Nongame and Heritage Trust Publications

DISTRIBUTION AND STATUS OF CAROLINA BAYS IN SOUTH CAROLINA

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ABSTRACT

Carolina bays are elliptical depressions found in the unconsolidated sediments of the Atlantic Coastal Plain. Known to science since the late 1700's, their formation remains a mystery, though several theories have been proposed. Carolina bays share several characteristics aside from their elliptical shape. The long axes of all bays are aligned along a northwest-southeast direction, and many bays have deposits of thick sand along their southeast and northeast edges. Bays act as basins which collect rain water which they hold perched above the normal water table. Bays support a variety of plant communities, ranging from vegetated lakes to grass-sedge prairies to cypress-gum swamps.

In 1983, the South Carolina Heritage Trust Program initiated a survey of Carolina bays in South Carolina. Bays were identified on black and white aerial photography of the coastal plain counties provided by the U. S. Agricultural Stabilization and Conservation Service. Each bay was measured, examined for disturbance, plant cover and surrounding land use. Bays which were less than 30 percent disturbed became the subject of field work, the goal of which is to identify a series of bays for protection under the Heritage Trust Program. 2651 Carolina bays, two acres or larger, were identified from 29 coastal plain counties. Using data gathered at the Savannah River Site, we estimate that approximately 4000 bays of all size classes occur in South Carolina. This estimate is far lower than any previously reported in the literature.

Carolina bays have undergone significant disturbance, half of all bays recorded had one-fifth or more of their ellipse disturbed. We estimate that between 400 to 500 relatively intact

bays remain in South Carolina. The number of bays remaining in exemplary condition is far smaller than 400 to 500.

Types of disturbances observed in the bays included ditches, row crops, pine plantations, logging, residential and commercial development, roads, rights-of-way and farm ponds. More than 80 percent of the bays sampled had multiple disturbance types evident.

The relatively intact bays we visited supported plant communities recognizable as being associated with wetlands and showed minor amounts of disturbance. There were nine plant (or natural) communities associated with these bays. Thirty-six plant species of concern representing 80 collections (populations) were recorded from bays during this study - all of which are being added to the Heritage Trust data-base.

We have concluded that there are far fewer bays in South Carolina than had been previously believed and that most of them have been significantly altered. Of the 219 relatively intact bays found during the study, only 36 have been identified as protection projects of the Heritage Trust Program.

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Introduction

Carolina bays are shallow, poorly drained, elliptical or oval depressions found throughout the Atlantic Coastal Plain.

These features were first described by early naturalists such as John Lawson and John Bartram (Savage 1982) as percoarsons (pocosins), from the Indian word meaning swamp on a hill. The terms bay and bay swamp were given to these features based on the abundance of the bay trees (sweetbay, red bay and loblolly bay) associated with them.

State geologist Michael Tuomey (1848) was the first to note the distinctive shape of the Carolina bays. Tuomey compared these features to race courses and differentiated them from lime sinks.

With Tuomey's description of the unique shape of bays and the subsequent discovery of the near parallelism of their axes, much research and debate focused on the origin of these features.

Glenn (1895) noted nine characteristics common to bays and which any origin theory must take into account:

1) Their oval shape.

2) Their northwest-southeast orientation.

3) The parallelism of their axes.

4) Their sand rims raised above the general level.

5) Their interior surfaces below the general level.

6) The difference between their interior soils and those of the surrounding area.

7) Their relatively shallow depths.

8) Their flat sandy bottoms beneath their interior fill.

9) Their apparent independence of inflowing or outflowing streams.

While not all of these characteristics apply to every bay, some such as the shape and orientation, generally do. These characteristics make identification of Carolina bays from aerial photographs relatively easy.

Preliminary reports on the biology of various Carolina bays, especially in North Carolina, began to flourish in the early part of this century. Much of this work was, of course, related to the documentation of bays, and to origin theories (Brown 1911, Frey 1948, Hutchinson 1944, Wells 1928, to cite a very few).

Savage (1982) and Sharitz and Gibbons (1982) have summarized the literature concerning origin theories for Carolina bays. Origin theories vary greatly among researchers and currently no one theory is widely accepted.

Kaczorowski (1977) proved, through the use of scale model experiments and field verification, that wind and wave action can produce an elliptical form, when acting upon an existing circular depression in unconsolidated sediment.

Prouty (1952) presented an estimate of the number of Carolina bays, described both overlapping bays and "heart-shaped" bays and presented data from magnetometer studies on particular bays. Prouty estimated there were conservatively 500,000 bays located between northeast Florida and southeast New Jersey.

The majority of research on Carolina bays to date has focused on the geologic aspects of these features. Floristics of particular bays or series of bays have been discussed by Buell

(1946), Whitehead (1981), Frey (1949), Wharton (1978), Porcher (1966), Kelley and Batson (1955) and Schalles et al. (1989).

Faunal associations in Carolina bays have been the subject of numerous studies at the Department of Energy's Savannah River Site (SRS), in Aiken, Barnwell and Allendale Counties, South Carolina. Ecologists from the Savannah River Ecology Laboratory, located on the SRS, have monitored amphibian and reptile populations in bays, and have sampled other vertebrate and invertebrate taxa. This research is summarized in Sharitz and Gibbons (1982).

Schalles et al. (1989) has presented data on soil and water chemistry of Carolina bays at the SRS. Sharitz and Gibbons (1982) have summarized the literature on human alteration and disturbance to Carolina bays. Forestry, agriculture, drainage systems and peat mining are identified as major alterations or threats to these systems. No figures are given for the number of altered bays, percentage disturbance of individual bays, or cumulative percentage disturbance to Carolina bays.

The relationship between Carolina bays and the more widespread phenomenon of coastal plain pocosins has been the subject of a great deal of study since about the middle part of this century; Sharitz and Gibbons (1982) and Ash et al. (1983) provide comprehensive bibliographies.

Carolina bays usually are isolated, temporary wetlands. Some exceptions are Lake Waccamaw in North Carolina and Woods Bay in South Carolina which are springfed, permanent lakes. Unaltered bays would fall generally into the palustrine wetlands classification as defined by the U.S. Fish and Wildlife Service (Cowardin et al. 1979). Recent concerns over wetland losses are responsible for status surveys (Tiner, 1984) and protection efforts for wetland resources.

Chuck Roe (1983) of the North Carolina Heritage Program indicated that North Carolina's bays were in jeopardy. The North Carolina Heritage Program had begun a study of bays in their state and had also begun protection efforts for bays that were significant, unaltered natural areas.

In 1983, the South Carolina Heritage Trust Program, having perceived a need to inventory and protect Carolina bays in South Carolina, began a long-term study of these features. Little information on the status of bays was available and Prouty's 1952 estimate of bay abundance was the only one in existence.

Carolina bays, in general, were approved as a protection priority of the South Carolina Heritage Trust Program in 1983. This same year the Carolina bay project was initiated. This project was designed to inventory bays, assess disturbance, observe ecological and geomorphic characteristics of bays and identify the least altered, most significant bays for inclusion as Heritage Trust protection projects.

Methods

Our Carolina bay project consisted of two phases, aerial photography interpretation and a field study.

Black and white aerial photography covering all thirty coastal plain counties in South Carolina was examined for presence of bays. The photography series used was an Agricultural

Stabilization and Conservation Service made series between 1972 and 1983. However, the majority of South Carolina coastal plain counties were flown between 1979 and 1981 (see Table 1 for dates of aerial photographs).

Carolina bays were identified based solely on their characterisitc elliptical shape. Presence of a bay was noted by a technician and confirmed by one of the authors. Each bay identified was assigned a unique number and its position on the aerial photo determined by using a grid overlay.

Each bay was measured on the photo grid to the nearest sixteenth of an inch along its long axis, not including a sand rim if one existed. Bays or baylike features with long axes less than four hundred and sixteen feet (1\8 inch by photo scale) were excluded from this study. These small bays, averaging less than two acres, were difficult to clearly document as bays due to some loss of ellipticity as the long axis length decreased. The possibility of confusing these bays, or potential bays, with other features on the landscape also was believed to be high. Each bay was examined for disturbance or alteration and this was recorded as a visual estimate of percent disturbance to the entire bay and sand rim if one was present. The type or types of disturbance or alteration to individual bays, including sand rims was noted.

An attempt was made to categorize each bay's vegetative composition based on aerial photography. However, this approach was abandoned as we felt that the potential for inaccuracy was too high.

Each bay was examined for the presence of bay overlap, or multiple rims. When overlapping bays occurred they were noted as either being overlapped by another bay or overlying another bay, and the estimated percent of the bay which was underlying another bay was recorded. In the case of overlapping bays, each bay was recorded as an individual occurrence.

Each bay was examined on the aerial photograph for the presence of a sand rim. For the purpose of this study a sand rim was defined as a feature distinct from both the bay proper and the surrounding landscape. The Quadrant or Quadrants in which the sand rim occurred was noted for each bay and the general condition of the sand rim was noted for each bay with a sand rim.

The surrounding land use was noted for each bay identified.

The field study phase of the Carolina bay project began in the spring of 1983, after the aerial photography phase had been completed for several counties (see Table 2 for dates of field study).

Bays were selected for field study based on their estimated percent disturbance. In general, no bay estimated to be greater than twenty percent altered was visited. In counties such as Marlboro and Darlington, with high numbers of highly altered bays, some bays greater than twenty percent altered were visited. In Horry County, which had a high number of relatively intact bays, no bay greater than ten percent altered was visited.

Each bay selected for field study was mapped on a South Carolina Highway Department county map to facilitate field location. Mapped bays were labelled with a unique identification number derived from the aerial photograph on which they were located.

Disturbance or alteration and surface water depth were recorded for each bay visited. Plant species comprising the canopy, shrub layer and herbaceous layer were recorded and the

Table 1.

Dates of Aerial Photos Used in this Study

County	Year
Dorchester	1970
Charleston	1973
Colleton	1973
Darlington	1975
Aiken	1979
Allendale	1979
Barnwell	1979
Beaufort	1979
Berkeley	1979
Edgefield	1979
Hampton	1979
Jasper	1979
Marion	1979
Saluda	1979
Williamsburg	1979
Clarendon	1980
Dillon	1980
Georgetown	1980
Sumter	1980
Bamberg	1981
Calhoun	1981
Chesterfield	1981
Florence	1981
Kershaw	1981
Lee	1981
Lexington	1981
Marlboro	1981
Orangeburg	1981
Richland	1981
Horry	1983

Table 2.

Dates of Field Surveys

County	Survey Dates
Saluda	Sept. 1987
Lexington	May 1984
Edgefield	Sept. 1987
Aiken	May 1984, Sept. 1987
Barnwell	May, June 1983, Aug. 1984
Orangeburg	June, August 1983
Calhoun	May 1984
Allendale	July, August 1987
Bamberg	May, June 1984
Hampton	June 1987
Colleton	June 1987
Dorchester	September 1985
Jasper	May 1988
Charleston	October 1985
Berkeley	May 1987 (1 bay Aug. 1987)
Richland	August, September 1984
Kershaw	April 1985
Cheraw	April 1985
Marlboro	April 1987
Darlington	April 1987
Lee	April, May 1985
Sumter	May, June, July 1985
Dillon	August 1986
Florence	July 1986
Marion	June, July 1986
Williamsburg	September 1986
Georgetown	September, October 1986
Horry	May, June 1986
Clarendon	July, August 1985

Note: No Carolina bays were identified from Beaufort County, hence no field survey was performed.

presence of rare plant species was noted. Bays with relatively intact wetland plant communities were assigned to one or more natural community classifications (Nelson 1986).

The maintenance of an endangered/threatened plant species list within the Nongame and Heritage Trust Program allowed us to concentrate on particular bays for several species of concern. An attempt was made to confirm the presence of these potential species, and voucher specimens were prepared when appropriate. Specimens of vascular plants made during this process are housed at the Moore Herbarium of the University of South Carolina (USCH). (See Appendix 1 for collection list.) Some bryophytes were collected, and were identified by Lewis E. Anderson at the Duke University Herbarium (DUKE), where voucher specimens are deposited. Duplicates of most of these bryophyte collections are at USCH.

A general protection priority recommendation was made for each bay visited, based upon integrity of the bay, natural communities present, presence of rare plants, presence of intact sand rim and other considerations. The ranking system used for setting protection priorities among these bays is presented in Appendix 2.

Results

Number and distribution of bays

2651 Carolina bays two acres or larger (long axis greater than four hundred and sixteen feet) were identified in 29 counties (excluding the SRS in Aiken and Barnwell Counties). Carolina bays were found in every coastal plain county except Beaufort.

Number of bays per county ranged from a low of three in Chesterfield County to a high of 410 in Horry County (Figure 1). Bays are not distributed evenly across the Coastal

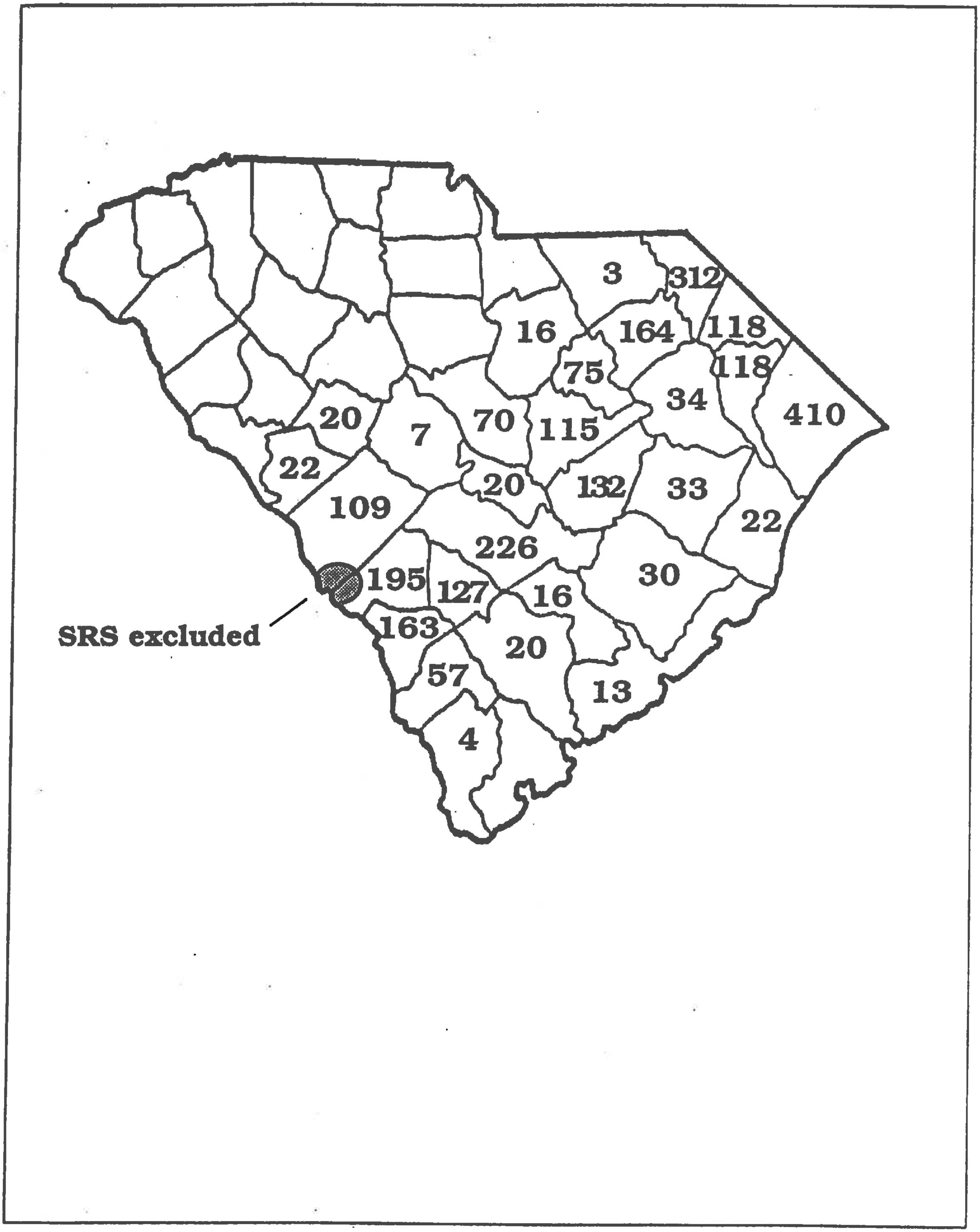

Figure 1. Map showing number of Carolina Bays in each county

Plain. Areas of high bay density occur in three regions; Aiken, Orangeburg, Barnwell, Allendale, and Bamberg Counties; Sumter and Clarendon Counties; and Darlington, Chesterfield, Dillon, Marion and Horry Counties (Figure 2). These areas of high bay density correspond to the areas of high density presented by Prouty (1952) in his bay distribution map for the eastern U.S.

Size Distribution

Long axis lengths were measured for all 2651 Carolina bays. The mean length for the entire sample was 2080.5 feet with a standard error of 178.0. Table 3 presents the mean long axis length and standard error for each county. Values ranged from a low of 684.4 feet for Lexington County (N=7) to a high of 5094.2 feet for Georgetown County (N=22).

For purposes of analyzing the size distribution of Carolina bays, as well as other observations on bays, we divided the Coastal Plain into four regions (Quadrants) (Figure 3). The Santee River was used to define the North Coastal Plain and South Coastal Plain. The U.S. Department of Agriculture's General Soil Map of South Carolina (Smith and Hallbrick, 1979) was used to delineate upper coastal plain counties and lower coastal plain counties.

Bays located in the lower coastal plain were larger than bays in the upper coastal plain and bays in the north coastal plain were larger than in the south coastal plain (Figure 4). Bays located in Quadrant 1 (upper coastal plain, south of the Santee River) were significantly smaller than bays in the other Quadrants. Analysis of variance revealed that

Table 3.

Mean long axis and standard error for bays by County

County	N	X	Standard Error
Saluda	20	1031.25	63.19
Lexington	22	1212.13	74.56
Edgefield	7	684.42	38.36
Aiken	109	905.90	37.26
Barnwell	195	1502.00	72.00
Orangeburg	226	1378.02	103.87
Calhoun	20	1458.15	179.44
Allendale	163	1764.90	102.92
Bamberg	127	2061.78	141.36
Hampton	57	2207.35	168.70
Colleton	20	2916.40	625.11
Dorchester	16	2916.31	495.51
Jasper	4	1405.50	156.27
Charleston	13	3364.92	420.54
Berkeley	30	2659.43	403.18
Richland	70	1038.60	50.59
Kershaw	16	1445.31	178.85
Cheraw	3	1666.67	318.05
Marlboro	312	1697.41	96.78
Darlington	164	1976.42	131.45
Lee	75	1924.82	179.94
Sumter	115	2014.30	203.87
Dillon	118	2259.60	248.77
Florence	34	2873.52	469.50
Marion	118	3065.17	299.31
Williamsburg	33	3995.81	752.42
Georgetown	22	5094.22	892.42
Horry	410	1813.56	77.18
Clarendon	132	2001.06	170.71

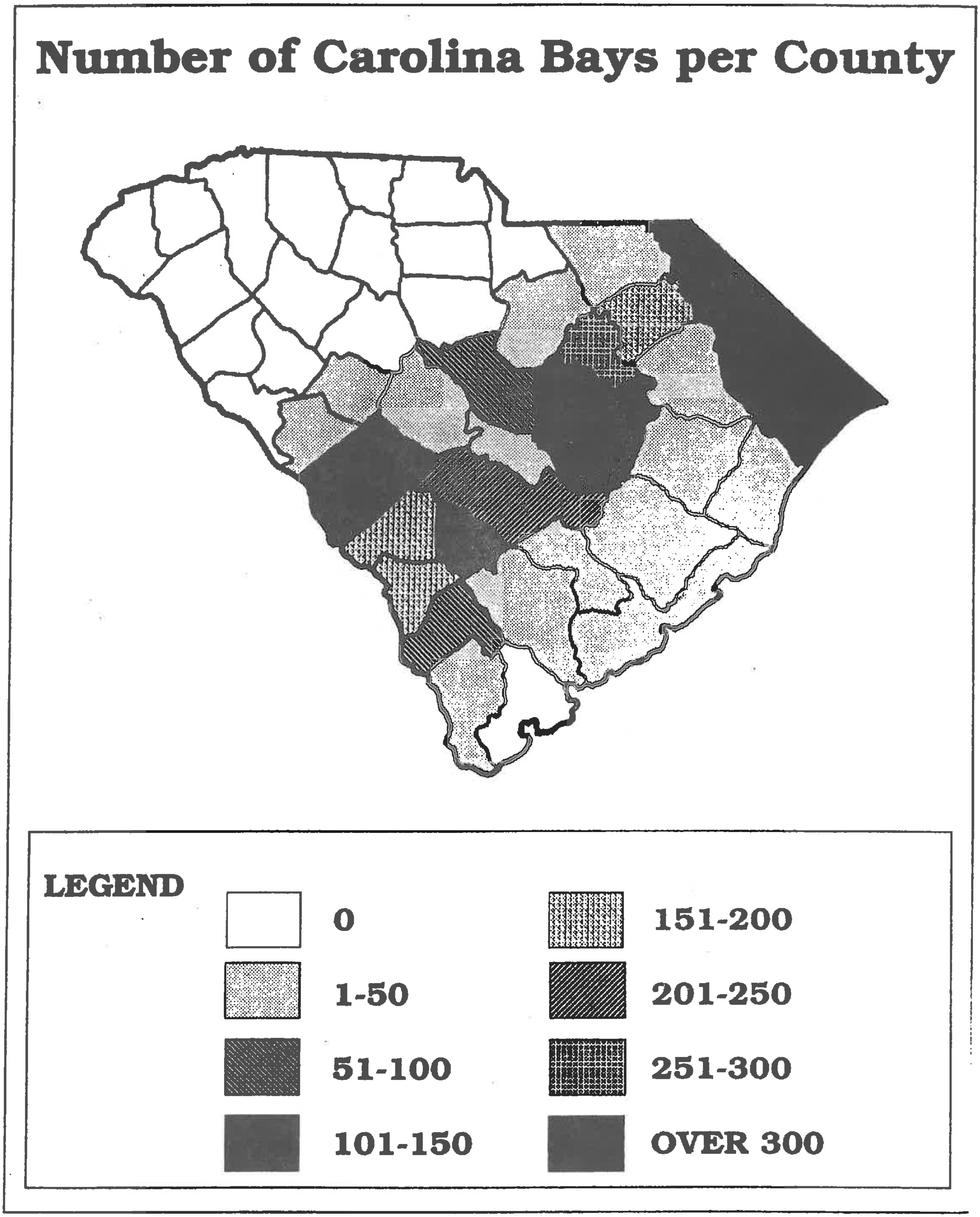

Figure 2. Map showing distribution of Carolina Bay occurrences in South Carolina

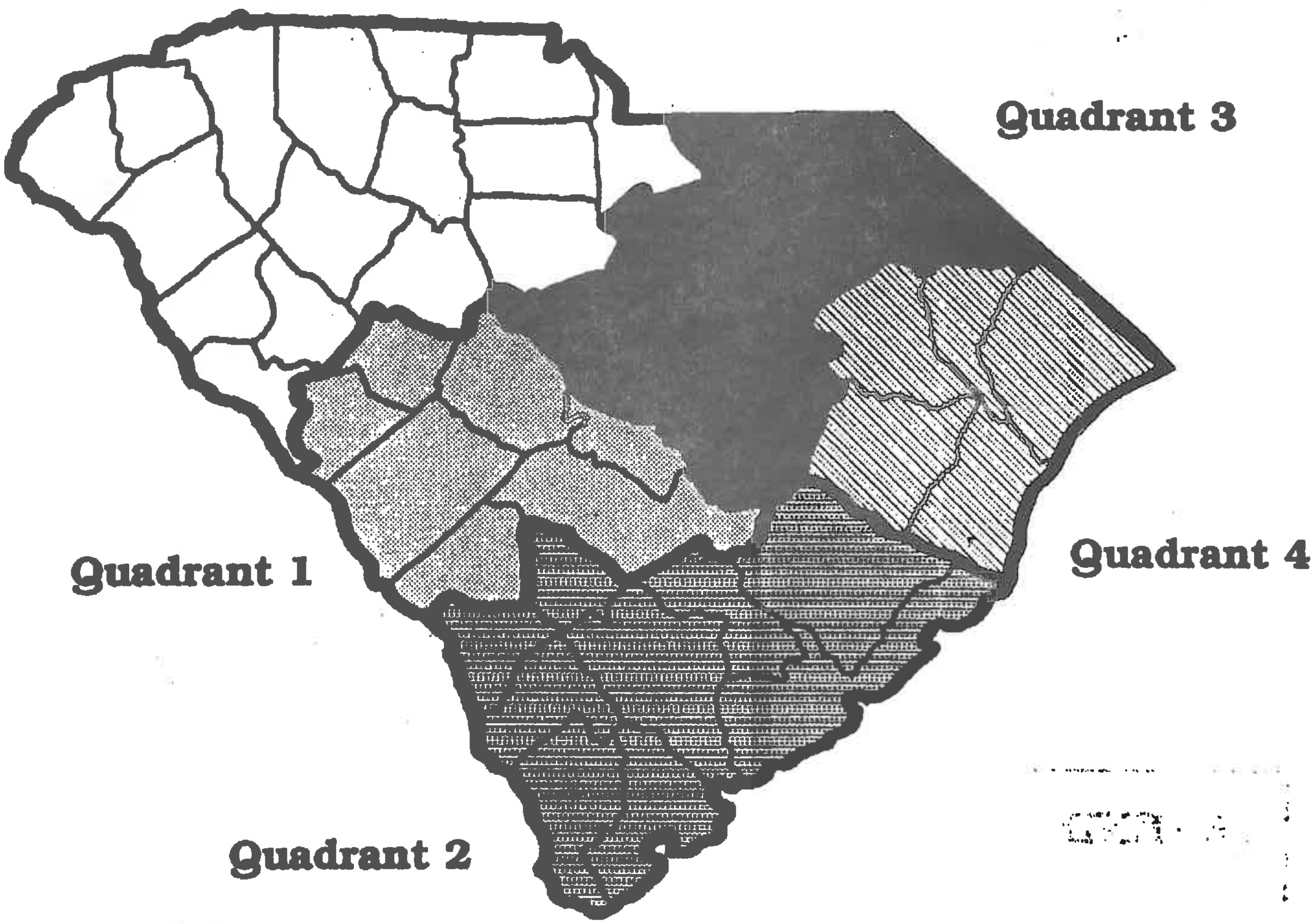

Figure 3. Map showing the four quadrants of coastal plain used in bay study

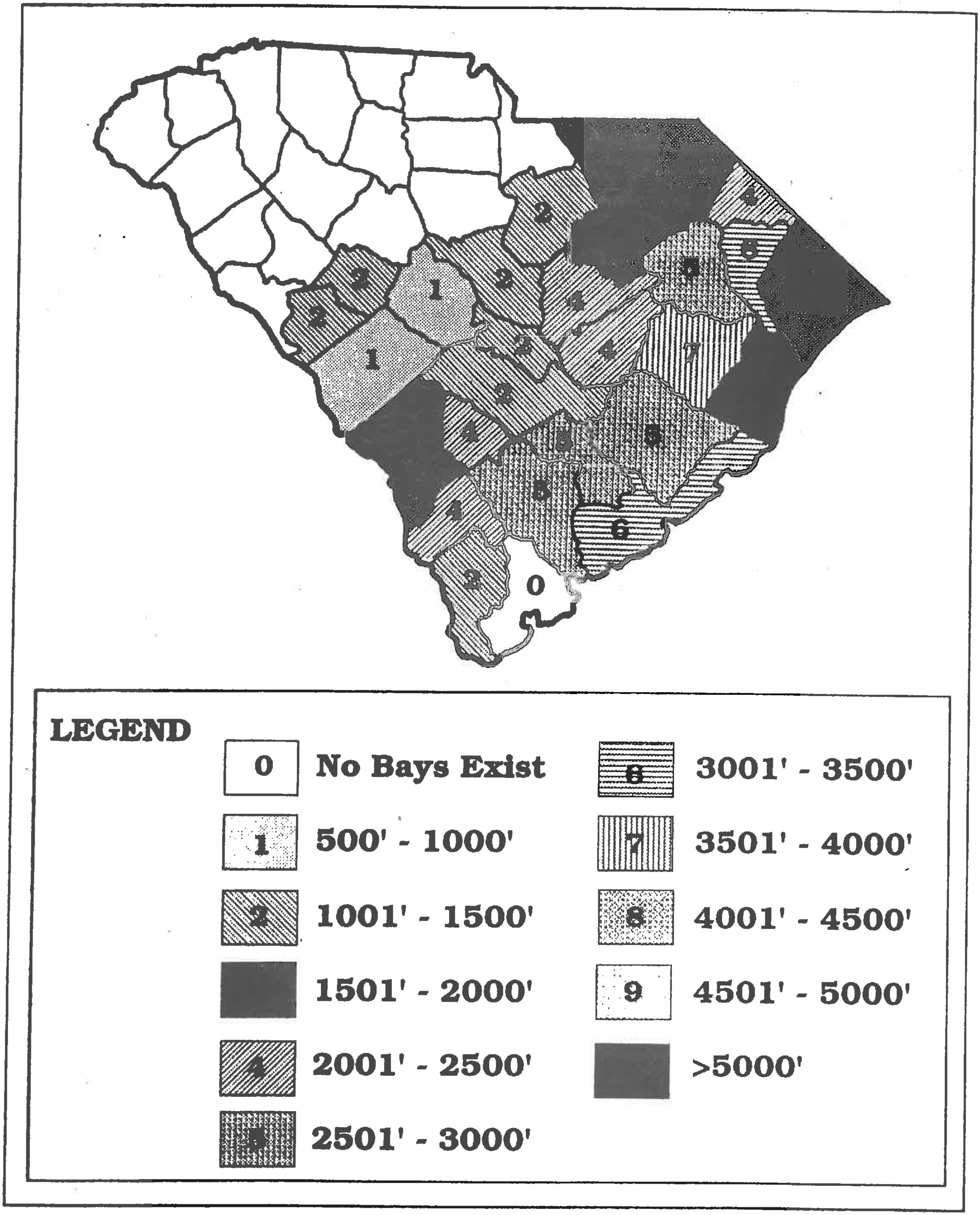

Figure 4. Map showing the mean long axis length (in feet) of bays by county

significant differences existed between mean long axis lengths of bays from the 29 counties ($F = 10.54$, $Pr > F = .0001$). Duncan's Multiple Range Test (Table 4) revealed that bays of the lower coastal counties were larger and that size of the bays did tend to decrease as a function of distance from the coast.

Extremely large bays (long axis lengths greater than 10,000 feet) were uncommon (Figure 5), but 25 were identified in 12 counties (Figure 6). Twenty-two of these bays are located north of the Santee River.

The largest bay identified, located in Dillon County, had a long axis length of 18,748 feet (approximately 3 1/2 miles). This bay has been completely converted to agriculture.

Disturbance

Aerial Photography

An estimate of percent disturbance or alteration was made for 2648 of the 2651 Carolina bays identified through the aerial photography study. Figure 7 presents the frequency distribution of the estimated percent disturbance for this total sample. These figures indicate that bays tended to be either relatively intact, up to ten percent disturbed or almost totally altered, i.e., 91-100% disturbed. Sixty-two percent of the bays in the sample were estimated to be ten percent or greater disturbed and half the sample was estimated to be twenty percent disturbed (Figure 8).

Analysis of estimated percent disturbances by region indicates significant differences between all four Quadrants (Figure 9) with Quadrant three (northern upper coastal plain) displaying the highest mean estimated percent disturbance per bay (55.3%). No real

Table 4.

Duncan's Multiple Range Test for Long Axis Length

Dependent Variable: LALEN

County	N	Mean	Duncan Grouping					
Georgetown	22	5094.2			A		B	
Williamsburg	33	3995.8			A		B	
Charleston	13	3364.9			C		B	
Marion	18	3065.2		D	C		B	
Colleton	20	2916.4		D	C	E	B	
Dorchester	16	2916.3		D	C	E	B	
Florence	34	2873.5		D	C	E	B	
Berkeley	30	2659.4		D	C	E	F	
Dillon	118	2259.6		D	C	E	F	G
Hampton	57	2207.4		D	C	E	F	G
Bamberg	127	2061.8	H	D	C	E	F	G
Sumter	115	2014.3	H	D		E	F	G
Clarendon	132	2001.1	H	D		E	F	G
Darlington	164	1976.4	H	D		E	F	G
Lee	75	1924.8	H	D		E	F	G
Horry	410	1813.6	H	D		E	F	G
Allendale	163	1764.9	H	D		E	F	G
Marlboro	312	1697.4	H			E	F	G
Chesterfield	3	1666.7	H			E	F	G
Barnwell	195	1502.0	H				F	G
Calhoun	20	1458.2	H				F	G
Kershaw	16	1445.3	H				F	G
Jasper	4	1405.5	H				F	G
Orangeburg	226	1378.0	H				F	G
Edgefield	22	1212.1	H					G
Richland	70	1038.6	H					G
Saluda	20	1031.2	H					G
Aiken	109	905.9	H					G
Lexington	7	684.4	H					

* Counties with same letter are not significantly different.

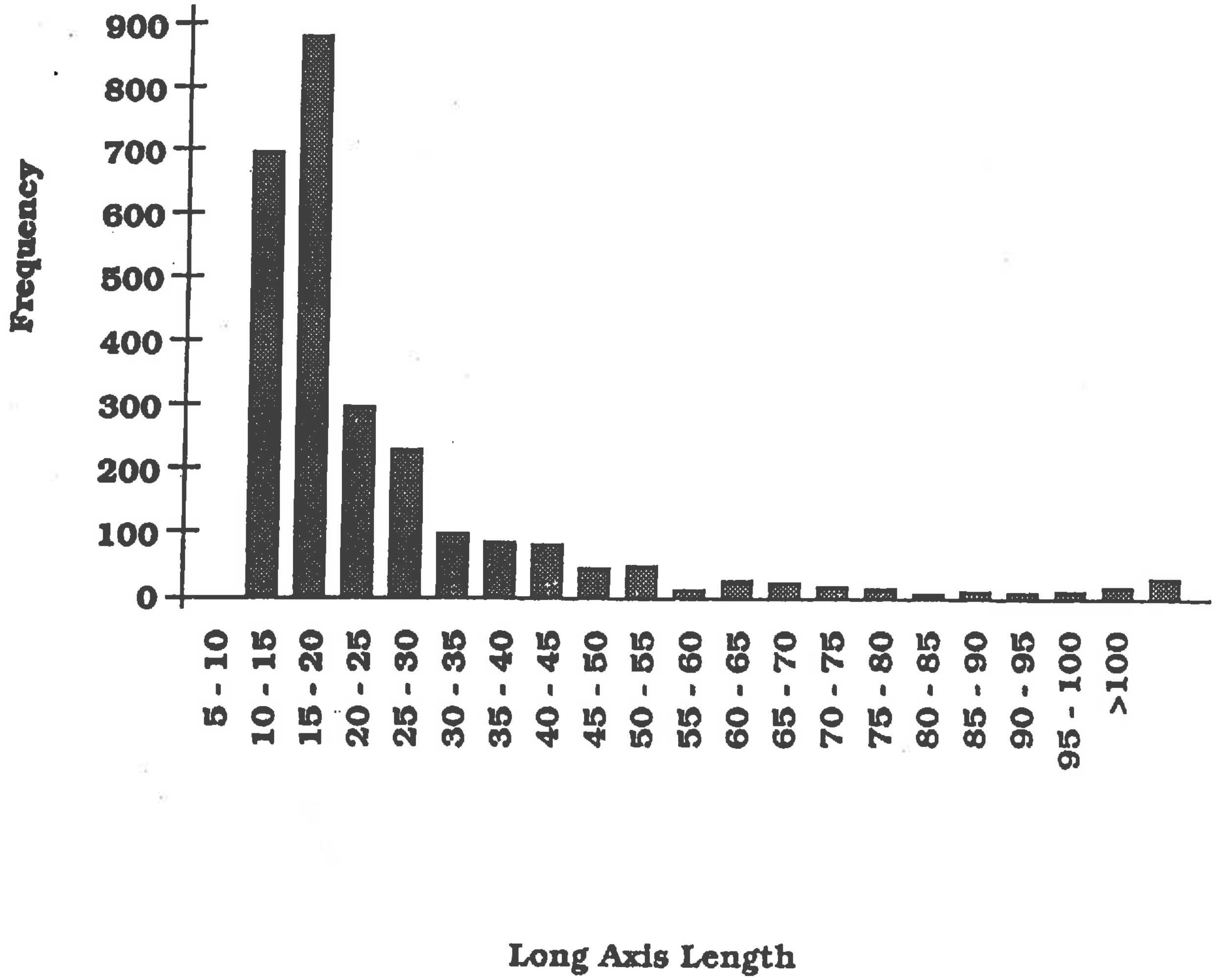

Figure 5. **Distribution of long axis lengths (in feet X 100) for all bays**

Large Bays

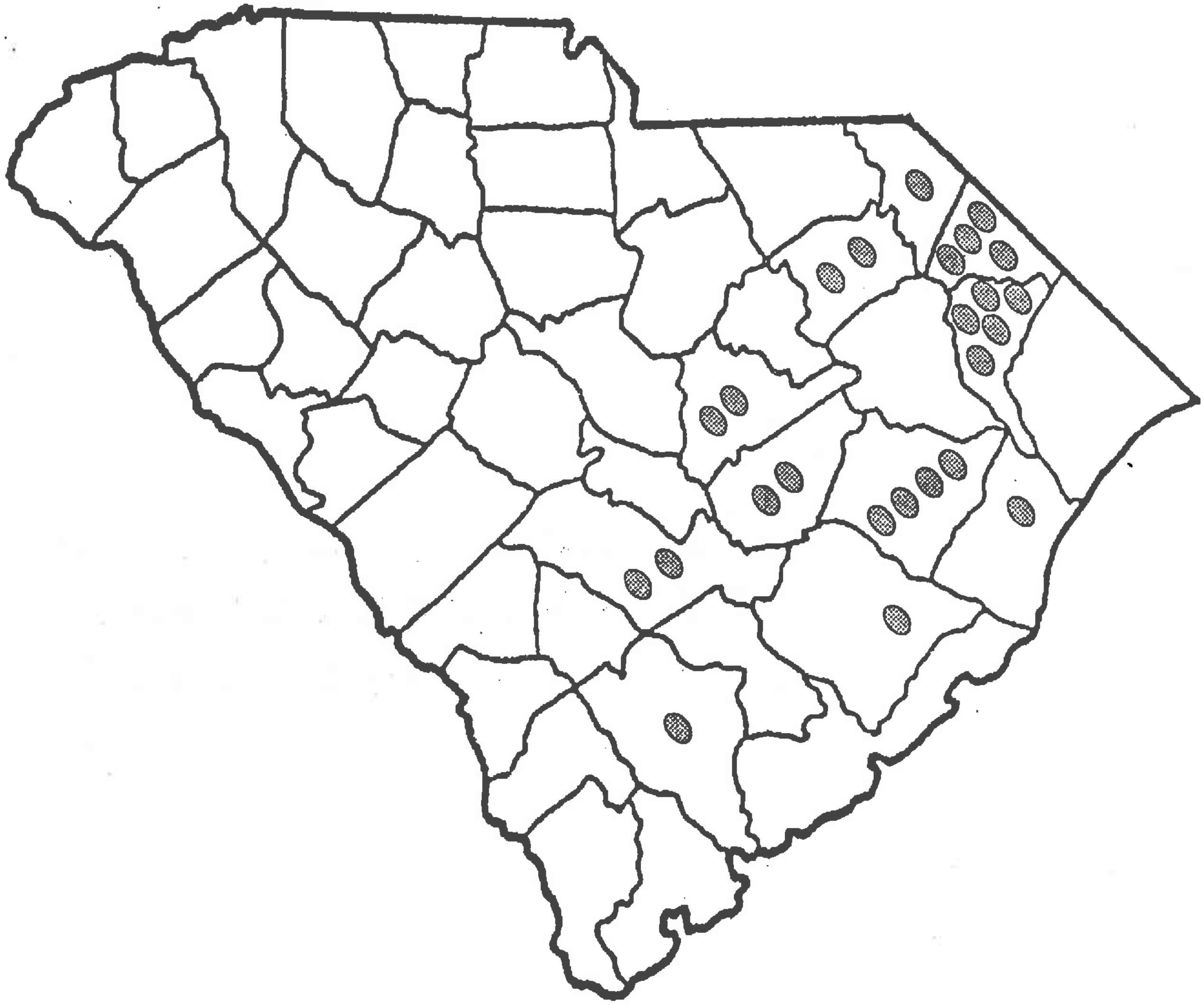

Figure 6. Map showing distribution of bays with long axis lengths in excess of 10,000 feet

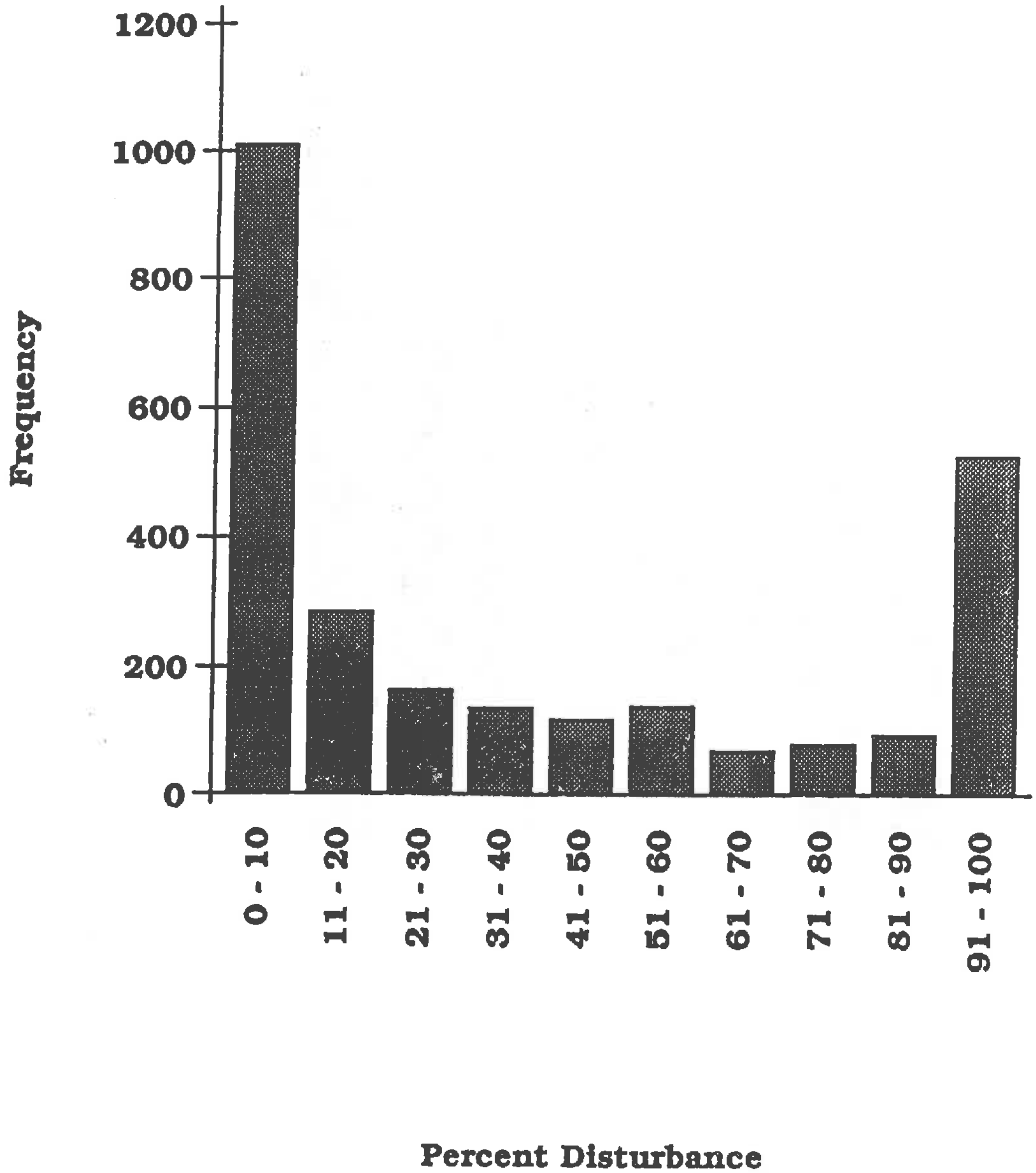

Figure 7. Distribution of estimated disturbance for South Carolina bays in this survey

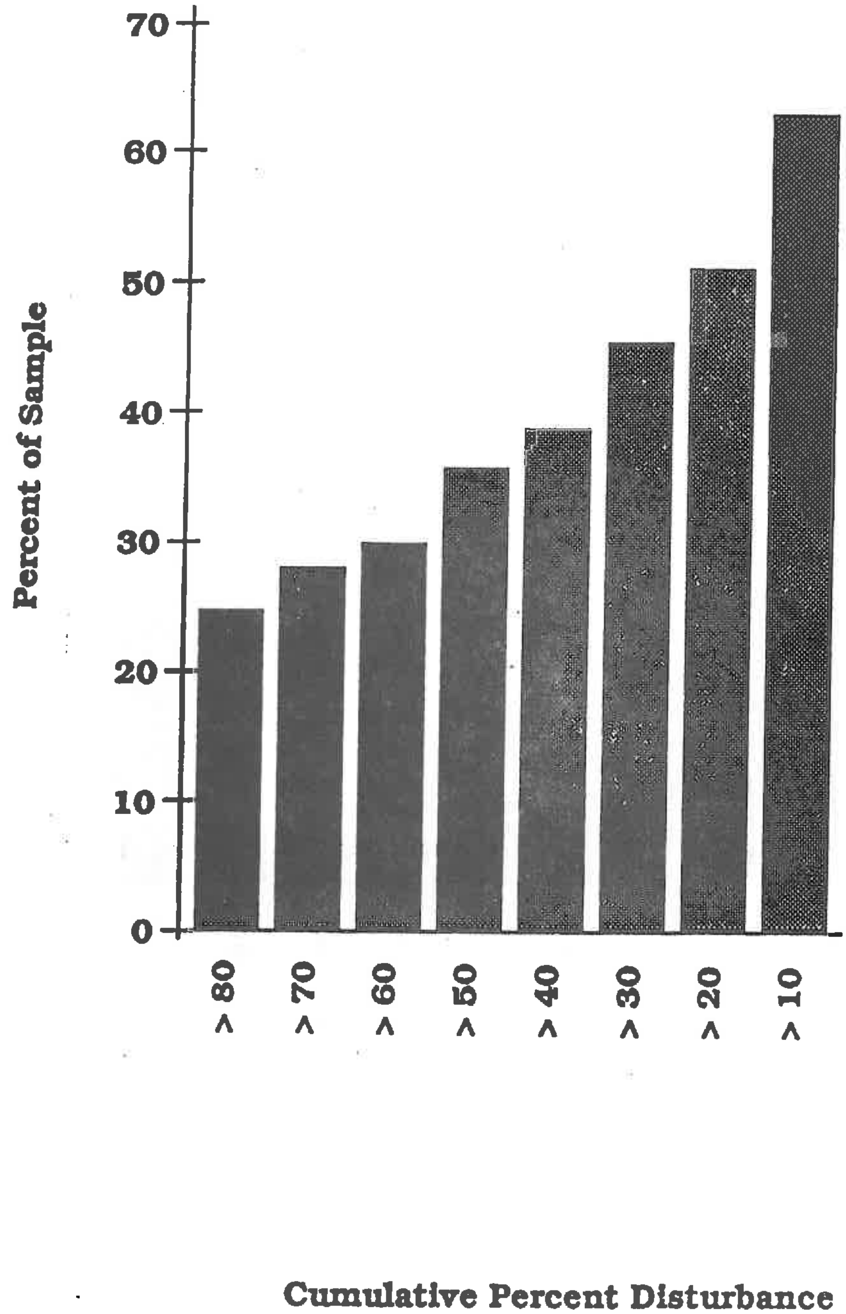

Figure 8. **Cumulative percent disturbance for all bays**

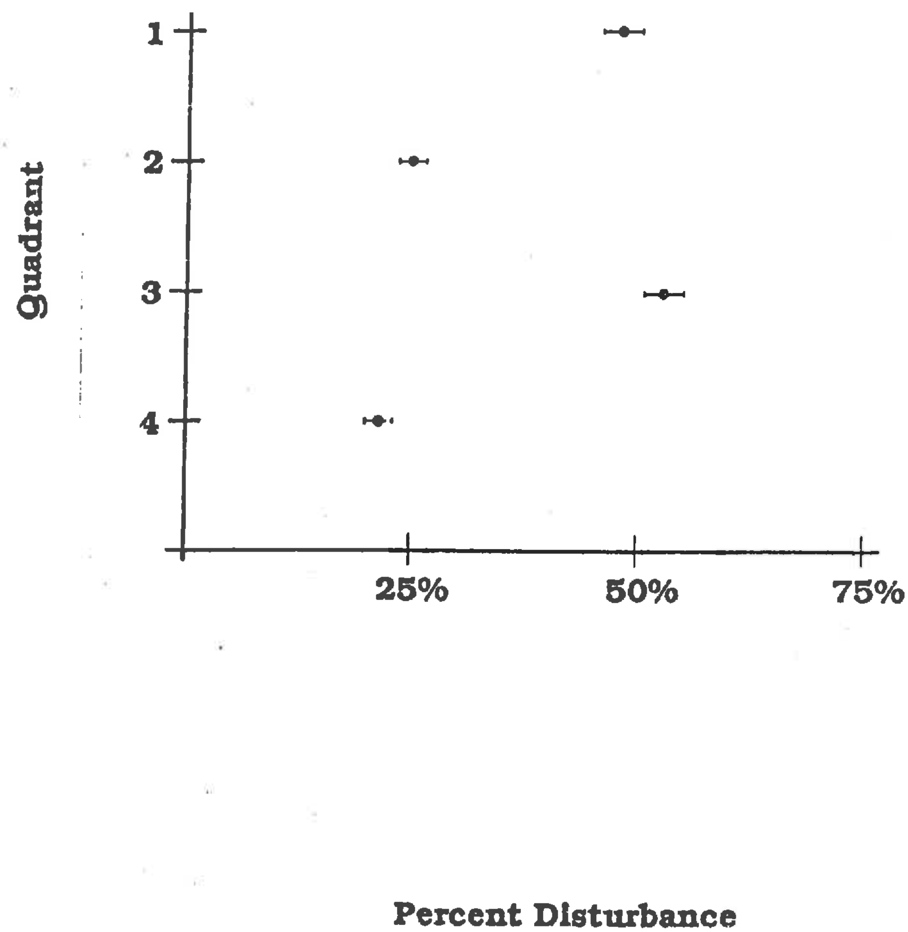

Figure 9. Mean and .975 confidence interval for percent disturbance by quadrant

difference existed for mean estimated percent disturbances between bays located north of the Santee River (Figure 10) and bays located south of the Santee River. A significant difference was found between bays of the lower coastal plain and upper coastal plain, indicating that upper coastal plain bays have been more highly disturbed or altered.

Ten disturbance types (Figure 11) found within bays were identifiable from the aerial photography. More than one disturbance type was possible from an individual bay.

Row crops (agriculture), ditches and logging operations were the most common disturbance types recorded from bays. Roads through the margin or edge of a bay were separated from roads that bisected a bay. Residential development was separated from commercial development based on the size of the structures and amount of clearing for construction.

Ninety-seven percent of the bays in this sample exhibited some type of disturbance, and 81% exhibited more than one disturbance type. Most of the bays exhibited two or three disturbance types (Figure 12).

Certain disturbance types differed in their frequency in different regions of the coastal plain. Ditches were more common in Quadrant three (northern upper coastal plain) (Figure 13). Row crops and pine plantations were more common in the lower coastal plain (Figure 13). Residential development was more common north of the Santee River and logging was least common in Quadrant one (Southern Upper Coastal Plain) (Figure 13). No other significant differences were found for disturbance types among the different regions.

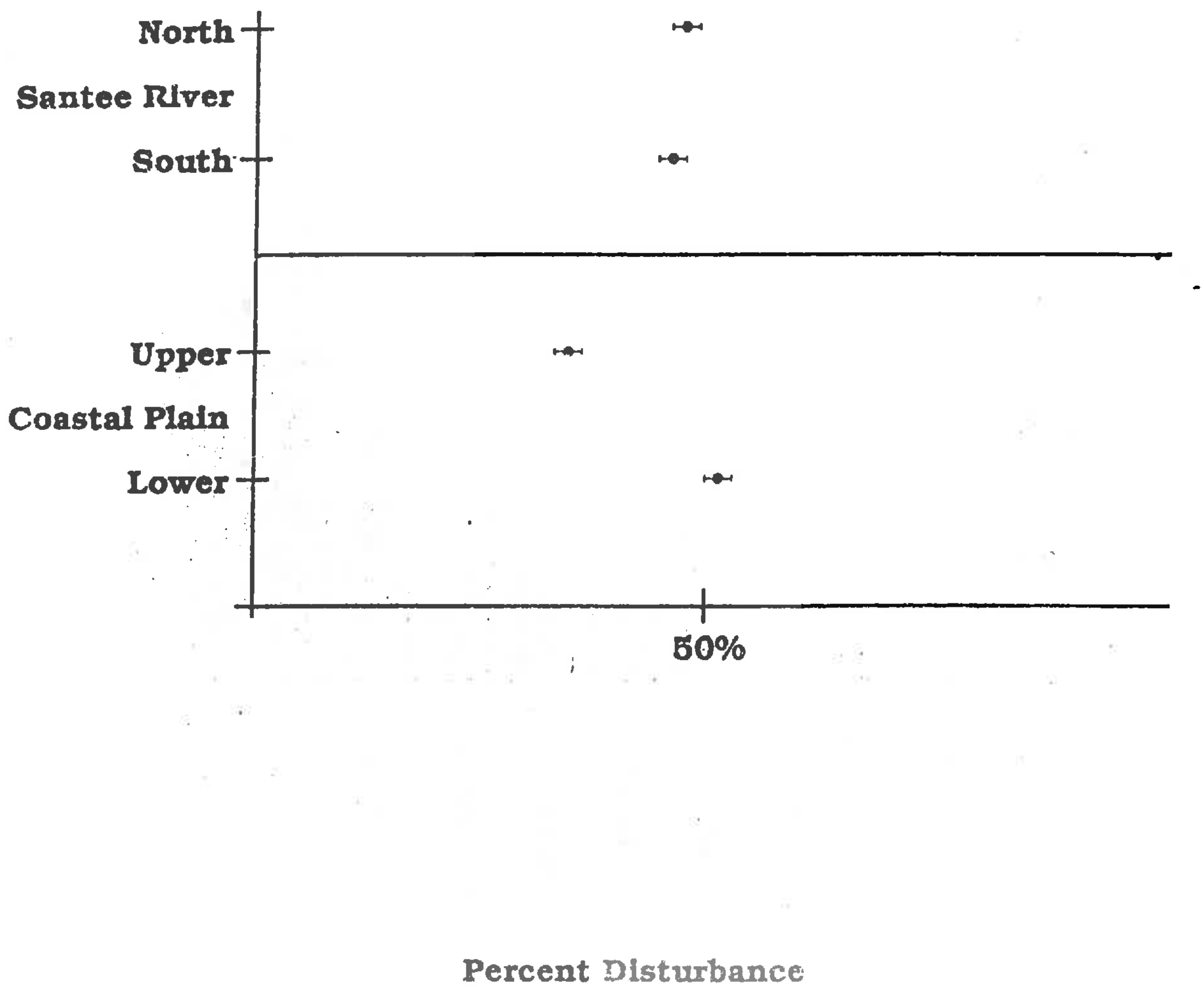

Figure 10. Mean and .975 confidence interval for percent disturbance by north vs. south of Santee River and upper vs. lower coastal plain

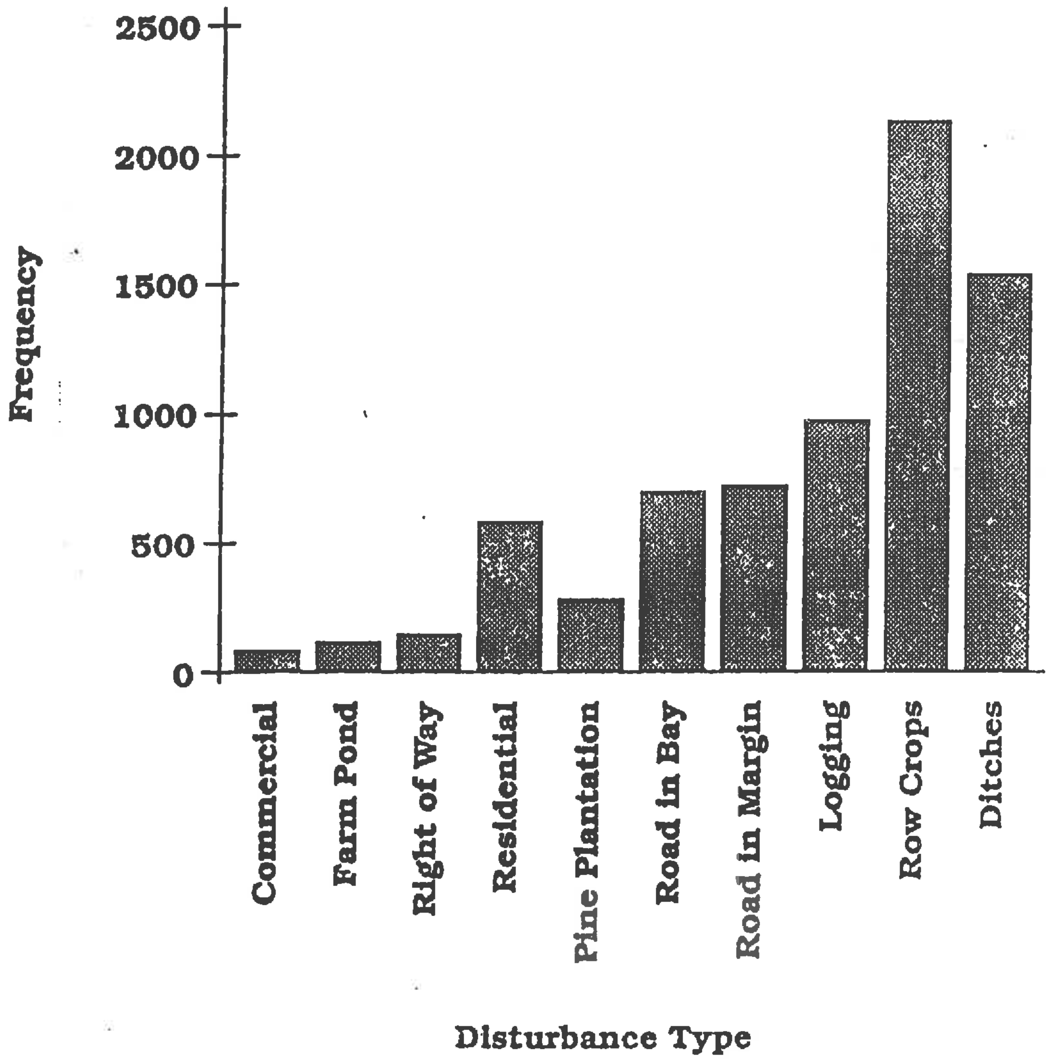

Figure 11. Distribution of disturbance types found in all bays

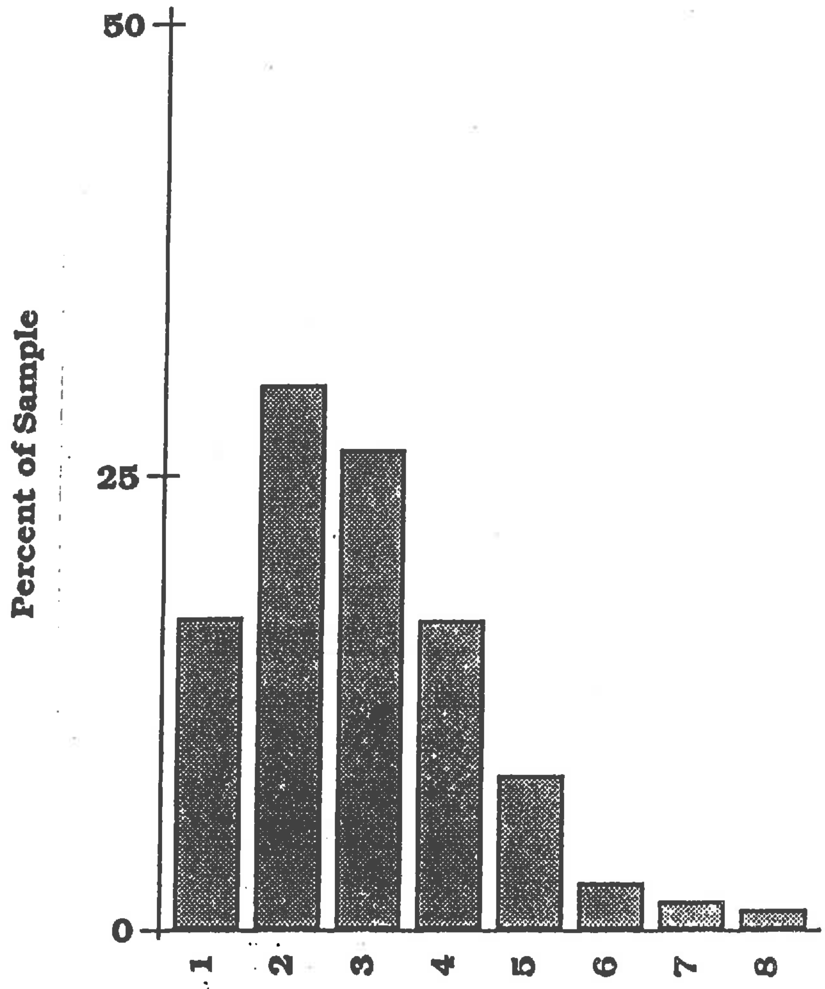

Figure 12. Cumulative number of disturbance types found in individual bays

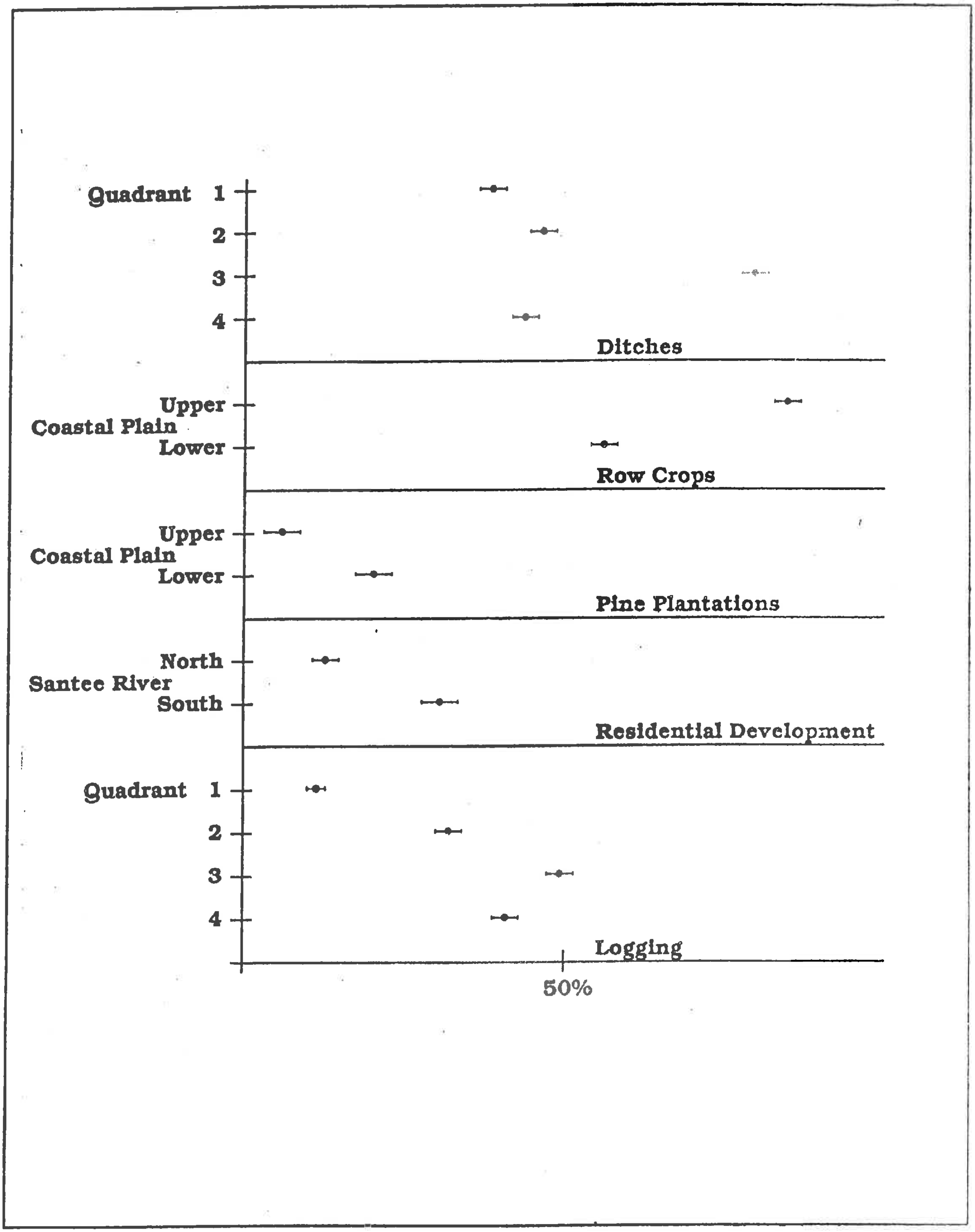

Figure 13. Mean (and .975 confidence interval) occurrence of ditches, row crops, pine plantations, residential development and logging operations per bay by quadrant, upper or lower coastal plain, or north or south of the Santee River

Field Study

Six hundred and thirteen bays were selected for field study. Of the bays visited 219 were judged to be relatively intact, supporting recognizable wetland vegetation and exhibiting little alteration or disturbance. Two hundred and thirty-four of the bays visited had been functionally altered or disturbed since the aerial photography was made.

Of the bays visited, 160 were determined to be totally altered, though this was not evident from the aerial photography. These supported dense canopies of loblolly pine, water oak, sweetgum and other early successional, invasive species. These bays were in general dry, having been drained and probably logged, and were interpreted as representing a total alteration of the bay hydrology. We have termed such bays regrowth communities.

Regrowth bays and totally altered bays accounted for 64% of the bays visited. Extrapolating these numbers to the remaining bays estimated as less than 20% disturbed (1297 total, of which 613 were visited) gives an estimate of between 400 and 500 relatively intact bays remaining in South Carolina. This represents only 15 to 18% of the original 2651 bays two acres or greater in size.

Sand rims

Sand rims were found associated with only 271 bays (Table 5). Sand rims were most common north of the Santee River (Figure 14). In Horry County 142 bays had sand rims,

Table 5.

Sand rims

Quadrant	Number of Occurrences
Southeast	248
Southwest	159
Northeast	71
Northwest	11

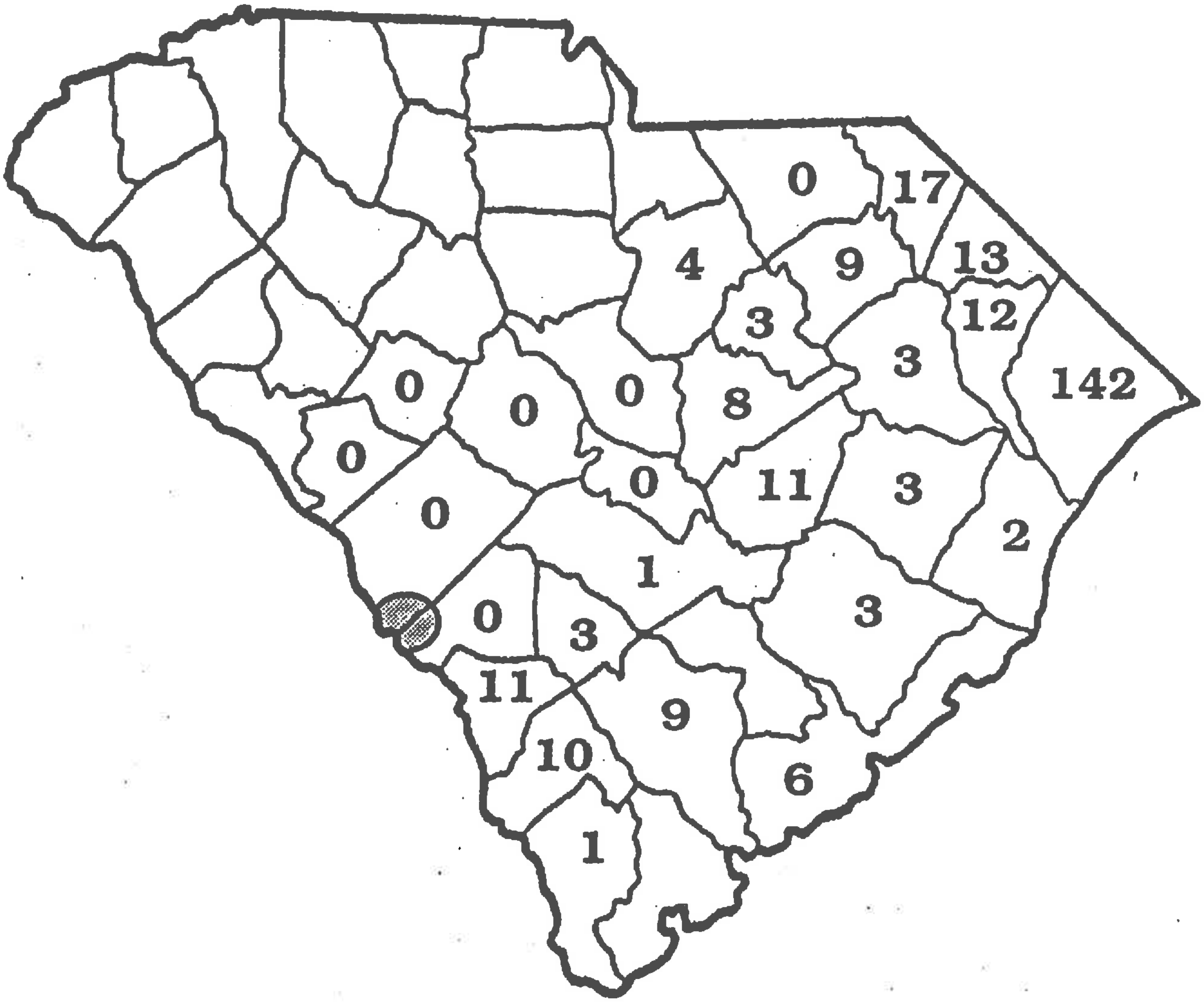

Figure 14. Map showing the number of sand rim occurrences by county

more than any other county. Sand rims can occupy one or more Quadrants of a bay's perimeter. Horry County is the only county in which sand rims completely encircle bays.

Bay overlap

Overlapping bays, heart-shaped bays, or multiple sand rims (not including single sand rims occurring in more than one Quadrant of a bay's perimeter) were all treated in this study as representing bay overlap features, and were recorded for 457 bays. Examples of these features were found in every county except Saluda and Aiken (Figure 15). Horry County with 194 occurrences displayed more bay overlap features than any other county. Marion County ranked second with 69. In these two counties most of these overlap occurrences were associated with bay complexes, clusters, or groupings of individually occurring or overlapping bays.

Surrounding Land Use

Row crops (agriculture) were most common as a surrounding land use in Quadrant one (southern upper coastal plain) (Figure 16). Row crops were in general more common south of the Santee River.

Pine plantations were most common in Quadrant four (northern lower coastal Plain) (Figure 16) and in general more common north of the Santee River.

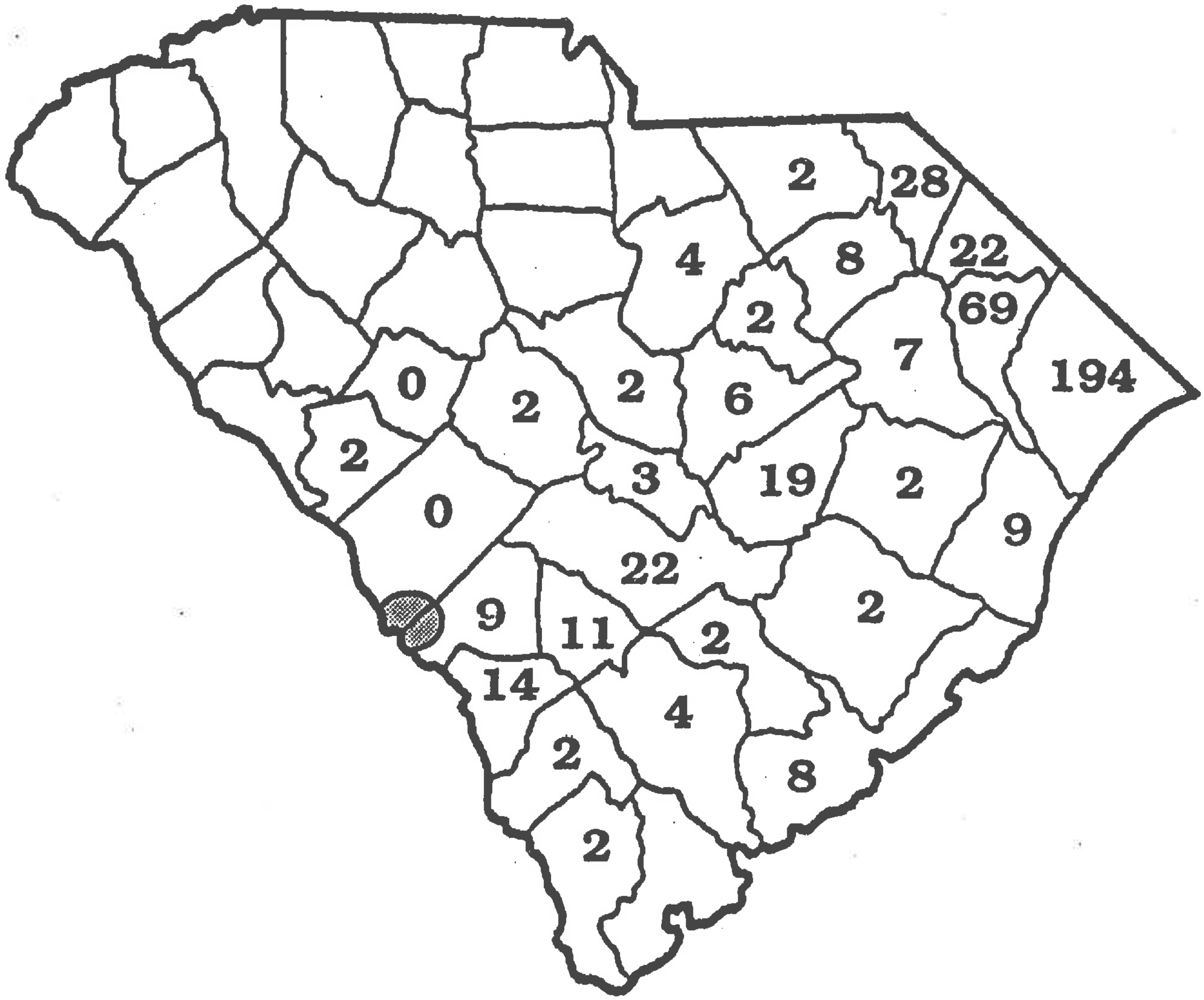

Figure 15. Map showing the number of bays displaying overlap by county

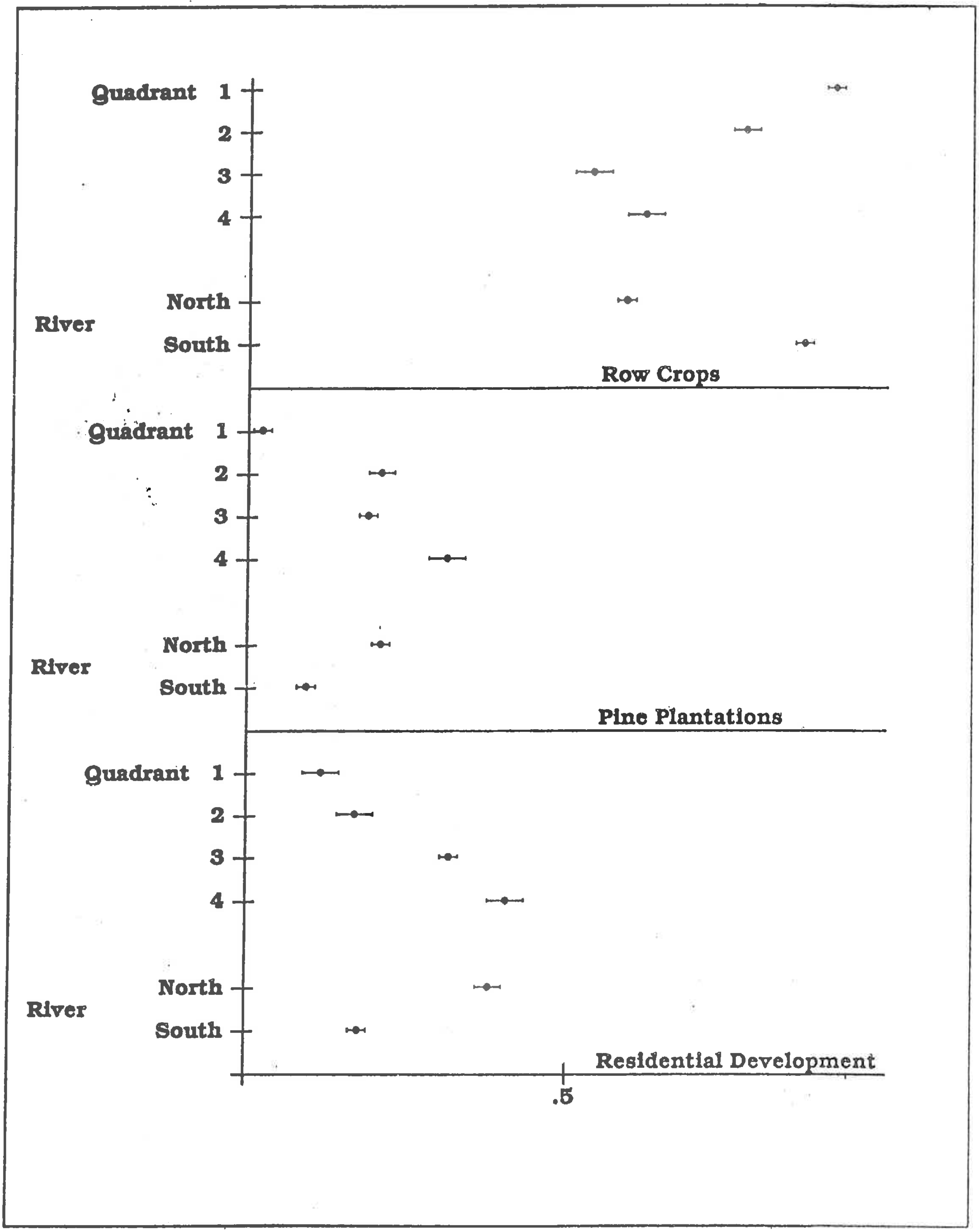

Figure 16. Mean and .975 confidence interval for surrounding land us occurrence by type

Residential development was most common north of the Santee River (Figure 16), especially in Quadrant four (northern lower coastal plain).

Natural Communities and Carolina Bays

Due to the large number of bays identified for field inspection, quantitative studies of frequency and variation of natural ecosystems were not attempted. Field inspection involved an overall assessment of disturbance at each bay and the recording of all communities present. In several cases, major disturbance since the time of aerial photography and prior to this survey eliminated bays from further study; no effort was made to categorize communities from severely disturbed or destroyed bays.

A useful breakdown of the array of natural ecosystems in bays was the goal of this study. Standard field forms were completed for each bay, detailing as far as possible, obvious communities present. A list of common and scientific names of plant species discussed here is presented in Appendix 3. Eleven natural ecosystems are considered here as comprising the Carolina bays studied. The breakdown is based on an adaptation of the hierarchy described in Cowardin et al. (1979). Bays examined in the field and remaining in "good" condition since the time of aerial photography invariably could be assigned to more than one of these ecosystems.

1. Terrestrial Systems

Xeric Sandhill Scrub - This distinctive upland community (Nelson 1986, Schafale and Weakley 1985) occurs on sand rims.

Xeric Sandhill Scrub on bay rims is generally composed of the same species occurring on the fall-line sandhills. Canopy elements are longleaf pine, sometimes mixed with loblolly pine. The subcanopy is made up mostly of turkey oak, with blackjack oak, post oak and scrub post oak of lower importance and usually in that order. Shrubs may be frequent, including blueberries, hawthorn and horse-sugar. Dwarf pawpaw is sometimes present in abundance on open sand, along with dwarf chinkapin. Sand rims of the northeast Quadrant (north of the Santee River) frequently support colonies of dwarf azalea. Typical herbaceous species on sand rims include sand carnation, *Rhynchospora megalocarpa* (a beak rush), prickly pear, wiregrass and tread-softly. Sand rims tend to be very easily differentiated from other bay community types. However, it may be difficult to distinguish the edges of sand rim vegetation when the bay itself is dominated by pocosin-related communities. Otherwise, it is usually fairly easy to determine boundaries between the rim and the bay proper.

Good examples of Xeric Sandhill Scrub on sand rims are rare, due to previous cutting, especially for pine. Sand rims, due to their relative elevation above adjacent land have been, in many cases, the best possible location for roads through a given area. Additionally, many rims have been the victims of sand-robbing: "borrow-pits" of various sizes, mostly small, have been observed commonly on sand rims throughout the study. Very often, the development of borrow-pits allows localized populations of wetland species, not necessarily associated with xeric sands, to occur; these borrow-pits are invariably more moist than the surrounding landscape, sometimes containing some standing water. Naturally occurring wet sandy swales may occur on extensive sand rims. These are usually dominated by grasses, sedges, bog-buttons and bladderworts, but often support various weedy species.

Xeric sandhill communities, whether associated with bays or not, are likely to be fire-maintained. Naturally occurring species on these sites are to varying degrees fire tolerant. Unless wiregrass and other grasses are present in great abundance, or unless the pines present are closely spaced, the fire-carrying capacity of xeric sandhills is rather low, however. Litter from pines and oaks, if accumulated in sufficient quantities, can provide fuel for localized fires. In general, fire may play an important role in the successional dynamics of some examples of this community. The most barren examples may not be fire maintained. Human impact on this community largely entails forestry practices and disturbance of the soil. The logging of pines on these sandhills generally promotes the increase of oaks, especially when fires are actively suppressed (Bozeman 1971). Sandhill sites, in general, are slow to recover from alteration induced by logging practices.

Of the 23 plant species of concern addressed within this study, only Venus' fly-trap can be expected from sand rims. This plant is generally found at the ecotone between xeric sandhill scrub and pocosin systems, and only within Quadrant 4.

Oak-hickory forest - Widely distributed across much of the state, variants of this broadly-defined community type are fairly infrequent in Carolina bays. These forests may be fairly narrow, existing in a ringlike configuration on the moderately steep slopes of certain bays, between the outer sand rim (if present) and a wetter interior. Dominant canopy species include white oak, water oak, willow oak, mockernut hickory, red maple, black gum, and to a widely varying extent, loblolly pine. The subcanopy is fairly distinct, including flowering dogwood and young canopy species. Shrubs include devil's walking stick, red buckeye, pawpaw, wild azalea, sweet pepperbush and sassafras. Towards the center of bays exhibiting oak-hickory stands the preponderance of shrubby species usually increases, especially when an ecotonal shrub-border is encountered. Showy herbaceous plants in oak-hickory forests include wild petunia, partridge berry, Indian pipes, snakeroot and wild violet; otherwise the herbaceous component of these forests tends to be dominated by muscadine and poison ivy. Switch cane is occasionally present in these forests, sometimes as fairly extensive, widespread brakes.

Disturbance to this community, most often in the form of timber cutting, invariably produces a less heterogeneous canopy, composed mostly of red maple, sweet gum and loblolly pine. This disturbance, or "regrowth" forest was very commonly encountered throughout the geographic study area, and was not limited to sites (presumably) previously occupied by oak-hickory forests. In fact, the widespread occurrence of regrowth forests makes the designation of oak-hickory forests as a natural bay component somewhat problematic. In some cases, various exotic tree species are persisting or naturalizing within these oak-hickory forests. These include chinaberry and red mulberry, which are most likely to arrive from house sites adjacent to bays.

Fire is rarely a natural factor in this community. Following any deep fires, this community is replaced by more shrubby growth, thus expanding the area of shrub border that may be adjacent to it. Many of the shrubs within this community sprout vigorously following fire. The developing "regrowth" community following fire will almost certainly include a higher proportion of sweetgum, and potentially loblolly pine. Light gaps may be created through an otherwise thick canopy in mature examples of this community, following windfall of trees. These gaps are quickly colonized by a number of weedy species, especially blackberries, pokeweed, fireweed and others, eventually giving way to shrubby immigrants (e.g. devil's walking stick) or a gradual filling in by whatever shrubs may be already present.

Human alteration is primarily from lumbering or timber operations. Various "regrowth" canopies which develop following such disturbance, always include red maple, sweetgum, and loblolly pine. Wetter examples of this community, particularly where they form ecotones with non-alluvial swamps, generally contain black gum and at least some pond cypress. Oak-hickory forests that have been flooded due to alteration of the water table apparently approach the canopy aspect of non-alluvial swamps.

Due to questions remaining about the natural occurrence of this community in bays, it has not been included within the community breakdown (Figure 17). However, variants of oak-hickory forest may be found in bays throughout the four Quadrants. No elements of concern have been identified from this community.

2. Palustrine Systems

Non-alluvial Swamp - A broad range of seasonally-flooded forested wetlands occurs in many Carolina bays. Non-alluvial swamp is the name given in this study to those sites dominated by combinations of broad leaved tree species and pond cypress in varying proportions. Pond cypress may be nearly absent in these communities, or it may be a co-dominant. Broad-leaved species occurring as co-dominants are black gum, red maple and sweetgum, the last two usually most important in swamps having received some disturbance.

Varying cycles of flooding characterize these swamps. During the dry season there may be no standing water at all, except in deep pools. Shrubby species (fetterbushes, Virginia willow, myrtle-leaved holly, blueberry) are often restricted to elevated patches, often in association with tree bases (or stumps). Herbaceous plants include cinnamon fern, royal fern, chain ferns, three-way sedge, duck weeds, wood germander, water horehound, pickerel weed, crowfoot pennywort, green arum, water willow, and water lily, and species of *Eleocharis* and *Rhynchospora*.

In very few cases, pond cypress is apparently replaced in bays by the more commonly riverine bald cypress. We have located one bay (Clarendon County) which contains water tupelo, a river swamp associate, in addition to black gum. These species may indicate prolonged flooding regimes within the bays they occupy.

Since they are nearly always flooded, fire is probably never a significant factor within these systems. Fallen logs within these swamps provide numerous microhabitats for herbaceous species, and shrubby "islands" may develop at spots receiving adequate light, especially following removal of canopy members.

The draining of these swamps by ditches plays a major part in their conversion to secondary regrowth forests, which are by nature much drier. Conversely, increased hydroperiod of these sites probably favors the slow development of pond cypress ponds, or truly swamp tupelo-dominated sites, depending on which of the two species was most dominant prior to

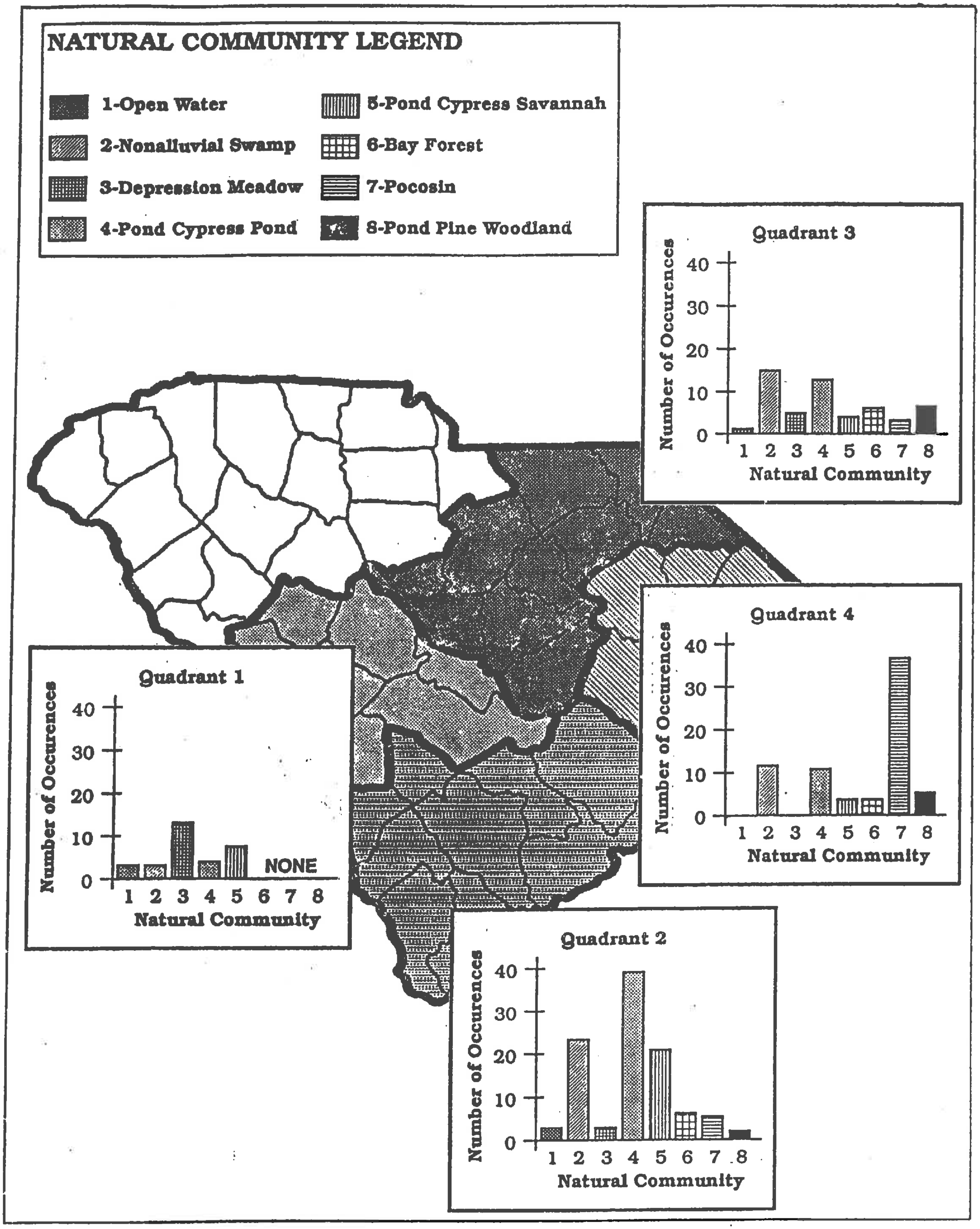

Figure 17. Distribution of natural communities associated with bays by quadrant

increased hydroperiod. Selective timbering of non-alluvial swamps usually allows an increased population of shrubby species to develop in light gaps, especially around resultant stumps.

Most non-alluvial swamps occur in Quadrant 2 (with 22 examples), followed by Quadrants 3 and 4 (with 13 and 11 examples respectively).

Pond Cypress Pond - This community has a canopy composed overwhelmingly of pond cypress. Black gum and red maple are usually present, but in smaller numbers. Shrubs present usually include myrtle-leaved holly, sweet pepperbush and fetterbush, which often form isolated thickets much as in non-alluvial swamps. The herbaceous flora of pond cypress ponds is similar to that of non-alluvial swamps, including water lily, bladderworts, three-way sedge, cinnamon fern and pickerel weed. These ecosystems are characterized by very long hydroperiods, and are nearly permanently flooded. Fires may occur rarely during dry-down years, when appreciable fuel loads have developed. Unless fires are frequent, however, their effects are limited. The removal of black gum may be effected by fires, maintaining the dominance of pond cypress. Windfall within the canopy may occur, opening up light gaps and allowing a more or less temporary introduction of other species. These are ultimately replaced again by pond cypress. Pond cypress ponds are probably closely related to non-alluvial swamps, but conceivably with a longer hydroperiod and lower species diversity.

These ponds are frequently drained by ditching. A decrease in the hydroperiod allows the establishment of many broad-leaved canopy species, including black gum, red maple, and sweet gum and a much increased level of shrubby growth. Such altered ponds closely resemble non-alluvial swamps, if not completely drained. If ditching is extensive, effective drainage does occur, and oak-hickory forest or regrowth forest may eventually replace the pond cypress pond.

Removal of cypress from the ponds allows, similarly, an increase in the proportion of broad-leaved species, especially black gum. Pond cypress ponds within bays are most abundant in the lower coastal plain (36 sites in Quadrant 2).

Elements of concern most likely occurring in this community are sarvis holly and *Hypericum harperi*. Little bur-head and *Paspalum dissectum* are potentially present during periods of drying, with the latter of these two species sometimes forming extensive zones.

Pond Cypress Savanna - This community is characterized by a thin, discontinuous canopy composed almost entirely of pond cypress, with black gum present in smaller numbers. Although floristically similar to pond cypress ponds, differences in hydrology rather easily separate the two. Flooding is apparently of limited duration in pond cypress savannas. The dynamics of this savanna type approximate those of pine savannas, including moisture and fire regimes.

Most of the bays dominated by pond cypress savanna are located in the lower portion of the coastal plain (18 sites in Quadrant 2), with a few others near the adjacent boundaries of Quadrants 1, 3, and 4.

Pond cypress savannas are probably the most floristically diverse of all Carolina bay community types, and showy vernal and autumnal flowering occurs in those which remain in good condition. The dominant herbaceous species within these savannas are always sedges (especially *Carex striata*)and grasses. *Hypericum fasciculatum*, *H. galioides*, or both are commonly scattered within this community, along with numerous showy forbs. In addition to *Hypericum*, myrtle-leaved holly is a common shrubby component, usually scattered within a given savanna on low hillocks or next to tree bases. Many of the plant species of concern associated with bays are most likely to be found in pond cypress savannas. These are Canby's cowbane, awn-petaled meadow beauty, Baldwin's nut-sedge, *Stillingia aquatica*, Boykin's lobelia, pondspice, *Helenium pinnatifidum*, Tracy's beakrush, and *Rhynchospora inundata*.

This community, though experiencing periodic flooding, probably burns naturally much more often than pond cypress ponds. The burning of a more substantial herbaceous layer - one not dependent on periodic dry-downs to develop - removes less tolerant black gum and various shrubs, especially myrtle-leaved holly. The natural fire dynamics of these savannas are not completely known, but may approach those of pine savannas on more upland sites.

Effective ditching within these communities allows the establishment of more black gum and other broad-leaved canopy species. Myrtle-leaved holly and the members of shrub borders will also proliferate in such artificially dried savannas.

<u>Depression Meadows</u> - Open grassy flats characterize depression meadows, which are essentially devoid of woody vegetation. This community is fairly rare in South Carolina, and is restricted largely to the western part of the coastal plain (Quadrant 1, and rarely from the adjacent areas of Quadrants 2 and 3). Depression meadows are occasionally flooded, but presumably have no standing water for much of the year. Several good examples of depression meadows occur in ring shapes around open water lakes (see treatment following) and technically

may represent an ecotonal zone between open water and a drier zone. A very rich herbaceous flora is found within depression meadows.

The herbaceous flora of depression meadows is, in general, similar to that found in pond cypress savannas, except that grasses and sedges do not always form as dense a ground cover. Further, species zonation is often apparent in depression meadows (Kelly and Batson 1955), with a high degree of concentricity around the lowest point.

Unlike pond cypress savannas, depression meadows exhibit less diversity in the number of grass and sedge species, but have a proportionally larger number of forbs. Showy, characteristic plants include species of *Aster*, *Boltonia*, *Xyris*, *Ludwigia*, and *Solidago*. Rare taxa found within depression meadows include awn-petaled meadow beauty, quill-leaf, amphicarpum, little bur-head, creeping seedbox, rose corcopsis, Robbins' spike-rush, harperella and *Hypericum adpressum*.

The absence or near absence of woody species in this ecosystem probably involves naturally periodic fires. However, the invasion of this community by woody species in the absence of fire is apparently very slow, suggesting that the dynamics of these meadows is complex, certainly involving lengthy hydroperiod, and possibly edaphic factors.

Depression meadows have much in common, floristically, with open water lakes within Carolina bays, but are differentiated from them in being less frequently flooded. The drainage of surface water into depression meadows and their impoundment would probably result in an approximation of a natural open-water lake.

Pocosin - Bays dominated by pocosin in South Carolina are mostly located in the eastern portion of the coastal plain, essentially those counties within Quadrant 4. Of 43 pocosin-dominated bays examined, 35 are from Quadrant 4, the rest are scattered near the adjacent portions of Quadrants 2 and 3. In South Carolina, "classic" pocosin land is not always associated with Carolina bays, much as with the case in North Carolina. In general, pocosin sites in South Carolina found outside Carolina bays are floristically equivalent to those that are within bays. Bays dominated by pocosins characteristically have a substrate of peat to varying depths. Within the deepest peat-based substrates are found the lowest pocosins, with a minor canopy component of tree species, and an overwhelming predominance of low growing shrubs.

Shrubs, many of which are species of *Ilex* and members of the *Ericaceae* dominate pocosins within bays. Common species include fetterbushes, maleberry, dangleberry, mayberry, highbush blueberry, black highbush blueberry, creeping blueberry, wild azalea, swamp azalea, inkberry and gallberry, along with (usually) stunted or short loblolly bay, and pond pine. Additional widespread woody species are chokeberry, zenobia, small black blueberry, and sheep-kill. Bamboo-vine is a nearly universal viny component of this canopy, in some situations forming extensively tangled bowers on top of the shrubs. The floors of these pocosins are highly shaded, with a depauperate herbaceous flora. These habitats are often dominated by extensive mats of litter, with herbaceous species generally occupying wetter, or otherwise open areas, usually toward the bay periphery. Herbs in such situations include various species of bog buttons, fringed orchid, bladderworts, panic grass and broom sedge. Extensive mats of various *Sphagnum* species are also commonly found on the wettest sites within pocosins. A few rare taxa are known from many bay pocosins. Leatherleaf may be locally abundant in some sites. Spoon flower is usually restricted to wet holes caused by previous deep burns, or by excavations. Venus' fly-trap and swamp milkweed are most likely to occur at pocosin-sand rim ecotones, rather than within the pocosin interior.

Natural and artificial dynamics of pocosins and related communities are investigated at length elsewhere (Sharitz and Gibbons 1982, Ash et al. 1983). Although, pocosins are genrally fire-maintained, usually burning fairly frequently (at least once every 6 - 10 years), some sites, especially on very deep peats or wetter areas, may persist without fire. The suppression of fire leads to the establishment of tree species, especially at the edges of the pocosin. Repeated deep burns of pocosins in North Carolina may result in the development of small lakes; these have not been seen in this study.

Pond Pine Woodland - Easily defined, good examples of this community as a dominating feature of bays are extremely rare. Of the examples listed within this report, seven are from Quadrant 3, with five in Quadrant 4. This community is clearly closely related to pocosins, and probably represents a form of it on shallower peaty soils. Pond pine is the overwhelmingly dominant canopy component of this community, with most of the trees rarely taller than about 30 feet. In addition, canopy elements of the similar bay forest (see below) may occur as well, especially loblolly bay, red bay and sweetbay. Sourwood is an occasional canopy member of this community. Shrubs and herbs present, in general, are the same as those found within pocosins, but usually not with as high diversity.

Frequent fires in this community cause it to revert to a pocosin. Pond pine woodlands may occur as islands or in a netlike arrangement within a lower pocosin, probably restricted to areas of shallower peat with more mineral soils.

Potential elements of concern within this community are the same as those for pocosins.

Bay Forest - This rare community is restricted to Quadrants 2, 3 and 4, essentially within the same distribution of pocosins and pond pine woodlands. Bay forests, as the name implies, are dominated by loblolly bay, sweetbay and red bay, roughly in that order. Pond pine may form a significant portion of the canopy and understory of these forests, which are definitely best classified as broad-leaved and evergreen. Tall members of the pocosin community, most often species of fetterbush and hollys, often form a dense undergrowth in such sites. Otherwise, the shrubby pocosin species are best represented toward the periphery of these forests (as they are in pond pine woodlands).

Naturally occurring fire may cause the reversion of this ecosystem to pocosin. As with pond pine woodlands, these forested wetlands may occur in scattered patches or a netlike arrangement, often on slightly drier ground.

Potential elements of concern within this community are the same ones as for pocosins.

Shrub Border - In part as a matter of convenience, this community is designated to incorporate the often ring-like band of shrubby vegetation very commonly observed toward the center of bays. These borders represent transitions from higher, dryer ground to a wetter bay interior, and represent ecotones. Pond cypress savanna, pond cypress pond, nonalluvial swamp, and to a lesser extent, depression meadows are bay communities which may be separated from a surrounding oak-hickory forest or from an adjacent sand rim by such a shrub border.

Species composition of shrub borders varies greatly from site to site; some borders encountered were dominated by a very few species. All the species encountered in shrub borders are expected components of pocosin systems. Obviously, the close floristic relationship between pocosin and "shrub border" suggests the existence of a single ecosystem type, and in fact, the overall impression attained within a well-developed shrub border is that of a pocosin. However, bays with discernible shrub borders, as opposed to true pocosins, are clay-based, and are found for the most part outside of Quadrant 4. Additionally, dynamics involving hydrology probably greatly affect the differentiation of true pocosin and shrub borders, certainly involving flooding regimes and burning cycles. Nearly all of the woody species found within it are typically pocosin plants, with highly flammable foliage. Following fires, most of these shrubs sprout profusely from the roots, and so effect tangled, impenetrable thickets. Shrub borders are likely to be taller, and potentially less diverse, when fire is suppressed. It may be added here that many intact bays probably owe their survival to a wide, forbidding shrub border.

As with oak-hickory forests, this community is not included within the state-wide breakdown of communities in Figure 13. Shrub borders may be expected in great variation throughout the study area.

Pondspice has been located within the shrub border of one bay in Kershaw County. Leatherleaf is a potential member of this community in Quadrants 2, 3 , and 4.

3. Aquatic Systems

<u>Open Water Lake</u> - Natural lakes are extremely rare in bays within South Carolina. The designation Open Water Lake includes those ecosystems that are generally constantly flooded up to a depth of 3-4 feet. Woody vegetation, except for rare isolated islands, is lacking. Six examples of this community type are known from South Carolina, with none in Quadrant 4. In dry seasons, open water lakes may contract appreciably, with depression meadow then appearing along the edges. The alternating cycle of lake contraction and expansion is closely related to the development of any associated depression meadow. These lakes may dry down completely in drought years, but only temporarily. Spring fed bays may never dry completely.

Emergent and floating vegetation is usually extensive within open water lakes. Water lily, cow lily, yellow lotus, water shield, and heartleaf, along with many grasses and sedges, are common in these lakes. Rare taxa known from open-water lakes are *Rhynchospora inundata* and Tracy's beakrush. Other potential elements include quill-leaf, *Paspalum dissectum*, awn-petaled meadow-beauty, creeping seedbox and little bur-head.

Fire is never a factor, except during dry seasons when the lake has dried down considerably, and even then it is unlikely that appreciable fuel loads would have developed. Both open water lakes and depression meadows may have woody vegetation suppressed by similar dynamics.

Rare/Threatened/Endangered Plant Taxa

Plant species considered rare, threatened or otherwise noteworthy are listed here, alphabetically by family. Each species treated is briefly described, along with notes on previous distributional knowledge and collections resulting from this study. Where noted, collections made serve as vouchers. All collections are deposited at the Moore Herbarium of the University of South Carolina.

Echinodorus parvulus Engelm. (Alismataceae).

Common name: "Little bur-head."

This easily overlooked, diminutive plant is apparently widely distributed (Godfrey and Wooten 1979) in eastern North America, but populations are highly localized. Very few collections from South Carolina exist, these being from Aiken, Saluda and Sumter Counties. An additional collection (Nelson and Bennett 3563) adds Bamberg County to the known distribution. This plant is also present along stretches of the Waccamaw River in Horry County, where the ecosystem present may in fact duplicate certain features of Carolina bay hydroperiodicity.

Sagittaria isoetiformis J. G. Sm. (Alismataceae).

Common name: "Quill-leaf."

Godfrey and Wooten (1979) indicate the natural range of this small perennial as southeastern North Carolina to central peninsular Florida and west to south Alabama. It is very rare in South Carolina and entirely restricted to Carolina bays, known previously to this study from only a few counties. An additional site (Nelson and Bennett 3608) is from Barnwell County. This species is most likely to be found in depression meadows or at the edges of open water lakes.

Peltandra sagittaefolia (Michx.) Morong (Araceae).

Common name: "Spoonflower."

This aquatic plant occurs from eastern North Carolina south to Florida and west to Mississippi. It is believed to be very rare in the Carolinas though its status is undetermined at present. In South Carolina, it is known only from wet peaty pools in Carolina bays, in association with pocosins.

Ilex amelanchier M. A. Curtis in Chapman (Aquifoliaceae).

Common name: "Sarvis-holly."

Not normally a component of Carolina bays, this shrubby species has been located in one bay, somewhat altered, in lower Richland County (Nelson and Bennett 3686). *Ilex amelanchier*, now known from several coastal plain counties, is apparently more widespread than previously thought. It is found in a number of forested wetland situations. It currently has an undetermined status in South Carolina.

Teesdalia nudicaulis R. Brown (Brassicaceae).

This weedy annual mustard, more common in the northeast, is now known from a few sites in the sandhills of South Carolina. It is not a wetland species and the only bay-associated site for it to date is a roadside right-of-way along a bay sand rim in Kershaw County (Nelson and Bennett 3824).

Lobelia boykinii T. and G. (Campanulaceae).

Common name: "Boykin's lobelia."

Ranging from southern Delaware and South Carolina to northern Florida, this rhizomatous perennial has been considered rare in South Carolina (Radford et al. 1968). Numerous collections have been made during this study from much of the area studied, except for Quadrant 4. Additional collections (Nelson and Bennett 5751, 5770) are from Allendale County, and thus extend its pattern of occurrence from Aiken, Bamberg, Barnwell, Hampton, and Sumter Counties. This species is maintained within the Heritage Trust data base with undetermined status.

Coreopsis rosea Nuttall (Compositae).

Common name: "Rose coreopsis."

This attractive perennial species occurs from New England south to South Carolina, usually in highly localized populations. It is not listed for the flora of the Carolinas (Radford et al. 1968), but has been located in a number of depression meadows within Quadrant 1 bays during the period of this study.

Helenium pinnatifidum (Nuttall) Rydb. (Compositae).

Common name: "Savanna butterweed."

Restricted to the coastal plain from southeastern North Carolina to southern Florida and the eastern Florida panhandle, this showy perennial is very infrequent in South Carolina. It is nearly always found in bays dominated by pond cypress ponds or savannas, sometimes flooded extensively. The South Carolina distribution of Radford et al. (1968) has been expanded to include Orangeburg County (Nelson and Bennett 5555). The status of this species in South Carolina is undetermined.

Eleocharis robbinsii Oakes (Cyperaceae).

Common name: "Robbin's spike-rush."

This species ranges widely across much of North America, often occurring in great abundance in aquatic systems. It is rare in the Carolinas; Radford et al. (1968) did not list it for South Carolina. Seven recent collections, mostly from depression meadows, indicate its presence in Carolina bays.

Rhynchospora tracyi Britton (Cyperaceae).

Common name: "Tracy's beak-rush."

This rhizomatous perennial sedge occurs from South Carolina Florida and west to Mississippi. Four counties (Allendale, Bamberg, Barnwell and Berkeley) are listed for South Carolina (Radford et.al, 1968); recent collections include sites from Orangeburg (Nelson and

Bennett 4303), and Hampton (Nelson and Bennett 5686) Counties, where it is most abundant in pond cypress savannas. This species currently has an undetermined status.

Rhynchospora inundata (Oakes) Fernald (Cyperaceae).

Known from Massachusetts south to Florida and then west to Louisiana, this perennial sedge is listed in South Carolina by Radford et al. (1968) from Berkeley and Dillon Counties on the coastal plain, and surprisingly, from Newberry County. Its status in South Carolina is undetermined at present. New collections of it include sites from Barnwell (Nelson and Bennett 3704), Clarendon County (Nelson and Bennett 4199), and Lexington County (Rayner 2001b) bays. Wet pond cypress savannas and open water lakes are expected sites for this plant.

Scleria baldwinii (Torr.) Steudel (Cyperaceae).

Common name: "Baldwin's nut-rush."

This robust nut-rush is sometimes abundant in open pond cypress savannas. It occurs naturally from South Carolina to Florida and west to Texas, but was listed by Radford et al. (1968) in South Carolina only in Orangeburg County. Recent collections, all from Carolina bays, have added Hampton, Allendale, Berkeley, Sumter and Charleston Counties to the known range.

Dionaea muscipula Ellis (Droseraceae).

Common name: "Venus' fly-trap."

Probably the best-known rare species associated with bays, Venus' fly-trap is historically known from the ecotones between pocosins and xeric sandhill scrub in Charleston, Georgetown, and Horry Counties. This Carolina endemic is considered state-threatened in South Carolina. Extant populations are known only from Horry County, and a recent collection (Nelson and Bennett 6665) has been made from a bay near Loris.

Cassandra calyculata (L.) D. Don (Ericaceae).

Common name: "Leather leaf."

This widely ranging shrubby species is scattered over much of the coastal plain of North Carolina; Radford et al. (1968) indicated no occurrences in South Carolina. It is now known from pocosin dominated bays in Horry, Marion and Sumter Counties (several collections by Pinson at the herbarium of the University of North Carolina). This species has an undetermined status at present.

Stillingia aquatica Chapman (Euphorbiaceae).

Previously known only from Hampton County, this species is now known from bays in Allendale and Barnwell Counties (Nelson and Bennett 5766, 5760, 5872, 3426, 3611, 5693). It is easily differentiated from *S. sylvatica* by its taller stature, branching only at the top of the stem, and occurrence in wet cypress savannas. It occurs from south-central South Carolina to Florida and west to Mississippi.

Hypericum harperi R. Keller (Hypericaceae).

This half-woody emergent *Hypericum* has previously been misidentified and has not until recently (Godfrey 1987) been pointed out as an element previously unrecognized in the state. It is nearly always collected only from wet pond cypress savannas, often in standing water over a foot deep. Its status in South Carolina is not yet determined.

Litsea aestivalis (L.) Fernald (Lauraceae).

Common name: "Pond-spice."

This species, previously considered one of the Southeast's rarest shrubs (Radford et al. 1968), is known only from Orangeburg, Jasper, Charleston, Berkeley and Georgetown Counties. It is now known to be more widespread than previously thought. Within bays, it is sometimes present in pond cypress savannas. A large population exists within a Kershaw County bay.

Rhexia aristosa Britt. (Melastomaceae).

Common name: "Awn-petaled meadow beauty."

This tuber-bearing meadow beauty has in the past been considered rare (Radford et al. 1968), restricted to Bamberg, Berkeley and Georgetown Counties. Fifteen new collections have been made of the species within Allendale (Nelson and Bennett 5858, 5874), Barnwell (Nelson and Bennett 3698), Clarendon (Nelson and Bennett 4182, 4193, 4191), Lee (Nelson and Bennett 4276), Marion (Nelson and Bennett 4769), Orangeburg (Nelson and Bennett 4295), Richland (Nelson and Bennett 3691, 3697, 3658, 3685) and Sumter Counties (Nelson and Bennett 4109). This species has been seen most abundantly on open depression meadows, but also occurs within open water lakes and pond cypress savannas. It is a candidate for federal listing as endangered or threatened.

Ludwigia spathulata T. and G. (Onagraceae).

Common name: "Creeping seedbox."

This species occurs only very locally from South Carolina to southwest Georgia, the Florida panhandle and southern Alabama. It is often found in dried-down cypress ponds, open water lakes, or depression meadows. Radford et al. (1968) reported a single Aiken County location for the two Carolinas. (This species has since been found as well in Lexington County, although not in a Carolina bay.) A recent collection from an open depression meadow (Nelson and Bennett 6067) is from Saluda County.

Amphicarpum muhlenbergianum (Schult.) Hitchcock (Poaceae).

This perennial grass occurs from Nouth Carolina to southern Florida, and west on the coastal plain to southern Alabama. It is one of only a few grass genera producing subterranean spikelets. Currently maintained within the Heritage Trust data base with unknown status, this species is rare, known previously from Orangeburg County (Radford et al. 1968). Additional sites are from Barnwell County, Aiken and Berkeley Counties.

Anthaenantia rufa (Ell.) Schultes (Poaceae).

This perennial grass occurs from North Carolina south to northern Florida, and west to eastern Texas. Radford et al. (1968) indicated 5 counties of occurrence for South Carolina; recent collections add Orangeburg (Nelson and Bennett 3719) and Charleston Counties (Rayner 1079). This plant is most likely to occur in bays dominated by pond cypress savannas. This species has an undetermined status at present.

Paspalum dissectum L. (Poaceae).

Often appearing in great abundance during drought periods, this annual grass may be found at depression meadows or pond cypress ponds. Listed only from Barnwell County by Radford et al. (1968), additional recent collections are from Saluda (Nelson and Bennett 6862) and Sumter Counties (Nelson and Bennett 6285). This species has an undetermined status at present.

Oxypolis canbyi (C. and R.) Fernald (Umbelliferae).

Common name: "Canby's dropwort."

Until this project, *Oxypolis canbyi* had been thought extant in fewer than five sites in North America. Seventeen populations in varying conditions are now known in South Carolina. Clearly, the species is much more frequent in the Southeast than previously thought. It is expected that future inventory efforts in Georgia may locate additional populations, adding to the four counties in which populations have been identified (Jones and Coile 1988). This species, a near-endemic to Carolina bays, is legally listed as federally endangered, and thus represents the highest ranked plant located during this survey. Populations exist in Allendale (Nelson and Bennett 5767), Barnwell (Nelson and Bennett 5913, 3620, 3702) Berkeley (Nelson and Bennett 5995), Clarendon (Jones s.n. Nelson and Bennett 4189), Hampton (Nelson and Bennett 5696), Lee (Nelson and Bennett 4269), Richland (Nelson and Bennett 3687), and Williamsburg Counties (Nelson and Bennett 4964). Two additional populations not associated with Carolina bays are in Bamberg and Colleton Counties.

Discussion

The abundance, variety, and nearly global geographic distribution of isolated, non-tidal wetlands has attracted the attention of ecologists and naturalists worldwide, and an impressive array of sources exists in the literature concerning these ecosystems. The development of focused interest on the biology of Carolina bays has been fairly recent, however. It appears likely that Carolina bays, as a group, share various features with other isolated wetland types. These features certainly include floristic and distributional aspects of vegetation, and to an extent, physical features such as substrate and origin. In North America, geomorphic features possibly related either functionally or through formation processes to Carolina bays include prairie potholes of the upper Midwestern U.S. and central Canada, clamshell ponds of the Alaskan coastal plain, bog and fen complexes of the northern U.S., vernal pools of California, and coastal ponds (including interdune ponds) of the Atlantic coast. Kaczorowski (1976, 1977) considers some of the physical relationships among Carolina bays and oriented lakes.

The only rangewide estimate of Carolina bays to date is Prouty's (1952) in which he predicted three and a half bays with long axis lengths of 500 feet or greater, per square mile, to be found throughout the Atlantic Coastal Plain. This led to his estimate of 140,000 bays, of moderate to large size. Prouty "guessed" that there might be 500,000 bays of all size classes found throughout the Atlantic Coastal Plain.

Schalles et al. (1989) presented an estimate of Carolina bays found on the SRS. Of the 194 bays reported from this site, 132 were 1.9 acres or greater and would likely have been identified and counted by our study. Combining SRS data with ours gives an estimate of 2783 Carolina bays of approximately two acres or greater in South Carolina.

Small bays, less than 1.9 acres, accounted for only 32% of the bay sample from the SRS. Assuming that ratio applies across the state, we estimate that approximately 4000 bays of all size classes exist in South Carolina. This number is undoubtedly high, as the SRS is located in an area of high bay density and would bias estimates.

Prouty's estimates were based on counts made from Bladen County in North Carolina, an area of extremely high bay density (Prouty 1952). Schalles et al. (1989) counted 194 bays on the SRS, an area of some 300 square miles. Based on these data one would predict 1.5 bays of all size classes per square mile, less than half of Prouty's estimate. It is the our opinion that this number is also high, due to the fact that the SRS is also located in an area of high bay density.

The estimate of 4000 bays of all size classes throughout South Carolina's coastal plain, which we report, may also be high, being based on the ratio of small to large bays found on the SRS, an area of high bay density.

Extrapolating Prouty's estimate of 500,000 bays, eighty percent of which are shared equally by North and South Carolina leads to an estimate of 200,000 bays in South Carolina. Our estimate of 4000 bays is approximately two orders of magnitude less than Prouty's, and even if we undercounted by 100% would still be far less than the previous estimates.

Carolina bays were never as common or abundant as has been believed in the past. This false sense of abundance and a general disdain for wetlands has likely accounted for lack of concern over the alteration and abuse these systems have undergone.

Data from aerial photography indicated that only 1297 bays examined were relatively intact (less than 20% altered). Field studies revealed that many of these bays were in fact regrowth communities, representing altered hydrologic conditions. These studies also revealed that in the time between the aerial photography being made and the field studies ($\bar{X}$ = 6.6 yrs., Std. dev. = 3.37), 234 of the 613 bays visited (38% of the sample) had been functionally altered.

The estimate of 400 to 500 relatively intact bays remaining in South Carolina (presented in the Disturbance section) is based on both the functionally altered bays (highly disturbed) and the regrowth bays (which also represent functionally altered wetland systems though they support intact vegetative communities). It is with caution that we present this estimate because to arrive at it we have used both the quantitative data from the aerial photography study and the qualitative data from the field study phase of this project.

It is the author's opinion that the findings of the field study indicate a much worse status for Carolina bays in our state than is revealed through the aerial photography study. Projecting the qualitative field study data to the quantitative aerial photography study data and applying this to the distribution of estimated disturbance for all bays would tend to greatly reduce the number of bays at the low percent disturbance end of the scale. Conversely, the number of bays at the high end, 90% to 100% disturbed (or altered) would increase.

While the aerial photography indicated that ditches as a disturbance type were secondary to row crops, field study indicated a different result. Ditches or ditch scars were found in virtually every bay visited. Many of these ditches were not apparent on photographs due to canopy closure or age of the ditch. Some of these ditches may have existed to drain uplands into a bay. Many, however, were attempts, either successful or not, to drain bays so the land could be used for other purposes. Many bays which have not been totally altered by ditching attempts show some response to the presence of a ditch. Whether these systems can be restored or reclaimed remains to be seen. This is, however, a question that must be addressed in light of the dramatic reduction of these systems.

Observations on the presence of sand rims indicate that in South Carolina they are not common features. Horry County is the exception to this observation and is also the county with the most extensively developed sand rims.

Horry County is also the county where the most bay overlap has been recorded. This observation, the number of sand rims and the distribution of natural communities lead to the conclusion that Horry County and to some degree, Marion, Dillon and Marlboro Counties have more in common with the peat based bays of the North Carolina outer coastal plain (Buell 1939, 1946; Wells and Boyce 1953) than with the majority of bays in South Carolina. Frey (1950) described "hard-bottomed" bays (sometimes referred to as clay-based bays) from the upper coastal plain terraces of North Carolina. The majority of bays in South Carolina appear to be of this "hard-bottom" variety, harboring little or no peat accumulation in their basins.

The distinction between the peat-based and clay-based bays is related to the geologic mechanisms which hold rainwater perched above the normal water table in these wetland ecosystems. Clay-based bays have a layer or "lens" of impervious clay located within the bay's basin. The basins of these bays are generally filled with a mineral soil overlying the clay layer

Peat-based bays are those bays which have thick deposits of peat within their basins. The perching mechanism for these bays is commonly believed to be a layer of humate-impregnated sand located below the peat deposit (Kaczorowski, pers. comm.).

Peat-based and clay-based bays can generally be separated by the natural communities associated with them. There are, however, some bays which contain communities associated with both peat-based and clay-based systems. These mosaic bays may have areas of mineral soil and peat soil or they may have shallower deposits of peat, which could allow for the development of non-peat associated communities. This is an area worthy of further study.

At least four bays believed to be spring fed were identified during this study. This phenomenon has been recorded for bays in North Carolina, most notably Lake Waccamaw (Frey 1949), but is uncommon.

One of the bays believed to be springfed in South Carolina is Woods Bay. This bay holds water year round and at one time actually supported a mill with water flowing from the bay. The three other bays considered to be springfed hold water throughout the year and have relatively deep basins.

Two phenomena concerning Carolina bays have led to recent interest in investigating unusual plant taxa within them. First, as isolated wetlands, bays almost always represent possible refugia for various species within a larger, less hospitable area. Surrounding lands are always more elevated, and usually drier, and the transition into a given bay may be very sharp. Wetland species within a given geographic area may be entirely restricted to any intact bays that may be present.

Second, bays have been historically regarded as very uninviting to humans. The terms "pocosin" and "bay" are sometimes interchanged (especially in the northeastern part of this state), and it seems likely that the prevalent notion of a bay is that of an impenetrable shrub thicket, i.e. a pocosin. The notion of bays as snake-and-insect-infested-swamps has further deterred most people. Until fairly recently, naturalists have also apparently avoided bays. The lack of past inventory of flora and fauna within Carolina bays has resulted in many gaps in our knowledge of species distribution, and it is only now that intensive study of bays has revealed a large number of new or noteworthy plant records.

Most of the natural communities (xeric sandhill scrub, pocosin, depression meadow, open water lake, pond cypress pond, pond cypress savanna) encountered in Carolina bays are rather easily definable. These particular communities are identified with some ease in the field. Further, they can all be broken down into plant communities at a much finer level.

Other communities (oak-hickory forest, bay forest, pond pine woodland) are less easily defined. At least part of the reason for this is an incomplete knowledge of the formational and/or successional dynamics involved with each, and our lack of understanding how they are related to non-bay examples elsewhere on the coastal plain.

Xeric sandhill scrub is widespread in South Carolina, including the fall line sandhills and nearly all of the coastal plain, especially on fluvial ridges. Oak-hickory forest is a very broadly-defined community type; bay-related variants of this community are found throughout the coastal plain. Systems defined as non-alluvial swamps are similarly found throughout the coastal plain, these commonly losing their distinction from riverine bottomland ecosystems in many places. Sites described as shrub borders are found throughout the coastal plain, most commonly as palustrine communities. Within bays, shrub borders are nearly always easily recognized, but they may not be in other situations, especially in association with pocosins.

Pocosin-related communities (bay forest, pond pine woodland, pocosin) in South Carolina as in North Carolina are associated with Carolina bays and other ecosystems. However, the distribution in South Carolina of this complex of communities associated with bays is centered in Horry County (Figure 17). There is, in our opinion, a strong correlation between distribution of peat-based bays and those dominated by communities of the pocosin complex. All the examples of pocosin, pond pine woodland, and bay forest located in this study were from bays with significant peat deposits. Clay-based bays (Hard Bottomed bays), apparently much more abundant in South Carolina than previously anticipated, support community types not related to pocosins.

The data indicating strong differences in the types of bays found in North and South Carolina have implications in future protection and conservation efforts aimed at these systems. While Prouty's estimate that North and South Carolina share equally 80% of the known bays may be correct (there are no data to refute or substantiate this estimate), the population of bays is very different. Clay-based bays are apparently uncommon to rare in North Carolina (Chuck Roe, 1983) and are a high priority for protection. In South Carolina, clay-based bays are common and widespread; peat-based bays, however, while not uncommon, are restricted in their distribution. Protection of a series of bays in either North or South Carolina cannot be assumed to have provided adequate representation for the diversity of natural communities associated with bays. Protection of bays should be a priority throughout their range.

Pond cypress ponds within Carolina bays are by far most numerous within Quadrant 2, the lower part of the outer coastal plain. Cypress holes, domes, or ponds not found within bays are almost certainly floristically equivalent, and may, as well, be most commonly distributed in the lower, outer coastal plain. Pond cypress savannas, though related to pond cypress ponds in distribution, are much less frequent. These savannas are very rare outside Carolina bays.

The most infrequently encountered communities in bays are depression meadows and open water lakes. Palustrine meadows are nowhere common in South Carolina, although the presence of frequently flooded freshwater marshes complicates the matter. Naturally occurring ponds in South Carolina may be restricted to interdune ponds of barrier island and mainland beach areas, and to open water lakes of Carolina bays. Thus, the community nearest to being endemic to South Carolina bays is open water lake.

Our knowledge of the distribution of plant elements of concern has been enlarged by this study. Very few new sites have been found for certain species, such as rose coreopsis. This particular species apparently occurs in a narrow geographical zone in South Carolina. Other species previously considered extremely rare have, not surprisingly, been found to occur in wider distributions. These include Canby's cowbane, awn-petaled meadow beauty, and Boykin's lobelia. It is likely that continued study of the floristics of Carolina bays would expand the known ranges of many of the taxa treated in this study. It is also likely that additional plant species, particularly aquatics, may be identified as significant within bays.

It is reasonable to believe that unusual species may be associated with unusual natural communities or geomorphic features. Such is the case with anomalous terrestrial communities such as cedar glades, granitic flatrocks, serpentine barrens, etc., which represent sites for comparatively high levels of endemism. This has not been the case within this study: no apparent plant endemics are yet known from Carolina bays. In South Carolina, awn-petaled meadow beauty and Canby's cowbane seem to be largely restricted to bays, but it can not be definitively maintained that they are absolutely restricted to them. *Harperella*, recently listed as Federally Endangered, is entirely restricted to Carolina bays supporting depression meadow communities in South Carolina. Throughout the remainder of its range, including Alabama, Maryland, and West Virginia, it also occurs in riverine habitats.

While faunal considerations were beyond the scope of this study it is important to note that several rare animal species are known from Carolina bays in South Carolina. The S.C. Heritage Trust database contains records for the following species recorded from Carolina bays: flatwoods salamander - Federal status review, Carolina gopher frog - Federal status review, broad-striped dwarf siren - special concern, and black bear - special concern.

As temporary wetlands, with fluctuating hydrologic cycles Carolina bays provide breeding habitat for numerous amphibian species (Sharitz and Gibbons, 1982). The availability of amphibians, amphibian larvae and aquatic invertebrates provides a resource which can be exploited by semi-aquatic, relatively mobile species of reptiles such as water snakes, yellow-bellied turtles, alligators,and by wading birds.

The pulsed nature of many Carolina bay energy cycles is little understood and warrants further research. Numbers of amphibians captured at drift fences encircling Carolina bays at the Savannah River Site indicate that these systems have high productivity (Sharitz and Gibbons 1982) though this may not be obvious at the level of primary productivity.

The status of Carolina bays as relatively endangered systems, the habitat these provide for rare plants and animals as well as numerous common species, and their unique role in South Carolina's history and natural history combine to make them a high priority for protection by the S.C. Heritage Trust Program.

Assessment of the relatively intact bays, which were recorded during the field study, led to the approval of thirty-six protection projects for the Heritage Trust Program (Figure 18). Protection efforts are underway for these bays, and to date all or parts of seven bays or bay complexes have either been acquired or registered by the Heritage Trust Program.

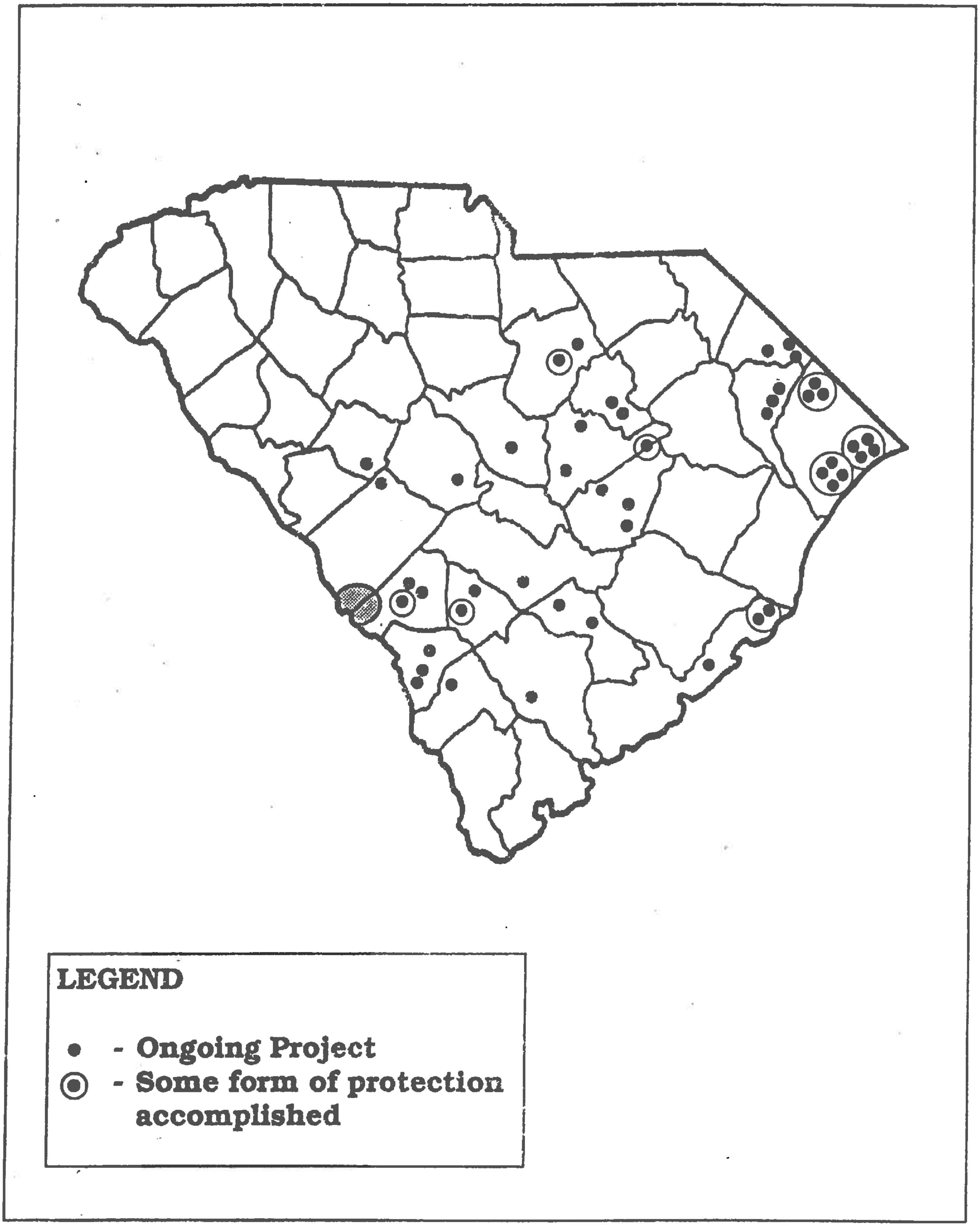

Figure 18. Carolina Bays approved as protection projects by the Heritage Trust Program

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Appendix 1.

Alphabetized List of Common and Scientific Plant Names

Common Name	Scientific Name
Amphicarpum	Amphicarpum muhlenbergianum (Schult.) Hitchc.
Awn-petaled meadow beauty	Rhexia aristosa Britt.
Bald cypress	Taxodium distichum (L.) Richard
Baldwin's nut-sedge	Scleria baldwinii (Torr.) Steud.
Bamboo-vine	Smilax laurifolia L.
Black Highbush blueberry	Vaccinium atrococcum (Gray) Porter
Black gum	Nyssa sylvatica Marsh. var. biflora (Walt.) Sarg.
Blackberries	Rubus spp.
Blackjack oak	Quercus marilandica Muenchh.
Bladderworts	Utricularia spp.
Blueberries	Vaccinium spp.
Bog-buttons	Lachnocaulon spp.
Boykin's lobelia	Lobelia boykinii T. & G.
Broom sedge	Andropogon virginicus L.
Canby's cowbane	Oxypolis canbyi (C. & R.) Fern.
Chain fern	Woodwardia virginica (L.) Smith
Chain fern	Woodwardia areolata (L.) Moore
Chinaberry	Melia azedarach L.
Chokeberry	Sorbus arbutifolia (L.)Heynhold
Cinnamon fern	Osmunda cinnamomea L.
Cow lily	Nuphar luteum (L.) Sibth. & Smith
Creeping blueberry	Vaccinium crassifolium Andrews
Creeping seedbox	Ludwigia spathulata T. & G.
Crowfoot pennywort	Hydrocotyle ranunculoides L.f.
Dangleberry	Gaylussacia frondosa (L.) T.&G.
Devil's walking stick	Aralia spinosa L.
Duck weed	Lemna spp.
Duck weed	Spirodela spp.
Duck weed	Wolfiella spp.
Dwarf azalea	Rhododendron atlanticum (Ashe) Rehder
Dwarf chinkapin	Castanea pumila (L.) Miller
Dwarf pawpaw	Asimina parviflora (Michx.)

	Dunal
Fetterbush	Lyonia lucida (Lam.) Koch.
Fetterbush	Leucothoe racemosa (L.) Gray
Fireweed	Erechtites hieracifolia (L.) Raf.
Flowering dogwood	Cornus florida L.
Fringed orchid	Habenaria cristata (Michaux) R. Br.
Gallberry	Ilex coriacea (Pursh) Chapman
Green arum	Peltandra virginica (L.) Kunth
Harperella	Ptilimnium nodosum (Rose) Math.
Hawthorn	Crataegus spp.
Heartleaf	Nymphoides spp.
Highbush blueberry	Vaccinium corymbosum L.
Holly	Ilex spp.
Horse-sugar	Symplocos tincforia (L.) L'Her.
Indian pipes	Monotropa uniflora L.
Inkberry	Ilex glabra (L.) Gray
Leatherleaf	Cassandra calyculata L. D. Don
Little bur-head	Echinodorus parvulus Engelm.
Loblolly bay	Gordonia lasianthus (L.) Ellis
Loblolly pine	Pinus taeda L.
Longleaf pine	Pinus palustis Miller
Maleberry	Lyonia ligustrina (L.) DC.
Mayberry	Vaccinium elliottii Chapman
Mockernut hickory	Carya tomentosa (Poir.) Nutt.
Muscadine	Vitis rotundifolia L.
Myrtle-leaved holly	Ilex cassine L. var. myrtifolia (Wah.) Sarg.
Panic grass	Panicum spp.
Partridge berry	Mitchella repens L.
Pawpaw	Asimina triloba (L.) Dunal
Pickerel weed	Pontederia cordata L.
Poison ivy	Rhus radicans L.
Pokeweed	Phytolacca americana L.
Pond cypress	Taxodium ascendens Brongn.
Pond pine	Pinus serotina Michx.
Pondspice	Litsea aestivalis (L.) Fern.
Post oak	Quercus stellata Wang.
Prickly pear	Opuntia compressa (Salis.) Macbr.
Quill-leaf	Sagattaria isoetiformis J.G.Sm.
Red bay	Persea palustris (Raf.) Sarg.
Red buckeye	Aesculus pavia L.

Red maple	Acer rubrum L.
Red mulberry	Morus rubra L.
Robbins' spike-bush	Eleocharis robbinsii Oakes
Rose coreopsis	Coreopsis rosea Nutall
Royal fern	Osmunda regalis L. var. spectabilis (Willd.)Gray
Sand carnation	Stipulicida setacea Michx.
Sarvis holly	Ilex amelanchier
Sassafras	Sassafra albidum (Nutt.) Nees
Scrub post oak	Quercus margaretta Ashe
Sheep-kill	Kalmia angustifolia L.
Small black blueberry	Vaccinium tenellum Aiton
Snakeroot	Sanicula canadensis
Sourwood	Oxydendrum arboreum (L.) DC.
Spoonflower	Peltandra saggitaefolia (Michaux) Morong
Swamp azalea	Rhododendron viscosum (L.) Torrey
Swamp milkweed	Asclepias pedicollata Walter
Sweetbay	Magnolia virginiana L.
Sweet pepperbush	Clethra alnifolia L.
Sweetgum	Liquidambar styraciflua L.
Switch cane	Arundinaria gigantea (Walt.) Muhl.
Three-way sedge	Dulichium arundinaceum (L.) Britton
Tread-softly	Cnidoscolus stimulosus (Michx.) Engelm. & Gray
Tracy's beakrush	Rhynchospora tracyi Britt.
Turkey oak	Quercus laevis Walter
Venus' Fly-trap	Dionaea muscipula Ellis
Virginia willow	Itea virginica L.
Water Oak	Quercus nigra L.
Water horehound	Lycopus spp.
Water lily	Nymphaea odorata Aiton
Water shield	Brasenia schreberi Gmelin
Water tupelo	Nyssa aquatica L.
Water willow	Decodon verticillatus (L.) Ell.
White oak	Quercus alba L.
Wild azalea	Rhododendron canescens (Michx.) Sweet
Wild petunia	Ruellia caroliniensis (Walt.) Steudel

Wild violet	Viola affinis LeConte
Willow oak	Quercus phellos L.
Wiregrass	Aristida sp.
Wood germander	Teucrium canadense L.
Yellow lotus	Nelumbo lutea (Willd.) Persoon
Zenobia	Zenobia pulverulenta (Bartram) Pollard

Appendix 2.

Carolina Bay Ranking System

Carolina bays approved as protection projects have been ranked by Heritage Staff of the South Carolina and Marine Resources Department. The system used to rank bays was one in which numerical values were assigned to the bay features. These are as follows:

1. Size -

0	-	50 acres	1 point
50	-	100 acres	2 points
100	-	200 acres	3 points
200	-	500 acres	4 points
500	-	1000 acres	5 points
1000	-	2000 acres	7 points
2000	-	4000 acres	9 points
4000	-	6000 acres	10 points

2. Plant Communities - 1 point for each plant community present plus 1 point for rare communities (i.e. pine savanna or depression meadow).

3. Plant and animal elements of concern - 1 point for each element plus 2 points for G1, NC or Federally Endangered.

4. Disturbance - minus 1 point for every 5% over 10%.

5. Sand rim - intact, good shape equals 1 point.

6. Rookeries - 2 points (white bird rookeries).

Appendix 3.

Collections of Plants from Carolina Bays,
Arranged by Family

Family	Genus	Species	County	Collection Number
Acanthaceae	Ruellia	caroliniensis	Hampton	5642
Aceraceae	Acer	rubrum	Marlboro	5286
Alismataceae	Echinodorus	parvulus	Bamberg	3563
	Sagittaria	graminea	Allendale	5929
	Sagittaria	graminea	Orangeburg	5556
Anacardiacaeae	Rhus	toxicodendron	Lexington	3317
	Rhus	radicans	Hampton	5591
	Rhus	radicans	Marlboro	5280
Annonaceae	Asimina	parviflora	Dillon	5956
Aquifoliaceae	Ilex	coriacea	Berkeley	5472
	Ilex	coriacea	Clarendon	6563
	Ilex	glabra	Berkeley	5474
	Ilex	myrtifolia	Calhoun	3356
Araceae	Peltandra	virginica	Clarendon	6567
Bromeliaceae	Tillandsia	usneoides	Hampton	5597
Campanulaceae	Lobelia	boykinii	Allendale	5751
	Lobelia	boykinii	Allendale	5770
	Lobelia	boykinii	Hampton	5639
	Lobelia	boykinii	Hampton	5673
	Lobelia	boykinii	Hampton	5694
	Lobelia	canbyi	Berkeley	6002
	Lobelia	nuttallii	Dillon	5947
	Lobelia	nuttallii	Hampton	5634
	Lobelia	nuttallii	Horry	6666
Caprifoliaceae	Viburnum	nudum	Dillon	5830
	Viburnum	obovatum	Colleton	5550
Clethraceae	Clethra	alnifolia	Allendale	5792
Commelinaceae	Tradescantia	rosea	Calhoun	3352
Compositae	Aster	concolor	Dillon	6257
	Aster	tortifolius	Clarendon	5940
	Boltonia	asteroides	Aiken	6063
	Chaptalia	tomentosa	Charleston	6302
	Coreopsis	delphinifolia	Allendale	5876
	Coreopsis	falcata	Berkeley	6710

	Coreopsis	rosea	Aiken	6294
	Coreopsis	rosea	Saluda	6083
	Eupatorium	leptophyllum	Allendale	7068
	Eupatorium	leucolepis	Clarendon	5939
	Eupatorium	recurvans	Allendale	7069
	Eupatorium	rotundifolium	Berkeley	5987
	Eupatorium	semiserratum	Allendale	5856
	Helenium	pinnatifidum	Berkeley	5396
	Helenium	pinnatifidum	Orangeburg	5555
	Iva	microcephala	Aiken	6075
	Iva	microcephala	Allendale	6949
	Iva	microcephala	Edgefield	6100
	Liatris	regimontis	Dillon	5958
	Pluchea	camphorata	Aiken	6081
Compositae	Pluchea	foetida	Dillon	5827
	Pluchea	rosea	Allendale	5740
	Pluchea	rosea	Allendale	5866
	Pluchea	rosea	Sumter	4035
	Sclerolepis	uniflora	Aiken	6059
	Sclerolepis	uniflora	Allendale	5863
	Sclerolepis	uniflora	Clarendon	6755
	Silphium	dentatum	Allendale	5764
	Silphium	dentatum	Clarendon	5936
	Solidago	gigantea	Clarendon	5938
Convolvulaceae	Bonamia	patens	Allendale	5878
	Bonamia	patens	Allendale	5924
	Bonamia	patens	Dillon	5955
	Cuscuta	compacta	Bamberg	3413
Cruciferae	Rorippa	sessiliflora	Berkeley	5404
Cyperaceae	Carex	complanata	Aiken	3255
	Carex	gigantea	Clarendon	6568
	Carex	glaucescens	Allendale	5778
	Carex	striata	Allendale	5739
	Carex	striata	Calhoun	3331
	Carex	striata	Berkeley	5996
	Carex	striata	Hampton	5675
	Carex	venusta	Bamberg	3454
	Carex	vulpinoidea	Colleton	5553
	Cyperus	erythrorhizos	Aiken	6074
	Cyperus	erythrorhizos	Allendale	5787
	Cyperus	globulosus	Allendale	5788
	Cyperus	odoratus	Allendale	6944
	Cyperus	ovularis	Allendale	5784
	Cyperus	retrorsus	Berkeley	5992

Dichromena	colorata	Berkeley	5406
Dichromena	colorata	Hampton	5676
Dichromena	latifolia	Allendale	5768
Dulichia	arundinacea	Clarendon	4139
Dulichium	arundinaceum	Clarendon	6751
Dulichium	arundinaceum	Dillon	5825
Eleocharis	baldwinii	Saluda	6070
Eleocharis	melanocarpa	Allendale	5885
Eleocharis	microcarpa	Berkeley	6706
Eleocharis	obtusa	Calhoun	3333
Eleocharis	robbinsii	Edgefield	6097
Eleocharis	robbinsii	Saluda	6088
Eleocharis	tricostata	Calhoun	3351
Eleocharis	tuberculosa	Berkeley	6003
Eleocharis	tuberculosa	Dillon	5829
Eleocharis	vivipara	Colleton	5541
Fimbristylis	autumnalis	Allendale	6943
Fimbristylis	autumnalis	Berkeley	5994
Fimbristylis	spadicea	Clarendon	6753
Fuirena	pumila	Allendale	6941
Fuirena	squarrosa	Allendale	5756
Psilocarya	nitens	Allendale	6945
Rhynchospora	careyana	Allendale	5759
Rhynchospora	careyana	Allendale	5925
Rhynchospora	careyana	Berkeley	5998
Rhynchospora	cephalantha	Berkeley	5993
Rhynchospora	cephalantha	Berkeley	5997
Rhynchospora	cephalantha	Hampton	5677
Rhynchospora	cephalantha	Hampton	5695
Rhynchospora	chalarocephala	Aiken	6076
Rhynchospora	chalarocephala	Allendale	5761
Rhynchospora	elliottii	Berkeley	6703
Rhynchospora	fascicularis	Berkeley	5989
Rhynchospora	fascicularis	Dillon	5952
Rhynchospora	glomerata	Allendale	5881
Rhynchospora	glomerata	Hampton	5599
Rhynchospora	gracilenta	Orangeburg	6914
Rhynchospora	gracilenta	Orangeburg	6924
Rhynchospora	harperi	Allendale	5750
Rhynchospora	harperi	Hampton	5691
Rhynchospora	inexpansa	Allendale	5782
Rhynchospora	inexspansa	Dillon	5954
Rhynchospora	macrostachya	Edgefield	6103
Rhynchospora	megalocarpa	Sumter	4000

	Rhynchospora	microcarpa	Aiken	6060
	Rhynchospora	microcephala	Dillon	5950
	Rhynchospora	perplexa	Allendale	5886
	Rhynchospora	pusilla	Allendale	5857
	Rhynchospora	tracyi	Allendale	5748
	Rhynchospora	tracyi	Allendale	5861
	Rhynchospora	tracyi	Allendale	5879
	Rhynchospora	tracyi	Allendale	5887
	Rhynchospora	tracyi	Hampton	5686
	Rhynchospora	wrightiana	Clarendon	6759
	Scirpus	cyperinus	Allendale	6931
	Scirpus	cyperinus	Saluda	6084
	Scleria	baldwinii	Allendale	5763
	Scleria	baldwinii	Allendale	5771
	Scleria	baldwinii	Berkeley	6001
	Scleria	baldwinii	Berkeley	6704
	Scleria	baldwinii	Hampton	5674
	Scleria	baldwinii	Hampton	5690
	Scleria	ciliata	Calhoun	3350
	Scleria	pauciflora	Clarendon	5937
	Scleria	pauciflora	Clarendon	6760
	Scleria	reticularis	Allendale	5873
	Scleria	reticularis	Allendale	5883
	Scleria	reticularis	Allendale	6946
	Scleria	reticularis	Barnwell	5914
	Scleria	reticularis	Berkeley	5999
	Scleria	reticularis	Edgefield	6098
	Scleria	reticularis	Edgefield	6104
	Scleria	reticularis	Hampton	5638
	Scleria	triglomerata	Dillon	5951
	Scleria	triglomerata	Dillon	5957
	Scleria	triglomerata	Dillon	5959
	Scleria	triglomerata	Hampton	5697
Diapensiaceae	Pyxidanthera	barbulata	Horry	6316
Dionaeaceae	Dionaea	muscipula	Horry	6665
Droseraceae	Drosera	capillaris	Hampton	5602
	Drosera	capillaris	Hampton	5641
	Drosera	intermedia	Allendale	5755
	Drosera	intermedia	Hampton	5689
Ericaceae	Gaylussacia	dumosa	Sumter	4002
	Gaylussacia	frondosa	Clarendon	6571
	Gaylussacia	frondosa	Sumter	4003
	Kalmia	carolina	Dillon	5942
	Kalmia	carolina	Sumter	3998

	Kalmia	hirsuta	Hampton	5631
	Leucothoe	racemosa	Allendale	5793
	Leucothoe	racemosa	Berkeley	5407
	Leucothoe	racemosa	Calhoun	3329
	Leucothoe	racemosa	Clarendon	4165
	Leucothoe	racemosa	Lexington	3321
	Lyonia	ligustrina	Sumter	3996
	Lyonia	lucida	Aiken	3263
	Lyonia	lucida	Berkeley	5408
	Lyonia	mariana	Sumter	3994
	Oxydendrim	arboreum	Sumter	3999
	Rhododendron	atlanticum	Horry	6317
	Rhododendron	atlanticum	Horry	6667
	Rhododendron	canescens	Bamberg	3410
	Vaccinium	atrococcum	Charleston	6301
	Vaccinium	atrococcum	Kershaw	5524
	Vaccinium	australe	Clarendon	6566
	Vaccinium	crassifolium	Sumter	4001
	Vaccinium	elliottii	Aiken	3252
	Vaccinium	elliottii	Marlboro	5279
	Vaccinium	fuscatum	Allendale	5779
	Vaccinium	virgatum	Lexington	3318
	Zenobia	pulverulenta	Berkeley	5410
	Zenobia	pulverulenta	Berkeley	5473
	Zenobia	pulverulenta	Clarendon	6750
	Zenobia	pulverulenta	Kershaw	5523
	Zenobia	pulverulenta	Sumter	3993
Eriocaulaceae	Eriocaulon	decangulare	Allendale	5762
	Lachnocaulon	anceps	Dillon	5946
	Lachnocaulon	anceps	Sumter	3997
	Lachnocaulon	minus	Clarendon	6556
Euphorbiaceae	Croton	capitatus	Aiken	6065
	Croton	capitatus	Sumter	4031
	Croton	elliottii	Barnwell	6030
	Crotonopsis	elliptica	Sumter	4108
	Euphorbia	gracilior	Kershaw	5522
	Sebastiana	fruticosa	Colleton	5549
	Stillingia	aquatica	Allendale	5760
	Stillingia	aquatica	Allendale	5766
	Stillingia	aquatica	Allendale	5872
	Stillingia	aquatica	Hampton	5693
	Tragia	urens	Hampton	5594
	Tragia	urens	Kershaw	5521
Fagaceae	Quercus	laevis	Bamberg	3421

	Quercus	laurifolia	Allendale	5789
	Quercus	margaretta	Allendale	5783
Gentianaceae	Sabatia	calycina	Orangeburg	6915
	Sabatia	difformis	Clarendon	6756
Gramineae	Aristida	virgata	Dillon	5949
	Chasmanthium	laxum	Clarendon	6758
	Erianthus	giganteus	Allendale	7073
	Hydrochloa	caroliniensis	Aiken	5911
	Leersia	hexandra	Aiken	5907
	Leersia	hexandra	Allendale	5855
	Leersia	hexandra	Allendale	6932
	Leersia	hexandra	Saluda	2580
	Panicum	anceps	Clarendon	6754
	Panicum	chamaelonche	Barnwell	6550
	Panicum	chamaelonche	Berkeley	6708
	Panicum	hemitomon	Allendale	5888
	Panicum	hemitomon	Hampton	5678
	Panicum	hemitomon	Lexington	3325
	Panicum	laxiflorum	Calhoun	3354
	Panicum	scabriusculum	Berkeley	6707
	Panicum	spretum	Allendale	5877
	Panicum	spretum	Allendale	5747
	Panicum	spretum	Horry	6670
	Panicum	verrucosum	Allendale	6929
	Panicum	verrucosum	Allendale	7070
	Panicum	verrucosum	Bamberg	6939
	Panicum	verrucosum	Berkeley	5990
	Paspalum	dissectum	Allendale	6948
	Paspalum	dissectum	Saluda	6862
	Paspalum	floridanum	Allendale	5860
	Paspalum	laeve	Bamberg	3564
	Phalaris	caroliniana	Calhoun	3332
	Sacciolepis	striata	Allendale	6937
	Sorghastrum	nutans	Allendale	7072
	Tridens	ambiguus	Allendale	7067
Haemodoraceae	Lachnanthes	caroliniana	Allendale	5776
	Lachnanthes	caroliniana	Clarendon	6757
Haloragaceae	Cabomba	pinnatum	Saluda	6086
	Proserpinaca	pectinata	Berkeley	6705
Hamamelidaceae	Hamamelis	virginiana	Allendale	5795
	Hamamelis	virginiana	Berkeley	5468
Hippocastanaceae	Aesculus	pavia	Hampton	5637
Hypericaceae	Hypericum	adpressum	Charleston	6305
	Hypericum	denticulatum	Aiken	6077

	Hypericum	denticulatum	Allendale	5927
	Hypericum	denticulatum	Edgefield	6102
	Hypericum	denticulatum	Orangeburg	6922
	Hypericum	fasciculatum	Allendale	5742
	Hypericum	fasciculatum	Allendale	5744
	Hypericum	fasciculatum	Allendale	5757
	Hypericum	fasciculatum	Allendale	5871
	Hypericum	fasciculatum	Hampton	5605
	Hypericum	fasciculatum	Hampton	5692
	Hypericum	fasciculatum	Hampton	5698
	Hypericum	galioides	Dillon	5824
	Hypericum	galioides	Lexington	3319
	Hypericum	gymnanthum	Allendale	6933
	Hypericum	harperi	Allendale	5746
	Hypericum	harperi	Allendale	5859
	Triadenum	virginianum	Saluda	6069
	Triadenum	virginicum	Bamberg	6938
Iridaceae	Iris	tridentata	Barnwell	6547
	Iris	virginica	Hampton	5687
Juglandaceae	Carya	tomentosa	Allendale	5785
Juncaceae	Juncus	bufonius	Bamberg	3422
	Juncus	effusus	Colleton	5552
	Juncus	effusus	Hampton	5592
	Juncus	marginatus	Berkeley	6709
	Juncus	polycephalus	Allendale	5758
	Juncus	polycephalus	Orangeburg	6925
	Juncus	repens	Allendale	5869
Labiatae	Lycopus	rubellus	Allendale	7071
	Lycopus	rubellus	Hampton	5596
	Lycopus	uniflorus	Orangeburg	6917
	Lycopus	virginicus	Richland	3710
	Pycnanthemum	flexuosum	Clarendon	5935
	Pycnanthemum	flexuosum	Dillon	6293
	Pycnanthemum	hyssopifolium	Allendale	5867
	Scutellaria	integrifolia	Bamberg	3420
	Stachys	hyssopifolia	Saluda	6061
	Stachys	hyssopifolia	Saluda	6824
	Stachys	hyssopifolia	Saluda	8307
	Teucrium	canadense	Allendale	5932
Lauraceae	Sassafras	albidum	Marlboro	5287
Lemnaceae	Lemna	aequinoctialis	Allendale	5923
	Lemna	aequinoctialis	Bamberg	3567
Lentibulariaceae	Utricularia	fibrosa	Allendale	5890
	Utricularia	inflata	Allendale	5796

	Utricularia	purpurea	Allendale	5741
	Utricularia	purpurea	Bamberg	3464
	Utricularia	subulata	Clarendon	6557
	Utricularia	subulata	Horry	7950
Liliaceae	Smilax	laurifolia	Dillon	5944
	Smilax	laurifolia	Sumter	3995
	Smilax	pumila	Allendale	5752
	Smilax	pumila	Hampton	5635
	Yucca	filamentosa	Dillon	5953
	Zigadenus	glaberrimus	Dillon	5948
Loganiaceae	Mitreola	petiolata	Allendale	5769
	Mitreola	sessilifolia	Allendale	5875
Loranthaceae	Phoradendron	serotinum	Calhoun	3355
	Phoradendron	serotinum	Lexington	3315
	Phoradendron	serotinum	Sumter	3992
Lythraceae	Decodon	verticillatus	Colleton	5540
	Lythrum	lanceolatum	Berkeley	5991
	Rotala	ramosior	Saluda	6068
Magnoliaceae	Liriodendron	tulipifera	Clarendon	4145
	Magnolia	grandiflora	Allendale	5772
	Magnolia	virginiana	Allendale	5790
	Magnolia	virginiana	Bamberg	3411
	Magnolia	virginiana	Hampton	5600
Malvaceae	Hibiscus	moscheutos	Allendale	5743
Melastomaceae	Rhexia	aristosa	Allendale	5858
	Rhexia	aristosa	Allendale	5874
	Rhexia	aristosa	Bamberg	6735
	Rhexia	aristosa	Bamberg	8256
	Rhexia	aristosa	Sumter	4109
	Rhexia	mariana	Allendale	5862
	Rhexia	mariana	Allendale	5882
	Rhexia	mariana	Allendale	5884
	Rhexia	nashii	Dillon	5828
	Rhexia	virginica	Allendale	5926
	Rhexia	virginica	Barnwell	5912
Moraceae	Morus	rubra	Lexington	3322
Nelumbonaceae	Nelumbo	lutea	Allendale	5891
Nymphaeaceae	Nuphar	luteum	Lexington	3327
	Nymphaea	odorata	Allendale	5791
	Nymphaea	odorata	Allendale	6089
	Nymphaea	odorata	Lexington	3320
	Nymphaea	odorata	Lexington	3328
	Nymphaea	odorata	Sumter	4033
Nyssaceae	Nyssa	aquatica	Clarendon	6569

	Nyssa	sylvatica	Aiken	3264
	Nyssa	sylvatica	Lexington	3316
Oleaceae	Chionanthus	virginicus	Berkeley	5469
Onagraceae	Ludwigia	alternifolia	Allendale	5933
	Ludwigia	decurrens	Saluda	6072
	Ludwigia	leptocarpa	Saludak	6073
	Ludwigia	linearis	Aiken	6080
	Ludwigia	linifolia	Orangeburg	6923
	Ludwigia	palustris	Saluda	6062
	Ludwigia	repens	Berkeley	5409
	Ludwigia	spathulata	Saluda	6067
	Ludwigia	sphaerocarpa	Allendale	5865
	Ludwigia	sphaerocarpa	Edgefield	6096
	Ludwigia	sphaerocarpa	Saluda	6087
	Ludwigia	suffruticosa	Allendale	5864
	Ludwigia	suffruticosa	Clarendon	6752
Orchidaceae	Goodyera	pubescens	Bamberg	3481
	Habenaria	blephariglottis	Dillon	5943
	Habenaria	repens	Allendale	6930
	Spiranthes	laciniata	Allendale	5749
	Spiranthes	laciniata	Hampton	5688
Osmundaceae	Osmunda	cinnamomea	Clarendon	6565
	Osmunda	cinnamomea	Hampton	5598
Palmae	Sabal	minor	Colleton	5548
Pinacaea	Pinus	echinata	Lexington	3314
	Pinus	elliottii	Allendale	5753
	Pinus	elliottii	Allendale	5765
	Pinus	serotina	Charleston	6303
	Pinus	serotina	Sumter	4112
	Pinus	taeda	Allendale	5868
	Pinus	taeda	Bamberg	3565
	Pinus	taeda	Clarendon	6564
Polygalaceae	Polygala	lutea	Hampton	5603
Polygonaceae	Polygonum	convolvulus	Aiken	5906
	Polygonum	densiflorum	Richland	3709
	Polygonum	hirsutum	Allendale	5889
	Polygonum	hydropiperoides	Allendale	5930
Polypodiaceae	Polypodium	polypodioides	Orangeburg	6916
Pontederiaceae	Pontederia	cordata	Calhoun	3330
	Pontederia	cordata	Hampton	5595
Primulaceae	Lysimachia	lanceolata	Aiken	5908
Rosaceae	Amelanchier	canadensis	Marlboro	5281
	Aronia	arbutifolia	Hampton	5604
	Sorbus	arbutifolia	Clarendon	6572

Salicaceae	Populus	heterophylla	Calhoun	3349
	Salix	caroliniana	Berkeley	5399
	Salix	nigra	Aiken	3251
Saxifragaceae	Itea	virginica	Allendale	5794
	Itea	virginica	Bamberg	3412
	Itea	virginica	Berkeley	5403
	Itea	virginica	Clarendon	6570
	Itea	virginica	Hampton	5593
Scrophulariaceae	Bacopa	caroliniana	Allendale	5880
	Bacopa	caroliniana	Barnwell	5910
	Gratiola	neglecta	Bamberg	6940
	Gratiola	ramosa	Allendale	5928
	Lindernia	monticola	Barnwell	5909
	Verbascum	virgatum	Calhoun	3353
Taxodiaceae	Taxodium	ascendens	Clarendon	4140
Theaceae	Gordonia	lasianthus	Berkeley	5471
	Gordonia	lasianthus	Berkeley	5988
Turneraceae	Piriqueta	caroliniana	Allendale	5786
	Piriqueta	caroliniana	Hampton	5633
Umbelliferae	Hydrocotyle	ranunculoides	Colleton	5539
	Hydrocotyle	verticillata	Allendale	6934
	Oxypolis	canbyi	Allendale	5767
	Oxypolis	canbyi	Barnwell	5913
	Oxypolis	canbyi	Berkeley	5995
	Oxypolis	canbyi	Hampton	5696
	Sanicula	canadensis	Allendale	5781
Urticaceae	Boehmeria	cylindrica	Allendale	5931
Violaceae	Viola	lanceolata	Berkeley	5402
Xyridaceae	Xyris	ambigua	Dillon	5945
	Xyris	jupicai	Allendale	6936
	Xyris	jupicai	Orangeburg	6919
	Xyris	jupicai	Edgefield	6099
	Xyris	laxifolia	Berkeley	6000
	Xyris	platylepis	Aiken	6078
	Xyris	platylepis	Allendale	5870
	Xyris	platylepis	Saluda	6071
bryophytes	Climacium	americanum	Dorchester	8257
	Climacium	americanum	Orangeburg	6955
	Ditrichum	pallidum	Clarendon	6763
	Entodon	seductrix	Bamberg	6950
	Polytrichum	perigionale	Clarendon	6762

Sphagnum	affine	Dorchester	8258
Sphagnum	cuspidatum	Orangeburg	3982
Sphagnum	lescurii	Clarendon	8461
Sphagnum	lescurii	Saluda	8503
Sphagnum	lescurii	Sumter	3988
Sphagnum	macrophyllum	Orangeburg	6954
Sphagnum	palustre	Sumter	3989
Sphagnum	palustre	Sumter	3990
Sphagnum	perichaetile	Clarendon	8460
Sphagnum	trinitense	Clarendon	6761
Sphagnum	trinitense	Clarendon	6764