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WETLAND ALTERATION TRENDS ON THE NORTH CAROLINA COASTAL PLAIN

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Abstract: This study examines the magnitude and causes of wetland alterations within the North Carolina coastal plain. Utilizing soil maps, photointerpretation, and National Wetland Inventory Maps, we assessed wetland alterations between presettlement, the early 1950s, and the early 1980s on 27 randomly selected sample sites. Wetland alterations were defined and assessed in terms of the support of wetland function and values (i.e., uses). The study found that 51.3% of the historic wetlands in the sample had been altered by the early 1980s such that they no longer fully supported their original wetland functions and values. Between the early 1950s and the early 1980s, approximately 15.9% of the historic wetlands were altered such that original functions and values were not fully supported. The percentage of alteration differed greatly between estuarine and palustrine wetlands. Palustrine wetlands experienced a mean percent alteration of 52.4% by the early 1980s, while only 12.2% of the estuarine wetlands were altered. Between the early 1950s and the early 1980s, 16.9% of the historic palustrine wetlands were altered, as compared to only 9.9% of the estuarine wetlands. The conversion of wetlands for forestry caused 52.8% of the total alteration, followed by agriculture, which caused 42.2% of the total loss of wetlands. Urbanization, road construction, and rural residential development accounted for only a small percentage of the total loss of wetlands. The State of North Carolina needs to reevaluate the effectiveness of its wetland protection strategies (both administrative and legislative) to control future alterations of palustrine wetlands. Further work is also needed to determine recent trends in wetland alterations between the early 1980s to the 1990s, which may reflect more recent federal and state regulatory actions. Finally, similar survey work needs to be completed for the entire state to more fully understand wetland alteration trends in North Carolina.

Key Words: wetlands, wetland alteration, coastal plain, estuarine, palustrine.

INTRODUCTION

Many attempts have been made to assess the extent of wetland alteration throughout the nation. It has been estimated that by the 1980s, only 53% of the original 221 million wetland acres (89 million ha) remained in the conterminous United States (Dahl 1990). A study sponsored by the United States Fish and Wildlife Service (USFWS) estimated that some 11.4 million acres (4.6 million ha) of wetlands were lost between the mid-1950s and the mid-1970s (OTA 1984). This represents a five percent loss in the nation's wetlands during this twenty year period.

However, these figures represent national averages for wetland alterations. Some areas of the country have experienced significantly greater alterations, including the Southeast. Hefner and Brown (1985) reported that 84% of the nationwide losses occurred in the USFWS's

Southeast Region. They also identified eastern North Carolina as an area that experienced particularly large losses.

Originally, North Carolina contained approximately 7.8 million acres (3.2 million ha) of wetlands (DEHNR 1991). By the mid–1970s, the state still contained some 5.7 million acres (2.3 million ha) (Hefner and Brown 1985), which represents about 17% of the state's land area. The state has also been found to contain some 70% of the nation's pocosin wetlands (Richardson et al. 1981). The fact that North Carolina has experienced major wetland losses has been noted by others (OTA 1984, Hefner and Brown 1985). Unfortunately, it is difficult to assess these losses because no complete statewide historical inventory of wetland resources exists. In addition, wetland definitions and the distinction between loss, alteration, and conversion often vary between surveys. Many of the earlier surveys consider the alteration of a wetland from its natural condition to be a "loss" of wetlands. However, many pine plantations and some agricultural lands are still wetlands subject to 404 permits. This fact tends to confuse the discussion of wetland status and trends.

To address these shortcomings, the current study was designed to provide an updated sample survey of the status of wetlands in the coastal plain region of North Carolina. Using the best available information, this study examined a variety of wetland types and their relative extent within the coastal plain. The study assessed the percentage of wetland alterations since European settlement and for the period from the early 1950s to the early 1980s. For this later period, the study documented the type of development responsible for wetland alterations. This study also examined the extent of wetlands that qualify as isolated or above headwaters under Clean Water Act regulations. As a result, the study provides valuable information on the status of wetlands in eastern North Carolina and development pressures that have affected them.

METHODS

Wetland Definition and Classification

This study used the wetland definitions presented in the Federal Manual for Identifying Jurisdictional Wetlands (FICWD 1989) and the classification scheme from Cowardin et al. (1979). FICWD (1989) recommends examination of hydrology, vegetation, and soils for wetland determinations. For the purposes of this study, primary emphasis was given to hydrophytic vegetation and hydric soils. This is consistent with the Federal Manual, which states that the presence of wetland hydrology can usually be assumed if hydric soil and hydrophytic vegetation are present.

The presence of hydric soil and hydrophytic vegetation was determined using soil surveys, National Wetland Inventory (NWI) maps, aerial photographs, and random field checking. Essentially, wetlands were defined as areas that had natural wetland vegetation on hydric soils and unaltered hydrology (e.g., without ditches). Wetlands were considered altered in areas where a natural vegetative community existed on hydric soil in the 1950s, but the areas' vegetation or hydrology were sufficiently disturbed to alter wetland structure, function, or values by the early 1980s.

Discussion of wetlands often is confounded by confusion between wetland functions versus values. Wetlands provide a wide variety of functions, such as carbon storage or ground-water recharge. A subset of these functions are protected by various laws. These are called values or uses (e.g., water quality control or endangered species habitat) (Mitsch and Gosselink 1986). The essential difference between these categories is that values (uses) are protected by various laws (especially the Clean Water and Endangered Species Act). If a function is not protected by law (such as carbon storage or oxygen production), then that ability of a wetland is not relevant in the regulatory realm. Our analysis addresses wetland alterations in terms of adverse impacts to wetland values (uses) rather than strictly ecological functions.

Wetlands provide a variety of values or uses, some of which are protected by legislation such as the Clean Water and Endangered Species Acts (Table 1). Under the Clean Water Act, every state is required to produce a biennial 305(b) report on the status and trends of water quality, including wetlands. In this report, water (and wetland) quality are to be designated as either supporting, partially supporting, or not supporting uses. EPA Guidance for these three categories (U.S. EPA, 1989) defines them as follows (1) supporting—uses fully attained with no evidence of modification of the natural community, (2) partially supporting—uses partially supported with some community modification, and (3) not supporting—uses clearly not supported with definite community modification. Wetlands in this study will be discussed in terms of use support to be consistent with these federally mandated guidelines.

For this study, the *Supporting* wetlands category includes those wetlands that have had little disturbance and consequently have intact vegetation, soils, and hydrology. These wetlands generally support their natural values and functions such as those listed in Table 1. These wetlands were identified using NWI maps and hydric soil maps. The State of Vermont has made the same conclusion about use support by wetlands identified on NWI maps. O'Brien (1990) concluded after a detailed, random study that 93% of the wetlands depicted on the NWI maps had significant uses requiring protection through the state's 401 Certification program.

The *Partially Supporting* category includes those wetlands that retain wetland status and most wetland values but have experienced alterations in hydrologic regime or vegetative composition. As an example, creation of pine plantations in wetlands can result in a wetland community that only partially supports the original wetland functions and values of a site. Pine plantations may still recharge ground-water, can retain water onsite for flood control, can still remove some nutrients, and certainly have some wildlife value (DEHNR 1991). However, conversion to pine plantations can reduce these uses compared to the unaltered wetland. For example, Lynch (1982) found lower breeding bird densities and diversity in loblolly pine plantations than in natural loblolly-bay forest. However, the pine plantations still provided wildlife habitat. Allen and Campbell (1988) found that conversion of natural wetlands to pine plantations caused short-term impacts on water quality, including increased nutrient runoff and soil erosion. Both studies found that the uses of the wetland were not entirely removed but were altered so as to be defined by us as partially supported.

Nonsupporting wetlands have had most or all of their uses entirely removed. This study considers wetlands converted to agriculture or developed for urban uses as not supporting original wetland uses. In both cases, the severity of disturbance has entirely removed some or all of the uses once provided. For example, a parking lot removes wildlife habitat, ground-water recharge, and nutrient removal capabilities (DEHNR 1991). Similarly, although agricultural conversion probably does not alter ground-water recharge completely, it does remove aquatic life and nutrient-removal uses. Therefore, agricultural and urban development were considered to convert wetlands into the nonsupporting category. This is often referred to as wetland loss by many scientists and conservation organizations. However, if aquaculture or rice cultivation were widespread in North Carolina, then these agricultural activities might be partially supporting since some wildlife and aquatic life uses are present in these types of agriculture (DEHNR 1991).

Study Area

This study focused on the North Carolina Coastal Plain. Within this region, a total of 27 study sites were selected (Figure 1). These sites were based on 7.5 minute (1:24,000 scale) topographic quadrangles. These quadrangles were selected randomly using a map index and a random number table. From each quadrangle, one quarter was then randomly selected as a study site.

Table 1. Wetland values and functions.

Wildlife habitat
Fisheries habitat
Shoreline anchoring
Food chain support
Flood dissipation and storage
Nutrient retention and removal
Groundwater recharge
Groundwater discharge
Sediment trapping
Recreation
Endangered species
Plant and animal diversity

From DEHNR 1991.

Consequently, each study site comprised one-fourth of a topographic quad, approximately 4,024 ha (9,943 acres).

For each study site, areas of hydric soil were determined using published soil surveys or information from the county Soil Conservation Service office. A list of hydric soils in North Carolina was used to identify those mapped soil series considered hydric (USDA 1989). These areas were drawn onto a 1:24,000 topographic base map by overlaying or by using a zoom transfer stereoscope when rescaling was required. Hydric soil area was determined for each map by planimetering each area twice and using the average value. It should be pointed out that some non-hydric soil series can contain hydric inclusions, and hydric areas can contain non-hydric inclusions. These were not included in the hydric soil maps and consequently were not included in the estimate of original wetland area.

Hydric soil area was used as a baseline figure reflecting wetland area prior to development. This estimation is ecologically sound because the list of hydric soils includes those soils that are sufficiently wet under undrained conditions to support the growth and regeneration of hydrophytic vegetation (USDA 1989). This implies that wetland hydrology and vegetation were present on hydric soil prior to alterations caused by development. Scott *et al.* (1989) found a good correlation between the presence of hydric soils and wetland vegetation for a geographically diverse series of sites and for a variety of wetland and upland communities. Moorhead (1991) found a strong correlation between hydric soils and wetland vegetation in North Carolina, with less than 2% of the wetlands occurring on non-hydric soil. Consequently, it was decided that use of hydric soil information was the best means of estimating historic wetland area in the absence of a comprehensive historic inventory such as the General Land Office Surveys, which are available for the upper Midwest.

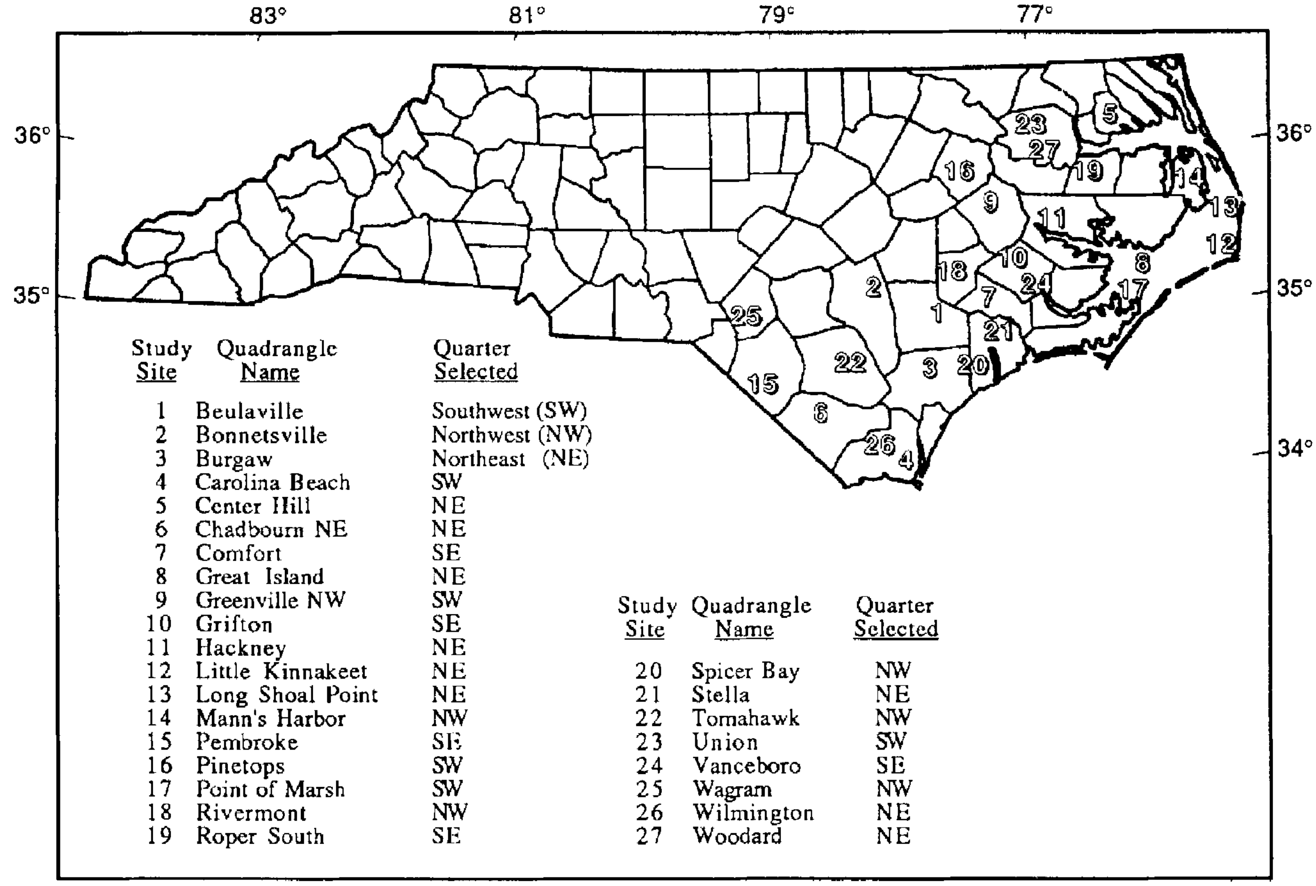

Figure 1. Location of study sites in North Carolina.

National Wetlands Inventory maps for 25 sites were overlayed on the hydric soil maps, and NWI wetlands lying on hydric soil were identified as wetlands present in the early 1980s. NWI maps were unavailable for two sites: Pembroke and Wagram. These sites were mapped by Steve Leonard, Wetland Specialist with the Division of Soil and Water Conservation, North Carolina Department of Environment, Health, and Natural Resources.

Black and white photographs were used for most of the analysis of wetland development. Aerial photographs at a scale of either 1:20,000 or 1:24,000 for the period 1951–1956 were borrowed or purchased. Orthophotoquads (1:24,000 scale), dated from 1979 to 1983, were borrowed from the U.S. Geological Survey. These photographs and orthophotoquads were interpreted for the cause and extent of wetland development. The causes of wetland alteration were determined by examining land use patterns by photointerpretation and fieldchecking. For example, wetland impact due to forestry was determined to occur when the site was ditched, drained, and converted to pine plantations. In addition, no hydrologic control structures (i.e., flashboard risers, flood gates, weir dams, etc.) were observed during field checks.

Early 1950s photographs were not available for Dare or Hyde counties, which include four study sites. Wetland alterations on these sites were analyzed using photorevised topographic maps and field visits. None of these sites have been greatly impacted by man. In fact, all of them are at least partially owned by the United States government. The Great Island study site is entirely protected as part of Swan Quarter National Wildlife Refuge. The Little Kinnakeet site is largely protected as part of the Cape Hatteras National Seashore. The study sites at Long Shoal Point and Mann's Harbor are partially included in the Alligator River National Wildlife Refuge. Impacts on these sites are limited to roadway maintenance and boat ramp construction.

Sixteen of the 27 sites were visited by the authors or Division of Environmental Management staff. These sites were examined to verify the effectiveness of wetland drainage and the type of development that caused the alteration. Table 2 summarizes photography, NWI dates, and the extent of field verification for each site.

Maps were produced for each site that showed 1980s and 1950s wetlands. These maps identified the type of wetland in the 1980s using NWI terminology and the cause of any wetland alterations since the 1950s.

Many of the sample sites also included large bodies of water, such as major rivers, sounds, and lakes. These areas were not included in total land area. Consequently, the land surface of the sample sites varied from 418 to 4,024 ha (1,033 to 9,943 acres).

This study also assessed the extent of headwaters and isolated wetlands. Headwater wetlands were defined as NWI wetlands located above the 5 cfs (141.5 l/s) average flow line in the watershed. This definition corresponds to the Nationwide 26 Permit from the U.S. Army Corps of Engineers. These locations were taken from the U.S. Army Corps of Engineers headwaters maps in Wilmington, North Carolina. Isolated wetlands were identified as NWI wetlands with no stream connections on the appropriate 1:24,000 USGS topographic map. However, there are many wetlands smaller than the minimum mapping size of approximately 0.4 ha (1 acre) for the NWI, which means that very small isolated wetlands were not included in this analysis.

RESULTS

Wetland Types and Alterations

The 27 study sites encompassed a variety of wetland types, including both estuarine and palustrine wetlands. Palustrine wetland types, especially forested areas, were more common than estuarine wetlands. Forested wetlands totaled 69% of the 1980s wetlands documented in the study—38,412 ha (15,545 acres) out of 55,326 ha (22,391 acres) (Table 3). Other common wetland types included estuarine emergent marsh, palustrine scrub-shrub areas, and estuarine scrub-shrub wetlands. Wetland areas and alterations for the early 1980s for each wetland type indicate that less than 5% of all wetlands were altered, except for Palustrine forested which showed a 41% alteration from the 1950s.

The sample sites contained a substantial percentage of historic wetlands, as indicated by an average of 60.7% hydric soils (Table 4). An estimated 52% of the total land on the coastal plain was once hydric soils (wetlands); however, this percentage varied greatly between counties. For example, Hyde, Tyrrell, Dare, Camden, Washington, and Currituck Counties (located near the coast) had greater than 85% hydric soils (Figure 1). By contrast, Richmond, Hoke and Harnett Counties (farther inland) had less than 20% hydric soils (DEHNR 1991).

This variation in the study sites suggested that each area should be analyzed separately for the specific types of wetland alteration and ecosystem characteristics. Each site comprised a set of unique conditions such as wetland types, land area, and amount of hydric soil. This variation within the sample could not be considered by simply totaling the areas of historic, 1950s, and 1980s wetlands. The mean percent alteration and confidence intervals for each time period were calculated separately for estuarine wetlands, palustrine wetlands, and the entire sample to give an overall trend (Table 5).

By the early 1950s, an average of 34.9% of the historic wetlands were altered sufficiently to place them in partially or nonsupporting categories (Table 5). By the early 1980s, an additional 15.9% (7.9% + 8.0%) of the historic wetlands were altered to fall in these combined categories. Consequently, an estimated 51.3% of the original wetlands in the North Carolina coastal plain no longer fully supported their uses by the early 1980s. Of the historic wetlands that are still viable systems, about 49.3% fully supported their uses (Table 5).

The percentage of alteration differed greatly between

Table 2. Aerial photograph, map dates and field checking for each study site in the N.C. wetland trends survey.

Study Site	1950s Photos	NWI	1980s Ortho-photos	Site Visit?
Beulaville	1955	1983	1983	No
Bonnetsville	1951	1983	1980	No
Burgaw	1956	1982	1983	Yes
Carolina Beach	1956	1982	1980	Yes
Center Hill	1955	1982	1982	No
Chadbourn NE	1951	1983	1979	No
Comfort	1955	1982	1982	No
Great Island	*	1983	1983	No
Greenville NW	1954	1982	1982	Yes
Grifton	1954	1982	1982	No
Hackney	1954	1982	1982	Yes
Little Kinnakeet	*	1983	1975	Yes
Long Shoal Point	*	1982	1975	Yes
Mann's Harbor	*	1982	1982	Yes
Pembroke	1951	—	1981	Yes
Pinetops	1954	1982	1982	Yes
Point of Marsh	1958	1982	1982	No
Rivermont	1951	1982	1982	No
Roper South	1955	1982	1982	Yes
Stella	1955	1983	1983	Yes
Spicer Bay	1955	1982	1980	Yes
Tomahawk	1951	1983	1982	No
Union	1955	1982	1982	Yes
Vanceboro	1954	1981	1982	No
Wagram	1956	—	1981	Yes
Wilmington	1956	1982	1982	Yes
Woodard	1954	1982	1982	Yes

* Great Island was examined using a 1951 topographic map. No changes have occurred.
Little Kinnakeet was examined using a 1948 topographic map, photorevised to 1983.
Long Shoal Point was examined using a 1951 topographic map. No changes have occurred.
Mann's Harbor was examined using a 1953 topographic map photorevised to 1974.

Table 3. Wetland extent by category in the North Carolina coastal plain survey.

Wetland Category	1950s Wetlands Hectares Acres	1980s Wetlands Hectares Acres	Extent Altered 1950s–1980s Hectares Acres	% Alt.
Palustrine	26,295	15,545	10,750	
Forested	64,977	38,412	26,565	40.9
Palustrine	874	853	21	
Scrub-shrub	2,160	2,107	53	2.5
Palustrine	130	124	6	
Emergent	323	307	16	4.9
Palustrine	25	124	−99	
Unconsolidated Bottom	62	307	−245	
Palustrine	7	7	0.0	
Aquatic Bed	18	18	0.0	0.0
Estuarine Intertidal	5,155	5,144	11	
Emergent	12,738	12,712	26	0.2
Estuarine Intertidal	507	483	24	
Scrub-shrub	1,254	1,194	60	4.7
Estuarine Subtidal	94	111	17	
Unconsolidated Bottom	232	275	−43	

Wetland categories taken from Cowardin et al. (1979).

Table 4. Percentage of hydric soil for each study site in the N.C. wetland trends survey.

Study Site	Percentage of Hydric Soils
Beulaville	46.7
Bonnetsville	25.9
Burgaw	77.3
Carolina Beach	33.5
Center Hill	67.2
Chadbourn NE	46.5
Comfort	51.6
Great Island	100.0
Greenville NW	63.3
Grifton	67.2
Hackney	72.4
Little Kinnakeet	37.1
Long Shoal Point	100.0
Mann's Harbor	98.9
Pembroke	50.2
Pinetops	41.7
Point of Marsh	100.0
Rivermont	36.9
Roper South	100.0
Stella	69.6
Spicer Bay	39.6
Tomahawk	58.7
Union	68.9
Vanceboro	56.7
Wagram	24.7
Wilmington	26.1
Woodard	78.8

estuarine and palustrine wetlands. Estuarine wetlands experienced a mean percent alteration of 12.2% of the historic wetlands by the early 1980s. Over 80% of this total alteration occurred between the early 1950s and the early 1980s, consisting of 9.9% of the historic estuarine wetlands (Table 5). By contrast, 52.4% of the historic palustrine wetlands were altered by the early 1980s. Between the early 1950s and early 1980s, 16.9% of the historic palustrine wetlands were altered; 41% of the total palustrine alteration.

However, the actual extent of estuarine wetland alterations is unclear due to the large confidence interval for estuarine alterations. Only eight study sites included estuarine wetlands, and the mean percent alteration for these wetlands ranged from 0.0% to 79.8% from presettlement to the early 1980s. The highest percentage, 79.8%, is unusually high because of the small amount of original estuarine wetland on the Hackney study site. The estimate of estuarine wetland alterations does indicate that these wetlands have experienced smaller alterations than palustrine. However, the large confidence interval indicates that the figure of 12.2% is only an approximation of the true extent of alteration.

Alterations Types

Alterations were classified into several development types. The total area of alteration was determined for each development type between the 1950s and 1980s.

Table 5. Percentage of wetlands alterations in the North Carolina coastal plain (including 95% confidence interval).

	Estuarine	Palustrine	All Wetlands
Percent altered by early 1950s	2.3 (3.7)	40.6 (8.8)	34.9 (9.2)
1950s–1980s			
Percent altered to partially supporting	0.0	8.9 (7.0)	7.9 (6.3)
Percent altered to non-supporting	9.9 (20.7)	8.0 (8.6)	8.0 (7.5)
Percent altered by early 1980s	12.2 (20.3)	52.4 (11.4)	51.3 (12.6)
Percent supporting in early 1980s	87.8 (20.3)	41.7 (10.7)	49.3 (12.4)

Activities responsible for the most wetland alterations were forestry (53%) and agriculture (42%), followed by urbanization (2%) and military construction (1%). Other causes of alteration included road construction and rural residential development (Table 6). As discussed earlier, forestry impacts resulted in the partially supporting wetland designation, while other development generally resulted in the nonsupporting or loss designation.

These figures do not include gains in wetlands caused by creation of ponds. In some cases, ponds were created in wetlands or on hydric soil. Ponds created in unaltered wetlands were treated as a conversion from one type of wetland to another. Ponds created on hydric soil with altered vegetation (such as an agricultural fields) were treated as a wetland creation. A total of 116 ha (288 acres) of ponds were created on the study sample sites between the early 1950s and early 1980s. There were also gains in wetland habitat where ponds were created in upland areas. A total of 99 ha (245 acres) of such ponds were created between the 1950s and 1980s. These figures primarily represent construction of farm ponds but also include excavated ponds in estuarine areas.

Headwater/Isolated Wetlands

A total of 36% of all early 1980s coastal plain wetlands surveyed are located in watersheds above the 5 cfs (141.5 l/s) average flow mark, and thereby qualify as headwaters wetlands under the Nationwide 26 Permit of the Clean Water Act regulations of 1977 (PL. 92–500). Estuarine wetlands are always considered below headwaters. Fifty-nine percent of palustrine freshwater wetlands were found to be headwater wetlands.

In addition, about 8% of the total wetlands surveyed

Table 6. Causes of wetlands alteration on the North Carolina coastal plain: 1950s–1980s.

Type of Development	Percent of Total Alteration
Forestry	52.8
Agriculture	42.2
Urban	2.2
Military	0.8
Other	2.0

(or 11% of the palustrine) are hydrologically isolated. About one-half of the total number of isolated wetlands are less than or equal to 2 ha (5 acres) in size. As discussed earlier, numerous small <0.4 ha (<1 acre), isolated wetlands are not represented by these figures. Of the entire area of isolated wetlands, about 1% are less than or equal to 2 ha in size, but they make up about one-half of the total number of isolated wetlands.

DISCUSSION

Wetland Alteration

In the sample analyzed for this study, 51.3% of the original wetlands on the North Carolina coastal plain have been altered. Our findings are almost identical to the national average for the conterminous 48 states of 53% lost by the 1980s and to the statewide average for North Carolina of 49% (Dahl 1990). If this sample is representative of the coastal plain, there is a 95% probability that between 39% and 64% of this area's historical wetlands have been altered. This range is similar to the pocosin wetland loss and altered percentages presented by Richardson (1983).

A sizeable portion of the wetland alterations in North Carolina has occurred within the last thirty years. During this period, a total of 15.9% of the original wetlands surveyed were altered sufficiently to place them in the partially supporting or nonsupporting categories. This amounts to nearly a third of the historic percent alteration. Considering that much of eastern North Carolina has been under development pressure for up to three hundred years, it is startling that a third of the total wetland alteration has occurred within such a short span of time.

Causes for these alterations differ markedly from national trends, primarily due to the substantial involvement of the forest industry in wetland alterations in North Carolina (Table 6). Nationally, agriculture is responsible for the major share of wetland alterations for the period between the 1950s and 1970s (OTA 1984). In the national statistics, forestry is included as a portion of the 6% classified as 'other' (OTA 1984). In North Carolina, forestry and agriculture have altered nearly similar amounts of wetland. However, conversion to forestry generally results in wetlands that partially support some of their original uses rather than nonsupporting wetlands. Consequently, it could be said that unlike agriculture, conversion for forestry does not always result in a total "loss" of wetlands.

The forest industry is a major owner of forested and scrub-shrub wetlands in North Carolina. Wilson (1962) identified this industry as the major owner of forested wetlands within his study area. In the early 1980s, 44% of the pocosins in North Carolina were owned by large timber operations and 18% by federal and state forestry agencies (Richardson 1983). Pocosins are a widespread wetland community in eastern North Carolina and include both palustrine forested and palustrine scrub-shrub areas. Given this degree of ownership, it is not surprising that the forest industry is a major factor in wetland alterations in North Carolina.

A substantial difference was observed between estuarine and palustrine wetlands in our study. Overall, estuarine wetlands experienced much smaller alterations than palustrine wetlands. This may partially reflect the small area of estuarine wetlands included in the sample and the number of coastal study sites under total protection due to public ownership. However, the low level of development probably also reflects the greater protection afforded estuarine wetlands by state and federal regulations and the different types of development pressure threatening them.

Stockton and Richardson (1987) analyzed coastal wetland development using U.S. Army Corps of Engineer permitting records. Between 1970 and 1984, 1738 ha (4,295 acres) of coastal wetlands were altered due to authorized development under the Coastal Area Management Act (CAMA), the Dredge and Fill Law, and Section 404 of the Clean Water Act. This included development in only 2% of the salt marsh wetlands inventoried by Wilson (1962). The largest alterations occurred due to permitted activity by utility companies.

Stockton and Richardson (1987) also found a significant decrease in the area of annual alterations after the state became the lead agency in the permitting process. In each of the years 1970, 1971, and 1973, over 400 ha (988 acres) were permitted for development. In 1978, the Coastal Area Management Act came into effect. After 1978, the area approved for alteration did not exceed 50 ha (124 acres) for any year in the study period. The difference in wetland alterations before and after CAMA is significant even after discounting several large projects in the early 1970s.

Headwater and Isolated Wetlands

Headwaters and isolated wetlands constitute a significant percentage of the wetlands in the coastal plain: 36% are headwaters, while an additional 8% are isolated. These wetlands are provided only a bare modicum of protection by the Clean Water Act since the provisions of the Nationwide Permit 26 allow filling of up to 4 ha (10 acres) of wetlands without extensive permit review. The North Carolina Division of Environmental Management does routinely review the filling of these wetlands through its 401 Water Quality Certification Program, but permits have almost never been denied (Dorney, unpublished data).

Future Research Needs

Further study of coastal plain wetlands should include data comparing development trends from the early 1980s to the early 1990s. These data would help assess whether the rate of wetland development has changed in recent years. It would also determine if the restrictions placed on wetland conversion by the 1985 and 1990 Food Securities Acts, especially the 'Swampbuster' provisions, have affected the amount of alterations due to agriculture. Similarly, these data may detect the impact of enhanced Section 404 regulatory activities.

There is also a need for more information on inland wetland alterations in North Carolina. This study did not include the piedmont or mountain regions of the state. Although these regions contain a small percentage of the state's total wetlands (DEHNR 1991), these wetlands are a valuable resource that receive only limited protection compared to the coastal salt marshes. Consequently, a similar study should be conducted to assess the status of these inland wetlands.

Finally, the state of North Carolina needs to clarify its stance on the importance of wetlands. This study primarily focused on those wetlands that retain natural functions and values, since the Division of Environmental Management is most interested in protecting those existing uses. It is time for North Carolina to reevaluate the effectiveness of its wetland protection strategies. It has been shown that protective legislation has reduced the alterations of tidal wetlands (Stockton and Richardson 1987). It is time to consider similar regulation and legislation to control the alterations of valuable fresh water wetlands of North Carolina.

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