

# North Carolina Ecosystem Response to Climate Change: DENR Assessment of Effects and Adaptation Measures

*DRAFT*

## Freshwater Tidal Wetlands

### Ecosystem Group Description:

Freshwater tidal wetlands occur in sites where flooding occurs in response to lunar or wind tides, but where the water has less than the 0.5 parts per thousand salt content used to define fresh water. Tidal fresh waters occur in rivers, where freshwater flow keeps out salt water, and along the large sounds where distance from seawater inlets keeps the water fresh. Tidal Cypress-Gum Swamps occupy vast areas at the mouths of large rivers and also occur at the mouths of smaller creeks and occasionally along the sound shoreline. They are dominated by swamp black gum, water tupelo, and bald cypress. Understory trees, shrub, and herb layers are generally sparse and low in diversity. Tidal Freshwater Marshes occur in the lowermost parts of some tidal rivers and creeks and, more commonly, in large flats along the shorelines of freshwater sounds. The vegetation is generally strongly zoned and often very diverse in at least some zones. Two distinct variants are recognized, one with very slightly salty (oligohaline) water, the other completely fresh.

### Ecosystem Level Effects:

#### Predicted Impacts of Climate Change:

Climate Change Factor:	Likelihood:	Effect:	Magnitude:	Comments:
Coastal Erosion	High	Neg	High	Already occurring along the sounds, and likely to increase with increased storm intensity.
Increased Temperature	High	Mix	Low	
Drought	High	Neg	Low	Drought in systems along rivers may cause salinity variation.
Flooding	High	Mix	Low	Freshwater flooding will cause salinity variation.
Wind Damage	High	Neg	Med	
Storm Surge	High	Neg	High	Brings temporary pulses of salt that act as a disturbance.
Sea Level Rise -- Salt Intrusion	High	Neg	High	Likely to convert large area to salt marsh. May accelerate erosion of organic soils.
Sea Level Rise -- Inundation	High	Neg	High	

These systems are likely to be among the most severely affected by expected climate change. Changes caused by rising sea level are the greatest threat, but increased intensity of storms, both in rainfall and wind, are also important. The Climate Wizard median temperature model (Maurer et al., 2007) predicts a rise in average annual temperature along the coast of North Carolina of around 3.5 degrees by 2050. Rising average temperature may be important, though similar systems and many of the species range well to the south.

The freshwater tidal wetlands in the southern part of the state are mostly associated with rivers and large

creeks. Lunar tides dominate, and tidal amplitude can be several feet in the lower portions. Rising sea level can be expected to shift the zone of tidal influence upstream. Permanent inundation and conversion to brackish water can be expected in the downstream portions. Slopes to uplands are relatively steep, and inland shifts other than along river courses are likely to be relatively small.

The northern tidal wetlands are mostly along the sounds and are driven by wind tides. This region has been subsiding due to geologic forces, so that relative sea level rise has been more significant here than farther south. Permanent inundation and shoreline erosion are already occurring gradually and can be expected to accelerate. The zone of tidal influence is likely to shift upstream along large rivers like the Roanoke, Chowan, Tar, and Scuppernong. Elsewhere, large expanses of freshwater tidal wetlands lie along estuarine shorelines with very gentle slope upward to low-lying wetlands. Tidal influence can be expected to penetrate farther inland into nonriverine wetlands in some of these areas, allowing the potential for inland migration. In other portions, abrupt slopes to uplands, development, or lack of any higher land adjacent will make migration impossible.

An additional crucial issue in the northern coastal region is the fate of the Outer Banks. Albemarle Sound, Currituck Sound, and the upper Pamlico River are freshwater and driven by wind tides because of the nearly continuous barrier islands along the coast and lack of tidal inlets. This situation is a recent natural development and is unlikely to last as sea level continues to rise. Formation of new inlets will turn extensive freshwater areas into brackish or salt water. New inlets will allow the influence of lunar tidal fluctuations into wind tidal areas.

There is also a significant chance of a more drastic collapse of the Outer Banks. Stan Riggs (personal communication 2010) indicates that, within historic times, most of what is now the narrow barrier islands of the Outer Banks were underwater shoals, and that Pamlico Sound was open to ocean waters. Increased storm intensity and rising sea level make a return to such a configuration possible. Barrier islands that are not artificially stabilized can naturally migrate inland to keep pace with rising sea level, but the limited sand supply and deeper water behind them make long-term migration of these islands unlikely. The current artificial stabilization, which prevents overwash and natural migration, will make the demise of these islands likely to occur sooner. If much of the Outer Banks is lost, some sound areas that now are sheltered will become exposed to lunar tides and storm waves, resulting in increased shoreline erosion as well. Stan Riggs (personal communication 2010) indicates that, before the Outer Banks developed in historic times, not only were the sounds salty, but the shape of the bay led to a larger lunar tidal amplitude than now occurs in this part of the coast. Such changes could occur gradually, as barrier islands narrow and disappear. But it could also happen catastrophically, if a large storm destroys a large length of barrier islands at one time. Catastrophic loss of narrow barrier islands was observed in Louisiana with Hurricane Katrina.

Changes in input of fresh water may also be significant to these systems. Most of the freshwater tidal wetlands in the northern part of the state have limited freshwater input from rivers, but the input of freshwater from creeks and from sheetflow may be important. Changes in salinity associated with recent droughts have been observed, and may have had effects on existing vegetation. An increase in drought frequency or severity would make such effects more important. Conversely, an increase in extreme rainfall events could bring increased freshwater inputs at times, resulting in more fluctuation of salinity than now occurs.

Increased intensity of wind, other than its effect on wave erosion along the shoreline, is likely to be significant only for the forested freshwater tidal wetlands. It is likely to be less important than changes in salt levels and tides, but could alter forest structure or contribute to the shift from swamp forests to

marshes.

Increased average temperature and warmer winters could affect competitive relations among species and allow more southern species to migrate into these systems. A few species in freshwater marshes are at their southern range limited in North Carolina and could be lost from the state. If there are rapid changes in salinity, they may have difficulty migrating northward.

### **Predicted Ecosystem Responses:**

Ecosystem Response:	Likelihood:	Effect:	Magnitude:	Comments:
Exotic species invasion	Med	Neg	Med	Phragmites is already invading, but disturbances associated with climate change may increase it. Other exotics such as <i>Triadica sebifera</i> may expand.
Compositional Change	Med	Mix	Low	
Structural Change	High	Neg	High	Much conversion of tidal swamp to marsh. Some additional structural change in surviving swamps with increased storm damage.
Inland Migration	High	Mix	High	Some areas of inland migration will result in less acreage but some could increase.
Acreage Change	High	Neg	High	Drastic losses are likely if the Outer Banks collapse

This Ecosystem Group is likely to experience drastic changes in extent and to see significant movement of communities. The extensive tidal wetlands in northeastern North Carolina will be affected most because of very gentle land slopes and because of the potential for drastic changes in the sheltering barrier islands. Because of steeper slopes, narrower estuaries, higher tidal ranges, and systems that are in equilibrium with numerous existing barrier island inlets, the changes will be less drastic in southeastern North Carolina.

If the Outer Banks are breached, abrupt changes in salinity would cause drastic shifts in community types and composition over large areas in the region where this Ecosystem Group is most extensive. Salt-intolerant species would be killed and freshwater marshes would become brackish or salt marshes. Tidal swamps may be killed and become brackish marshes. Farther inland, swamps may be killed by saltier storm surges but develop as freshwater marshes. Dominant brackish marsh plants likely can establish quickly, but it is unclear if time will be needed for the full complement of species to establish.

Where salinities don't change catastrophically, communities should be able to migrate inland. There is natural connectivity along river floodplains and along the flatter shorelines. Tidal swamps and freshwater marshes in river valleys will move upstream into river swamps. Tidal swamps and freshwater marshes along shorelines will move inland into nonriverine swamps if the land slope is gentle. The net change in acreage of communities will vary with the slope of the land. If there is a steepening or abrupt change in land slope inland, communities along shorelines may be squeezed and become smaller or disappear. In other places, the land slope may favor more extensive tidal swamps or marshes at particular stands of sea level. Tidal freshwater marshes are currently developing along some stretches of shoreline that did not previously have them.

In river valleys, there are always likely to be suitable sites for tidal communities to move into, and the local extent may not change much. However, the flat, featureless floodplains that mark most tidal swamps are a result of sediment and organic matter accumulation as sea level rose at the end of the Pleistocene. If sea level rises far enough, tidal effects will move into the more topographically variable floodplains upstream. This would restrict the extent of tidal swamp habitat, but it is still likely to remain extensive.

Increased penetration of storm surges, beyond the expected inland migration with sea level rise, may or may not have a major additional effect. Penetration of storm surges is likely part of what determines the current boundary between tidal freshwater marshes and swamps, and of tidal and non-tidal swamps. However, if hurricanes become more intense, there may be more disturbance of Freshwater Tidal Wetlands by salt intrusion as well as by wind.

If increased storm frequency produces more wave impact on shorelines, some marshes or swamps may be eroded at increased rates. If storm surges are more frequent, chronic disturbance may shift the ecological character of the marshes to some extent. However, they are already subject to fairly frequent disturbances, and the vegetation naturally recovers quickly from these disturbances.

Organic soil stability is a major question, particularly in northeastern North Carolina. Peats which are stable in freshwater conditions can be rapidly oxidized by sulfur bacteria if oligohaline or brackish waters reach them. However, many oligohaline tidal freshwater marshes, tidal swamps, and even brackish marshes occur on organic soils, yet appear to be stable. If they become unstable, rapid loss of much of their extent could occur. We need to know more about what circumstances cause organic soils to rapidly decay.

Community composition may change with warmer temperatures. There is significant connectivity among tidal wetlands along the coast, so migration should be possible. The appearance of species native to comparable ecosystems farther south should not be regarded as a problem. Manatees, spoonbills, and possibly other species may be able to persist in North Carolina in the future climate.

Invasive plants may increase. *Phragmites australis* is already a severe problem in many freshwater marshes. The disruptions created by shifting communities and catastrophic events may increase its spread. There is particular concern that it may take over newly developing marshes before native species have a chance to establish. Chinese tallow tree (*Triadica sebifera*) is a major problem farther south and is already appearing in North Carolina. It is likely to be more invasive with warmer temperatures.

## Habitat Level Effects:

### Natural Communities:

Third Approximation Name:

Comments:

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Tidal Cypress--Gum Swamp

Tidal Cypress-Gum Swamps are extensive along shorelines and along drowned river valleys (e.g. Cape Fear, Neuse, and Chowan River). Tidal swamps will migrate inland along rivers and along low shorelines. Brownwater, blackwater, or nonriverine swamps gradually develop the character of tidal swamps by replacement of the shrub and herb layers. The gum-cypress canopy may remain intact, but any pines or white cedars are likely to die. Most major patches have room to migrate inland, so they are unlikely to be reduced drastically. However, very rapid rise in sea level or breach of barrier islands could kill existing swamps before new swamps have a chance to develop.

Tidal Freshwater Marsh

Our types of Tidal Freshwater Marsh are rare globally. The most extensive examples are around Currituck Sound. The Currituck Banks are not as vulnerable to collapse as the Outer Banks farther south, but development of new inlets and a return of salt water is likely at some time. Other extensive Tidal Freshwater Marshes are at river mouths and should be able to migrate upstream if sea level rise is not too fast. Marshes are already developing along the lower Alligator River, where they did not exist before. Marshes may develop at the mouth of the Roanoke River and at other places where they don't now exist. Other existing marsh areas will be lost to erosion and submergence. The net effect will certainly be a loss of extent, but the magnitude of change is uncertain and depends on the rate and degree of sea level rise and on the fate of the barrier islands. Marshes could be squeezed between rising sea level and uplands – this will be locally determined, depending on land slope. Phragmites is a major threat.

Tidal Cypress-Gum Swamps turn into Tidal Freshwater Marshes with rising sea level. Accumulating stress causes tree crowns in the swamps to thin and shrub and herbaceous layers to develop. Storm surges or increased stress finally kill the canopy trees, resulting in a marsh. Cypress trees may survive as a sparse presence in the marsh. If the rate of sea level rise increases, this pattern may shift, with less time for marsh vegetation to develop beneath thinning canopies. Cypress is more tolerant of low levels of salt than are other trees, and the presence of surviving cypress trees in the new marshes may help stabilize them.

**LHI Guilds:**

Guilds with Significant Concentration in Ecosystem Group:    Comments:

General Marshes	These habitats are not as highly threatened and animals can use brackish marshes as well as fresh.
Freshwater Marshes	These habitats include interior marshes also. They are probably not greatly threatened overall, but breaching of the barrier islands would greatly reduce the amount in the northeast part of the state.
Cypress-Gum Swamp Forests	Overall habitat extent will decline because inland cypress—gum swamps will decline some, but will remain extensive.

Freshwater swamps and marshes are not confined to the tidewater region but have some of their most extensive examples along the coast, particularly in the Albemarle and Currituck Sounds and at the mouths of the Cape Fear, Neuse, Tar, and Roanoke Rivers. Members of the guilds associated with these habitats can occur in similar habitats in inland areas, although many are currently known only or primarily from along the coast. Extensive loss of coastal habitats due to breaching of the barrier islands is likely to have major impacts to these guilds, although most should be able to survive, particularly if tidal freshwater habitats are able themselves able to migrate inland, keeping ahead of both sea-level rise and saltwater intrusion.

**Species Level Effects:**

<b><u>Plants</u></b>	Element Rank:	Endemic	Major Disjunct	Extinction/Extirpation Prone	Status: US/NC	Comments:
Ptilimnium ahlesii	G1/S1				FSC/SR-L	Very rare. Probably can migrate inland.
Minuartia godfreyi	G1/S1				FSC/E	This species reaches the northern limit of its range in NC.
Aeschynomene virginica	G2/SH			Yes	T/E	Extremely rare or already lost from North Carolina.
Oenothera riparia	G2G3/S2S3				/SR-L	Occurs in more inland areas. Likely to be able to migrate upstream.

<i>Cardamine longii</i>	G3/S1			/SR-T	
<i>Carex decomposita</i>	G3/S2			/SR-T	
<i>Lilaeopsis carolinensis</i>	G3G5/S2			/T	Occurs around freshwater sounds, where it may be subject to catastrophic salinity changes.
<i>Bacopa innominata</i>	G3G5/SH			/SR-P	
<i>Ptilimnium costatum</i>	G4/S1			/SR-P	Very rare. Probably can migrate inland.
<i>Carex hormathodes</i>	G4G5/S1			/SR-P	
<i>Eleocharis cellulosa</i>	G4G5/S2			/SR-P	
<i>Limosella australis</i>	G4G5/S1			/SR-P	Very susceptible if sounds become brackish. It is at its southern range limit, and may suffer from warmer temperatures.
<i>Eriocaulon aquaticum</i>	G5/S2			/SR-P	
<i>Crinum americanum</i>	G5/SH			/SR-P	This species has not been seen in NC in recent years.
<i>Eleocharis rostellata</i>	G5/S2			/SR-O	Can occupy freshwater or brackish marshes, but degree of salt tolerance is unknown. Needs burning of marshes to maintain habitat. Limited extent within NC is a major concern.
<i>Ranunculus hederaceus</i>	G5/SH			/SR-D	Can occupy freshwater or brackish marshes, but degree of salt tolerance is unknown. This species is at the southern end of its range in NC, but has not been seen in recent years; may already be gone. Warmer climate may be a problem.
<i>Leptochloa fascicularis</i> var. <i>maritima</i>	G5T3T4Q/S1			/SR-O	Needs burning of marshes. May not be able to migrate if sounds become brackish.

Small plants of low interior marshes appear to need fire to maintain their habitat. All plant species of Tidal Freshwater Marshes would be harmed by catastrophic shift to saltier water. Those on the sounds rather than along rivers might not be able to migrate to more inland areas.

Some rare species in this habitat are particularly rare or threatened in NC. Several rare plant species are at the southern end of their range in NC. Some of these have not been relocated in recent years, despite searches (*Aeschynomene virginica*, *Ranunculus hederaceus*, *Crinum americanum*). Because rare plants of this habitat type are particularly likely to be impacted by climate change, it is especially important to assess their status and range in NC now. Thorough field surveys and threat assessment are needed.

### **Terrestrial Animals**

Species:	Element Rank:	Endemic	Major Disjunct	Extinction/ Extirpation Prone	Status: US/NC/WAP	Comments:
<i>Problema bulenta</i>	G2G3/S1		Yes	Yes	FSC/SR/	Completely tied to tidal freshwater marshes. Only a single population is known from North Carolina, in the tidal portion of the Cape Fear River. The next nearest population may be in Charleston, South Carolina.
<i>Anacamptodes cypressaria</i>	G2G4/SU				/SR/	Largest known population in the state is in the Albemarle-Pamlico Peninsula.

				Associated primarily with non-riverine swamps.
Euphyes dukesi	G3/S1	Yes	/SR/	North Carolina populations all occur along ecotones between tidal freshwater marshes and tidal swamp forests. Larvae feed on Carex, including hyalinolepis, which occur farther inland, possibly allowing some migration upstream as coastal habitats become more brackish.
Acronicta perblanda	G3G4/S1S2	Yes	/SR/	Known in North Carolina only from the vicinity of Core Creek. Next nearest documented population is in South Carolina. Probably not strictly tied to tidewater habitats, but general habitat requirements are not well understood.
Rallus elegans	G4/S3B,S3N		/W1,W3/P	
Botaurus lentiginosus	G4/S1B,S3N		/SR/P	
Ixobrychus exilis	G5/S3B		/SR/P	

No terrestrial animals are endemic to this Ecosystem Group within North Carolina, although the rare skipper (*Problema bulenta*) occurs solely within tidal freshwater marshes throughout its range, from New Jersey to southern Georgia. Duke's skipper (*Euphyes dukesi*) is also restricted to these habitats along the Atlantic coastal portion of its range, although it also occurs inland in Florida, and in the Mid-West region. Although the reasons for these restrictions are not clear, the larvae of both species feed on plants that occur well inland from the coast, even in North Carolina, both of these species are potentially susceptible to extirpation from the state if they or their specialized habitats cannot keep pace with the effects of sea-level rise and saltwater intrusion.

## Combined Threats and Synergistic Impacts:

### Importance of Climate Change Factors Compared to Other Ecosystem Threats:

Threat:	Rank Order:	Comments:
Climate Change	1	
Invasive Species	2	Phragmites, Triadica, possibly others.
Logging/Exploitation	3	Logging is a threat to some Tidal Cypress-Gum Swamps.
Fire	3	Lack of fire allows unnatural vegetation succession in some freshwater marshes.
Flood Regime Alteration	4	May be locally important.

Because these systems are so subject to sea level, tidal movement, water salinity, and storms, these effects of climate change are the greatest threats. Deliberate exploitation is limited because of extreme wetness. Some of the Tidal Cypress-Gum Swamps can be logged, while others are in protected status and others are too wet for logging equipment. *Phragmites australis* is currently a significant threat to Tidal Freshwater Marshes. While *Phragmites* may not be more competitive under warmer temperatures, the disruptions caused by climate change are likely to make marshes more susceptible to its invasion. There is a significant risk that it could come to dominate newly developing and migrating marshes before the native vegetation can become established.

Fire is needed in some Tidal Freshwater Marshes. Some rare plants and some subtypes of these communities have become rare because of loss fire.

Alteration of flood regimes in rivers may affect these systems. Some areas are fresh largely, or at least partly, because of dilution of sea water by river input. Increased water withdrawal or inter-basin transfer may increase this problem in the future. The effects are local, affecting primarily the mouth of the altered rivers, but could be important cumulatively.

## Recommendations for Action:

### Interventive Measures:

Intervention:	Importance:	Feasibility:	Comments:
Control Invasive Species	High	Med	
Conduct Prescribed Burns	Med	High	
Allow Barrier Islands to Migrate	Med		Reduces the risk of catastrophic loss of islands
Protect/Expand Remaining Examples	High	High	Need to focus on examples that will be likely to persist or migrate.
Restore/Maintain Hydrology	High	High	Existing drainage ditches and canals bringing salt water into wetlands is a serious threat. Tide gates or blocking ditches are needed.

While many existing marshes are likely to be lost, there is a need to protect the examples that are most likely to persist, to protect those that will be able to migrate inland, and to protect those that will be the seed source for newly developing marshes. While few freshwater marshes are likely to remain where they now are, the potential for diverse, resilient Tidal Freshwater Marshes in the future depends on a robust seed source for their biota. Besides protecting existing good examples, management, such as prescribed burning, that improves the vigor and species richness of these communities in the short run should contribute to better prospects for the marshes of the future.

There is also a need to protect the areas that will become Tidal Freshwater Marshes as sea level rises. Most of these are likely Tidal Cypress-Gum Swamp at present. Tidal Cypress-Gum Swamps with mature cypress trees in them may lead to marshes with a tree component that will improve their resistance to erosion.

There is a corresponding need to protect sites that will become Tidal Cypress-Gum Swamp in the future. Because most of the dominant trees are the same and can persist in the transition to tidal conditions, protecting mature Nonriverine Swamp Forest and Brownwater or Blackwater Cypress-Gum Swamp areas will allow more rapid development of Tidal Cypress-Gum Swamps.

There is a great need to control invasive species. Phragmites currently exists along forest roads and ditches in wetlands that are likely to become Tidal Freshwater Marsh in the future. These populations appear stable at present but represent a significant threat. Developing marshes will be particularly susceptible to invasion. Control of Phragmites to remove the seed source may be crucial to the development of marshes dominated by native species. Tidal Cypress-Gum Swamps currently don't have significant invasive species problems, but Chinese tallow tree and other species are likely to increase with warmer temperatures. Early control of species that have proven more invasive farther south will be less costly and less ecologically disruptive than

allowing populations to become large.

Freshwater marshes with 10-30% cypress cover occur naturally in a number of places, presumably where marshes have developed in former tidal swamps. Cypress was probably present in many nonriverine swamp that are now becoming marshes, but was lost to logging. Planting cypress would allow that component to be present in the developing marshes. The cypress naturally present in freshwater marshes does not appear to be reproducing and is probably relict. Cypress probably has little effect in the marsh interior. Where it occurs on freshwater shorelines, it may help stabilize the shoreline against wave erosion. Where the adjacent waters are brackish, cypress is unlikely to survive once it becomes exposed on the shoreline. It is also unlikely that cypress would survive if fresh water becomes brackish because of a barrier island breach.

Because shoreline erosion is a source of loss of Freshwater Tidal Wetlands beyond the effect of inundation, erosion control measures may help prolong their survival. However, measures that alter the shoreline, whether sea walls, "soft" structures, or plantings of off-site species, are potentially destructive to these communities.

Much of what happens to Freshwater Tidal Wetlands will depend on what happens to the barrier islands. Some changes are inevitable, but management on the islands will make a difference to their fate. Natural overwash processes allow islands to migrate inland with rising sea level. Islands that are artificially stabilized by development or by artificial dune buildings tend to erode and become narrower, and are more likely to be breached or eroded away. Inlet migration is also part of the process by which barrier islands maintain themselves. While formation of new inlets will cause changes in the sounds, allowing it to proceed is likely to allow more gradual adaptation to saltier conditions and to reduce the risk of catastrophic changes.

## **Ecosystem Group Summary:**

Freshwater Tidal wetlands are likely to be highly vulnerable to the effects of climate change. The predicted increase of storms, shoreline erosion, sea level rise and the intrusion of salt water will convert freshwater wetlands into saltwater or brackish. If a catastrophic hurricane were to breach the Outer Banks, freshwater marshes would be abruptly exposed to brackish or salt water, lunar tides, and wave action. This abrupt change would not allow for the gradual migration of these communities, particularly along the northern coast. Priority to increase resilience in these systems should be placed on protecting areas that will be likely to persist or migrate, blocking ditches that are now allowing saltwater into freshwater wetlands, and controlling Phragmites in these areas.

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