

Carolina Bays: An Ecological Site Description (ESD) and Middle School Educational Module

By

Samuel J. Ford

Submitted to the Graduate Faculty of
North Carolina State University
In partial fulfillment of the
Requirements for the Degree of
Master of Natural Resources

Assessment and Analysis Option

Raleigh, NC

April 4, 2021

Approved by advisory committee:

Zakiya Leggett, chair

Michael Vepraskas

Kathryn Stevenson

Table of Contents

Section 1: Carolina Bays: An Ecological Site Description (ESD).....	1
References: Carolina Bays: An Ecological Site Description (ESD).....	16
Section 2: North Carolina Wetlands - An Educational Module on Carolina Bays.....	17
References: North Carolina Wetlands – An Educational Module on Carolina Bays.....	35

Carolina Bays: An Ecological Site Description (ESD)

MRLA 153A

This MLRA ranges from Virginia (3%) down to Florida (10%) and passes through North Carolina (29%), South Carolina (30%), and Georgia (28%). This MLRA lines up with EPA Level III Ecoregion 63 – Middle Atlantic Coastal Plains and 75 Southern Coastal Plains. The EPA Ecoregion Level IV for this MLRA are 63h, 63n, 63e, 63c, 63b, 75j, 75f, 75g, and 75h (USDA, 2006; EPA. n.d.).

Physiography

This area is a part of the coastal plain of the Atlantic plain. The slope of this area is relatively flat with many shallow valleys and meandering streams and rivers. The slopes can become steep near the banks of streams and rivers. The elevation of this area ranges from 25 to 165 feet. The local relief is typically less than 35 feet (USDA, 2006).

Geology

The area is made mostly of unconsolidated coastal sediment that are Tertiary and Quaternary in age. The sediments are a mixture of river-laid sediments found in old riverbeds, terraces, flood plains, and deltas. The young sediments are made of clay, sand, gravel, and silt. Beneath the surface, Cretaceous marine, near-shore shale, sandstone, and limestone are found as bedrock. Swamps were commonly found in this area before being drained for agriculture. The water table is typically close to the surface and it is common to have soils with restricted drainage (USDA, 2006).

Soils

The most common soils found in this area are Spodosols and Ultisols. The soils have a thermic temperature regime, have an aquic or udic moisture regime, and siliceous or kaolinitic mineralogy. The soils are typically very deep, well drained to very poorly drained, loamy or clayey soils. The soils found in this area are Paleaquults, Paleudults, Kandiudults, Albaquults, Alaquods, and Haplosaprists (USDA, 2006).

Biological Resources

The dominant canopy vegetation is pine-oak forests. The uplands consist of loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), red maple (*Quercus rubra*), and oaks (red and white species). The bottomland consists of red maple (*Quercus rubra*), water tupelo (*Nyssa aquatica*), swamp blackgum (*Nyssa biflora*), bald cypress (*Taxodium distichum*), and sweetgum (*Liquidambar styraciflua*). The dominant understory is longleaf uniola (*Chasmanthium sessiliflorum*), cutover muhly (*Muhlenbergia capillaris*), toothache grass (*Ctenium aromaticum*), panicums, little bluestem (*Schizachyrium scoparium*), and associated grasses and forbs. The wildlife present is typical of the southeast which consist of white-tail deer (*Odocoileus virginianus*), racoons (*Procyon lotor*), squirrels (*Sciuridae sp.*), opossums (*Didelphidae sp.*), bobwhite quail (*Colinus virginianus*), turkey (*Meleagris gallopavo*), skunks (*Mephitidae sp.*), and bobcats (*Lynx rufus*) (USDA, 2006).

MRLA 153B

This MLRA ranges from Virginia (17%) down to Florida (5%) and passes through North Carolina (35%), South Carolina (22%), and Georgia (21%). This MLRA lines up with EPA Level III Ecoregion 63 Middle Atlantic Coastal Plains and 75 Southern Coastal Plains. The EPA Ecoregion Level IV for this MLRA are 63h, 63n, 63e, 63c, 63b, 75j, 75f, 75g, and 75h (USDA, 2006; EPA, n.d.).

Physiography

This area is a part of the coastal plain of the Atlantic plain. The slope of this area is relatively flat with many shallow valleys and meandering streams and rivers then terminate into estuaries along the Atlantic coast. The slopes can become steep near the banks of streams and rivers. The elevation of this area ranges from sea level to 25 feet. The local relief is typically around 3 feet (USDA, 2006).

Geology

The area is made mostly of unconsolidated coastal sediment that are Tertiary and Quaternary in age. The sediments are a mixture of river-laid sediments found in old riverbeds, terraces, flood plains, and deltas. The young sediments are made of clay, sand, gravel, and silt. The islands and coasts are covered in sand derived from these sediments. Beneath the surface, Cretaceous marine, near-shore shale, sandstone, and limestone are found as bedrock. The aquifers in this area are near the surface, so nitrate contamination is an issue in some areas (USDA, 2006).

Soils

The most common soils found in this area are Alfisols, Entisols, and Histosols. The soils have restricted drainage and a thermic temperature regime, have an aquic or udic moisture regime.

The northern area has mixed mineralogy while the southern area has mixed clays with siliceous sand mineralogy. The soils are typically very deep loamy or clayey soils. The soils found in this area are Endoaquults, Umbraquults, Endoaqualfs, Albaqualfs, Hapludults, Alaquods, Psmments, and Aquents. The Histosols in this area are associated with the Great Dismal Swamp and pocosins (USDA, 2006).

Biological Resources

The dominant canopy vegetation is pine-oak forests. The uplands consist of loblolly pine (*Pinus taeda*) and oaks (red and white species). The bottomland consists of oaks (*Quercus sp.*), water tupelo (*Nyssa aquatica*), swamp black gum (*Nyssa biflora*), bald cypress (*Taxodium distichum*), and sweetgum (*Liquidambar styraciflua*). The dominant understory is longleaf uniola (*Chasmanthium sessiliflorum*), panicums, little bluestem (*Schizachyrium scoparium*), switch cane, inkberry, large gallberry, greenbrier, wax myrtle, cabbage palm, and associated grasses and forbs. The wildlife present is typical of the southeast which consist of white-tail deer (*Odocoileus virginianus*), racoons (*Procyon lotor*), squirrels (*Sciuridae sp.*), opossums (*Didelphidae sp.*), bobwhite quail (*Colinus virginianus*), turkey (*Meleagris gallopavo*), skunks (*Mephitidae sp.*), bobcats (*Lynx rufus*), minks, otters, and muskrats (USDA, 2006).

MRLA 133A

This MLRA ranges from Virginia (5%) down to Florida (8%) and over to Louisiana (1%) passes through North Carolina (7%), South Carolina (4%), Georgia (21%), Mississippi (24%) and Tennessee (4%). This MLRA lines up with EPA Level III Ecoregion 65 Southeastern Plains. The EPA Level IV Ecoregions are 65p Southeastern Floodplain and Low Terraces and 65l Atlantic Southern Loam Plain (USDA, 2006; EPA, n.d.).

Physiography

This area has gently undulating valleys and sloping to steep uplands. It becomes flatter the closer to the coastlines. The streams are narrow near their source and then become broad meandering channels as they approach the coast. The elevation of this area ranges from 80 to 655 feet. The elevation decreases from the interior to the coast. The local relief is typically 10 to 20 feet but can be 80 to 165 feet in some areas (USDA, 2006).

Soils

The most common soils found in this area are Ultisols, Entisols, and Inceptisols. The soils have somewhat excessively drained to poorly drained drainage classes, a thermic temperature regime, and aquic or udic moisture regimes. The soils are typically very deep, loamy, with siliceous or kaolinitic mineralogy. The soils found in this area are Hapludults, Kandiudults, Fragiudults, Paleudults, Fluvaquents, Endoaquepts, Quartzipsamments, and Paleaquults (USDA, 2006).

Biological Resources

The dominant canopy vegetation is pine-oak forests. The overstory consists of loblolly pine (*Pinus taeda*) and oaks (red and white species), slash pine (*Pinus elliottii*), shortleaf pine (*Pinus echinata*), sweetgum (*Liquidambar styraciflua*), and yellow-poplar (*Liriodendron tulipifera*).

The understory consists of dogwood (*Cornus sp.*), gallberry (*Ilex glabra*), and farkleberry (*Vaccinium arboreum*). Other understory is panicum's (*Panicum sp.*), little bluestem (*Schizachyrium scoparium*), greenbrier (*Smilax sp.*), common sweetleaf (*Symplocos tinctoria*), American holly (*Ilex opaca*), southern bayberry (*Myrica cerifera*), Elliott bluestem (*Andropogon gyrans*), native lespedezas (*Lespedezas sp.*), and associated grasses and forbs. The wildlife present is typical of the southeast which consist of white-tail deer (*Odocoileus virginianus*), racoons (*Procyon lotor*), squirrels (*Sciuridae sp.*), opossums (*Didelphidae sp.*), bobwhite quail (*Colinus virginianus*), turkey (*Meleagris gallopavo*), skunks (*Mephitidae sp.*), and bobcats (*Lynx rufus*) (USDA, 2006).

Carolina Bays

Ecological Site Concept

These systems are found in the Coastal Plain region from Virginia to Florida. The sites extend from the coast to the fall line, which separates the Coastal Plain from the Piedmont. They are predominantly found in North Carolina and South Carolina. The sites are oriented along their long axis on a northwest to southeast direction. The sizes of the sites are variable, they can be less than a hectare to thousands of hectares. The soils within the sites can vary, some may have mineral soils, mucky mineral soils, or even deep organic soils. The sand rims typically surround most Carolina Bays are typically sandy mineral soils with higher elevations along the southeast

rim. Some sites are underlain by an impervious clay layer which inhibits vertical movement of water. The hydrology is mostly controlled by precipitation and evaporation. There are a few cases of the wetlands having streams running through them, influenced by groundwater inputs, or being permanently ponded such as Lake Waccamaw. Typically, they are not influenced by surface runoffs as they occur on landscapes that are flat (Sharitz, 2003). The vegetation in the sites is variable since the sites can have varying degrees of saturation throughout the year. The canopy is typically composed of pine species such as pond pines (*Pinus serotina*), the understory is typically composed of bay tree species such as loblolly bay (*Gordonia lasianthus*). These sites are also home to rare species such as *Lysimachia asperifolia* (Dimick, et. al., 2010).

Vegetation

The vegetation of Carolina Bays is dependent on the hydrology and soil type found within the bays. Because the bays have such high diversity hydrology and soil types it allows for the bays to have high biodiversity across all types of bays. The following are examples of Carolina Bays types along with associated hydrology, soil, and vegetation.

- 1) **Lakes:** The hydrology associated with lakes is permanently pond, with organic and/or mineral soils. The dominant plants found in the bay type are Water lily (*Nymphaea odorata*) Maidencane (*Panicum hemitomon*), Pickerelweed (*Pontederia cordata*), Soft rush (*Juncus effusus*) and shoreline shrubs like Buttonbush (*Cephalanthus occidentalis*) and Wax myrtle (*Myrica cerifera*) (Sharitz, 2003).
- 2) **Small depressional ponds:** The hydrology associated with small depressional ponds is permanently flooded in the center of the bay, with mineral and organic sediments. The dominant plants found in the bay type are species are bladderworts (*Utricularia* spp.),

fragrant waterlily (*Nymphaea odorata*), banana-lily (*Nymphoides aquatica*), yellow waterlily (*Nuphar lutea*), maidencane (*Panicum hemotomom*), and sedges (*Eleocharis* spp.) (Sharitz, 2003).

- 3) **Vernal pools:** The hydrology associated with vernal ponds is seasonally flooded, with various types of soils. The dominant plants found in this bay type are Southern cutgrass (*Leersia hexandra*), sedges (*Carex* spp.), rosette grasses and panicgrasses (*Dicanthelium* spp.), panicums (*Panicum* spp.), Indian pennywort (*Centella asiatica*), bladderworts (*Utricularia* spp.), and sundews (*Drosera* spp.) (Sharitz, 2003).
- 4) **Pond cypress ponds:** The hydrology associated with pond cypress ponds is temporarily ponded; the soils are generally mineral. The dominant plants found in the bay type are pond cypress (*Taxodium ascendens*) with other trees and shrubs like black tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum*), myrtle-leaved holly (*Ilex myrtifolia*), and fetterbush (*Lyonia lucida*) (Sharitz, 2003).
- 5) **Non-alluvial swamps:** The hydrology associated with non-alluvial swamps is seasonally saturated or slightly flooded; soils are mucky mineral or organic soils. The dominant plants found in the bay type are pond cypress (*Taxodium ascendens*), bald cypress (*T. distichum*), pond pine (*Pinus serotina*) and broad-leaved trees such as swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), and sweetbay magnolia (*Magnolia virginiana*) (Sharitz, 2003).
- 6) **Pond cypress savannahs:** The hydrology associated with pond cypress savannahs is seasonally to temporarily flooded, with mineral soils. The dominant plants found in the bay type are pond cypress (*Taxodium ascendens*) and other trees including swamp tupelo (*Nyssa biflora*); shrubs like sarvis holly (*Ilex Amelanchier*), swamp titi (*Cyrilla*

racemiflora); numerous graminoids such as madeincane (*Panicum hemitomom*), panicum's (*Dicanthelium* spp.), and sedges (*Carex* spp.), (*Rhynchospora* spp.) (Sharitz, 2003).

- 7) **Depression Meadows:** The hydrology associated with depression meadows is seasonally flooded; the soils are mineral. The dominant plants found in the bay type are panicums (*Panicum* spp.), rhynchospora (*Rhynchospora* spp.), netted nutrush (*Scleria reticularis*), handsome Harry (*Rhexia virginica*), Carolina redroot (*Lachnanthes caroliniana*), and yellow-eyed grasses (*Xyris* spp.). (Sharitz, 2003).
- 8) **High pocosins:** The hydrology associated with high pocosins is temporarily flooded; the soils are Histosols. The dominant plants found in the bay type are evergreen shrubs and low trees such as fetterbush (*Lyonia lucida*), swamp titi (*Cyrilla racemiflora*), honeycup (*Zenobia pulverulenta*), gallberry (*Ilex glabra*) with laurel greenbrier (*Smilax laurifolia*); pond pine (*Pinus serotina*) (Sharitz, 2003; Dimick, et. al., 2010).
- 9) **Small depression pocosins:** The hydrology associated with small depression pocosins is seasonally flooded, with sandy soils. The dominant plants found in the bay type are fetterbush (*Lyonia lucida*), swamp titi (*Cyrilla racemiflora*), gallberry (*Ilex glabra*), pond pine (*Pinus serotina*), red maple (*Acer rubrum*), and swamp bay (*Persea palustris*) (Sharitz, 2003).
- 10) **Pond pine woodlands:** The hydrology associated with pond pine woodlands temporarily flooded, with Histosols and mineral soils with organic surface layers. The dominant plants found in the bay type are pond pine (*Pinus serotina*) and red maple (*Acer rubrum*); also, evergreen shrubs and trees such as loblolly bay (*Gordonia lasianthus*), sweetbay magnolia (*Magnolia virginiana*), loblolly pine (*Pinus taeda*), swamp bay (*Persea*

palustris) and red maple (*Acer rubrum*); shrub layer of swamp titi (*Cyrilla racemiflora*), fetterbush (*Lyonia lucida*) and other evergreen or semi-evergreen species (Sharitz, 2003; Dimick, et. al., 2010).

- 11) **Bay Forests:** The hydrology associated with bay forests is temporarily flooded with Histosols and mineral soils with organic surface layers. The dominant plants found in the bay type are predominantly evergreen trees such as loblolly bay (*Gordonia lasianthus*), sweetbay magnolia (*Magnolia virginiana*), swamp bay (*Persea palustris*); may include swamp tupelo (*Nyssa biflora*), red maple (*Acer rubrum*), pond pine (*Pinus serotina*), loblolly pine (*Pinus taeda*); shrub layer with fetterbush (*Lyonia lucida*), swamp titi (*Cyrilla racemiflora*), and others (Sharitz, 2003; Dimick, et. al., 2010)

Table 1. Dominant plant species found in Carolina Bays. Source: (Caldwell, et. al., 2007; Sharitz, 2003)

Trees	<i>Pinus serotina</i> <i>Nyssa biflora</i> <i>Gordonia lasianthus</i> <i>Taxodium asendens</i> <i>Acer rubrum</i> <i>Pinus teada</i> <i>Nyssa sylvatica</i> <i>Magnolia virginiana</i> <i>Persea palustris</i>
Shrubs	<i>Persea palustris</i> <i>Lyonia lucida</i> <i>Cyrilla racemiflora</i> <i>Ilex glabra</i> <i>Zenobia pulverulenta</i>
Herbaceous	<i>Smilax laurifolia</i> <i>Vaccinium corymbosum</i> <i>Lachnanthes caroliniana</i> <i>Scleria reticularis</i>

Water Features

Influencing water features

These site's inputs come from precipitation and losses come from evaporation. Very few sites have naturally occurring streams that provide inputs and losses of water. There are sites that are also ponded year-round. The sites can be subjected to frequent flooding and ponding due to soils with poor drainage (Dimick, et. al., 2010).

Soil Features

The rim of the bays is typically made up of well drained sandy soils such as Torhunta, Lynn Haven, and Leon series. Closer to the center of the bays the soils increase in organic matter content and those soil series are Pamlico and Croatan. The soils in the center are poorly drained to very poorly drained soils (Caldwell, et. al., 2007).

Torhunta soil series (Coarse-loamy, siliceous, active, acid, thermic Typic Humaquepts) is a very poorly drained soil with moderately rapid permeability. The mean annual temperature is 63 degrees F and mean annual precipitation is 48 inches. The soil can be found with slopes from 0 to 2 percent. The water table is at or near the surface for 2 to 6 months out of the year. (Natural Resources Conservation Service, 1999).

Lynn Haven soil series (Sandy, siliceous, thermic Typic Alaquods) is a poorly to very poorly drained soil with moderate to moderately rapid permeability. The annual temperature is 68 degrees F and a mean annual precipitation of 55 inches. The soil can be found with slopes from 0 to 5 percent. (Natural Resources Conservation Service, 2009)

Leon soil series (Sandy, siliceous, thermic Aeric Alaquods) is a very poorly and poorly drained soil that can contain a Bh layer. The mean annual temperature is 68 degrees F and the mean

annual precipitation is 65 inches. The soil can be found with slopes from 0 to 5 percent. (Natural Resources Conservation Service, 2014)

Pamlico soil series (Sandy or sandy-skeletal, siliceous, dysic, thermic Terric Haplosaprists) is very poorly drained soils with 16 to 51 inches of organic material underlain by sandy sediment. The mean annual temperature is 63 degrees F and mean precipitation of 48 inches. The slope for this soil series is less than 1 percent. (Natural Resources Conservation Service, 1999)

Croatan soil series (Loamy, siliceous, dysic, thermic Terric Haplosaprists) is a very poorly drained soil with 16 to 51 inches of organic material underlain by loamy textured marine and fluvial sediments. The mean annual temperature is 65 degrees F and mean annual precipitation of 51 inches. The soil is saturated for 8 to 10 months of the year and have a slope from 0 to 2 percent. (Natural Resources Conservation Service, 2008)

Ecological Dynamics

State and Transition Models are used to visually represent the movement of an ecological site as it transitions from one ecological state to another. The following figure (Figure 1) models the transition of Carolina Bays between ecological states and describes how the transitions occur.

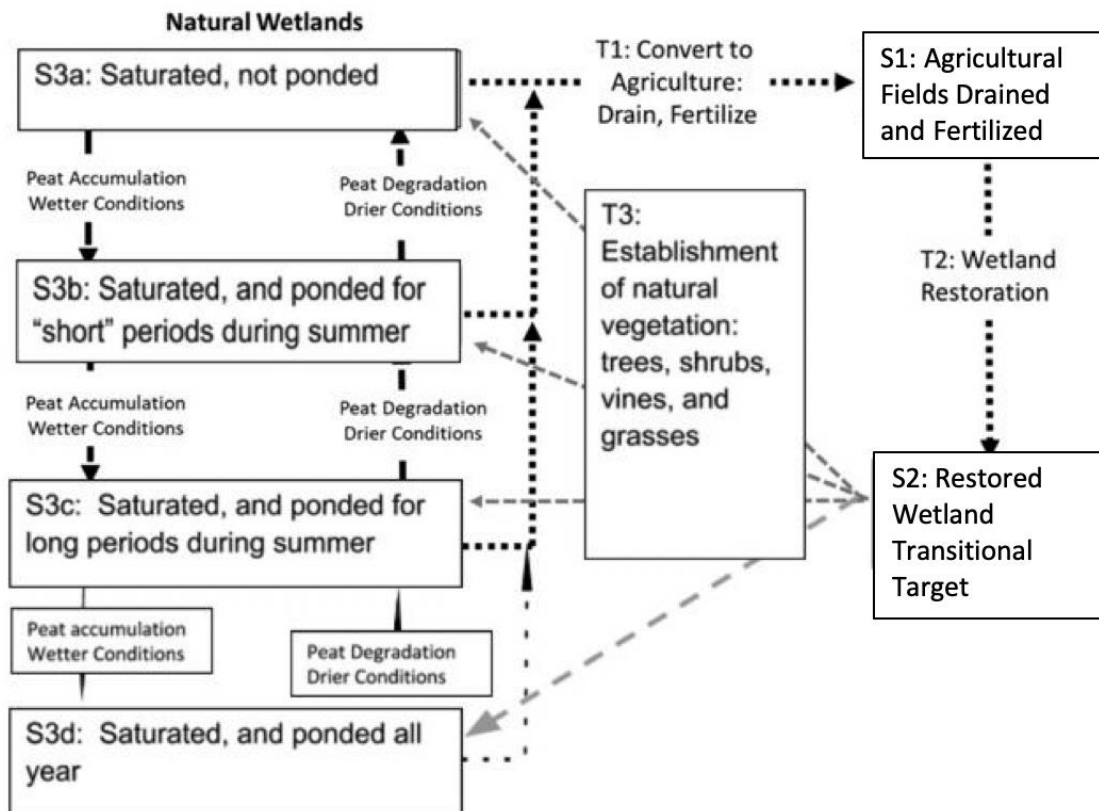


Figure 1. State and transition model for natural Carolina Bay wetlands that converted to agriculture and then restored back to a wetland. The states of natural wetlands (e.g., S3a, S3b, S3c, S3d) will have different plant communities depending on the hydrology

State and Transition Model

Many Carolina Bays have been drained to be converted into fields for agricultural use. More recently the bays have been being converted back to wetlands for the goal of restoring the natural functions of a wetland.

State 1 (S1): Agriculture Field

An agricultural field is an area or plot of land that has undergone a land use change to be cultivated for crops (see figure 1).

Transition 1 (T1): To create the conditions for crop production to be successful, the area needs to be drained of the water by ditching it. Once the area has been drained the

vegetation needs to be removed, and then it needs to be fertilized. These areas may need to be limed as well.

State 2 (S2): Restored Wetland Transitional Target Community

Restored wetlands are areas that have been converted to another type of land use, such as agricultural fields, and then converted back into a wetland. This is done by restoring natural hydrology and native vegetation. The goal of restoring wetlands is to create an environment where native plant species can grow and return the benefits of wetlands to the area (Ewing, 2006).

Transition 2 (T2): To create conditions for a wetland to be restored, the area's hydrology needs to be restored. This is done by filling in the ditches and blocking the drains to restore the water table to the original elevation. Once the drains and ditches have been removed, native vegetation is planted such as pond pines (*Pinus serotina*) and pond cypress (*Taxodium ascendens*) (Ewing, 2006).

State 3 (S3): Natural Wetland

Natural wetlands are wetlands that have the establishment of native vegetation and function as wetland should. The wetland can have different hydrologies depending on the location of the wetland. Depending on the hydrology of the wetland also determines the vegetation that will be able to grow (Sharitz, 2003).

S3a: Saturated, not ponded

S3b: Saturated, and ponded for “short” periods during summer

S3c: Saturated, and ponded for longer periods of time

S3d: Saturated, and ponded all year

Transition 3 (T3): Establishment of natural vegetation: trees, shrubs, vines, and grasses

Transition 3 happens after the wetlands have been restored back to the natural hydrology and native plant species are present without being planted. Plants such as gallberry (*Ilex glabra*), sweet bay magnolia (*Magnolia virginiana*), and swamp titi (*Cyrilla racemiflora*). Native grasses and herbaceous plants also are present in the natural wetlands.

Transitions for State 3:

There are four sub-states for the natural wetland. Each sub-state has a specific hydrology that will influence the plant community present, and the thickness of organic soil layers. Moving from one sub-state will only occur if the hydrology of the sub-state has changed to either make it wetter or drier as shown in the figure. (Ewing, 2006).

References: Carolina Bays: An Ecological Site Description (ESD)

Caldwell, P. Vepraskas, M. J. Skaggs, R. W. & Gregory, J. D. (2007). Simulating the Water Budgets of Natural Carolina Bay Wetlands. *Wetlands*, 27(4), pp. 1112-1113. [https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212\(2007\)27\[1112:STWBON\]2.0.CO;2](https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212(2007)27[1112:STWBON]2.0.CO;2)

Dimick, B. P. Stucky, J. M. Wall, W. Vepraskas, M. J. Wentworth, T. J. & Arellano, C. (2010). Plant-Soil-Hydrology Relationships in Three Carolina Bays in Bladen County, North Carolina. *Castanea*, 75(4), pp. 407-420. <https://doi-org.prox.lib.ncsu.edu/10.2179/09-063.1>

Environmental Protection Agency, Level III and IV Ecoregions of the Continental United States. (n.d.). Retrieved December 18, 2020, from <https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states>

Ewing, J.M. Vepraskas, M.J. (2006). Estimating Primary and Secondary Subsidence in an Organic Soil 15, 20, AND 30 Years After Drainage. *Wetlands*, 26(1), pp. 119–130. [https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212\(2006\)26\[119:EPASSI\]2.0.CO;2](https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212(2006)26[119:EPASSI]2.0.CO;2)

Natural Resources Conservation Service, (2008). Croatan Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/C/CROATAN.html

Natural Resources Conservation Service, (2014). Leon Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/L/LEON.html

Natural Resources Conservation Service, (2009). Lynn Haven Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/L/LYNN_HAVEN.html

Natural Resources Conservation Service, (1999). Pamlico Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/P/PAMLICO.html

Natural Resources Conservation Services, (1999). Torhunta series. https://soilseries.sc.egov.usda.gov/OSD_Docs/T/TORHUNTA.html

Sharitz, R.R. (2003). Carolina bay wetlands: Unique habitats of the southeastern United States. *Wetlands*, 23, 550–562. [https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212\(2003\)023\[0550:CBWUHO\]2.0.CO;2](https://doi-org.prox.lib.ncsu.edu/10.1672/0277-5212(2003)023[0550:CBWUHO]2.0.CO;2)

United States Department of Agriculture, Natural Resources Conservation Service. (2006). Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296.

North Carolina Wetlands - An Educational Module on Carolina Bays

Introduction

This educational module focuses on Carolina Bays as an example of wetlands in North Carolina to teach the importance of environmental conservation. The lesson plans found within the module are intended for middle school use to reinforce *NC Essential Standards and the Next Generation Science Standards* centering on environmental stewardship and the relationship between soil management, water conservation, and human health. Middle school represents a pivotal time to build environmental literacy (EL) in students, defined by the North Carolina Office of Environmental Education as “the ability to make informed decisions about issues affecting shared natural resources while balancing cultural perspectives, the economy, public health and the environment” (2017). Environmental curricula can be used to prepare students to face complex problems like water quality issues or loss of habitat and biodiversity while improving academic performance in the core subjects of reading, math, science, and social studies (SEER, 2009).

As students’ progress through middle school, their interest in math and science tends to decline, and this includes interest in the natural sciences as well (Found & Smith, 1996). Even students in 8th grade compared to those in the 6th grade have shown a slower rate of improvement in environmental literacy standards after multiple EL lessons (Stevenson et al., 2013). Since curricula for younger students may have a higher propensity for changing behaviors and attitudes, yet because older students still benefit from EL lessons, this module is designed to fit across the 6th, 7th, and 8th grade curricula. The lessons in this module engage students in a cross-cutting curriculum that explores environmental science concepts and prepares students to think critically about the world around them. The goal is for students to understand, analyze, and address major environmental challenges facing the state and the nation, objectives in support of the North Carolina Environmental Literacy Plan (2017).

This project focuses on one of the most important yet often most overlooked environments - wetlands. Wetlands reduce flooding, provide natural filtration for sediments and pollutants, and create viable habitat for many species (NOAA, 2017). These ecosystems are found throughout the world and are permanently or periodically covered in water throughout the year. Wetland conservation is incredibly important for water quality, pollution control and biodiversity, and wetlands provide an excellent model for teaching the importance of environmental stewardship.

How To Use This Module

There are three lessons in this module that build upon one another. The first lesson covers the basic definition of wetlands and has students describe the relationships among precipitation, runoff, and wetlands. The second lesson focuses on Carolina Bays as an example of wetlands in North Carolina. The third lesson continues to use Carolina Bays to explain the importance of stewardship and restoration of wetlands. Each lesson includes interactive virtual components that can be used in remote learning environments as well as in-person instruction. These lessons have not been tested on students, but they have been reviewed by North Carolina Middle School Science Certified teachers.

Standards Covered

North Carolina Essential Standards

- **NCES. 6.L.2 Understand the flow of energy through ecosystems and the responses of populations to the biotic and abiotic factors in their environment.**
 - *NCES.6.L.2.3 Summarize how the abiotic factors (such as temperature, water, sunlight, and soil quality) of biomes (freshwater, marine, forest, grasslands, desert, tundra) affect the ability of organisms to grow, survive and/or create their own food through photosynthesis.*
- **NCES.7.E.1 Understand how the cycling of matter (water and gases) in and out of the atmosphere relates to Earth's atmosphere, weather and climate and the effects of the atmosphere on humans.**
 - *NCES.7.E.1.2 Explain how the cycling of water in and out of the atmosphere and atmospheric conditions relate to the weather patterns on Earth.*
- **NCES.8.E.1 Understand the hydrosphere and the impact of humans on local systems and the effects of the hydrosphere on humans**
 - *NCES.8.E.1.1 Explain the structure of the hydrosphere including: water distribution on Earth, local river basins and water availability.*

Next Generation Science Standards - Grade Level Disciplinary Core Ideas

- **MS-LS2-5** - Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.
- **MS-ESS2-4** - Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.

Lesson 1

What Are Wetlands?

Essential Question

What are wetlands and why are they important?

Objective

- Students will be able to define wetlands and describe the main characteristics of wetland habitats.
- Students will be able to describe relationships among precipitation, runoff, and wetlands.

Background

Ecosystems are defined as the animal and plant communities that interact with each other in an environment. The life found in an ecosystem depends on the abiotic (nonliving) factors such as temperature, rainfall, and the surface features of the land. There can be many ecosystems within a larger biome, which describes a larger area that shares the same characteristics and biodiversity. There are six main types of biomes - taiga, tundra, deciduous forest, tropical rainforest, desert, and grassland. Wetlands are an important ecosystem that can be found in these different biomes; though they all share the name of wetland, no two are the same. Wetlands provide functions such as water filtration, flood and erosion control, and habitat for a wide diversity of plants, animals, fish, and insects. They are also recreational hot spots, providing a space for people to fish, canoe, bird-watch, hike, and enjoy the great outdoors.

Wetlands can have high biodiversity, meaning they have the capability to support a variety of plants and animals. When the vegetation within and around the wetland dies, it begins to decompose or breaks down and becomes “detritus,” or food for microbes, insects, and small fish. Once these organisms eat the detritus they become food for the larger fish, birds, and animals, creating an interconnected web. Wetlands also provide an area of refuge for migratory birds such as ducks and geese. Wetlands are important in the water cycle. The wetlands retain water for long periods giving the surface water time to seep into the ground and recharge the groundwater, or to evaporate and return to the atmosphere. These processes are all part of the “water cycle” which recycles all the water we use to ensure we never run out of water. Wetlands are also an important ecosystem for the nitrogen cycle. Nitrogen can be washed into the wetland from outside water sources in the form of nitrates. Nitrates are absorbed by the vegetation in the wetlands or undergo denitrification and are released back into the atmosphere in the form of nitrogen gas. Ammonia-N is most commonly transported into wetlands by surface runoff. Ammonia-N can undergo several processes like being absorbed by plants, released back into the atmosphere through volatilization, or undergo nitrification and be converted into nitrates and nitrites.

Wetlands are covered with water for the whole or part of a year. This causes the soils found in wetlands to be saturated for at least part of the year and to have no oxygen in the soil. Plants need their roots to absorb oxygen, and so plants that can bring oxygen to their roots through saturated soils are the only ones which can grow in wetland soils. These soils are referred to as hydric soils and are often fertile - one of the reasons people have historically drained wetlands for farmlands or other development. The plants that can naturally grow in

wetlands are referred to as hydrophytes, which can range from giant cypress trees to mosses and grasses.

Materials

- Computer & TV to show videos and websites
- Baking sheet
- Modeling clay
- Jar of clean water
- Jar of muddy water
- Sponge

Introduction

- 1) Review the concept of biomes with students using this short 4 minute [video](#). Have them recall the six major biomes (taiga, tundra, deciduous forest, tropical rainforest, desert, and grassland). Ask students to describe the different characteristics of each one.
- 2) Explain that within each biome, there are multiple different ecosystems that can exist. One such ecosystem is wetlands. Show different pictures of different wetland types-- freshwater & saltwater marshes, bogs, swamps, etc. Have students brainstorm what type of plants and animals might live in a wetland.

Activities

- 1) Show students this [video](#) from the National Ocean Service website briefly explaining what wetlands are.
- 2) Break students into groups and assign each group one-two questions from the list below. Students will use the [National Geographic Encyclopedia entry](#) on wetlands to answer the questions, either printed or virtually. Give students 20-25 minutes to read in their groups and search through the text for the answers. Once everyone has finished with their questions, have each group present their findings to the whole class. (*tip: give students in the groups roles such as Transcriber, Presenter, or Timekeeper to help with group work. Set an expectation for how long their answers should be.*)

Breakout Group Questions (assign one-two per group):

- Why were wetlands historically considered wastelands? What would people do to wetlands in order to develop (construct buildings, towns, cities, etc) in these areas?
 - a) *Wetlands were traditionally seen as a waste of land, as they were not suitable for farming or development. To fix this “problem” people drained wetlands (example of Washington, DC built upon a drained wetland).*
- What is the word used to describe the types of soil found in wetlands? How do these soils affect the other life found in wetlands?

- a) *Wetland soils are referred to as hydric soils, meaning saturated with water/in a moist environment. The type of plants growing in the soil depend upon the saturation of these hydric soils. The types of plants in turn determine the types of animals that can survive in an area.*
- Does an area have to be completely covered with water the entire year to be classified as a wetland? Explain why or why not. Where does the water in wetlands come from?
 - a) *Wetlands do not have to be covered by water for the entire year--periodic water saturation can also denote a wetland. The water can come from a variety of sources, including groundwater, rivers, lakes, or seawater in coastal areas.*
- Give a description of the three major types of wetlands.
 - a) *Swamps, marshes, and bogs are considered the three main wetlands. Swamps can be freshwater or saltwater and are permanently saturated with water and trees. Marshes can also be freshwater (the Everglades are an example of this type) or saltwater. Marsh wetlands fringe the outside of rivers, bays, and coastlines. Swamps and marshes are often found in warmer climates, while the third major type of wetland, bogs, are found in colder climates. Bogs form in depressions in land with a high water table, meaning groundwater is near the surface. Peat, decayed organic matter formed in these bogs, is a fuel source for many parts of the world.*
- Explain the importance of wetlands to our environment.
 - a) *Giant sponges or reservoirs of water; water-treatment plants by filtering water; home to a wide array of biodiversity*
- Wetlands are sometimes referred to as water-treatment facilities. How do wetlands filter water?
 - a) *The plants, fungi, and algae absorb many of the harmful chemical or excess nutrients from fertilizers that runoff into wetlands. Pollutants not used by the organisms are trapped in the sand and soils at the bottom of wetlands, causing the water that cycles back into other bodies of water to be cleaner than before.*
- Explain the importance of wetlands to our economy, particularly our fishing industry.
 - a) *Over 75% of the fish and shellfish harvest in the entire world are linked to wetlands. People use wetlands for hunting, birdwatching, hiking, and other recreational purposes. Americans spend more than \$100 billion on recreational activities in wetlands each year, according to the National Fish and Wildlife Service.*

- 3) Further explain how wetlands provide the important ecosystem services of water filtration and flood prevention by using a demonstration of wetlands capturing runoff.
1. Pre-make a sample wetland by spreading out modeling clay in a thin layer on half of the baking sheet to create land sloping downhill. The empty part of the cookie sheet represents a body of water (for example an ocean).
 - If working with a smaller group of students, they can create the sample wetland themselves. Make sure that the modeling clay has a slight slope downward from one end of the baking sheet to the middle. This will allow the water used later to flow downward.
 2. Tell students that the modeling clay represents land, while the empty part of the baking sheet represents an ocean or other body of water. Ask students what they think will happen if it rains on the land (runoff).
 3. Demonstrate runoff by pouring a cupful of the clean water (representing rain) onto the raised end of the clay. It should run down the sloped clay to the empty end of the sheet.
 4. Put down a sponge down in between the modeling clay and the river. The sponge represents a wetland.
 5. Repeat the rainwater demonstration and ask students what they observe (the sponge collects a lot of the water, minimizing the amount that gets into the body of water).
 6. Ask students what could happen in a reverse scenario, for example when a hurricane occurs and brings up ocean water more inland than normal. What purpose will the sponge serve? (the wetland can absorb most of the seawater, preventing further flooding inland and damage to farms, homes, and other ecosystems)
 7. Now demonstrate how wetlands not only absorb water but also filter out pollutants such as excess fertilizers or sediments. Using the muddy water this time, pour a cupful onto the top of the clay to represent runoff.
 8. Ask students to compare the muddy water in the jar to the water that ended up in the body of water in the pan (the water in the body of water will be slightly cleaner due to the sponge absorbing some of the sediments).
 9. Ask students to describe how they think polluted water (represented by the muddy water) could negatively affect fish and other wildlife in the body of water.

***This activity is modified from**

https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/EE/Field_Trip/Wetland%20in%20a%20Pan.pdf

And from

<https://ecosystems.psu.edu/outreach/youth/sftrc/lesson-plans/water/6-8/wetland>

Conclusion

- 1) Have students create a “tweet” explaining what wetlands are. They need to write their explanation in 140 characters or less that includes a relevant hashtag.

Lesson 1 References

“Wetland in a Pan.” *The Watercourse and Environmental Concern INC.* 1995.

https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/EE/Field_Trip/Wetland%20in%20a%20Pan.pdf Accessed 14 Dec. 2020.

Mykut, J. “Wetland in a Pan.” *Penn State Department of Agricultural Sciences.*

<https://ecosystems.psu.edu/outreach/youth/sftrc/lesson-plans/water/6-8/wetland> Accessed 14 Dec. 2020.

Lesson 2

Carolina Bays: A Unique Wetland Habitat

Essential Question

What types of wetlands are here in North Carolina?

Objective

- Students will be able to identify Carolina Bays' unique characteristics.
- Students will create an example of a Carolina Bay wetland.



Figure 3. Ponded Carolina Bays. Source: Nickens, T.E. (2016). *Riddle of the North Carolina Bays*.



Figure 2. Antioch Church Bay in Hoke County. Source: Photo by Ken Taylor/ Wildlife Images.

Background

Carolina Bays are a unique wetland type found in the Atlantic Coastal Plain from Florida up to New Jersey, but they are predominantly found in North and South Carolina. Carolina Bays are not what is typically thought of as a bay along the coast; they get their name from the bay trees that are found along the rim of the wetland. The wetlands are all an elliptical shape positioned in a northwest to southeast orientation (see fig 2). They can vary in size from just a few hundred yards to over five miles wide. No one Carolina Bay is the same as the next, one could be permanently ponded like Bladen Lakes (see fig 1) or Lake Waccamaw, others can be bogs, or they can be seasonally ponded. The flora and fauna composition of the Carolina Bays can vary just as much as the size. Some are bay forests with a dense understory of briars and vines, and others can be forests with longleaf pines and scattered cypress trees. All of the Carolina Bays have sandy rims which is an ideal habitat for Venus fly traps to grow and thrive. The bays get their water mostly from precipitation, but some acquire the water from groundwater. The bays that have streams use the streams as a discharge area instead of using the streams as a water source. The formation of the Bays is not fully understood and there are multiple theories on how they were formed. There are two main theories on the formation, the first is that

a meteor hit the earth up near the great lakes (Younger Dryas extinction event, extinction of Mammoths) and the debris landed on the Atlantic coast and caused the wetlands to be formed. The other main theory is that wind and wave action caused the Carolina bays to be formed (see fig 3). There are other theories too such as large schools of fish digging out a spawning area when it was covered by the ocean, subsurface limestone sinkholes, and giant prehistoric beavers who created the wetlands. There is still much debate surrounding the formation of the Carolina Bays, and more theories are being created through the research of scientists.

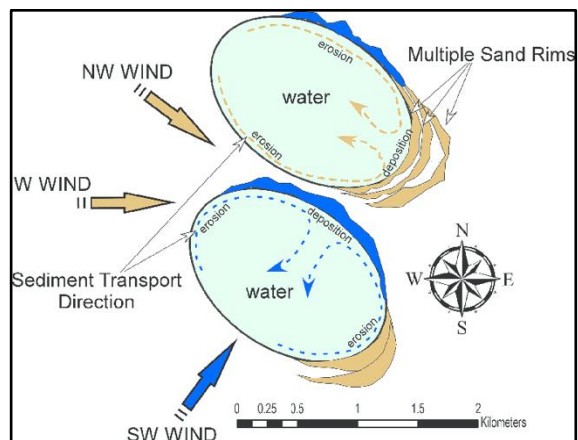


Figure 4. Carolina Bay Formations. Source: (Moore et al., 2016)

Materials

Computer & TV

Card sort activity - copies for student groups

Student access to computers

Introduction

- 1) Review with students what they have already learned about wetlands and their characteristics. You can do this through having students quickly write and share a six-word story about wetlands to start class.

Example of Six-Word Story:

Wetlands	provide	valuable
services	for	everyone




- 2) Have students recall reading about the Everglades, Chesapeake Bay, and other famous wetlands in the United States in the National Geographic article from Lesson 1. Ask students if they know of any wetlands in North Carolina and have them share what they know (students may think of marshes found in the Outer Banks).





Activities

- 1) Show students photos of Carolina Bay wetlands--ask them to imagine flying over the southeastern coast and seeing these unique depressions in the land--what would they think caused them? Explain that there has been much mystery and debate around the formation of these wetlands for many years, with explanations ranging from meteorite showers, to wind formation, to giant schools of fish digging depressions into the ocean floor with their tails back when oceans covered the region!
- 2) Use this short video resource from [UNC-TV](#) on Coastal Wetlands to introduce students to Carolina Bays. About 6 minutes in length, the video covers theories of Carolina Bay formation and showcases several around the Southeast.

- 3) Read together with students through this [article](#) from Our State magazine introducing Carolina Bays and their unique habitats. This article will be used later in the lesson to help students construct their essays.
- 4) Use a card sort activity to have students work in small groups to match the description to the plant or animal species native to Carolina Bays. Be sure to explain that these are just a small sample of the wide array of biodiversity in Carolina Bays since these wetlands vary greatly from location to location. Alternatively, this card sort can be turned into a Kahoot or Quizizz to be used for remote learning.

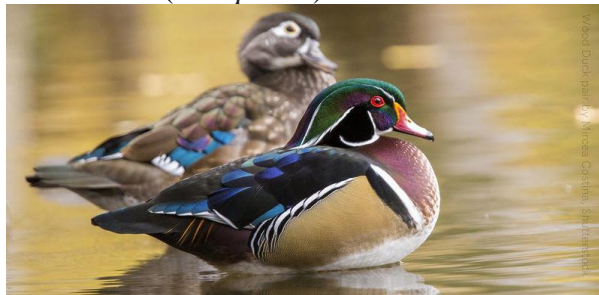
Biodiversity Card Sort

Description	Name & Picture
<ul style="list-style-type: none"> ● A pine tree adapted for life in wetlands. ● The cones are serotonous, meaning they need fire to open. ● There are three needles in each fassical (bundle) and they are twisted around each other. 	<p>Pond Pine (<i>Pinus serotina</i>)</p> 
<ul style="list-style-type: none"> ● Have roots that show above the ground or water called “knees” ● Trunks are buttressed “wide at the bottom” for support in wetland soils. ● The heartwood is rot-resistant, so they have been used as fence post, cabinets, and boats. 	<p>Bald cypress (<i>Taxodium distichum</i>)</p> 
<ul style="list-style-type: none"> ● Leaves have a sweet smell. They smell like the bay leaf herb used in cooking. ● The leaves are evergreen, meaning they are green year round. 	<p>Loblolly bay (<i>Gordonia lasianthus</i>)</p> 

<ul style="list-style-type: none"> ● Native habitat is the coastal plain of North Carolina (Wilmington Area), but is easily grown in greenhouses. ● Carnivorous plants that get their food from flies, gnats, and other insects. ● On North Carolina's rare plant list. 	<p>Venus flytrap (<i>Dionaea muscipula</i>)</p> 
<ul style="list-style-type: none"> ● Provide resting areas for reptiles and insects ● Provide hiding places for fish from predators like birds and ambush areas for larger predatory fish. ● Are found in calm areas of freshwater 	<p>Water lily (<i>Nymphaeaceae sp.</i>)</p> 
<ul style="list-style-type: none"> ● On the North Carolina rare plant list ● These plants reproduce using spores, not seeds ● The name come from their dangling greenery 	<p>Southern Maidenhair-Fern (<i>Adiantum capillus-veneris</i>)</p> 
<ul style="list-style-type: none"> ● Also known as the cottonmouth ● North <u>America's</u> only venomous water snake ● Can reach sizes up to 4 feet long 	<p>Water moccasin (<i>Agkistrodon piscivorus</i>)</p> 

- One of the federally protected waterfowl
- Males are called Drakes and females are called Hens
- They can fly up to 30 miles per hour.

Wood duck (*Aix sponsa*)



- These animals have a 6 foot wingspan.
- Diet consists of fish, amphibians, reptiles, and small mammals.

Great blue heron (*Ardea herodias*)



- 4 to 7 feet from tail to nose
- They are omnivores with most of their diet consisting of fruits and berries
- Cubs stay with their mothers for 2 years

Black Bear (*Ursus americanus*)



Conclusion

- 1) Based on what students learned in the lesson, they will be able to write an essay sharing what they've learned using specific examples and vocabulary words.

Mystery of the Bays

- Essay Prompt
 - You've been hired by the state of North Carolina as a private investigator to determine the cause of massive land depressions all along the Southeast coast that create unique wetland ecosystems. Choose one of the formation theories of these Carolina Bays and write a reflection on how they could have formed. Include a description of the physical conditions and habitats that support the biodiversity of the Carolina Bays.
- Use at least three vocabulary words (or form of the words) as part of your supporting details:
 - Ecosystem Land depressions
 - Habitat Native wildlife
 - Environment Formation

Extensions

- 1) Students can check out the [NWS Wetland Mapper](#) to look for other wetlands in North Carolina and across the country. Use this [video](#) from the US Fish & Wildlife Service as an introduction to the NFWS Wetland Mapper.

Reflection Questions:

- Ask students why they think it's important to classify areas of land as wetlands
 - Ask students if they think there might be other wetlands that are being discovered today
- 2) Take students to experience a Carolina Bay in person! The N.C. Division of Parks and Recreation preserves multiple Carolina bays in the state parks system, including Jones and Salters lakes in Jones Lake State Park, and Singletary Lake within Bladen Lakes State Forest. For more information, go to [ncparks.gov](#). The Nature Conservancy protects several Carolina bays in North Carolina, including Antioch Bay and Hamby's Bay in Hoke County, and portions of both Stateline Prairie Bay and the McIntosh bay complex in Scotland County. For details, visit [nature.org](#), and click on North Carolina.

Lesson 2 References

Sasser, Janna. "Naturalist's Notebook: Carolina Bays: Another Man's Treasure." *North Carolina Sea Grant*. <https://ncseagrant.ncsu.edu/coastwatch/previous-issues/2015-2/autumn-2015/carolina-bays-another-mans-treasure/> 2015, Accessed 14 Dec. 2020.

"Spotlight On Strategies: Six-Word Stories." *Discovery Education*. <http://blog.discoveryeducation.com/wp-content/uploads/2014/04/SOS-11-6-Word-Story.pdf> Accessed 14 Dec. 2020

“Stem: Watch on Wetlands.” *Project Learning Tree*. <https://www.plt.org/stem-strategies/watch-on-wetlands/> Accessed 14 Dec. 2020.

Moore, Christopher & Brooks, Mark & Mallinson, David & Parham, Peter & Ivester, Andrew & Feathers, James. (2016). The Quaternary evolution of Herndon Bay, a Carolina Bay on the Coastal Plain of North Carolina (USA): implications for paleoclimate and oriented lake genesis. *Southeastern Geology*. 51. 145-171.

Lesson 3

Wetland Restoration: Re-Establishing Healthy Ecosystems

Essential Question

How are wetlands used to maintain healthy ecosystems and improve human life?

Objective:

- Students will be able to describe the importance of wetland restoration.
- Students will relate the importance of wetland functions to their own needs and daily lives.

Background

It wasn't until the 1970's that the United States government started to protect wetlands. Prior to that, wetlands were seen primarily as a waste of land and were routinely drained for agriculture and development. For example, in the 1960s Walt Disney drained hundreds of acres of wetland swamps in Florida to build the Disney World theme park [that](#) so many of us enjoy today. In 1977, the Environmental Protection Agency (EPA) passed the Clean Water Act, which regulated pollutants entering waterways across the states. Even though wetlands were not technically included in the act, courts interpreted them to be included since waterways like streams, rivers, and oceans could not be protected without also protecting the wetlands surrounding them. Wetlands were then further defined and protected in later laws.

Carolina Bays are included in this history of wetland drainage for other more "practical" uses. These areas were typically drained to become farmland because the areas are typically very flat, and many remain in agricultural use to this day. The soil is typically infertile meaning the area needs to be fertilized and possibly limed to be productive in an agricultural setting. However, these Carolina Bays, along with other wetlands, can be restored to their natural state over time. Environmental scientists, soil scientists, and engineers can reverse the drainage by filling in ditches that have been used to drain water, and the water table will rise, and the area will return to its natural wet state. Returning the hydrology of the area can happen quickly after filling in the drains and ditches. As the water table rises, the hydric vegetation and native animals will return, increasing the biodiversity in the area. Once wetlands are functioning as they are supposed to, they can once again offer important environmental services such as water filtration and erosion control. Recall the benefits of wetlands discussed in Lesson 1.

Materials

Computer & TV

Printed copies of the *Case Study: Savannah River Sites*

Introduction

- 1) Use this National Geographic [video](#) as a hook to interest students. The video shows the Nature Conservancy blasting through 1950s-era levees in the Williams River Delta in southern Oregon to save the wetlands and endangered fish species.
- 2) Explain to students that humans have begun to understand the importance of these wetlands that were once considered useless, including Carolina Bays. Now that we recognize how vital these ecosystems are, scientists and conservationists are working to

restore them to their natural states. Carolina Bays don't have levees or dams blocking them, instead ditches have been dug to drain out the water from these ecosystems. To restore them, these drainage ditches are filled back in with soil and native vegetation is brought in and replanted.

Activities

- 1) Students will read a case study of a Carolina Bay restored to its natural state to understand that return of native vegetation and wildlife is used as a marker of successful wetland restoration. Students will work in groups to read through the case study. Have students use the following literacy strategies to make sense of the text:
 - a) Highlight unfamiliar words.
 - b) Underline important parts of the text.
 - c) Circle what you have questions about.
 - d) Write one summary sentence for each paragraph explaining the main idea.
 - e) As a group, write an overall conclusion statement explaining if you think the restoration project was successful or not and why.

Case Study: Savannah River Sites

There are over 300 Carolina bays or bay-like depression wetlands on the Savannah River Site (SRS) near Aiken, South Carolina. An estimated two-thirds were disturbed before the government took over the land. These isolated wetlands range from small ephemeral depressions to large permanent ponds of 10-50 hectares in size. They provide habitat to support a wide range of rare plant species, and many vertebrates (birds, amphibians, bats). Historical impacts to the Carolina bays at SRS were primarily associated with agricultural activities. Bays were often drained, tilled and planted to crops.

The consequence was a loss in the wetland hydrologic cycle, the native wetland vegetation, and associated wildlife. Twenty of the Carolina Bays were selected for a restoration project. Pre-restoration characterizations of soil, hydrology, vegetation and wildlife were performed within each site, to be used as a baseline for evaluating restoration success. Of the twenty bays, sixteen were initially being restored and the remainder were planned to serve as unrestored controls. Undisturbed bays of similar size were selected for use as reference sites.

To restore the wetlands, trees that had been planted for agriculture in the bays' interior were harvested and drainage ditches were plugged with clay to re-establish prior hydrological conditions. The plugged drainage ditches prevent water from draining out and allows the underground water table to rebuild and create wetland conditions. This project began in 1998 and the final report on the restoration progress was published in 2006.

Native tree species and herbaceous wetland plant species like grasses were measured at the beginning and end of the restoration efforts. Both increased at the restored sites. Amphibians were captured and counted to see if there was an increase over time in their populations at the restored sites. This data was not conclusive, since unexpected rainfall and drought conditions affected the populations of the frogs, salamanders, toads, and lizards more than the restoration project.

Bird populations were also measured to see if there were increases in species over the restoration timeline. Use the three graphs to compare the restored, reference, and control bays to see if bird species increased at restored Carolina Bays (see fig 6.1 & 6.2). Species richness means the number of different bird species. Abundance means the amount of birds.

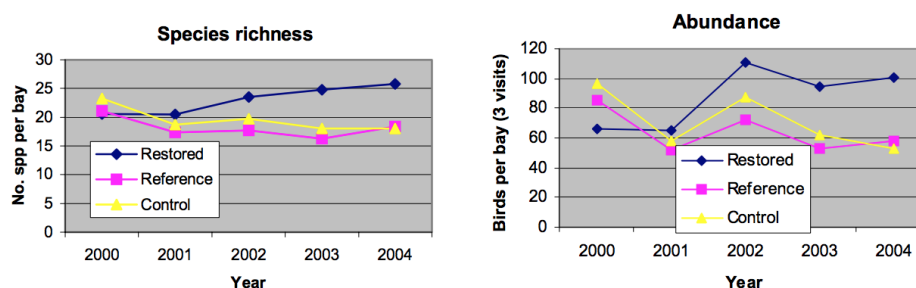


Figure 6.1. Species richness and abundance of restored, reference and control bays.

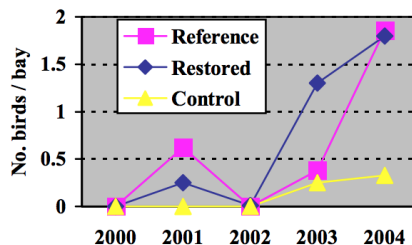


Figure 6.2. Number of wetland birds observed in restored, reference and control bays.

This case study is adapted from *The Carolina Bay Restoration Project: Status Report II (2000-2004)*. Prepared by Christopher Barton. From <https://www.osti.gov/servlets/purl/886951>

- 2) After reading through the **Case Study: Savannah River Sites** in groups and coming up with their conclusion statements, have groups share out their conclusions to the whole group.

Conclusion

- 1) Discuss why it might not be clear yet whether the restoration project was successful.
- 2) Ask students to think of other types of data scientists would need to collect to measure the return of these Carolina Bays to their natural state.

Extension

- 1) In addition to restoring natural wetlands, scientists and engineers have figured out how to construct new wetlands to recreate wetland conditions and use these them to filter wastewater. Compare and contrast three different common designs of constructed wetlands that are commonly used.
 - a) [Free Water Surface Flow](#)
 - b) [Horizontal Subsurface Flow](#)
 - c) [Vertical Subsurface Flow](#)

Choose the design that would be the best fit for your school or home. Explain why you made your choice.

Adapted from

Project Learning Tree - STEM: Watch on Wetlands lesson

Lesson 3 References

Barton, Christopher. “*The Carolina Bay Restoration Project - Status Report II 2000-2004.*” United States: N. p., 2006. Web. doi:10.2172/886951.<https://www.osti.gov/servlets/purl/886951>

“Stem: Watch on Wetlands.” *Project Learning Tree*. <https://www.plt.org/stem-strategies/watch-on-wetlands/> Accessed 14 Dec. 202

References: North Carolina Wetlands - An Educational Module on Carolina Bays

Barton, Christopher. “*The Carolina Bay Restoration Project - Status Report II 2000-2004.*” United States: N. p., 2006. Web. doi:10.2172/886951.<https://www.osti.gov/servlets/purl/886951>

Fouad NA, and Smith PL. “A test of a social cognitive model for middle school students: Math and science.” *Journal of Counseling Psychology*. Vol 43. 1996, pp. 338–346.

Hoody, L. “The Effects of Environment-based Education on Student Achievement.” *State Education and Environment Roundtable*. 2000. <http://www.seer.org/pages/research/educfeff.pdf>. Accessed 14 Dec. 2020.

Moore, Christopher & Brooks, Mark & Mallinson, David & Parham, Peter & Ivester, Andrew & Feathers, James. (2016). The Quaternary evolution of Herndon Bay, a Carolina Bay on the Coastal Plain of North Carolina (USA): implications for paleoclimate and oriented lake genesis. *Southeastern Geology*. 51. 145-171.

Mykut, J. “Wetland in a Pan.” *Penn State Department of Agricultural Sciences*. https://ecosystems.psu.edu/outreach/youth/sftrc/lesson_-_plans/water/6-8/wetland Accessed 14 Dec. 2020.

NOAA. “What is a wetland?” *National Ocean Service Website*. <https://oceanservice.noaa.gov/facts/wetland.html> Accessed 14 Dec. 2020

Office of Environmental Education and Public Affairs. “Smart Minds Greener Future.” *North Carolina Environmental Literacy Plan*. 2017. <https://files.nc.gov/deqee/documents/files/elp-plan-2017.pdf> Accessed 14 Dec. 2020

Sasser, Janna. “Naturalist’s Notebook: Carolina Bays: Another Man’s Treasure.” *North Carolina Sea Grant*. <https://ncseagrant.ncsu.edu/coastwatch/previous-issues/2015-2/autumn-2015/carolina-bays-another-mans-treasure/> 2015, Accessed 14 Dec. 2020.

“Spotlight On Strategies: Six-Word Stories.” *Discovery Education*. <http://blog.discoveryeducation.com/wp-content/uploads/2014/04/SOS-11-6-Word-Story.pdf> Accessed 14 Dec. 2020

“Stem: Watch on Wetlands.” *Project Learning Tree*. <https://www.plt.org/stem-strategies/watch-on-wetlands/> Accessed 14 Dec. 2020.

Stevenson KT, Peterson MN, Bondell HD, Mertig AG, and Moore SE. “Environmental, Institutional, and Demographic Predictors of Environmental Literacy among Middle School Children.” *PLOS ONE* 8(3): e59519. 2013. <https://doi.org/10.1371/journal.pone.0059519>

“Wetland in a Pan.” *The Watercourse and Environmental Concern INC*. 1995. https://www.fws.gov/uploadedFiles/Region_1/NWRS/Zone_2/Inland_Northwest_Complex/Turnbull/Documents/EE/Field_Trip/Wetland%20in%20a%20Pan.pdf Accessed 14 Dec. 2020.