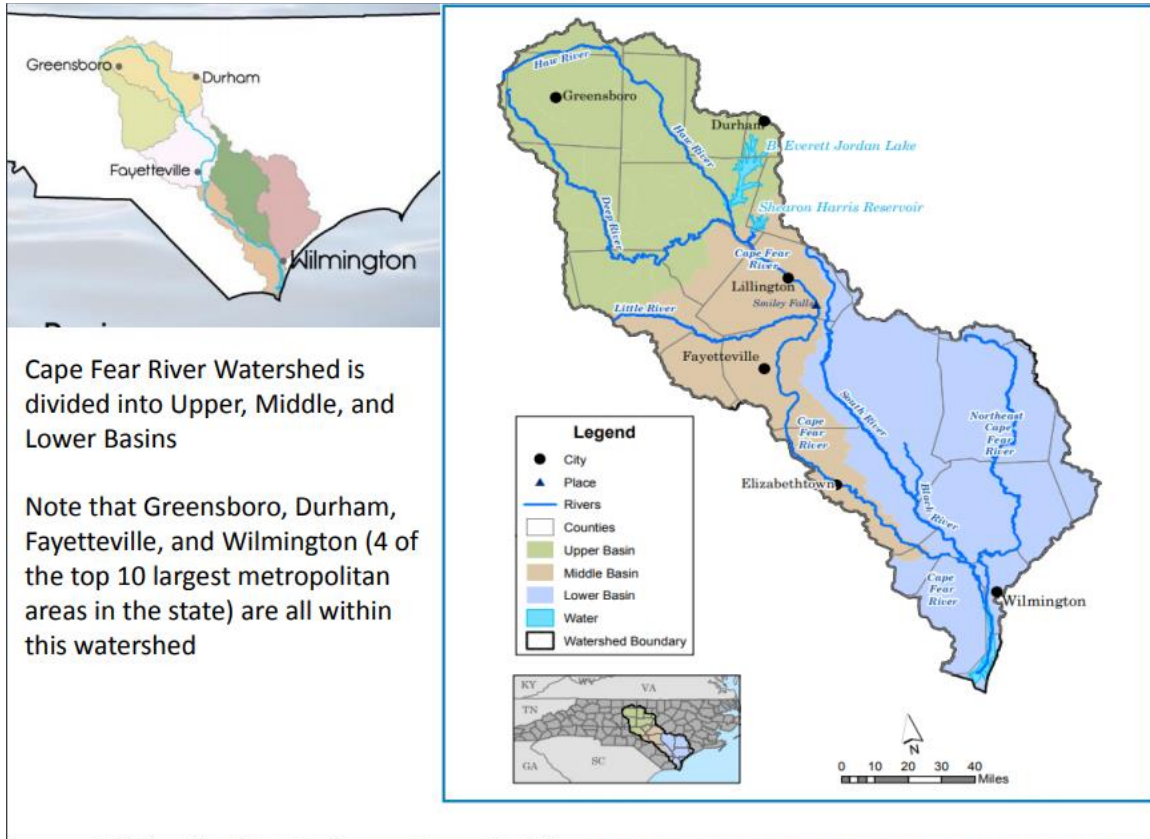


NC Natural History Final

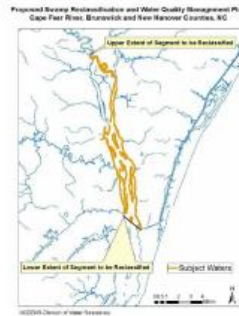
Rivers and Water Quality Issues



What are some other issues on the Cape Fear River?

Perfluorinated Compounds (PFAS)
Nutrient Loading – Animal Operations
Microcystins during hot/dry weather
Reclassification of the Lower Cape Fear River and Estuary
Deepening of the Harbor

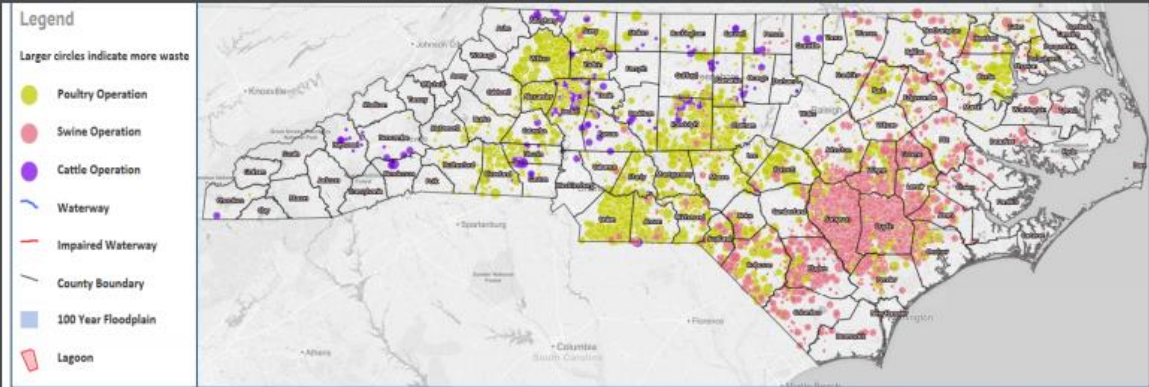
Algae blooms in river arrive with hot weather



→ HIDE CAPTION

A 2000 aerial photo of Fayetteville Works on the Cumberland-Bladen county line. The site, home to several plants, one of which makes Geis, is about 100 miles upstream from Wilmington. [COURTESY OF THE FAYETTEVILLE OBSERVER]





Poultry and Swine CAFOs in and near 100-Year Floodplain

OPERATIONS			
	Within Floodplain	Nearby Floodplain	Total
Poultry	30	16	46
Swine	62	47	109

ANIMALS			
	Within Floodplain	Nearby Floodplain	Total
Poultry	1,845,704	864,989	2,710,693
Swine	235,829	169,588	405,417

ANIMAL WASTE PRODUCED PER YEAR			
	Within Floodplain	Nearby Floodplain	Total
Poultry	18,567 tons	8,330 tons	26,897 tons
Swine	201,751,264 gallons	169,699,555 gallons	371,450,819 gallons

Lots of Animals on CAFOs

(Concentrated Animal Feeding Operations)
Duplin and Sampson counties in Cape Fear Watershed have more pigs than anyone in the world

- 10 billion gallons of wet animal waste (swine and cattle) produced each year in North Carolina, the equivalent of 15,000 Olympic-size swimming pools
- Annually, poultry operations in the state produce more than 2 million tons of dry animal waste
- 4,145 waste pits make up 6,848 acres of North Carolina's countryside.

PFAS Summary

- Large # of perfluoroalkyl compounds
- Uses: Surface coatings and protectant formulations (have unique surfactant properties). Use includes coatings for paper and cardboard, carpet, leather, textiles that enhance repellency of soil/water/grease, fire fighting foams, and non-stick coatings on cookware
- PFAS very stable/persistent in environment; resistant to biodegradation, photoxidation, hydrolysis. They have low volatility and are persistent in soil and water. They easily leach into the soil and groundwater. They are found everywhere and in all environmental media
- Major exposure pathways: Food, water, ingestion of dust, and hand to mouth transfer from products like treated carpets
- Longer molecules like PFOA/PFOS (C8) have longer resident times in body at 8 years and 5.4 years, respectively

Possible negative health outcomes:

1. Liver damage
2. Pregnancy-induced hypertension/pre-eclampsia
3. Increase thyroid disease
4. Increased asthma diagnosis
5. Decreased fertility
6. Decreases in birth rate
7. Increases in cholesterol
8. Possibly carcinogenic: increase in testicular and kidney cancer

Perfluorobutyric acid (PFBA)
 Perfluorohexanoic acid (PFHxA)
 Perfluoroheptanoic acid (PFHpA)
 Perfluorooctanoic acid (PFOA)
 Perfluorononanoic acid (PFNA)
 Perfluorodecanoic acid (PFDeA)
 Perfluoroundecanoic acid (PFUA)
 Perfluorobutane sulfonic acid (PFBS)
 Perfluorohexane sulfonic acid (PFHxS)
 Perfluorooctane sulfonic acid (PFOS)
 Perfluorododecanoic acid (PFDoA)
 Perfluorooctane sulfonamide (PFOSA)
 2-(N-Methyl-perfluorooctane sulfonamide) acetic acid (Me-PFOSA-AcOH)
 2-(N-Ethyl-perfluorooctane sulfonamide) acetic acid (Et-PFOSA-AcOH)

GenX (PFPrOPrA)

Water quality issues are a major issue in North Carolina. North Carolina has 17 different watersheds, the Cape Fear River Watershed being the largest. The Cape Fear River Watershed is home to approximately 30% of the North Carolina population and supplies over 20% of the state. Greensboro, Durham, Fayetteville and Wilmington, four of the top ten largest metropolitan areas in the state, are all located within this watershed. Issues that have had a significant impact on the Cape Fear River include, nutrient loading, perfluorinated compounds, microcystins during hot and dry weather, and the reclassification of the Lower Cape Fear.

Concentrated animal feeding operations in the Cape Fear River Watershed have caused nutrient loading in the river when disasters strike. Duplin and Sampson counties, to the north of New Hanover County, have more pigs than anywhere in the world. Over 10 billion gallons of wet animal waste are produced each year in North Carolina and over 2 million tons of dry waste is created by poultry operations. A single hog can create over 1,400 pounds of manure, and we have over 9.3 million pigs in the state. Many of these operations are found in the Cape Fear River floodplain and when Hurricane Florence struck, a lot of these farms were flooded, which killed millions of chicken, turkey and swine and released large amounts of animal waste.

Perfluoroalkyl compounds are another major issue in the watershed. These chemicals are manufactured by Chemours in Fayetteville. They have a wide range of applications and are used for everything from surface coatings to fire retardant foams. The problem with PFAS chemicals is the fact that they are very stable, they are resistant

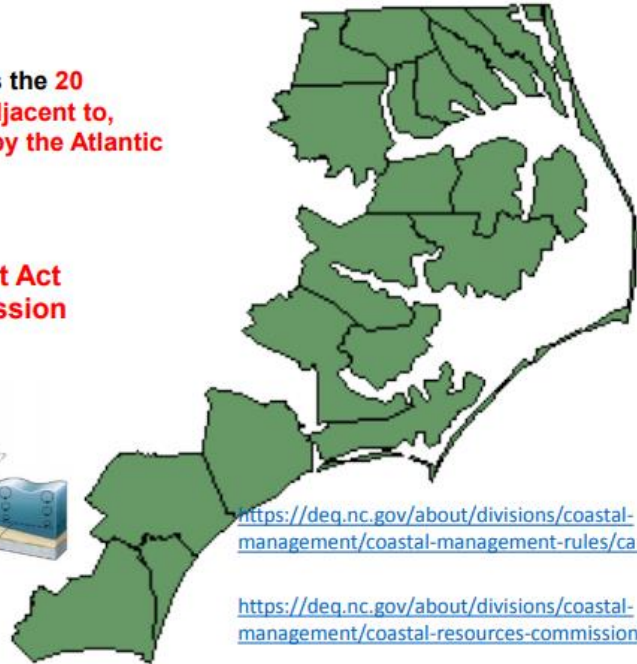
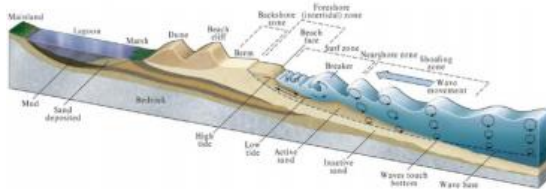
to biodegradation and they can easily leach into the soil or groundwater. These chemicals were once regularly released into the Cape Fear, and even though they no longer are, they have remained in the watershed ever since due to their low volatility. There are a number of negative health effects associated with these chemicals, including liver damage, increased change of thyroid disease, low fertility and many others. After listening to Hank's presentation on hyporheic exchange and these chemicals in the Cape Fear, I really wonder what we will be able to do about this issue.

Coastal Zone

What is the Coastal Zone?

North Carolina's coastal zone includes the **20 counties that in whole or in part are adjacent to, adjoining, intersected by or bounded by the Atlantic Ocean or any coastal sound(s).**

CAMA – Coastal Area Management Act
CRC – Coastal Resources Commission

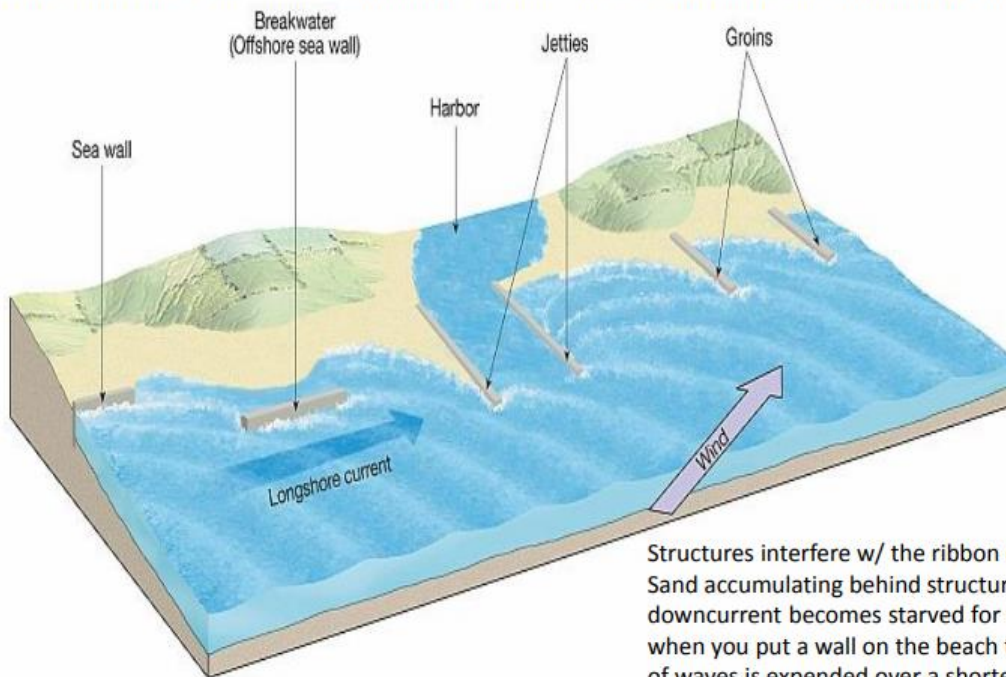


<https://deq.nc.gov/about/divisions/coastal-management/coastal-management-rules/cama>

<https://deq.nc.gov/about/divisions/coastal-management/coastal-resources-commission>

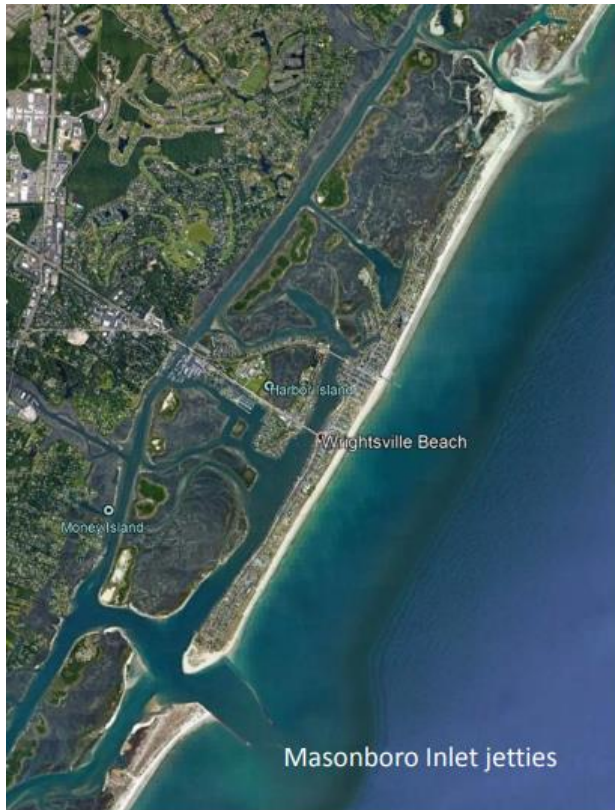
Why did these organization come into being/rationale for them? The Findings of Legislature in 1970s - It is hereby determined and declared as a matter of legislative finding that among **North Carolina's most valuable resources are its coastal lands and waters.** The coastal area, and in particular the estuaries, are among the **most biologically productive regions of this State** and of the nation. Coastal and estuarine waters and marshlands **provide almost ninety percent (90%) of the most productive sport fisheries on the east coast of the United States.** North Carolina's **coastal area has an extremely high recreational and esthetic value which should be preserved and enhanced.**

People get worried when sand moves on the beach, particularly if structures have been placed on the beach and sand loss puts them at risk or the tourist beach is compromised. This is what has led to the “engineering” of many beaches, which means structures and adding sand.



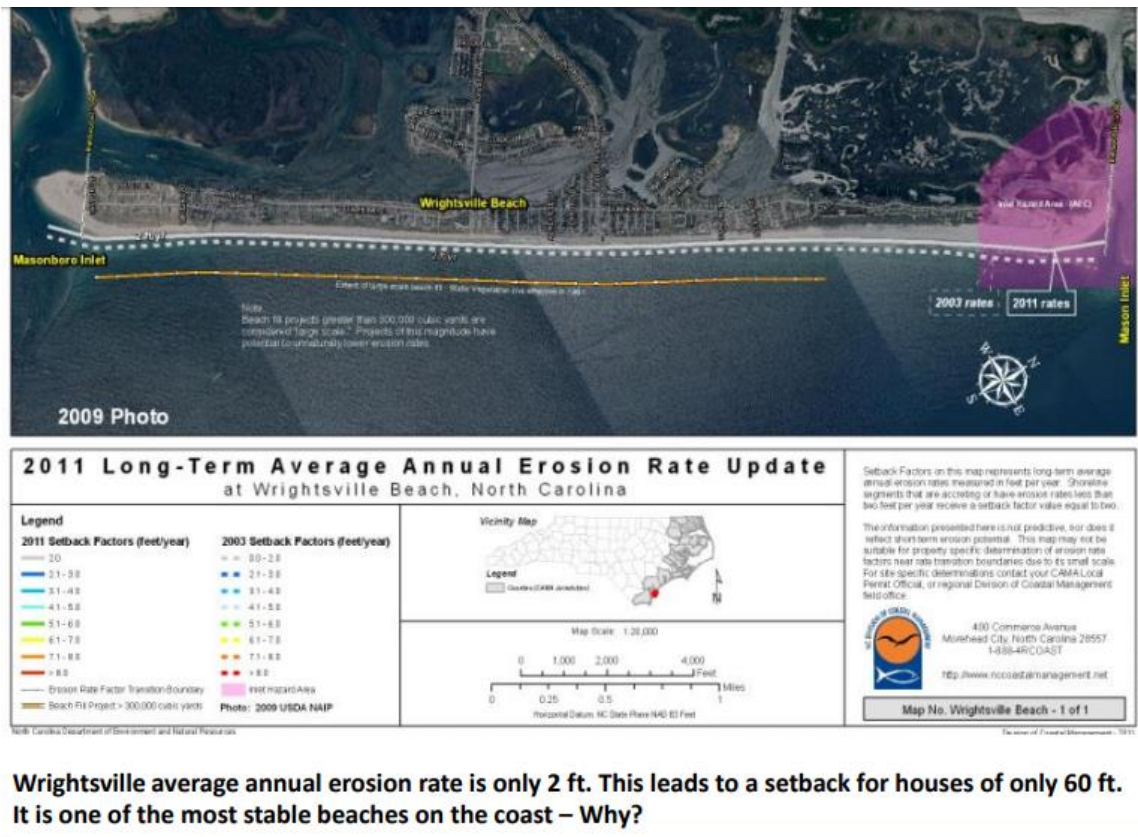
Structures interfere w/ the ribbon of sand. Sand accumulating behind structures means downcurrent becomes starved for sand. And when you put a wall on the beach the energy of waves is expended over a shorter distance = more erosion

Coast-perpendicular: Jetties, Groins
Coast-parallel: Seawalls, Breakwaters, Sandbags



JETTIES keep inlets open for navigation





Wrightsville average annual erosion rate is only 2 ft. This leads to a setback for houses of only 60 ft. It is one of the most stable beaches on the coast – Why?

North Carolina's Coastal Zone includes the 20 counties that are adjacent, adjoining, intersected or bounded by the Atlantic Ocean and any coastal sounds. North Carolina's most valuable resources are its coastal land and waters. The coastal zone, and its estuaries in particular, have been determined to be the most biologically productive regions of the state, and these areas have an extremely high recreational/aesthetic value that should be preserved. When the North Carolina General Assembly adopted the Coastal Area Management Act (CAMA) in 1974, it also created the Coastal Resources Commission (CRC). This body establishes policies for the NC Coastal Management Program and adopts rules for both CAMA and the NC Dredge and Fill Act. The CRC consists of 13 members, eleven of which have specific expertise in areas including land development, coastal engineering, marine science, coastal agriculture, commercial fishing and more.

The coastal zone is highly dynamic and is controlled by a wide variety of processes that operate on a range of spatial and temporal scales. Some of these processes and properties include, tidal range, waves, longshore sediment transport, inlet migration, change in sea level, storms, and development. The intersection between science and policy is extremely apparent in the coastal zone, especially on the beach. Our beaches are a major tourist draw and maintaining the beach for tourism, real estate and recreation is no easy task. Some may say it is a futile one.

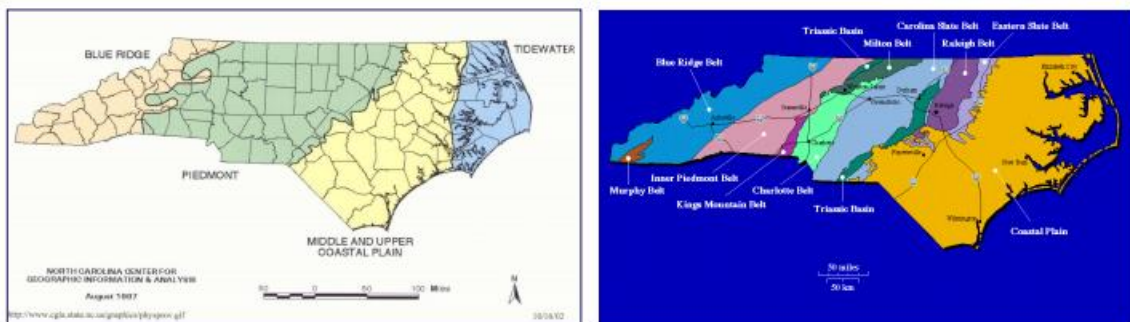
The fact is, sand moves, islands rollover, sea level is rising, and storm patterns are changing. Development on barrier islands will continue to face issues related to these

environmental factors, and currently we have several strategies that are used to engineer our beaches. These include hard structures, like jetties, groins, and seawalls, along with softer approaches like beach nourishment. Utilization of these approaches has consequences though and can alter the natural processes that occur in the surf zone permanently. For example, the jetty installed on the north side of Masonboro Island to stabilize the inlet for navigation in 1980, resulted in accretion of sediment immediately south of the jetty, but has left much of the central and southern portion of the island in a sediment starved state. Meanwhile, Wrightsville Beach, immediately North of Masonboro remains relatively stable due to its regular beach nourishment projects.

North Carolina Geology

North Carolina: Physiography and Geology

Note the correlation and trend (NE-SW orientation) of the physiographic provinces with the geology. Plate Tectonics, rock types, and weathering have led to these relationships



1. **Blue Ridge (10%)** – mountainous area containing all 3 rock types w/ ages of rocks from 0.5 - >1.0 billion years. Highest Peak – Mt. Mitchell @ 6,684', highest east of Mississippi
2. **Piedmont (45%)** – elevations ~600 – 1500' (185 – 460 m) dominated by metamorphic and igneous rock types (Paleozoic). Separated from the Coastal Plain by the fall line
3. **Coastal Plain (45%)** – low gradient, thick soils and sedimentary rocks. Recent to Upper Cretaceous age rocks. Rocks progressively younger toward coast.

Origin of the Appalachian Mountains



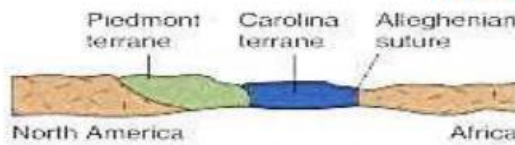
C Ordovician – Silurian (Taconic Orogeny)

Taconic



D Devonian – Mississippian (Acadian Orogeny)

Acadian



E Pennsylvanian – Permian (Alleghenian Orogeny)
North America and Africa joined

Alleghenian



F Triassic – Rifting begins. Breakup of Pangaea starts

Triassic Rifting

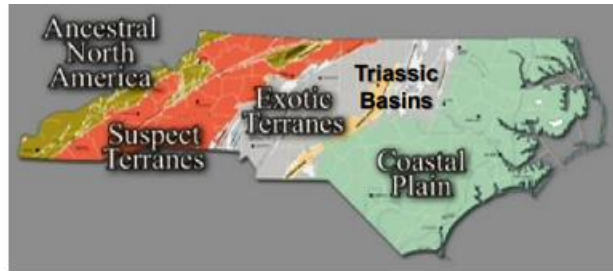
Series of episodic collisions of island arc, convergent ocean continent, and finally the continental collision that welded material onto North America to form the Eastern seaboard and Appalachian Mts.

Three main tectonic events:

1. Taconic – 470 – 440 m.a.
(Ordovician – Silurian)
2. Acadian – 380 – 340 m.a.
(Devonian – Early Carb.)
3. Alleghenian – 330 – 270 m.a.
(Late Carb. – Permian)

And followed by the rifting in the Triassic to form the Basins and ultimately the Atlantic

Subdivisions of NC Geology/Provinces
Descriptions of the Major Geo Areas



<https://naturalsciences.org/learn/learning-resources/exploring-nc>

- **Ancestral North America:** Much of the Blue Ridge; this was the edge of the North American continent approx. 500 million years ago (Cambrian time). Everything to the east of this area was added as plates and arcs after that time.
- **Suspect Terranes,** in many cases have unknown origins. The area is highly metamorphosed (pressure, heat) so it is difficult to establish direct relationships of the origin. Some may be part of the North American edge but others are likely parts of welded on island arcs or plates.
- **Exotic Terranes** are part of volcanic island/arcs that were added throughout the Paleozoic to the edge of the continent. These are definitely part of the major tectonic events mentioned above.
- The **Triassic** (light yellow) formed when rifting began to open the Atlantic Ocean.
- The **Coastal Plain** formed from continental (weathering and erosion of mountainous areas; some believe over 20,000 ft; ~6,000 m) materials being carried by rivers to the ocean and shallow limestones being deposited in shallow seas

The state of North Carolina has a long a varied geologic history. The state can be divided into three distinct physiographic provinces: the Blue Ridge, the westernmost mountainous region that contains metamorphic, igneous and sedimentary rocks; the Piedmont, North Carolina's hill country which is dominated by metamorphic and igneous rocks; and the Coastal Plain, which features a low gradient, thick soils and sedimentary rocks that get progressively younger as one heads east, towards the coast.

The three physiographic provinces have a northeast to southwest trend or alignment that is the result of plate tectonics, rock types and years of weathering. The northeast to southwest trend is not only apparent in the geology, it can be observed in the various land use types and plant distributions throughout the state. For example, the Blue Ridge is home to conifers and deciduous trees. The Piedmont has a plethora of deciduous trees, and cities that are developed along the Fall Line, the boundary where the faster flowing streams of the Piedmont give way to the slowly moving, meandering streams of the Coastal Plain. The Coastal Plain is home to abundant farming operations, and extensive wetlands in the far eastern portion of the state.

A series of episodic collisions welded material onto the North American continent, giving rise to the Appalachian Mountains and Piedmont in what is today North Carolina. These tectonic events are also the reason why the rocks have a northeast to southeast orientation. Prior to the Taconic Orogeny, which occurred between 470 and 440 million years ago, a subduction zone offshore of the American Continent created a volcanic island arc. This island arc then collided with the eastern boundary of the

American Continent, and its material was welded onto both the Piedmont terrane and North American craton. After the Taconic Orogeny, the Acadian Orogeny was the result of the eastward subduction of the Ancestral Atlantic oceanic crust underneath the Carolina Terrane, which occurred between 380 and 340 million years ago. The mountain range that resulted from the Alleghanian Orogeny, the collision of the African and North American Continent between 330 and 270 million years ago, has since weathered and reduced to the hills we know as the Piedmont. The formation of the Coastal Plain in eastern North Carolina occurred most recently. This is the result of the weathering and erosion of mountainous areas, transportation of this material by river, along with shallow limestone being deposited in shallow seas.

Ev-Henwood



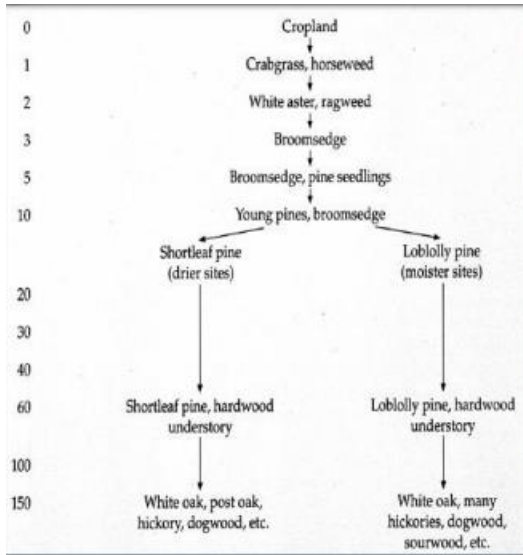
Ev-Henwood Preserve (174 acres)

(1/3 of property has a joint easement with the Coastal Land Trust)

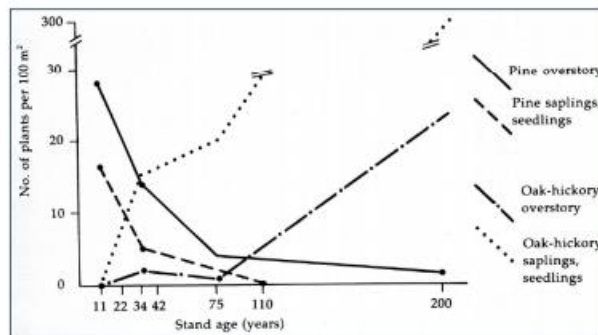
**Note different appearance
2008 vs 2013; time of year
and vegetative growth**

Characteristics:

- Upland wooded area dominated by oaks, hickories, w/ areas of loblolly pines and a slope area of beech. The lowland area and floodplain contain cypress, gum, tupelo, etc. Succession on much of the property; old fields to forest
- Has historical/archaeological significance: ?used by native American Sioux, occupied since 1790 by Henry family and others; use for naval stores
- Numerous Nature trails: upland to transition to wetland
- Part of N.C. Coastal Plain Birding Trail



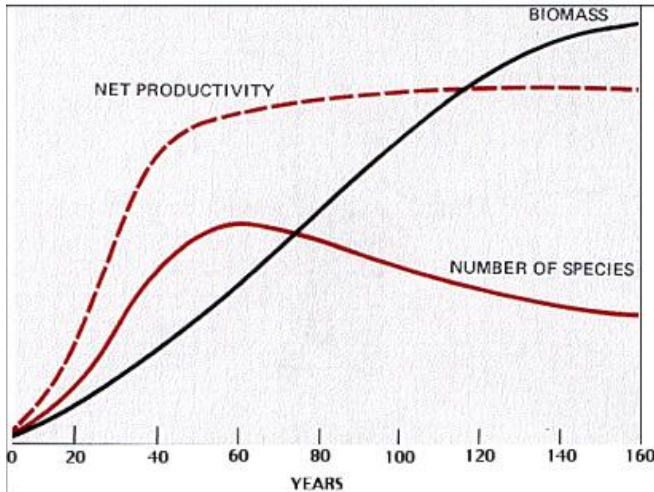
1942 Publication (Oosting) – Old Field Succession in NC Upper Coastal Plain and Piedmont












Old Field Succession – gradual replacement of one community with another until a climax, stable community/ecosystem is reached.

**Plowed Field – Grasses – Shrubs and Pines –
Hardwoods**

There is a gradual/directional change in structure of the ecosystem with changes in plant dominance, productivity and biodiversity.



Ev-Henwood Common Plants, Communities, and Points of Interest			Identify Upland and Wetland Obligate and Facultative Plants Wetland Obligate: Bald Cypress (<i>Taxodium distichum</i>) Wetland Facultative: Red Bay (<i>Persea borbonia</i>) Facultative: Loblolly Pine (<i>Pinus taeda</i>) Upland Facultative: American Beech (<i>Fagus grandifolia</i>) Upland Obligate: Prickly Pear (<i>Opuntia stricta</i>)
			
Bald Cypress (GUS, 6' diam.) (<i>Taxodium distichum</i>)	Loblolly Pine (<i>Pinus taeda</i>)	American Beech (<i>Fagus grandifolia</i>)	
			
American Holly (<i>Ilex opaca</i>)	Red Bay (<i>Persea borbonia</i>)	Laurel Oak (<i>Quercus laurifolia</i>)	
			
Moss and Lichens	Lichen "field" in dry upland	Wetland/floodplain along creek	http://rsgisias.cnel.usace.army.mil/nwpl-static/data/docs/lists_2014/Regions/pdf/reg_AGCP_2014v1.pdf

Ev-Henwood Nature Preserve is a 174-acre preserve that is owned by UNC Wilmington and is located in Brunswick County. Archaeological suggests that this area was most likely used by Sioux-speaking Native Americans, prior to the arrival of the white man. The property was purchased by the Henry family in the 1790's and was used primarily for farming and logging. Farm crops include corn, peas, beans, sweet potatoes, peanuts, cotton, pears, grapes hay, and soybeans. The property was also used in the Naval stores industry. Currently, the goals for the preserve are to restore a small acreage to longleaf pine ecosystem, re-establish fields to study old field succession, inventory plants and animals, and monitor the water quality of Town Creek.

Old-field succession is the gradual replacement of one community with another until a climax, or stable community/ecosystem is reached. In Ev-Henwood, some of the old farmland has been allowed to transition into hardwood forest over time. In general, cropland transitions into plots of land dominated by crabgrass and horseweed. Eventually, pine seedlings and shrubby species begin to grow and ultimately the area becomes a hardwood forest. At the beginning of this process net productivity, biomass and species richness increases. Around the same time net productivity plateaus, 50-60 years into the process, the number of species peaks and begins to decline, while biomass remains increasing. Today most of the upland wooded areas are dominated by oak and hickory forest, but there are areas of Loblolly Pine and a slope area of Beech. The lowland area and floodplain hold cypress, gum and tupelo.

Town Creek, which runs through the preserve, is a blackwater river. It has little sediment, and a lot of tannins from the swamp and organic matter. This gives the water its characteristic tea color. It is classified as swamp water. Large Bald Cypress (*Taxodium distichum*) can be found in the wetlands surrounding the creek. They are obligate wetland species that almost always occur in wetlands under natural conditions. Red Bay (*Persea borbonia*) is an example of a facultative wetland plant occurring in the wetlands around the creek. Facultative wetland plants occur in wetlands but also may occur in non-wetland areas.

Natural Resources

Tar & Turpentine

- English parliament offered a bounty for any Carolinian colonists becoming involved in the naval stores industry during the 1720s.
- Great Britain was highly dependent on trade by ships.
- The industry took off in Duplin county as early as the 1730s.
- Turpentine was used as a water-repellent.
- Tar was used to preserve wooden vessels against rot.
- Both of these products were derived from the long lead pine trees in the forests of early NC.
- By the 1850s North Carolina produced over 95% of the naval stores in the country.



A worker extracting resin.
North Carolina History Project.

Retrieved from: <http://www.northcarolinahistory.org/commentary/103/entry>



Notching and scraping trees



Example of a Notched tree



Collecting and loading tar



Notching and scraping tools



Painting of kiln



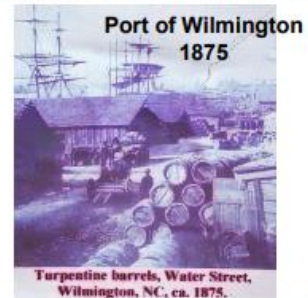
Turpentine still



Model of tar kiln (tarkle)



Evidence of kiln in Green Swamp



Port of Wilmington
1875

Turpentine barrels, Water Street,
Wilmington, NC, ca. 1875.

Cultivation of Rice

Upland- This rice is grown in well drained soil with no surface water accumulation. It relies solely on rainfall, and is susceptible to drought and insects. This method typically has a lower yield, but was common in the Carolinas during the late 17th and early 18th centuries.



Tidal – Rice is planted on areas prone to flooding on deltas or along rivers. Flooding controlled weeds and insects, which were a serious problem in the colonial Carolinas. This method exploded after the Revolutionary War during which many Upland fields were destroyed. It allowed for increased rice production per slave. This was the type of cultivation that took place along the Cape Fear.

Image: North Carolina Colony Rice Field, Most likely Upland
Retrieved from: <http://ushistoryimages.com/north-carolina-colony.shtml>

Rice & the Cape Fear

- The climate along the lower Cape Fear is ideal for rice cultivation.
- Large flood-prone swamp areas allowed for tidal cultivation.
- Proximity to Wilmington meant an ideal location for gentlemen planters to establish plantations.
- Brunswick County had plenty of open land, much of which was gifted to noble families by the Lord's Proprietors of the English King during the 17th and 18th centuries.

Lower Cape Fear river.
New Hanover Public Library.



Two of North Carolina's most important historical exports are Naval Stores and Rice. Both of these export products have played a pivotal role in shaping the State's natural environment and communities in the Coastal Plain.

Naval stores are goods that are used in the construction and maintenance of ships, the primary means of long distance transportation and trade during the colonial era. Over the years Naval stores has referred to everything used in the shipbuilding process, including wood and cloth, but towards the end of the Colonial period, the industry in North Carolina was centered around three key products, tar, pitch and turpentine, all of which were derived from the ubiquitous Long Leaf Pine (*Pinus palustris*). At the height of their colonial power, Great Britain was dependent on trade by ships and offered a bounty for any Carolinian colonists involved with the naval stores industry in the 1720s. Over the next few years the industry took off in Duplin County and by the 1770's North Carolina was responsible for 70% of tar exports, 50% of turpentine exports, and approximately 60% of the naval stores industry as a whole. Just under 100 years later in the 1850s, North Carolina was responsible for over 95% of the naval stores produced in the entire country. Over this entire time period, Wilmington was the shipping capital. However, after the end of the Civil War, the naval stores industry experienced a sharp decline due to the rise of the ironclad ships and the loss of large amounts of pine forest in the state.

The naval stores industry was heavily reliant on physically demanding slave labor. The tar and resins, harvested for anti rot and water repellant properties, were harvested using a few intensive methods. Notching and scraping was performed using a variety of metal hand tools to cut into the living Long Leaf Pines, and extract their resins. A spicket and bucket were placed below these notches and the valuable resins were allowed to flow and collect. This raw product was then distilled in large copper boiling pots to make valuable products like turpentine and rosin. Dead wood was slowly burned in tar kilns. As the wood slowly burned, the resins would flow through a series of trenches where it could then be collected and barreled.

In addition to Naval stores products, rice was also a valuable North Carolina export that came from our neck of the woods, Brunswick and New Hanover County in the Lower Cape Fear Watershed. Rice was introduced into the southern colonies in the 1600's, and our most valuable rice crop, Carolina Gold, was likely being planted prior to the American Revolution. Similar to the Naval stores industry, the rice cultivation labor force was primarily African American. Rice had been cultivated in West Africa for hundreds of years, and slaves from West Africa were highly prized for their knowledge of rice cultivation. Rice was initially grown in wet upland areas, but as time went on, most of the rice fields were developed along rivers, and smaller creeks to take advantage of tidal flooding. In particular, the climate along the lower Cape Fear is ideal for rice production and the large flood-prone swamp areas allow for tidal cultivation. Lowland rice cultivation was serious work. Manmade canals and wetland rice fields had to be dug by hand because oxen would sink in the muck. Although the loss of slave labor after the Civil war resulted in a steep decline in rice production, there is still some small production to this day and the old canals are still evident if viewed from the air.