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ARTICLE

Diverse Characteristics of Wetlands Restored under the Wetlands Reserve Program in the Southeastern United States

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Abstract The Wetlands Reserve Program (WRP) restores converted or degraded wetlands on private working lands; however, the nature and outcomes of such efforts are undocumented in the Southeastern U.S. Identification of wetland types is needed to assess the program's conservation benefits, because ecological functions differ with hydrogeomorphic (HGM) type. We reviewed >100 WRP projects across the Southeast Piedmont–Coastal Plain to characterize their wetland types and to evaluate whether restoration practices favored original or modified functions. The projects encompassed four HGM types and diverse pre-restoration conditions. Nearly half were converted wetlands retired from active agriculture; the remainder were either drained vegetated wetlands or forested bottomlands degraded by timber harvest. Hydrology-repair practices varied by wetland type and prior condition, with differing functional implications. Depressions and flats typically were restored, whereas low-order riparian sites and prior-agriculture floodplains were often modified to enhance water retention. Timber-harvested floodplains were restored by removing barriers to water flow and biotic connectivity. Vegetation restoration was generally passive, but tree planting was frequent on prior-agriculture sites. Field surveys suggested that most projects had positive indicators of wetland hydrology, vegetation, and faunal use. The variety of Southeastern WRP wetlands has implications for ecosystem services at local and landscape scales.

Keywords Coastal Plain region, USA · Conservation Effects Assessment Project (CEAP) · Ecosystem services · HGM · Wetland restoration · Wetlands Reserve Program

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Introduction

Wetland degradation and conversion result in the loss of significant ecosystem services that include floodwater storage, water-quality improvement, carbon sequestration, and wildlife habitat. Agriculture and other working-land uses are well documented causes of historical wetland damage and loss (e.g., Dahl 2000). In the United States, the Conservation Title of the Farm Bill provides financial incentives to private agricultural landowners for implementing various conservation practices that can reduce the adverse environmental impacts of agriculture and enhance the provision of natural habitat (Mausbach and Dedrick 2004; Johnson and Monke 2010). Certain practices are aimed specifically at recovering or improving the ecological functions of wetlands on working lands (Brinson and Eckles 2011).

Interest in accountability for the multi-billion dollar funding of Farm Bill programs led the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) to establish the Conservation Effects Assessment Project (CEAP), a national-scale effort to measure the environmental benefits of federal conservation programs and practices (Mausbach and Dedrick 2004; Duriancik et al. 2008). Under the "CEAP–Wetlands" component, region-based studies are being conducted to assess and quantify the ecosystem services derived from wetland conservation practices (Eckles 2011). The core practice is Wetland

Restoration, which has been implemented mainly under the Wetlands Reserve and Conservation Reserve Programs. These two programs have been applied extensively in agriculture-dominated regions such as the Northern Great Plains and the Mississippi Alluvial Valley, where the nature and outcomes of the restoration practice have been fairly well studied (reviews in Gleason et al. 2011; Faulkner et al. 2011). However, other U.S. regions have received much less attention (Eckles 2011). In particular, a review for the Southeast Piedmont–Coastal Plain (De Steven and Lowrance 2011) found that information on restorations under Farm Bill programs was scarce to non-existent, with little indication of what kinds of wetlands were targeted or what specific practices were used to rehabilitate them.

Two features of the Southeast have important implications for assessing the regional benefits provided by wetland practices and programs (De Steven and Lowrance 2011). First, agriculture is a relatively smaller land use compared to forested land (~20 % vs. >60 %; USDA 2006); this potentially limits the landscape extent of program activity compared to agricultural regions. Second, the Southeast has abundant and diverse wetland hydrogeomorphic (HGM) classes, despite historical wetland losses to both agricultural and forestry activities (Hefner and Brown 1985; Hefner et al. 1994). Wetland diversity complicates assessment because HGM types differ in hydrodynamics and thus in their principal ecosystem services (Brinson and Reinhardt 1998; Smith et al. 2008). Knowledge of the wetland types being restored and their interactions with specific practices would enhance the ability to assess the services gained from conservation programs.

Wetland restoration on Southeastern program lands is accomplished mainly through the Wetlands Reserve Program (WRP), established nationwide in 1995. The WRP provides funds for restoring degraded wetlands with an eligible history of agricultural use, and also offers one-time, per-area payments for enrolling the wetland tracts into permanent or 30-year conservation easements. Non-easement, 10-year agreements fund restoration costs only. Landowner participation is voluntary and based on mutually agreed goals. The program's traditional emphasis has been to maximize benefits for migratory waterfowl and other wildlife, but other ecosystem services may be addressed also. As part of the CEAP–Wetlands effort, we analyzed the characteristics of wetland restorations on Southeastern WRP lands and assessed coarse-scale evidence for success. Analogous to work by Gwin et al. (1999) on compensatory-mitigation wetlands, we also evaluated how practices used for restoration might affect wetland functions from a hydrogeomorphic perspective. Gwin et al. found that mitigation projects often created 'atypical' HGM types by modifying sites to enhance water retention. A similar outcome is possible under the WRP, which views restoration in broad terms and allows establishing managed wetlands for wildlife-habitat objectives. Here we present the study findings in relation to these questions: 1) what wetland HGM types are being restored, and by what methods?, 2) do the principal restoration practices result in original or modified HGM functions?, and 3) irrespective of HGM effects, does restoration successfully establish functional wetland conditions? Based on a survey of more than 100 projects completed over a 12-year period, this summary provides the first systematic description of WRP wetland restorations in the Southeastern United States.

Methods

Under the CEAP–Wetlands framework, the Southeast region encompasses the Piedmont and Coastal Plain physiographic province spanning from South Carolina to Mississippi, but excluding the Mississippi Alluvial Valley (MAV) and the south Florida Okeechobee–Everglades system as separate, distinctive eco-regions (Brinson and Eckles 2011; De Steven and Lowrance 2011). Our study examined restoration projects across three Southeast states with the majority of reported WRP activity: South Carolina (SC), Georgia (GA), and the "Coastal Plain" portion of Mississippi (MS). For purposes of the study, a 'project' is a defined wetland or wetland tract with coordinated planning that may involve multiple landowner contracts.

A sample of projects was chosen by first obtaining all NRCS database records of completed WRP restorations that were reported for the three states during a fixed time period (2000–2008). It can take 2–4 years to finish a restoration after a site is enrolled, so the reporting time period captured an enrollment period spanning the first 9–10 years of the nationwide WRP. By basing the selection on a wide span of reporting years, we obtained a broad cross-section of projects without pre-determined selection bias for any wetland attributes analyzed. After the addition of some projects whose records were missing in the NRCS database, the final sample consisted of 109 WRP projects enrolled during 1996–2004 and completed over 12 years (1998–2009) (Table 1). This represented over half of SC contracts and nearly all GA and MS contracts for the enrollment period, providing a broadly representative sample of completed projects up to a recent date. The projects occurred in all physiographic sub-regions (Piedmont, Hilly Coastal Plain, Coastal Flats, Mississippi Loess Uplands). Nearly all WRP tracts (95 %) were in perpetual or 30-year conservation easements, reflecting the enrollment options that landowners chose most often.

WRP contract files in NRCS State and Field Offices were examined to assemble relevant data for the projects. All projects were on private lands, and all information was

Table 1 Features of 109 Southeastern WRP restoration projects evaluated, by state and overall

Feature	South Carolina	Georgia	Mississippi[a]	All
Number of restoration projects	78	17	14	109
Number of WRP contracts	87	19	12	118
Total area enrolled (ha)	10,690	2,914	964	14,568
WRP enrollment year (range)	1996–2004	1996–2004	1997–2002	1996–2004
Project completion year (range)	1998–2009	1998–2009	2000–2007	1998–2009
Projects field-surveyed (number)	29	13	11	53

[a]Coastal Plain only (excludes the Mississippi Alluvial Valley sub-region of the state)

compiled under confidentiality provisions required by the Farm Bill. Each project was characterized for its original wetland HGM type, habitat condition before restoration, area of the easement/tract, relative areas of hydric and non-hydric soils, and the principal methods (practices) used for restoration. Wetland types were identified to HGM class or subclass based on topographic maps (USGS 30′x60′ and 7.5′). Prior habitat condition (in active agriculture vs. other land cover) was determined from aerial photos and other file notes. Easement size and restoration practices were obtained from written project plans; practices included ditch plugging, dike construction, installing water-control structures, and vegetation planting. Areas of hydric and non-hydric soils were estimated from overlays of WRP tract boundaries onto NRCS Web Soil Survey maps (at http://websoilsurvey.nrcs.usda.gov/app/). In addition, each project was scored for whether the functional outcome of the main hydrology-repair practice would be to *restore* or *modify* the wetland's inherent hydrodynamic pattern and functions; i.e., whether the wetland retained its original HGM character or was altered to behave as a different HGM type (cf. Gwin et al. 1999). Appropriate to class variables, three-way contingency analyses (log-linear models with likelihood-ratio chi-square tests; Sokal and Rohlf 1981) were used to test if frequency of the various practices differed in relation to wetland type and prior habitat condition, including a test for type-by-condition interaction. Interaction tests are reported only if significant. For functional outcomes (restored, modified, or no change), chi-square analysis was used to test if outcome frequencies differed between wetland types.

We assessed the field status of project wetlands with a coarse-scale approach. Restoration under the WRP is not compensatory or explicitly reference-based; the emphasis is on achieving habitat and functional success rather than emulating specific wetland communities. Pre-restoration field data suitable for measuring progress are also non-existent. Therefore, as an indication of project success, we used qualitative methods to determine if a sample of restored sites met ecological criteria for functional wetland conditions. Approximately half of the projects (n=53) were visited and scored for field indicators of wetland hydrology, vegetation, and faunal presence. Nearly all GA and MS projects were included (n=13 and 11, respectively), omitting a few redundant or newly-completed sites. The selected SC projects were a random sample (n=29) stratified by HGM type and prior habitat condition, excluding some extremely large sites that were not feasible for survey. Time since restoration averaged 6 years (range 2–11 years) for all 53 projects.

One-day site visits were conducted during July–August 2010. These are optimal months for determining plant composition and relative duration of growing-season wetness, although the region experienced below-normal rainfall and summer drought in that year (NOAA 2010). Each site was assessed with spot-surveys at 1–4 wetland locations per site (number scaled to wetland size); the number of locations per site was limited by time and area constraints, but it included different wetland cover types if these were evident from aerial photographs. Upland areas were not surveyed. We assessed wetland conditions by using an adaptation of the scoring method for routine wetland determinations (ACOE Environmental Laboratory 1987), omitting soil indicators because WRP site eligibility is based on presence of hydric soils. At each location, we traversed the general area and noted presence/absence of 10 primary and 5 secondary field indicators of existing or recent inundation/saturation (from ACOE 2008). We also recorded all 'dominant' plant species in four strata (tree, sapling/shrub, herb, woody vine), where a dominant was any species comprising ~20 % or more of total stratum cover by visual estimation. Species were classed as to wetland indicator category (Reed 1997), native status (USDA 2011), and (if non-native) potential 'invasiveness' based on regional exotic-species rankings (at www.invasive.org/south/ and www.invasiveplantatlas.org). Quantitative sampling for fauna was not possible, but at each location we noted any presence of aquatic or wetland-dependent animals in 7 broad taxon groups (wading birds, waterfowl, fish, aquatic insects, amphibians, reptiles, mammals).

Data were compiled to site level and summarized into ecological metrics for the hydrologic and vegetation conditions at each project wetland. Metrics included the number and frequency of hydrology indicators, species richness of the dominant plants, and relative percentages of native, hydrophytic (FAC or wetter), and wetland (OBL, FACW) species. A Prevalence Index (mean wetland-indicator score weighted by species frequency; ACOE 2008) and an index of 'floristic quality' (Floristic Assessment Quotient for Wetlands, FAQWet4 of Ervin et al. 2006) were also calculated for each site. Percent hydrophytic species equates to the Dominance Test, where values >50 % indicate hydrophytic vegetation (ACOE 2008). The Prevalence Index is scaled from 1 (OBL) to 5 (UPL); values <3 can indicate hydrophytic vegetation, but values <2.5 more strongly indicate wetland conditions (National Research Council 1995). The FAQWet4 index is based on a scale from 5 (OBL) to −5 (UPL) and incorporates frequency-weighted percent species nativity; the index lacks a fixed range, but values >0 generally indicate hydrophytic vegetation and high values (10–20) suggest a predominance of native wetland (OBL, FACW) species. Differences in metrics with respect to project HGM type and prior habitat status were tested with either 2-way ANOVA (for continuous variables) or 3-way contingency analyses (for class variables). Relationships between ecological metrics and project age (time since restoration) were tested with Pearson correlations. SYSTAT® (SPSS, Inc.) was used for all statistical analyses.

Results

Characteristics of the Wetland Restorations

We found that the WRP projects encompassed four general HGM types: *depressional*, wet *flat*, and two riverine subclasses, riparian *headwater* and mainstem *floodplain* (Fig. 1a). Depressions were identifiable as distinct topographic basins. Flats were areas lacking topographic relief, often with ill-defined patterns of mapped hydric soils; very large "Carolina bays" (~100 ha or larger) were classed with flats based on similar topographic and hydrologic traits. Riparian headwater sites were narrow flat banks or incipient channels of small creeks (1st- to 3rd-order). Mainstem floodplain sites were wide and topographically heterogeneous alluvial bottoms or braided channels on large rivers (4th-order and higher). A few riverine sites were tidally influenced. SC and GA projects included all four HGM types, whereas MS projects were headwater or floodplain types only (Fig. 1a). Most projects consisted of a single wetland type, but a few (6 %) had a smaller secondary wetland of a different type on the project tract.

There was substantial variation in pre-restoration habitat condition. While many sites were in active agriculture (cropping or pasture) at the time of WRP enrollment, many others appeared to have natural vegetation (Fig. 1b). Nearly all projects (except SC floodplains) had records of past ditching, tile drainage, or channelization, which suggested that the prior-vegetated sites had been abandoned from older agricultural use or perhaps were never drained effectively. Floodplain prior condition diverged by state: the prior-agriculture floodplains were in MS (plus one in GA), whereas nearly all vegetated floodplains were in SC, with only 33 % of the latter having any record of past ditching. The SC floodplains represented a State Special Initiative begun in 2002 to enroll degraded wetlands with 'problematic' soils (i.e., lacking some hydric traits but subject to flooding). In effect, such wetlands were forested bottomlands where water flows and movements of aquatic biota were impaired by past timber-harvest activities such as road construction, clear-cutting, soil rutting, and debris accumulation. Forest harvest typically had occurred at least 5–7 years before enrollment. Two of three GA floodplain sites were also forested bottomlands with similar history.

Project size was highly variable, ranging from a few hectares to several hundred hectares or more (Table 2). Large tracts could include several wetland areas plus adjacent uplands. Flat and floodplain tracts were larger, on average, than depression and headwater tracts (ANOVA on log-transformed data, $df=3, 105$, $P<0.001$). The timber-harvested floodplains averaged 3 times larger than the prior-agriculture floodplains (Table 2; ANOVA, $df=1, 35$, $P<0.05$), with bottomland forest easements ranging to a maximum of ~1,100 ha (11 km^2).

Although all project wetlands were associated with mapped hydric soils, these soils were diverse, represented collectively by 73 series of mineral, histic, or organic types. WRP easements are also permitted to include 'upland' areas, but the extent can be difficult to determine, especially on large floodplains with a complex mosaic of hydric and non-hydric soils. Excluding floodplains, the estimated percent of tract area that was upland habitat ranged from near 0 % to 69 % (based on non-hydric soils or planned upland practices). Approximately 65 % of wet-flat projects had substantial uplands (comprising at least 20 % of tract area), compared to 44 % of depression and headwater projects (log-likelihood chi-square, $df=1$, $P=0.11$).

Hydrology Repair and Functional Outcomes

Practices to repair hydrology differed with wetland type and prior habitat condition (Fig. 2). Ditch plugging or tile-drain removal (for 'unmanaged' hydrology) was used mainly on flats and depressions (60 % and 24 % of projects, respectively). Installing some form of water-level control occurred on 55 % of all projects, but it was very frequent (>70 %) on headwater sites and on prior-agriculture floodplains. Planned water-management systems included moist-soil units for open habitats and green-tree reservoirs on forested sites. Semi-enclosed, diked impoundments (a sub-category of water-control) were especially common on prior-

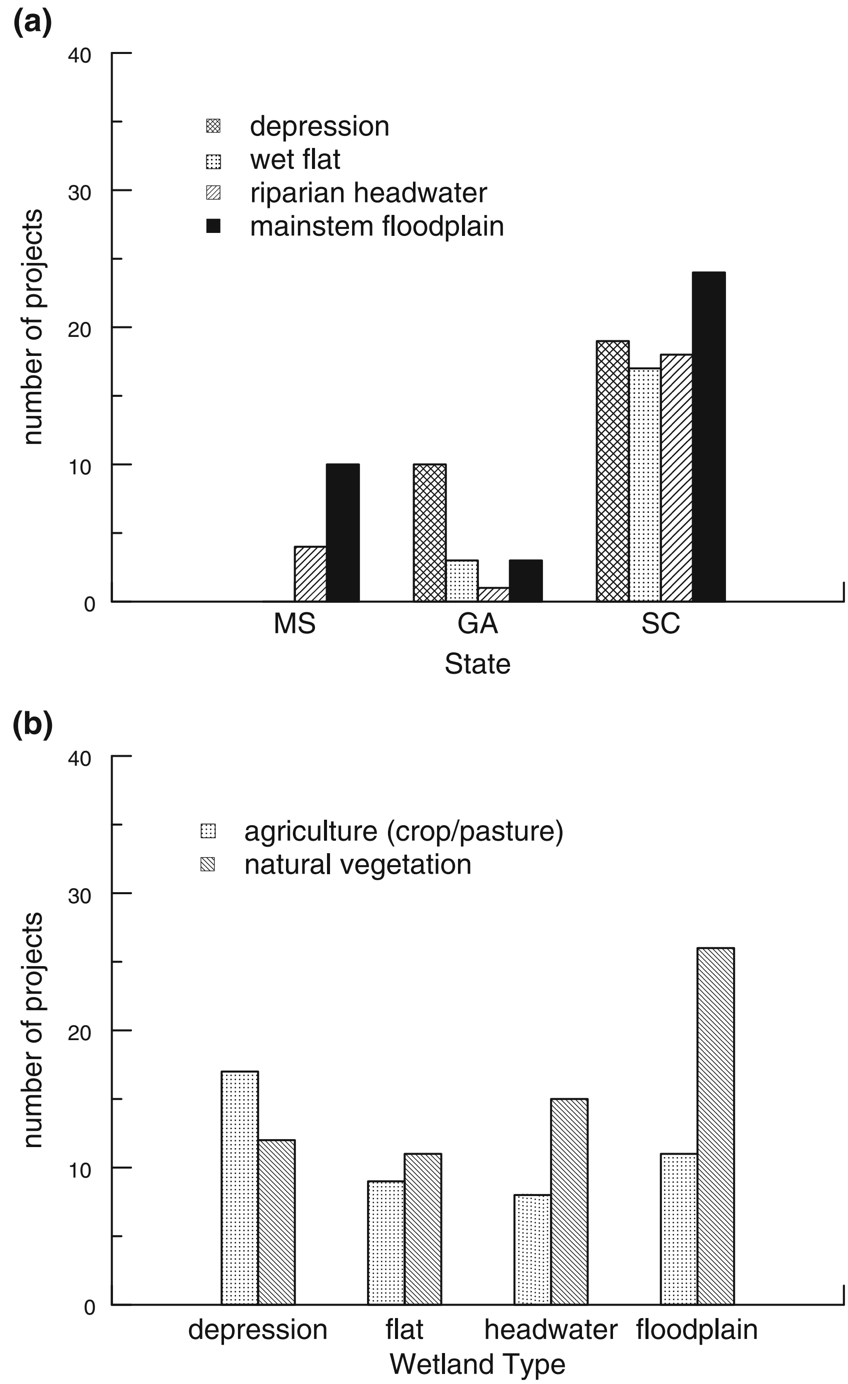

Fig. 1 Wetland HGM types and pre-restoration habitat conditions for 109 Southeastern WRP projects. **a** Frequency of wetland types by state. **b** Frequency of prior habitat conditions by wetland type

agriculture headwaters and floodplains (88 % and 45 % of projects, respectively). On the headwater sites, either creek flows were impounded directly or diked 'depressional' ponds were built on adjacent creek banks. On the floodplain sites, the impoundments were often developed from existing flood-prevention dikes. In contrast, frequent practices on vegetated (forested) floodplains were breaching roads/dikes and installing rock-fill crossings or stream-crossing structures (Fig. 2) to increase hydrologic and biotic connectivity across the floodplain and to the river. Small, managed impoundments could be established on these tracts, although some were pre-existing from earlier land use.

Excavating small areas of "macrotopography" (swales, potholes) was a secondary hydrologic practice for enhancing water-depth variety in a wetland, principally on prior-agricultural flats (Fig. 2). In rare cases where a primary repair method proved infeasible, macrotopography was used to provide some water storage in lieu of full restoration. Finally, 11 % of projects had no hydrology practices applied at all; typically this occurred when it was found that past site

Table 2 Easement/tract size and wetland area of 109 Southeastern WRP projects, where wetland area is estimated as the % of easement area with hydric soils

Wetland HGM type	*n*	Easement area (ha)		Wetland area (ha)	
		Mean	Range	Mean	Range
Depression	29	45	2–249	27	2–168
Flat	20	151	5–779	114	4–748
Riparian headwater	23	34	4–167	24	3–135
Mainstem floodplain (all)	37	256	4–1093	209	4–886
Timbered floodplains	26	321	12–1093	263	10–886
Prior-agriculture floodplains	11	101	4–270	83	4–212

drainage was no longer effective, or when the tract (usually a forested floodplain) enhanced the habitat value of an adjacent existing WRP easement without needing hydrologic repair.

WRP projects are broadly regarded as wetland 'restoration', but a hydrology practice may *restore* original hydrodynamic (HGM) function, *modify* it to create different HGM function, or result in no change if no hydrology repair occurred. For example, blocking drainage would restore the inherent hydrodynamics of ditched depressions and flats, whereas constructing impoundments would alter riverine wetlands that normally are driven by surface flows and overbank flooding. From this perspective, the applied practices resulted in differing functional outcomes (Fig. 3). Most hydrologic regimes of depressions and flats were essentially restored (76 %), with or without added water-control. In contrast, 83 % of headwater sites were modified (enhanced) to create managed impoundments within a low-order riverine setting. Functional outcomes for floodplains differed based on how prior condition influenced restoration practices (Fig. 3). Most forested floodplains were restored by breach/crossing practices (50 %) or protected without hydrologic repair (31 %), whereas most prior-agriculture floodplains (82 %) were modified for managed impoundments and limited connectivity to adjacent rivers.

Vegetation Restoration and Upland Habitat

Practices to restore wetland vegetation varied with prior habitat condition and by state. Tree planting was frequent on prior-agriculture tracts (35–82 % of projects per wetland type), but not on prior-vegetated sites (Fig. 2). Active reforestation was typical on MS projects (93 % of sites), given that all were prior-agriculture riverine lowlands. On such tracts, a mix of 5–8 bottomland species (e.g., oaks, *Quercus* spp.; green ash, *Fraxinus pennsylvanica*; baldcypress, *Taxodium distichum*) was planted across areas outside of the managed moist-soil units. The approach favored heavy-seeded oaks on the presumption that light-seeded species would colonize naturally (see King and Keeland 1999). Passive revegetation was favored in SC and GA, with supplemental use of planted trees (47 % of GA projects and 12 % of SC projects). Planting was done mainly in depressions and flats and was based on microsite, typically with 1–2 wetland species (cypress, *Taxodium ascendens or T. distichum*; swamp tupelo, *Nyssa biflora*) placed centrally and 2–3 bottomland oak species on higher wetland margins. On a few depressions and flats, vegetation restoration consisted solely of allowing natural recovery after removal of livestock grazing. Likewise, timber-harvested floodplains were not actively reforested, but instead were left to regenerate naturally.

Upland areas, when present, were restored to natural vegetation and/or managed with various 'wildlife habitat' practices. In SC and GA, practices on non-floodplain uplands included establishing native early-succession grassland or longleaf pine (*Pinus palustris*) forest, both of which might be managed with prescribed fire; these practices were planned on nearly 60 % of the non-floodplain tracts with available uplands. Planting agricultural grains (e.g., corn, sorghum) in small wildlife-food plots was planned on almost 50 % of all projects, including on floodplains.

Field Condition of Project Wetlands

Of the 53 project sites visited in late summer 2010, most had multiple positive metrics of hydrology function and wetland vegetation, irrespective of wetland type (Table 3). No metrics were correlated with time since restoration (Pearson correlations, all *P* n.s.). With respect to hydrology, 38 sites (72 %) were inundated or saturated despite summer-drought conditions, and 7 other sites without visible water (13 %) had at least 3 other primary indicators of recent inundation. The number of hydrology indicators averaged 4–5 per site (Table 3), but six sites that were dry when visited (3 depressions, 3 flats) had either no or few other indicators. Hydrology indicators did not differ with prior habitat condition (all *P* n.s.). Nearly all sites with installed water-control structures had water present when sampled, but the apparent extent of water-level management was variable. Of 28 sites with control structures or impoundments, an

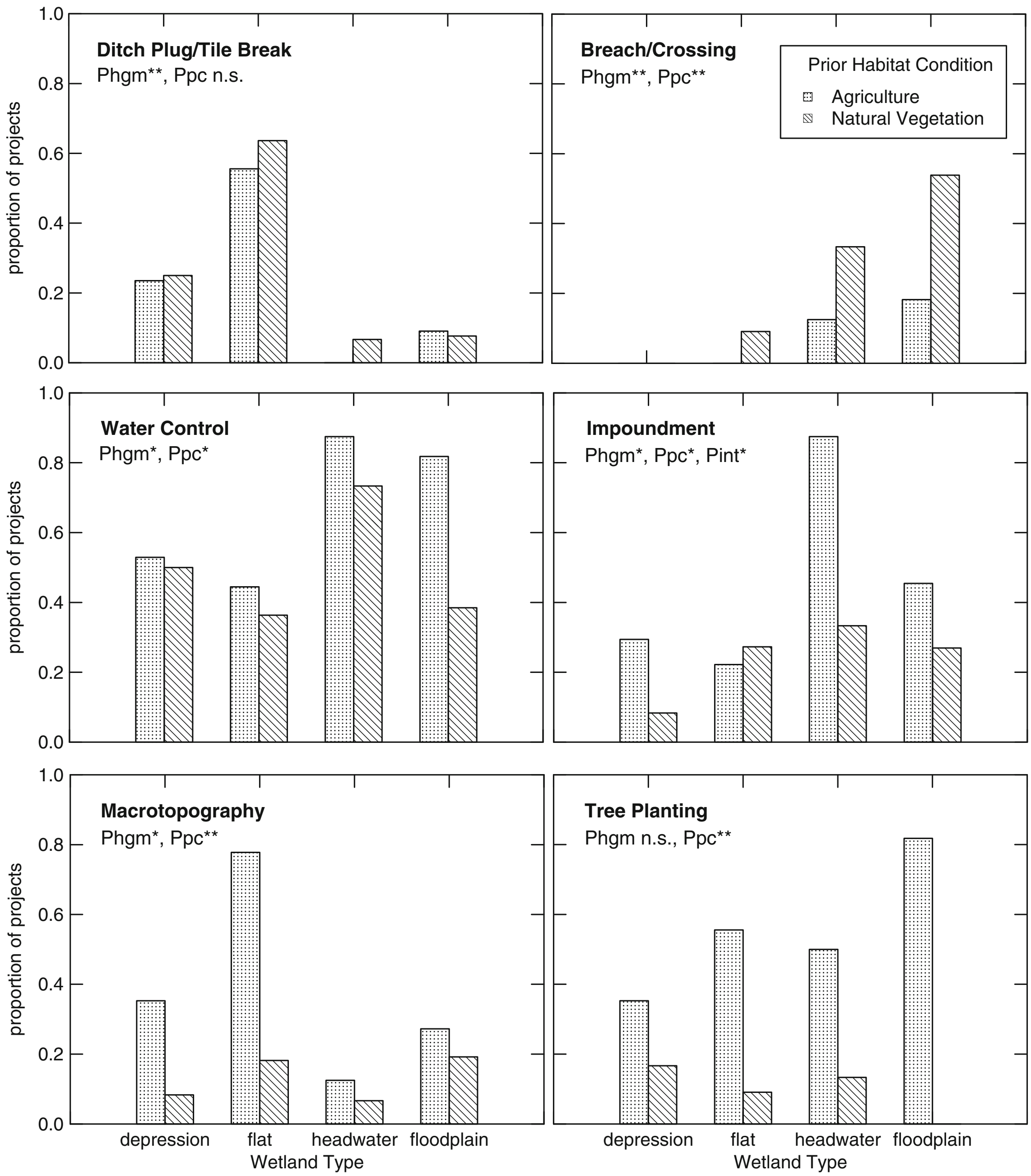

Fig. 2 Proportion of WRP projects in a given wetland type and prior habitat condition that used each of 6 restoration practices. *P*-values from chi-square tests for effect of wetland HGM type (Phgm, *df*=3) and prior condition (Ppc, *df*=1) are noted by ** $P \leq 0.01$; * $P \leq 0.05$; n.s., not significant. Only one P-value for type-by-condition interaction (Pint, *df*=3) was significant

estimated 57 % were being actively managed, 18 % were not managed, and the rest (25 %) could not be determined.

Almost 380 plant taxa were recorded as dominants across all sites; the list included aquatic plants (5 %), grasses and sedges (31 %), forbs (29 %), and woody species (35 %). Overall, the dominant vegetation averaged 88 % hydrophytic species, 63 % wetland species, and 95 % native species, with little difference among wetland types (Table 3). Prevalence Index and FAQWet4 values averaged 2.1 and 10.7, respectively, indicating native wetland vegetation. An apparent difference in species richness (Table 3) was likely an artifact of differing numbers of survey locations per site (mean of ~2 in depressions/flats versus ~3 in headwaters/floodplains). No site had less than ~60 % hydrophytic species as dominants; however, 6–8 sites (mainly depressions or flats) had <40 % wetland (OBL/FACW) species and/or a Prevalence Index >2.5, and most of these were sites with few to no hydrology indicators.

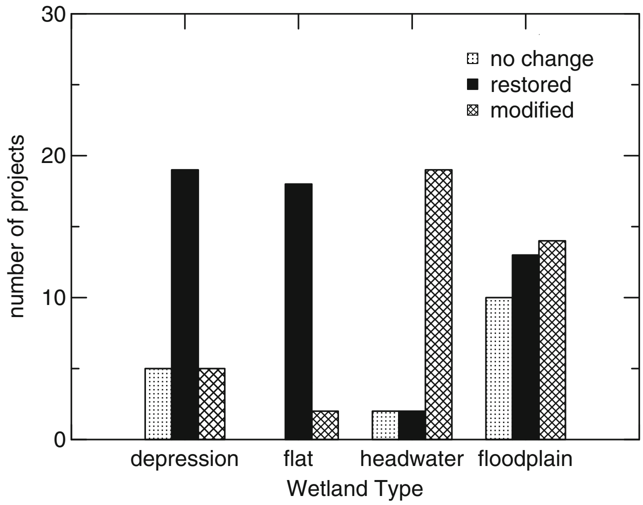

Fig. 3 Effective functional outcomes (no change, restored, or modified) of hydrology repair practices applied to 109 WRP projects. Relative frequency of outcomes differed among wetland types (chi-square, df=6, P<0.001)

Vegetation metrics did not differ with prior habitat condition, except for a few related to species nativity. One or more non-native species was recorded in 74 % of agricultural sites vs. 46 % of prior-vegetated sites (chi-square, df=1, P<0.05). Nonetheless, percent nativity was high, averaging 92 % (±1 SE) in agricultural sites and 97 % (±1 SE) in vegetated sites (ANOVA, df=1, 45, P<0.01), and with the respective number of non-native dominants per site averaging 1.8 (±0.4 SE) and 0.9 (±0.3 SE) species (ANOVA, P<0.05). Of the 31 non-natives recorded, most were naturalized old-field species or species that may have been planted as part of moist-soil management. One or more of 10 potentially 'invasive' non-natives was detected in 43 % of sites, either as an occasional plant or abundant locally, with no difference between prior habitat conditions (chi-square test, df=1, P n.s.). The most frequent invasives were *Lonicera japonica* (Japanese honeysuckle, 16 sites), *Ligustrum sinense* (Chinese privet, 15 sites), *Triadica sebifera* (Chinese tallow, 5 sites), and *Alternanthera philoxeroides* (alligatorweed, 5 sites).

Systematic evaluation of tree-planting success was not feasible; however, on the actively reforested agricultural floodplains, we recorded an average of 6 tree species (range 4–10) in well-developed sapling strata. These were a mix of planted species and light-seeded volunteers such as black willow (*Salix nigra*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), and sycamore (*Platanus occidentalis*). For other project types, anecdotal conversations with NRCS staff suggested that plantings of wetland trees (*Taxodium* and *Nyssa* spp.) had variable success, typically owing to drought-related seedling mortality.

The dominant habitat type of individual projects ranged from open-water or emergent vegetation to shrub wetlands and aggrading forests (Table 4). Depressions and flats were mainly open-emergent, shrub, or forested (84 % of sites), whereas most headwaters and floodplains (93 %) were either forested or had a mix of managed open-emergent wetland plus regenerating or planted trees. Generally,

Table 3 Field indicators of wetland hydrology and vegetation in 53 WRP project sites. Data are either the number of sites or the mean per site (±SE), with P-values from 3-way contingency analyses or 2-way ANOVAs, respectively. **P≤0.01; *P≤0.05; n.s., not significant

Field Indicator	Wetland HGM Type				
	Depression	Flat	Headwater	Floodplain	P
Hydrology Indicators					
Sites with water present	8	7	10	13	n.s.
Sites with water or with ≥3 other primary hydrology indicators	10	8	12	15	*
Total hydrology indicators	3.8±0.5	4.0±0.7	4.9±0.6	5.5±0.6	n.s.
Vegetation Indicators					
Total dominant plant species	21.1±2.8	20.9±2.2	29.5±2.2	30.9±2.9	**
Percent hydrophytic species[a]	86.2±3.4	89.9±3.3	86.5±2.0	90.5±1.6	n.s.
Percent wetland species[a]	63.5±6.4	59.5±6.7	59.0±4.0	68.6±4.0	n.s.
Prevalence Index	2.1±0.2	2.1±0.2	2.2±0.1	2.0±0.1	n.s.
FAQWet4 Index	9.9±1.4	8.8±1.4	10.3±0.9	13.1±1.2	n.s.
Percent native species	95.0±1.8	94.7±2.1	93.0±1.5	95.5±1.7	n.s.
Total non-native species	0.9±0.4	1.2±0.5	2.2±0.5	1.2±0.5	n.s.
Sites with ≥1'invasive' non-native species	4	3	8	8	n.s.
Total 'invasive' non-native species	0.4±0.2	0.5±0.3	1.1±0.3	0.7±0.2	n.s.
Number of projects visited	14	11	13	15	

[a] hydrophytic species are FAC or wetter (ACOE 1987); wetland species are OBL and FACW

Table 4 Principal vegetation habitats of 53 WRP project sites. Values are the number of projects representing a given vegetation class. Habitat-class frequency differed among wetland types (chi-square $P<0.01$)

Vegetation habitat class	Wetland HGM type			
	Depression	Flat	Headwater	Floodplain
Open-emergent wetland	6	2	1	1
Shrub wetland	4	2	0	0
Forested wetland	3	4	4	7
Mixed (open/wooded)	1	3	8	7

78 % of prior-agriculture sites were re-established as open or mixed habitats, whereas 69 % of prior-vegetated sites were shrub or forested wetland (chi-square $P<0.01$).

Data on faunal use of wetlands was necessarily limited, since detailed surveys could not be conducted. Roughly 30 % of sites had no standing water by late summer, thus precluding detection of aquatic taxa. However, wetland-dependent or aquatic animals were seen at 47 % of all project sites. In GA and MS, where faunal observations were more complete, one or more of the 7 taxon groups was seen in >75 % of sites, with the number of observed faunal groups averaging 2–3 per site. Wading birds, waterfowl, and/or amphibians occurred at nearly 60 % of the GA and MS sites.

Discussion

Farm Bill program wetlands have been understudied in part because of privacy and access constraints; however, the CEAP–Wetlands assessment (Eckles 2011) will enhance opportunities for wider examination. The most-studied WRP efforts to date have been in major agricultural regions (e.g., Great Plains, Mississippi Alluvial Valley), where there may be one dominant wetland type and where converted wetlands on highly altered croplands are targeted for restoration (King et al. 2006; Faulkner et al. 2011; Gleason et al. 2011). Our broad assessment of projects in a mixed land-use region revealed several contrasts and unexpected program versatility. Southeastern WRP wetlands are characterized by multiple HGM types and by varied pre-restoration conditions that include cropped or grazed sites, drained wetlands with semi-natural vegetation, and timber-harvested bottomlands with no contemporary cropping history. Restoration approaches were partly adjusted to wetland type and initial condition, but with differing functional outcomes. Rapid field surveys indicated generally successful establishment of functional wetlands with a native flora and habitat favorable to wetland-dependent wildlife.

Wetlands in the Southeastern WRP

The characteristics of the enrolled wetlands reflected inherent program flexibility. The WRP is generally thought to target prior-converted or farmed wetlands on croplands; however, program guidelines allow for eligibility of hydrologically degraded wetlands in various working-land settings, including rangelands and "forest production" lands (NRCS 2009). Individual states can establish priority rankings for habitats of concern in relation to the prevailing patterns of land use and landowner participation. In Coastal Plain Mississippi, low- and high-order riverine wetlands were most often converted to cropland and thus were priortized for restoration (although high competitive demand for the WRP in the MAV portion of the state tends to limit the number of Coastal Plain enrollments). The other two states also targeted recovery of certain distinctive wetlands uncommon in Mississippi (e.g., isolated depressions, Carolina bays), and South Carolina developed an option in 2002 to address degraded bottomland habitats. Collectively, these approaches yielded a region-wide diversity of restored wetland types, initial conditions, and ecosystem services that may be recovered. There may be a similar variety of WRP wetlands in other mixed land-use regions of the U.S., but the extent is unknown because HGM type generally has not been used for tracking program wetlands.

Functional Effects of WRP Restorations

The WRP can broadly address recovery of wetland functions, but its traditional focus on wildlife benefits influences restoration methods. Hydrology 'enhancement' (water-level control, partial impoundments, macrotopography) is allowed on up to 30 % of a restored tract (NRCS 2009), though in reality the spatial extent may be greater. WRP projects also may incorporate other targeted wildlife-management techniques (vegetation manipulation, food plots, etc.; Strader and Stinson 2005), thus constrasting with mitigation or ecological restorations that focus on maximizing equivalency to undisturbed wetlands (e.g., Kentula 2000; Zedler 2000; Reiss et al. 2009). The traditional wildlife-oriented practices may sometimes result in poor 'ecological fit' between management goals and natural ecosystem processes (Euliss et al. 2008).

On many of the Southeastern projects, hydrology repair involved installing some form of water-level control, reflecting an explicit or implicit landowner desire for waterfowl habitat. An HGM perspective illustrated that the principal repair methods would recover inherent hydrologic functions in some cases, but substantially modify them in others (see Smith et al. 2008). Blocking ditches/drains in depressions and flats tends to re-establish natural rainfall-driven hydrologic regimes and functions, with added water control altering hydroperiod timing but not the basic functional type. Similarly, the breach/crossing practices applied on forested floodplains promote natural flooding dynamics and hydrologic connectivity. Conversely, on low-order riparian sites, installing small dams or impoundments produces an atypical 'depression-in-riverine' geomorphic setting. Gwin et al. (1999) had observed a similar pattern of depressions created within riparian wetlands for mitigation purposes—an exchange of one functional type for another. While enhancing water retention and allowing for periodic de-watering, these semi-enclosed riparian impoundments can reduce hydrologic and biogeochemical functions related to surface flows and flood pulsing (Smith et al. 2008). Impoundments on prior-agriculture floodplains can have similar effects but reflect practical trade-offs. Such tracts may be adjacent to other private farm properties, which constrains the ability to allow natural river flooding. Instead, managed moist-soil units and excavated swales add hydrologic variety to agriculturally leveled sites, while retaining the flood-control dikes that provide landowner access to the mix of open and reforested habitats.

WRP Project Success

Whether wetlands were restored or modified, the field surveys indicated that most projects (85–87 %) are providing functional hydrology and wetland habitat. Diverse vegetation communities were dominated by native hydrophytic species that are common in natural wetlands. Some potentially invasive species occurred locally, but non-natives appeared less frequent overall compared to other regions where exotics may comprise >20 % of the restored flora (e.g., Aronson and Galatowitsch 2008; Gleason et al. 2008). Consistent with their younger successional age, prior-agricultural sites had more open vegetation communities, sometimes with remnant old-field species. Few other field indicators differed based on prior habitat status, suggesting that restoration improved wetland conditions in the more degraded agricultural sites relative to already vegetated sites. Wetland and aquatic fauna were seen at many project sites, although frequency of habitat use or species-specific habitat quality could not be quantified.

Achieving close resemblance to reference wetlands is not an explicit success goal for WRP projects, partly because they are not compensatory for permitted wetland losses. At minimum, the project sites had a plant composition indicative of native wetlands, but more complete floristic data would be needed to evaluate similarity to possible reference plant communities. The task is complex for Southeastern wetlands, where the historic communities are often unknown and where species composition is highly variable. Riverine wetlands are naturally forested, but depressions and flats can support a range of vegetation types depending upon temporal variability in hydroperiod, frequency of fire, and other factors (De Steven and Lowrance 2011). We would expect the greatest floristic divergence from natural communities in the managed wetlands, which are maintained in early-succession stages with a relatively narrow suite of plant species. Wetlands that were vegetated before restoration would likely be more similar to natural communities.

A small percentage of WRP projects (11–15 %) appeared to be less successful hydrologically, possibly reflecting incompatibility between project goals and site hydrogeomorphic limitations. Most of the drier sites were depressions and flats, some of which can have inherently temporary or saturation-driven hydroperiods that cannot be enhanced easily (Rheinhardt et al. 2002; De Steven et al. 2010). The remaining drier sites were first-order stream features that may naturally flood only temporarily or intermittently, resulting in unsuccessful enhancement with ditch plugs or dikes. Failure to recognize such site limitations can lead to unsatisfactory outcomes relative to expectations, particularly when the goal is a floodable waterfowl pond. Even where a practice can enhance water retention, inappropriate application may result in poor wetland quality (Euliss et al. 2008). For example, we noted that on two agricultural floodplains where deep macrotopography had been excavated, the resulting ponds were stagnant with turbid water, anoxic sediments, and depauperate biota. Attention to HGM settings could improve project success by identifying site-compatible practices and realistic expectations for hydrology restoration. Projects that re-establish or mimic natural processes are most likely to be self-sustaining in the long run (Smith et al. 2008). For example, inherently drier wetland sites that may not be favorable for waterfowl could still provide important habitat for other fauna (e.g., amphibians) that rely on temporary or highly dynamic hydroperiods (e.g., Snodgrass et al. 2000).

Implications for Ecosystem Services and Assessment

The variety of program wetlands has implications for ecosystem services at local and landscape scales. Most Southeast Coastal Plain states have relatively few WRP enrollments (20–50 per state) compared to high numbers in some agriculture-dominant regions (>400–500 per state), although South Carolina now has >200 contracts (NRCS data; cf. De Steven and Lowrance 2011). Because landowner participation is opportunistic, most Southeastern project types (depression, flat, low-order riparian, farmed floodplains) are spatially scattered and would provide ecosystem services mainly at a local scale. These projects have varied easement sizes that reflect both wetland geomorphology and the amounts of land that landowners offer for enrollment; however, native wetland plant communities may be supported irrespective of wetland type and size. Smaller wetland easements might lack sufficient area to form core habitat for some wildlife species, but they could still provide corridor or stepping-stone areas to larger wetland habitats within the regional forest-mosaic landscape. Local wetland functions (hydrologic, biogeochemical, biologic) may vary with the extent of restored upland buffer habitat, which differed considerably among easements. Targeted studies that quantify the ecosystem services of these local projects could assist future project planning by identifying ways to optimize multiple environmental benefits (Brinson and Eckles 2011).

Compared to other project types, the forested floodplain projects offer unique potential to provide ecosystem services at a watershed/landscape scale by encompassing large, topographically complex areas. Easements typically span the breadth of a floodplain or braided channel system from the river to the upland terrace. With restoration methods that encourage natural floodplain hydrodynamics, there are synergistic benefits for habitat, floodwater storage, water quality, and other riverine functions that also affect environmental quality in downstream estuarine habitats. Total area of floodplain tracts in South Carolina had reached 19,000 ha by 2010, with nearly all in perpetual easements (SC-NRCS State Office data). In several river systems, the program was able to assemble small groups of adjacently owned tracts, ranging singly from 20 to 1,100 ha, into larger patches of river corridor habitat totaling 250–1,600 ha (2.5–16 km^2) or more. The field visits suggested that these degraded floodplain tracts have vigorous tree regeneration, though it will take many years to assess the eventual forest composition and stand quality. Long-term prospects for recovery are favorable, given that the harvested forests had successfully regrown from widespread historic logging during the previous century (Sharitz and Mitsch 1993; Lockaby et al. 1997).

The study results will assist future CEAP–Wetlands efforts to develop regional models for quantifying the ecosystem services delivered by wetland practices and programs. Conceptually, the Southeastern WRP sites reflect a complex condition gradient from highly degraded to minimally disturbed, including sites restored from row-cropping, grazing, timber-harvest, or simple drainage. Restoration practices seek to 'move' degraded sites closer to natural wetland functioning (NRCS 2006). Knowledge of wetland types is key to understanding the principal services affected as well as the potential trade-offs resulting from choice of practices and goals. Initial habitat condition offers a means to estimate 'gains' in services, since semi-natural vegetated sites have likely retained or recovered some wetland functions compared to more degraded and younger agricultural sites. While the scope of the WRP allows for a variety of targeted goals, incorporating an HGM and site-condition framework could improve assessments of cumulative benefits and performance relative to regional resource concerns (Brinson and Eckles 2011).

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