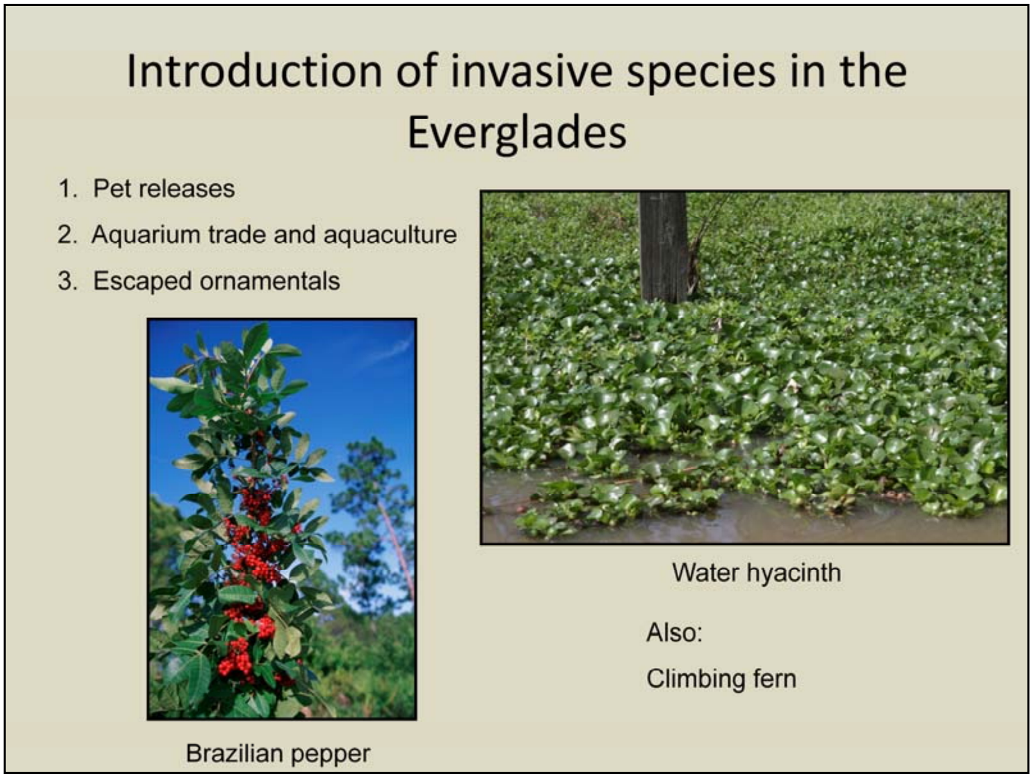
Walking catfish – aquarium trade

Mayan cichlid – aquarium trade

Spotted tilapia - aquaculture

Oscars – aquarium trade

Photo credits:
Water lettuce - Southwest Florida Water Management District
Mayan cichlid – U.S. Geological Survey



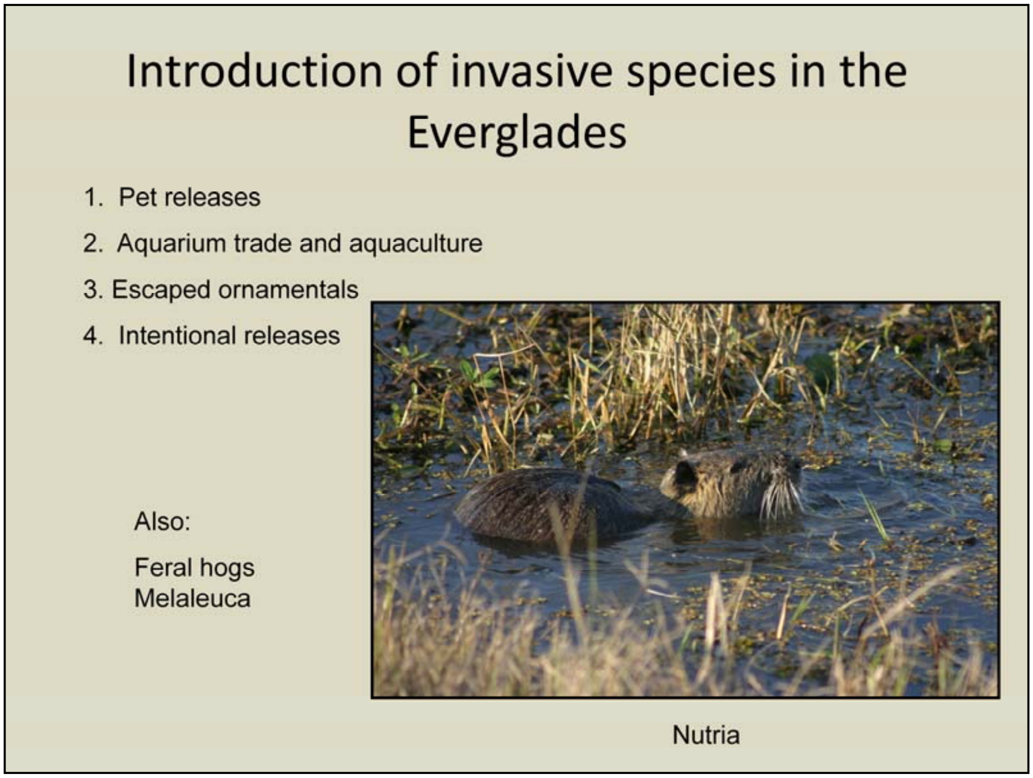
3. Escaped ornamentals – attractive plants that were intentionally planted near homes but escaped into natural habitats

Brazilian pepper (*Schinus terebinthifolius*) – An ornamental tree introduced in the late 1800s and has established in mangrove stands in Everglades National Park.

Water hyacinth (*Eichhornia crassipes*) – A floating aquatic brought into Florida in the 1880s for its attractive flowers. Now occupies acres of rivers and lakes where it reduces biodiversity, blocks waterways and interferes with flood control.

Climbing fern (*Lygodium microphyllum*) – An recent Old World species that overwhelms native vegetation in kudzu-like fashion. As it climbs into native trees it breaks off branches and increases the probability of fire reaching the forest canopy.

Photo credits:
Brazilian pepper – U.S. Fish and Wildlife Service, George Gentry
Water hyacinth – U.S. Fish and Wildlife Service, Steve Hillebrand



4. Intentional introductions and accidental releases

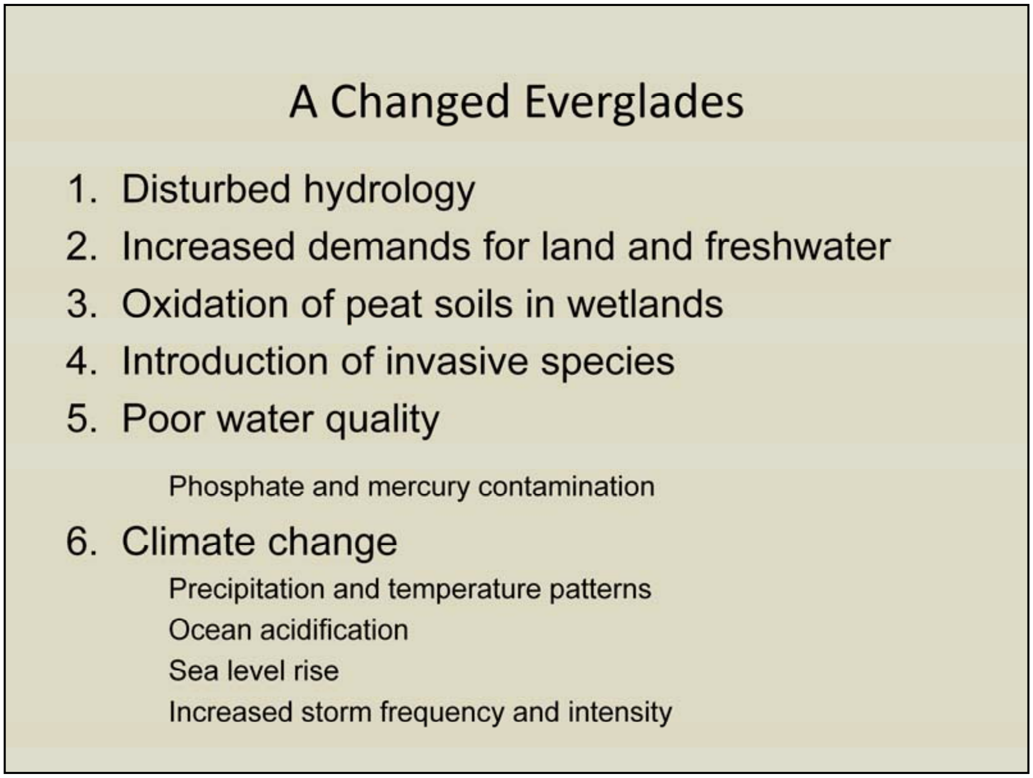
Nutria

Nutria, or coypu, (*Myocastor coypus*) were first introduced into the U.S. in 1899 in California to develop a new fur-production industry. Intentional releases after the collapse of the industry and unintentional escapes have resulted in feral populations in at least 15 states, including Florida. 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. When population levels and grazing intensity are high, there is little time for the recovery of wetland plants. Nutria have also impeded restoration efforts by uprooting and eating baldcypress seedlings. Ironically, nutria were intentionally introduced into some southern wetlands to control the water hyacinth (*Eichhornia crassipes*), another invasive species.

Feral hogs Feral hogs pose a major threat to the Everglades by disturbing soils and digging up and consuming native vegetation. They have also spread trichinosis to the endangered Florida panther.

Melaleuca (*Melaleuca quinquenervia*) – A native Australian tree in the myrtle family brought into southern Florida in 1906 to help drain the Everglades. This rapidly growing tree outcompetes native vegetation and is considered one of the region's worst problem species. The estimated annual cost of this species alone to the Florida economy is $160 million.

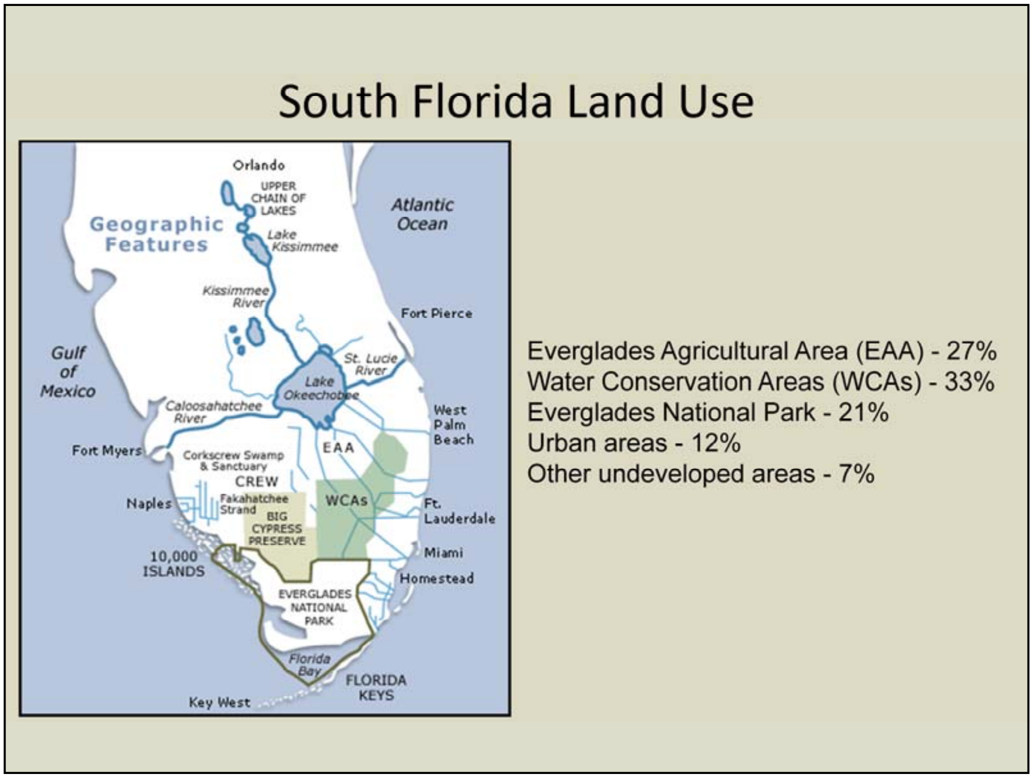
Photo credit: U.S. Fish and Wildlife Service, Steve Hillebrand



5. Water quality is compromised primarily due to agricultural and urban runoff. Phosphate fertilizer especially used to fertilize sugar cane and vegetable fields causes eutrophication of downstream waters and hypoxic conditions in Florida Bay. The decline of coral reefs in the Florida Keys has been attributed in part to water contamination that originates in the south Florida watershed. Phosphorus-laden water also promotes cattails over sawgrass and other native plants, often creating pure stands of cattails.

Mercury contamination is also an issue and has been detected at unsafe levels in fish, alligators and Florida panthers. South Florida receives some of the highest levels of inorganic mercury deposition in the U.S., mostly from rainfall. The primary sources of mercury are believed to be municipal incinerators and coal-fired electric plants on Florida's southeast coast as well as those outside the region. The conversion of inorganic mercury into the highly toxic methyl mercury is driven by sulfate-reducing bacteria found naturally in the vast areas of wetland soils in the Everglades. The release of mercury from Everglades soils is accelerated by the altered hydrology and soils disturbance.

6. Our understanding of the effects of climate change on the Everglades have advanced rapidly since 2000. Potential impacts on the Everglades ecosystem due to climate change include changes in precipitation and temperature patterns, ocean acidification, sea level rise, and the potential for storms of greater frequency and intensity. Restoration efforts must take climate change into account along with other impacts.



During the 20th century the Everglades was compartmentalized into lands dedicated for specific land uses:

Everglades Agricultural Area ("EAA" on map, 27% of area) – a large area south of Lake Okeechobee dedicated to sugar cane and vegetable farming

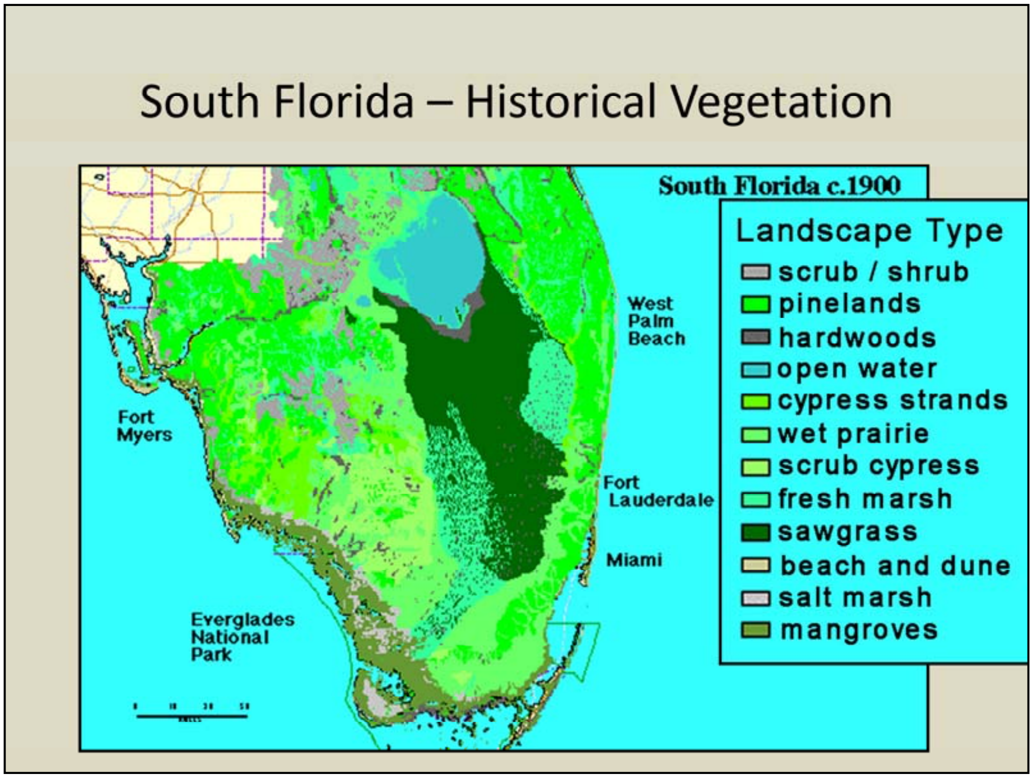
Water Conservation Areas ("WCA" on map, 33%) – an area of canals and reservoirs that lies between the agricultural area and Everglades National Park

Everglades National Park (21%) – occupies the southernmost portion of the Florida peninsula

Urban areas (West Palm Beach, Fort Lauderdale, Miami, Naples, etc., 12%)

Other undeveloped areas (7%)

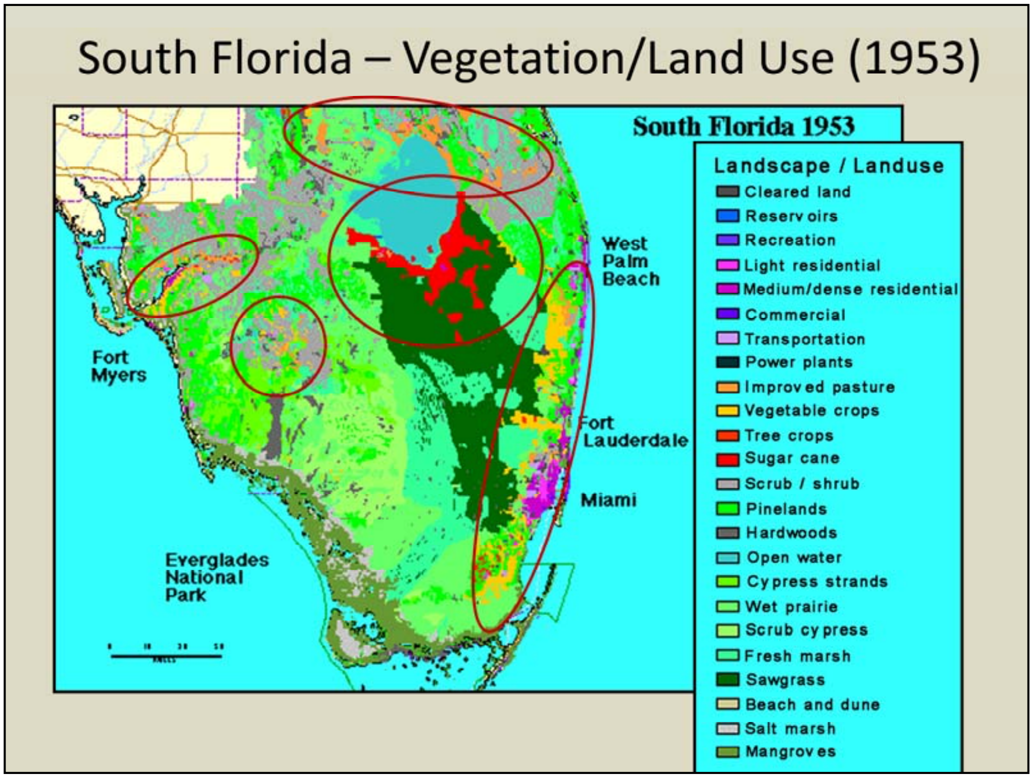
Photo credit: South Florida Water Management District



The original condition of the vegetation of South Florida has already been described. It is shown here for comparison to the next two slides.

Photo credit:

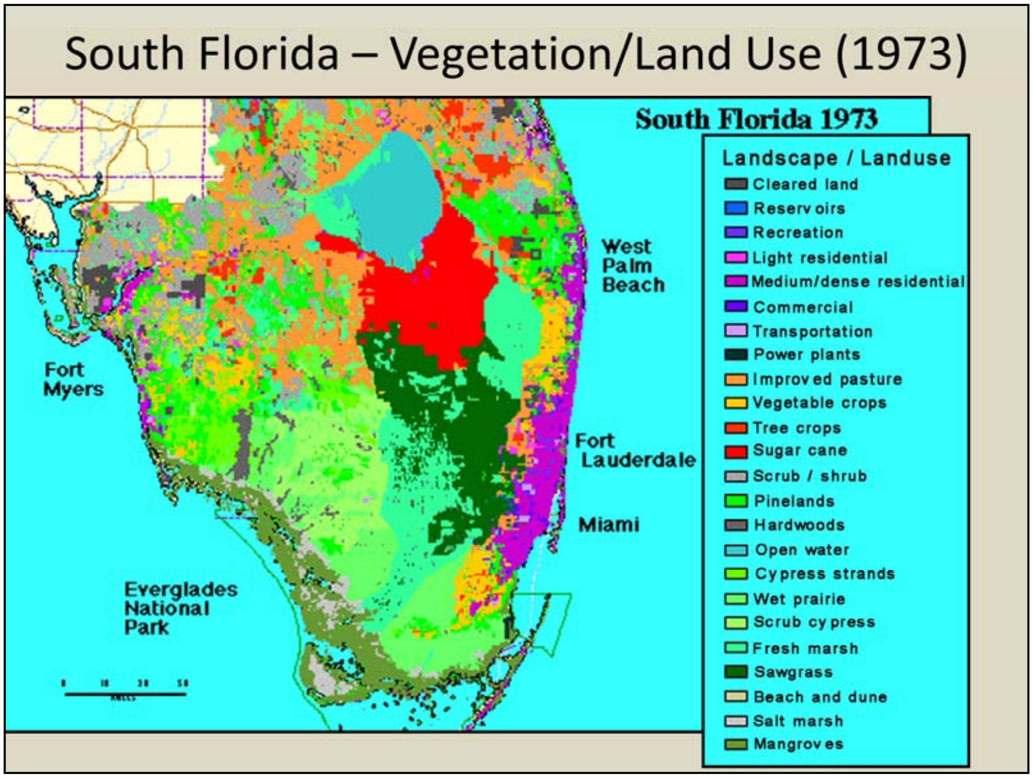
ETE is made possible through a cooperative agreement with the NASA Goddard Space Flight Center and is supported by NASA's Learning Technology Program (LTP),



This vegetation/land use map of southern Florida in 1953 shows many of the same features of 1900, but with the addition of urban/residential and commercial development on the East coast (purple and magenta) and large agricultural areas, particularly sugar cane fields (red), pasture (orange) and vegetable crops (light orange) as well as reservoirs and power plants. By 1973, most of the pinelands that once covered southern Florida were replaced with commercial areas, crop fields, and pasture lands. Even the majority of the sawgrass south of Lake Okeechobee had disappeared. Sugar cane fields now grow there.

Photo credit:

ETE is made possible through a cooperative agreement with the NASA Goddard Space Flight Center and is supported by NASA's Learning Technology Program (LTP).

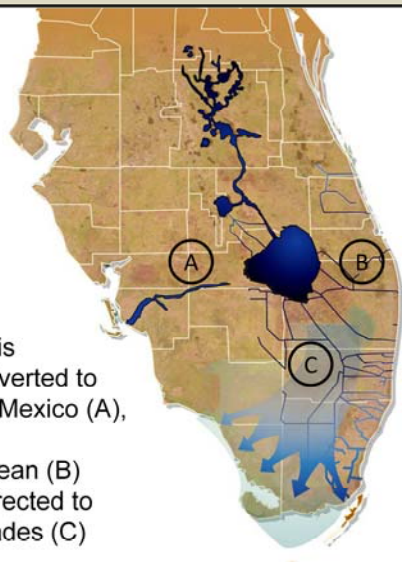


By 1973, the majority of the sawgrass south of Lake Okeechobee had been replaced by sugar cane fields (red). Urban residential and commercial areas, vegetable crop fields, and pasture lands have all expanded dramatically from the 1953 image.

Photo credit:

ETE is made possible through a cooperative agreement with the NASA Goddard Space Flight Center and is supported by NASA's Learning Technology Program (LTP).

Restoration of the Everglades



Water that is currently diverted to the Gulf of Mexico (A), and the Atlantic Ocean (B) will be redirected to the Everglades (C)

Comprehensive Everglades Restoration Plan (CERP)

- Ecosystem-based
- Uses best available science
- Adaptive management

See notes slide 40 (page 51)

Photo credits: The Comprehensive Everglades Restoration Plan (CERP)

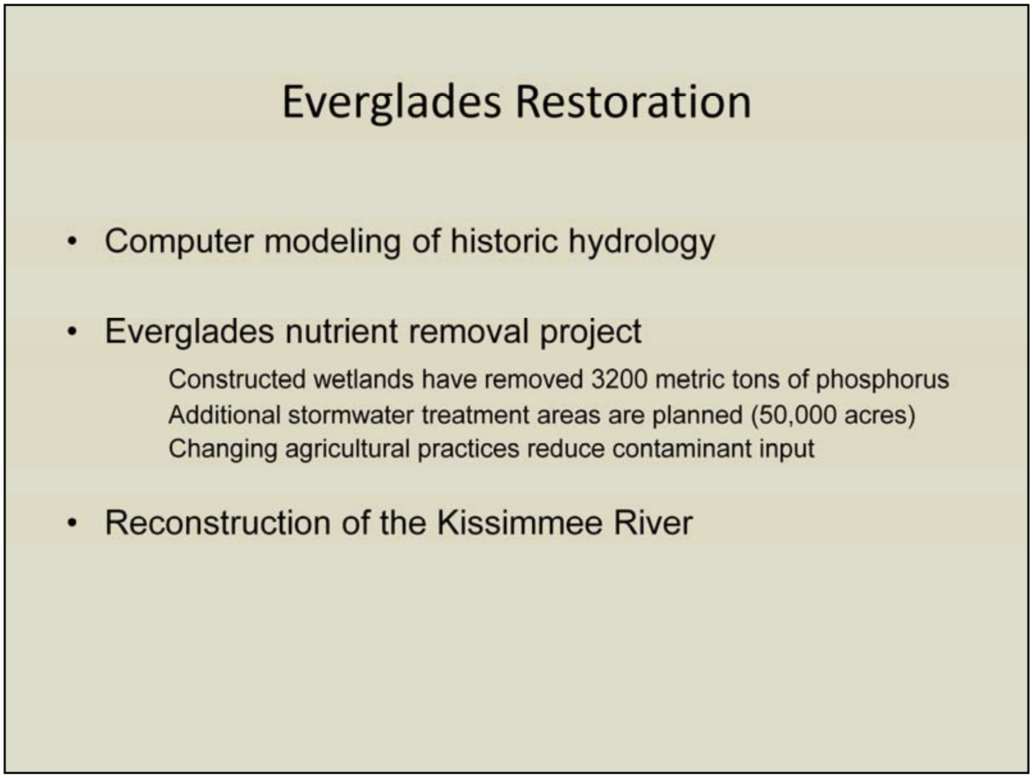
Notes slide 40 (page 51)

The overall goal of the Everglades restoration effort is to transform a highly engineered ecosystem riddled with canals and levees into an interconnected system of natural wetlands that flood and drain in a manner that resembles the historic hydrology. Once the hydrology is restored it is hoped that other indicators such as water quality and biodiversity will improve as well. The Everglades restoration effort has its origins in the early 1980s when the governor of Florida initiated the Kissimmee River Restoration Project and has been ongoing ever since.

In 2000 the Comprehensive Everglades Restoration Plan (CERP) was approved by Congress in the Water Resources Development Act and provides the framework for Everglades restoration. The plan is a cooperative effort of the U.S. Army Corps of Engineers and the state of Florida (South Florida Water Management District). It will take approximately 30 years to implement and was originally estimated to cost $7.8 billion. Federal funding for the restoration effort is approximately $165 million per year.

CERP takes an ecosystem-based approach and uses the best available science to guide the decision-making process. Due to the difficulty of implementing such a large and complex restoration project, as well as a fair amount of scientific uncertainty, the plan also takes an adaptive management approach. Adaptive management is sometimes described as “learning by doing.” In other words, once a management goal is established (e.g., reduced phosphorus levels), a plan is implemented “on the ground” that attempts to achieve that goal (e.g., establishing constructed wetlands as stormwater treatment areas). A monitoring plan is then put in place that checks to see if the desired outcome (lower phosphorus levels) is being realized. If it is, the plan is continued and perhaps expanded; if it is not, adjustments are made to improve the outcome. The cycle of planning, implementing, monitoring and evaluating is continued throughout the lifetime of the plan.

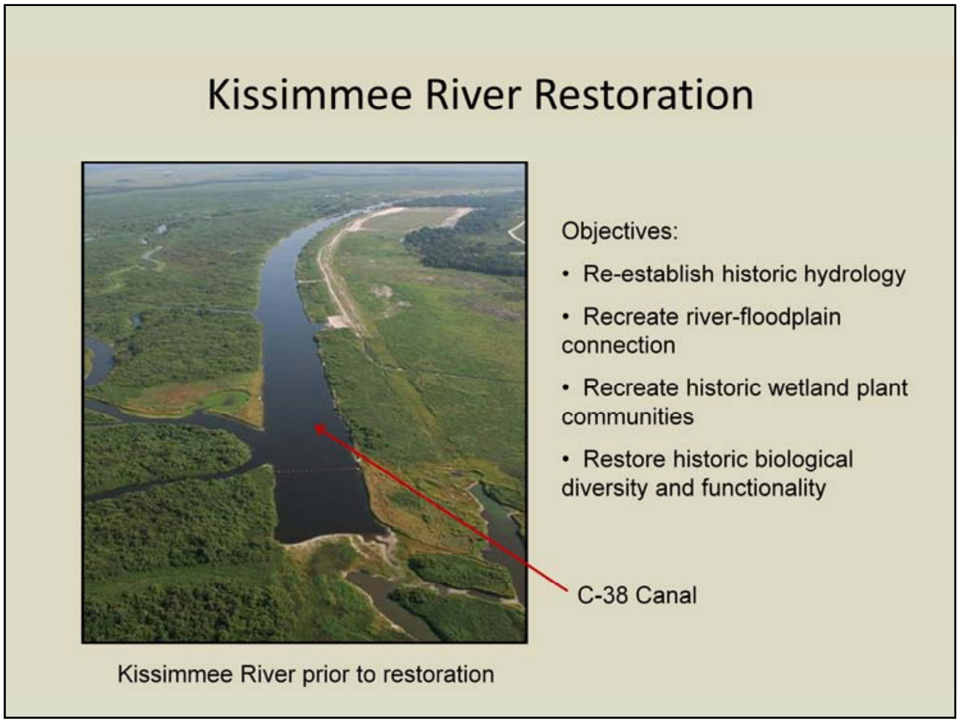
The diagram shows the expected pattern of water flow through southern Florida once CERP is fully implemented. In part, the CERP captures fresh water that was once diverted to the Gulf of Mexico and the Atlantic Ocean and redirects most of it to the Everglades. The remainder will serve agricultural and municipal water needs in the area. The pattern (quantity, timing and distribution) more closely resembles the historical hydrology than the current pattern.



Computer modeling of historic hydrology has been used to determine past hydrological conditions, especially inundation patterns, flow volumes, and the timing of flooding. Our ability to develop effective ecological models has enhanced our understanding of the complex relationship between the hydrology and ecology of the Everglades and is being used to establish targets for the restoration.

Constructed wetlands – Everglades Nutrient Removal Project – in 1994 a 3700-acre wetland was constructed in the Everglades Agricultural Area to remove phosphorus from contaminated water. An estimated 3200 metric tons of phosphorus have been removed to date. However, soil phosphorus levels still exceeded target levels in 49% of the Everglades marsh in 2005. An additional 50,000 acres of new wetlands designed to treat stormwater are planned. Agricultural practices are also being changed to reduce the amount of fertilizer and other contaminants that reach natural waterways. Runoff from agricultural fields had decreased by 55% since restoration began. Also, some cattle operations now collect waste, separate liquids and solids, use the liquid portion for irrigation and process solids into a fertilizer that is applied outside the watershed. Mercury concentration in fish has declined since the 1990s, but is still present in two-thirds of the Everglades marsh at levels that may be harmful to birds and mammals.

Reconstruction of the Kissimmee River and restoration of 26,000 acres of adjacent wetland. It will probably cost 100 times as much to put the curves back into the Kissimmee as it did to take them out. Kissimmee River restoration is shown on the following slides.



As described earlier, the Kissimmee River historically meandered approximately 103 miles from Lake Kissimmee to Lake Okeechobee through a 1-2 mile wide floodplain supporting a mosaic of wetland plant and wildlife communities. When channelization was complete in 1971, two-thirds of the historical floodplain was drained.

The Kissimmee River Restoration (KRR) Project covers about 3,000 square miles in an area from Orlando south to Lake Okeechobee.

The KRR project is intended to restore over 40 square miles of river and floodplain ecosystem including 43 miles of meandering river channel and 27,000 acres of wetlands. Restoration efforts will re-establish an environment conducive to the fauna and flora that existed there prior to the channeling efforts in the 1960s. The following are the Army Corps of Engineers goals and objectives to restore the ecological integrity of the damaged ecosystem:

- re-establish historic hydrologic conditions
- recreate the historical river/floodplain connectivity
- recreate the historic mosaic of wetland plant communities
- restore the historic biological diversity and functionality

In the upper basin, restoration efforts consist of improvements to two canals, changes in managing water levels in the lakes of the upper basin and acquisition of lands that will be restored to wetland. In the lower basin, approximately 22 miles of the C-38 Canal will be filled and nine miles of the original river channel will be excavated. Water control structures and locks will also be removed, resulting in a more natural fluctuation of water levels that will enhance marshes around the lakes and re-establish the river's hydrology. Fish and wildlife habitat in the river's floodplain will be enhanced as a result.

Photo credit: U.S. Army Corps of Engineers

Initial steps of the Kissimmee River Restoration required backfilling Canal C-38 as seen in this December 2006 photograph.

Photo credit: U.S. Army Corps of Engineers

Kissimmee River Restoration

Backfilling of C-38 Canal
March 2007

Completion of backfill in this portion of C-38 Canal - March 2007

Photo credit: U.S. Army Corps of Engineers

Looking north up C-38 canal, post-construction - August 2007. Meandering river channel seen in foreground now carries water flow, rather than the canal. Over one-third of the Kissimmee River has been restored.

Photo credit: U.S. Army Corps of Engineers

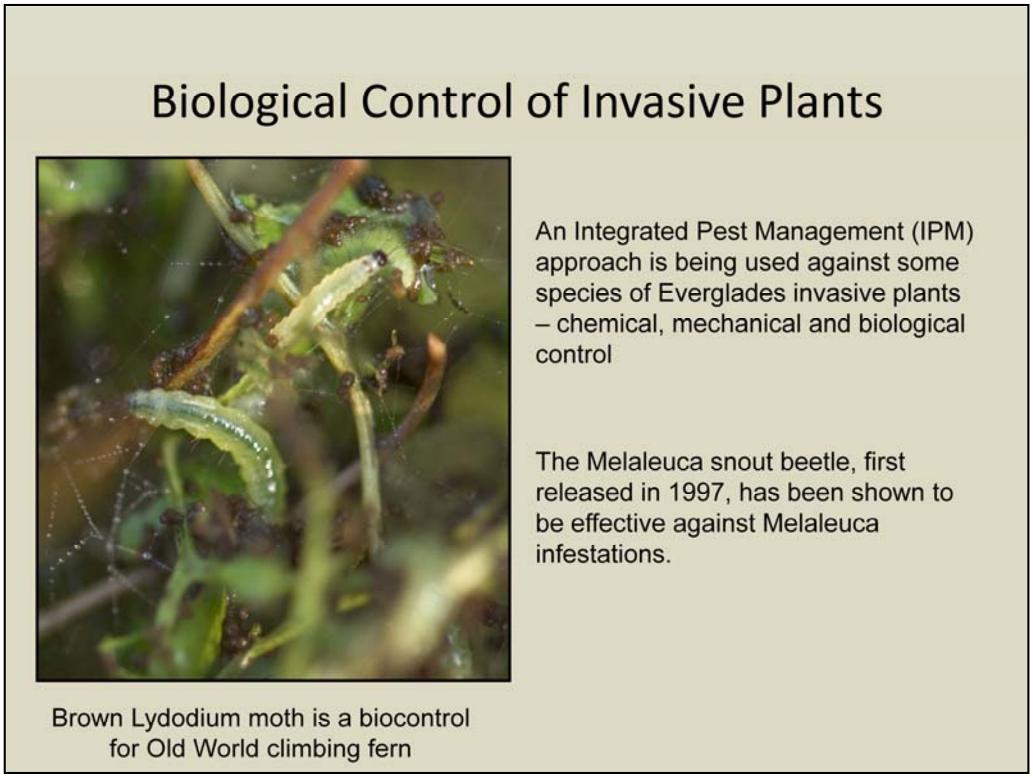
Everglades Restoration

- Computer modeling of historic hydrology
- Everglades Nutrient Removal Project
- Reconstruction of the Kissimmee River
- Removal of invasive plants

Removal of invasive plants is ongoing, but costly and controversial.

Some invasive plants have been around long enough to be used as food and habitat by native wildlife. Also, the extreme measures required to remove and prevent the re-establishment of some species is seen by some as more damaging than the invasive plants themselves. Heavy herbicide spraying, for example, may be required and, in some cases topsoil has been removed to prevent the establishment of Brazilian pepper. Nevertheless, if Everglades restoration has a chance to be successful, most agree that invasives must be brought under control and new introductions must be prevented. New screening tools are being developed that attempt to predict the threat that a species poses for invasion.

Photo credits:
Left (water hyacinth removal) – U.S. Fish and Wildlife Service, John and Karen Hollingsworth
Right (Brazilian pepper control) – U.S. Fish and Wildlife Service, Steve Hillebrand



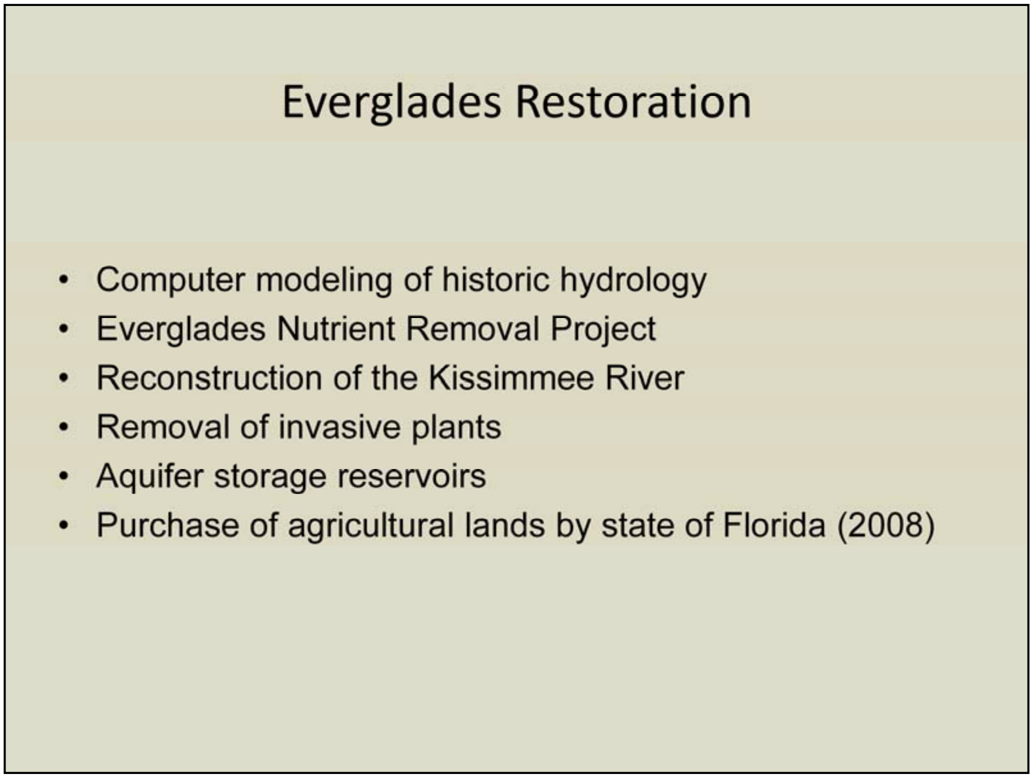
An Integrated Pest Management (IPM) approach is being used against some species of Everglades invasive plants. IPM employs a variety of methods - chemical, biological and mechanical – in an effort to maximize effectiveness while minimizing environmental risk.

Photo is larvae of Brown Lydodium moth (*Neomusotima conspurcatalis*), a biocontrol for a relatively recent invader - Old World climbing fern.

The most long-term and most effective campaign has been against Melaleuca. After two decades of effort, the species that once covered thousands of acres is now being brought under control. Five different insect species were imported from Australia as candidates for introduction. The first to be approved for release was the Melaleuca snout beetle (*Oxyops vitiosa*) in 1997. Both larvae and adults feed on Melaleuca. On South Florida test sites, reduced flowering and seed production has been observed. A redistribution program (collection and dispersal of adults) assures that the species will establish in all 22 of Florida's counties that have Melaleuca infestations.

See Cuda, et al. (2009) for details

Photo credit: Southwest Florida Water Management District



Aquifer Storage Reservoirs – plan to store excess surface water during high water and pump into underground aquifers for storage and then to pump back up when needed to maintain flows. Some scientists have serious reservations about this part of the restoration plan, suggesting that water stored in aquifers may have accumulated contaminants that would have harmful effects on the ecosystem. Many would prefer to see the removal of more barriers to natural flow.

See *NRC panel pokes holes in Everglades scheme*. Science 9 February 2001.

In 2008, a $1.75 B purchase of 187,000 acres of agricultural lands south of Lake Okeechobee by the state of Florida from the U.S. Sugar Corporation was proposed. The U.S. Sugar Corporation is the largest sugar cane producer in the nation. However, by October of 2010, the deal had been scaled back to 26,800 acres (42 mi^2) for $197 million due to the economic recession. Farming will be allowed to continue until 2014 and then the Army Corps of Engineers will flood the land. This should also end the use of phosphate fertilizer in these areas. The state plans to recreate strategically placed wetlands where sugar cane was once grown. Some of the land may be swapped with other landowners to create a contiguous system. This system is expected to increase storage capacity and may make the planned (but unproven) aquifer storage reservoirs obsolete.

Restoration of the Everglades is a large-scale, expensive and long-term endeavor. Most wetland restoration projects by comparison are tiny. It is best described as a “work in progress.” Humans have never before embarked on such an ambitious ecological restoration project. There are divergent views by different stakeholders and an element of scientific uncertainty; however, adaptive management and an ecosystem-based approach are commonly cited as reasonable approaches by most involved. The importance of getting the hydrology right is emphasized in the unofficial motto of the restoration effort, “Wet it and they will come.”

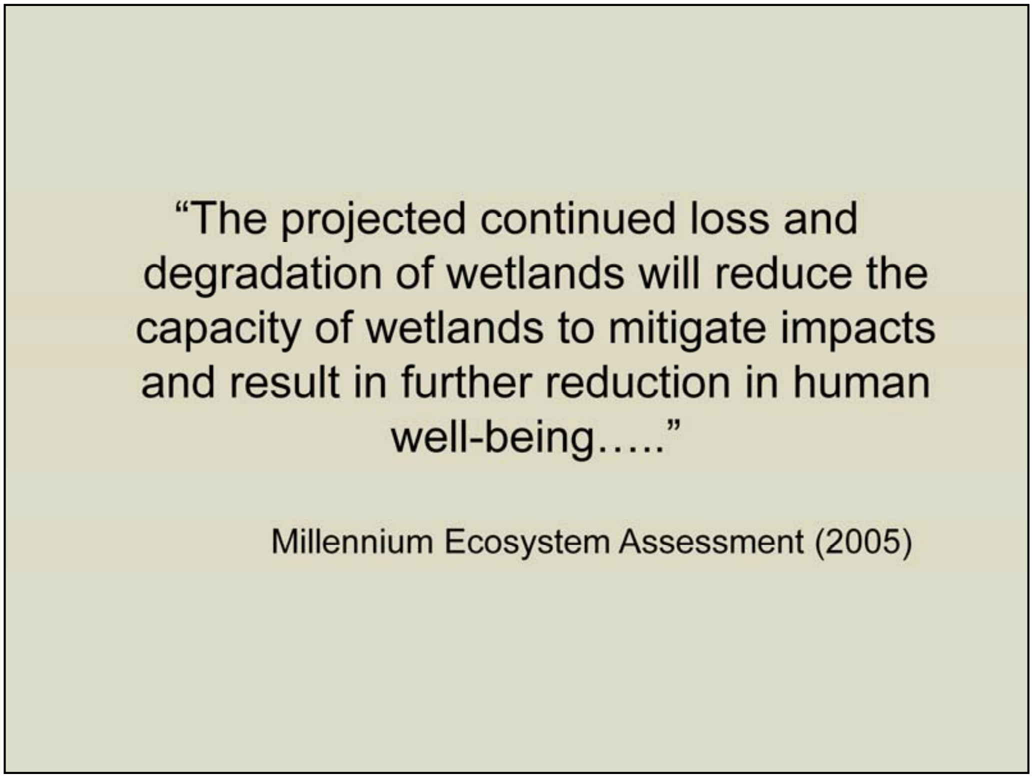
As an example of some of the challenges faced by a restoration of this magnitude:

Restoration efforts will increase water flow to the Everglades. This increased flow may flood tree islands in the central Everglades, which provide essential roosting and nesting habitat for snail kites, wood storks and other wading birds. The Miccosukee Tribe is also concerned about the loss of tree islands, which are used for ceremonial purposes. The tribe also has 100,00 hectares of flood-susceptible land holdings within the Everglades including large residential areas and a $50 million casino.

See *Everglades restoration plan hits rough waters*. Science 19 May 2000.

Photo shows wood storks along the Kissimmee River in the Everglades representing the desired future condition.

Photo credit: U.S. Army Corps of Engineers



The Everglades Ecosystem Restoration Project is one of the largest and most ambitious examples of wetland restoration. It represents one of society's responses to past and future wetland losses. The importance of wetland conservation efforts such as this to "human well-being" is illustrated in this quote from the Millennium Ecosystem Assessment completed in 2005.

"The projected continued loss and degradation of wetlands will reduce the capacity of wetlands to mitigate impacts and result in further reduction in human well-being….."

Millennium Ecosystem Assessment (2005)

Wetlands (and coastal wetlands in particular) ... "are usually the first casualty in the endless battle to tame our surroundings and because they are situated in our most densely populated areas." Grant, D. Protecting Coastal Wetlands. Underwater Naturalist 26:1-11.

1. Effective wetland restoration will require large-scale watershed level approaches that are based on the ideals of ecosystem management.

2. Only 25% of U.S. wetlands in the lower 48 are under federal ownership, most of the remaining 75% is privately owned. Therefore, wetland protection must involve private landowners. As a result, wetland protection often falls into the category of conflicts between private property rights advocates and those that see a public role for wetlands protection. Public education on the ecological importance of wetlands, paired with tax incentives, purchase from willing sellers and other cooperative programs will play an important role in encouraging private landowners to protect and conserve wetlands.

3. New strategies will need to recognize the connections that exist between our economy, our well-being and the sustainability of wetland ecosystems.

4. In addition to the societal challenges to an ecosystem-based approach, there are scientific challenges as well. For example, we still lack a comprehensive, standardized inventory of the wetland resource. The distribution of wetland types, the ecosystem services they provide and threats to those services is required to assess the current condition. Only then will we be able to develop strategies to conserve that resource and convince decision-makers that the strategies are based on sound reasoning – that essential services are provided by wetlands, that human activities impact these services and that there are resultant impacts on human well-being (MEA 2005).

5. A meaningful conservation strategy would be a challenge even if threats to wetlands remained static. However, it is now clear that if anything, the trajectory of threats to wetlands is likely to get steeper as human populations increase and the effects of climate change are exerted upon this resource.

Summary – Wetland Restoration

- Wetland restoration is the return of a wetland from a disturbed or altered condition to some improved condition
- Common elements include the removal of physical stressors, restoration of hydrology, the control of invasive species, re-establishment of native plants and animals, and monitoring
- The Everglades Ecosystem of South Florida has been the focus of large-scale restoration since the 1980s
- Historical degradation of the Everglades has been characterized by disturbed hydrology, growing demands for land and freshwater, oxidation of peat soils, introduction of invasive species and poor water quality
- Everglades restoration emphasizes the return of historical hydrological conditions, the use of wetlands to improve water quality, the reconstruction of the Kissimmee River and the control of invasive species
- Broad-scale, ecosystem based approaches are likely to result in the most effective restoration projects

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Wetland Restoration in the Everglades – Resources

Wetland Restoration and Conservation

Biebighauser, T.R. 2007. Wetland drainage, restoration and repair. Univ. Press of Kentucky, Lexington, KY 273 pp.

The Conservation Foundation. Protecting America's wetlands: An action agenda. World Wildlife Fund, Washington, D.C.

Cuda, J.P., et al. 2009. Classical biological control of weeds with insects: Melaleuca weevil. ENY-823 (IN 172). Entomology and Nematology Department, Florida Cooperative Extension Service, Univ. of Florida.
www.edis.ifas.ufl.edu

DeWeerdt, S. 2004. Reflections on the pond. Conservation Magazine 5(1).
www.conservationmagazine.org
http://www.conservationmagazine.org/2008/07/reflections-on-the-pond/

Doremus, H. and A. Dan Tarlock. 2008. Water war in the Klamath Basin. Island Press, Washington, D.C.

This book examines the battle over the Klamath Basin, which straddles the southern Oregon-northern California border. The controversy represents a classic clash between competing interests for limited natural resources. Wetlands management and restoration plays a pivotal role as much of the basin was drained for farmland early in the 20th century.

Ducks Unlimited. 2010. Marsh terraces as a conservation practice.
www.ducks.org/Louisiana/LouisianaConservation/1724/MarshTerracesasaConservationPractice.html

Egan, D. and E.A. Howell. 2005. The historical ecology handbook. Island Press, Washington, D.C. 488 pp.

Although not written specifically for wetlands, this guide provides some general practices used to determine the historical conditions of a landscape. Modern wetland restoration approaches often use historical conditions as targets for restoration efforts.

Hammer, D.A. 1997. Creating freshwater wetlands. 2nd ed. CRC Press, Boca Raton, Florida. 406 pp.

Harwell, M.A. 1997. Ecosystem management of South Florida. BioScience 47:499-512.

This article describes the application of ecosystem management to the South Florida regional ecosystem dominated by the Everglades.

Hodder, J., et al. 2005. Unraveling complexity: building an understanding of Everglades restoration. Frontiers in Ecology and the Environment 3:170-171.

This brief article describes an interesting approach to teaching Everglades restoration to undergraduates. It is based on an analysis of Skylar, et al. (2005).

Keddy, P.A., et al. 2009. Wet and wonderful: The world's largest wetlands are conservation priorities. BioScience 59:39-51.

Kusler, J.A. and M.E. Kentula (eds.). 1990. Wetland creation and restoration: The status of the science. Island Press, Washington, D.C. 591 pp.

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

Mitsch, W.J., et al. 1998. Creating and restoring wetlands. BioScience 48:1019-1030.

This article describes an experimental approach to wetland restoration at Olentangy River Wetland Research Park at The Ohio State University.

Mitsch, W.J. and R.F. Wilson. 1996. Improving the success of wetland creation and restoration with know-how, time and self-design. Ecological Applications 6:77-83.

The authors argue that the relatively high failure rate of wetland mitigation projects could be reduced with a greater understanding of wetland function, allowing the system time to establish (15-20 years for freshwater marshes) and allowing for the self-designing capacity of wetlands.

Naiman, R.J. and K.H. Rogers. 1997. Large animals and system-level characteristics in river corridors. BioScience 47:521-529.

Nakamura, K., et al. 2006. River and wetland restoration: Lessons from Japan. BioScience 56:419-429.

Ramsar Convention on Wetlands
The Ramsar Convention Secretariat, Gland, Switzerland.
www.ramsar.org.

Rood, S.B. 2003. Flows for floodplain forests: A successful riparian restoration. BioScience 53:647-656.

Skylar, F.H., et al. 2005. The ecological-societal underpinnings of Everglades restoration. Frontiers in Ecology and the Environment 3:161-169.

South Florida Ecosystem Restoration Task Force. 2010. New Science: Advancing understanding of the South Florida ecosystem. Information Brief Series May 2010. 4 pp.
www.sfrestore.org

Streever, B. and J. Zelder. 2000. To plant or not to plant. BioScience 50:188-190.

Tiner, R.W. 1995. Wetland restoration and creation.

Tiner, R.W. 2003. Restoring wetland and streamside/riparian buffers.

U.S Geological Survey. Wetland restoration bibliography.
http://www.usgs.gov/science/cite-view.php?cite=1335
http://www.npwrc.usgs.gov/resource/literatr/wetresto/

U.S. Army Corps of Engineers and South Florida Management District. 2010 Comprehensive Everglades Restoration Plan.
www.evergladesplan.org

Zelder, J.B. and J.C. Calloway. 1999. Tracking wetland restoration: Do mitigation sites follow desired trajectories? Restoration Ecology 7:69-73.

Zelder, J.B. (ed.). 2001. Handbook for restoring tidal wetlands. Marine Science Series. CRC Press LLC, Boca Raton, Florida.

NOTE: Although this module emphasizes wetland restoration efforts in the Everglades, there are certainly several other large-scale projects that could be discussed. The following is a partial list:

Mesopotamian marshlands (southern Iraq and Iran)
Aral Sea
Mississippi River Basin / Prairie Pothole Region
Delaware Bay
Chesapeake Bay
Mississippi Delta (Louisiana)
South San Francisco Bay

NOTE: There are also a number of non-governmental organizations engaged in wetland restoration. The following is a sampling of some of the more prominent ones:

Ducks Unlimited www.ducks.org
The Nature Conservancy www.tnc.org
Chesapeake Bay Foundation www.cbf.org
Isaac Walton League of America www.iwla.org
Audubon Society www.audubon.org

Wetland Restoration in the Everglades – Video Resources

Trail of the Cougar. 2002. NATURE. DVD 60 min.
www.pbs.org

This NATURE episode on cougars includes a 10-minute segment on the biology, status and conservation of the Florida panther, an iconic species of the Florida Everglades.

Water's Journey – Everglades: Restoring Hope. 2006. DVD 60 min.
Water's Journey – Everglades: Currents of Change. 2006. DVD 60 min.
www.karstproductions.com
Karst Productions, Inc.
5779 NE County Road 340
High Springs, FL 32643
1-888-354-2376
$39.95 for both

These two videos document the natural history, historical degradation and restoration of the Everglades. Excellent animations are included. Detailed notes and approximate time markers for each video follow. This should allow instructors to select the most appropriate segments for their courses.

Water's Journey – Everglades: Restoring Hope. 2006. DVD 60 min.

0:00
INTRODUCTION

- Everglades described as Florida's "original Magic Kingdom"
- After 100 years of human impact the Everglades are the focus of the largest restoration ever attempted

HISTORY OF FLOOD CONTROL

- Hurricane Wilma threatened south Florida as the strongest hurricane ever recorded
- The South Florida Water Control Center is responsible for water management and flood control
- Waters of Lake Okeechobee are held back by a system of levees and dams
- Low-lying south Florida (like New Orleans) is prone to flooding
- In the 1920s several hurricanes caused extensive south Florida flooding, killing over 3000 people
- War was declared on water and a dike 40 feet high and 80 miles long was constructed to reduce flooding risk
- Water was declared an "enemy of the state," yet water supports the unique biodiversity found in the Everglades

0:10

CHANGES TO THE SOUTH FLORIDA WATERSHED

- Computer simulation of south Florida water flow illustrates sheet flow through a "river of grass" and the transformation of this system over a period of 50 years that resulted in loss of about half of the Everglades
- Everglades ecology and management will be illustrated using video from water level (kayaking and diving) and from the air (aerial photography from helicopter)
- The south Florida watershed extends as far north as just south of Orlando and Florida's famous theme parks
- Headwaters of the Everglades start in the Kissimmee River Basin (Lake Russell)
- Cypress swamp – most of large cypress trees were logged in the last century
- Draining of the Everglades began in the late 1800s by re-routing the Kissimmee River directly into Lake Okeechobee and diverting water both east and west to the ocean
- The Army Corps of Engineers describes water as the "scourge of mankind" and attempts to control the "monster of Lake Okeechobee"
- The meandering Kissimee River was transformed into a 56-mile, 30 feet deep canal and over half a million acres of wetlands were drained for agricultural use
- Phosphorus-rich water from runoff went directly into Lake Okeechobee and then was diverted by canals into the Gulf of Mexico to the west and the Atlantic Ocean to the east
- Once the system was completed in 1971, it was already apparent that it never should have been built

0:20

KISSIMMEE RIVER RESTORATION

- Some ranchland is being converted into natural and treatment wetlands
- Suburban sprawl into agricultural land is occurring and loss of agricultural land is a concern
- Farmers say that "houses are the final crop"
- The Kissimmee River is a meandering connection between Lake Kissimmee to the north and Lake Okeechobee to the south
- Straightening of the Kissimmee River and the loss of its associated wetlands results in a loss of the filtering function of marshes and provides a direct pipeline of contaminated water into the Everglades
- Restoration efforts include back-filling the canal and putting meanders back into the Kissimmee River
- When this is done, the ecosystem recovers rapidly, bird diversity and abundance increases and, as a result of increased "dwell time" in natural wetlands, the natural filtering function is restored
- Lake Okeechobee is the 4th largest lake in the U.S., but its size has decreased due to the construction of levees and it has had persistent water quality problems, especially increased phosphorus enrichment causing algal blooms
- Explosive algal blooms and plant growth result in excess decomposition which depletes water of dissolved oxygen causing dead zones
- One restoration goal is to re-direct water south to the Everglades

0:30

CHANGING AGRICULTURAL PRACTICES

- Best management practices (BMPs) for agricultural waste management are being used to reduce contaminant input into waterways
- Direct discharge from livestock operations (confined animal feeding operations) is a primary source of contamination
- BMPs include waste collection and separation of liquids and solids
- Liquids are used for irrigation of crops and solids are processed for fertilizer use outside the basin
- Computer simulation of water flow emphasizes the flow of contaminated water from agricultural and urban areas to Lake Okeechobee all the way to coastal estuaries
- Restoration puts water “back where it belongs”

THE EVERGLADES AGRICULTURAL AREA

- Everglades Agricultural area (EAA) is a huge (1 million acres) rich agricultural area that lies south of Lake Okeechobee
- This is a highly productive agricultural area due to the subtropical climate and the rich peat soils (“black gold”)
- Peat soils were produced over long periods of time due to partial decomposition of aquatic vegetation and accumulation of organic matter
- However, once wetlands are drained, the peat soils can easily erode and are lost to biological oxidation (decomposition); once exposed to air organic material is released as carbon dioxide to the atmosphere
- Sugar industry has been a powerful political force supported by government subsidies to sugar cane farmers
- U.S. tried to reduce the economic power of Fidel Castro in Cuba by promoting sugar production in the Everglades
- At its height, per capita consumption of Everglades sugar in the U.S. was about 40 pounds per year

0:40

- Demand for agricultural land, flood control and the mentality of needing to control the natural world for the benefit of mankind all led to the decline of the Everglades
- Draining of the Everglades for flood control and agricultural use (from the Everglades Agricultural Area) was a public decision, supported by 90% of voters

WATER CONTAMINATION AND ITS IMPACTS

- Reducing the phosphorus content of Everglades soil and water is a costly and elusive goal of Everglades restoration.
- A 10 ppb limit on phosphorus has been established and the combination of changed agricultural practices along with wetland restoration has reduced phosphorous by 55%
- One sugar cane operation in EAA has 150 ppb phosphorus coming in and 90 ppb going out, suggesting that phosphorus is being removed by their operation
- There has been some pressure to sell sugar lands (NOTE: See update in *NCSR Wetland Mitigation Module*).

- The decline of the Everglades had an impact on Native Americans of the Everglades – the Seminole and Nikasookee tribes
- Fish are no longer eaten due to mercury contamination
- “Nature ties everything together”
- Sue Newman – wetland scientist studies impacts of phosphorus in Everglades
- Cattails, although native to the Everglades, become a nuisance due to phosphorus enrichment
- There is a community shift that promotes pure stands of cattails that replace a more open and diverse plant community
- Cattail stands are too dense to support wetland wading birds
- Stormwater Treatment areas (STAs) are used to extract phosphorus from Everglades water
- Phosphorus levels drop as you go south

0:50

- Calcareous periphyton are the base of Everglades food webs and its presence indicates a healthy ecosystem condition
- Everglades are a unique, low-nutrient system and addition of phosphorus disrupts natural balance of species
- Periphyton deposit calcium rather than phosphorus giving algae a filmy, whitish appearance

STORMWATER TREATMENT AREAS (STAs)

- The global loss of wetlands has reinforced our understanding of the nutrient removal function of wetlands
- Storm water treatment areas are located 20 miles west of West Palm Beach
- Over 10 million more people have settled in south Florida in the past 40 years placing additional strain on the system
- STAs recreate a wetland that was once present and divert contaminated water through a series of cells, each performing a slightly different function – a staged process based on different species’ ability to process water at different levels of contamination.
- Computer simulation illustrates flow of contaminated water from Everglades Agricultural Area to pump station to treatment cells of cattails, then submerged aquatic plants to periphyton and then south to Everglades.
- Over 2200 metric tons of phosphorus have been removed using STAs and best agricultural management practices over the past decade
- Further improvements will require implementation on a massive scale
- Summary of restoration efforts
- Over one-third of the Kissimmee River has been restored to its natural course
- Lake Okeechobee improvement continues and is of highest priority
- Runoff from agricultural fields has declined by 55%
- STAs continue to remove phosphorus from Everglades water and 50,000 additional acres are planned
- There is however, continued loss of natural wetlands to urban development

0:60 END

Water's Journey – Everglades: Currents of Change. 2006. DVD 60 min.

0:00
INTRODUCTION

- Florida's population is over 22 million and that number increases as more tourists visit
- The past 100 years of Everglades degradation are summarized along with current efforts to restore the "river of grass"
- Everglades was originally described as a "disease-ridden wasteland" that would yield "untold riches if drained"
- Content of previous production (*Everglades – Restoring Hope*) are summarized (Kissimmee River, agricultural practices, storm water treatment areas, etc.)

0:10
TREE ISLANDS

- At elevations only slightly above the water level, tree islands within the Everglades marsh are the only dry land available
- Although they account for only about 10% of the area of the Everglades, they account for about half of its biodiversity
- Environmental scientist, Fred Sklar studies and monitors rates of soil creation and loss by using a white feldspar powder to mark time in soil horizons
- A 5-year marker indicates that soils in this area are being built and organic material is accumulating
- Soil building and water levels (the right amount of water delivered at the right time) is critical to the biodiversity of the Everglades (feeding and nesting behavior of birds is used as an example)
- Mike Owen monitors hurricane impacts on Everglades – examines impacts of high and low water levels

0:20
UNIQUE EVERGLADES BIODIVERSITY

- Alligators as a keystone species – top predator and alligator depressions produce a unique habitat
- Golden Gate Estates was a planned development that was stopped due to concerns about habitat loss – canals filled
- Ghost orchids are among the most endangered Everglades plant species – occupy unique Everglades habitat – the Tachahatchee Strand (the "Amazon of Florida")
- Less than 300 ghost orchids are known to occur in Florida
- Require clean, low nutrient water
- One farmer reserves agricultural land for water treatment wetlands and uses a closed loop irrigation system that recycles irrigation water, thereby reducing the leaching of phosphorus into the Everglades
- Night exploration for Everglades species is illustrated – spiders, alligators

0:30

THE IMPACT OF INVASIVE SPECIES

- Invasive plants and animals pose an additional threat to Everglades biodiversity
- *Lygodium* (Old World climbing fern) – outcompetes native vegetation, increases fire risk to canopy trees and their sheer weight can break tree branches
- There are several intentional introductions – e.g., Melaleuca – originally introduced from Australia to help drain wetlands; over 1 million acres have been removed but over 2 million acres remain
- Burmese pythons – intentional releases from pet trade also invasive

THE ROLE OF FIRE

- Role of fire in Everglades – historically lightning causes and later set by Native Americans
- Serve to increase soil fertility, keep out invasives and remove thick understory in a "gentle burn"
- Second in importance only to water
- Historical and current fire suppression has been the rule, but some attempts to reintroduce fire through prescribed burns (must be limited due to risk to human structures)

EXAMPLES OF SUSTAINABLE DEVELOPMENT

- Veneta Bay – an example of a sustainable development in the Everglades
- Flowing waterways restored creating wildlife habitat, storm water treatment areas and flood protection
- Although population growth is inevitable, sustainable developments like these may minimize environmental impact
- Native landscaping is promoted rather than manicured lawns

0:40

- Tamiami Trail – a roadway in the Everglades that presents barricades to water flow
- Restoration efforts are trying to restore sheet water flow by creating openings in or removing roads

COASTAL ECOSYSTEMS – MANGROVES AND ESTUARIES

- Mangroves are found in coastal areas where they serve as "giant strainers," provide important protected areas for juvenile fish, protect the coast against hurricanes and storm surges
- Estuaries provide habitat for most of Florida's recreationally important fish species
- Coastal development is a threat to mangrove and estuary ecosystems
- In Florida Bay, saltwater intrusion has resulted in a proliferation of more saltwater species; sea grasses die creating more algal blooms and decreasing water quality
- The Florida Keys coral reef in Florida Bay is the only reef in North America
- Central and South Florida Flood Control
- Fish among mangrove roots and a nursery area
- Everglades water flows into coral reefs and far out into ocean – illustrates interconnected nature of these ecosystems
- Coral reefs described as the "rainforests of the sea"

MARINE ECOSYSTEMS – CORAL REEFS AND OPEN OCEAN

- Florida Keys National Marine Sanctuary
- Scientists study phosphorus impacts on coral reefs
- Elkhorn corals affected and are covered and replaced by algae
- Coral bleaching due to climate change (elevated temperatures) is also evident
- Coral diseases (red band and black band disease) also appear to be caused by climate change

0:50

- "Aquarius" is an underwater research station used to study biodiversity of marine and coral reef ecosystems (stationed at 60-foot depth)
- Reefs are downstream from entire Everglades ecosystem
- Loss of mangroves impacts water quality
- Decline of marine environment means loss of food sources and recreational opportunities
- Open ocean in gulf Stream is located 6 miles offshore
- Fluorescene dye is used to demonstrate water currents
- "We have chosen growth as a mark of success"
- Summary of main points

0:60 END

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.