CHAPTER 5. WETLANDS

Wetlands are widely recognized as habitats vital to fisheries production in North Carolina and elsewhere (Mitsch and Gosselink 1993; Graff and Middleton 2003). This chapter defines and describes wetland habitats found in coastal North Carolina and documents their current distribution, ecological role, biological function, current status, trends, threats, and management needs.

Coastal wetlands border vital nursery areas and serve as the primary buffer between land and water-based impacts.

5.1. DESCRIPTION AND DISTRIBUTION

Definition

Wetlands are wet areas commonly referred to as swamps or marshes. Wetlands, as defined by federal regulations [40 CFR 230.3(t)] and EMC rules [15A NCAC 2B .0202(71)], are "…areas that are inundated or saturated by an accumulation of surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." The boundary between wetlands and deepwater habitat (i.e., submerged aquatic vegetation) is defined as the maximum depth where rooted emergent vegetation (i.e., marsh grasses) can be found - generally <6ft (2m) below mean low water during the growing season (Figure 5.1). The EMC and federal regulatory definitions include nontidal freshwater wetlands not subject to CRC rules. The CRC refers to coastal wetlands as "marshlands," defined as "any salt marsh or other marsh subject to regular or occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses), provided this shall not include hurricane or tropical storm tides" [G.S. 113-229(n)(3)]. The CHPP will focus primarily on wetlands that are connected to coastal water bodies by surface water of sufficient depth to allow fish utilization. These "connected" wetlands are hereby termed "riparian wetlands" because they border streams and other water bodies.

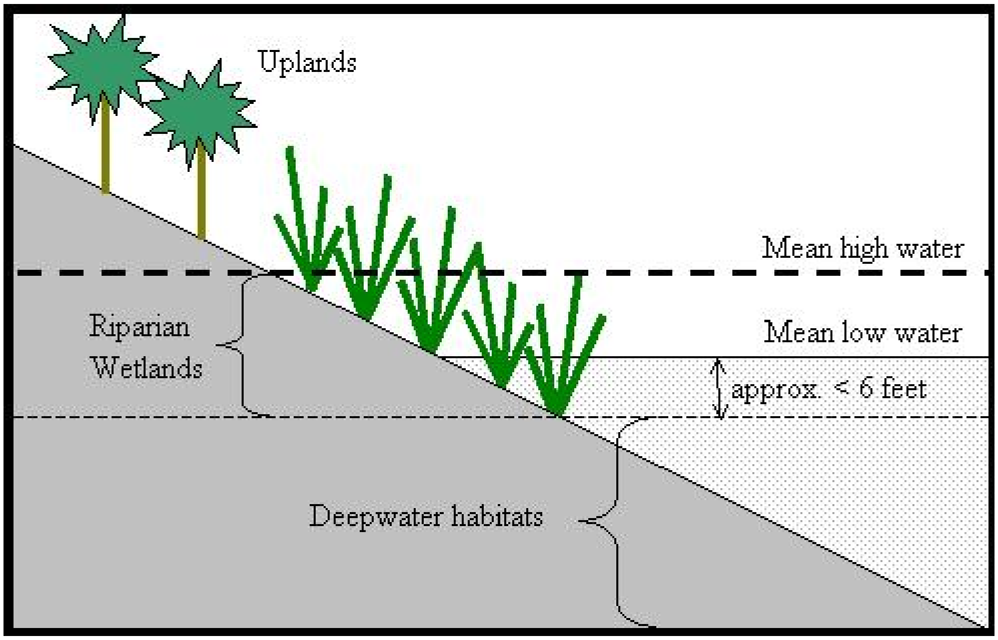


Figure 5.1. Graphic depiction of the conceptual boundaries among riparian wetlands, uplands, and deepwater habitats.

Description

Riparian wetlands can be differentiated into four broad wetland classes based on their landscape position within drainage networks (hydrogeomorphology): estuarine, riverine, headwater, and flat/depressional (Sutter 1999).

- **Estuarine wetlands** are generally found along the margins of estuaries and sounds. Estuarine wetlands include salt/brackish marsh, estuarine shrub/scrub and estuarine forests.
- **Riverine wetlands** are those in which hydrology is determined or heavily influenced by proximity to a perennial stream of any size. Overbank flow from the stream exerts considerable influence on the hydrology of larger streams. Riverine wetlands include freshwater marshes, bottomland hardwood forest, and riverine swamp forest.
- **Headwater wetlands** exist in the uppermost reaches of local watersheds upstream of perennial streams. Headwater systems may contain channels with intermittent flow, but the primary sources of water input are precipitation, overland runoff, and groundwater discharge rather than overbank flow from a stream.
- **Flat/depressional wetlands** are generally not in direct proximity to surface water. While they are isolated from or hydrologically disconnected from surface water, the hydrology of depressional wetlands is primarily determined by groundwater discharge, overland runoff, and precipitation. Flat/depressional wetlands include pocosins, pine flats, depressional swamp forest, hardwood flats, maritime swamp forests, and some managed pinelands. They are also referred to as non-riparian wetlands.

While fish occupy riverine and estuarine wetlands (Map 5.1a-d) during periods of regular inundation, headwater and flat/depressional wetlands (Map 5.2) are generally not directly utilized by fish. However, there are some exceptions. The pocosins adjacent to the Alligator and Northeast Cape Fear rivers have surface drainage to coastal waters (Brinson 1991). However, the primary focus of this chapter is the riparian wetlands found in estuarine and riverine systems.

Estuarine wetlands

- **Salt/brackish marsh** is defined by DCM using the CAMA definition for coastal wetlands. Salt/brackish marsh is therefore defined by the plant species it contains: smooth cordgrass, black needlerush, glasswort, salt grass, sea lavender, bulrush, saw grass, cattail, salt-meadow grass, and salt reed-grass [G.S. 113-229(n)(3)].
- **Estuarine forested wetlands** are subject to occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses). Examples include pine-dominated communities with rushes in the understory or fringe swamp communities, such as those that occur along large back barrier estuaries like Albemarle and Pamlico sounds. Estuarine forested wetlands are common in upper estuarine sections of coastal rivers.
- **Estuarine shrub/scrub** is any shrub/scrub dominated community subject to occasional flooding by tides, including wind tides (whether or not the tide waters reach the marshland areas through natural or artificial watercourses). Typical species include wax myrtle and eastern red cedar. Examples include areas along the sound shorelines of barrier islands.

Riverine wetlands

- **Freshwater marshes** are defined by DCM as herbaceous areas that are flooded for extended periods during the growing season. Included are marshes within lake systems, managed impoundments, some Carolina Bays, and other non-tidal marshes (i.e., marshes which do not fall into the salt/brackish marsh category). Typical communities include species of sedges, millets, rushes and grasses that are not specified in the coastal wetlands regulations. Also included are giant cane, arrowhead, pickerelweed, arrow arum, and smartweed. Such marshes occur in the coastal waters of the Trent River near New Bern and along parts of the Cape Fear and Northeast Cape Fear rivers.
- **Bottomland hardwood forests** and **riverine swamp forests** are generally forested, or occasionally shrub/scrub, communities usually occurring in floodplains, that are semi-permanently to seasonally flooded. Bottomland hardwood forests contain mostly oaks (overcup, water, laurel, swamp, chestnut), sweet gum, green ash, cottonwoods, willows, river birch, and occasionally pines, while riverine swamp forests contain generally cypress, black gum, water tupelo, green ash and red maple. These swamps occur throughout the shoreline areas of coastal rivers.

Headwater wetlands

- **Headwater swamps** are wooded, riverine systems along small, intermittent tributary streams. Headwater swamps include hardwood-dominated communities with soil that is moist most of the year. Channels receive their water from overland flow and rarely overflow their banks.

Flat/depressional wetlands

- **Non-riverine swamp forests** are very poorly drained, non-riverine forested, or occasionally shrub/scrub, communities which are semi-permanently to temporarily flooded. Typical species include cypress, black gum, water tupelo, green ash and red maple (Sutter 1999).
- **Pocosins** are palustrine shrub/scrub communities (i.e., non-estuarine shrub/scrub) dominated by evergreen shrubs, often mixed with pond or loblolly pines. Pocosins typically occur on saturated, acid, nutrient poor, sandy or peaty soils; usually removed from large streams, and subject to periodic burning.
- **Wet forested flats** are poorly drained interstream flats not associated with rivers or estuaries. They are seasonally saturated by high water table or poor drainage. Species vary greatly but often include sweet gum and red maple. This category includes some hardwood flats, pine flats, and pine plantations.
- **Maritime Swamp Forests** are forested communities characterized by stunted growth due to the stresses imposed by its proximity to salt spray from the ocean. Typical vegetation includes live oak, red cedar, red maple, and swamp tupelo.

Habitat requirements

Estuarine wetlands

Salt/brackish marsh plants grow at salinities from 0.5 to >35 ppt (Wiegart and Freeman 1990). Within this salinity range, salt marsh plants persist in low-energy protected areas where the rate of sediment building (accretion) exceeds the rate of sediment loss (through erosion) or subsidence (Mitsch and Gosselink 1993). Inorganic sediments are deposited by river currents, tidal creeks and ocean overwash on and adjacent to the marsh platform (Wiegert and Freeman 1990; Mitsch and Gosselink 1993). Deposition from sediment-laden creek water causes side levees of higher elevation (low marsh) and coarser particle size than the sediments in the marsh interior (high marsh).

Erosion and sedimentation are natural processes that can result in changing distributions of marsh vegetation. The rate of erosion is dependent on shoreline orientation, fetch, water depth, bank height, sediment composition of bank, shoreline vegetation, presence of offshore vegetation, and boat wakes (Riggs 2001). In general, all of the Albemarle-Pamlico estuarine system, which is a drowned river system, is in a state of shoreline recession (Riggs and Ames 2003). South of Bogue Sound, estuarine erosion is severe only in portions of drowned river estuaries such as the Cape Fear, New, and White Oak rivers, and along the ICW and navigational channels. The remaining narrow, shallow estuaries are generally not eroding, as the marshes and flats vertically accrete sediment to keep up with rising sea level. Riggs (2001) mapped the shoreline types and shoreline areas where erosion was noticeable. Shoreline erosion rates have been estimated for portions of the coast by various studies including Stirewalt and Ingram (1974), USDA Soil Conservation Service (1975), Hartness and Pearson (1977), Riggs et al. (1978), and Hardaway (1980). Their results are summarized and compared in Riggs (2001). These studies are helpful in indicating where major erosion problems are occurring.

The zonation of vegetation in salt/brackish marsh is largely determined by variations of salinity and drainage of sediment porewater (Wiegert and Freeman 1990). Porewater salinity in the levees tends to remain similar to that of adjacent estuarine waters because of the frequent exchange of water and better internal drainage (due to coarser sediment) than the more isolated high marsh. Porewaters of the short cordgrass zone often are hypersaline during times of warm, dry weather, high rates of evapotranspiration, and minimal water exchange. In the high marsh, precipitation (and groundwater occasionally) creates salinities that may be low enough to support shrubs and other plants intolerant of high salinities (wax myrtle, groundsel-tree, and marsh elder). Some species are restricted in the low marsh because of high porewater salinity, frequent inundation, and high-sulfide porewaters associated with frequent inundation. Consequently, there is greater species richness in the high marsh because of the less stressful conditions.

Riverine wetlands

The development of tidal freshwater marshes is similar to that of salt/brackish marsh. Freshwater marshes have a higher number of plant species than their salt/brackish counterpart due to lower salinity in freshwater areas (Mitsch and Gosselink 1993; SAFMC 1998a). Tidal freshwater marshes can also be divided into low and high zones. Species in low marshes are more fleshy and succulent (e.g., arrowheads, pickerel weed, wild rice) than those in the high marsh (e.g., cattails, reeds). Competition and inundation frequency and duration are among the most important factors determining the presence and zonation of tidal freshwater marsh, although variation in salinity along stream margins reduces the number of species (Odum et al. 1984). Tidal freshwater marsh plants are usually more sensitive to toxic levels of soluble iron, manganese, or sulfide compounds that can accumulate in tidal freshwater marsh soils and can be excluded by levels of these substances that have little effect on typical salt/brackish marsh species (Odum et al. 1984).

The plant community in nontidal (inland) freshwater marshes is very similar to its tidal counterpart. However, the hydrology of nontidal wetlands is more variable than tidal wetlands that receive regular inundation. Water levels in inland marshes are determined by the type of water body in which they occur. Water levels in isolated marshes within a small watershed are controlled more by the balance of precipitation and evapotranspiration than anything else (Mitsch and Gosselink 1993).

Riverine swamp forests typically occur along low lying margins of rivers and lakes where they receive seasonal flooding (Wharton et al. 1982). Fish use of flooded riverine forested wetlands depends on the timing and duration of inundation. The frequency and magnitude of flooding in swamp forests depends on the land use characteristics of the watershed, bank height, the degree of stream channelization, and tidal influence. Depth and duration of flooding determine whether an area is bottomland hardwood forest or swamp forest. Bottomland hardwood and swamp forest wetlands are generally irregularly to seasonally flooded (Sutter 1999). Overbank flooding and surface and groundwater discharge are likely sources of inundation in riverine swamp forests (Wharton et al. 1982). The source of inundation varies with the type of river or stream. Wetlands adjacent to large rivers receive overbank flow from flood pulses or tidal flows, whereas water level in small blackwater tributaries is influenced more by groundwater discharge and local precipitation (Wharton et al. 1982). For example, the water budget of a small blackwater stream (Creeping Swamp) in coastal North Carolina showed that water loss consisted of 61% evapotranspiration, followed by baseflow (20%), overland runoff (17%) and seepage to groundwater (2%) (Winner and Simmons 1977). The relatively low input from overland flow allows the mainstem river to have more influence on small blackwater streams at high river flows. When the mainstem channel is low, water level in blackwater streams is controlled more by local precipitation. The sporadic inundation of swamps bordering blackwater streams allows temporary use by opportunistic fish at high mainstem river flows.

Headwater swamps

The requirements of headwater swamps are similar to small tributary streams referenced above. The main difference between riverine forested wetlands and headwater wetlands is their position in the watershed: headwater wetlands are the highest hydrologic points in the watershed.

Distribution

By 1994, the DCM had used GIS technology to map and classify wetlands in the 20 coastal counties using National Wetland Inventory (NWI) maps, Natural Resource Conservation Service digital soils maps, satellite imagery (1988, 1994), and hydrography maps as source data (Sutter 1999). Analyses showed there were a total of 1.3 and 2.2 million acres of riparian and non-riparian wetlands, respectively, in the CHPP management area of those counties. The classification error for wetlands was approximately 11% (Shull 1999), making the total figure for wetlands acreage in coastal North Carolina between 3.1 and 3.9 million acres.

Riparian wetlands covered 7% of the land area in coastal river basins of North Carolina in 1994, and riverine forested wetlands was the most abundant class of the three riparian wetland classes (Table 5.1). Riparian wetlands are not distributed evenly among CHPP management units (MUs) (Map 5.1a-d). The Cape Fear MU contained the largest area of riparian wetlands, followed by the Neuse and Albemarle (Figure 5.2). The greatest proportions of estuarine wetlands were in Core-Bogue, Southern Estuaries, and Pamlico MUs, whereas the Roanoke, Cape Fear, and Neuse had the highest proportion of riverine wetlands (Figure 5.2). The greatest percentage of total land cover in riparian wetlands was in the Southern Estuaries MU (13%), where the dominant wetland type was salt/brackish marsh (Table 5.1).

Salt/brackish marsh

- The total area of salt/brackish marsh in coastal North Carolina was 198,168 acres in 1994, which comprised 17% of all riparian wetland types.
- The greatest acreage (63,601 acres) of salt/brackish marsh was in the Pamlico MU.
- Salt/brackish marsh occurs in all the CHPP management units except the Chowan, Roanoke, and

Table 5.1. Total acreage of riparian wetland types by CHPP management unit. [Source: DCM wetland mapping data (current as of 1994).]

	Riparian Wetlands							
	Estuarine			**Riverine**				
Management Unit	**Salt/Brackish Marsh**	**Estuarine Forest**	**Estuarine Shrub/Scrub**	**Freshwater Marsh**	**Bottomland Hardwood**	**Riverine Swamp Forest**	**Headwater swamps**	**% of total land area**
Albemarle	44,758	231	8,279	4,897	8,890	140,501	2,200	**11.3**
Cape Fear	9,640	18	363	13,443	40,018	211,888	5,606	**4.9**
Chowan	0	0	0	1,028	24,868	74,974	2,143	**11.8**
Core-Bogue	22,274	57	4,048	325	941	3,768	1,696	**9.7**
Neuse	14,386	26	1,367	3,878	68,175	146,400	9,283	**7.0**
New/ White Oak	9,143	71	2,242	665	7,134	22,229	1,530	**8.5**
Pamlico	63,601	303	8,802	4,105	254	616	611	**5.5**
Roanoke	0	0	0	1,888	37,788	123,045	2,477	**7.4**
S. estuaries	21,996	66	1,115	302	1,387	9,002	824	**13.2**
Tar/ Pamlico	12,370	193	1,658	2,272	38,127	97,258	4,789	**5.8**
Total	**198,168**	**965**	**27,874**	**32,803**	**227,582**	**829,681**	**31,159**	**6.9**
% of wetland types	**14.7**	**0.1**	**2.1**	**2.4**	**16.9**	**61.5**	**2.3**	**na**

Coastal Ocean.

Estuarine shrub/scrub

- There was a total of 27,874 acres of estuarine shrub/scrub habitat in North Carolina in 1994, which comprised 2% of riparian wetland areas (Table 5.1).
- The greatest acreage (8,279) of estuarine shrub/scrub habitat was in the Albemarle MU.
- Estuarine shrub/scrub habitat is not present in the Chowan and Roanoke MUs.

Estuarine forests

- There was a total of 965 acres of estuarine forest in the CHPP management area, comprising less than 1% of the riparian wetlands (Table 5.1).
- The greatest acreage of estuarine forested wetlands was in the Albemarle and Pamlico MUs (231 and 303 acres, respectively).
- Estuarine forest wetlands are not present in the Chowan and Roanoke MUs.

Freshwater marsh

- Freshwater marsh covered a total area of 32,803 acres in 1994 and comprised 2% of these riparian wetlands (Table 5.1).
- The greatest acreage (13,443) of freshwater marsh was in the Cape Fear MU.
- Freshwater marsh occurred in all CHPP MUs except the Coastal Ocean.

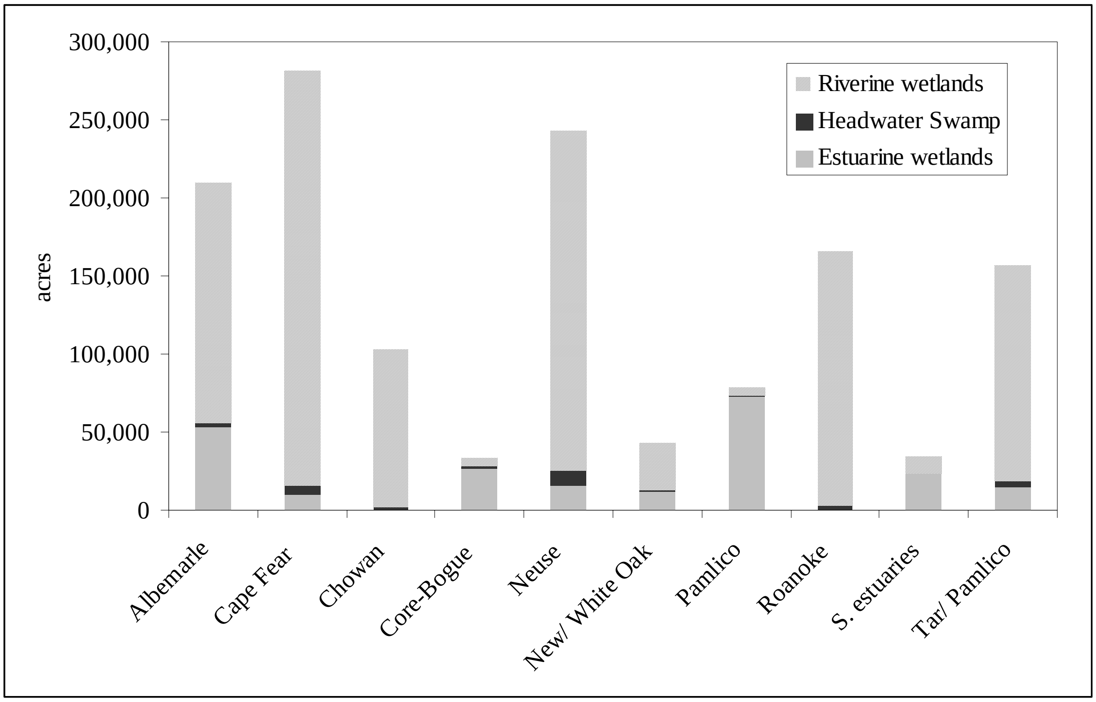


Figure 5.2. Relative amount and proportion of these riparian wetland classes among CHPP management units. [Source: DCM wetland mapping data (current as of 1994).]

Bottomland hardwood and riverine swamp forests

- The combined total acreage of bottomland hardwood forest and riverine swamp forest in 1994 was 1,057,263, which comprised 78% of all riparian wetlands in the CHPP management area (Table 5.1).
- The greatest area (251,906 acres) of bottomland hardwood and riverine swamp forest was in the Cape Fear MU (Table 5.1).
- Bottomland hardwood forests occur in all MUs except the Coastal Ocean.

Headwater swamps

- The total area of headwater swamps in the CHPP management area in 1994 was 31,159 acres, which comprised 2% of all riparian wetlands (Table 5.1).
- The greatest acreage of headwater swamps was in the Neuse (9,283 acres), Cape Fear (5,606 acres), and Tar-Pamlico MUs (4,789 acres).
- Headwater wetlands occur in all CHPP MUs except the Coastal Ocean.

5.2. ECOLOGICAL ROLE AND FUNCTIONS

Wetlands are well known for the ecological services they provide. Wetland services improve the quality of adjacent habitats with their capacity for water control and filtration. They can also protect upland habitats from erosion. Wetlands play a vital role in providing abundant food and cover for juvenile and adult finfish and shellfish. Support and documentation of these important functions are provided in this section.

Ecosystem enhancement

The flood control and water quality benefits of wetlands have been extensively studied (Mitsch and Gosselink 1993). By spreading and slowing flood waters, wetlands decrease flooding in adjacent upland areas and downstream areas. Some wetlands can store flood waters and slowly release it to surface and groundwater systems during periods of low flow (Mitsch and Gosselink 1993). Bottomland hardwood forest along the Mississippi River before European settlement stored floodwater equivalent to about 60 days of river discharge. The storage capacity of these wetlands today has been reduced to about 12 days (Mitsch and Gosselink 1993). Consequently, flooding has increased along the lower Mississippi River. Mitsch and Gosselink (1993) concluded that wetlands reduce downstream flooding most effectively with (1) increasing wetland area, (2) increasing distance of wetland downstream, (3) increasing size of flood, (4) increasing proximity to upstream wetlands, and (5) decreasing upstream storage such as reservoirs.

An important water quality benefit of wetlands is their ability to foster settlement from sediment-laden water, resulting in deposition of suspended solids (inorganic sediment and organic matter) among the vegetation (Mitsch and Gosselink 1993). Under favorable conditions, toxic chemicals and nutrients (especially phosphorus) are also retained in some wetlands due to adsorption to sediment particles (Wolfe and Rice 1972; Mitsch and Gosselink 1993). Rooted vegetation stabilizes unconsolidated sediment, reducing erosion and turbidity in adjacent aquatic habitats. Along eroding estuarine shorelines, wetlands also provide an important buffer against wave-induced turbulence (Riggs 2001). The buffering effect of wetland vegetation improves water clarity for submerged vegetation and benthic algae (Mitsch and Gosselink 1993) while also reducing sediment additions necessary for creation of new shallow water habitat (Rogers and Skrabal 2001). Consequently, both wetland and non-wetland shorelines play an important role in maintaining the function of the estuarine system. *Maintaining a natural proportion and relative position of wetland and non-wetland shorelines will be a vital component of habitat restoration and management.*

Another water quality benefit of wetlands stems from their low-oxygen soil (anaerobic or reducing). Anaerobic soils play a vital role in the nitrogen cycle by transforming ammonia and nitrate (organic waste product or fertilizer) into nitrogen gas (denitrification) (Mitsch and Gosselink 1993). In agricultural watersheds receiving fertilizer-enriched runoff, denitrification plays a important role in the world's nitrogen balance (Mitsch and Gosselink 1993). Nitrogen cycling is important to fisheries because high concentrations of nitrate can be toxic to fish, and nitrogen over-enrichment can result in algal blooms and hypoxia that contribute to stress and fish kills. Even moderate hypoxia can result in death of benthic invertebrates (Diaz and Rosenburg 1995; Taylor and Eggleston 2000; Sagasti et al. 2001), a major food source for crabs and demersal fish (Taylor and Eggleston 2000). Temporary and permanent retention of nutrients, such as phosphorus, are facilitated by particle deposition and burial as well as formation of organic matter in the sediment by roots and rhizomes (Mitsch and Gosselink 1993). Forested (streamside) wetlands in agricultural drainages have been shown to remove approximately 80% of the phosphorus and 90% of the nitrogen from the water (<http://www.epa.gov/owow/wetlands/facts/fact3.html>, July 2001). Stream headwaters are the site of most active uptake and retention of nutrients in riverine systems (Peterson et al. 2001). A study of denitrification in a headwater creek (Culvert Creek, North Carolina) found that marsh vegetation had the greatest potential for denitrification, compared to marsh sediment and flashboard risers (water control structures) (<http://www2.ncsu.edu/ncsu/CIL/WRRI/reports/report317.html>, 2003). The combination of nutrient uptake and retention makes headwater wetlands very important in controlling nutrient enrichment downstream.

Mitsch and Gosselink (1993) concluded that nutrients are probably stored in salt/brackish marshes fringing estuaries with limited water circulation (i.e., back barrier sounds), whereas wetlands in funnel-shaped (trunk) estuaries export more nutrients. There is also evidence that salt/brackish marshes act as a source of nutrients during the growing season and a sink in winter and spring (Woodwell et al. 1979). Compared to plant uptake, however, leakage of nitrogen from a Georgia salt marsh was small (Haines

1979). Nitrogen uptake in salt/brackish marsh is, on average, somewhat less than that in freshwater marshes (Mitsch and Gosselink 1993). The nutrients are also released by erosion and decomposition of wetland vegetation. Retention and controlled release of particles, toxic chemicals and nutrients can improve water quality downstream. Therefore, if bottomland hardwood forests or headwater swamps are lost upstream, the potential for erosion, flooding, sedimentation, algal blooms, and fish kills increases downstream.

Productivity

Because of the abundant supply of water, nutrients, and sunlight, wetland plant communities can be one of the most biologically productive ecosystems in the world (Teal 1962; Teal and Teal 1969; Mitsch and Gosselink 1993; SAFMC 1998a). Some of the high primary production (creation of organic compounds through photosynthesis) of wetland vegetation is transferred to adjacent aquatic habitats via detritus and microalgae (Peterson and Howarth 1987; Wiegert and Freeman 1990; Mitsch and Gosselink 1993). However, wetland plant species vary in their rate of decomposition, with leafy, succulent, low vegetation decomposing the quickest and woody, high vegetation the slowest (Mitsch and Gosselink 1993). Therefore, production from vegetation in woody, forested wetlands is converted more slowly into detritus than vegetation in marsh wetlands with leafy, succulent vegetation. Inundated wetland plants also exude dissolved organic substances contributing to epiphytic growth on their stems and leaves (Mitsch and Gosselink 1993).

Salt/brackish marsh growth in the low marsh is limited by self-shading, where other habitat requirements are met, whereas growth in the high marsh can be affected by a number of factors, including high salinity, sulfides, scarcity of iron, and lack of nitrogen (Wiegert and Freeman 1990). Accounting for phytoplankton in the water column and algae on the sediment surface, productivity of low marsh (*Spartina alterniflora*) in a Georgia tidal creek was 1,539 g carbon/m^2/yr while production in the high marsh was somewhat lower (about 1,350 g carbon/m^2/yr) (Wiegert and Freeman 1990). In North Carolina, Stroud (1976) reported somewhat higher salt/brackish marsh production in low marsh (1660 g carbon/m^2/yr), but much lower production in the high marsh (750 g carbon/m^2/yr). In both North Carolina and Georgia, above ground production was about 20% greater than below-ground production (Mitsch and Gosselink 1993).

Primary production in salt/brackish marshes is converted into fish production through several pathways. Using sulfur, carbon, and nitrogen isotopes to trace organic matter flow in the salt marsh estuaries of Sapelo Island, Georgia, Peterson and Howarth (1987) found two major sources of organic matter used in fish production: *Spartina* (detritus) and algae. The relative importance of each source is determined by the feeding mode, size, location, and trophic position of the marsh and estuarine consumers (Peterson and Howarth 1987). For example, benthic microalgae probably support herbivorous snails, whereas detritus supports sheepshead minnows, mummichogs, and their prey. Attached algae can be found on the marsh grass itself, the intertidal mudflats, and the shallow subtidal bottom near the marsh. Pinckney and Zingmark (1993) compared production rates of benthic microalgae in various bottom types in an estuarine system (North Inlet, South Carolina). Short *Spartina* marsh accounted for the greatest amount of microalgal productivity (44.6%) in the system, followed by intertidal mudflats (22%), tall *Spartina* marsh (18%), and shallow subtidal bottom (<1 m mean low water) (13%). Sand flats accounted for only 3% of the total annual microalgal production (Pinckney and Zingmark 1993).

Productivity in riverine forested wetlands in North Carolina has been reported to be much lower than in salt/brackish marsh, representing about 523-677 g carbon/m^2/yr of leaf and twig litter (Brinson 1977; Mulholland 1979). However, the total production of forested wetlands may be similar to that of salt/brackish marsh when stem growth and below ground production are taken into account. The export of detritus from these riverine forested wetlands can be significant (Mitsch and Gosselink 1993). Mulholland and Kuenzler (1979) found that organic export was higher from river basins containing more deepwater swamps than other riparian habitats. From a Louisiana swamp forest, Day et al. (1977)

measured an export rate of 10.4 g carbon/m^2/yr. By contrast, salt/brackish marshes can have an organic export rate as high as 100 g carbon/m^2/yr (Wiegert et al. 1981). However, export rates in swamp forest can vary greatly with submersion regime and temperature. For example, higher temperatures (allowing faster decomposition) and frequent inundation increase the export rate of tidal swamp forests in tidal fresh waters of the Cape Fear River.

Fish utilization

It is estimated that over 95% of the finfish and shellfish species commercially harvested in the United States are wetland-dependent (Feierabend and Zelanzy 1987). Wetlands provide numerous ecological services to coastal fishes (Table 5.2). For example, one of the most important characteristics of riparian wetlands are their combination of shallow water and thick vegetation, which provides nursery habitat for young fish. The use of wetlands by finfish and shellfish is presented first, followed by documentation of specific functions for selected species.

Salt/brackish marsh

Finfish and shellfish using salt/brackish marsh fall into several categories based on location and timing of use. Year-round residents of the marsh include small forage species such as killifish, mummichogs, sheepshead minnows, gobies, grass shrimp, bay anchovies, and silversides (SAFMC 1998a). Transient species include those spawning near the marsh, but inhabiting deeper channels (i.e., river herring), and those spawned in deeper waters using marsh habitat as nursery or foraging areas. Among transient species, some prefer the edge of salt/brackish marsh (i.e., red drum, flounder) while others are found near marsh edge on unvegetated bottom (i.e., spot, croaker). Some species are not found in the marsh, but derive substantial food resources from the marsh plants as detritus (i.e., menhaden; Lewis and Peters 1994) or from microalgae produced on the marsh surface. Of fishery species in North Carolina, penaeid shrimp and red drum are considered critically linked to marsh edge habitat (SAFMC 1998a)[59].

Freshwater marsh

Fishery and forage fish inhabiting tidal and non-tidal freshwater marshes include largemouth bass, bluegill, warmouth, black crappie, chain pickerel, southern flounder, white perch, mummichog, bay anchovy, inland silversides, river herrings, striped bass, and sturgeon (Mitsch and Gosselink 1993). The nature and degree of association with freshwater marsh habitat depend on the species. For example, striped bass and river herring are not only abundant along marsh edge, but also in open water areas adjacent to the marsh edge. Bluegill, black crappie, largemouth bass, and warmouth are found almost exclusively near shoreline structures such as marsh grass. Mosquitofish are an important forage species and a “mosquito control agent” closely associated with freshwater marsh habitat (Odum et al. 1984).

[59] More information on salt/brackish marsh can be found in the Nursery function section of this chapter.

Table 5.2. Partial listing of fish and their use of wetland habitat in coastal North Carolina.

Species*	Wetland Functions [1]					Fishery [2]	Stock Status [3]
	Nursery	Foraging	Refuge	Spawning	Corridor		
ANADROMOUS AND CATADROMOUS FISH							
American eel		X	X		X	X	
Sturgeon spp.	X	X	X		X	X [4]	O
River herring (alewife & blueback herring)	**X**	**X**	**X**	**X**	**X**	**X**	**O-Albemarle Sound, U-Central/Southern**
Striped bass	X	X	X		X	X	V-Albemarle Sound, Atlantic Ocean, O-Central/Southern
ESTUARINE AND INLET SPAWNING AND NURSERY							
Atlantic rangia clam	X	X	X	X			
Banded killifish	**X**	**X**	**X**	**X**			
Bay anchovy	X	X		X			
Blue crab	**X**	**X**	**X**		**X**	**X**	**C**
Cobia	X	X			X	X	
Grass shrimp	**X**	**X**	**X**	**X**			
Mummichog	**X**	**X**	**X**	**X**			
Naked goby	X	X	X	X			
Red drum	**X**	**X**	**X**		**X**	**X**	**R**
Sheepshead minnow	**X**	**X**	**X**	**X**			
Silversides	X	X		X			
Spotted seatrout	**X**	**X**	**X**		**X**	**X**	**V**
MARINE SPAWNING, LOW-HIGH SALINITY NURSERY							
Atlantic croaker	**X**	**X**	**X**		**X**	**X**	**C**
Atlantic menhaden	X	X			X	X	V
Shrimp	**X**	**X**	**X**		**X**	**X**	**V**
Southern flounder	**X**	**X**	**X**		**X**	**X**	**O**
Spot	**X**	**X**	**X**		**X**	**X**	**V**
Striped mullet	**X**	**X**	**X**		**X**	**X**	**C**
MARINE SPAWNING, HIGH SALINITY NURSERY							
Black sea bass	X	X	X		X	X	O- south of Hatteras, V- north of Hatteras
Pinfish	**X**	**X**	**X**		**X**	**X**	
Summer flounder	**X**	**X**	**X**		**X**	**X**	**V**

* Scientific names listed in Appendix I. Names in **bold** font are species whose relative abundances have been reported in the literature as being generally higher in wetlands than in other habitats. Note that lack of bolding does not imply non-selective use of the habitat, just a lack of information.

[1] Sources: Wharton et al. 1982; Odum et al. 1984; Wiegert and Freeman 1990; Mitsch and Gosselink 1993; Micheli and Peterson 1999; Minello 1999; NOAA 2001.

[2] Existing commercial or recreational fishery. Fishery and non-fishery species are also important as prey.

[3] V=Viable, R=Recovering, C=Concern, O=Overfished, U=Unknown (DMF 2003a)

[4] Fishery species under harvest moratorium

Bottomland hardwood and riverine swamp forest

There is a strong relationship between fishery yields and forested river floodplains (Mitsch and Gosselink 1993). A study on the Suwanee River floodplain (Florida/Georgia) found that fish production was much greater in floodplain sloughs than in the main river (Holder et al. 1970). A similar study of fish standing stock on river floodplains in North Carolina has not been conducted. Fish use of riverine forested wetlands is generally restricted to periods of seasonal inundation, which occurs mostly during winter and spring. By contrast, riverine wetlands below Lock and Dam #1 on the Cape Fear River receive regular tidal inundation (C. Hackney, UNC-W, pers. com., 2003). Seasonal flooding in riparian forested wetlands also increases the productivity of riverine systems by connecting the mainstem river with the abundant organic material found on forested floodplains (Wharton 1982; Junk et al. 1989). For example, numerous studies have shown a correlation between sunfish and largemouth bass spawning success and the timing and extent of floodplain inundation (Wharton et al. 1982). In North Carolina, seasonal high water in riverine systems generally occurs from winter to spring. Summer conditions (falling water levels, increasing temperatures, and low dissolved oxygen) exclude most fish from forested wetlands areas. Only fish adapted to low oxygen conditions continue to inhabit wetland areas as long as they contain water (i.e., bowfin, gar, mudminnows, killifish; Wharton et al. 1982). A study on fish use of creek floodplains in North Carolina documented several common species using channels in the floodplain (Walker 1984). Those species included several small sunfish species, redfin pickerel, bowfin, brown bullheads, redear sunfish, pumpkinseed, bluegill sunfish, green sunfish, and small forage species (e.g., shiners, darters, killifish, and crayfish). Estuarine-dependent species found on river floodplains include hickory shad, blueback herring (Wharton et al. 1982), and alewife (SAFMC 1998a). The tidal swamp forests in the Cape Fear estuary are also inhabited by blue crabs and other transient estuarine species (C. Hackney, UNC-W, pers. com., 2003).

Flat/depressional wetlands

Fish use of normally isolated wetlands (i.e., pocosins along the Alligator and Northeast Cape Fear rivers) depends on many factors. A study conducted on the Savannah River floodplain found that fish use was limited to wetlands that dried infrequently, were most connected to intermittent water bodies, and had an elevation closest to the nearest permanent water body (Snodgrass et al. 1996). Pocosins that are located directly adjacent to salt/brackish marsh or other riparian wetlands are potential fish habitat. Biotic interactions and characteristics of the wetlands had relatively less influence on fish community structure than the wetland's landscape position. The study also noted that only widespread, colonizing species were correlated with landscape position, suggesting more complicating factors controlling colonization rates (i.e., variation in water level more related to local rainfall than overflow). *As sea level continues to rise and low-lying pocosins near coastal North Carolina waters transform into marshes, they will become more important as primary nursery areas for estuarine-dependent fish (Brinson 1991). Therefore, a similar study should be conducted in North Carolina to determine what pocosin areas are actually used by fish, and the contribution of those fish to overall production in the estuary.*

Specific biological functions

Nursery

The large expanses of shallow water and thick vegetation found in riparian wetlands provide abundant food and cover for larval, juvenile and small organisms (Graff and Middleton 2003). Nursery habitat is not only provided by the dense structures, but also by the shallow depth of water itself, which provides refuge from aquatic fish predators (review in Rozas and Odum 1987). The aversion to shallow water among large, deep-bodied aquatic predators is a common behavior, which indirectly protects smaller fish.

Salt/brackish marsh

Along with the shallow soft bottom and shell hash areas they border, salt/brackish marshes along the North Carolina coast are probably the most recognizable nursery habitat for estuarine-dependent species. The majority of Primary and Secondary Nursery Areas designated by the MFC are located in soft bottom areas surrounded by salt/brackish marsh. Even though salinity and transport mechanisms are the key physical factors affecting the species composition in nursery habitats in Pamlico Sound and its tributaries (Ross and Epperly 1985; Noble and Monroe 1991; Ross 2003), marsh wetlands are a vital component of estuarine nursery habitat. Minello et al. (2003) concluded that the relative nursery value of salt marshes in Atlantic coast estuaries appears to be higher than open water, but lower than submerged aquatic vegetation.

Most of the juveniles of fishery species found in salt/brackish marsh nurseries were spawned offshore during winter. The larvae were transported through inlets and into estuarine waters where they settled in the upper (low salinity) or lowermost (high salinity) reaches of estuarine creek systems (Ross 2003). The peak of juvenile settlement generally occurs in spring through early summer, although the peak is correlated more with water temperature (Ross and Epperly 1985). Settlement in upper reaches is particularly beneficial to spot and croaker, where growth and survivorship are enhanced compared to lower reaches (Ross 2003). If movement to general regions of the estuary is largely passive (Pietrafesa et al. 1986; Pietrafesa and Janowitz 1988), the viability of spot and croaker stocks could be reduced by hydrodynamic conditions resulting in more settlement to lower regions of the estuary (Ross 2003). This settlement pattern could also occur in other estuarine-dependent species.

According to DMF's juvenile abundance survey data, the dominant species in high salinity marshes behind the Outer Banks and Core Sound include pinfish, pink shrimp, black sea bass, gag, pigfish, red drum, gulf flounder, and summer flounder (Noble and Monroe 1991). However, the primary nursery habitat in these areas is submerged aquatic vegetation. Juvenile spot, brown shrimp, striped mullet, and southern flounder are abundant along the western shores of Pamlico and Core sounds and their tributaries (Epperly and Ross 1986; Noble and Monroe 1991). In the Newport River estuary, juvenile southern flounder showed a distinct preference for marsh edge habitat over other habitats, but only during fall (Walsh et al. 1999). The juvenile southern flounder were most abundant in more turbid, upper regions of the estuary.

During spring through fall, brackish marshes in the Albemarle-Pamlico estuary are dominated by juvenile Atlantic menhaden, striped mullet (Epperly and Ross 1986), silversides, anchovies (Nelson et al. 1991) and more demersal species such as Atlantic croaker, brown shrimp, blue crab, and southern flounder (Noble and Monroe 1991). In higher salinity marshes of the Pamlico Sound, spotted seatrout, weakfish, silver perch, and red drum are also abundant (Noble and Monroe 1991). Juvenile red drum reach their highest abundance in brackish marsh (Tagatz and Dudley 1961; Nelson et al. 1991; C. Peterson, UNC-CH, pers. com., 2003). Fish use of low salinity (brackish) marsh habitat in estuaries of North Carolina was studied by Rozas and Hackney (1984), who found a combination of freshwater and estuarine species in low-salinity, intertidal creeks. The most abundant species were spot, grass shrimp, bay anchovy, and Atlantic menhaden. They also reported three seasonal peaks in abundance in low salinity marshes: (1) spring peak with influx of juvenile spot, Atlantic menhaden, Atlantic croaker, and southern flounder; (2) summer peak of grass shrimp; and (3) fall peak of bay anchovies and grass shrimp.

A study in Galveston Bay, Texas, found that juvenile brown shrimp, white shrimp, blue crab, spotted seatrout, and southern flounder were most abundant along salt/brackish marsh edge habitat compared to inner marsh, shell bottom, SAV, and shallow, non-vegetated bottom (Minello 1999). In another Texas estuary, low marsh supported higher abundances of brown shrimp, blue crabs, daggerblade grass shrimp, white shrimp, and striped mullet, although there was little difference between low and high marsh for white shrimp and striped mullet (Rozas and Zimmerman 2000). Resident estuarine species, such as gulf killifish and sheepshead minnow, were most abundant in high marsh.

Habitat types derived from salt/brackish marsh (i.e., peat blocks) can also provide important nursery habitat for certain species. Peat blocks are generally found along eroding marsh shorelines, where they serve as firm substrate for the attachment of sessile invertebrates and refuge for juvenile blue crabs in western Pamlico Sound (D. Eggleston, NCSU, pers. com., 2001). Szedlmayer and Able (1996) found that, in a New Jersey estuary, juvenile black seabass were more abundant in sponge-peat habitats (associated with eroding marsh) compared to eelgrass beds, upper estuary, subtidal creeks, marsh channels, and open bay areas.

Freshwater marsh

Studies documenting the use and significance of freshwater marsh for larval and juvenile fish in North Carolina are lacking. Freshwater marshes comprise only a very small portion of riparian wetlands in coastal North Carolina. A study conducted in Virginia found that larvae and juvenile fish represented 79% and 59% of the total number of fish collected at tidal freshwater and salt marsh sites, respectively (Yozzo and Smith 1997). McIvor and Odum (1987) found reduced predation by large carnivorous fish in the shallow water (<3ft or <1m) of freshwater tidal creeks, possibly due to unfavorable water quality, the physical constraints of shallow water, and/or increased predation from predatory birds (i.e., herons).

Bottomland hardwood and riverine swamp forest

Forested wetlands are important nursery areas for anadromous and resident freshwater species along coastal rivers and creeks in North Carolina (Wharton et al. 1982; DMF 2000c). Forested wetlands are also important for some transient estuarine species (i.e., spot, croaker, southern flounder, blue crab) in the lower Cape Fear River (Mallin et al. 2001c; C. Hackney, UNC-W, pers. com., 2003). The timing and extent of flooding are critical to fish use of bottomland hardwood and riverine swamp forest. Larval and juvenile river herring have been collected near flooded riverine wetlands in North Carolina (DMF 2000c). Studies of larval fish abundance and diversity on Mississippi River floodplains suggested that nearly 50% of fish species inhabiting the river used the floodplain as a nursery (Gallagher 1979). Unchannelized sections of the Missouri River produced 2 to 2.5 times more fish than channelized sections (Groen and Schmulbach 1978). In general, vegetated shoreline inundation during spring and early summer has been correlated with increased year-class strength of largemouth bass, sunfish, and yellow perch (Nelson and Walburg 1977; Strange et al. 1982; Ploskey 1986).

Foraging

Salt/brackish marsh

Few aquatic species feed directly on living plant tissue in salt/brackish marsh (i.e., periwinkle), and their productivity is very low compared to that of detritivores and consumers of microalgae (Wiegert and Freeman 1990; Steel 1991; SAFMC 1998a). However, biotic interactions with primary consumers can result in degradation or loss of wetlands. Recent study results from the southeastern United States suggest that blue crab predation on plant-eating snails may prevent the snail from overgrazing the marsh grass (Silliman and Bertness 2002).

Detrital and bacterial production from salt/brackish marsh exhibit some of the highest recorded values per unit area of any ecosystem in the world (Wiegert and Evans 1967). Slow-moving or sessile species residing in salt/brackish marsh and contributing to secondary production include fiddler crabs, mud snails, amphipods, oysters, clams, and ribbed mussels (Wiegert and Freeman 1990). Based on data from Georgia marshes, biomass of these resident species exceeded 15 g carbon/m^2, and consisted of 80-200 fiddler crabs, 400-700 periwinkle snails or mud snails, and 7-8 mussels (Wiegert and Freeman 1990). The resident estuarine fishes (i.e., killifish, grass shrimp, sheepshead minnow) are an important link between estuarine production and transient predatory fish populations (Wiegert and Freeman 1990; Kneib 1997). Salt-brackish marsh edge also provides important feeding areas for blue crabs, red drum, flounder, seatrout and other large predators searching the edge of complex structure near deeper water, as illustrated by greater predation on grass shrimp with increasing depth in shallow-estuarine water (Clark et al. 2003).

It has been estimated that 45% of salt marsh production is exported to the estuarine system in the form of detritus, dissolved organic matter, and transient nekton (i.e., grass shrimp and killifish; Teal 1962). The biomass of secondary production going in and out with the tide (fish, shrimp) is less well known than resident species biomass (Kneib and Wagner 1994). The exported production of brown and white shrimp is probably the best known and most significant to coastal fisheries (Turner 1977; Wiegert and Freeman 1990). The estimated yield of shrimp from North Carolina was 107 lb per acre of intertidal vegetated bottom (Turner 1977), where intertidal vegetation included "salt marsh macrophytes, *Spartina* spp. [and] *Juncus* spp.." However, recent research suggests that wetlands vary greatly in their role as exporters or importers of organic matter (Wiegert and Freeman 1990). This variation could be the result of variable erosion or deposition rates among seasons or wetland areas.

Freshwater marsh

Compared to salt/brackish marsh, most living vegetation in freshwater marshes can be more readily consumed by insects, crayfish, muskrats, waterfowl, and carp (Mitsch and Gosselink 1993; SAFMC 1998a). However, herbivory is still minor in freshwater marshes (Mitsch and Gosselink 1993). Together with phytoplankton and benthic algae, organic matter from the emergent vegetation is the source of primary production in freshwater marshes. The export of this production (in the form of particulate detritus) to other systems is less understood than that of salt marshes (Mitsch and Gosselink 1993), but is probably similarly affected by the rates of erosion and water exchange between wetlands and open water systems. Because many freshwater marshes in North Carolina generally occur in slow-moving, backwater areas, export of detritus is probably less significant compared to salt marshes.

The detritus that remains in the marsh provides food for meio- and macrobenthic communities consisting of nematode worms, chironomid fly larvae, mysids, snails, and amphipods (Odum et al. 1984; Mitsch and Gosselink 1993; SAFMC 1998a). The macrobenthic community, in turn, provides abundant food for small fish, grass shrimp, crayfish, crabs, and waterfowl. Large fish feeding within the marsh include chain pickerel, bowfin, and gars (Odum et al. 1984). Many other large, aquatic predators (i.e., largemouth bass, crappie) feed along the edge of freshwater marshes where there is deep water nearby for refuge (Odum et al. 1984).

Bottomland hardwood and riverine swamp forest

Although riverine forests contain vast stores of organic matter, much of it is not rapidly converted into particulate organic matter for secondary production (Mitsch and Gosselink 1993) because woody material and leaves break down more slowly than succulent vegetation in marshes. In spite of this, riverine forested wetlands still produce abundant invertebrate food, such as copepods, ostracods, amphipods, isopods, oligochaetes, flatworms, crayfish, and terrestrial insects (Wharton et al. 1982; Mitsch and Gosselink 1993). Fish species and life stages adapted for feeding in riverine swamp forests include adult mosquitofish, gar, bowfin, carp and chain pickerel, along with early life stages of many other species (Wharton et al. 1982; Mitsch and Gosselink 1993). Other species, such as largemouth bass and catfish, are opportunistic predators within the flooded forest.

Refuge

Adult or small aquatic organisms find refuge from predators and adverse weather conditions on and among the dense leaf canopies found in salt/brackish and freshwater marshes (Mitsch and Gosselink 1993; SAFMC 1998a; Graff and Middleton 2003). Many small resident species, such as grass shrimp and killifish, reside within emergent stands of vegetation (Pattilo et al. 1997; SAFMC 1998a; Minello 1999; Rozas and Zimmerman 2000). A recent study on predation risk and prey distribution in shallow-water estuarine habitats found that predation on grass shrimp increased with increasing depth during the day, and decreased across all depths at night (Clark et al. 2003). The study's results highlight the importance of a refuge from predation during the daytime and a relaxation of predation at night. Large, somewhat less mobile organisms also find refuge in the vegetation. For example, Micheli and Peterson (1999) found that adult blue crabs utilized marsh edge habitat in preference to unvegetated, open water habitat in a North Carolina estuary, presumably as refuge from predation.[60]

[60] The refuge function of marshes for juvenile species is discussed in the nursery function section.

The structure provided by freshwater marsh vegetation and forested wetland margins provides excellent refuge for sunfish, crappie, largemouth bass, and other ambush predators, as well as slow-moving benthic invertebrates (e.g., crayfish). Numerous studies have documented the vegetated habitat preference of largemouth bass, bluegill, and other freshwater ambush predators (review in Savino and Stein 1989).

Spawning

The stems and leaves of wetland vegetation provide a surface for attachment of eggs. The combination of egg-laying structures, abundant food and relative scarcity of predators (Power et al. 1995) in seasonally flooded wetlands makes them an ideal spawning area. River herring are an important coastal species that spawn adhesive eggs in flooded swamps, oxbows, and along stream edges (Wharton et al. 1982; DMF 2000c). Spawning of river herring in North Carolina occurs during elevated spring flows from March through May in small tributaries (DMF 2000c).

The structural complexity of marsh vegetation and intertidal submersion regime in salt/brackish marsh provide spawning habitat for forage species such as killifish (including mummichogs), silversides, gobies, and grass shrimp (Anderson 1985; Pattilo et al. 1997). The number of species spawning in salt marsh habitat is low compared to the number of estuarine species spawning offshore and in deep channel habitat (Table 2.3). Nevertheless, many of the species spawning in wetlands are also important food items for transient fishery species.

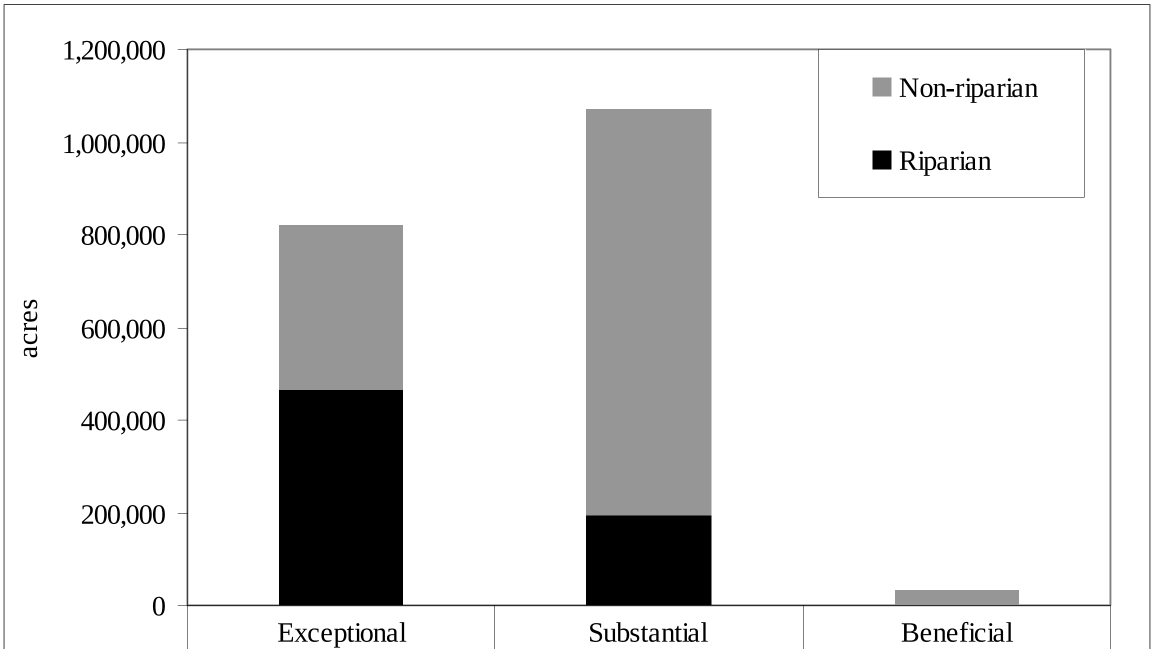
Corridor and connectivity

Within the marsh, elevation and proximity to open water are important influences on the distribution of fish. Rozas and Odum (1987) found that shallow water and greater distance from deep water typically meant lower abundance of large predatory fish (Rozas and Odum 1987). Marsh edge is also more utilized when adjacent to SAV or shell beds where small organisms can take refuge at low tide (Rozas and Odum 1987; Irlandi and Crawford 1997; Micheli and Peterson 1998). Increased utilization is possible because small organisms need to move only a short distance to return to the marsh at high tide. Rozas and Odum (1987) compared fish and shellfish densities in tidal creeks with and without adjacent SAV beds. They found that grass shrimp numbers greatly declined when artificial SAV was removed from a tidal creek. However, fish numbers (mostly mummichogs and banded killifish) were not significantly reduced. The results suggest a higher relative importance of wetland vegetation near SAV beds for grass shrimp. Irlandi and Crawford (1997) found that pinfish were more than twice as abundant in intertidal marshes adjacent to SAV beds than in marshes adjacent to completely unvegetated bottom. The movement of pinfish between the intertidal marsh and subtidal grass beds could provide an important link in the transfer of secondary production from the marsh to adjacent aquatic habitats, and vice versa. Micheli and Peterson (1998) found that marsh edge provides corridor function by facilitating the access of blue crabs to oyster reefs and enhancing the intensity of predation on smaller macroinvertebrates. Isolated oyster reefs had higher densities of those smaller macroinvertebrates. *These studies show the importance of considering optimal locations for SAV and wetland restoration/creation projects.*

Functional significance

Functional value of wetlands was incorporated into DCM's North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS), which is a GIS wetland functional assessment model. The primary objective of the NC-CREWS wetland functional assessment is to provide users with information about the relative ecological importance of wetlands for use in planning and the overall management of wetlands. Thirty-eight separate wetland functions were used to evaluate each mapped wetland area within the 20 coastal counties. Each wetland is given a rating of "Exceptional", "Substantial", or "Beneficial" Functional Significance. The overall rating was based on individual ratings for nonpoint source function, floodwater cleansing, landscape and watershed attributes, surface runoff storage, floodwater storage, shoreline stabilization, terrestrial wildlife habitat functions, and aquatic life habitat functions (Sutter 1999). NC-CREWS provides an excellent rating system, but it was not specifically developed to locate the best habitat for coastal fisheries. Wetland properties such as primary production, structural complexity, depth and submersion regime were not included in this particular model. However, the ‘aquatic life habitat functions’ component of CREWS provides an area within which coastal fish habitat can be found. The aquatic life habitat function of NC-CREWS includes anadromous fish, other fish species, and amphibian/invertebrate habitat (Sutter 1999).

The NC-CREWS categories corresponded fairly well to riparian and non-riparian habitat categories used in CHPPs. Riparian wetlands included the following DCM wetland types: salt/brackish marsh, freshwater marsh, estuarine shrub/scrub, bottomland hardwood, riverine swamp forest, headwater swamp, and estuarine forest. Most intact riparian wetlands were rated “Exceptional” in function (Figure 5.3). The majority of non-riparian wetlands were rated as “Substantial.” There were virtually no riparian wetlands in the “Beneficial” significance category. *The significance of riparian wetlands further justifies the need to enhance their protection*.



	Exceptional	Substantial	Beneficial
Non-riparian	356,747	877,052	34,170
Riparian	463,479	194,594	87

Figure 5.3. Results from North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS) in CAMA counties grouped by CHPP riparian and non-riparian wetland categories. [Source: DCM wetlands data (current as of 1994)]

5.3. STATUS AND TRENDS

Status of wetland habitat

Various estimates have been made of the original extent of North Carolina’s wetlands. The DWQ and North Carolina Water Resources Research Institute staff have examined hydric soils from the published and draft county soil surveys (DWQ 2000a). These studies estimate that North Carolina had about 7.2 million acres of wetlands prior to European colonization. Of that original extent, 95% was in the Coastal Plains. In another study, Dahl (1990) estimated that by the mid-1980s, only about one-half of North Carolina’s original wetlands remained. The trend in wetland loss for North Carolina mirrors national trends (Dahl 1990).

According to DWQ (2000a), approximately 66% of North Carolina's original wetland extent remains and 83% of its original salt marsh, bottomland hardwood, and swamp forest (Table 5.3). However, the 83% figure is only a rough estimate because the DWQ study did not distinguish between depressional and riverine swamp forest. Pocosins have suffered even greater losses (48% remaining from the 1950s). The figures also do not account for wetland losses after 1993. The amount for remaining wetlands in North Carolina will be updated later in this chapter with more recent permit statistics.

Table 5.3. North Carolina wetland acreage estimates. [Source: NC Division of Water Quality 305(b) report (DWQ 2000a)]

Wetland type		Wetland Acreage			
		Original Extent[1]	1990's	Change	% remaining
Non-riparian	Pine savannah	3,643,000	28,000	-3,615,000	1%
	Pocosin	1,366,000	655,000	-711,000	48%
	Wet pine flatwood	0	2,212,000[2]	2,212,000	
Riparian	Bottomland hardwood	1,481,000	1,207,000	-274,000	81%
	Salt marsh	209,000	183,000	-26,000	88%
	Swamp forest	476,000	413,000	-63,000	87%
TOTAL		7,175,000	4,706,000	-2,469,000	66%

[1] Based on descriptions of native vegetation found on hydric soils from SCS county soil surveys from the 1950s.
[2] Based on original extent of pine savannahs.

The DCM wetlands types use three modifiers to indicate human disturbance: 1) partially drained, 2) cutover, or 3) cleared. These modifiers were not meant to account for all wetlands modified or "lost." The inclusion of modifiers was simply a way to show how some of the wetlands remaining today have been degraded or modified (M. Lopazanski, DCM, pers. com., 2003). According to U.S. Fish and Wildlife Service's National Wetlands Inventory maps, partially drained wetlands are, or have been, partially ditched/drained. Cutover wetlands are wetland areas in which satellite imagery from 1994 indicates a lack of vegetation where it was present in 1988. Cleared wetlands are areas containing hydric soils for which satellite imagery indicated a lack of vegetation in both 1988 and 1994. Cutover wetlands have likely retained wetland hydrology and soil characteristics, while cleared and drained wetlands are probably no longer functional wetlands.

Using the DCM modifiers for human disturbance, more non-riparian wetlands have been lost than riparian wetlands. As of 1994, 98,773 and 387,498 acres of riparian and non-riparian wetlands, respectively, were mapped as degraded or modified (Tables 5.4 and 5.5). Among riparian wetland types, riverine swamp forests were most often mapped as modified by drainage, followed by salt/brackish marshes, and bottomland hardwood forests (Table 5.4 and Maps 5.1a-d). A quantifiable trend in wetland degradation is apparent for cutover wetlands. During 1988-1994, the rates of cutover for riparian and non-riparian wetlands were 2,919 and 6,719 acres/year, respectively (DCM, unpub. data). Although wetland hydrology and soil are maintained in these areas, the trees will take years to recover.

Table 5.4. Acres of modified riparian wetland types in coastal area. [Source: DCM wetland mapping (current as of 1994).]

Riparian wetlands	Bottomland Hardwood	Estuarine Forest	Estuarine Shrub/Scrub	Freshwater Marsh	Headwater Swamp	Riverine Swamp Forest	Salt/Brackish Marsh	Total area
Cleared[1]	4,183	0	318		822	2,985		**8,308**
Cutover[2]	7,840	5	535		2,853	6,280		**17,513**
Drained[1]	13,548	19	2,195	2,550	2,583	22,715	29,242	**72,852**
TOTAL	**25,571**	**24**	**3,048**	**2,550**	**6,258**	**31,980**	**29,242**	**98,673**

[1] Unknown time period of impact; current as of 1994

[2] Impacted from 1988-1994

Table 5.5. Acres of non-riparian wetland types impacted in 1994 in coastal areas. [Source: DCM wetland mapping (current as of 1994).]

Non-riparian wetlands	Depressional Swamp Forest	Hardwood Flat	Maritime Forest	Pine Flat	Pocosin	Total area
Cleared[1]	3,755	8,091	142	4,610	1,986	**18,584**
Cutover[2]	5,686	13,388	138	15,748	5,356	**40,316**
Drained[1]	61,830	70,536	17	95,933	100,282	**328,598**
TOTAL	**71,271**	**92,015**	**297**	**116,291**	**107,624**	**387,498**

[1] Unknown time period of impact; current as of 1994

[2] Impacted from 1988-1994

Within DWQ coastal river basins, Clean Water Act section 401-permitted wetland impacts over a period of four fiscal years (1997-2001) indicate a potential conversion of 3,817 wetland acres to non-wetland uses (Figure 5.4). Losses in fiscal years 1999/2000 and 2000/2001 were relatively small compared to 1997/1998 and 1998/1999. The relatively large losses in those earlier years resulted from two large projects (Buckhorn Reservoir in Wilson County and Global Transpark in Lenoir County). However, it should be noted that section 401 water quality certifications (from DWQ) precede section 404 permits (from the U.S. Army Corps of Engineers or COE) that may never be issued. In addition, some permitted impacts never occur. There were an additional 11,580 acres of pocosin wetland (non-riparian) lost after repeal of the federal Tulloch Rule[61]. However, most of this acreage had its hydrology restored through an intensive state and federal enforcement effort. There are also an unknown number of wetland acres lost each year from unauthorized projects and small projects not requiring confirmation by DWQ. Thus, the

[61] See "Land use and wetland conversion" section for more information

amount of impacted wetland acres may be underestimated. The DWQ is working to resolve the issue of tracking unauthorized and cumulative, small impacts (DWQ 2000a).

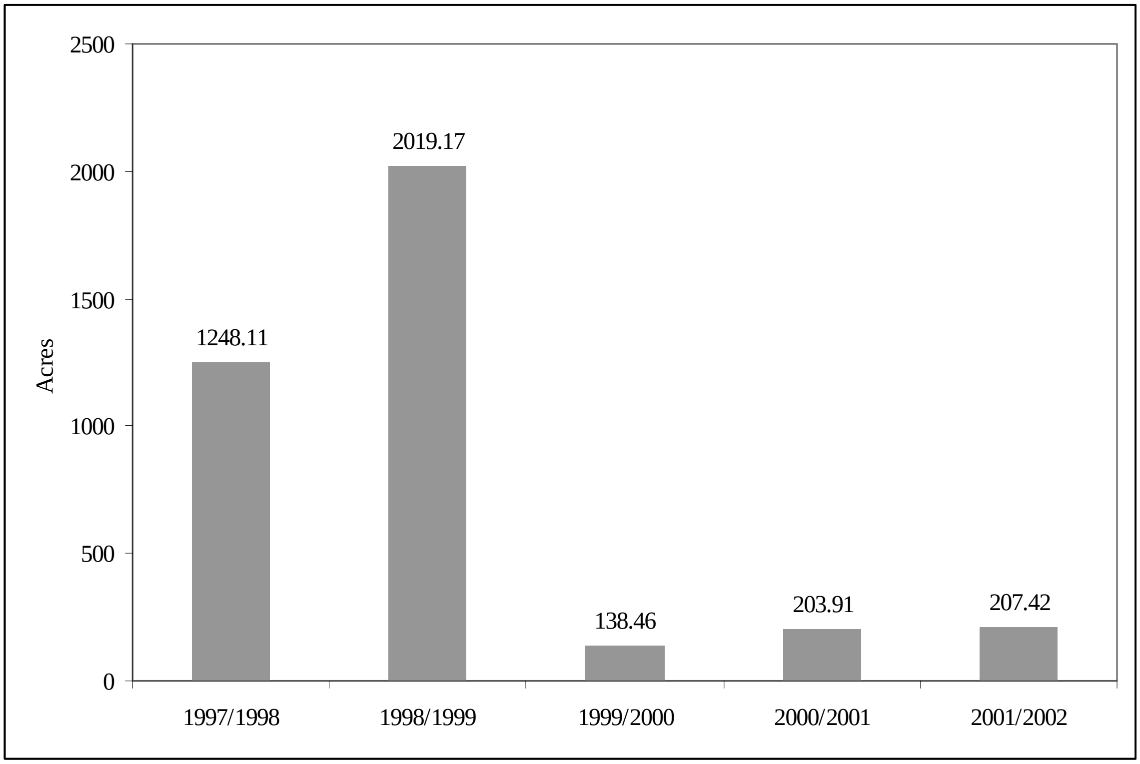


Figure 5.4. Total DWQ 401 Permitted Wetland Impacts (acres) during 1997-2002 in the seven Coastal river basins (excluding the Lumber River basin). Note: These data are for permanent wetland loss and do not include impacts from CAMA, Corps of Engineers Nationwide Permits 12 and 33, and Corps of Engineers Regional General Permit 030 since these impacts are temporary or are impacts to water (e.g., drainage).

In addition to conversion caused directly by humans, wetlands are also being lost to erosion resulting from sea level rise and shoreline hardening (Riggs 2001). Based on a recent study of 21 field sites and then extrapolated to the entire length of estuarine shoreline in northeastern North Carolina, annual wetland losses are approximately 802 acres/year, most of which are mainland brackish marsh habitat (Riggs and Ames 2003). When the cumulative effects of permitted wetlands impacts from 1997 to 2001, unpermitted wetland impacts (after repeal of Tulloch Rule), estimated coastal erosion loss from 1993 to 2001, and total estimated wetland losses prior to 1993 (DWQ 2000a) are added together, the total loss of wetlands in DWQ coastal river basins could be as much as 2,491,515 acres (1993-2002). This total estimated wetland loss still leaves 65% of the estimated original extent of wetlands in North Carolina (DWQ 2000a). However, this figure does not account for wetlands gained through restoration or creation, either by natural processes or restoration/creation effort. It also does not account for losses between 1993 and 1997 that were not attributable to erosion.

Status of associated fishery stocks

Of the ten fishery stocks with higher relative abundance in wetlands (Table 5.2), two are Overfished, three are Concern, one is Recovering, and four are Viable. There are an approximately equal number of Viable and Concern stocks showing some preference for wetland habitat. The two wetland-enhanced[62]

[62] Wetland-enhanced species are those showing some documented preference for wetland habitat.

stocks listed as Overfished were river herring (alewife and blueback herring in Albemarle Sound) and southern flounder. Wetland-enhanced species of Concern included blue crab, striped mullet, and Atlantic croaker.[63] The one Recovering species was red drum. The Viable species were spotted seatrout, spot, summer flounder, and shrimp.

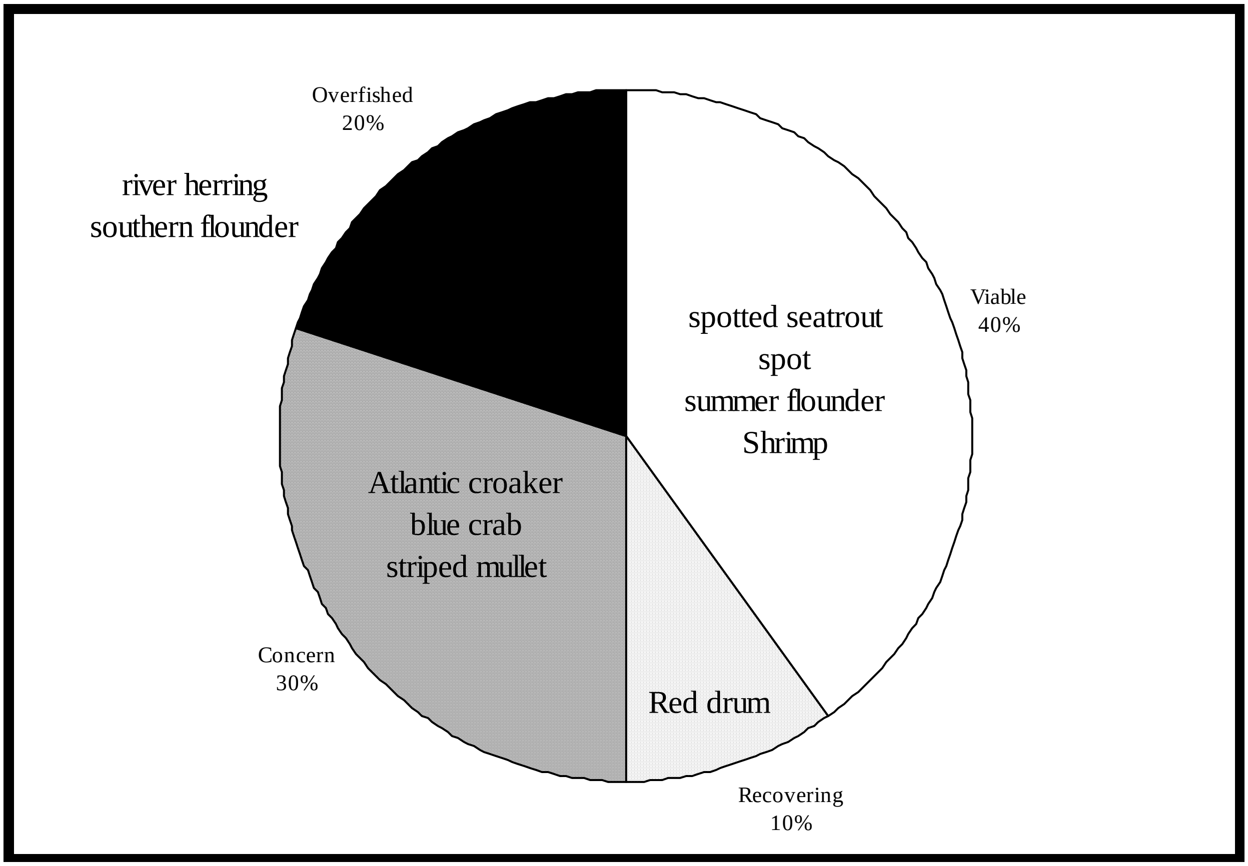


Figure 5.5. Percent of wetland-enhanced fish stocks classified as Overfished, Concern, Recovering, or Viable in the 2003 North Carolina Division of Marine Fisheries stock status report (DMF 2003a).

While most of the concern over declining fish stocks has focused on overfishing, habitat loss and degradation can also prevent recovery or make a stock more susceptible to overfishing. For example, impassable obstructions of migratory corridors to spawning grounds can prevent stock recovery despite fishing restrictions. In other cases, regional reductions or loss of one habitat can make a stock more susceptible to overfishing by reducing the diversity or total amount of suitable habitat available. *A strategy for enhancing fisheries, as required by the Fisheries Reform Act of 1997, must therefore involve both habitat protection/enhancement and prevention/reduction of overfishing.*

Wetland restoration

The loss of wetlands and need for alternative pollution control methods prompted restoration/creation efforts beginning in the late 1980s and early 1990s (Mitsch and Gosselink 1993). Actual restoration of wetlands is accomplished through compensatory mitigation and voluntary initiatives. The purpose of compensatory mitigation is to replace wetland functions that are lost through permitted impacts to

[63] A more detailed evaluation of wetland-enhanced species and their status can be found in the Chapter 6 (i.e., nursery area statistics).

wetlands (WRP 2002). Many wetland restoration projects involve simply restoring the natural hydrologic condition, while others include greater design considerations. Depending on the purpose of restoration/creation, design considerations include hydroperiod, nutrient/pollutant loading rates, seasonal flood pulses, flow patterns, water retention times (Mitsch and Gosselink 1993), and/or soil type.

While there have been many successful projects implemented nationwide, there have been failures attributed to lack of proper hydrology (Mitsch and Gosselink 1993). More recent studies in North Carolina found that mitigation sites restored by the N.C. Department of Transportation (DOT) relied too much on hydrologic criteria, leading to reduced survivorship of planted seedlings in some excavated areas with non-wetland soil (Rheinhardt and Brinson 2002). They also found that reference sites were rarely utilized in measuring the success of restoration. Presently, all DOT monitoring is stopped after permit conditions are satisfied. With these considerations in mind, it will be difficult to determine gains in wetland acreage. *Rheinhardt and Brinson (2002) encouraged long-term monitoring of restoration projects using success criteria based on hydrology, soil, and vegetation characteristics at established reference sites.*

<u>North Carolina Wetlands Restoration Program</u>

The North Carolina Ecosystem Enhancement Program (EEP) was established in July 2003 as an innovative program to restore, enhance, and protect the State's wetlands and waterways. The Ecosystem Enhancement Program combines an existing wetlands restoration initiative by the Department of Environment and Natural Resources (Wetlands Restoration Program) with ongoing efforts by the N.C. Department of Transportation to offset unavoidable environmental impacts from transportation-infrastructure improvements. The U.S. Army Corps of Engineers joined as a sponsor in the historic agreement. The mission of the EEP is to restore, enhance, preserve and protect the functions associated with wetlands, streams and riparian areas, including but not limited to those necessary for the restoration, maintenance and protection of water quality and riparian habitats throughout North Carolina's 17 river basins[64]. To accomplish this mission, the WRP works closely with the DWQ and other resource agencies to identify watersheds (14-digit hydrologic units) in each river basin that exhibit both the need and opportunity for restoration. These areas are called "Targeted Local Watersheds" and receive priority for WRP planning and restoration project funds. Based primarily on water quality, habitat, land cover, and public comment, staff identify "Targeted Local Watersheds" that are believed to be the best areas for the program to implement wetland, stream, and riparian restoration projects, and nutrient reduction projects. The goal is to concentrate multiple projects within small watersheds to address real watershed degradation symptoms instead of isolated problem areas scattered more broadly across a basin or larger watershed. This focus works toward implementing long-term watershed restoration and protection benefits. The WRP encourages other government entities and funding organizations to consider implementing watershed and habitat improvement projects within these areas as well as maximize state, federal and local funding sources based on multiple watershed planning objectives. Multiple complementary projects focused in small watersheds will provide the greatest ecological benefit to North Carolina's streams, rivers, lakes, estuaries, and wetlands. This approach also helps maximize program funds and programmatic benefits, creating an environment for partnership and collaboration among various state, federal and local programs.

Compensatory mitigation[65] is often required with the issuance of a 401 Water Quality Certification and/or

[64] More information on EEP website (www.nceep.net).

[65] The data presented in this section are based on the Division of Water Quality's Wetlands/401 Unit's Water Quality Certification Database. This database tracks wetland and streams losses that are authorized through the issuance of a 401 Water Quality Certification. Issuance of a 401 Water Quality Certification is required before the Corps of Engineers can issue a Section 404 Permit authorizing the fill or alteration of wetlands and/or streams. Although in the majority of cases the impacts authorized by the 401 Water Quality Certification are consistent with the impacts authorized by the Section 404 Permit, the amount of impact authorized by the Section 404 Permit may be less than that authorized by the 401 Water Quality Certification and, in some cases, a Section 404 Permit may never be issued. In addition, the authorized impacts may not occur during this

Section 404 permit to impact wetlands. However, not all project impacts are mitigated with the creation or restoration of wetlands. Based on compensatory mitigation requirements, permittees may choose to conduct the compensatory mitigation themselves, request to make a payment to the DENR Wetlands Trust Fund for Compensatory Mitigation, or purchase credits from private mitigation banks (if the impacts occur within their mitigation service area). Donation of land for wetlands restoration or creation also satisfies wetland mitigation requirements [EMC rule 15A NCAC 02R .0403 (e)(1-2)]. Land donations preserving wetlands do not satisfy the rule. *Land acquisition for preservation should also be an option for wetlands mitigation. However, the amount of land preserved should be more than the area impacted because the preservation will not offset the adverse impact.* Preservation of high quality lands is an option to meet compensatory mitigation needs in advance of expected impacts during the Ecosystem Enhancement Program's Transition Period (July 2003-July 2005). Preservation sites are intended to supplement achieving compliance with compensatory mitigation requirements.

The WRP is required by statute to report on both compensatory and non-compensatory (i.e., non-regulatory) restoration work accomplished in North Carolina annually. In fiscal year 2001-2002, eighty-one 401 Water Quality Certifications issued statewide required wetland or stream mitigation. Of those, 69% were satisfied through payment to the Wetlands Trust Fund. Compensatory mitigation requirements for 7% were satisfied through payment to private mitigation banks, while the remaining 23% conducted compensatory mitigation on-site. The amount of compensatory mitigation in North Carolina coastal river basins during fiscal years 1999-2002 was approximately 650 acres (WRP 2000, 2001, 2002) (Table 5.6). During that same time period, there were 550 acres of wetlands impacted in coastal river basins[66]. There is also some voluntary creation or restoration of wetlands. During fiscal years 1999-2002, 17.25 acres of wetlands were voluntarily restored or created in coastal river basins through non-regulatory restoration practices (i.e., North Carolina Coastal Federation projects funded by Clean Water Management Trust Fund).

Table 5.6. The amount (acres) of compensatory mitigation and non-regulatory gains (voluntary restoration/enhancement) in coastal river basins from 1999-2002. (Sources: WRP 2000, 2001, and 2002)

Fiscal year	Non-regulatory Gains-Restoration/ Creation	Compensatory mitigation	Total
1999/2000	9.25	150.40	159.65
2000/2001	2.00	288.60	290.60
2001/2002	6.00	195.65	201.65
TOTAL	17.25	634.65	651.90

The WRP evaluates the costs of restoration projects on an annual basis. These costs can vary based on site conditions and restoration methods. Based on two riparian wetland projects in fiscal year 2001-2002, the cost of restoration in 2002 was $20,000-25,000/acre (WRP 2002). The cost includes site identification, site acquisition, project design, construction management, site restoration, post monitoring, and long-term management. The cost of restoring 4.11 acres of coastal wetlands in 2002 was even higher at $101,148/acre.[67]

fiscal year and in some cases may never occur. The DWQ is increasing its efforts to monitor and track the impacts that actually occur.

[66] The total number of wetlands impacted includes impacts of less than one acre. Impacts of less than one acre do not require compensatory mitigation as a condition of the 401 Water Quality Certification, though they may result in a substantial loss of wetland resources (WRP 2002).

[67] For additional information regarding 401/404 compensatory mitigation requirements, visit DWQ's website at <http://h2o.enr.state.nc.us/ncwetlands/>. For additional information concerning the WRP, visit <http://h2o.enr.state.nc.us/wrp/>.

The rate of wetland loss documented by 401 permit records does not account for functional equivalency, which is the replacement of full ecological functions specific to a wetland type. Currently, wetlands losses and gains are tracked on an acre-for-acre basis. The wetland type lost is not always mitigated by the creation of a similar wetland type. In fact, there is little consideration for maintaining a natural mix of wetland types on the landscape. *Rheinhardt and Brinson (2002) recommended the tracking of restoration efforts by river basin and hydrogeomorphic class so that restoration can maintain a balanced distribution of classes on the landscape.* For example, the loss of riverine wetlands in the Neuse River basin should be mitigated by the creation or restoration of riverine wetlands in the Neuse River basin. The new Ecosystem Enhancement Program is tracking restoration efforts associated with Department of Transportation projects.[68]

Other initiatives

Federal, state, local, and private organizations and individuals conduct voluntary initiatives. The Wetlands Reserve Program of the Food, Agriculture, Conservation, and Trade Act of 1990 authorized the U.S. Department of Agriculture (USDA) to purchase easements from landowners who agree to protect or restore wetlands. The goal of USDA's Pilot Wetlands Reserve Program was to restore one million acres of cultivated crops to wetlands by 1995 (Bales and Newcomb 1996). The USDA pays 75% of the restoration cost to landowners, and NRCS and FWS assist in completing the restoration plans. As of 2001, there were more than 6,500 restoration projects nationwide that encompassed nearly 1,075,000 acres (NRCS 2002). By 1992, there were about 15,000 acres of cultivated land enrolled in the North Carolina program (Bales and Newcomb 1996). By 2002, total program enrollment in North Carolina had exceeded 26,000 acres (NRCS 2003). Project costs vary throughout the country. In 2001, the average cost of purchasing and restoring a permanent easement was approximately $1,200 per acre. The average cost of purchasing and restoring a 30-year easement was around $770 per acre. Restoration cost-share agreements, which do not include easement acquisition costs, averaged around $450 per acre (NRCS 2003).

The Conservation Reserve Enhancement Program (CREP) is another state/federal program intended to improve not only wetlands, but also other riparian habitats in North Carolina. The program is focused on impaired water bodies in the Chowan, Neuse, and Tar-Pamlico river basins, and the Jordan Lake area (all Nutrient Sensitive Waters). The program can pay up to $50,000 per person, per fiscal year to replace marginal agricultural land with forested riparian buffers, grassed filter strips or wetlands. For the enrollment of 100,000 acres in North Carolina, federal and state obligations over a 15-year period are approximately $275 and $54 million, respectively (<http://www.fsa.usda.gov/crpstorpt/CREP/default.htm>, April 2003). During 1999-2003, 19,081 acres were enrolled in this program in North Carolina (calculated from USDA website, April 2003). However, the proportion of this acreage in wetland restoration or creation was not reported.[69]

In addition to the programs discussed above, other state programs involved in the restoration of wetlands include DWQ's 319 Program, Clean Water Management Trust Fund, and the Division of Water Resources' Grant Program (WRP 2002).[70]

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[68] See "Recent trends" subsection under "Land use and wetland conversion" below for more information.
[69] More information on the CREP program can be found on the USDA's website (<http://www.fsa.usda.gov/dafp/cepd/crpinfo.htm>).
[70] Information on these programs is provided on the WRP website (<http://h2o.enr.state. nc.us/wrp/index.htm>).

Existing management measures

Legislation and regulatory programs

Alteration or destruction of wetlands are currently regulated by federal and state agencies. Numerous federal regulations and incentives affecting wetlands were included in the River and Harbors Act of 1899; the Clean Water Act of 1972 (and its amendments); the Food Security Act of 1985; the Food, Agriculture, Conservation, and Trade Act of 1990; the Emergency Wetlands Resources Act of 1986; and the Coastal Zone Management Act of 1972 (Bales and Newcomb 1996).

The River and Harbors Act gives the COE the authority to regulate certain activities in navigable waters. These activities include some that can damage or destroy wetlands such as diking, deepening, filling, excavating, and placement of structures. Section 404 of the Clean Water Act requires that the COE regulate the discharge of dredge or fill material into wetland areas. Permit applications are reviewed by the U.S. Environmental Protection Agency (EPA) and U.S. Fish and Wildlife Service (FWS). The Corps can deny the permit based on FWS or NMFS recommendation. States were given the authority to approve, apply conditions to, or deny 404 permits by Section 401 of the Clean Water Act. The authority is applied in North Carolina by DWQ with the 401 Water Quality Certification program.

While issuance or denial of Section 404 permits are the most widely used federal management tools protecting wetlands, most farming, ranching, and silviculture activities are exempt from such permits (Bales and Newcomb 1996). These exemptions were reduced by the “Swampbuster” provisions of the Food Security Act of 1985 and its amendments. “Swampbuster” provisions discourage (through financial disincentives) the draining, filling, or other alterations of wetlands for agricultural use. However, there are exemptions from the disincentives if the farmer agrees to restore the altered wetland or some other wetland area converted to agriculture. Cutover wetlands impacts between 1988 and 1994 are likely the result of silviculture operations.

There are also section 404 and 401 general permits issued for projects causing minimal individual and cumulative environmental impacts. These permits are important because the activities they cover do not require wetland restoration. The most frequently used, but no longer issued, 404 general permit is Nationwide Permit 26, which applied to wetland fills less than 10 acres in size. This permit had the following general conditions: (1) the wetland must be located adjacent to a stream and above headwaters, or (2) the wetland must be isolated (equivalent to flat/depressional hydrogeomorphic class). Nationwide Permit 26 probably contributed primarily to loss of flat/depressional wetlands noted earlier in the Status and Trends section. Some other activities covered under federal general permits include:

- Fish and wildlife harvesting,
- Survey activities,
- Minor road crossings,
- Modifications of existing marinas,
- Maintenance dredging of existing basins,
- Boat ramps with no discharge to wetlands, and
- Cleanup of hazardous and toxic waste.

The Emergency Wetlands Resources Act of 1986 required states to address wetland protection in their Comprehensive Outdoor Recreation Plans in order to qualify for federal funding. Other wetland protection incentives were provided by the Coastal Zone Management Act, which required coastal states to adopt coastal zone management programs in order to be eligible for federal funding and technical assistance. As a result, the Coastal Resources Commission (CRC) was subsequently established in North Carolina. The DCM was later established as the operational arm of the CRC. Rules promulgated by the CRC apply to North Carolina’s 20 coastal counties.

Within coastal counties, the CRC forbids projects that can violate water quality standards of estuarine resources, including coastal wetlands [CRC rule 15A NCAC 07H .0207]. The CRC rules also state that activities directly impacting wetlands shall not have significant adverse impacts. The CRC prohibits disposal of fill in coastal wetlands and dredging activities in all but the most narrow fringing wetlands [CRC rule 15A NCAC 07H .0208 (b) (1) (A, C)]. Furthermore, CRC rules require that bulkheads and riprap be constructed landward of coastal wetland areas. However, CRC and EMC rules allow bulkhead backfilling of small, freshwater wetlands landward of coastal wetlands following the size threshold criteria for permitting wetland impacts[71], resulting in a cumulative loss of wetlands that might provide for marsh migration with sea level rise. *To minimize these losses, all but the most miniscule of wetland impacts should be subject to permitting.*

Encouraged by the progress of wetland regulations, "No Net Loss" policies were developed by the federal government in the late 1980s (Wiebe and Heimlich 1995). But despite their achievements, wetland regulations are still considered by the public a "taking" of property that should be discontinued or financially compensate the landowner. The central problem of wetland protection remains how to protect wetlands for public benefit when the majority of converted or remaining wetlands are privately owned. These factors have led to increasing reliance on land acquisition and direct incentives for protecting remaining wetlands. Increasing public awareness of wetlands benefits (i.e., reducing flood levels, velocities, and damage) encourages greater acceptance of wetland regulations, as well as voluntary actions.

<u>State and federal regulatory designations</u>

Several state regulatory designations provide additional protection of wetlands, such as area designations for:

- Estuarine Shoreline Areas of Environmental Concern [CRC rule 15A NCAC 07H .0205-207];
- Nutrient Sensitive Waters [EMC rule 15A NCAC 02B .0101(e)(3)];
- Primary Nursery Areas [MFC rule 15A NCAC 03N .0102(a)];
- Shellfishing Waters [EMC rule 15A NCAC 02B .0101(d)(3)];
- High Quality Waters [EMC rule 15A NCAC 02B .0101(e)(5)];
- Outstanding Resource Waters [EMC rule 15A NCAC 02B .0101(e)(4)].

The CRC-designated Estuarine Shoreline Area of Environmental Concern (AECs) extends landward 75 feet from the high water mark along estuarine shorelines, upstream to the line separating Coastal and Inland Fishing Waters (Figure 2.6 in Chapter 2). The Estuarine Shoreline AEC increases to 575 feet along shorelines of EMC-designated Outstanding Resource Waters. Any development planned within this area must obtain a Coastal Area Management Act (CAMA) permit. Hard surfaces, such as buildings, paved parking lots and roads, must cover no more than 30% (25% along ORWs) of the project area within the Area of Environmental Concern, unless the development incorporates an innovative design that provides stormwater protection equal to or exceeding the protection of the 30% limitation. However, certain activities (i.e., agriculture and silviculture) not involving excavation or filling of coastal wetlands are exempt from a CAMA permit. The Coastal Shoreline AEC, which includes estuarine and public trust shorelines to the upstream extent of navigable waters, also includes a 30-foot buffer from high tide elevation in which only water-dependent uses are allowed. However, the vegetation in this buffer does not have to be natural, and it can be mowed. There are exemptions allowing non-water dependent structures within 30 feet of the high water mark. For example, the full buffer is not required if it would preclude the placement of residential structures on a lot, parcel, or tract that was platted before June 1,

[71] Projects impacting less than 1/3 acre of wetland within 50 feet of the high water line are exempt from 401 water quality certifications, as well as projects impacting less than 1 acre within 150 feet of the high water line [EMC rule 15A NCAC 02H .0506 (c)(2)]. There is no minimum area criteria for mitigation when dealing with designated unique wetlands [EMC rule 15A NCAC 02H .0506(e)]. However, unique wetlands will likely not be designated on private lands without the approval of the land owner.

1999 (if certain criteria are met) [CRC rule 15A NCAC 7H .0209 (e)(1)]. There are also exemptions for lots platted before June 1, 1999 or surrounded by existing development [CRC rule 15A NCAC 07H .0209 (e)(2)(A)].

Along Nutrient Sensitive Waters in the Tar-Pamlico and Neuse river basins, the EMC has established a buffer width of 50 feet directly adjacent to intermittent streams, perennial streams, lakes, ponds, and estuaries, excluding wetlands [EMC rule 15A NCAC 02B .0233 (3)]. The first 30 feet of the buffer (Zone 1) must be virtually undisturbed natural vegetation. However, within the 20 CAMA counties, Zone 1 is measured from the landward edge of coastal wetlands [EMC rule 15A NCAC 02B .0233 (4)(a)(iii)]. The zone of undisturbed natural vegetation could therefore include some freshwater wetlands not covered under CRC rules. The second 20 feet of the buffer (Zone 2) can be mowed grass and/or harvestable trees. While the buffer rules for Nutrient Sensitive Waters provide more protection for wetlands than CRC buffer rules, there are many exemptions [EMC rule 15A NCAC 02B .0233 (6)]. Most of the exemptions (over 35 in all) are for infrastructure associated with development (e.g., utility lines, drainage ditches, roads/bridges).

Waters designated as PNAs by the MFC are given additional consideration of impacts by DCM prior to issuing development permits. Only maintenance dredging is allowed, and only within existing basins and channels. There are no other special requirements on water-dependent, development-related activities in wetlands surrounding PNAs (i.e., bulkheads, piers). However, all designated PNAs and SA waters are classified HQW and receive additional protection from discharge and development under EMC and CRC rules. Rules dealing with approved Shellfishing Waters protect wetlands by prohibiting new marina construction that could result in loss of some fringing wetlands and increased boat traffic and associated impacts [CRC rule 15A NCAC 07H .0208 (b)(5)(E)].

All coastal areas classified as Outstanding Resource Waters also have significant wetland coverage. Outstanding Resource Waters and their more stringent regulations [EMC rule 15A NCAC 02B .0225 (e)] encompass approximately 6% of the riparian wetland habitat in coastal North Carolina, the majority of which is salt/brackish marsh and riverine swamp forest. Those areas also cover 2% of non-riparian wetlands. There is also a larger Area of Environmental Concern (extending 575 feet from mean high water) adjacent to ORW waters, within which there is a built-upon area limit of 25% [CRC rule 15A NCAC 07H .209 (g)]. The limit on impervious surfaces could help prevent loss of wetlands within the AEC. *The effectiveness of ORW-related rules in protecting wetlands and other habitats should be examined and changed as necessary*. *Appropriate management strategies should be developed by the EMC, MFC and CRC to protect wetland areas designated as Strategic Habitat Areas by the MFC.*

The federal government protects wetlands by designating them Essential Fish Habitat (EFH). The designation of EFH for coastal wetlands means several things. First, the regional fishery management councils must identify measures to conserve, restore, or enhance Essential Fish Habitat. They must also recommend actions that will minimize the adverse effects of fishing on habitat. Most recommendations target federal agencies (i.e., Corps of Engineers or Environmental Protection Agency) whose projects may affect fish habitat. Basically, any state or federal activity that could harm habitat for federally managed fish stocks is subject to review by NMFS (NOAA Fisheries). Federally managed fish stocks include those occurring in federal waters (i.e., tuna, sharks, panaeid shrimp, red drum). Coastal wetlands are designated EFH for red drum and shrimp. Areas of EFH requiring the most protection are termed Habitat Areas of Particular Concern (for more information see Chapter 8).

Land ownership and management

In addition to regulatory designations, wetlands also receive protection by virtue of ownership and management. Protected lands are owned and managed by federal, state, county, and municipal governments, as well as conservation organizations, other nonprofit organizations and land trust properties. These protected lands cover 217,289 ac of riparian wetlands and 434,746 ac of non-riparian wetlands, representing approximately 16 and 26% of all riparian and non-riparian wetlands, respectively, in coastal North Carolina.[72] Based on the amount of 1994 wetlands within protected areas, 74% of wetlands are not protected by land ownership, although this amount does not account for regulatory restrictions and area designations on lands not managed for conservation. It also does not include lands with restoration cost-share agreements in the Wetland Reserve Program.

Within areas protected by conservation ownership and management, some wetlands types are more represented than others. Of the riparian wetland types, estuarine shrub/scrub, salt/brackish marsh, and estuarine forests are the most protected (28-52%; see Table 5.7). The riparian freshwater wetlands are relatively less protected (7-28%). Among hydrogeomorphic categories, headwater wetlands receive the least protection (6%). Most headwater wetlands are outside of estuarine shoreline AECs, and thus are not protected by CRC use standards. Projects impacting these small wetlands may often require only a

Table 5.7. The amount and percentage of each wetlands type in eastern North Carolina within protected lands. Only undisturbed wetlands indicated on DCM GIS mapping of the Coastal Plains are included. (Source: CGIA's BasinPro3 coverage, "Land Managed for Conservation")

Wetland class	Wetland type	Protected (ac)	Total (ac)	% Protected
Riparian	Salt/Brackish Marsh	74,038	198,168	37.36
	Estuarine Shrub/Scrub	14,417	27,874	51.72
	Estuarine Forest	274	965	28.38
	Freshwater Marsh	9,091	32,803	27.71
	Bottomland Hardwood	16,301	227,582	7.16
	Riverine Swamp Forest	101,400	829,681	12.22
	Headwater Swamp	1,769	31,159	5.68
	TOTAL RIPARIAN	*217,289*	*1,348,232*	*16.12*
Non-riparian	Pocosin	299,225	507,117	59.01
	Maritime Swamp Forest	1,666	3,438	48.46
	Non-riverine Swamp Forest	101,154	215,305	46.98
	Pine Flat	74,912	296,591	25.26
	Hardwood Flat	15,041	165,077	9.11
	Managed Pineland	58,943	954,336	6.18
	TOTAL NON-RIPARIAN	*550,941*	*2,141,864*	*25.72*
TOTAL		**768,230**	**3,490,096**	**22.01**

general permit and no mitigation, or they may be exempt from a permit due to small size. Although there are no accurate records on the type of wetlands impacted by 401 Water Quality Certifications, headwater wetlands are believed to be one of the most heavily impacted wetland types (J. Dorney, DWQ, pers. com., 2003). *Due to the relative threat to, and ecological importance of, headwater wetlands, they should receive higher priority in wetland preservation/restoration efforts.*[73]

Statewide Wetland and Streams Management Strategy

In 1997, DENR received a grant from the EPA to develop a comprehensive, statewide plan to improve and simplify North Carolina's wetland and stream protection policies. The EPA provides financial, technical, and planning assistance to states interested in developing statewide wetland conservation plans. The EPA strongly supports development of statewide wetland conservation plans because these plans

[72] This information was obtained by overlaying DCM wetlands data with "Land Managed for Conservation" coverage from BasinPro3 (software developed by the North Carolina Center for Geographic Information and Analysis).
[73] Wetland acquisition and conservation programs are listed in Appendix J.

give states a framework to protect, restore, and create wetlands in an effective and efficient manner.

The objective of this strategy was to identify opportunities to make wetland, stream, and riparian buffer protection programs and conservation approaches work more efficiently and effectively in North Carolina. In 1999, a stakeholder Advisory Committee was convened to develop the strategy. The major stakeholder groups represented on the Advisory Committee include: agriculture, forestry, environmental groups, academics, industry, development, private consulting, local government, the COE, EPA, the Natural Resources Conservation Service, and North Carolina departments of Environment and Natural Resources, Transportation, Agriculture, and Commerce. Through a series of both private and public meetings, the committee identified eight priority issues that were further investigated by a smaller Technical Work Group in May 2000. These priority issues have been published in the Statewide Wetland and Stream Management Strategy (<http://h2o.enr.state.nc.us/ncwetlands/about.htm>, 2004) and are shown below:

- Unique wetlands – Examine the regulatory authority of the EMC and DWQ for unique wetlands, develop policy interpretations for definitions, and develop a list of candidate sites or a process to determine potential sites.
- Wetland and stream mitigation – Develop flexible wetland and stream mitigation options.
- Local government roles – Examine the involvement of local governments in wetland management/protection and develop potential mechanisms to encourage involvement.
- Wetland preservation – Inventory existing wetland preservation activities in North Carolina, develop wetland preservation goals, and examine mechanisms to encourage involvement.
- Wetland mapping – Examine existing and planned wetland mapping efforts, determine need for additional and improved mapping, explore mechanisms to carry out new mapping efforts, and examine the role of Geographic Information Systems in wetland and stream management.
- Environmental education – Examine existing wetland and stream education programs and activities, determine need for additional education opportunities, and recommend new and improved education activities.
- Regulatory structure and process – Examine the 401 Water Quality Certification Program's strengths and weaknesses, develop options to address weaknesses, and develop options for clarification.

Net loss

During 1999-2002, 651.90 acres of wetlands were created or restored in coastal river basins. Over that same time period, there have been 549.79 acres of permitted wetlands impacts (Figure 5.4) and an estimated 2,406 acres of coastal wetland lost to erosion (802 ac/yr x 3 yr). So the rate of wetland creation/restoration would appear to surpass the rate of loss from direct human causes. However, the total permitted impacts do not include the cumulative impact of very small losses that go untracked by permit authorities. *A study should be conducted to determine the cumulative impact of small wetland losses on the distribution and abundance of wetland types in a watershed. The cumulative loss could then be related to the nature and extent of development pressure in the watershed in order to formulate a model predicting untracked losses in other watersheds. But regardless of empirical evidence, small cumulative impacts may have a negative impact on fish habitat. Rules should be modified to reduce net loss of riparian wetlands from small cumulative dredge and fill projects (i.e., lower size threshold of wetland impacts that require permit or mitigation).*

5.4. THREATS AND MANAGEMENT NEEDS

Physical threats

Because physical alterations primarily impact wetlands, land use changes associated with population growth are the primary cause of wetland habitat loss today (Dahl 2000). Large-scale draining and ditching are prevalent agricultural impacts, whereas deforestation and fill are associated with silviculture activities and upland development. Shoreline stabilization is primarily a coastal phenomenon. Dredging access channels for upland boat basins can destroy wetlands, while bulkheading can increase erosion along adjacent wetland shorelines. The direct effects of land use changes and hydrologic modifications on riparian wetlands are discussed in the following sections.

Land use and wetland alteration

Historical conversions

The major cause of wetland loss and degradation has been conversion to agriculture, silviculture and upland development (including road construction). In the late 1800s and early 1900s, the greatest losses resulted from ditching and draining for agriculture. Several large agricultural drainage projects occurred during that period (Heath 1975), resulting in an estimated 1 million miles of drainage ditches and canals throughout the Coastal Plains of North Carolina (Wilson 1962). Much of the land around the Albemarle-Pamlico estuary was drained and must remain drained to accommodate existing agriculture and forestry. About one-third of the loss of wetlands has occurred since 1950 (Bales and Newcomb 1996). After 1950, conversion to managed forest and agriculture accounted for 53% and 42%, respectively, of wetland losses (Bales and Newcomb 1996). Many of the roads on the Albemarle-Pamlico Peninsula were constructed on top of spoil piles between canals to prevent flooding on the roads. Ditching of wetlands or uplands is also common in other areas of the coast for flood control and drainage. In many urbanized coastal areas, ditches and swales are typically constructed along neighborhood streets. The ditches often connect and drain into headwaters, which alters the natural hydrology of downstream systems (Pate and Jones 1981).

Many government policies restrict ditching and draining of wetlands. Drainage of low-lying farmland funded by the USDA's Natural Resources Conservation Service (NRCS) and mosquito ditching are no longer common practices. "Swampbuster" provisions of the 1985 Farm Bill discouraged the practice of draining wetlands for conversion to cropland. However, drainage channels for croplands are still maintained by drainage districts (DEHNR 1995a). Except for a short period from 1998 to 2000, there have been no new large-scale wetland drainage projects since the mid-1970s (Chicod Creek, Pitt and Beaufort counties, Tar-Pamlico MU). Prior to 1998, ditching/draining of wetlands was regulated by the COE. At that time, ditching required a federal 404 permit with a DWQ 401 certification, to ensure that water quality standards were not violated. When the federal court overturned the federal Tulloch rule in June 1998, the COE lost authority to issue permits for wetland ditching unless spoil was placed on adjacent wetlands. As a result, thousands of acres of wetlands were drained, primarily in Brunswick, New Hanover, and Pender counties (J. Steenhuis, DWQ, pers. com., 2002). Approximately 9,500 acres of wetlands were impacted in Brunswick County alone (DWQ 1999), and a total of approximately 11,580 acres of wetlands were impacted in the Coastal Plain. These losses are in addition to 401 Water Quality certification records. In Brunswick, New Hanover, Pender, and Onslow counties, 24% of the ditching was reported as forestry-related, 6% as agriculture-related, and 70% was done for development or other purposes (J. Steenhuis, DWQ, pers. com., 2002).

In 1999, the State of North Carolina determined that wetlands ditching and draining activities fall under its authority, constituting an illegal activity if proper approval is not obtained. In 1999, EMC adopted a wetland draining policy to ensure that required wetland conditions are maintained (<http://h2o.enr.state.nc.us/ncwetlands/ditch.html>, 1999). In addition, inspections were made of previously ditched wetlands to determine if the ditching was conducted in a manner that violated wetland standards. Where violations occurred, property owners were required to restore the natural hydrology through the filling of the ditches. Approximately 50% of the ditched wetlands have been restored, 22% are likely not to be restored, and the status of the remainder is undetermined (J. Steenhuis, DWQ, pers. com., 2002). Many of the remaining ditches, although not appearing to be violating water quality standards, continue to transport stormwater into coastal waters. *Additional monitoring is needed to better assess impacts where extensive areas of wetlands were drained. More DWQ staff are needed to inspect for compliance with water quality standards, including wetland draining.*

A violation of the Clean Water Act occurs if any wetland area benefiting water quality is converted to uplands, without a permit. The Corps of Engineers and EPA signed a Memorandum of Agreement describing the types of wetlands in which mechanical forestry site preparation activities required a permit (<http://www.epa.gov/owow/wetlands/guidance/silv2.html>, June 2004). The resulting list included all riparian wetlands. Prior to the memorandum, forestry operations were exempt from 401 or CAMA permits when the hydrology of the wetland area was maintained. The forestry exemption can be an issue when there is dispute concerning how forestry operations alter different wetlands types. Altering some wetland types would have a negative impact on downstream water quality (i.e., riparian wetlands), while altering other types would have little effect on water quality (i.e., some isolated wetlands). If a forestry operation allowed the exemption to alter a wetland benefiting water quality, and later sold the property to someone claiming the site had become an upland, the development may have been exempt from water quality permits and mitigation requirements. The Memorandum of Agreement between the COE and EPA should prevent mechanical forestry operations from altering any riparian wetland without obtaining a 404 permit or 401 Water Quality certification.

In a recent court case related to the drainage activities during 1998-2000, a development company claimed the forestry exemption when it ditched and drained over 200 acres of wetlands in Onslow county (N.C. Shellfish Growers Association and NCCF vs. Holly Ridge Associates; U.S. District Court for the Eastern District of North Carolina, Eastern Division, No. 02cv0053). The judge said the ditches and the site itself were all "point sources" of stormwater and sediment pollution, and therefore required discharge permits under the Act – even if the activities were for forestry purposes. In a related state case, an administrative judge ruled there was no credible evidence that the ditching and drainage were for the purpose of forestry. Holly Ridge Associates was found in violation of the Clean Water Act for not obtaining a CAMA permit, a 401 Water Quality Certification, and an NPDES discharge permit. Barring successful appeal[74], the latter case should prevent other land development and forestry companies from ditching or draining riparian wetlands without NPDES permits. *Any ditching activity resulting in nonpoint source pollution in North Carolina's rivers and sounds should require an NPDES permit. The EMC's constraints on discharges in SA waters could then be extended to drainage projects, in addition to traditional point source discharges (i.e., wastewater treatment plants).*

The cutover wetland acreage from 1988 to 1994, noted in the Status and Trends section (above), was likely the result of silviculture operations. The alterations occurred in both forested riparian and non-riparian wetlands (17,513 and 40,316 acres, respectively; Tables 5.4 and 5.5). The majority of alterations were to non-riparian forested wetlands. Using the rate of cutover impacts from 1988 to 1994, approximately 21,000 more acres of riverine forested wetland may have been impacted from 1994 to 2003. As long as wetland hydrology is maintained, this is a relatively minor issue. If upland development replaced these cutover riparian wetlands, there could have been a violation of the Clean Water Act.

In addition to conversion to upland development, agriculture, and silviculture, many wetlands were also converted to deepwater habitat. Based on national trends during the mid-1970s, the major source of coastal wetland loss was conversion to deep water habitat (e.g., boat basins, navigation channels), followed by upland development (Hefner and Brown 1985). The CRC currently prohibits dredging through all but the most narrow fringing marshes [CRC rule 15A NCAC 07H .0208 (b)(1)(A)]. Many acres of wetlands were dredged for the Intracoastal Waterway (1930s), boat basins, and connecting channels before dredge and fill and CRC rules were implemented. The primary dredging activities still occurring within North Carolina's coastal waters are maintenance or improvement dredging of existing navigation channels (DEHNR 1995a). These projects have a relatively minor effect on existing wetlands. However, small non-coastal wetlands, contiguous to coastal wetlands, are still lost to the backfilling of

[74] As of August 16, 2004, Holly Ridge Associates is appealing the court decision.

bulkheads.

Recent trends

To examine recent trends in wetland conversion, an analysis of wetland impact sources was performed on approximately 6% of the total number of 401 certification records from the DWQ database, covering a time period from 1997 to 2003 (1,213 of 18,700 total records). The data were filtered to include only those records within CHPP management units (based on geographic coordinates) having a date, project type (excluding wetland restoration/creation), and area impacted (DWQ, unpub. data). The analysis is unbiased toward certain impact types assuming the data represent a random subsample. Impact source categories for analysis of 401 permit records consist of the following:

- *Water control* includes the construction of impoundments, reservoirs, ditches, canals, water intakes, storm drains, stormwater ponds, and other activities designed to alter water flows. Note: some water control projects are related to transportation.
- *Upland development* includes isolated ponds, residential lots, commercial facilities, utility cables/pipelines, wastewater treatment plants, schools, churches, and other activities converting wetland habitat to uplands or supporting upland development.
- *Mining* includes quarry and sand pit construction or expansion, and other mining sources.
- *Agriculture/aquaculture* activities include irrigation ponds, farm construction, clearing land for animal operations, fish hatcheries, fish farms, spray fields, and similar activities that disturb wetland hydrology. Note: most agriculture activities are exempt from requiring 401 permits.
- *Transportation* includes construction of roads, highways, bridges, and culverts.
- *Water-dependent development* includes piers, docks, marinas, navigation channels, boat ramps, shoreline stabilization structures, channel relocation, and similar activities and structures associated with waterways.

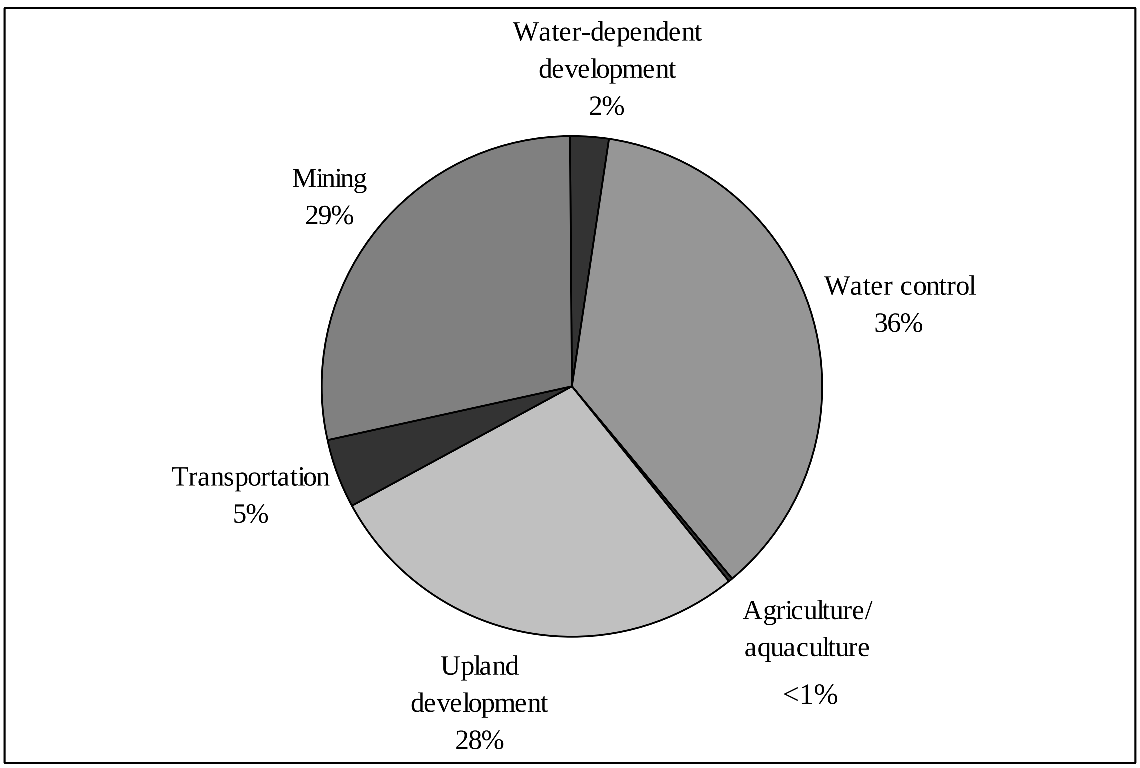


Figure 5.6. Sources of wetland impact in eastern North Carolina. [Source: subset of DWQ Section 401 certification records (1997-2003), with location coordinates within CHPP management units.]

The most recent trends (1997-2003) in wetland loss show water control projects as the major source of wetland impacts (36% of impacted acres) (Figure 5.6), followed by mining (29%) and upland development (28%). The vast majority of mining impacts occurred during a single project in 1997 when PCS Phosphate was issued a permit to destroy 1,268 acres of wetlands in Beaufort County (U.S. District Court for the Eastern District of North Carolina, Eastern Division, No. 02cv0053). Activities least impacting wetlands included agriculture/aquaculture (<1%), transportation (5%), and water-dependent development (2%) (Figure 5.6).

Projects by N.C. Department of Transportation accounted for 23% of permitted wetlands impacts during 1997-2003, based on 11% of 18,700 permit records (DWQ, unpub. data). The DOT spends more than $80 million each year mitigating the impact of bridges and other road crossings on wetlands (*Water Resources Research Institute News*, March/April 2003), causing considerable delays in road construction. In recognition of the problems resulting from these delays, DOT, DENR, and COE have developed a program to improve efficiency and provide sufficient mitigation, the Ecosystem Enhancement Program (EEP). The new program, established through an agreement among agencies, brings together mitigation staff from the WRP and DOT under DENR's umbrella. The EEP will estimate potential wetland impacts very early in the roadway planning process (*Water Resources Research Institute News*, March/April 2003). Prior to mitigation, potential impacts will be evaluated in a watershed context, having targeted priority areas for mitigation efforts. Functional assessment will be conducted prior to the permitting process for the transportation project. Priorities will be consistent with DWQ basinwide planning reports, Coastal Habitat Protection Plans, and Wetland Restoration Plans. Once in place, mitigation projects will be monitored to determine their effectiveness in replicating wetland functions. *Eventually, the EEP should include mitigation planning for upland development and other approaches to habitat enhancement, restoration, and preservation.*

Shoreline stabilization

Shoreline stabilization is modification of the natural shoreline to prevent or reduce landward migration of the shoreline. The purpose of shoreline stabilization is protection of man-made structures and property, including natural features. As shoreline development increases in conjunction with rising sea level, waterfront structures will be threatened more often and property owners will likely have greater interest to protect their property. Shoreline stabilization in estuarine areas generally utilizes hard stabilization techniques. Bulkheads are the primary hard stabilization structure.

Construction of seawalls and jetties are primarily oceanfront practices; they are discussed in the Soft Bottom and Water Column chapters (Chapters 2 and 6). Soft stabilization includes beach bulldozing or beach nourishment, which are also discussed in the Soft bottom chapter (Chapter 6). This section will discuss the extent of estuarine shoreline stabilization that has already occurred in North Carolina, impacts of this activity on riparian wetlands, and management needs to reduce or minimize such impacts.

Physical and biological effects

Hard stabilization techniques have fairly severe impacts on coastal habitat, including accelerated erosion, loss of shallow intertidal bottom, loss of fringing marshes, increased scouring and turbidity in nearshore waters, and obstruction to fish migration where structures are perpendicular to the shoreline (Walton and Sensabaugh 1979; Pilkey and Wright 1989; Pilkey et al. 1998; Peterson et al. 2000c). Two managed fishery species strongly linked to fringing marsh are penaeid shrimp and red drum (SAFMC 1998a). Other important estuarine-dependent fish species that utilize wetlands during larval and juvenile life stages include gag, snapper, Spanish mackerel, striped bass, and river herring (SAFMC 1998a). Degradation and loss of wetland habitat from shoreline hardening impacts these species, as well as many others.

Bulkheads impact wetlands in several ways. During construction, heavy equipment and backfilling may destroy vegetation above the high water line (wetland and transitional wetland plants), where bulkhead construction is allowed. Along the CRC's Estuarine Shoreline AEC, a 30 foot buffer above the high water line is established in which only water-dependent uses are allowed ([CRC rule 15A NCAC .07H .0209] provides exceptions to the buffer requirement). Rather than allowing natural vegetation to recolonize the area, property owners generally plant landscape scrubs and lawn grasses. These plants are not as effective at deterring erosion or reducing and cleansing stormwater as natural vegetation. Increased nutrients and toxins from fertilizers and pesticides used on the lawn enter the water with the runoff (Watts 1987). Bulkheads also prevent shoreward migration of fringing wetlands as sea level rises, resulting in eventual drowning and loss of existing wetlands (Titus 1988).

McDougal et al. (1987) found that nearshore wave impact increases as the horizontal length of the structure increases. Therefore, the cumulative effect of multiple, contiguous bulkheads has a greater impact on adjacent natural shoreline habitat than the effect of individual structures that are spatially distinct. Scouring action at the toe of bulkheads results in deepening of the adjacent water, thus reducing or eliminating intertidal habitat. Shallow water habitat is also reduced because the bulkhead structure prevents transport of sediment to other areas (Riggs 2001). The added turbulence at the base of bulkheads prevents vegetation from reestablishing after construction (Knutson 1977). Garbisch et al. (1973) showed that marsh vegetation waterward of bulkheads experienced a 63% mortality post-construction due to stress from increased turbulence and scour. This loss of habitat reduces benthic food resources for juvenile, anadromous, estuarine-dependent, and surf fish, as well as shore birds, which are highly dependent on shallow intertidal habitat for feeding (Byrne 1995; DMF 2000a; Peterson et al. 2000c). The deepening also increases the feeding efficiency of large piscivorous fish on small and juvenile fish that occupy the shallow waters adjacent to the structure (Rozas 1987).

Several studies have documented lower relative abundance and diversity of invertebrates and juvenile fish adjacent to bulkheaded shorelines compared to unaltered marsh, beach, or forested wetland habitats:

- Peterson et al. (2000c): On the Gulf coast, the most abundant species groups along unaltered marsh and beach shorelines (including habitat for penaeid shrimp, crabs, gobies, grass shrimp, drums species, and shad/herring species) were least abundant along bulkhead or rubble shorelines. In addition, diversity was lowest adjacent to bulkheads.
- Byrne (1995): In a Barnegat Bay lagoon, New Jersey, littoral fish and shrimp abundance were consistently and significantly lower at bulkheaded sites. The differences were attributed to lower levels of structural complexity, since SAV, macrophytic algae, snags, overhanging and submerged branches, and woody debris were absent from the bulkheaded sites, but present at the unaltered sites.
- Ellifrit et al. (1972): Fewer clams (*Venerupis japonica*) were present near bulkheaded areas compared to natural areas. The difference was attributed to less favorable conditions for settling and survival of clam larvae.
- Gilmore and Trent (1974): For all groups combined, benthic organisms were numerically and volumetrically less abundant in bulkheaded canals than in natural marshes. Crustaceans were over three times less abundant.
- Mock (1966): Brown and white shrimp abundance was 80% less in front of a bulkheaded shoreline compared to naturally vegetated shoreline. The difference was attributed to lower abundance of organic detritus and benthic macroinvertebrates, deeper water, and less intertidal vegetation.
- Bulkheads reduce or degrade spawning and nursery habitat for anadromous fish (SAFMC 1998a; DMF 2000a). Cumulative impacts of bulkheads have been specifically cited as a contributing factor to the decline of chinook salmon on the Pacific coast (Taylor 1999).
- O'Rear (1983) found that early larval river herring in the tributaries of the Chowan system were highly associated with the stream edge and waters with minimum flow. Shoreline hardening impacts the stream edge on which these larvae depend, and can accelerate flow, thereby making areas adjacent to bulkheads less suitable for use by larval or juvenile anadromous fish.

Most of the studies on the biological impact of bulkheads on fish and their habitat were not conducted in North Carolina. However, a recent study by the WRC (Waters and Thomas 2001) examined impacts of bulkheads and other hardened shorelines (i.e., rock revetments) on fish utilization in northeastern North Carolina waters, particularly spawning success and juvenile recruitment of anadromous fish species. They found significantly lower abundance and species diversity of fish adjacent to bulkheads, compared to forested wetland shoreline and rip rap. The study also found higher abundances of juvenile fish along rip-rap and natural shoreline than along bulkheads, and a comparable number of quality size gamefish. The difference in juvenile abundance was attributed to both greater complexity of rip-rap and natural shoreline, and their location near shallower water. These results indicate a reduction in nursery function along bulkheaded shorelines.

Vertical hardened structures are also problematic for marine species that move between water and land during their life cycle. Along the estuarine shoreline, bulkheads are a physical barrier to animals such as the eastern mud turtle, yellow-bellied turtle, and northern diamondback terrapin (a species of "concern" in North Carolina) that live and feed in the marsh, but nest above the high tide line (Ernst and Barbour 1972).

Cumulative effects

North Carolina's policies and rules for estuarine erosion management allow landowners to protect their property from erosion, while attempting to minimize the impacts of erosion control structures. Past and current CRC rules have greatly reduced losses of wetlands and shallow bottom by restricting placement of vertical structures in or seaward of coastal wetlands, and restricting backfilling of the associated landward wetlands. Although currently used techniques may effectively protect waterfront property, immediate and long-term impacts to wetlands often occur, and alteration of sediment supply affects natural shoreline processes and wetland migration. In addition, bulkheads are sometimes permitted and constructed where an erosion problem is not evident. The DCM is working towards permitting stabilization methods only where an identifiable erosion problem occurs. *Better criteria to define an "erosion problem" and aid in proper utilization of erosion control structures are needed and should be developed by the DCM and CRC.*

While a single bulkhead may have little effect on adjacent habitat, the cumulative impact of multiple bulkheads along estuaries can result in significant habitat degradation. Between 1984 and 2000, DCM issued permits to bulkhead approximately 457 miles of shoreline (11.7% of the estimated 3,900 miles of estuarine shoreline). During this time period, the amount of bulkheading permitted annually along the coast has ranged from eight to 91 miles (Figure 5.7). These numbers must be considered with caution since there may be data entry errors. In addition, the CAMA permits include repairs, replacements, or projects that may not have been done or completed. Numbers appear to increase sharply from 1997 to 2000, probably due to the large number of repairs following a series of damaging hurricanes (during 1996 – 1999) and to the strong economy of the mid-1990s. The highest number of bulkhead permits issued annually occurred in 1999. The total amount of bulkheading per county has ranged from less than one mile in Gates County to 109 miles in Beaufort County and 79 miles in Dare County (Figure 5.8). Beaufort, Dare, Carteret, and Currituck counties have the greatest total lengths of permitted bulkheads. In these counties, the percent of hardened shoreline along major waterbodies ranges from roughly 8% to 32%. Because of the limitations of the current database on bulkheading, and the potential impacts to habitat, particularly nursery areas, *there is a need to more accurately assess where and how much of the estuarine shoreline is hardened. With more accurate information, the level of impact to marine resources can be assessed.*

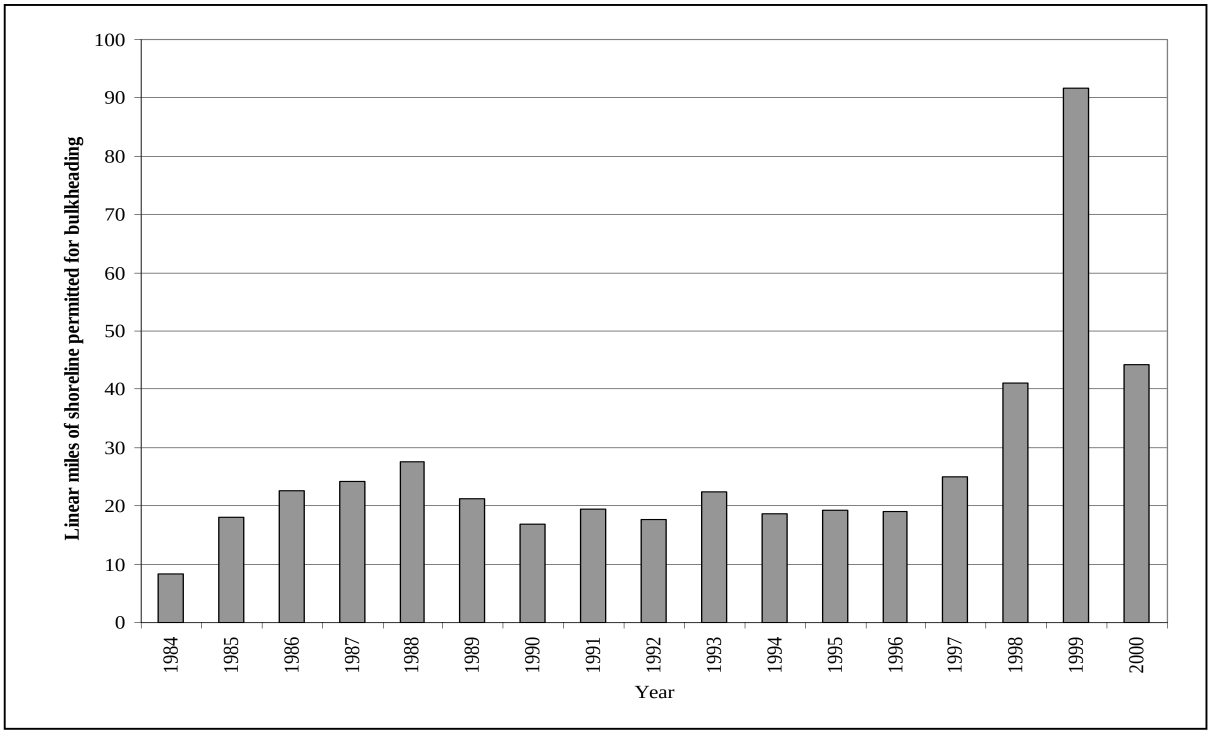


Figure 5.7. Linear miles of bulkheading authorized by Division of Coastal Management permits annually, 1986-2000. (Source: DCM, unpub. data)

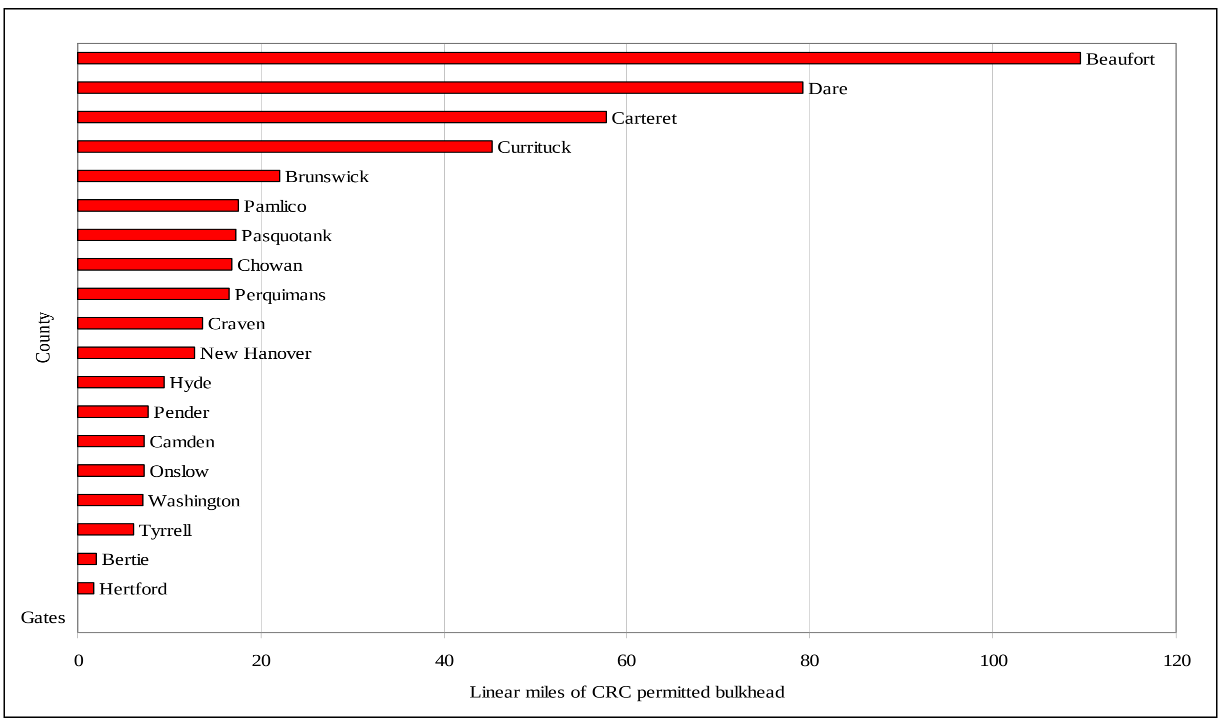


Figure 5.8. Linear miles of bulkheading authorized by Division of Coastal Management permits during 1986-2000. (Source: DCM, unpub. data)

A pilot study conducted by DMF along approximately seven miles of estuarine shoreline in the southern portion of the coast (Pages Creek and Intracoastal Waterway in New Hanover County) found that approximately 21% of the shoreline within the study area was hardened in 1984. By 2000, 37% of the shoreline in the same area was hardened. The most affected area of shoreline was along the ICW, where boat wakes and greater fetch increase erosion problems; 54% of the area examined was hardened. However, even along a protected creek (Pages Creek) with a wide marsh fringe and little obvious erosion, 38% of the shoreline has been hardened. Along Yeopim Creek, a tributary of Albemarle Sound, approximately 1% of the shoreline was hardened in 2000. *The methodology used for assessing shoreline hardening (examination of aerial photographs) could be used for a larger portion of the coast to spatially delineate and quantify where and how much of the shoreline is hardened.*

Although CRC rules state that sloping riprap or vegetation, rather than vertical seawalls/bulkheads, should be used where possible [CRC rule 15A NCAC 07H .0200 (7)(E)], bulkheads continue to be constructed at a rate greater than that associated with alternative shoreline protective methods. Recognizing the extensive, and at times inappropriate, use of bulkheads in North Carolina's estuaries, DCM modified the permitting process in 2001, requiring a General Permit for bulkhead construction less than 500 linear ft (rather than an exemption) and a Major Permit for those greater than 500 linear ft. Also, in 2000, the Estuarine Shoreline Stabilization Subcommittee was established by the CRC to review the estuarine shoreline rule development process. Although not yet adopted by the CRC, the Subcommittee developed a set of principles and concepts to guide further development of any shoreline stabilization rule changes:

1) The State of North Carolina has the authority under CAMA and the Dredge and Fill Act to regulate placement and installation of shoreline stabilization measures.
2) Only property owners with demonstrable erosion problems* may be eligible to obtain a permit to stabilize the shoreline. * CRC will define "erosion problem".
3) Stabilization techniques should be appropriate for site and erosion forces present.
4) Measures with the least adverse environmental effects are preferred (General preference for soft structures).
5) The goals of establishing standards for estuarine and public trust shorelines are:
    a) To safeguard and perpetuate the natural productivity and biological, economic and aesthetic values of natural ecological conditions of the estuarine system (Protection of Habitat and Water Quality).
    b) To insure that the development or preservation of the land and water resources of the coastal area proceed in a manner consistent with the capability of the land and water for development, use, and preservation based on ecological considerations (Appropriate Development For Site).
    c) To insure the orderly and balanced use and preservation of our coastal resources on behalf of the people of North Carolina and the nation (Protection of Public Trust and Private Property Rights).
6) CRC will create development standards for stabilization technique/measures:
    a) Soft Measures
        i) Grading and Planting
        ii) Wetland Planting
    b) Hard Measures
        i) Bulkheads
        ii) Groins and Jetties
        iii) Breakwaters
        iv) Sills
        v) Revetments
        vi) Wave-boards (wooden breakwaters)
    c) Combinations
7) Stabilization measures shall be located as far landward as feasible.
8) CRC will set standards for existing stabilization projects:
    a) Allowing for tying with existing stabilization projects and adjoining lots
    b) Allowing for hardened structures on constructed canals and basins
    c) Allowing in kind/in place repair
    d) Allowing for in kind/in place replacement
9) Allow for larger footprint for riprap for achieved desired slope (1 : 1 ½).
10) CRC will attempt to keep criteria and standards simple to understand and implement.
11) CRC will gather public input on the above principles and provide guidance on the concepts prior to DCM developing draft rule text.

In addition, a science-based panel, the Estuarine Biological and Physical Processes Work Group, was formed by DCM to develop recommendations for shoreline stabilization rules that adequately take into account and reflect the dynamic nature of the estuarine system (DCM 2002). The approach the group took was to evaluate which erosion control methods would be effective on various shoreline types, considering the ecological functions of each shoreline type. Wetland shoreline categories included swamp forest and marsh shorelines, and sediment banks with a marsh or swamp forest fringe. Erosion control options included vegetative planting, beach fill, marsh toe revetment, rock sill, wood or rock breakwater, gabions, groins, riprap, and bulkheads. Non-vertical structures, such as rock sills, oyster reefs or marsh toe revetments, where suitable for erosion control, can have more habitat advantages than vertical structures, since they provide three dimensional structure and areas of refuge for fish and invertebrates. A channel left between sills allows juvenile fish access to the inner marsh. However, even this structure can increase erosion on adjacent shorelines, albeit much less than on shorelines next to bulkheads. Marsh grass planting creates the least erosion along adjacent shorelines, but offers the least protection of property. Advantages and disadvantages of each effective erosion control method were discussed and the preferred methods that minimize impacts to the hydrological, biogeochemical, and ecological functions of each specific shoreline type were ranked. For example, adjacent to a high bluff with a sand fringe, a bulkhead structure may be preferred over a rip-rap rock structure. However, along a low-lying upland with a marsh fringe, a wood or rock structure on the waterward edge of the marsh would be preferred over a wood or rock structure on the upland edge of the marsh, and bulkheads would not be an appropriate option. This effort is still underway and needs review by the Estuarine Shoreline Stabilization Subcommittee once complete (DCM 2002).

The CRC should revise estuarine shoreline management rules using best available scientific information, including the recommendations from the Estuarine Shoreline Biological and Physical Processes Work Group to minimize impacts to natural shoreline and nearshore fish habitat functions. As part of the process of modifying shoreline management rules, accurate estuarine shoreline erosion rates are needed to aid in identifying "erosion problems," determining adequate shoreline setbacks, and determining appropriate erosion control methods where necessary. Wherever possible, sections of estuarine, non-vegetated shoreline with very little hard stabilization should remain unaltered to provide "new" sediment for shallow water habitats (Riggs 2001). Some consideration should also be given to the type of material used in rock structures because oysters more readily colonize oyster cultch material or limestone marl, than granite.

Impervious surfaces

The increase of impervious surface in coastal North Carolina causes loss and degradation of both riparian and non-riparian wetlands. Impervious surfaces affect wetlands indirectly by preventing infiltration into the soil and shallow groundwater tables, thus reducing discharge to certain groundwater-dependent wetlands. The increased peak flow in urbanized watersheds (Schueler 1994) can result in greater bank erosion and channel incision in riparian wetlands located near impervious surfaces and their associated drainage networks.[75]

Channelization and ditching

Channelization is the deepening and straightening of a natural stream or dredging of a new channel for the primary purpose of improving drainage of adjacent lands (NC Sea Grant 1999). These activities can affect the slope, depth, width and roughness of the channel, thus changing the dynamic equilibrium of the stream (including associated wetlands). Channelized streams are deeper, more variable in flow, and less variable in depth than natural streams (Orth and White 1993). These differences affect primarily smaller species and life stages using wetlands and shallow stream margins, habitats that are reduced by channelization. In many channelized streams in the middle and lower Coastal Plain, storm flows are confined primarily to the main channel rather than passing through wetlands. This change greatly reduces the natural beneficial functions of wetlands to filter pollutants and regulate water flow between uplands and coastal waters. In addition, the riparian zone (including the natural woody vegetation along the sides of the stream) is often removed in the process of channelization (NRC 2002). Consequently, loading and movement of sediment and other nonpoint source pollutants are often greater in channelized streams than in natural streams, which can have negative effects on water quality and fish habitat (White 1996; EPA 2001). Channelization also increases channel cross-section and flow capacity, thus reducing the frequency of overbank flow events that allow fish access to the wetlands. The remaining wetlands exist with an altered hydrology, relying more on overland flow from upland areas and groundwater discharge, and/or overbank flow from unchannelized stream segments nearby.

[75] Refer to Chapter 2 for more information on impervious surfaces.

Although new channelization for flood control and drainage has greatly decreased, the existing alterations continue to alter flow and salinity patterns.[76] *Dechannelization of streams, restoration of wetland hydrology, use of alternative drainage techniques, and on-site BMPs are therefore needed to maintain and restore wetlands, flows and salinity patterns in downstream areas. In addition, increased funding and educational outreach to farmers and other landowners are needed for projects that restore natural stream and wetland functions.*

Dredging for navigation

Dredging impacts wetlands indirectly by limiting the amount of shallow water habitat available for colonization. The spoil from dredging can also be used to create shallow water habitat. At a number of sites, the COE has established wetlands as part of their management of dredge spoil islands; the spoil islands in Pamlico Sound west of Oregon Inlet are good examples. However, CRC rules generally require confining all dredging material to an upland area landward of regularly or irregularly flooded marsh [15A NCAC 07H .0208]. In recent years, cooperative interagency projects have resulted in some beneficial uses of dredge materials, such as creation of marsh and water bird nest sites.

Boating

The most detrimental effect of boating on wetlands is probably loss of vegetation from wave action. The actual impact of boat wakes on wetlands has not been quantified (SAFMC 1998a; Riggs 2001). Erosion from boat traffic along the Intracoastal Waterway and elsewhere is readily observable and is likely responsible for substantial (or just localized) loss of fringing wetland habitat (Riggs 2001). The loss of fringing wetland can result in increased erosion of waterfront property along the Intracoastal Waterway. As the human population of coastal North Carolina increases, so will the impact of boater-induced wave turbulence. The number of registered boats in North Carolina increased by 26% from 1990 to 2000 (see Figure 4.3 in Chapter 4). *There is a need to amend WRC no wake zone authority to include consideration for erosion in strategic wetland areas*. Currently, the issue of human safety is the only issue driving the WRC's authority (habitat protection is not a consideration). *There should also be increased public awareness of the impact of boat wakes on wetland shorelines.*

Marinas, docks, and piers

Direct impacts to wetlands through marina construction are minimized since current CRC rules encourage marina construction in upland basins. Marinas, docks, and piers can impact wetlands indirectly by shading and associated boat traffic. Shading results in the loss of plant growth and vigor beneath the dock structures. A study in South Carolina compared stem densities of *Spartina* under docks with stem densities five meters away from docks (Sanger and Holland 2002). The results of the study indicated an average reduction in stem density of 71% under the docks. The study concluded that although shading of *Spartina* by docks reduces stem density, the total impact on wetland habitat was minor. It was estimated that by the year 2010, only 0.02 to 0.24% of the total salt marsh area in South Carolina would be affected by dock shading. However, local effects in areas with many docks could be significant.

The number of pier general permits issued in coastal North Carolina has risen from about 250 in 1990, to about 800 in 2002 (DCM, unpub. data; Figure 5.9). Additional numbers of large piers are also constructed every year throughout the coastal area. To minimize shading effects in North Carolina, CRC rules require a dock height of three feet above wetland substrate, and a pier width of no greater than six feet. As in South Carolina, the impact of dock and pier shading on wetland vegetation on a coast-wide basis may be minor at present, but the impact will likely increase over time as more piers are constructed.

[76] See Chapter 2 section on channelization and ditching.

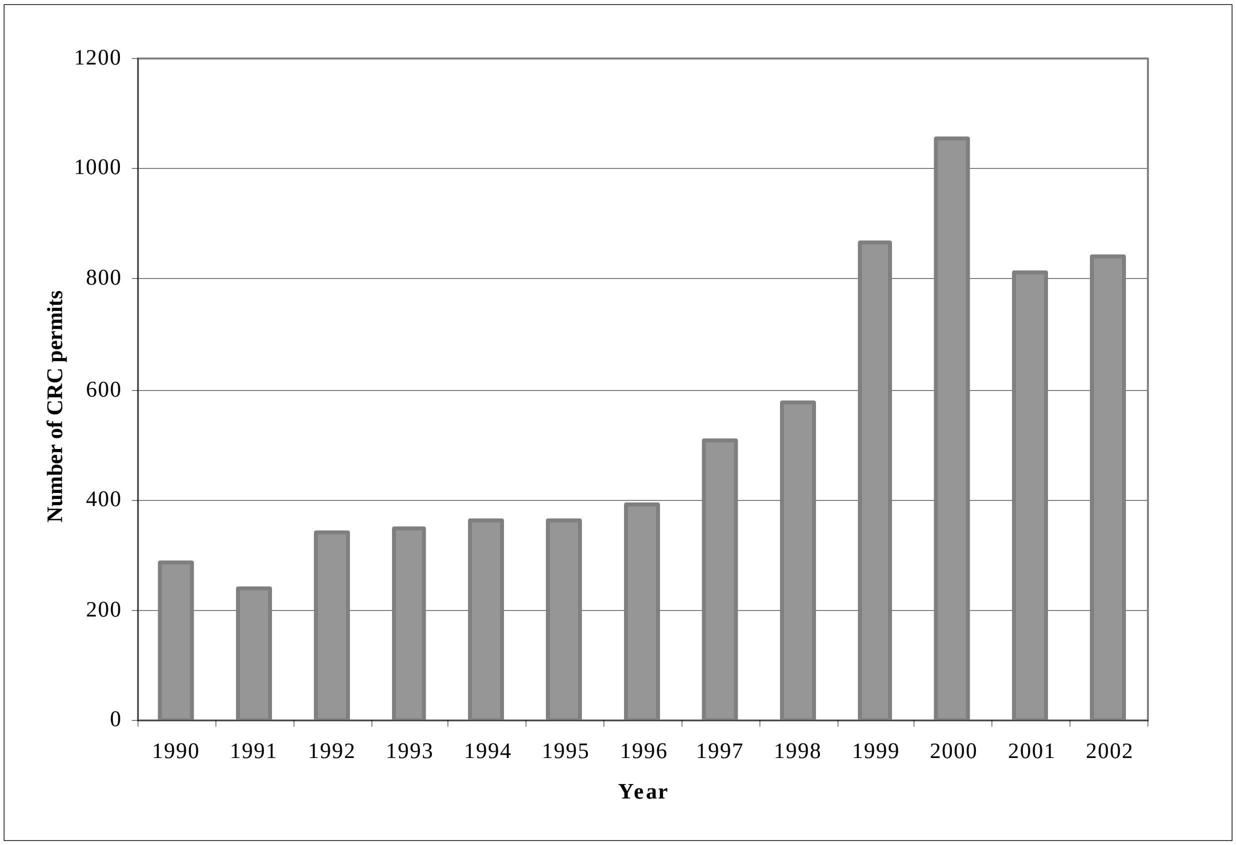


Figure 5.9. Annual number of CAMA general permits issued by the North Carolina Division of Coastal Management for piers, 1990-2002. (Source: DCM, unpub. data)

Water quality degradation

Excess nutrients can result in undesirable changes in the wetland plant community (Lamers et al. 2002). The effect of changes in the plant community on fish use of wetlands is unknown. However, the effect of excess nutrients on fish use of wetlands could be problematic. Algal blooms in and around emergent vegetation can cause very low dissolved oxygen levels at night, resulting in fish kills (see Chapter 2).

Another potential issue regarding the water quality of wetlands (especially freshwater marsh) is sulfate (SO_4^{-2}), a water-soluble, abundant form of sulfur that commonly occurs in nature (e.g., soil and minerals). Elevated sulfate concentrations can enter surface waters and eventually reach wetlands from a number of man-made sources, including: runoff from mining and agriculture, industrial waste discharge and atmospheric deposition (Lamers et al. 2001; EPA 2002a; Lamers et al. 2002). Sulfates are used in a variety of industries, including, but not limited to, mining, processing (e.g., wood pulp, metal finishing, leather), sewage treatment, and manufacturing (e.g., chemical, dye, glass, textile, soap, insecticide, fungicide) (Greenwood and Earnshaw 1984). Approximately 30% of sulfate in groundwater may be from the atmosphere, while the remaining 70% is from organic processes (EPA 2002a). In contrast, Moore (1991) reported that greater than 45% of sulfates detected in rivers originated from human activities. Dissolved or free sulfide (HS^-) can be highly toxic to rooted plants in freshwater wetlands where there is an insufficient amount of iron (Fe). Typically, sulfate-reducing bacteria convert sulfate to hydrogen sulfide (H_2S), pyrite (FeS_2), or iron sulfide (FeS). Sulfate over-enrichment may cause HS^- to accumulate in sediments, and the subsequent toxicity leads to rooted plant communities composed of a few highly sulfur-tolerant species. The effect of these changes in plant community structure on fish use of marsh wetlands is unknown. Lamers et al. (2002) demonstrated that FeS_x oxidation during desiccation, FeS_x

oxidation due to nitrate pollution, and atmospheric sulfur (S) pollution threatened the water quality of freshwater wetlands via eutrophication and HS^- accumulation. The degree of HS^- accumulation did not vary among wetland soil types with different humus profiles (Lamers et al. 2001). *The susceptibility of freshwater wetlands to sulfate pollution should be evaluated in coastal North Carolina. Results should provide the measure of iron concentrations in wetland sediment necessary to evaluate susceptibility.*

Introduced and nuisance species

A major non-native species issue concerning wetlands is the spread of *Phragmites* species (common reed) into salt/brackish marsh areas (Weinstein and Balletto 1999). Since the early 1900s, *Phragmites australis* has been replacing other salt/brackish marsh vegetation along the Atlantic coast at a rate of about 1% to 6% of the marsh surface per year (Weinstein and Balletto 1999). *Phragmites* forms dense, monotypic stands of vegetation that could alter fish use of the marsh. Recent research comparing fish use of *Phragmites* and *Spartina* marsh in New Jersey found no distinct habitat preference among large fish and decapod crustaceans (e.g., shrimp) (Able and Hagan 2000). On the other hand, *Phragmites* had a negative effect on larval and juvenile fish abundance (Able and Hagan 2000; Able et al. 2003). A study in Connecticut salt marshes found no difference between use of reed-dominated tidal marshes and typical tidal marsh vegetation by mummichogs (Fell et al. 1998).

Sea level rise and storm events

Rising sea level is a major threat to coastal wetlands in North Carolina. Analyses of data from tide gauge stations in Hampton, Virginia, and Charleston, South Carolina, from 1921 to 2000 (Riggs 2001), show sea level rising along the Atlantic coast by about 3.35 mm per year (1.1 ft per 100 years). Gauge data specific to North Carolina are available only for 20 years, but suggest a slightly greater rate of approximately 4.57 mm per year (1.5 ft per 100 years). The combination of sea level rise and storm events causes erosion of wetlands at a rate of approximately 802 acres/year (Riggs 2001). The importance of coastal erosion is further emphasized by the relatively low amount of permitted coastal wetland impacts from 1999 to 2002 (WRP 2001), compared to estimated erosion losses. Compared to sea level rise, the rate of wetland building or accretion is slightly less, but of the same order of magnitude: approximately 1.20 mm per year (Hackney and Cleary 1987). Loss of wetlands from sea level rise is exacerbated along steeply sloping shorelines or where wetland migration is otherwise restricted (i.e., where bulkheads are present). A recent study of salt marsh response to sea level rise in New England found that low marsh vegetation (*Spartina alternaflora*) was replacing high marsh vegetation (*Spartina patens*, *Distichlis spicata*, and *Juncus gerardi*) (Donnelly and Bertness 2001). If the rate of sea level rise increases significantly over the next century, many low marsh areas in New England and elsewhere will likely drown (Donnelly and Bertness 2001). *Buyers and owners of coastal property should be aware of sea level rise and the potential for loss of wetlands and property. Updated and accurate coast-wide estuarine erosion rates are needed for the CRC and EMC to determine adequate development guidelines and rules along the coast (DCM 2002). Priorities for coastal wetland protection should also acknowledge sea level rise, and protect gently sloping areas upland of coastal wetlands to allow for landward migration of coastal wetlands with sea level rise.*

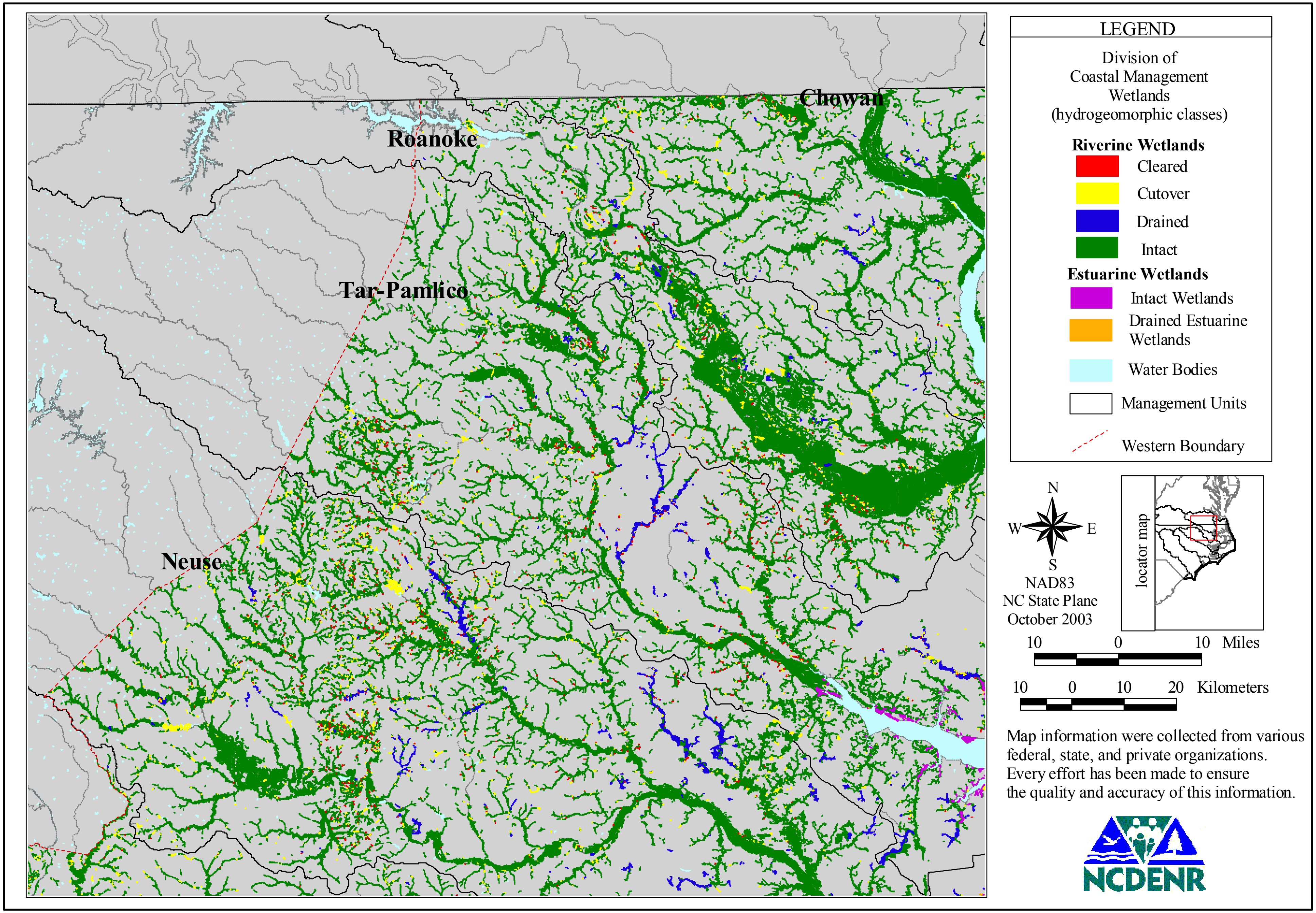
Tropical storm surge events can degrade or erode low salinity wetlands by bringing in high salinity water, as well as flooding from rainfall. Freshwater species cannot tolerate high salinity, while salt/brackish species cannot tolerate the freshwater flooding, resulting in a total loss of wetland vegetation in some areas (Baldwin and Mendelssohn 1998). With rising sea level, the impact of storm events on dieback of coastal wetlands can be substantial (Riggs 2001). Loss of wetlands due to increasing salinity and flooding has been documented in Louisiana estuaries (Webb 1997). Loss of wetlands from storm surge events and erosion in North Carolina (Riggs 2001) did not distinguish losses due to vegetation dieback from overall erosion. Vegetation dieback is important because it could actually accelerate erosion of coastal wetlands. *Research is needed on site-specific erosion and accretion rates and their relationship with sea level rise and storm events (Brinson and Moorhead 1989). Specific research is also needed to* *determine processes that control the upper limits of peat accumulation, which is the foundation of coastal wetland development in the Albemarle-Pamlico system (Moorhead and Brinson 1995).*

5.5. SUMMARY OF WETLANDS CHAPTER

Wetland habitat is unique among the coastal fish habitats because it is not entirely submerged but occurs in and above the water. There are many different types of wetlands throughout the coast, many bordering the rivers and sounds, while others are hydrologically isolated. While each wetland type is unique, these different types provide similar ecological functions. Wetlands are highly effective and well recognized for their value as a natural filter, trapping and filtering pollutants from upland runoff; as well as serving to buffer the effects of floods by storing, spreading, and slowing stormwater runoff. Like SAV, wetlands are highly productive biologically, but because of their expansive coverage and biomass, produce much more organic matter, which is broken down and utilized by multiple species adjacent to wetlands and elsewhere. It has been estimated that over 95% of the United States' commercially harvested finfish and shellfish are wetland dependent. The combination of shallow water and thick vegetation provides excellent nursery habitat for juvenile fish. The majority of MFC-designated Primary Nursery Areas consists of wetlands and adjacent shallow water and soft bottom. Fish found commonly in or near freshwater marshes and swamps include bluegill, largemouth bass, river herring, and striped bass. In and adjacent to estuarine wetlands, killifish, spot, red drum, flounder, penaeid shrimp, striped mullet, pinfish, blue crab, and other species are abundant. In addition to supplying food and acting as nursery habitat for numerous species, riparian wetlands also provide a relatively safe corridor for fish moving among the other nearshore habitats.

It is estimated that as much as 40-50% of North Carolina's original wetland coverage has been lost, primarily due to ditching, channelization, and filling for agriculture and development. From the early 1800s to the early 1900s, agriculture accounted for the majority of wetland losses. From about 1950 to the 1990s, conversion to forestry and agriculture accounted for 53% and 42% of wetland losses in North Carolina. Although the rate of wetland loss has slowed, losses continue to occur. Mitigation for permitted losses and voluntary restoration efforts in some areas have partially offset some recent losses, but the type of wetland gained is often not equivalent to what was lost. Degradation and loss of wetlands can impact many species, including overfished stocks of river herring and southern flounder, as well as stocks designated with the Concern status such as blue crab and striped mullet.

There are multiple threats to wetland habitat today, primarily due to physical destruction and hydrological alteration. Ditching and draining for development, construction of new dams, mining activity, and filling for new development accounted for the majority of permitted wetland losses in recent years. Construction of roads, infrastructure, and water dependent-development, including dredging for marinas and navigation channels, also results in smaller, site-specific losses and contributes to cumulatively large wetland losses. Estuarine shoreline stabilization causes gradual, long-term wetland loss by limiting sediment inputs needed for maintenance and expansion of wetlands, and by blocking landward migration as sea level rises. Because wetlands are critical to a large number of fishery species, but have been greatly reduced in spatial coverage from their original extent, ongoing initiatives such as wetland restoration, land acquisition and preservation, and agricultural cost-share BMPs need to be enhanced. There should also be additional initiatives implemented to protect and enhance wetland habitat. The many fishery and water quality functions provided by wetlands make their preservation and restoration along North Carolina's coast a high priority for protection of all coastal fish habitats.



Map 5.1a. Location of riparian wetland areas derived from maps produced by DCM (1994) in the upper areas of the Roanoke, Tar-Pamlico, Neuse and Chowan basins.

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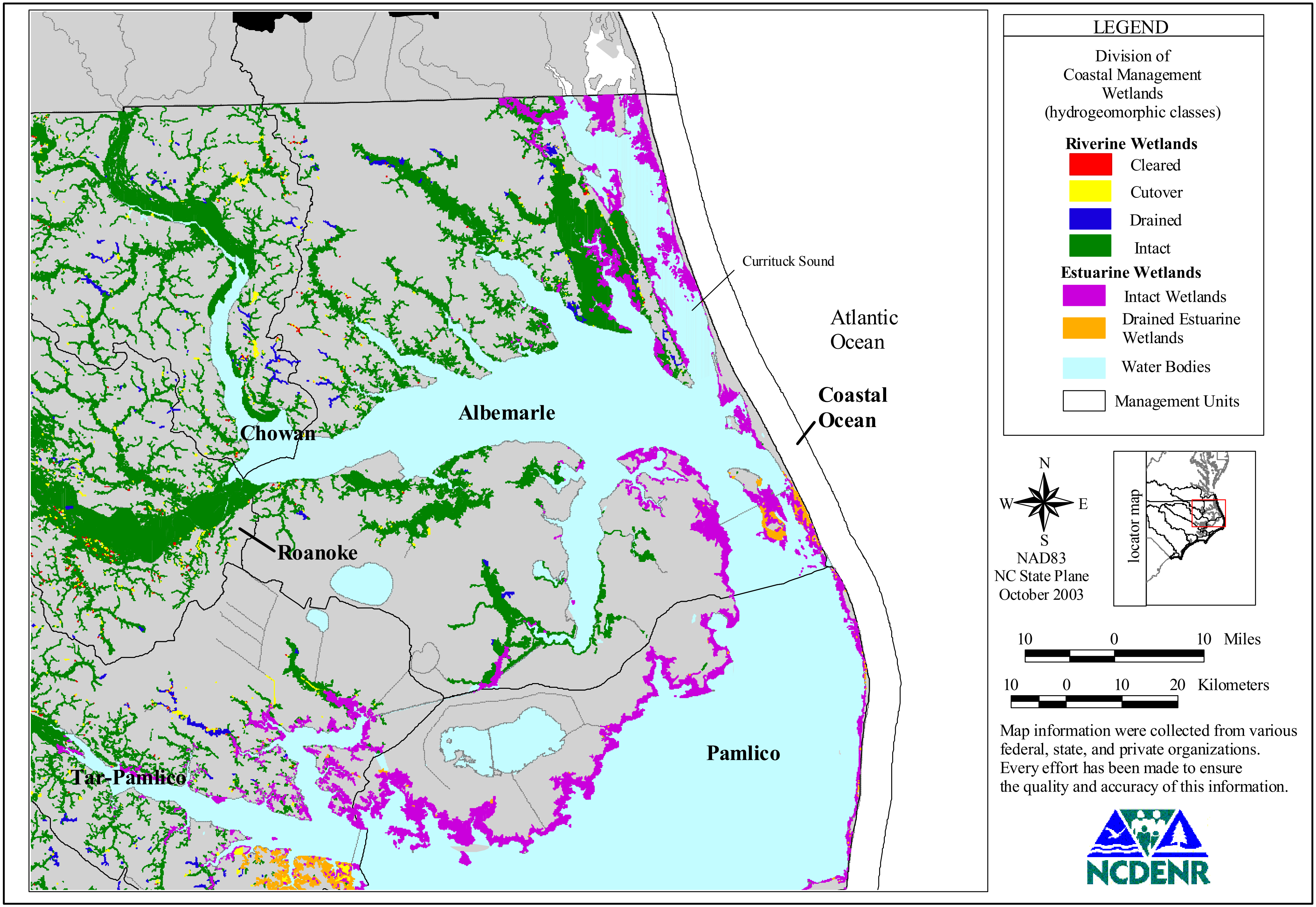

Map 5.1b. Location of riparian wetland areas derived from maps produced by DCM (1994) in northeastern North Carolina.

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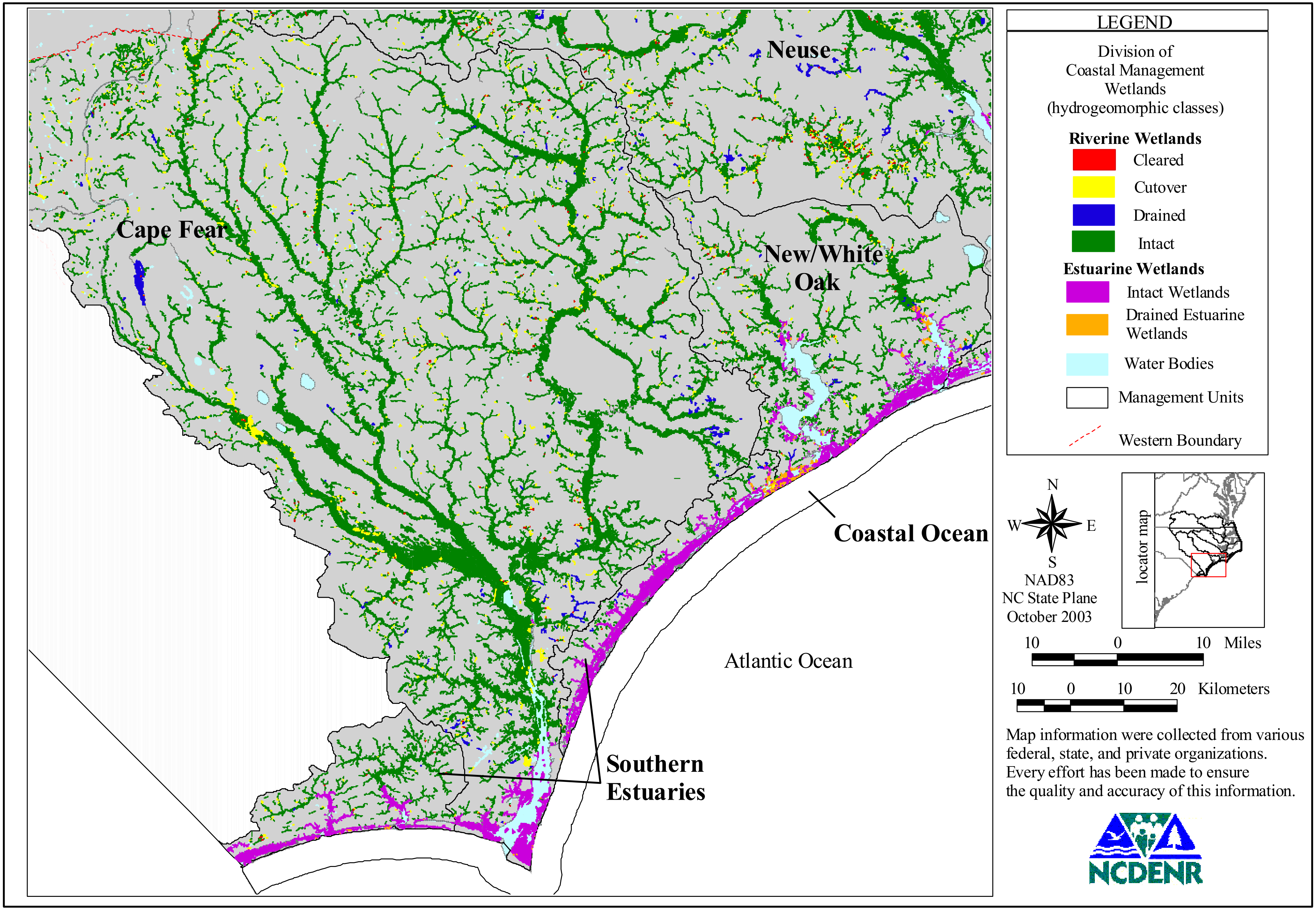

Map 5.1c. Location of riparian wetland areas derived from maps produced by DCM (1994) in southeastern North Carloina.

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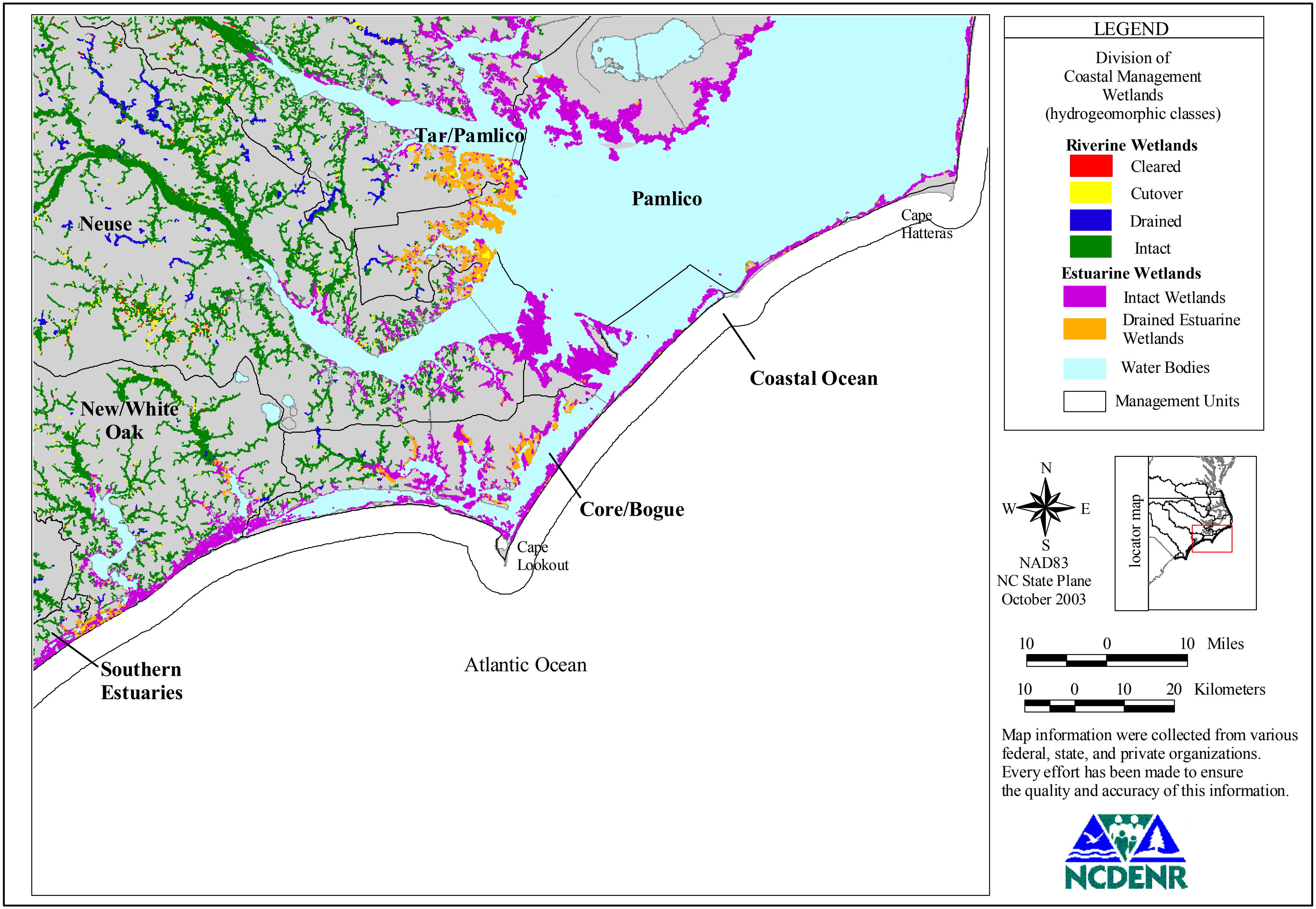

Map 5.1d. Location of riparian wetland areas derived from maps produced by DCM (1994) in central coastal area of North Carolina.

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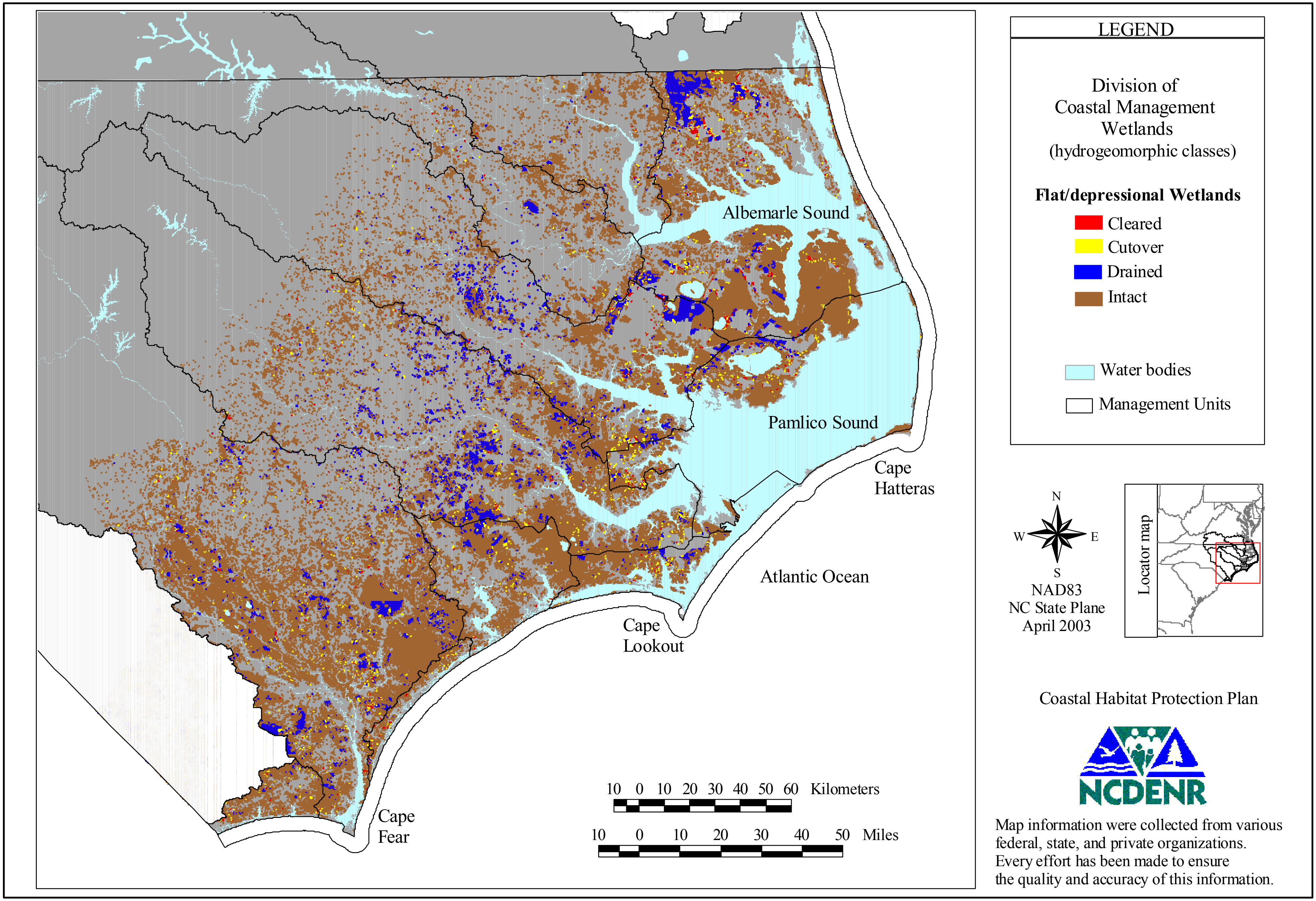

Map 5.2. Location of flat/depressional wetland areas derived from maps produced by DCM (1994).

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