

DE-AI09-00SR22188

TECHNICAL REPORT

2004

04-14-R

**Vegetation Establishment Success in Restored Carolina Bay Depressions on the  
Savannah River Site, South Carolina – Phase One**

**Final Report**

Cooperative Agreement No. 01-CA-11330135-457  
between  
The University of Georgia Research Foundation  
and  
The USDA Forest Service, Southern Research Station

Rebecca R. Sharitz  
and  
John M. Mulhouse  
Savannah River Ecology Laboratory  
Drawer E  
Aiken, SC 298902

May 2004

Station Representative/Project Coordinator:  
Diane De Steven  
Center for Forested Wetlands Research  
USDA Forest Service, Southern Research Station,  
Charleston SC

*Received 7/21/04*

**Summary:** Successful wetlands restoration must re-establish or enhance three parameters: wetland hydrology, hydric soils, and hydrophytic vegetation (Mitsch and Gosselink 2000). On the Savannah River Site, South Carolina, restoration of small Carolina bay depression-wetlands was initiated in FY 2001 to provide wetland acreage for mitigation banking (US DOE 1997). Sixteen small depressions that had historically been drained for agricultural purposes were selected for restoration, and an additional four were initially chosen to serve as non-restored controls. Restoration treatments included plugging the existing ditches to increase water volume retention and wetland hydroperiod and clear-cutting removal of woody vegetation in the interiors. Planned endpoints of the restoration were herbaceous meadow and forested savanna bay interiors, and pine savanna and pine/hardwood forested bay margins (Barton and Singer 2001). To promote forested savanna interiors, saplings of bald cypress and swamp tupelo were planted following removal of the woody species.

A pre-restoration vegetation survey conducted in the summer of 2000 revealed that the bays were relatively similar in species richness and composition, with a few exceptions. All contained wetland species (obligate or facultative wetland) in their interiors, though some bays had very few. The 2001 vegetation survey that followed the removal of woody vegetation from the bay interiors revealed a substantial increase in groundcover species richness and, despite drought conditions, an increase in the abundance of wetland species. By 2002, species richness declined somewhat in most bays. However, by 2003, following heavy rains and increased inundation in the bays, the number of species decreased considerably; those that remained were chiefly wetland herbaceous species and facultative woody species. Successful establishment and survival of cypress saplings in the forested savanna bays was higher than that of tupelo during the first year following planting. This trend continued and by 2003 tupelo survival was very low (usually less than 30%). The average height of cypress saplings by 2003 was almost always  $>1$  m. Richness of woody species in shrub plots by 2003 averaged 8 (s.e. 0.8), the majority of which were facultative. Many of these were sprouts from the cut stumps. Hardwoods were essentially removed from the pine savanna upland margins during thinning, while some pines remained. Both hardwoods and pines were abundant in the pine/hardwood bay margins. Annual monitoring is expected to continue for five years post-restoration as required to evaluate restoration success and for crediting the restored acreage into the mitigation bank.

**Introduction:** Substantial losses of wetlands in the United States have led to increased concern for protection of wetland resources and for restoration of degraded wetland ecosystems. In the southeastern Atlantic Coastal Plain, small Carolina bay wetlands have been severely altered by human activities, especially ditching, draining, and conversion to agricultural use. Carolina bays are shallow elliptical depressions, which range from seasonally saturated to semi-permanently inundated, and are of ecological significance as habitat for several biological communities and rare species (Sharitz 2003). There are approximately 300 Carolina bays and “bay-like” depressions on the Department of Energy’s Savannah River Site (SRS), of which more than two-thirds were ditched or disturbed prior to federal occupation (Kirkman et al. 1996).

The SRS Carolina bay restoration project was initiated, in part, to provide restored wetland acreage for mitigation banking on the site (US DOE 1997). It is a collaborative effort of the US Forest Service (both the Savannah River Institute on the SRS and the Center for Forested Wetlands Research (CFWR) in Charleston, SC), the Savannah River Ecology Laboratory (SREL), and investigators from several regional universities. In the context of wetland mitigation, the restoration effort has three components: 1) to restore wetland hydrologic conditions in bays that historically were ditched and drained, 2) to document hydric soil features after hydrologic restoration, and 3) to restore the vegetation to predominantly hydrophytic species. The SREL component of this restoration focuses on the vegetation, in collaboration with the CFWR.

To restore the vegetation, experimental treatments were designed to promote two different wetland communities in the interiors of the bays: 1) open herbaceous meadow, and 2) forested wetland savanna. Restoration of both types is desirable for enhancing landscape-level biodiversity since the two communities have different plant composition (De Steven and Toner 1997, 2004) and may support different wildlife assemblages (Kilgo 1999). In addition, because of debate about the impacts of buffer-zone structure and management on wetland properties and wildlife usage (Burke and Gibbons 1995, Semlitsch 1998, Buhlmann and Gibbons 2001), the treatments were designed to evaluate how two alternative strategies for bay margin management affect the structure and function of the restored wetlands. One strategy is to manage the margins as unburned, closed-canopy mixed pine-hardwoods, and the other is to manage the margins as open-canopy pine woodlands that are periodically burned.

Sixteen small depressions were selected for restoration, and four control (un-restored) sites were initially selected for comparison (Table 1). All twenty bays had been previously ditched and drained, and all contained trees, many of facultative status. Restoration treatments included plugging the existing ditches to increase water volume retention and wetland hydroperiod, and clear-cutting removal of woody vegetation in the interiors of the depressions. Eight of the bays were designated to be “herbaceous interior” bays, and restoration of wetland vegetation relied on natural re-colonization of species from the seed bank and from dispersal. It was anticipated that soil disturbance resulting from timber removal, associated with a recovery of wetland hydrologic conditions, would promote the development of herbaceous emergent wetland vegetation. To promote development of forested wetland savannas in the interiors of the remaining

eight bays, saplings of bald cypress (*Taxodium distichum*) and swamp tupelo (*Nyssa sylvatica* var. *biflora*) were planted at an approximate density of 300 saplings/acre in each of the "forested interior" bays (Table 1).

For mitigation purposes, yearly monitoring of the hydrologic condition, soils, and vegetation development is required over a five-year period following restoration (US DOE 1997). Success of vegetation restoration is best evaluated by measuring changes in species composition and coverage from the pre-restoration condition, since it may take much longer than five years to achieve the full composition of species that is characteristic of unimpacted "reference" wetlands (especially for forested systems). A pre-restoration vegetation survey of all bays was performed in the summer of 2000, prior to clear-cutting and closure of the ditches (see Sharitz 2002). One bay (147) was subsequently determined to be a functioning wetland and was omitted as a control. The goal of this final report is to provide summaries of vegetation response during the 2001, 2002, and 2003 growing seasons.

Table 1. Restored and control Carolina bays, with designated margin and interior experimental treatments.

Bay No.	Size in Hectares (Acres)	Margin Treatment	Interior Treatment
5	1.19 (2.95)	P/H	H
108	1.05 (2.61)	Control	Control
118	1.04 (2.57)	Control	Control
124	0.86 (2.12)	P	F
126	1.53 (3.78)	P	H
131	1.04 (2.57)	P	F
147*	3.32 (9.21)	Control	Control
171	1.42 (3.52)	P/H	H
5001	0.54 (1.35)	P/H	H
5011	0.95 (2.34)	P	H
5016	0.78 (1.92)	P/H	F
5055	0.30 (0.75)	Control	Control
5071	0.85 (2.12)	P/H	F
5092	1.36 (3.37)	P	F
5128	0.77 (1.83)	P/H	F
5135	0.28 (0.69)	P	H
5184	0.81 (2.02)	P	F
5190	0.60 (1.49)	P	H
5204	0.66 (1.63)	P/H	F
5239	1.70 (4.21)	P/H	H

Margin treatments: P = pine savanna, P/H = pine hardwood.

Interior treatments: H= herbaceous meadow, F = forested savanna. \*147 was subsequently omitted as a control site since it had not been effectively drained and had retained wetland vegetation.

**Methods:** Protocols for pre-restoration vegetation sampling within the interiors and margins of the bays were described in Sharitz (2002) and summarized in the revised project study plan (De Steven and Sharitz 2003). During the summer of 2001, eight permanently marked plots (each 2 x 2 m) were established in the interiors of the 16 restoration bays to be used for post-restoration monitoring of the herbaceous vegetation. Plots were arrayed along four transects extending from the center or deepest area outward to the margin of each bay in such a way as to sample both central and peripheral areas of the wetland. All groundlayer plant species ( $\geq 1$  m) were identified and their coverage recorded as cover classes (using a Daubenmire scale) in the summers of 2001, 2002, and 2003. The mid-points of the assigned cover classes were used to compute total and relative percent cover by Region 2 National Wetland Indicator (NWI) category (Reed 1988).

In 2003, the 2 x 2 m groundlayer plots in the 16 restored bays were expanded to 5 x 5 m, and woody species  $\geq 1$  m were identified and their cover determined in the expanded plots. Again, mid-points of cover classes were used to calculate total and relative percent cover by NWI category. In addition, upland margins of the eight pine savanna bays (thinned margins) were re-sampled in 2002 following the same protocols used in the pre-restoration sampling. Basal area ( $m^2/ha$ ) of stems  $\geq 10$  cm diameter at breast height (dbh) was calculated for pine and hardwood species. These measurements and calculations were similar to those done for the wetland interiors of the bays prior to restoration.

In May 2001, 100 saplings each of bald cypress and swamp tupelo (if available) were marked in each of the planted bays, and their initial heights measured. Survival and growth were measured again at the end of the first growing season, and over-winter survival was assessed in May 2002 and 2003. Height of saplings was measured in May 2003. This direct measure of actual survival of a marked sample of the planted population of woody saplings in each bay provides the most accurate measure of tree establishment success.

**Results:** Richness of the groundcover vegetation in the interiors of the bays averaged 21 species prior to restoration (Table 2), and increased to an average of 43 species in 2001 (Table 3). In 2002, richness averaged 36 species (Table 4), but by 2003 had declined to 13 species as, following heavy winter rains and subsequent inundation of the bay interiors, many species unable to survive inundation disappeared (Table 5). Before restoration, most vegetation cover was comprised of facultative species, although wetland species were present (Table 2). Directly following restoration, the abundance of wetland species increased (Table 3), yet by 2002, the drought conditions had resulted in a decrease in these species and an expansion of non-hydric vegetation (Table 4). Substantial rainfall in the winter of 2002 drastically reduced overall cover by 2003; non-hydric species declined, and obligate wetland species were the majority of the remaining vegetation (Table 5). The richness of woody vegetation in wetland interiors by 2003 averaged 8 (s.e. 0.8) species, and the vast majority of cover was comprised of facultative species (Table 6). *Liquidambar styraciflua* was the most widespread species in eight

bays, while *Acer rubrum*, *Quercus* spp., and *Pinus* spp. were abundant at several sites.

In 2000, the basal area of hardwoods was generally higher than that of pines in the wetland interiors, often because pine was essentially absent (Table 7). There were four bays in which an obligate wetland species (*Nyssa biflora*) was observed and only one in which an upland species (*Quercus velutina*) was recorded; all other woody species were facultative wetland or facultative. These trees were removed from the bay interiors during the restoration process. The basal area of pines in the bay margins prior to restoration was nearly four times greater than that of hardwoods. By 2002, following restoration, thinning of the eight pine savanna margins reduced average hardwood basal area to  $0.6 \text{ m}^2/\text{ha}$  (s.e. 0.4) from a pre-thinning average of  $4.5 \text{ m}^2$  (s.e. 0.6; Table 7). This average is greater than the actual post-restoration basal area in most of the bay margins due to a relatively high post-thinning basal area of hardwoods in the margin of one bay (5135). The average basal area of pine dropped from  $18.2 \text{ m}^2/\text{ha}$  (s.e. 3.2) to  $6.9 \text{ m}^2/\text{ha}$  (s.e. 0.6). No thinning was performed in the pine/hardwood margin treatments.

At the time of planting, bald cypress saplings were taller than water tupelo saplings (Tables 8 and 9). While there was very little change in the height of either species during the first growing season, by 2003 the mean height of cypress saplings ranged from 89.7 cm to 164.2 cm and was below 1 m only in Bay 5184, which had been planted initially with just 24 trees. Generally, tupelo heights also increased in each bay by 2003 (mean = 41.4–82.9 cm), although, due to almost complete mortality in one bay, the overall mean remained the same as 2001 (54.0 cm; Table 9). Tupelo survivorship was consistently low; 2–75% (mean = 25%; s.e. 8) of saplings were alive by 2003 (Table 9). Survival of cypress was much higher than tupelo by the summer of 2003 (54–96%) and, overall, more than 80% (s.e. 5) of the cypress plantings had persisted (Table 8).

Table 2. Species richness of the 2000 (prior to restoration) groundcover vegetation in control and restored Carolina bays. Also presented is the total percent cover (and number of species) and relative percent cover comprised by National Wetland Indicator (NWI) categories.

Bay No.	Total No. Spp.	Spp. ID'd	Cover 2000			Relative cover 2000		
			Obl/Facw %	Fac %	Non-hydric%	Obl/Facw %	Fac %	Non-hydric%
<i>Controls</i>								
108	26	26	1.4 (3)	28.5 (14)	6.0 (9)	0.04	0.79	0.17
118	13	11	0.1 (2)	1.8 (9)	0.0 (0)	0.06	0.94	0.00
5055	36	30	7.2 (10)	24.4 (12)	8.9 (8)	0.18	0.60	0.22
<b>mean</b>	<b>25</b>	<b>22</b>	<b>2.9 (8)</b>	<b>18.2 (12)</b>	<b>5.0 (9)</b>	<b>0.09</b>	<b>0.78</b>	<b>0.13</b>
<b>s.e. (n=3)</b>	<b>6.7</b>		<b>2.2 (2.5)</b>	<b>8.3 (3.5)</b>	<b>2.6 (2.8)</b>	<b>0.04</b>	<b>0.10</b>	<b>0.07</b>
<i>Restored</i>								
5	29	23	80.8 (12)	6.6 (10)	0.04 (1)	0.92	0.08	0.00
124	16	14	3.0 (3)	13.4 (8)	0.1 (3)	0.18	0.81	0.01
126	20	18	1.5 (3)	24.0 (11)	0.3 (4)	0.06	0.93	0.01
131	11	11	3.0 (3)	18.5 (8)	0.0 (0)	0.14	0.86	0.00
171	27	25	18.1 (10)	18.5 (10)	1.0 (5)	0.48	0.49	0.03
5001	21	21	2.1 (6)	11.3 (11)	7.3 (4)	0.10	0.55	0.35
5011	15	14	18.7 (5)	3.3 (7)	0.2 (2)	0.85	0.15	0.01
5016	17	16	10.2 (8)	0.8 (8)	0.0 (0)	0.93	0.07	0.00
5071	28	28	3.1 (4)	63.2 (13)	18.9 (11)	0.04	0.74	0.22
5092	25	22	4.0 (6)	9.4 (12)	0.4 (4)	0.29	0.68	0.03
5128	12	12	0.3 (2)	6.3 (9)	1.5 (1)	0.04	0.78	0.19
5135	17	16	17.5 (5)	7.3 (7)	1.6 (4)	0.66	0.28	0.06
5184	25	21	5.6 (4)	22.2 (12)	2.0 (5)	0.19	0.75	0.07
5190	34	32	1.3 (4)	25.4 (16)	20.0 (12)	0.03	0.54	0.43
5204	5	5	0.0 (1)	2.0 (3)	1.3 (1)	0.01	0.61	0.38
5239	18	16	2.1 (4)	19.8 (10)	0.5 (2)	0.09	0.88	0.02
<b>mean</b>	<b>21</b>	<b>19</b>	<b>9.5 (5)</b>	<b>16.1 (10)</b>	<b>3.7 (4)</b>	<b>0.28</b>	<b>0.61</b>	<b>0.12</b>
<b>s.e. (n=19)</b>	<b>1.9</b>		<b>4.2 (0.7)</b>	<b>3.3 (0.7)</b>	<b>1.4 (0.8)</b>	<b>0.07</b>	<b>0.06</b>	<b>0.03</b>

NWI category follows Reed (1988). Obl/Facw% indicates wetland species with an NWI category of Facw or wetter. Fac% indicates Fac+ and Fac species. Jurisdictional guidelines consider Fac and Fac+ species to be hydrophytic.

Table 3. Species richness of the 2001 groundcover vegetation of control and restored Carolina bays. Also presented is the total percent cover (number of species) and relative percent cover comprised by National Wetland Indicator (NWI) categories.

Bay No.	Total No. Spp.	Spp. ID'd	Cover 2001			Relative cover 2001		
			Obl/ Facw%	Fac %	Non-Hydric%	Obl/ Facw%	Fac %	Non-Hydric%
<i>Controls</i>								
108	23	21	0.4 (6)	12.1 (17)	1.1 (9)	0.03	0.89	0.08
118	8	7	0.1 (2)	0.7 (6)	0.0 (0)	0.15	0.85	0.00
5055	20	17	18.1 (5)	4.3 (11)	2.1 (4)	0.74	0.17	0.08
<b>Mean</b>	<b>17</b>	<b>15</b>	<b>6.2 (4)</b>	<b>5.7 (11)</b>	<b>1.0 (4)</b>	<b>0.31</b>	<b>0.64</b>	<b>0.05</b>
<b>s.e. (n=3)</b>	<b>4.6</b>		<b>5.9 (1.2)</b>	<b>3.4 (3.2)</b>	<b>0.6 (2.6)</b>	<b>0.22</b>	<b>0.23</b>	<b>0.03</b>
<i>Restored</i>								
5	.	.	.	.	.	.	.	.
124	60	59	21.9 (29)	22.7 (13)	7.5 (7)	0.42	0.44	0.14
126	55	52	49.4 (22)	62.8 (14)	22.8 (16)	0.37	0.47	0.17
131	6	5	0.5 (3)	11.9 (2)	0.0 (0)	0.04	0.96	0.00
171	44	41	95.7 (29)	38.8 (8)	0.4 (4)	0.71	0.29	0.00
5001	53	49	13.4 (27)	16.0 (14)	6.6 (8)	0.37	0.44	0.18
5011	42	41	69.9 (24)	4.1 (9)	1.3 (8)	0.93	0.05	0.02
5016	18	16	23.5 (11)	1.5 (5)	0.0 (0)	0.94	0.06	0.00
5071	42	42	20.1 (14)	72.1 (13)	24.8 (15)	0.17	0.62	0.21
5092	61	59	51.9 (22)	40.9 (13)	57.4 (24)	0.35	0.27	0.38
5128	49	45	59.2 (24)	7.7 (12)	3.1 (9)	0.85	0.11	0.04
5135	27	26	77.3 (9)	6.7 (10)	3.3 (7)	0.89	0.08	0.04
5184	66	52	12.2 (22)	26.9 (17)	8.3 (13)	0.26	0.57	0.17
5190	43	39	20.6 (15)	81.3 (12)	35.6 (12)	0.15	0.59	0.26
5204	41	36	8.2 (17)	13.7 (10)	10.5 (9)	0.25	0.42	0.32
5239	45	44	26.9 (25)	16.5 (8)	13.6 (11)	0.47	0.29	0.24
<b>mean (w/o 5)</b>	<b>43</b>	<b>40</b>	<b>36.7 (20)</b>	<b>28.2 (11)</b>	<b>13.0 (10)</b>	<b>0.48</b>	<b>0.38</b>	<b>0.15</b>
<b>s.e.(n=15)</b>	<b>4.2</b>		<b>7.4 (2.0)</b>	<b>6.6 (1.0)</b>	<b>4.2 (1.7)</b>	<b>0.08</b>	<b>0.07</b>	<b>0.03</b>

Bay 5 was not sampled in 2001 as this bay was not harvested and therefore no woody vegetation was removed. Thus, vegetation was assumed to be similar to that in 2000. NWI category follows Reed (1988). Further explanations as in Table 2.

Table 4. Species richness of the 2002 groundcover vegetation of control and restored Carolina bays. Also presented is the total percent cover (number of species) and relative percent cover comprised by National Wetland Indicator (NWI) categories.

Bay No.	Total No. Spp.	Spp. ID'd	Cover 2002			Relative cover 2002		
			Obl/ Facw%	Fac %	Non-Hydric%	Obl/ Facw%	Fac %	Non-Hydric%
<i>Controls</i>								
108	24	22	0.2 (3)	10.7 (13)	2.6 (6)	0.01	0.80	0.19
118	7	7	0.1 (1)	0.9 (5)	0.1 (1)	0.06	0.88	0.06
5055	15	14	0.1 (1)	3.9 (8)	8.4 (5)	0.01	0.32	0.68
<b>Mean</b>	<b>15</b>	<b>14</b>	<b>0.1 (2)</b>	<b>5.2 (9)</b>	<b>3.7 (4)</b>	<b>0.03</b>	<b>0.66</b>	<b>0.31</b>
<b>s.e. (n=3)</b>	<b>4.9</b>		<b>0.0 (0.7)</b>	<b>2.9 (2.3)</b>	<b>2.5 (1.5)</b>	<b>0.02</b>	<b>0.18</b>	<b>0.19</b>
<i>Restored</i>								
5	41	39	35.6 (19)	13.1 (11)	6.0 (9)	0.65	0.24	0.11
124	40	39	23.4 (18)	22.1 (10)	8.9 (11)	0.43	0.41	0.16
126	36	36	23.1 (12)	60.1 (13)	27.5 (11)	0.21	0.54	0.25
131	21	21	20.0 (10)	18.6 (6)	31.4 (5)	0.29	0.27	0.45
171	27	27	37.8 (12)	28.5 (9)	6.7 (6)	0.52	0.39	0.09
5001	48	47	36.5 (23)	17.3 (14)	32.0 (10)	0.43	0.20	0.37
5011	33	32	33.7 (14)	15.1 (8)	14.2 (10)	0.53	0.24	0.23
5016	23	22	26.8 (10)	1.8 (7)	5.3 (5)	0.79	0.05	0.16
5071	36	33	1.4 (9)	43.8 (12)	19.9 (12)	0.02	0.67	0.31
5092	55	53	17.9 (13)	29.0 (16)	34.5 (24)	0.22	0.36	0.42
5128	30	29	52.8 (18)	10.8 (6)	2.5 (5)	0.80	0.16	0.04
5135	25	25	23.6 (8)	13.0 (9)	3.1 (8)	0.59	0.33	0.08
5184	46	43	7.9 (14)	25.3 (19)	28.3 (10)	0.13	0.41	0.46
5190	36	36	24.6 (12)	25.1 (13)	15.4 (11)	0.38	0.38	0.24
5204	28	28	13.5 (13)	14.2 (7)	14.1 (8)	0.32	0.34	0.34
5239	48	44	12.4 (16)	14.4 (12)	43.4 (16)	0.18	0.20	0.62
<b>mean</b>	<b>36</b>	<b>35</b>	<b>24.4 (14)</b>	<b>22.0 (11)</b>	<b>18.3 (10)</b>	<b>0.41</b>	<b>0.32</b>	<b>0.27</b>
<b>s.e.(n=16)</b>	<b>2.5</b>		<b>3.2 (1.0)</b>	<b>3.5 (0.9)</b>	<b>3.2 (1.2)</b>	<b>0.06</b>	<b>0.04</b>	<b>0.04</b>

Bay 5 interior was harvested manually in early 2002. NWI category follows Reed (1988). Further explanations as in Table 2.

Table 5. Species richness of the 2003 groundcover vegetation of control and restored Carolina bays. Also presented is the total percent cover (number of species) and relative percent cover comprised by National Wetland Indicator (NWI) categories. Due to high water, some bays had fewer than eight plots, as noted below.

Bay No.	No. Plots	Cover 2003				Relative cover 2003		
		Total No. Spp.	Spp. ID'd	Obl/ Facw%	Fac %	Non-hydric%	Obl/ Facw%	Fac %
<i>Controls</i>								
108	8	23	21	0.3 (5)	6.6 (12)	3.9 (4)	0.03	0.61
118	0	.	.	.	.	.	.	0.36
5055	8	17	17	0.1 (2)	21.9 (12)	11.1 (3)	0.00	0.66
<b>Mean</b>	<b>20</b>	<b>19</b>		<b>0.2 (4)</b>	<b>14.3 (12)</b>	<b>7.5 (4)</b>	<b>0.02</b>	<b>0.64</b>
<b>s.e (n=2)</b>	<b>3.0</b>			<b>0.1 (1.5)</b>	<b>7.7 (0)</b>	<b>3.6 (0.5)</b>	<b>0.02</b>	<b>0.03</b>
<i>Restored</i>								
5	8	12	12	24.8 (7)	3.7 (5)	0.0 (0)	0.87	0.13
124	8	35	35	11.8 (20)	28.8 (10)	1.3 (5)	0.28	0.69
126	5	8	8	1.7 (4)	1.5 (4)	0.0 (0)	0.53	0.47
131	4	5	5	0.9 (2)	1.0 (3)	0.0 (0)	0.47	0.53
171	6	4	4	0.1 (1)	2.8 (3)	0.0 (0)	0.03	0.97
5001	8	8	7	0.4 (2)	4.6 (5)	0.0 (0)	0.09	0.91
5011	8	25	25	42.3 (18)	11.9 (4)	0.3 (0)	0.78	0.22
5016	4	6	6	21.6 (5)	0.3 (1)	0.0 (0)	0.99	0.01
5071	8	17	16	5.8 (7)	14.3 (8)	0.4 (1)	0.28	0.70
5092	8	13	13	4.3 (8)	2.5 (5)	0.0 (0)	0.63	0.37
5128	8	16	15	3.3 (10)	18.1 (5)	0.0 (0)	0.15	0.85
5135	8	11	11	9.5 (5)	19.3 (6)	0.0 (0)	0.33	0.67
5184	8	24	23	4.3 (10)	10.8 (12)	0.1 (1)	0.28	0.71
5190	8	4	4	34.9 (3)	0.1 (1)	0.0 (0)	1.00	0.00
5204	8	10	10	56.7 (6)	18.9 (4)	0.0 (0)	0.75	0.25
5239	7	12	12	4.1 (7)	3.8 (5)	0.0 (0)	0.52	0.48
<b>Mean</b>	<b>13</b>	<b>13</b>		<b>14.1 (7)</b>	<b>8.9 (5)</b>	<b>0.1 (1)</b>	<b>0.50</b>	<b>0.50</b>
<b>s.e.(n=16)</b>	<b>2.2</b>			<b>4.3 (1.3)</b>	<b>2.2 (0.7)</b>	<b>0.1 (0.4)</b>	<b>0.08</b>	<b>0.002</b>

NWI category follows Reed (1988). Further explanations as in Table 2.

Table 6. Richness of woody species >1 m tall in 5 x 5 m plots in restored Carolina bays in 2003. Also shown is the total mean percent cover (and richness (*n*)) comprised by National Wetland Indicator (NWI) categories. The relative percent cover of species in each indicator category is also presented.

Bay No.	Total No. Species	Cover 2003			Relative cover 2003		
		Obl/ Facw%	Fac %	Non- hydric%	Obl/ Facw%	Fac %	Non- hydric%
5	8	0.6 (2)	23.4 (6)	0.0 (0)	2.3	97.7	0.0
124	13	1.3 (2)	59.1 (7)	1.1 (4)	2.1	96.1	1.7
126	7	10.6 (1)	12.2 (4)	8.1 (2)	34.3	39.5	26.2
131	7	1.0 (2)	1.4 (5)	0.0 (0)	42.1	57.9	0.0
171	8	3.2 (1)	10.9 (7)	0.0 (0)	22.5	77.5	0.0
5001	9	0.1 (2)	14.9 (7)	0.0 (0)	0.8	99.2	0.0
5011	7	0.1 (1)	24.4 (5)	0.4 (1)	0.3	98.0	1.8
5016	6	1.0 (1)	5.4 (5)	0.0 (0)	15.7	84.3	0.0
5071	11	1.0 (2)	29.9 (9)	0.0 (0)	3.2	96.8	0.0
5092	12	10.3 (4)	8.3 (8)	0.0 (0)	55.0	44.6	0.3
5128	9*	0.1 (1)	22.8 (7)	0.0 (0)	0.3	99.7	0.0
5135	8	2.3 (1)	24.0 (6)	0.1 (1)	0.1	90.9	0.003
5184	10	2.7 (4)	14.4 (6)	0.0 (0)	15.8	84.2	0.0
5190	0	0.0 (0)	0.0 (0)	0.0 (0)	0.0	0.0	0.0
5204	7	0.4 (1)	24.1 (6)	0.0 (0)	1.5	98.5	0.0
5239	11	1.3 (4)	19.1 (7)	0.0 (0)	6.3	93.7	0.0
<b>Mean</b>	<b>8</b>	<b>2.3 (2)</b>	<b>18.4 (6)</b>	<b>0.6 (1)</b>	<b>12.6</b>	<b>78.7</b>	<b>1.9</b>
<b>s.e. (<i>n</i>=16)</b>	<b>0.8</b>	<b>0.8 (0.3)</b>	<b>3.5 (0.5)</b>	<b>0.5 (0.3)</b>	<b>4.3</b>	<b>7.2</b>	<b>1.6</b>

NWI category follows Reed (1988). Further explanations as in Table 2.

Table 7. Total basal area ( $m^2/ha$ ) of hardwood and pine species  $\geq 10$  cm dbh in the interior of control and restored Carolina bays prior to restoration. Also shown are total basal area ( $m^2/ha$ ) of hardwood and pine species in the upland margins prior to and following restoration. Only bays with thinned margins were re-sampled in 2002. Averages are presented for all bays in the interior and upland 2000 samples and the post-restoration basal areas of the eight bays re-sampled in 2002 are compared to the pre-restoration areas of those bays in 2000.

Bay no.	Interior 2000		Upland 2000		Upland 2002	
	Hardwood	Pine	Hardwood	Pine	Hardwood	Pine
5	8.2	1.7	0.0	0.0	X	X
108	20.1	0.0	3.7	26.2	X	X
118	15.3	3.3	0.0	0.0	X	X
124	21.5	0.0	3.3	23.3	0.6	9.1
126	21.7	0.0	6.1	14.7	0.3	5.3
131	7.7	0.0	2.3	35.2	0.6	7.2
171	12.5	0.0	8.0	11.6	X	X
5001	4.4	38.5	3.8	18.4	X	X
5011	11.1	0.0	4.8	16.4	0.0	5.6
5016	13.5	0.0	8.5	13.5	X	X
5055	16.5	0.3	5.9	15.1	X	X
5071	11.6	44.0	9.3	17.9	X	X
5092	45.4	0.0	5.2	19.0	0.0	8.9
5128	7.2	14.5	2.2	17.4	X	X
5135	9.8	6.3	5.3	8.8	3.1	6.3
5184	26.9	13.8	6.7	6.5	0.0	4.8
5190	28.4	30.7	2.1	21.9	0.0	8.0
5204	48.2	0.0	5.0	24.2	X	X
5239	34.9	9.4	5.0	14.0	X	X
<b>mean</b>	<b>19.2</b>	<b>8.5</b>	<b>4.6</b>	<b>16.0</b>		
<b>s.e.(n=20)</b>	<b>2.8</b>	<b>3.1</b>	<b>0.6</b>	<b>1.9</b>		
<b>mean</b>			<b>4.5</b>	<b>18.2</b>	<b>0.6</b>	<b>6.9</b>
<b>s.e. (n=8)</b>			<b>0.6</b>	<b>3.2</b>	<b>0.4</b>	<b>0.6</b>

Table 8. Survival and height (mean  $\pm$  standard deviation) of marked bald cypress (*Taxodium distichum*) saplings from May 2001 until May 2003.

Bay No.	No. of Saplings Marked	Mean Height 05/01			Mean Height 09/01			Mean Height 05/03		
		(cm)	S.D.	% Surviving 09/01	(cm)	S.D.	% Surviving 05/02	(cm)	S.D.	
124	100	103.9	15.8	92	102.8	27.6	91	87	115.6	41.2
131	100	99.0	18.4	88	88.7	31.0	85	79	111.8	40.3
5016	100	106.7	14.0	98	113.7	20.0	97	95	151.4	37.2
5071	100	105.9	17.2	92	113.2	22.8	90	84	122.6	38.4
5092	100	101.7	21.4	91	103.6	29.2	89	65	124.8	40.8
5128	100	101.1	16.5	98	104.7	19.8	97	96	130.6	33.0
5184	24*	96.8	18.7	71	73.2	33.0	58	54	89.7	36.2
5204	47*	110.7	24.7	96	134.9	35.5	96	91	164.2	43.9
<b>mean</b>		<b>103.2</b>		<b>90.8</b>	<b>104.4</b>		<b>87.9</b>	<b>81.8</b>	<b>126.3</b>	
<b>s.e. (n=8)</b>				<b>3</b>			<b>4</b>	<b>5</b>		

Height in 05/01 = initial height at planting; height in 09/01 = height at end of the first growing season; % surviving 05/02 = percent alive at beginning of second growing season; height in 05/03 = height at beginning of third growing season. \*total number of bald cypress found planted in these bays.

Table 9. Survival and height (mean  $\pm$  standard deviation) of marked water tupelo (*Nyssa sylvatica* var. *biflora*) saplings from May 2001 until May 2003.

Bay No.	No. of Saplings Marked	Mean Height 05/01			Mean Height 09/01			Mean Height 05/03		
		(cm)	S.D.	% Surviving 09/01	(cm)	S.D.	% Surviving 05/02	(cm)	S.D.	
124	100	60.1	17.0	68	51.2	21.3	52	26	75.9	21.6
131	100	62.0	14.8	82	54.5	21.9	47	12	76.1	17.7
5016	100	59.1	8.6	90	71.8	18.7	78	32	82.9	23.5
5071	100	51.4	13.8	75	48.9	15.1	60	17	42.5	19.9
5092	100	52.8	12.3	89	56.9	12.1	82	2	0	0
5128	100	51.7	14.4	85	54.8	13.6	82	75	61.4	13.9
5184	100	54.9	19.5	75	44.4	15.7	53	14	41.4	13.7
5204	100	56.7	18.4	71	52.4	18.2	47	18	51.7	16.3
<b>mean</b>		<b>56.1</b>		<b>79.5</b>	<b>54.4</b>		<b>62.6</b>	<b>25.1</b>	<b>54.0</b>	
<b>s.e. (n=8)</b>				<b>3</b>			<b>5</b>	<b>8</b>		

Tree heights in Bay 5092 were not measured during sampling in 2003 due to high water. Other explanations as provided for Table 8.

**Data Management:** Data files, including spreadsheets and metadata, are delivered to the Forest Service Project Coordinator, Diane De Steven, as they are completed. This is an ongoing process, and additional data files will be delivered as they are completed. To date, the following files have been delivered:

Ground layer vegetation:

1. CBayRestoration\_groundlayer\_2000.xls (groundlayer vegetation in the bay interiors and on the margins pre-restoration)
2. CBayRestoration\_groundlayer\_2001.xls (groundlayer vegetation in the bay interiors and on the margins of the 8 pine savanna bays first year post-restoration)
3. CBayRestoration\_groundlayer\_2002.xls (groundlayer vegetation in the bay interiors and on the margins year two following restoration)
4. CBayRestoration\_groundlayer\_2003.xls (groundlayer vegetation in the bay interiors and on the margins year three following restoration)

Wetland tree and shrub data:

5. CBayRestoration\_wetlandtreedata\_2000.xls (trees and shrubs in bay interiors pre-restoration)
6. CBayRestoration\_shrubdata\_2003.xls (shrubs in bay interiors and on the margins year three following restoration)

Upland tree data:

7. CBayRestoration\_uplandtreedata.xls (trees and shrubs around bay margins pre-restoration and around margins of the 8 pine savanna bays following thinning)

Planted sapling data:

8. CBayRestoration\_treeseedlings.xls (survival and height of planted cypress and tupelo saplings)

Seedbank data:

9. CBayRestoration\_seedbank\_final.xls (composition of seed bank of bays pre-restoration)

This completes Phase One of the study of vegetation establishment success in the restored Carolina bay depressions. Phase Two, which will continue the study into FY 2006, will be funded under a separate cooperative agreement between the Forest Service and the University of Georgia.

**Literature Cited:**

Barton, C. and J. Singer. 2001. *Carolina bay restoration: SRS wetland mitigation. Revision 1.* Center for Forested Wetlands Research, Charleston, SC. 101 p.

Buhlmann, K. A. and J. W. Gibbons. 2001. Terrestrial habitat use by aquatic turtles from a seasonally fluctuating wetland: implications for wetland conservation boundaries. *Chelonian Conservation and Biology* 4:115-127.

Burke, V.J. and J.W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: A case study of freshwater turtles in a Carolina bay. *Conservation Biology* 9:1365-1369.

De Steven, D. and R.R. Sharitz. 2003. Vegetation dynamics in restored Carolina bay depression wetlands on the Savannah River Site, South Carolina. Establishment report and study plan revision. 13 pp.

De Steven, D., and M. Toner. 1997. Gradient analysis and classification of Carolina bay vegetation: A framework for bay wetlands conservation and restoration. Report for USDA Forest Service, Savannah River Forest Station. 42 pp. + appendices.

De Steven, D. and M. Toner. 2004. Vegetation of Upper Coastal Plain wetlands: environmental templates and wetland dynamics within a landscape framework. *Wetlands* 24:23-42.

Kilgo, J. C. 1999. Avian community response to restoration of Carolina bays and management of surrounding buffers. Draft study plan for Savannah River Institute. 8 pp.

Kirkman, L. K., R. F. Lide, G. R. Wein and R. R. Sharitz. 1996. Vegetation changes and land-use legacies of depression wetlands of the western coastal plain of South Carolina 1951-1992. *Wetlands* 16:564-576.

Mitsch, W. J. and J. G. Gosselink. 2000. *Wetlands*. 3<sup>rd</sup> Ed. John Wiley & Sons, Inc. New York.

Reed, P. B. Jr. 1988. National list of plant species that occur in wetlands: 1988. U.S. Fish and Wildlife Service, NERC-88/23, St. Petersburg, FL.

Sharitz, R. R. 2002. Vegetation monitoring in restored Carolina bays. Project Report to USDA Forest Service, Savannah River Institute, New Ellenton, SC.

Sharitz, R. R. 2003. Carolina bay wetlands: unique habitats of the southeastern United States. *Wetlands*. 23:550-562.

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. *Conservation Biology* 12:1113-1119.