Rare Vascular Plant Taxa Associated with the Longleaf Pine Ecosystems: Patterns in Taxonomy and Ecology

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ABSTRACT

Ecological, taxonomic and biogeographical characteristics are used to describe the group of 187 rare vascular plant taxa associated with longleaf pine (*Pinus palustris*) throughout its range.

Taxonomic and growth form distributions mirror the patterns of common plus rare taxa in the flora. Most of the species have rather narrow habitat preferences, and narrow geographic ranges, but a few rare species with broad habitat tolerances and wider geographic ranges are identified.

Ninety-six local endemics are associated with longleaf pine ecosystems. This incidence is as high as in other comparably-sized endemic-rich areas in North America.

A distinct geographic trend in rare species composition is indicated. Species fall into 4 groups: Florida longleaf associates, south Atlantic coastal plain, east Gulf coastal plain, and west Gulf coastal plain species.

Distributional factors that produce rarity must be considered in the development of conservation strategies. Overall, conserving longleaf communities rangewide will protect large numbers of rare plant taxa in Southeastern United States.

INTRODUCTION

Recently Hardin and White (1989) effectively focused conservationists' attentions on the high numbers of rare species associated with wiregrass (*Aristida stricta*), a grass that dominates the ground layer of longleaf communities through a large part of its range, and over a broad range of longleaf habitats. The rare associates of wiregrass include a remarkably high number (66) of local endemics, among the highest in North America in areas of comparable size. In the face of continued longleaf pine habitat losses to, and modifications by, human activities (Frost et al. 1986, Noss 1988, Means and Grow 1985) conserving these species is an enormous conservation challenge.

Naturalists' concepts of rare species include species with narrow geographic distributions, species that inhabit rare and very specific habitats, and species that occur in small numbers (Rabinowitz et al.1986). Clearly there are ecologically distinct kinds of rare species. The factors that cause these rarities also vary (Harper 1981, Cody 1986, Fiedler 1986), and inevitably the strategies required to conserve them will differ.

The purposes of this study are to (1) identify the rare species associated with longleaf pine ecosystems rangewide; (2) characterize the rare species taxonomically and ecologically, in order to identify patterns that may distinguish this group from the general flora; (3) identify variations in rarity of longleaf pine associates; and (4) discuss the implications of the results for species conservation.

In assembling the list of rare species associated with longleaf pine ecosystems, "associated with the longleaf ecosystem" was broadly defined. It included species co-occurring with longleaf pine, and species occurring in habitats that are or were likely to have been affected by natural processes (e.g.fire) in adjacent or nearby longleaf pine communities. More specifically, rare plants in the longleaf landscape are found in both forested and non-forested communities. Forested communities may be dominated by longleaf pine, or mixtures of longleaf pine

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with other pines (*Pinus ellioitti, P. clausa, P. taeda*) or with mixed hardwoods (most notably various *Quercus* spp.). Longleaf pine-dominated forests that contain rare plant species vary across a broad moisture gradient, including the Xeric and Mesic Pine Communities of Christensen (1988), and the Xeric, Subxeric, Mesic and Seasonally-Wet Longleaf Pine Woodlands of Peet and Allard (1993). Canopies in these forested types vary from closed canopy forests with well-developed woody understories to sparse canopies with species-rich herbaceous ground layers and no mid-story, variously referred to as savannas or grass sedge bogs. Some rare species associated with longleaf pine forested communities may also be found in forests without a longleaf pine component, however forest species not somewhere associated with longleaf pine are not included in this study. Non-forested vegetation types include herbaceous species assemblages of some seepage bogs, pond edges and transitions between savannas and shrub bog (pocosin) communities. (See Christensen 1979, 1988, for review and vegetation descriptions of coastal plain vegetation. Peet and Allard 1993 describe communities with longleaf pine in the canopy. Various state- specific vegetation classifications include Nelson 1986, Shafale and Weakley 1990, and Florida Natural Areas Inventory 1990.)

Rarity was identified using the Natural Heritage Program ranking system, which was developed to help identify and set priorities for rare species conservation (Morse 1987). Heritage ranks are based on the species biology, especially number and distribution of known occurrences, as well as habitat and population threats and vulnerabilities to loss. Species present in small numbers and in very narrow geographic areas are intuitively associated with rare species. The ranking methodology is standardized, and provides a common parameter for estimating "rarity" of taxa across political units.

METHODS

Data

Botanists for Natural Heritage Programs or other local experts in 8 states (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas) provided lists of species associated with longleaf pine ecosystems. Lists also included current Global Ranks (G-ranks) as listed in 1990. Note that these ranks change as the knowledge bases about individual species change.

Taxonomy followed various authorities (Radford et al. 1968, Kartez 1992, Godfrey and Wooten 1979, 1981, among others). Except to eliminate taxonomic redundancy, I made no attempt to reconcile the diverse taxonomies with a single authority. All species submitted were included.

Heritage G-ranks indicate rangewide status. G-ranks range from 1 through 5, representing critically imperilled species through widespread, abundant and secure species. The ranking system includes ranks for historical occurrences (H) and taxa thought to be extinct (X). It provides for uncertainty by allowing the identification of several possible ranks (e.g. G1G3), and by using modifiers (?, U) that indicate that the rank is in question or unknown (e.g. G?, G2?). Such uncertainty arises especially in taxonomically difficult taxa and in cases where rangewide status surveys are not complete. For this analysis, the highest possible G-rank was assigned to each taxon.

G1, G2, and G3 are ranks indicative of rarity throughout a taxon range. G4 and G5 ranks are assigned to biologically secure taxa, but they may be rare in parts of their ranges, typically at the edges. The entire list included all G-ranks, but most of the analyses in this study were limited to G1, G2, and G3 species, henceforth "rare" taxa. Most of the taxa are species, though several subspecific taxa (varieties, subspecies) were identified.

All will be referred to as "species" or taxa interchangeably. Appendix 1 lists all species initially included in this study.

Additional data on rare species were taken from Hitchcock (1950), Gleason (1952), Radford et al. (1968), Correll and Johnston (1970), Small (1972), Godfrey and Wooten (1979, 1981), Wunderlin (1982), MacRoberts (1984), and Clewell (1985). Taxa were classified as annual or perennial. Following Hardin and White (1989) flowering seasons were classified as spring (March-May), summer (June-August), fall (September-November), winter (December-February).

Species were classified as one of eight growth forms. These forms were selected to represent various strategies for acquiring and allocating aboveground resources. (1) Large graminoids include large grasses and sedges, typically tussock forming and with blades that occupy the "ground layer canopy". Individual leaves may last more than 1 growing season. (2) Small graminoids include small grasses and sedges which display leaves lower in the ground layer (blades usually up

to 10 cm long). They may form small tussocks or tufts, or small clumps via rhizomes. The third and fourth groups, rosette species, have a basal rosette present for a significant portion of the growing season, often present at flowering. Protected in the graminoid matrix, such low growing rosettes may escape low intensity fires. (3) Rosette species may have scapose flowering stalks that contribute little to carbon gains, or (4) may have leafy flowering stalks with effective photosynthetic surfaces. (5) The fifth group are erect, solitary (or nearly so) leafy stems; these are deciduous with aboveground parts dying during part of the season. (6) A sixth group consists of plants that display leaves in tall leafy clumps (e.g. *Sarracenia leucophylla, Baptisia simplicifolia*); they are herbaceous and deciduous. (7) Trailing and creeping species, that do not invest resources in supporting tissues, make up the seventh group. (8) The last group includes species that invest resources in woody support structures. In the absence of fire they initiate seasonal growth from meristems located above the ground, thereby increasing height, and perhaps capacity to pre-empt resources, through time (shrubs and trees).

Habitats were classified into 6 categories roughly representing a moisture gradient. Site moisture condition often has been identified as a primary environmental factor determining species composition in coastal plain and sandhills vegetation (Wells and Shunk 1931, Kologiski 1977, Christensen 1979, Walker and Peet 1983, Christensen 1988, Bridges and Orzell 1989, Abrahamson and Hartnett 1990,). Habitat classes follow: (1) upland longleaf or mixed longleaf pine-hardwood woodlands and forests; (2) mesic savannas and flatwoods; (3) seasonally wet savannas and flatwoods; (4) depressions, seepage bogs, transitions into shrub bog communities; (5) ponds, pond edges, stream edges, marshes, ditches; (6) other habitats (typically without longleaf pines present) in the longleaf landscape, e.g. mixed hardwood forests. The most commonly described habitat class (the primary habitat) was recorded for each taxa. Also the habitat most different from the primary habitat class was identified; in cases where only a primary habitat was identified, the second habitat was set equal to the former. Taxa were scored as being associated with disturbed habitats (e.g. fields, ditches, roadsides) or having no such associations.

Geographic distribution data were determined from submitted state lists, and flora accounts. In some cases, the presence of a rare species could not be confirmed in a particular state. In these cases, data were coded as "missing".

Indices of Habitat Breadth and Geographic Distribution

An index of Habitat Breadth (HB) was calculated as the absolute value of the difference between the primary habitat and the secondary habitat. Values ranged from 0 through 5, but were grouped into 3 classes (B): narrow (B=1), medium (B=2), wide (B=3).

An index of Geographic Breadth was calculated as the number of states occupied. Values ranged up to 8, and were grouped into 3 geographic distribution classes (G): 1 or 2 states (G=1); 3 or 4 states (G=2); greater than 4 states (G=3).

Analyses

Cluster analysis and correlational analysis techniques were performed using SYSTAT (1986), a statistical package for microcomputers.

RESULTS AND DISCUSSION

Heritage G-ranks

A total of 389 species, including all G-ranks were identified as rare plant taxa associated with longleaf pine ecosystems. Of these, 187 (48.1%) are considered rare or vulnerable (to extinction) throughout their respective ranges (G1-G3); 35 (8.9%) were unranked. Although the number of taxa is about twice the 191 species listed by Hardin and White (1989), the relative abundances of G1-G3 species (63.9%) and unranked species (11%) are comparable. Several factors may have contributed to the significant increase in the number of species reported. First, the geographic area of consideration increased by 2 states, Louisiana and Texas. This expansion, which covered the range of longleaf pine where wiregrass does not grow, increased the list by about 30 taxa. It is also likely that the respondents included a broader range of habitats (e.g. pond edges, pocosin margins that do not contain *Aristida stricta*) within the areas of study overlap. Finally, recent conservation efforts throughout the range of longleaf pine have resulted in an increase in the knowledge of longleaf pine systems. The comparatively large increases in difficult-to-identify plant families (Asteraceae,

Cyperaceae, Poaceae; Table 1) are consistent with increased survey work in longleaf communities.

Among rare taxa most have G-ranks of 2 or 3 (39% and 48%).

represents a strategy for persistence in a fire dependent system. The annuals survive fire as seeds available to germinate in the post-fire conditions.

Rare species may be found flowering during all seasons of the year. About one fourth of the species flower during the spring, or spring and summer; half flower during the summer months; and the remaining quarter are species that flower in the summer and fall, or fall. Only one species, *Gentiana pennelliana*, endemic to northwest Florida, flowers typically in the winter. These flowering times are presented as "typical", because they may vary considerably relative to the time of the last fire (Robbins and Myers 1989, Platt et al. 1988).

Table 1.
Numbers of all species and rare species in the 10 most common plant families.

FAMILY NAMES	ALL TAXA	RARE TAXA
Asteraceae	55	32
Cyperaceae	45	16
Poaceae	34	15
Lamiaceae	18	13
Fabaceae	18	10
Liliaceae	19	9
Scrophulariaceae	11	8
Ericaceae	11	4
Orchidaceae	11	3
Xyridaceae	10	5
TOTAL FAMILIES IN THE STUDY:	76	54

Taxonomic Distributions

A total of 76 plant families were represented; 54 in the rare species group (Table 1). The most common families in this study are cited as the most common families in many longleaf pine vegetation studies (For a review see Christensen 1988.), suggesting that there is nothing taxonomically distinctive about the majority of rare species. However, the relative abundance of monocots in the rare taxa list, 38% is somewhat greater than the relative abundances in the floras covered by Radford et al. (1968), and Clewell (1985), 24 and 27% respectively.

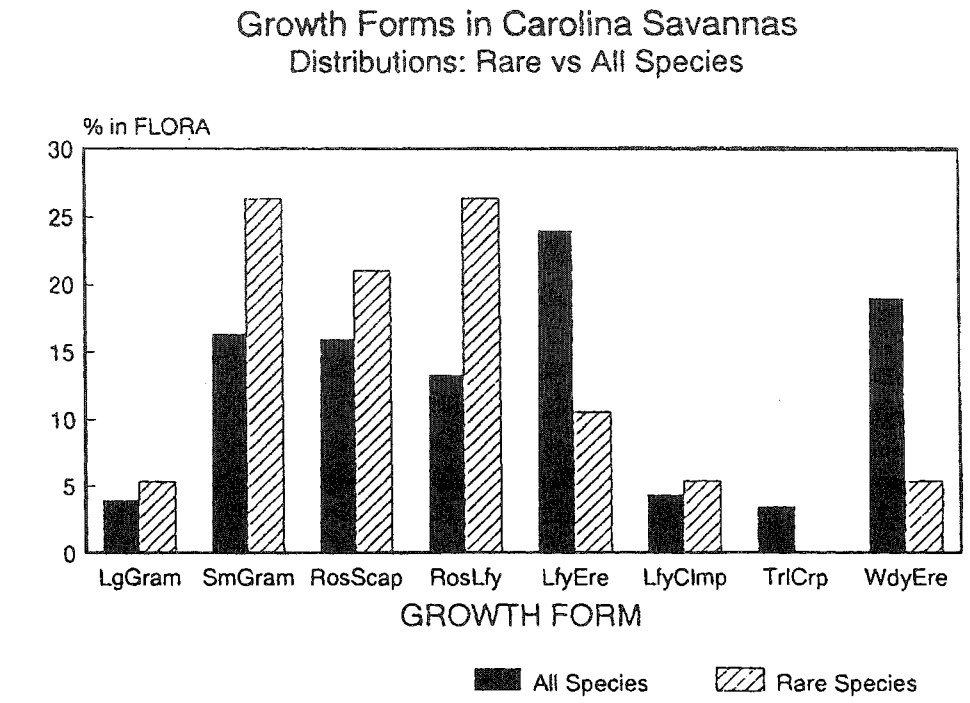
Flowering Phenology and Longevity

The vast majority of rare species are perennials (93.5%). These include both short-lived and long-lived taxa. Most of these show some adaptations to survival in fire-dependent systems. Adaptations observed in fire dependent habitats include perennating structures well-protected underground, meristems protected near the ground by surrounding insulating tissues, fire-induced flowering and seed production, basal sprouting capabilities. All of these strategies are represented among the rare species in longleaf communities. The annual growth habit of 14 species (6.5%) itself

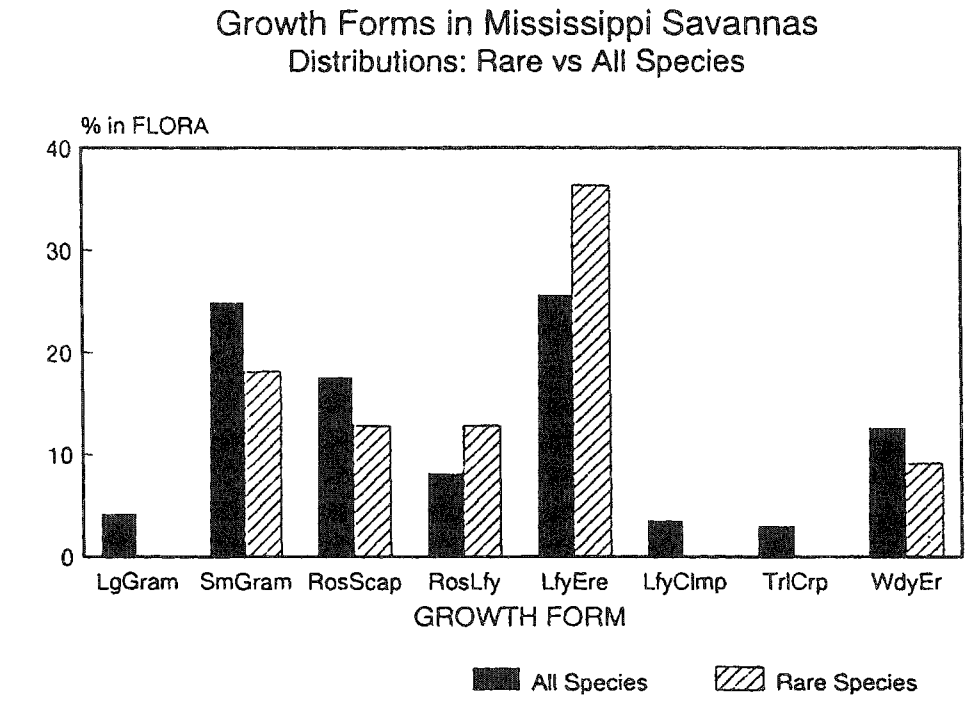
Growth Forms

Figure 1 shows the distribution of growth forms among species from studies of longleaf pine vegetation in the Carolinas (Taggart 1990) and in Mississippi (Norquist 1984). Both studies focused on moist pine savannas, communities with a sparse tree canopy and herbaceous understory. Taggart sampled 48 sites between the Congaree-Cooper River System, South Carolina and the Neuse River, North Carolina. Norquist sampled 7 savannas in southern Mississippi. The studies included 230 and 233 species, respectively.

The distribution of growth forms among all species, and among the rare species in these savanna studies are shown. In both studies, large graminoids and woody shrubs are found in small numbers. Forms characterized by small



Total 230 spp; Rare 34 spp; Taggart 1990



Total 230 spp;Rare 11 spp; Norquist 1984

Figure 1. Growth form distributions for all species and the rare species component sampled in 2 studies of mesic savanna vegetation. Taggart (1990) sampled vegetation in the Carolinas; he recorded a total of 230 species, 19 of which are rare species. Norquist (1984) sampled Mississippi savannas; she reported a total of 233 species, 11 of them rare.

aboveground biomass accumulations, i.e. small graminoids, rosette forms and solitary, leafy stems are the most common. This pattern holds for both studies, and for the entire and rare species lists.

Among the rare species in the current study, the most abundant form is the leafy, erect, solitary stems form (Table 2). Rosette forms are about half as common, while the least common forms among rare species are the large graminoids and creepers/trailers.

Forms common among the rare taxa in this study are also common in the Taggart and Norquist studies, and most likely common in the flora as a whole.

some of the longleaf pine rare plant associates may benefit from some prescribed disturbance regime, particularly one that approximates natural disturbance events like tree blowdowns.

Most of the rare species have relatively narrow tolerances of moisture conditions (HB<3; see Methods). Only 14 rare species inhabited a wide range of moisture conditions (HB>3). About half of these were found primarily in upland woodlands, and about the same number in seasonally flooded flatwoods and savannas. All are known to occur in habitats other than longleaf pine dominated ones, and most were G3 species. This small group includes *Rhus michauxii, Tetragonotheca ludoviciana,*

Table 2. Distribution of rare taxa by primary habitat (A) and growth form (B). Numbers are numbers of taxa; percentages are presented parenthetically (%). See text for a more detailed descriptions of the habitat and growth form classifications.

(A) Habitat Distribution		
Upland Longleaf or Mixed Pine/Hardwood Forests and Woodlands	45	(24.2)
Mesic Flatwoods/Savannas	13	(7.0)
Seasonally Flooded Flatwoods/Savannas	51	(27.4)
Depressions in Wet Flatwoods/Savannas, ecotones to shrub bogs, seepage bogs	43	(23.1)
Pond margins, Marshes, Ditches	27	(14.5)
Other Habitat in Longleaf Landscapes (e.g. adjacent upland and bottomland hardwood forests)	7	(3.8)
(B) Growth Form Distribution		
Large graminoids	6	(3.2)
Small graminoids	26	(13.4)
Rosettes-scapose	34	(18.3)
Rosettes-leafy	30	(16.1)
Leafy, erect	57	(30.6)
Tall leafy clumps	7	(3.8)
Creeping/sprawling	5	(2.7)
Woody, erect	22	(11.8)

Habitats

The distribution of rare species among primary habitats is shown in Table 2. Rare longleaf pine associates are much more likely to be found in wetter habitats (Habitats 3-5, 65%) than in better drained, upland sites (Habitat 1, 24.2%). Twelve percent of the rare species may be found in disturbed habitats. Generally, disturbance species are associated with wetter habitats. Of the species found in (1) seasonally flooded flatwoods and savannas, (2) depressions, bogs and transition communities, and (3) ponds, streams and marshes, 13%, 26% and 27% respectively are disturbance species. While disturbed habitats may not be commonly considered rare plant habitat, it is clear that

Hexastylis lewisii, Astragalus michauxii, Amsonia ludoviciana, and *Coreopsis helianthoides.*

Biogeography

The numbers of rare species found in each state, and the number of species restricted to each state are shown in Table 3. Florida has the largest number of rare species, 126; about 1.5 times the number in North Carolina which has the second highest. Florida also has about 6 times the number of single state endemics than Texas, the runnerup.

Hardin and White (1989) suggested that the number of local endemics could be estimated as species with a G-rank of 1-3, and occurring in 1 or 2 states. This was based on their combined experience with Heritage data sets, and Gentry's (1986) definition of local endemics as species with distributions covering about 50,000 km2. Using this estimator, 96 local endemics are associated with longleaf pine throughout its range. Hardin and White estimated 66 locally endemic plant taxa associated with wiregrass, about 67% of the current report. The apparent increase is proportionate with the increase in the number of rare taxa identified.

A K-means clustering algorithm (Hartigan 1975, Hartigan and Wong 1978, SYSTAT 1986) was applied to the geographic distribution data to produce 4 clusters of species. The composition of the clusters are presented in Appendix 2. One group of 80 species contained all of the Florida endemics, along with a small group of Atlantic Coastal Plain species. A second group contained 58 species that have Atlantic Coastal Plain distributions, i.e. are common to the Carolinas, Georgia and eastern Florida. The species in group 3 (29 species) were distributed along the Eastern Gulf Coastal Plain from the panhandle of Florida and south Georgia through Mississippi and eastern Louisiana. There were fewer species that occurred in Alabama, perhaps reflecting the lack of seasonally wet savanna and flatwoods habitat in Alabama (Frost et al 1986). The final group of 20 represent West Gulf Coastal Plain species restricted to western Louisiana and Texas. One Louisiana and 7 Texas endemics were included: *Bartonia texana, Crataegus berberifolia, Hibiscus dasycalyx, Leavenworthii texana, Lesquerella pallida, Liatris cymosa* and *Thalictrum texanum; Rudbeckia scabrifolia* (LA).

The strong geographic trends indicated by the clustering analyses are consistent with the trends reported by Peet and Allard (1993). Throughout the range of longleaf pine, there are many rare species, but the composition of that rare component varies considerably between the Atlantic and Gulf Coastal Plains, and between the East and West Gulf Coastal Plains.

Types of Rarity

Although the G-ranking system was developed to help prioritize conservation efforts, its determination incorporates some aspects of rarity, specifically the numbers and distributions of populations and individuals. Low numbers of occurrences and narrow distributions are intuitively associated with rare species. G-ranks used as indicators of rarity confound these factors.

Another approach to describing types of rarity was proposed by Rabinowitz (1981, 1986). She suggested that classes of rarity may be defined by 3 components of distribution and abundance: geographic distribution, habitat specificity, local abundance. Distributions may cover large geographic areas or may be comparatively small (local endemics). Similarly, habitat preferences may be very specific or not. Finally, some species are rare wherever they are found (always sparse), while others may be locally abundant in limited locations. Dichotomizing each variable, she presented a 2x2x2 matrix as a rarity classification. Truly common species have a wide geographic distribution, inhabit a variety of habitats and are locally abundant. Rare species exhibit some combination of the following conditions: narrow geographic distributions, specific habitat requirements, always present in low numbers.

In application, the G-ranking system is probably best correlated with geographic distribution

Table 3. Number of rare taxa occurring in and restricted to each state. Species occurring in up to 2 states are considered local endemics. 96 species are identified as local endemics associated with longleaf pine ecosystems.

State	# of taxa reported	# of single state taxa
North Carolina	87	3
South Carolina	74	0
Georgia	76	0
Florida	126	35
Alabama	58	1
Mississippi	59	0
Louisiana	47	1
Texas	34	6

(sensu Rabinowitz). The number-of-occurrences component of the G-rank may be related to geographic breadth, or to habitat abundance, the latter being a function of the natural rarity of very specific habitats, or the rarity of habitats induced anthropogenically. Naturally rare habitats are exemplified by geologic phenomena such as serpentine outcrops (Cody 1986). Among longleaf communities, seepage bogs may fall into that category (Hardin and White 1989). A Pearson correlation analysis confirmed that G-rank (varies inversely with rarity) was positively correlated with geographic breadth (coef= 0.514), and to a lesser degree with habitat breadth (coef =0.175). Rarer species (low G-rank) have narrower geographic distribution and narrower habitat preferences than less rare species. The strong correlation with geographic distributions suggests G-ranking is strongly weighted by this variable.

To consider 2 dimensions of rarity identified by Rabinowitz, rare species were put into the nine classes defined by all combinations of 3 levels of geographic breadth and 3 levels of habitat specificity. The species were distributed among the cells as shown in Table 4. The largest number of species fell into the category of both geographically narrow and habitat specific (local endemic habitat specialists). The fewest were in the group defined as geographically widespread and low habitat specificity (the generalist group) as might be predicted in an analysis of species selected as rare. The left column (cells 1,1; 1,2; 1,3) had more G1 species relative to the whole, while the right column and habitat generalists in the central column (cell 2,3) have relatively more G3 species. There were no apparent patterns associated with growth form distributions. Relatively high numbers of disturbance associated species were found in cells with intermediate habitat tolerances (cells 2,1; 2,2; 2,3) and in the generalist cell. Even among species pre-selected as rare, various types of rarity are apparent relative to habitat and geographic factors.

Data were not available to evaluate the importance of local abundance patterns (sensu Rabinowitz) in describing types of rarity in the set of longleaf pine associates. Both "always sparse", and "somewhere abundant" species do occur in the data set. Considering only Florida species, most of the rare taxa, even the most geographically limited and habitat specific are common somewhere. For example, all the habitat specific endemics of the northwest Florida flatwoods are locally abundant somewhere. These include species of diverse growth forms such as *Baptisia simplicifolia, Hymenocallis henryae, Nolina atopocarpa, Verbesina chapmanii,* and *Linum westii. Harperocallis flava* is problematic. There are very few known locations for this federally endangered monospecific, monogeneric member of the lily family. The largest population (estimated at 8000-10000 individuals), occurs on a highway right-of-way, a very artificial habitat. It is certainly locally abundant in this location, however populations in more natural conditions never exceed several hundred individuals. *Spigelia gentianoides* is exceptional in being found in small numbers in all of its known locations (<10). The relatively few numbers of "everywhere" rare species was also noted by Rabinowitz (1986).

Hardin and White (1989) suggested several factors that contribute to the high numbers of rare species associated with wiregrass systems, a subset of longleaf systems. (1) Habitat destruction and loss was cited as a major contributor: species arerare because their once more common habitats are di-

Table 4. Distribution of rare species among cells in a matrix defined by 3 levels of habitat breadth and 3 levels of groegraphic distribution breadth. Numbers of species are indicated. To facilitate discussion, cells are defined by numbers shown in parentheses.

	GEOGRAPHIC DISTRIBUTION:		
HABITAT BREADTH:	Narrow	Medium	Wide
Narrow	(1,1) 66 "specialists"	(2,1) 9	(1,3) 13
Medium	(1,2) 31	(2,2) 17	(3,2) 18
Wide	(1,3) 16	(2,3) 11	(3,3) 9 "generalists"

minished. Indeed the original distribution of longleaf has been decreased to 5-10% of original the area, and remaining parcels are variously degraded by previous land uses. (2) They note the dependence of many species on very specific habitat types, citing the seepage bogs that are particularly sensitive to soil and hydrologic disruptions. This is consistent with current findings that over half of the rare species are associated with narrow habitat requirements. (3) Finally, Hardin and White cited the contribution of high numbers of southeastern coastal plain endemics (Gentry 1986) to the high rare species count, an observation confirmed in the current analysis.

Although the previous discussion suggests why there may be so many rare taxa associated with longleaf rangewide, the specific causes of rarity in individual taxa lie in the evolutionary history and species biology of each one. While understanding causes at the species level is needed to develop effective conservation strategies (Fiedler 1986), there is a remarkable paucity of life history information about this incredible list of rare species. A successful conservation program must include this research focus.

Conservation Considerations

One overall objective of a rare species conservation program is to maintain viable species populations well-distributed throughout the species range. An effective strategy must consider (1) the conditions that constitute threats to viability or distribution, and (2) the potential effects of such conditions.

Conditions that threaten viabilities may be intrinsic biological conditions, e.g. low reproductive effort and success (Harper 1981, Cody 1986, Fiedler 1986, Rabinowitz et al 1986). These conditions may be recognized, but are not likely to be changed by resource managers. A second category of threats consists of extrinsic, often anthropogenic threats. Historically and currently, the major threat to longleaf rare taxa are associated with site conversions to agriculture and timber production, and to other development (Frost et al. 1986, Noss 1988).

In considering the potential effects of human actions it is useful to consider (1) direct, (2) indirect and (3) cumulative effects. The extent of these effects varies with growth form, habitat requirements and geographic extents.

(1) Direct effects are localized, and affect the vigor of individuals. They vary with the nature of the disturbance. For example, the effects of point disturbances such as hand-planting trees may be less significant if the species is widely distributed across the site, than concentrated in small pockets that may, by chance, be impacted. Growth form may affect the vulnerability of a species to certain actions; more robust forms may be more tolerant of the soil disturbing activities of site preparation or trail construction, for examples. The perennial condition with significant underground parts, common to longleaf associates, suggests that, as a group, they will survive moderate disturbances. Finally, geographically narrow species are most at risk from direct effects: a single action could adversely impact a large portion of the extant individuals.

(2) Indirect effects may result from habitat alterations or population density changes which ultimately determine the species persistence at the site. Some disturbances alter habitat parameters, such as light availability or local hydrology. For species with very specific habitat requirements, the ultimate effect will be to reduce the local population viability. Many of the northwest Florida flatwoods endemics have narrow requirements for moisture regimes, e.g. *Harpercallis flava, Parnassia grandiflora, Verbesina chapmanii.* These species are particularly vulnerable to site preparation methods that change local moisture conditions. In contrast *Macbridea alba* and *Hedeoma graveolens* with broader habitat tolerances have been observed flowering in highly modified sites (personal observation).

(3) Cumulative effects include the cumulative effects of associated actions, and the cumulative effects of applying a given disturbance regime throughout all or part of a species range. Management for species conservation must take into account, for example, that even if rare species can tolerate the actions associated with a timber harvest, a dense young unburned stand that develops after planting may eventually reduce species viability. The cumulative effects of development, that is loss of suitable habitats, throughout the range of longleaf pine was identified as a major contributor to high numbers of rare species (Frost et al. 1986, Hardin and White 1989). Generally, species with wider geographic distributions are less susceptible to adverse cumulative effects. Based on the strong geographic trends in rare species distributions, it is essential that conservation efforts be applied throughout the range.

Finally, in biological systems where rare species concentrations are so high, the most efficient and effective approach to conservation undoubtedly involves efforts to conserve the variety of longleaf communities rangewide, as has been suggested by others (Frost et al. 1986, Noss 1988, Hardin and White 1989).

SUMMARY

A large number of rare plant species (187) are associated with longleaf pine throughout its range. Both taxonomically and with respect to growth forms, the rare taxa are represented in proportions similar to the flora as a whole. As a group most have narrow habitat requirements, and 75% are found in 4 or fewer states. Geographically distinct groups of species are associated with Florida, the South Atlantic Coastal Plain, The Eastern Gulf and Western Gulf Coastal Plains.

Conservation strategies to maintain species viabilities rangewide must consider habitat, biogeography, and species life history attributes. Although there is a broad awareness of the numbers of rare longleaf pine associates, there is an acute lack of information about the ecology and life history attributes of individual species. Certainly considerable research efforts will be needed before many of these species will be recovered or managed effectively. In the short term and probably in the long term as well, the most effective way to conserve large numbers of rare species will undoubtedly require conserving the diversity of longleaf pine communities rangewide. In preserving or restoring the structure and functions of the communities, large numbers of rare species will be conserved.

APPENDIX I

All species identified as rare vascular plant taxa associated with longleaf pine throughout its range. Species are listed alphabetically. Natural Heritage G-rank (GRANK), interpreted for this study as the highest suggested G-rank in the official Heritage list, are shown. G-rank = 0 indicates actual G-rank is unknown (U) or in question (?). The subset of species with G-ranks of 1, 2, or 3 were selected for analyses of "rare species".

Also shown are growth form (GF) code (1= large graminoid; 2= small graminoid; 3= scapose rosettes; 4= leafy rosettes; 5= erect leafy; 6= tall leafy clumps; 7= trailing; 8= woody). See text for further discussion.

Longevity (L) (A= annual; P= perennial) and flowering phenology (PH) (SU= summer; SF= summer/fall; FA= fall; WI= winter; SP= spring; SS= spring/summer) are indicated for each species.

Finally, a list of longleaf associates considered rare in Georgia were received after this paper was completed. This list is included at the end of Appendix 1 for information. This list was not included in the analyses in this paper.

Species Name	GF	L	PH	GRANK
Agalinis aphylla	5	A	FA	3
Agalnis filicaulis	5	A	FA	3
Agalinis linifolia	5	P	FA	3
Agalinis pseudaphylla	5	A	FA	2
Agalinis virgata	5	A	FA	3
Agrimonia incisa	4	P	FA	3
Allium sp.	3	P	.	0
Alophia drummondii	3	P	SP	4
Amorpha georgiana var. *confusa*	8	P	SU	2
Amorpha georgiana var. *georgiana*	8	P	SU	2
Amorpha schwerinii	8	P	SU	2
Amphicarpum purshii	2	P	FA	3
Amsonia glaberrima	5	P	SP	3
Amsonia ludoviciana	5	P	SP	3
Andropogon arctatus	1	P	FA	4
Andropogon capillipes	1	P	FA	3
Andropogon mohrii	1	P	FA	3
Andropogon perangustatus	1	P	FA	5
Aristida palustris	2	P	FA	4
Aristida rhizomophora	1	P	SU	2
Aristida simpliciflora	2	P	FA	2
Aristida spiciformis	2	P	FA	4
Arnoglossum ovatum	4	P	SF	4
Asclepias hirtella	5	P	SU	5
Asclepias humistrata	5	P	SS	4
Asclepias incarnata	5	P	SU	5
Asclepias michauxii	5	P	SU	4
Asclepias pedicellata	5	P	SU	3
Asclepias tomentosa	5	P	SS	3
Asclepias viridula	5	P	SU	2
Aster chapmanii	4	P	FA	2
Aster eryngiifolius	4	P	SU	0
Aster solidagineus	4	P	SF	5
Aster spinulosus	4	P	SU	1
Astragalus distortus var. *engelmannii*	5	P	SU	5
Astragalus michauxii	5	P	SS	3
Balduina atropurpurea	4	P	FA	2
Baptisia alba	6	P	SS	0
Baptisia albescens	6	P	SS	4
Baptisia hirsuta	6	P	SP	2
Baptisia simplicifolia	6	P	SU	2
Bartonia texana	5	A	SP	2

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Bartonia verna	5	A	SP	5
Befaria racemosa	8	P	SP	0
Bidens coronata	6	A	SF	5
Bigelowia nuttallii	4	P	SU	2
Botrychium alabamense	5	P	.	3
Buchnera americana	5	P	SU	3
Burmannia biflora	5	A	SP	4
Calamintha ashei	8	P	SP	3
Calamintha dentata	8	P	SS	3
Calamovilfa brevipilis	2	P	SU	3
Calamovilfa curtissii	2	P	FA	1
Calopogon barbatus	3	P	SP	4
Calopogon pallidus	3	P	SP	4
Canna flaccida	4	P	SU	5
Carex barrattii	2	P	SP	3
Carex canescens ssp. *disjuncta*	2	P	SU	5
Carex chapmanii	2	P	SP	2
Carex collinsii	2	P	SU	4
Carex exilis	2	P	SP	5
Carex impressinervia	2	P	.	2
Carex picta	2	P	.	4
Carex striata	2	P	SP	4
Carex tenax	2	P	SS	5
Carex turgescens	2	P	SS	3
Carex verrucosa	2	P	SF	5
Carphephorus pseudoliatris	4	P	FA	4
Chamaecyparis thyoides	8	P	SP	4
Chamaelirium luteum	3	P	SP	5
Chamaesyce cordifolia	7	A	SW	5
Chasmanthium ornithorhynchum	2	P	SU	4
Chrysogonum virginianum	3	P	SP	5
Chrysoma pauciflosculosa	4	P	FA	5
Chrysopsis hyssopifolia	4	P	FA	3
Cladium mariscoides	1	P	SF	5
Cleistes divaricata	3	P	SP	5
Cliftonia monophylla	8	P	SP	4
Clitoria fragrans	7	P	SP	3
Coelorachis tessellata	2	P	SU	5
Coelorachis tuberculosa	2	P	SU	3
Conradina canescens	8	P	SS	5
Conradina glabra	8	P	SP	1
Coreopsis basalis	5	A	SP	5
Coreopsis gladiata	4	P	SF	3
Coreopsis helianthoides	4	P	FA	3
Coreopsis integrifolia	4	P	SU	0
Coreopsis nudata	4	P	SU	3
Cornus alternifolia	8	P	SP	5
Crataegus berberifolia	8	P	SU	1
Croton argyranthemus	5	P	SS	5
Croton elliottii	5	P	SU	2
Ctenium floridanum	1	P	SU	2
Cuphea aspera	5	A	SU	2
Cyperus grayioides	2	P	.	3
Cyperus lecontei	2	P	SF	4
Deeringothemnus pulchellus	8	P	SP	1
Deeringothemnus rugelii	8	P	SP	1
Dicerandra odoratissima	8	P	FA	4
Dichanthelium erectifolium	2	P	SP	4
Dichanthelium hirstii	2	.	.	1
Dionaea muscipula	3	P	SU	3
Dodecatheon meadia	3	P	SP	5
Drosera filiformis	3	P	SU	5
Drosera intermedia	3	P	SP	5
Dryopteris ludoviciana	6	P	.	5
Dyschoriste oblongifolia	5	P	SP	4
Echinodorus parvulus	6	A	SP	2
Eleocharis elongatus	2	P	SU	5

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Eleocharis equisetoides	2	P	SU	4
Eleocharis melanocarpa	2	P	SU	4
Eleocharis robbinsii	2	P	SU	4
Eleocharis rostellata	2	P	SU	5
Elyonurus tripsacoides	1	P	FA	5
Eriogonum longifolium var. *gnaphalifolium*	5	P	SP	4
Erythrina herbacea	8	P	SS	5
Epigaea repens	7	P	SP	5
Eriocaulon kornickianum	3	P	SP	2
Eriocaulon texense	3	P	SP	3
Eryngium aquaticum	3	P	SF	4
Eupatorium leptophyllum	5	P	SF	4
Eupatorium resinosum	5	P	SF	2
Euphorbia telephioides	5	P	SU	1
Fothergilla major	8	P	SP	3
Fuirena simplex	2	P	SP	5
Gaillardia aestivalis	4	A	SF	5
Galactia mollis	7	P	SS	4
Gaylussacia frondosa	8	P	SP	5
Gentiana autumnalis	4	P	FA	3
Gentiana pennelliana	4	P	WI	3
Gnaphalium helleri var. *helleri*	5	A	FA	0
Gordonia lasianthus	8	P	SF	5
Gratiola brevifolia	5	P	SU	4
Gymnopogon chapmanianus	2	P	FA	2
Harperocallis flava	3	P	SS	1
Hartwrightia floridana	4	P	SF	2
Hedeoma graveolens	5	P	SU	2
Hedyotis nigricans var. *pulvinata*	7	P	SP	5
Helenium brevifolium	5	P	SU	4
Helenium drummondii	4	P	SP	4
Helenium pinnatifidum	4	P	SP	3
Helenium vernale	5	P	SP	3
Helianthemum arenicola	5	P	SU	3
Helianthemum rosmarinifolium	5	P	SU	4
Herbertia lahue ssp. *caerulea*	3	P	SP	3
Hexastylis lewisii	3	P	SP	3
Hibiscus aculeatus	8	P	SU	4
Hibiscus coccineus	8	P	SU	4
Hibiscus dasycalyx	8	P	SS	1
Hudsonia ericoides	8	P	SU	4
Hymenocallis henryae	3	P	SU	1
Hypericum adpressum	8	P	SU	2
Hypericum lissophloeus	8	P	SF	2
Hypericum lloydii	8	P	SU	0
Hypericum myrtifolium	8	P	SU	4
Hypericum nitidum	8	P	SU	0
Hypericum reductum	8	P	SS	0
Hypericum suffruticosum	8	P	SP	0
Hypoxis rigida	3	P	SP	0
Hypoxis sessilis	3	P	SP	4
Ilex amelanchier	8	P	SP	3
Ilex cassine	8	P	SP	5
Ilex myrtifolia	8	P	SP	5
Iva microcephala	8	P	FA	5
Juncus gymnocarpus	2	P	SU	2
Justicia crassifolia	4	P	SU	2
Kalmia cuneata	8	P	SU	3
Kalmia hirsuta	8	P	SU	4
Lachnanthes caroliniana	3	P	SU	4
Lachnocaulon beyrichianum	3	P	SU	2
Lachnocaulon digynum	3	P	SU	3
Leavenworthia texana	4	A	SP	1
Lechea torreyi	5	P	SU	4
Lesquerella pallida	4	A	SP	1
Liatris chapmanii	4	P	SF	0

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Liatris cymosa	4	P	SF	2
Liatris pauciflora	4	P	SU	0
Liatris provincialis	4	P	FA	2
Liatris squarrulosa	4	P	FA	4
Liatris tenuis	4	P	FA	2
Licania michauxii	5	P	SP	4
Lilium catesbaei	4	P	SU	4
Lilium iridollae	4	P	SU	1
Lilium superbum	4	P	SU	5
Lindera melissifolia	8	P	SP	2
Lindera subcoriacea	8	P	SP	2
Linum floridanum var. *chrysocarpum*	5	P	SF	0
Linum sulcatum var. *harperi*	5	P	SU	5
Linum westii	5	P	SU	2
Litsea aestivalis	8	P	SP	4
Lobelia boykinii	5	P	SU	2
Lophiola aurea	3	P	SU	3
Ludwigia alata	5	P	SF	3
Ludwigia lanceolata	5	P	SF	0
Ludwigia linifolia	5	P	SF	4
Ludwigia microcarpa	5	P	SU	3
Ludwigia suffruticosa	5	P	SF	5
Lupinus villosus	3	P	SP	5
Lycopodium cernuum	7	P	SS	5
Lycopus amplectens	5	P	SF	5
Lycopus cokeri	5	P	SF	2
Lysimachia asperulaefolia	5	P	SU	2
Macbridea alba	5	P	SU	1
Macbridea caroliniana	5	P	SU	2
Macranthera flammea	5	P	SU	3
Marshallia obovata	4	P	SU	4
Marshallia ramosa	4	P	SU	1
Marshallia tenuifolia	4	P	SU	4
Mayaca aubletii	7	P	SU	3
Melanthium virginicum	4	P	SU	5
Mikania cordifolia	7	P	SF	5
Muhlenbergia torreyana	1	P	SU	3
Myrica inodora	8	P	SU	4
Narthecium americanum	3	P	SU	2
Nemastylis floridana	3	P	FA	2
Nestronia umbellula	8	P	SP	3
Nolina atopocarpa	3	P	SU	3
Nolina brittoniana	3	P	SU	2
Oldenlandia boscii	5	P	SP	5
Onosmodium virginianum	5	P	SS	4
Ophioglossum petiolatum	6	P	.	5
Orbexilum lupinellum	5	P	SU	0
Orobanche uniflora	5	P	SP	4
Oxypolis canbyi	3	P	FA	1
Oxypolis filiformis	3	P	FA	5
Oxypolis ternata	3	P	FA	3
Palafoxia texana var. *ambigua*	5	P	FA	3
Panicum chamaelonche	2	P	SS	0
Panicum nudicaule	2	P	SU	3
Panicum rigidulum var. *combsii*	2	P	SU	0
Panicum strigosum	2	P	SS	5
Panicum tenerum	2	P	SU	4
Parnassia caroliniana	3	P	FA	2
Parnassia grandifolia	3	P	FA	2
Paronychia drummondii	5	A	SU	3
Parthenium integrifolium var. *mabryanum*	4	P	SU	5
Parthenium radfordii	4	P	SU	1
Paspalum bifidum	2	P	.	5
Paspalum monostachyum	2	P	.	4
Peltandra sagittifolia	6	P	SP	3
Penstemon multiflorus	5	P	SU	4
Petalostemon gracilis	5	P	SU	5

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Phacelia strictiflora	5	A	SP	5
Phaseolus sinuatus	7	P	SF	2
Phlox nivalis	7	P	SP	4
Phoebanthus tenuifolia	5	P	SU	3
Physostegia godfreyi	5	P	SU	3
Physostegia longisepala	5	P	SU	2
Pieris phyllyreifolia	8	P	SP	3
Pinguicula ionantha	3	P	SP	2
Pinguicula lutea	3	P	SP	4
Pinguicula planifolia	3	P	SP	3
Pinguicula primuliflora	3	P	SP	3
Pinguicula pumila	3	P	SP	4
Pityopsis flexuosa	4	P	FA	3
Plantago sparsiflora	3	P	SS	2
Platanthera blephariglottis	4	P	SU	4
Platanthera cristata	4	P	SU	5
Planthera integra	4	P	SU	3
Platanthera lacera	4	P	SU	5
Platanthera nivea	4	P	SU	5
Pleea tenuifolia	3	P	FA	3
Polansia erosa	5	P	SS	5
Polygala grandiflora	5	P	SS	5
Polygala hookeri	5	A	SU	3
Polygala nana	4	P	SU	5
Polygonella americana	8	P	SU	5
Polygonella articulata	5	A	FA	5
Polygonella polygama	8	P	SF	3
Polygonum hirsutum	5	P	SF	4
Prenanthes barbata	4	P	FA	2
Prenanthes sp.	4	P	.	2
Psoralea subulata	5	P	SS	3
Pteroglossapsis ecristata	3	P	SU	3
Pycnanthemum floridanum	5	P	SU	3
Pycnanthemum muticum	5	P	SU	5
Pycnanthemum setosum	5	P	SU	3
Pyxidanthera barbulata	3	P	SP	4
Pyxidanthera brevifolia	3	P	SP	2
Quercus laevis	8	P	SP	5
Quercus minima	8	P	SP	5
Quercus myrtifolia	8	P	SP	5
Quercus pumila	8	P	SP	5
Rhexia aristosa	5	P	SF	3
Rhexia cubensis	5	P	SF	0
Rhexia nuttallii	5	P	SS	0
Rhexia parviflora	5	P	SS	2
Rhododendron austrinum	5	P	SS	3
Rhododendron atlanticum	8	P	SS	4
Rhododendron chapmanii	8	P	SP	1
Rhus michauxii	8	P	FA	1
Rhynchospora alba	2	P	SU	5
Rhynchospora breviseta	2	P	SU	3
Rhynchospora capitellata	2	P	SU	5
Rhynchospora chapmanii	2	P	SU	4
Rhynchospora ciliaris	2	P	SU	4
Rhynchospora compressa	2	P	SU	4
Rhynchospora debilis	2	P	SU	4
Rhynchospora decurrens	2	P	SU	2
Rhynchospora divergens	2	P	SU	4
Rhynchospora globularis var. *pinetorum*	2	P	SU	5
Rhynchospora harperi	2	P	SU	3
Rhynchospora macra	2	P	SU	3
Rhynchospora miliacea	2	P	SU	5
Rhynchospora oligantha	2	P	SU	5
Rhynchospora pallida	2	P	SF	2
Rhynchospora pleiantha	2	P	SU	3
Rhynchospora scirpoides	2	A	SU	4
Rhynchospora stenophylla	2	P	SU	2

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Rhynchospora tracyi	2	P	SU	4
Rudbeckia auriculata	4	P	SU	2
Rudbeckia heliopsidis	4	P	SU	2
Rudbeckia mollis	4	P	SU	3
Rudbeckia nitida var. *nitida*	4	P	SU	3
Rudbeckia scabrifolia	5	P	SU	2
Ruellia noctiflora	5	P	SU	3
Ruellia pinetorum	5	P	SU	0
Sabatia brevifolia	5	A	FA	0
Sabatia campestris	5	A	SU	5
Sabatia difformis	5	P	SU	4
Sabatia macrophylla	5	P	SU	4
Sabatia quandrangula	5	A	SU	0
Salpingostylis coelestinum	3	P	SP	2
Salvia azurea	5	P	SF	4
Sarracenia leucophylla	6	P	SP	3
Sarracenia psittacina	6	P	SP	4
Sarracenia purpurea	3	P	SP	4
Sarracenia rubra var. *rubra*	6	P	SP	3
Sarracenia rubra var. *wherryi*	6	P	SP	3
Schizachyrium stoloniferum	1	P	SU	0
Schwalbea americana	4	P	SU	2
Scleria baldwinii	2	P	SU	3
Scleria georgiana	2	P	SU	4
Scleria minor	2	P	SU	3
Scleria reticularis	2	A	SU	3
Scleria verticillata	2	P	SF	5
Scutellaria cardiophylla	5	P	SU	3
Scutellaria floridana	5	P	SU	1
Selaginella arenicola ssp. *riddellii*	6	P	.	5
Selaginella ludoviciana	6	P	.	4
Setaria corrugata	2	A	FA	5
Seymeria pectinata	5	A	FA	4
Silene subciliata	5	P	SS	2
Solidago elliottii	4	P	SF	5
Solidago pulchra	4	P	FA	2
Solidago verna	4	P	SP	2
Spigelia gentianoides	5	P	SU	1
Spiranthes laciniata	3	P	SU	4
Spiranthes longilabris	3	P	SU	3
Sporobolus sp.	1	P	FA	0
Sporobolus teretifolius	1	P	FA	2
Stewartia malacodendron	8	P	SS	4
Stylisma aquatica	7	P	SU	3
Stylisma pickeringii var. *pickeringii*	7	P	SU	4
Syngonanthus flavidulus	3	P	SP	5
Talinum parviflorum	5	P	SU	5
Tephrosia mohrii	7	P	SP	2
Tetragonotheca ludoviciana	5	P	SS	3
Thalictrum cooleyi	5	P	SU	1
Thalictrum texanum	5	P	SP	1
Thelypteris noveboracensis	6	P	.	5
Tofieldia glabra	3	P	SF	2
Tofieldia racemosa	3	P	SU	5
Tridens carolinianus	2	P	SF	2
Tridens strictus	2	P	SF	5
Trillium pusillum	3	P	SP	3
Triplasis americana	1	P	SU	5
Utricularia geminiscapa	5	.	.	4
Utricularia purpurea	7	P	SS	5
Vaccinium macrocarpon	7	P	SP	4
Vaccinium tenellum	8	P	SP	5
Verbesina chapmanii	5	P	SU	2
Verbesina heterophylla	5	P	SU	2
Warea cuneifolia	5	A	SU	4
Warea sessilifolia	5	A	FA	2
Xanthorhiza simplicissima	6	P	SP	5

Appendix 1. Continued.

Species Name	GF	L	PH	GRANK
Xyris brevifolia	3	P	SU	4
Xyris difformis var. *floridana*	3	P	SF	5
Xyris drummondii	3	P	SU	3
Xyris elliottii	3	P	SS	4
Xyris fimbriata	3	P	SS	5
Xyris flabelliformis	3	P	SP	4
Xyris isoetifolia	3	P	SU	1
Xyris longisepala	3	P	SU	2
Xyris scabrifolia	3	P	SU	2
Xyris stricta	3	P	SU	3
Zigadenus densus	4	P	SP	5
Zigadenus leimanthoides	4	P	SU	5

Additional species in Georgia, not included in the analyses.

Agalinis divaricata
Amphicarpum muhlenbergianum
Asimina pygmea
Asimina reticulata
Baptisia arachnifera
Calopogon multiflorus
Ceanothus microphyllus
Ceratiola ericoides
Chamaecrista deeringiana
Chamaesyce dordifolia
Chrysopsis trichophylla
Dalea feayi
Dicerandra densiflora
Dicerandra radfordiana
Elliottia racemosa
Eriochloa michauxii
Eryngium aromaticum
Euphorbia exserta
Evolvulus sericeus var. *sericeus*
Galactia floridana
Gratiola hispida
Helianthus heterophyllus
Krameria lanceolata
Lechea deckertii
Liatris secunda
Matelea pubiflora
Palafoxia integrifolia
Dichanthelium strigosum
Paronychia rugellii
Paspalum giganteum
Penstemon dissectus
Pityopsis pinifolia
Polygala balduinii
Polygala leptostachys
Psilocarya corymbifera
Rhynchospora careyana
Rhynchospora culixa
Rhynchospora punctata
Sarracenia flava
Sarracenia minor
Selaginella arenicola ssp. *acanthonota*
Silene caroliniana
Sprianthes brevilabris
Stokesia laevis
Tephrosia chrysophpylla
Vernonia pulchella
Vigna luteola
Xyris serotina
Zornia bracteata

APPENDIX II

Results of KMEANS Cluster analysis of geographic data for rare species. Data indicating presence (1) or absence (0) in a state were used for the analyses. The mean of the presence value in a cluster could range between 0 and 1. A summary of Clustermean presence values in each state is shown in the first table below. Four (4) groups of species were identified; members of each group are listed in the remaining tables.

Summary of Mean Presence Values of each cluster in each state.

	CLUSTER NUMBER:			
STATE	1	2	3	4
NC	0.35	0.95	0.11	0.00
SC	0.26	0.93	0.11	0.00
GA	0.12	0.89	0.73	0.00
FL	0.65	0.89	0.90	0.00
AL	0.10	0.68	0.64	0.00
MS	0.01	0.60	0.89	0.10
LA	0.00	0.27	0.71	0.65
TX	0.00	0.15	0.25	0.95

Cluster 1:

Agalinis virgata
Amorpha georgiana var. *confusa*
A. georgiana var. *georgiana*
A. schwerinii
Amphicarpum purshii
Aristida rhizomophora
Asclepias tomentosus
A. virgata
Aster chapmanii
A. spinulosus
Baptisia hirsuta
B. simplicifolia
Calamintha ashei
C. dentata
Calamovilfa brevipilis
C. curtissii
Carex barrattii
C. chapmanii
C. impressinervia
Clitoria fragrans
Coelorachis tuberculosa
Conradina glabra
Ctenium floridanum
Cuphea aspera
Deeringothamnus pulchellus
D. rugelii
Dicerandra odoratissima
Dionaea muscipula
Eupatorium resinosum
Euphorbia telepheoides
Gentiana autumnalis
G. pennelliana
Gymnopogon chapmanianus
Harperocallis flava
Hartwrightia floridana
Hedeoma graveolens
Helenium brevifolium
Hymenocallis henryae
Hypericum lissophloeus
Justicia crassifolia
Kalmia cuneata
Liatris provincialis
Lilium iridollae
Linum westii
Lycopus cokeri
Lysimachia asperulaefolia
Macbridea alba
Marshallia ramosa
Muhlenbergia torreyana
Narthecium americanum
Nemastylis floridana
Nolina atopocarpa
N. britonniana
Oxypolis canbyi
Parthenium radfordii
Phoebanthus tenuifolia
Physostegia godfreyi
Pinguicula ionantha
Pityopsis flexuosa
Pycnanthemum floridanum
Pyxidanthera brevifolia
Rhexia parviflora
Rhododendron chapmanii
Rhus michauxii
Rhynchospora pallida
Rudbeckia auriculata
R. heliopsidis
Salpingostylis coelestinum
Scleria minor
Scutellaria floridana
Solidago pulchra
Solidago verna
Spigelia gentianoides
Thalictrum cooleyi

Appendix 2. Continued.

Helianthemum arenicola
Hexastylis lewisii
Xyris isoetifolia
X. longisepala
Tofieldia glabra
Verbesina chpamanii
V. heterophylla
Warea sessilifolia

Cluster 2:

Agalinis aphylla
A. linifolia
Andropogon capillipes
A. mohrii
Balduina atropurpurea
Botrychium alabamense
Carex turgescens
Corposis glabra
Coreopsis helianthoides
Croton elliottii
Dichanthelium hirstii
Fothergilla major
Helenium pinnatifidum
H. vernale
Hypericum adpressum
Ilex amelanchier
Juncus gymnocarpus
Lachnocaulon beyrichianum
Lindera melissifolia
Lobelia boykinii
Lophiola americana
Ludwigia alata
L. microcarpa
Macbridea caroliniana
Mayaca aubletii
Nestronia umbellula
Oxypolis ternata
Parnassia caroliniana
P. grandifolia
Peltandra saggitaefolia
Phaseolus sinuatus
Pieris phyllyreifolia
Plantago sparsiflora
Platanthera integra
Pleea tenuifolia
Polygonella polygama
Prenanthes sp.
Pycnanthemum setosum
Rhexia aristosa
Rhynchospora breviseta
R. decurrens
R. harperi
R. pleiantha
R. stenophylla
R. thornei
Rudbeckia mollis
Sarrecenia rubra var. *rubra*
Schwalbea americana
Scleria baldwinii
S. reticularis
Spiranthes longilabris
Sporobolus teretifolius
Stylisma aquatica
Tridens carolianus

Cluster 3:

Agalinis filicaulis
A. pseudaphylla
Agrimonia incisa
Amsonia glabra
A. ludoviciana
Aristida simpliciflora
Bigelowii nuttallii
Chrysopsis hyssopifolia
Coreopsis nudata
Echinodorus parvulus
Eriocaulon texense
Lachnocaulon digynum
Linum sulcatum var. *harperi*
Macranthera flammea
Panicum nudicaule
Pinguicula planifolia
P. primuliflora
Polygala hookeri
Pteroglassapsis ecristata
Rhododendron austrinum
Ruellia noctiflora
Sarracenia leucophylla
Sarracenia rubra var. *wherryi*
Tephrosia mohrii
Xyris drummondii
X. scabrifolia
X. stricta

Group 4:

Bartonia texana
Crataegus berberifolia
Cyperus grayioides
Eriocaulon kornickianum
Herbertia lahue
Hibiscus dasycalyx
Leavenworthia texana
Lesquerella pallida
Liatris cymosa
Liatris tenuis
Palafoxia texana var. *ambigua*
Paronychia drummondii
Physostegia longisepala
Prenanthes barbata
Psoralea subulata
Rudbeckia scabrifolia
Scutellaria cardiophylla
Silene subciliata
Tetrogonotheca ludoviciana
Thalictum texanum

LITERATURE CITED

Abrahamson, W.G., and D.C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103-149 *in* R.L.Myers and J.J. Ewel, eds. Ecosystems of Florida. The University of Central Florida Press, Orlando.

Bridges, E.L. and S.L. Orzell. 1989. Longleaf pine communities of the West Gulf Coastal Plain. Natural Areas Journal 9:246-263.

Christensen, N.L. 1979. The xeric sandhill and savanna ecosystems of the southeastern Atlantic coastal plain. Veroffentlichungen Geobotanischcen Institutes, ETH, Stiftung Ruble, Zurich. 68:246-262.

Christensen, N.L. 1988. Vegetation of the Southeastern coastal plain. Pages 318-363 *in* M.G. Barbour and W.D. Billings, eds. North American terrestrial vegetation. Cambridge University Press, New York.

Clewell, A.F. 1985. Guide to the vascular plants of the Florida panhandle. University Presses of Florida, Florida State University Press, Tallahassee, FL.

Cody, M.L. 1986. Diversity, rarity, and conservation in Mediterranean-climate regions. Pages 122-152 *in* M.Soule, ed. Conservation biology, the science of scarcity and diversity. Sinauer Associates, Sunderland, MS.

Correll, D.S. and M.C. Johnston. 1970. Manual of the vascular plants of Texas. University of Texas at Dallas, Richardson, TX.

Drury, W.H. 1980. Rare species of plants. Rhodora 82:3-48.

Fiedler, P.L. 1986. Concepts of rarity in vascular plant species, with special reference to the genus *Calochortus* Pursh (Liliaceae). Taxon: 35:502-518.

Florida Natural Areas Inventory. 1990. Guide to the Natural Communities of Florida. Florida Department of Natural Resources. Tallahassee, FL.

Frost, C.C., J.Walker, and R.K.Peet. 1986. Fire-dependent savannas and prairies of the Southeast: original extent, preservation status and management problems. Pages 348-357 *in* D.L.Kulhavy and R.N.Conner, eds. Wilderness and natural areas in the Eastern United States. Center for Applied Studies. Nacogdoches, TX.

Gentry, A.H. 1986. Endemism in tropical versus temperate plant communities. Pages 153-181 *in* M.E.Soule, ed., Consertion biology: the science of scarcity and diversity. Sinauer Assoc., Sunderland, MS.

Godfrey, R.K. and J.W. Wooten. 1979. Aquatic and wetland plants of southeastern United States--monocotyledons. University of Georgia Press, Athens GA.

Godfrey, R.K. and J.W. Wooten. 1981. Aquatic and wetland plants of southeastern United States--dicotyledons. University of Georgia Press, Athens GA.

Hardin, E.D. and D.L.White. 1989. Rare vascular plant taxa associated with wiregrass (*Aristica stricta*) in the Southeastern United States. Natural Areas Journal 9:234-245.

Harper, J.L. 1981. The meanings of rarity. Pages 189-203 *in* H. Synge, ed. The biological aspects of rare plant conservation. John Wiley and Sons, New York.

Hitchcock, A.S. 1950. Manual of the grasses of the United States. Second edidion. Revised by A. Chase. Two volumes. Dover Publishing, New York.

Hartigan, J.A. 1975. Clustering algorithms. John Wiley and Sons, New York.

Hartigan, J.A. and M.A. Wong. 1979. A K-means clustering algorithm: Algorithm AS 135. Applied Statistics 28:126-130.

Kartesz, R.L. 1992. Synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Second edition. Timber Press, Portland, OR (in press).

Kologiski, R.L. 1977. The phytosociology of the Green Swamp, North Carolina. North Carolina Agricultural Experiment Station, Technical Bulletin 250. Raleigh, NC.

MacRoberts, D.T. 1984. An annotated checklist and bibliography of the vascular plants reported to grow without cultivation in Louisiana. Bulletin of the Museum of Life Sciences 6:1-165. Louisiana State University, Shreveport, LA.

Means, D.B. and G. Grow. 1985. The endangered longleaf plant community. ENFO 85:1-12.

Morse, L.E. 1987. Rare plant protection, Conservancy style. The Nature Conservancy Magazine 37:10-15.

Norquist, H.C. 1984. A comparative study of the soils and vegetation of savannas in Mississippi. Masters thesis, Mississippi State University, Mississippi State, MS.

Nelson, J.B. 1986. The Natural Communities of South Carolina: Initial Classification and Description. S.C. Wildlife and Marine Resources Dept., Divisions of Wildlife and Freshwater Fisheries, Columbia, SC. 55. p.

Noss, R.F. 1988. The longleaf pine landscape of the southeast: Almost gone and almost forgotten. Endangered Species Update 5:1-8.

Peet, R.K. and D.J. Allard. 1993. Longleaf pine vegetation of the southern Atlantic and eastern Gulf coast regions: A preliminary classification. *In* The longleaf pine ecosystem: ecology, restoration and management. Eighteenth Tall Timbers Fire Ecology Conference Proceedings. Tallahassee, FL. (this volume)

Platt, W.J., G.W.Evans, and M.M.Davis. 1988. Effects of fire season on flowering forbs and shrubs in longleaf pine forests. Oecologia 76:353-363.

Rabinowitz, D. 1981. Seven forms of rarity. Pages 205-271 *in* H.Synge, ed., The biological aspects of rare plant conservation. John Wiley and Sons, New York.

Rabinowitz, D., S.Cairns and T. Dillon. 1986. Seven forms of rarity and their frequency in the flora of the British Iles. Pages 182-204 *in* M.E. Soule, ed. Conservation biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, MS.

Radford, A.E., H.E. Ahles, and C.R.Bell. 1968. Manaual of the vascular flora of the Carolinas. University of North Carolina Press, Chapel Hill, NC.

Robbins, L.E. and R.L. Myers. 1989. Seasonal effects of burning. Report to the Florida Game and Fresh Water Fish Commission. Tallahassee, FL.

Schafale, M.P. and A.S. Weakley. 1990. Classification of the Natural Communiites of North Carolina (Third Approximation). NC Natural Heritage Program, Divisions of Parks and Recreation, NC Department of Environment, Health and Natural Resources, Raleigh, NC. 325 p.

SYSTAT, Inc. 1986. SYSTAT: the system for statistics. SYSTAT, Incorporated. Evanston, ILL.

Taggart, J.B. 1990. Inventory, classification, and preservation of coastal plain savannas in the Carolinas. Ph.D. dissertation. University of North Carolina. Chapel Hill, NC.

Walker, J. and R.K. Peet. 1983. Composition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetatio 55:163-179.

Wells, B.W. and I.V. Shunk. 1931. The vegetation and habitat factors of the coarser sands of the North Carolina coastal plain: An ecological study. Ecological Monographs 1:466-520.

Wunderlin, R.P. 1982. Guide to the vascular plants of central Florida. University Presses of Florida, Gainesville, FL.