Changes in Wetlands on Nonfederal Rural Land of the Conterminous United States from 1982 to 1987

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ABSTRACT / Recent wetland area trends were estimated from the National Resources Inventory (NRI) for nonfederal rural lands for the period 1982–1987. NRI-based estimates of wetland area for states comprising the conterminous United States were highly correlated with estimates made by the US Fish and Wildlife Service and with estimates of coastal salt marsh wetlands made by the National Oceanic and Atmospheric Administration. Net wetland area declined by 1.1% (≈363,200 ha) during the five-year study period. Conversion to open water, primarily caused by natural flooding in western inland basins, was responsible for altering extensive wetland areas (≈171,400 ha). Of the human-induced wetland conversions, urban and built-up land was responsible for 48% of the wetland loss, while agricultural development was indicated in 37% of the converted wetland area. A decrease in rural land, and increases in both population, and urban and built-up land were associated with wetland loss among states. Potential reasons for wetland loss were different in 20 coastal states than in 28 inland states. Proportionately, wetland loss due to development was three times greater in coastal states than inland states, while agriculturally induced wetland losses were similar in both groups. The proportionate declines of forested vs nonforested wetlands were not significantly different among states.

The area and distribution of wetlands is a subject of great concern in the United States as policy makers try to balance environmental quality with economic development. Only in recent decades has society begun to recognize that wetlands are more than just impediments to progress and that their value to the public often exceeds the value of alternative land uses resulting from their conversions. Increased public interest in wetlands and recent legislation have extended the level of protection afforded to wetlands on nonfederal lands. Amidst public concern and the call for a landscape perspective to assess the cumulative effects of wetland loss and degradation (Bedford and Preston 1988), there remain few sufficient data to explore national and regional patterns associated with the rate of wetland conversion and the potential factors responsible for wetland habitat loss (Abernethy and Turner 1987, Cowan and Turner 1988).

One exception that is spatially extensive but temporally limited to a five-year period is the National Resources Inventory completed by the US Soil Conservation Service in 1987. The objectives of this study were to quantify recent national and regional trends in wetlands on nonfederal rural lands and to determine the relative importance of different land-use activities that have traditionally been implicated as major factors in wetland conversion. Specifically, we asked: (1) has the rate of wetland loss declined from previous estimates, (2) do the characteristics of converted wetlands differ from wetlands that were retained over the study period, (3) are there regions and wetland types that are experiencing a disproportionate loss of wetlands, and (4) has there been a shift in the relative importance of land-use activities that have historically been responsible for wetland conversion? While wetlands are also subject to loss and degradation due to indirect effects (i.e., sedimentation, pollution, etc.), we were not able to account for indirect effects with the available data.

Historical Context

Wetlands in the conterminous United States have declined from about 89 million ha at the time of settlement (circa 1780s) to about 42 million ha, representing a 53% decline in 200 years (Dahl 1990). Dahl

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(1990) states more emphatically that the rate of wetland loss has been approximately 24 ha/hr during these two centuries as the surface area of the lower 48 states has gone from 11% to 5% wetland. These wetlands were lost as the result of both natural processes and human activities associated with agricultural development, building homes, cities, roads, industries, and related efforts to compete in a growing world economy. Dahl's study reported that 22 states had lost over 50% of their wetlands and ten states (Arkansas, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri, and Ohio) had lost over 70% of their original wetland area. California lost the greatest percentage of its wetlands (91%), while Florida lost the greatest area of wetlands (3.76 million ha) during this period.

Shaw and Fredine (1956) suggested that 35% of the wetlands present in colonial times were lost by the mid-1950s. Between the mid-1950s and mid-1970s about 809,400 ha of wetlands were created while about 4,451,600 ha of wetlands were lost (Tiner 1984). This loss equates to 185,350 ha/yr, of which 177,700 ha were palustrine wetlands and the remainder were estuarine (Frayer and others 1983). The greatest losses occurred to palustrine forested wetlands (2.43 million ha), palustrine emergent wetlands (1.9 million ha), and palustrine scrub–shrub wetlands (156,600 ha).

The great loss of palustrine forested wetlands reported by Frayer and others (1983) were corroborated by Abernethy and Turner (1987). Using timber statistics from US Forest Service surveys, Abernethy and Turner (1987) estimated that there has been a selective loss of forested wetlands, up to five times higher than nonwetland forests, in the last 40 years. The loss of 2.74 million ha was mostly in the Mississippi River valley floodplain where conversion to agriculture caused the majority of the loss.

More recently, Tansey and Cost (1990) estimated that forested wetlands in coastal South Carolina and Florida declined by about 3% between 1979 and 1987, primarily due to agricultural (45%) and urban (45%) development. Much of the forested wetland conversion pattern in the southeastern United States appears to have occurred incrementally (Hefner and Brown 1984, Lee and Gosselink 1988). Consequently, assessing the overall impact of forested wetland conversion has been difficult because the impact of small incremental habitat conversions appears minor when evaluated individually (Committee on the Applications of Ecological Theory to Environmental Problems 1986), but cumulative effects make analysis of individual options in isolation risky (Costanza and others 1990, Burdick and others 1989). However, Hickman (1990) has suggested that further incremental losses of forested wetlands will be significantly curtailed because opportunities for forest wetland conversion have decline, public policies and the legal system have changed, and the state of the art of conducting economic appraisals has improved.

Agriculture has exerted great economic pressure for private landowners to convert natural habitats to productive cropland. Agriculture has historically been associated with a large part of the wetland loss. Indeed, some of the most fertile and productive agriculture soils in such areas as the Corn Belt, Northern Plains, Mississippi Delta and Southeastern States were wetlands that were drained for agricultural production. Agriculture was responsible for 87% of the wetland loss during the period 1954–1974, urban expansion accounted for 8%, and other activities accounted for just 5% of this loss (Frayer and others 1983, Tiner 1984).

More recently, however, Dahl and Johnson (1991) reported that wetland losses slowed from the mid-1970s to the mid-1980s. They noted that agriculture was responsible for about 54% of the losses, conversions to "other" land uses accounted for 41%, and conversion to urban land made up the remaining 5%. A substantial portion of the conversions attributed to "other" represented wetlands that were drained and cleared, but not yet put to a use identifiable from the aerial photographs used in their study.

Agricultural land-use conversions and urban expansion occur almost exclusively on nonfederal lands. Some of the earliest federal laws passed to afford wetland protection on private lands took the form of executive orders. Federal agencies were required to consider wetland protection in their land management policies by minimizing the destruction and degradation of wetlands. These requirements were by executive orders on Floodplain Management (EO 11988, May 1977) and Wetland Protection (EO 11990, May 1977). In what became one of the federal government's principal regulatory programs for wetland protection, Section 404 of the Federal Water Pollution Control Act (PL 92-500) as amended requires the issuance of a permit from the US Army Corps of Engineers for the discharge of dredged or fill material into waters of the United States. Although the 404 program prevented the destruction of many wetlands, much of the agricultural-caused wetland conversions were not regulated under Section 404 (Barton 1986). The concern for wetland protection on agricultural lands has been addressed recently with passage of the Food Security Act of 1985 (PL 99-198) and the Food, Agriculture, Conservation and Trade Act of 1990 (PL 101-624). These two omnibus farm acts include provisions that withdraw US Department of Agriculture farm program benefits from producers who convert wetlands to make crop production possible, and the latter act also has a wetland reserve provision that provides financial incentives for restoring privately owned wetlands.

Noted shifts in the relative importance of land-use factors contributing to, and recent legislation directed at decreasing the probability of, wetland conversion indicate the need for continual evaluation of the areal extent and distribution of wetland habitats across the United States. Although the US Fish and Wildlife Service has been mandated to conduct a national wetlands inventory (Wilen and Frayer 1990) and monitor wetland trends in the nation, the Resources Conservation Act of 1977 (PL 95-192) assigned the Secretary of Agriculture responsibility to conduct periodic appraisals of the status, condition, and trends of resources on nonfederal rural lands primarily for the purpose of evaluating national agricultural polices. The 1987 National Resources Inventory provided the most recent and most detailed data base to examine recent patterns in wetland dynamics on nonfederal lands.

Table 1. Wetland categories used to examine wetland trends from the 1987 NRI

Type and name (Shaw and Fredine 1956)	Category
1 Seasonally flooded basin	Inland fresh
2 Inland fresh meadow	
3 Inland shallow marsh	
4 Inland deep fresh marsh	
5 Inland open fresh water	
6 Shrub swamps	
7 Wooded swamps	
8 Bogs	
9 Inland saline flats	Inland saline
10 Inland saline marshes	
11 Inland open saline water	
12 Coastal shallow fresh marsh	Coastal fresh
13 Coastal deep fresh marsh	
14 Coastal open fresh marsh	
15 Coastal saline flats	Coastal saline
16 Coastal salt meadows	
17 Irregularly flooded salt marshes	
18 Regularly flooded salt marshes	
19 Sounds and bays	
20 Mangrove swamps	

Methods

The National Resources Inventory (NRI) conducted by the Soil Conservation Service in cooperation with Iowa State University Statistical Laboratory is a multiresource inventory and a primary source of data for evaluating US agricultural policy. The design for the 1987 NRI consisted of a stratified random sample of 107,000 primary sample units (PSUs). Most PSUs were 64.75-ha blocks of land within which were located three randomly selected points where soil, water, land use, and cover data are collected (US Department of Agriculture, Soil Conservation Service and Iowa State University Statistical Laboratory 1989). The NRI was implemented in all counties of the conterminous US, in Hawaii, and in US territories in the Caribbean. Alaska was excluded from the NRI. Each 1987 NRI data entry had corresponding entries for land-use characteristics in 1982. The 1982 land-use data were based on a similar inventory completed by the Soil Conservation Service (US Department of Agriculture, Soil Conservation Service and Iowa State University Statistical Laboratory 1987).

NRI data were collected only on nonfederal lands. Many wetlands occur on federally owned lands that were not sampled by the NRI and therefore are not accounted for in this examination of recent trends. A substantial area of 1982 wetlands was acquired by the federal government over the five-year study period. Although these wetlands are "lost" from the NRI inventory, they should not be considered converted wetlands. Similarly, some wetlands that were under federal ownership in 1982 were transferred to nonfederal ownership in 1987. Again, these acres should not be treated as new wetlands. We describe wetlands that were involved in transfer of ownership over the study period, but we ignore them in our assessment of factors contributing to wetland area dynamics.

Wetland determinations in the NRI were made using the 20 wetland types identified by Shaw and Fredine (1956) (Table 1). NRI sample points must have had evidence of the plant community or water regime as defined by Shaw and Fredine (1956) to have been included as a wetland at the time the determinations were made. Data were collected by visiting each NRI point in the field. Additionally, soil survey maps, aerial photographs, and related data were also examined to help make the determinations.

Cowardin and others (1979) authored a widely used wetland classification system used by Frayer and others (1983), Tiner (1984), Dahl and Johnson (1991), and Field and others (1991) that included rivers and deep-water habitats. Those categories of riv-

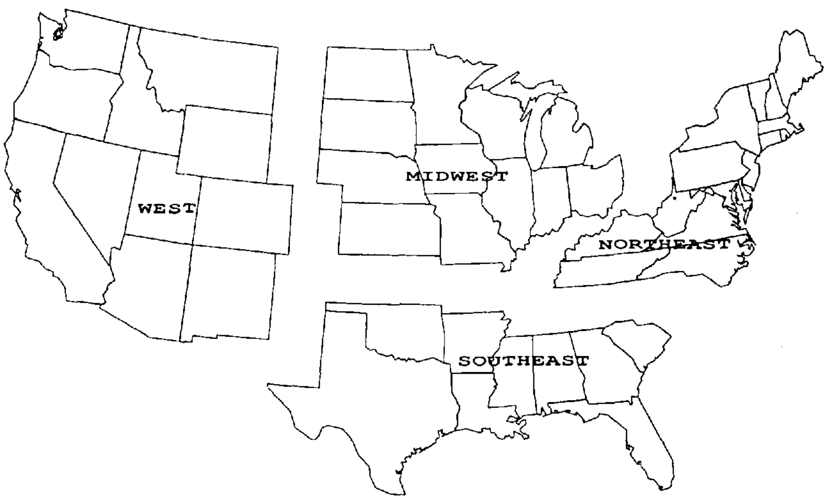

Figure 1. Regional boundaries used for NRI-based wetland trend analysis.

ers and deep-water habitats could not be assigned a wetland type as defined by Shaw and Fredine (1956). Therefore, lands classified as streams or as deep-water habitats were not included within our NRI-based wetland totals. NRI points that fell on aquatic habitats not assignable to wetland types were recorded as streams, waterbody <0.81 ha, water body 0.81–16.2 ha, lake, reservoir, estuary, and gulf or bay.

The 20 wetland types were grouped for much of this analysis under two criteria. First, area and trend data were compared among inland and coastal wetland categories including inland fresh, inland saline, coastal fresh and coastal saline (Table 1). Second, patterns in the distribution and loss of forested and nonforested wetlands were contrasted. Forested wetlands were defined as wetland types 7 (wooded swamp) and 20 (mangrove swamps), and wetland types 1 (seasonally flooded basins), 6 (shrub swamps), or 8 (bogs) if the NRI cover type was forest.

Most of the 1987 NRI data were designed to provide reliable estimates of major land-use and land-cover categories at a state level. Statistical uncertainty is greater for rare land types, such as wetlands, that occur infrequently across the landscape than for those such as forest, range, and agricultural lands that dominate the landscape. Furthermore, because wetlands are transitional between terrestrial and aquatic habitats, and often characterized by seasonal as well as long-term fluctuations in the hydrologic cycle, there is an inherent variance in their areal extent that can introduce additional uncertainty. To reduce the uncertainty of wetland area estimates, we report data that have been aggregated up to regions composed of multiple states. Wetlands are discussed by four broad geographic regions including the West, Midwest, Southeast, and Northeast (Figure 1).

Each NRI sample point was classified as to wetland status, land cover, land use, and ownership in each year of the inventory. If a point went from wetland to nonwetland, the 1987 land cover was used to assign the cause for the conversion.

Other land-use data elements from the NRI were also examined to provide insight into the observed patterns of wetland area, distribution, and losses. State totals were determined for the area of cropland, rural land, and urban and built-up land, as well as the change in each between 1982 and 1987. Population data were obtained from Bureau of Census reports (US Department of Commerce, Bureau of the Census 1983, 1990) for additional comparison with the wetland data. Change in land-use area and population, relative to total state area, were correlated against the change in wetland area in an effort to further describe factors contributing to wetland loss. Spearman's rank correlation coefficient was calculated for these comparisons because wetland loss was not normally distributed, as most wetland losses among states were relatively small. Nonparametric multiple response permutation procedures (MRPP) (Mielke and others 1976, 1981; Slauson 1988, Slauson and others 1991) were used to examine differences in wetland loss patterns associated with inland vs coastal wetlands, and forested vs nonforested wetlands.

NRI wetland data were compared with other areal estimates of wetlands (Dahl 1990, Field and others 1991) to determine the consistency among independent inventories. The level of consistency in independently derived estimates of wetland area was used as an indication of the reliability of the NRI-based descriptions of wetland loss patterns. NRI estimates of wetland area by state were correlated against other wetland estimates using Spearman's rank correlation.

Results and Discussion

Comparison among Wetland Area Estimates

Dahl (1990) used published reports of wetland area in the lower 48 states to estimate that there were 42,239,700 ha of wetlands in the mid-1980s. Dahl and Johnson (1991) implemented a statistically designed sampling procedure using aerial photography and estimated that there were 41,780,400 ha (±3.3%) of wetlands in the mid-1980s. Both of these studies reported on wetlands occurring on all lands regardless of ownership. The 1987 NRI estimated that there were 33,634,200 ha (±2.5%) of wetlands in 1982 on nonfederal rural lands in the conterminous United States. A state-by-state comparison of the NRI 1982 total with Dahl's (1990) data for wetlands in the early 1980s revealed that the two data sets were highly correlated ($r_s = 0.86$, $P < 0.0001$). Dahl's (1990) data generally estimated greater wetland area than the NRI, which is largely accounted for by the inclusion of federally owned land in his estimates. There also were inconsistencies between the data sets in how wetlands were defined. For some states, Dahl (1990) used National Wetlands Inventory maps (see Wilen and Tiner 1989) of the entire state prepared by the Fish and Wildlife Service using the Cowardin and others (1979) classification system. Where wetland mapping was not complete, an accurate or consistent accounting of wetland area was not always available. In this case, various sources were used to report the best available estimate (Dahl 1990, p. 4).

Field and others (1991) reported on the distribution and area of coastal wetlands in the conterminous U.S. as determined from grid sampling of National Wetlands Inventory maps. Comparing their estimates of coastal marsh in the 20 states with NRI-detected coastal wetlands revealed that they were also highly correlated ($r_s = 0.89$, $P < 0.0001$). The association between NRI estimates and those of Field and others (1991) was strengthened when the analysis was restricted to salt marshes ($r_s = 0.96$, $P < 0.0001$). Estimates of wetland area from Field and others (1991) were generally greater than those from the NRI for three primary reasons. First, the dates of the aerial photographs used by Field and others (1991, p. 14) ranged from 1972 to 1985, which may have yielded higher estimates of wetlands than did the NRI. Secondly, Field and others (1991) noted some differences in the classification of wetlands because the oldest maps did not use the detailed classification system that was used in the more recent wetland maps. Finally, Field and others (1991) included federally owned wetlands in their estimate that are substantial for coastal wetlands.

Changes in Federal Ownership of Wetlands

At total of 143,100 ha of 1982 nonfederal wetlands were acquired by the federal government from 1982 to 1987. The majority of federal acquisition occurred in the Southeast and Northeast where 73,000 and 54,000 ha, respectively, were transferred from nonfederal to federal ownership. There was a predominance of seasonally flood basins (25%), bogs (31%), and regularly flooded salt marshes (20%) comprising the wetlands acquired by the federal government.

A much smaller area of wetland underwent transfer from federal ownership in 1982 to nonfederal ownership in 1987 (22,800 ha). Nearly 86% of this area occurred in the West. The majority of this area (19,900 ha) was associated with more ephemeral wetlands types (seasonally flooded basins, inland fresh meadows, and inland saline flats).

Transfer of ownership does not represent a loss or gain of wetland area. Consequently, all inventory points that involved a change between federal and nonfederal land were ignored in our evaluation of wetland trends and factors contributing to wetland conversion.

Patterns in Wetland Area: 1982–1987

Trend results. There were 33.5 million ha of wetlands on nonfederal rural lands of the conterminous United States in 1982. By 1987, wetland habitats had declined to about 33.1 million ha (Table 2) for an average annual net loss of 72,600 ha/yr. This loss rate is about 40% of that reported for the period from the mid-1950s to the mid-1970s (Frayer and others 1983, Tiner 1984) and about 60% of the rate reported for the period from the mid-1970s to the mid-1980s (Dahl and Johnson 1991).

The total area of 1982 wetlands that did not retain their wetland status in 1987 was estimated to be 392,900 ha. A small area (≈30,000 ha) of wetlands were identified in 1987 that were not wetlands in 1982, representing 0.09% of the 1982 wetland total. These gained wetlands occurred primarily in the two most arid regions of the United States (West and Midwest) and likely reflect variation in precipitation over the five-year period. In general, western and mid-

Table 2. NRI-based estimates of wetland area in 1982 and 1987 (in 1000s of ha)

Region	Total area		Area		Retained (%)	Net change (1987–1982)	Change (%)
	1982[a]	1987[a]	Lost	Gained			
West	2,628.3	2,476.7	157.3	5.7	94.0	−151.6	−5.77
Midwest	10,347.3	10,314.0	51.6	18.3	99.5	−33.3	−0.32
Southeast	14,983.7	14,847.6	140.2	4.1	99.1	−136.1	−0.91
Northeast	5,531.8	5,489.6	43.8	1.6	99.2	−42.2	−0.76
Total	33,491.1	33,127.9	392.9	29.7	98.8	−363.2	−1.08

[a]Wetlands that were involved in a transfer of ownership between federal and nonfederal land are not included in these estimates.

Table 3. Wetland type composition (%) among wetlands that were lost, gained, or retained (only those wetland types comprising >5% are shown)[a]

Type	Name	Lost	Gained	Retained
1	Seasonally flooded basin	26.8	24.4	35.4
2	Inland fresh meadow	10.6	33.2	7.8
3	Inland shallow marsh	7.3	11.1	7.1
4	Inland deep fresh marsh	—	10.0	—
6	Shrub swamps	—	—	5.2
7	Wooded swamps	10.7	6.5	27.4
9	Inland saline flats	31.5	8.3	—

[a]Wetlands that were involved in a transfer of ownership between federal and nonfederal land are not included in these estimates.

western states witnessed drought conditions during the late 1970s to early 1980s (US Department of the Interior, Geological Survey 1991). Conversely, precipitation during the 1987 water year exceeded the 30-year mean over the same regions (US Department of the Interior, Geological Survey 1990). Other factors that may have contributed to these negligible gains in wetland area include: (1) increased prominence of wetland issues (and associated training of inventory personnel in wetland identification) could have increased the number of marginal wetland points being classified as wetlands, and (2) sampling error.

The net loss of wetlands between the two inventory years was about 1.1% or 363,200 ha (Table 2). The greatest absolute and proportionate loss of wetland habitats occurred in the West (151,600 ha, representing a 5.8% reduction). The Midwest incurred the lowest absolute and proportionate loss.

Wetlands that were lost, gained, or retained varied in their wetland type composition (Table 3). Wetlands that were lost were most likely to be inland saline flats (type 9) or seasonally flooded basins (type 1). As alluded to above, wetlands that were gained tended to be associated with wetland types characterized by ephemeral hydrology (types 1, 2, 3, and 9). Wetlands that were retained over the five-year period were most often seasonally flooded basins (type 1) or wooded swamps (type 7). The distribution of wetlands that were retained among wetland types was based on the 1982 wetland type. This ignored wetlands that were retained but changed wetland type. Of the wetlands that were retained, approximately 170,000 ha changed wetland type from 1982 to 1987. The majority of wetland type changes (60%) were associated with saltwater intrusion that occurred in the Southeast.

Inland fresh wetlands were the most abundant class of wetlands nationwide (Table 4), accounting for about 89% of the total wetland area. Although inland fresh wetlands lost the greatest area among the general wetland types, the proportionate loss was <1%. Conversely, coastal fresh wetlands and inland saline wetlands comprised 2% and 2.8% of the 1982 wetlands, respectively, yet incurred 7% and 13% reductions, indicating disproportionate losses. A net increase in coastal saline wetlands was observed between 1982 and 1987 and is attributed to saltwater intrusion in the Southeast where coastal fresh marshes were converted to coastal saline marshes.

Total wetland area and inland fresh wetland area were greatest in the Southeast (Table 4). Inland saline wetlands were most abundant in the West, where arid conditions promote evaporation. Coastal wetlands were most abundant in the Southeast and Northeast, occurring along the extensive Atlantic and Gulf of Mexico coasts of the United States. Regional losses by wetland type mirrored the regional distribution patterns. The West lost a disproportionate amount of wetlands primarily caused by the inundation of nearly 134,000 ha of inland saline wetlands.

Factors contributing to wetland loss. The land-use and land-cover classifications assigned to wetlands were nearly identical between 1982 and 1987. Wetlands in forest use accounted for approximately 56% of the 1987 total, 21% were classified as barren land (marsh, mud flats, salt flats, etc.), 9% of the wetlands occurred in habitats classified as rangeland, 7% were pasture, and 7% were cropland. We did not determine what

Table 4. Regional wetland patterns in the United States in 1982 and 1987 by broad wetland category (in 1000s of ha)

Region/category	1982[a]	1987[a]	Net change (%)	Percent deviation from expected[b]
National				
Inland fresh	29,842.9	29,641.4	−201.5 (−0.7)	−37.7
Inland saline	930.0	807.4	−122.6 (−13.2)	1,115.6
Coastal fresh	668.3	622.5	−45.8 (−6.8)	531.9
Coastal saline	2,049.9	2,056.6	6.7 (0.3)	−130.1
Total	33,491.1	33,127.9	−363.2 (−1.1)	
West				
Inland fresh	1,987.2	1,958.6	−28.6 (−1.4)	−75.0
Inland saline	593.2	471.4	−121.8 (−20.5)	256.0
Coastal fresh	—	—	—	—
Coastal saline	47.9	46.7	−1.2 (−2.5)	−56.6
Subtotal	2,628.3	2,476.7	−151.6 (−5.8)	430.8
Midwest				
Inland fresh	10,179.1	10,145.9	−33.2 (−0.3)	1.3
Inland saline	168.2	168.1	−0.1 (−0.1)	−81.5
Coastal fresh	—	—	—	—
Coastal saline	—	—	—	—
Subtotal	10,347.3	10,314.0	−33.3 (−0.3)	−70.3
Southeast				
Inland fresh	12,598.9	12,498.1	−100.8 (−0.8)	−11.9
Inland saline	155.2	154.7	−0.5 (−0.3)	−64.5
Coastal fresh	627.4	582.8	−44.6 (−7.1)	682.6
Coastal saline	1,602.2	1,612.0	9.8 (0.6)	−167.3
Subtotal	14,983.7	14,847.6	−136.1 (−0.9)	−16.2
Northeast				
Inland fresh	5,077.8	5,038.7	−39.1 (−0.8)	0.9
Inland saline	13.4	13.2	−0.2 (−1.5)	95.6
Coastal fresh	40.9	39.7	−1.1 (−2.7)	252.6
Coastal saline	399.7	397.9	−1.8 (−0.4)	−41.0
Subtotal	5,531.8	5,489.6	−42.2 (−0.8)	−29.7

[a]Wetlands that were involved in a transfer of ownership between federal and nonfederal land are not included in these estimates.

[b]Percentage difference between the expected area lost (defined by proportionately allocating the wetland area lost among wetland types or regions based on the 1982 area estimate) and observed area lost.

Table 5. Uses of land that were wetland in 1982 but were not wetland by 1987 (in 1000s of ha)

	Use in 1982							
1987 use	Cropland	Pasture	Range	Forest[a]	Other farm	Barren	Built-up	Total
Cropland	13.3	5.5	22.5	33.9		12.5		87.7
Pasture		0.7		5.4				6.1
Forest				1.2				1.2
Other farm		0.1		0.2				0.3
Barren				4.4		1.2		5.6
Built-up	3.7	10.6	18.3	68.6	1.1	16.7	1.6	120.6
Water	1.4	5.8	17.9	5.7	0.1	140.5		171.4
Total	18.4	22.7	58.7	119.4	1.2	170.9	1.6	392.9

[a]These data represent broad land uses where wetlands occurred, therefore they include some wetlands that occurred within forests, but that were not forested wetlands.

proportion of wetland habitats were subjected to livestock grazing.

The land-use category of greatest loss was 170,900 ha of wetland classified as "barren" in 1982 (Table 5). Most of these barren wetlands were marsh, mud flats, and salt flats, and nearly 82% of them were lost due to flooding by lakes. The next largest category of wetland loss was 119,400 ha of wetlands in forest use.

Approximately 57% of wetlands in forest use in 1982 became urban and built up, and 33% went to agricultural uses (cropland, pasture, and other farmland). About 58,700 ha of wetlands classified as "range" in 1982 were converted—31% was developed to urban, industrial, or residential uses; 30% was flooded by lakes; and the remainder went to cropland uses.

The largest cause of wetland loss (171,400 ha) was conversion to open water (not reservoirs), of which 160,500 ha were converted to inland lakes and 10,900 ha were converted to estuary. Of the wetlands converted to inland lakes, we estimated that 141,800 ha were likely the result of natural flooding. This estimate is based on those wetlands that were converted to lakes >16.2 ha. Conversions to smaller lakes includes an unknown proportion of wetlands that were inundated due to farm pond construction.

The majority of the area that was converted to inland lakes >16.2 ha involved inundation of inland saline wetlands (133,800 ha) in the West. Dry conditions prevailed over much of western and midwestern United States during the late 1970s and early 1980s (US Department of the Interior, Geological Survey 1991), but by 1987 Utah's Great Salt Lake and additional western inland basins were at record high water levels. The Great Salt Lake peaked in 1986 and 1987 at 1283.8 m, which was 3.6 m above its mean elevation (Hassibe and Keck 1991). Extensive areas of wetlands were flooded, including the 26,305-ha Bear River National Wildlife Refuge. By the late 1980s water levels had begun to recede to previous levels (R. Sennett, Soil Conservation Service, personal communication). Therefore, the extremely wet conditions created what is likely a short-term loss of inland saline wetlands in the West, which will likely return to wetland status. Recovery of wetland plant communities and functional values typical of those present in the early 1980s will likely take additional years. However, some areas of managed wetlands are being flushed with fresth water in an effort to reduce the salt levels and restore the vegetation (R. Sennett, Soil Conservation Service, personal communication). While there is some uncertainty over how many hectares of these flooded wetlands will return to their 1982 status, it is clear that much of this wetland loss is temporary and primarily natural rather than directly induced by human activities.

If we exclude wetland losses from natural flooding of inland lakes, then approximately 251,200 ha (or 50,200 ha/yr) of wetlands were lost primarily due to human-induced land-use conversion. The greatest human-induced loss of wetlands during the five-year interval occurred as 120,600 ha (48%) went to urban, industrial, or residential development. Agriculture was responsible for about 94,100 ha (37%) of wetlands that were converted, with 93% of those acres becoming cropland in 1987 and 6% converted to pastureland. About 20% of those farmland acres were also in agricultural uses in 1982 and were drained, presumably to improve production, while about 80% were converted from other land uses, mostly forest and rangeland. The remaining 15% of lost wetlands were converted to open water, barren land, or forest.

Wetland losses due to agriculture have declined since the mid-1950s. During the mid-1950s to mid-1970s, 87% of wetland losses were estimated to be due to agriculture (Tiner 1984). During the mid-1970s to the mid-1980s they were reported to be 54% (Dahl and Johnson 1991). Our data indicate a further decline to 37% during the 1982–1987 period. Multiple reasons are potentially responsible for the observed trend, including changes in commodity prices, reduced area of wetlands where drainage is economically feasible (Heimlich and Langner 1986), and more recently the apparent increased recognition of wetland values to society. The latter is expressed through increased public information, growing institutional recognition, and legislation such as the Wetland Conservation provisions of the Food Security Act of 1985 ("swampbuster") and the Food and Agricultural Act of 1990.

Other land use and population associations with wetland loss. Rural land declined by 2,284,000 ha as urban and built-up land increased by 1,607,200 had during this study's five-year period. Cropland increased by 569,300 ha during this period. Rural land that was lost either was converted to urban and built-up land, went to federal ownership, or became large waterbodies such as reservoirs. The highest correlation with wetland loss was found to be with the loss of rural land, followed by the increase in urban and built-up land (Table 6).

All measures of population density were correlated ($P < 0.002$) with wetland loss (Table 6). Both the increase in the metropolitan population and the increase in the nonmetropolitan population were associated with loss of wetlands (Table 6).

The observed changes in rural land and urban and built-up land were associated with observed population increases. Increases in the metropolitan population occurred in 45 of 48 states and increases in the nonmetropolitan population occurred in 40 states (US Department of Commerce, Bureau of the Census 1990). The change in population during 1980–1988

Table 6. Spearman's rank correlation coefficients and probabilities (below) of net wetland loss with changes in land-use and population characteristics for the conterminous United States, inland states, and coastal states

	r_s with wetland losses		
	48 states	28 inland states	20 coastal states
1982–1987 land changes[a]			
Crop	−0.292	0.108	0.177
	(0.0437)	(0.5830)	(0.4542)
Rural	−0.758	−0.516	−0.681
	(0.0001)	(0.0049)	(0.0009)
Urban and Built-up	0.589	0.239	0.439
	(0.0001)	(0.2213)	(0.0528)
1980–1988 population changes[a]			
Metropolitan	0.491	0.033	0.323
	(0.0004)	(0.8682)	(0.1644)
Nonmetropolitan	0.443	0.004	0.358
	(0.0018)	(0.9824)	(0.1325)
Total	0.466	0.005	0.346
	(0.0010)	(0.9779)	(0.1472)

[a]All land-use and population statistics were adjusted for differences in state area, therefore land use reflected state proportion and population reflected state density.

was highly correlated with changes in urban and built-up land ($r_s = 0.83$, $P = 0.0001$), rural land ($r_s = -0.68$, $P = 0.0001$), and cropland ($r_s = -0.38$, $P = 0.008$).

Patterns among Inland and Coastal Wetlands

Inland wetlands comprised 92% of the total wetland base in 1982. Despite the predominance of inland wetland types, when the 48 states were divided into two groups of 20 states with NRI-detected coastal wetlands and 28 states without NRI-detected coastal wetlands, it became apparent that different land use factors were responsible for the observed wetland conversions.

Proportionately, the transfer of wetlands to federal ownership during this period was about five times greater for coastal wetlands (45,600 ha or 1.6% of total coastal wetland area) than inland wetlands (98,700 ha or 0.32% of all inland wetlands). This indicates that federal protection occurred where the loss of wetlands was disproportionately high (see Table 4). While cropland increased in the inland states (1,883,200 ha) and decreased in the coastal states (−1,313,900 ha), the agriculturally induced conversions of inland wetlands were about the same in both groups (48,100 ha inland, 46,100 ha coastal states). There were no cases of agriculturally induced losses to coastal wetlands in the NRI. However, the biggest difference in the two groups of states was the conversion of wetlands to urban and built-up land that impacted, proportionately, three times as many wetlands in the coastal states than in the inland states. Coastal states lost 98,300 ha (0.5% of all wetlands in coastal states) of wetlands to urban and built-up development, of which 84,900 ha were inland wetlands and 13,400 ha were coastal wetlands. The 28 inland states lost only 22,000 ha (0.15% of wetlands in inland states) of wetlands to urban and built-up development. An interesting corollary to the above is that the population density of coastal counties was four times the national average in 1988 (Culliton and others 1990). The remainder of the coastal wetland losses was due to conversions to open water.

Changes in land use (decrease in rural land and increase in urban and built-up land) from 1982 to 1987 were more highly correlated with the loss of wetlands in coastal states compared to inland states (Table 6). Changes in population were not associated with loss of wetlands in either region. Consequently, the observed correlation with population change among all states must then be explained by basic differences in population growth in coastal vs inland regions. The two groups of states were found to be different ($P < 0.0001$; MRPP): The 20 states with coastal wetlands gained a greater density of metropolitan and nonmetropolitan population, gained more urban and built-up land, and lost a greater amount of rural and cropland than did the 28 states without coastal wetlands (Figure 2).

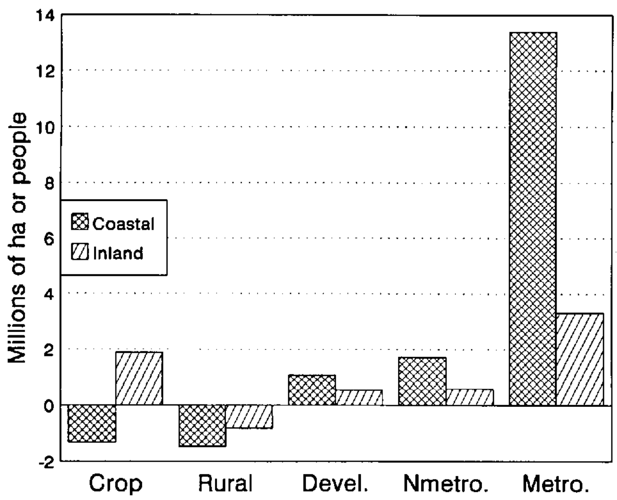

Figure 2. Changes in area of cropland, rural land, and urban and built-up (developed) land from 1982 to 1987 (US Department of Agriculture, Soil Conservation Service and Iowa State University Statistical Laboratory 1989) and changes in population by metropolitan and nonmetropolitan categories from 1980 to 1988 (US Department of Commerce, Bureau of Census 1990) in 20 coastal and 28 inland states.

Analysis of NRI data also revealed extensive degradation of coastal wetlands by conversion to open water. There were 113,100 ha of coastal fresh marsh and irregularly flooded salt marsh present in 1982 in the Southeast (all were in Louisiana) that became salt meadow, regularly flooded salt marsh, or estuary by 1987. About 67% of these recorded changes in Louisiana's coastal marshes occurred as salt marshes became deeper and regularly flooded, or became open water, while the remaining area went from fresh marsh to salt marsh or open water. Saltwater intrusion into fresh marshes results in the loss of freshwater vegetation, and a shift to brackish or salt marsh or open water. In some cases, the soil is eroded away as the vegetation is lost. In other cases actual subsidence occurs, which is often a natural geologic phenomenon. Although much of this degradation is recorded as change in wetland type rather than wetland loss, it actually represents a significant loss of habitat for many species of waterfowl, shorebrids, reptiles, fish, shellfish, and other aquatic organisms (Field and others 1991), many of which have been recognized as having suffered significant declines in abundance during this decade (Howe and others 1989, Chambers 1992).

The degradation and loss of coastal wetlands has recently become a subject of great concern (Scaife and others 1983, Deegan and others 1984, Cowan and Turner 1988, Costanza and others 1990, Field and others 1991, Chambers 1992, Chmura and others 1992). Models of coastal marsh dynamics indicate the long-term natural instability of coastal marshes (Chmura and others 1992). The costal zone is not homogeneous with respect to variations in geology, deltaic growth/decay cycles, human-induced changes in hydrology, and land-use changes, which led Cowan and Turner (1988) to conclude that the interaction between causal factors leading to wetland loss is variable and complex. Direct human-induced factors are most readily identified, but indirect and cumulative effects may be very significant but difficult to account for. In addition to direct conversions of wetlands, there is also the loss due to saltwater intrusion resulting from canal and channel construction for oil and gas exploration, transportation routes, and recreation. Demographic trends indicate that by year 2010, an estimated 54% of the US population will live within 50 miles of the coast (Edwards 1989). The disproportionate increase in population of coastal counties also contributes to increased degradation of valuable coastal, estuarine, and riverine environments.

It is widely recognized that estuaries serve not only as fishing grounds but also serve as nursery areas for young stages of fishery resources that may be exploited there or in coastal fisheries later in life. Over half of the US fishery harvest is estuarine-dependent in at least some life stages, while that fraction is much higher in some regions, such as the Gulf of Mexico (Houde and Rutherford 1993). Many estuarine-dependent fisheries have declined in recent year (Houde and Rutherford 1993, Chambers 1992). The major cause for most fishery population declines is broadly recognized to be overfishing; however, evidence now exists that many estuarine-dependent fish populations are also being affected by cumulative habitat degradation and loss (Chambers 1992). Over half of the nation's coastal wetlands have been lost (Tiner 1984, Dahl 1990), and many that remain are being degraded in quality (Chambers 1992).

Patterns among Forested and Nonforested Wetlands

Forested wetlands made up 55% of the total area of nonfederal rural wetlands, or 18.4 million ha, in 1982. Over 55% of the forested wetlands on nonfederal land occur in the Southeast and only about 1% of them occurred in the West, while the remainder were divided evenly between the Midwest and Northeast (Figure 3). Within regions, forested wetlands com-

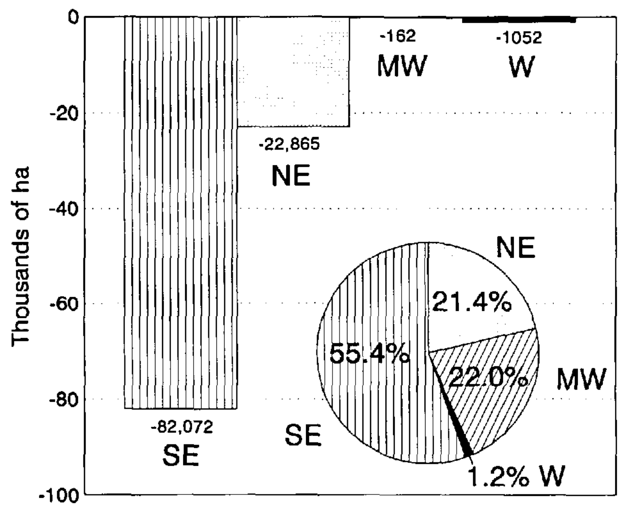

Figure 3. Hectares of forested wetlands lost by region (bars) and proportion of forested wetlands by region in 1987 (pie) (SE = Southeast, NE = Northeast, MW = Midwest, and W = West).

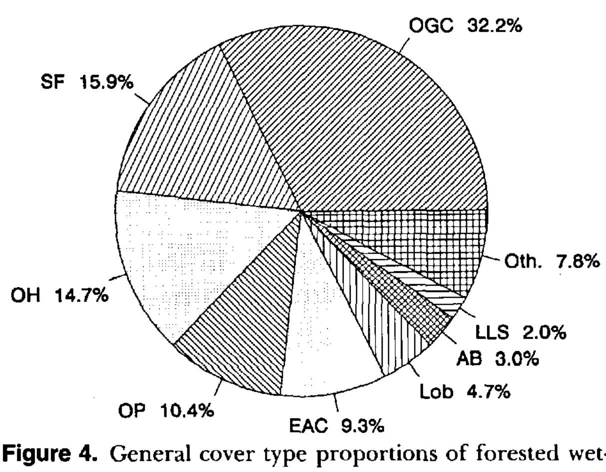

Figure 4. General cover type proportions of forested wetlands in the conterminous 48 states as determined by the 1982 NRI (OGC = oak–gum–cypress, SF = spruce–fir, OH = oak–hickory, OP = oak–pine, EAC = elm–ash–cottonwood, Lob = loblolly–shortleaf pine, AB = aspen–birch, LLS = longleaf–slash pine, Oth. = other).

prised 71% of all wetlands in the Northeast, 68% in the Southeast, 39% in the Midwest and just 9% in the West.

Oak–gum–cypress was the dominant cover type of forested wetlands in 1982. It represented 32% of the forested wetlands nationally (Figure 4), followed by spruce–fir (16%), oak–hickory (15%), oak–pine (10%), and elm–ash–cottonwood (9%). Forest cover type data were not available for 1987, but given the low proportionate loss of forested wetlands, it is likely that the composition of forested wetlands was similar in both years of the inventory. The dominant cover of forested wetlands in the West was hardwoods, which made up 56% of the cover. Spruce–fir was the dominant cover in the Midwest and occurred on 56% of the forested wetlands in the region, followed by elm–ash–cottonwood (22%). Oak–gum–cypress occurred on 51% and oak–hickory occurred on 19% of the forested wetlands in the Southeast. The Northeast had a more diverse distribution of cover types in its forested wetlands with oak–gum–cypress (20%), spruce–fir (17%), oak–hickory (15%), and elm–ash–cottonwood (13%) having a nearly equal contribution to the regional total.

A total of 83,400 ha of 1982 forested wetlands were acquired by the federal government by 1987. The focus of federal acquisition of forested wetlands was in the Northeast (48,400 ha) and the Southeast (31,200 ha).

Although the Northeast and Midwest had nearly equal amounts of forested wetlands in 1982, the Northeast region witnessed a considerably greater net loss of forested wetlands than did the Midwest (Figure 3). The Southeast region had a net loss of forested wetlands that was 3.5 times greater than in all other regions combined. Land-use factors contributing to the conversion of forested wetlands to nonwetland uses were consistent with those associated with all wetland types—58% converted to urban and built-up land, 32% to agricultural uses, and 10% associated with conversion to open water, barren land, or forest. In addition, 8600 ha of forested wetlands remained in wetland status but no longer support forest vegetation. Nearly all (92%) of the wetlands that were cleared of forest vegetation were seasonally flooded basins.

Consistent with the findings of Abernethy and Turner (1987), we found that forested wetlands experienced a disproportionate loss of area when compared to upland forest habitats. A total of 114,600 ha of forested wetlands (106,200 ha net loss) were converted to nonwetland status by 1987, yet upland forest habitats actually increased in area by 588,300 ha over the same period. Contrary to the comparison with upland forest habitats, we found no difference in the proportionate loss of forested vs nonforested wetlands during the period of study ($P = 0.24$; MRPP). While these wetland losses typically occur incrementally, their impacts are cumulative. The deleterious effects of cumulative impacts on forest-dependent faunal populations in the Tensas Basin of Louisiana were shown by Burdick and others (1989). The fact that those adverse effects occurred at the watershed scale implies that small, incremental losses result in negative impacts to wetland fauna.

Conclusion and Summary

Estimates of wetlands on nonfederal rural lands in the United States made by the 1987 NRI were found to be highly correlated with wetland estimates made by the Fish and Wildlife Service (Dahl 1990) and with estimates of coastal wetlands made by the National Oceanic and Atmospheric Administration (Field and others 1991). Although there was evidence for consistency in the areal extent of wetland habitats among independent inventories, the rate of wetland loss (72,600 ha/yr) was shown to have declined by 60% and 40% from estimates made for periods 20 and 10 years prior to the NRI, respectively.

Wetlands that converted to nonwetland status from 1982 to 1987 were predominantly wetland types characterized by an ephemeral hydrology (seasonally flooded basins and inland saline flats). Much of these wetlands were converted to open water as a result of natural flooding that occurred in the West. Conversely, retained wetlands were dominated by seasonally flooded basins and wooded swamps, presumably due to the higher conversion costs associated with the latter.

A land-use analysis of converted wetlands indicated that the western United States observed a disproportionate loss of wetland habitats, again due to the natural flooding that occurred in the arid inland basins during the mid-1980s. Wetland types that received differential conversion were coastal fresh wetlands in the Southeast and Northeast and inland saline wetlands in the West.

Of the human-induced wetland conversions, land development for urban, industrial, and residential (built-up) uses was indicated in 48% of lost wetland habitats. Agriculture was responsible in the conversion of 37% of wetlands, while the remaining 15% were converted to barren land, open water, or forest. These estimates indicate that the predominant cause of the most wetland loss has recently shifted from agriculture to urban development. These direct observations were supported by statistical correlations of wetland loss with the loss of rural lands, the increase of urban and built-up lands, and the increases in population. Wetlands in coastal states were found to be three times as likely to be lost due to development than were wetlands in inland states, while agriculturally induced wetland losses were similar between the two groups. The proportionate loss of forested wetlands was not different from the proportionate loss of nonforested wetlands.

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