XYRIS TENNESSEENSIS: STATUS SURVEY, HABITAT RESTORATION/MANAGEMENT CONCERNS, AND RELATION TO A NEW XYRID, *XYRIS SPATHIFOLIA*

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XYRIS TENNESSEENSIS: STATUS SURVEY, HABITAT RESTORATION/MANAGEMENT CONCERNS, AND RELATION TO A NEW XYRID, *XYRIS SPATHIFOLIA*

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XYRIS TENNESSEENSIS: STATUS SURVEY, HABITAT

RESTORATION/MANAGEMENT CONCERNS, AND

RELATION TO A NEW XYRID,

XYRIS SPATHIFOLIA

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VITA

James Mincy Moffett, Jr., son of James M. Moffett, Sr. and Ann Charlotte Stevens, was born March 7, 1961, in Emory, GA. He graduated from Marist High School in 1979. He attended The University of the South (Sewanee) for four years and graduated with a Bachelor of Arts degree in Economics in 1983. He then worked as a mortgage loan officer with Georgia Federal Savings & Loan while pursuing a Master of Business Administration from Georgia State University. He graduated in December 1987, and in April 1988 went to work as the Administrative Director for the international environmental organization, Greenpeace U.S.A., in Washington D.C. While there, he met and married his wife, Christina Davis, who also worked for Greenpeace U.S.A. They moved to Atlanta, GA in May 1995, where Mincy enrolled at Georgia State University as an undergraduate, taking basic science coursework in preparation for a graduate degree in botanical sciences and an eventual career change. He enrolled in the Botany Ph.D. program at Auburn University in 1997. In February 2000, Mincy's and Christina's daughter, Harper Ann, was born. In December 2004, they moved to Athens, GA, where Mincy began working for the Georgia Natural Heritage Program (GA Dept. of Natural Resources) as a conservation botanist while completing his degree.

DISSERTATION ABSTRACT

XYRIS TENNESSEENSIS: STATUS SURVEY, HABITAT RESTORATION/MANAGEMENT CONCERNS, AND RELATION TO A NEW XYRID, *XYRIS SPATHIFOLIA*

James Mincy Moffett, Jr.

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Xyris tennesseensis is a federally endangered, obligate wetland, perennial herb. It inhabits calcareous seeps, fens, and spring runs with a distribution restricted to the Interior Plateau and Ridge and Valley ecoregions in Alabama, Georgia, and Tennessee. The NatureServe network ranks this species as critically imperiled in each of the states in which it occurs, and imperiled overall. Given its specificity of habitat, limited distribution, and rarity/threat of extinction, *Xyris tennesseensis* is of considerable interest to the conservation community and to those entities charged with managing its populations. Results of a two-year U.S. Fish & Wildlife Service sponsored status survey of *X. tennesseensis* populations are reported here, as are the results from a

three-year Georgia Department of Transportation supported habitat restoration study of *X. tennesseensis* habitat. Serendipitously, during the USFWS status survey, a new species of *Xyris*, rarer still than *X. tennesseensis,* was discovered in the Ketona Glades of Bibb Co., AL, and is described and figured herein.

A status survey of 19 *X. tennessensis* populations confirmed this species' habitat specificity and tenuousness existence. *Xyris tennesseensis* sites were typically quite small with a mean area of ca. 500 m^2. Average population size was ca. 3,500 ramets (individual plants), although over 50% of the populations contained fewer than 1,000 ramets. Numbers of flowering spikes and seedlings were highly variable among sites, ranging from ca. 30 to 20,900, and from 0 to 7,900, respectively.

A three-year habitat restoration/management study was conducted to determine effects of the cutting of shrubs that were shading a population of *X. tennesseensis* on public land. Shrub cutting significantly increased flowering of *Xyris* on the site, although this effect was short-lived (only 2 years). There was also a significant increase in seedling production, but not total numbers of ramets. Floral visits were significantly more frequent to *Xyris* flowers located on cut plots. There was no *Xyris* seed bank found. While cutting shrubs can stimulate *Xyris* reproduction, it must be applied frequently in order to address woody regrowth and rapid development of herbaceous/graminoid competition.

A distinctive new xyrid from one of the Ketona Glades was found growing intermixed with *X. tennesseensis*, but is distinct from it. I distinguish this new taxon, *Xyris spathifolia* Kral & Moffett, from the latter, giving it species rank based upon observations of field-collected material, common garden trials, and herbarium surveys.

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I. INTRODUCTION

The plant family Xyridaceae is a relatively small one, located primarily in tropical and subropical regions of the world. In North America north of Mexico, the family is represented by a single genus, *Xyris*, with ca. 25 species. *Xyris* are generally considered obligate wetland heliophytes. As a genus of wetland plants, they have suffered from general habitat destruction and degradation. One species found only in the southeastern United States, the federally endangered *Xyris tennesseensis*, is not only at risk as a wetland plant, but is also extremely rare due to its unusual habitat requirement among North American xyrids for circum-neutral pH soils overlying calcareous substrates. In addition, it has been shown to be a poor competitor and quickly succumbs to ecological succession without periodic disturbance. Plant conservation efforts aimed at this species have included habitat and population surveys, as well as critical habitat management and restoration. In one instance, a habitat survey for *X. tennesseensis* discovered a new species of *Xyris* previously unknown to science that now appears to be North America's rarest xyrid.

The Xyridaceae is a monocotyledonous family of herbs, mostly pan-tropical and sub-tropical in distribution, with some limited occurrence in warmer parts of temperate North America. Of the ca. 380 species extant globally, most are found in South America (Govaerts and Lock 2006). The Guiana Highlands, Amazonia, and Brazilia are the largest centers of endemism, with lesser ones located in Africa and Australia (Kral 2000). The family consists of five genera: *Abolboda, Achlyphila, Aratitiyopea, Orectanthe*, and *Xyris*. *Xyris* is by far the largest genus in the family, with over 300 species (Govaerts and Lock 2006). By contrast, *Achlyphila* and *Aratitiyopea* are each monotypic, *Orectanthe* contains just two species, and *Abolboda* has ca. 40. The Xyridaceae has generally been regarded as allied with the Commelinaceae, Eriocaulaceae, Mayacaceae, and Poaceae, although inconsistencies and disagreements remain (Dahlgreen and Clifford 1982; Cronquist 1988; Angiosperm Phylogeny Group 1998; Judd et al. 1999). In North America north of Mexico, the Xyridaceae is represented solely by the genus *Xyris,* with ca. 25 species. The Flora of North America (Kral 2000) recognizes 21 species as of 2000, and a limited number of others have either been described or are in the process of being described (e.g., Ch. IV).

North American *Xyris* are all heliophytic obligate wetland plants, with the exception of *X. caroliniana*, which has a facultative wetland (FACW+) rating (U.S. Fish and Wildlife Service 1996). *Xyris tennesseensis*, a federally endangered wetland obligate, is almost exclusively restricted to the Ridge and Valley and Interior Plateau ecoregions of Alabama, Georgia, and Tennessee (U.S. Fish and Wildlife Service 1994a). It differs from most other species of southeastern U.S. *Xyris* in that it inhabits calcareous seeps, fens and spring runs, as opposed to the acidic, boggy, "mucky" substrates that typify the habitat of other *Xyris* (Kral 1979, 1990). All *Xyris* are heliophytic (Kral 2000) and, as such, prefer early successional habitats. *Xyris tennessseensis* is not tolerant of extensive shading and has declined at sites experiencing encroachment from trees and shrubs (Kral 1983). Efforts to remove these competitors and "open up" a site may be a beneficial component of a conservation strategy for this species (Patrick et al. 1995; Hogan 1996; Ch. III).

Plant conservation in the southeastern United States is a crucial, but incredibly challenging endeavor. Not only is this region endowed with exceptionally high levels of biodiversity (Stein et al. 2002), but it has also experienced some of the highest levels of recent population growth and land development in the U.S. (U.S. Census Bureau 2000). The southeastern U.S. is defined here, per Estill and Cruzan (2001), to include only those states occurring in Bailey's Humid Temperate Domain (Bailey 1998) and also occurring entirely south of the maximum extent of Pleistocene glaciation (Mayewski et al. 1981). It consists of 17 states/districts (AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, and WVA), although only the eastern ⅓ of TX, and the eastern ½ of OK, would actually be in the Humid Temperate Domain. These 17 states/districts are identical to the area of the country considered the "South" (one of four such statistical regions) by the U.S. Census Bureau (2000).

The southeastern U.S. is only 24.8% of the total surface area of the United States (U.S. Census Bureau 1990), yet supports disproportionately high portions of the nation's human population (36%) (U.S. Census Bureau 2000) and native vascular and nonvascular flora (44.8%) (NatureServe 2008). Human population growth in the south increased by 53 million during the period 1950-2000, the most of any region, and today it is the only region to have a population in excess of 100 million (U.S. Census Bureau 2000). Nationally, the U.S. has ca. 24,300 taxa in its flora (NatureServe 2008), using the concept of least-inclusive-taxonomic-unit (i.e. a described taxon of lowest rank, which could be a subspecies or a variety but, in this case, not a form, as they are not tracked by

NatureServe). Of these 24,300 taxa, nearly 11,000 are represented in the southeast. An analysis by state of both plant species richness and plant risk/threat using Stein (2002) places four southeastern states in the top 10 nationally for plant species richness (TX, FL, GA, and AL, in order) and another seven in the top 20 (NC, SC, VA, TN, LA, MS, and OK, in order). Using the same approach, the southeast has two states in the top 10 nationally for plants at risk (FL and GA, in order), and 6 more in the top 20 (TX, AL, NC, SC, TN, and VA, in order). Plant taxa with a NatureServe/Natural Heritage Program conservation status ranking of G1 (critically imperiled species), G2 (imperiled species), or T1 or T2 (critically imperiled/imperiled rankings for sub-specific taxa) number ca. 800 in the southeast, which is roughly 20% of the total number of G1/G2-ranked species found nationally (NatureServe 2008). Estill and Cruzan (2001) identified 808 species endemic to the southeast and considered 482 (60%) of them, representing 246 genera and 95 families, to be rare. Moreover, they also identified six centers or "hot spots" of endemism: 1) Central Peninsular Florida (including Lake Wales Ridge); 2) Apalachicola Region of the Florida Panhandle (Big Bend region to AL border); 3) Southern Appalachians (Blue Ridge southwestern NC and adjacent GA, SC, and TN); 4) Central Basin of Tennessee (Nashville Basin); 5) Mid-Atlantic Coastal Plain (coastal NC/SC border); and 6) Western Gulf Coastal Plain (coastal LA/TX border).

Given the number of plant species occurring in the southeastern U.S. and the level of habitat destruction and degradation associated with human population growth, active conservation/management at both the species and habitat levels are critical to the continued existence of many of these species, and to overall biodiversity. Plant conservation nationally involves both *in situ,* as well as *ex situ,* strategies. *In situ* efforts focus on habitat protection, acquisition, and/or the restoration and management of critical habitat for rare taxa (California Native Plant Society 2008; Center for Plant Conservation 2008; New England Wildflower Society 2008). Restoration and management may also incorporate rare plant reintroductions, augmentations, and the creation of new "safeguarding" populations (Affolter and Ceska 2007). *Ex situ* conservation supports *in situ* outplanting activities through propagation, in addition to "warehousing" genetic material through seed banking, and both germplasm and living collections (Guerrant et al. 2004; Farnsworth et al. 2006).

Xyris tennesseensis is a rare species in need of conservation attention (U. S. Department of Interior 1992; U.S. Fish & Wildlife Service 1994a). NatureServe (2008) considers this species to be imperiled at a global level (G2 ranking), and critically imperiled (S1) in each of the three states where it occurs. This species is recognized and protected as endangered not only at the federal level by the United States Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1991b), but also at the state level in Georgia and Tennessee by the Georgia Wildflower Preservation Act of 1973 (Georgia Department of Natural Resources 2008) and Tennessee Rare Plant Protection and Conservation Act of 1985 (Crabtree 2008), respectively. As of yet, Alabama provides no legal protection for rare plants.

This dissertation presents detailed information and analyses regarding the status of *X. tennesseensis* throughout its range, tests a conservation/management hypothesis regarding woody competition and shading, and describes a new rare *Xyris* species, *X. spathifolia*, found sharing the same habitat as *X. tennesseensis*. In Chapter II of the dissertation, results from a two-year survey of 19 *X. tennesseensis* habitats and populations will be presented. Habitat information includes physiographic, geologic, hydrologic, edaphic, climatic, and floristic information for each site, organized and displayed in an ecoregion format. Information on population size in terms of areal extent of population, numbers of plants (i.e., clumps and ramets), and reproductive output in terms of numbers of flowering spikes and seedlings, is also given. Chapter III involves hypothesis testing with pragmatic management implications. Many *X. tennesseensis* sites are suffering from woody plant encroachment and succession. Since natural disturbance factors have been disrupted, if not eliminated entirely, by modernity, some anthropogenic disturbance may be required for the conservation of certain species. Here, I examine the effects on *X. tennesseensis* population vigor and reproduction of manual removal (cutting) of a shrub (*Hypericum interior*) that was severely impacting (i.e. shading) one of the few legally protected populations of *X. tennesseensis*. And lastly, in Chapter IV, a new species of *Xyris* from the Ketona Glades of Bibb Co., AL (*X. spathifolia*) is described and contrasted to *X. tennesseensis,* with which it occurs syntopically.

II. SURVEY OF XYRIS TENNESSEENSIS (TENNESSEE YELLOW-EYED GRASS): HABITAT ANALYSIS, CENSUS, DEMOGRAPHICS AND STATUS REPORT

ABSTRACT

A two-year field survey was conducted of 19 populations of the federally endangered plant, *Xyris tennesseensis*. *Xyris tennesseensis* is an obligate wetland, heliophytic, perennial herb, restricted to calcareous seeps, fens, and spring runs in Alabama, Georgia, and Tennessee. It is known from ca. 40 sites (extant and historic) and is almost exclusively confined to the Interior Plateau and Ridge and Valley ecoregions. Mean site size was approximately 500 m^2 in area. Populations on average contained about 3,500 ramets, a physiologically independent member of a genet (i.e., an individual *Xyris* plant). Results of a reproductive spike census of most extant sites found numbers ranging from a low of 32 to nearly 21,000, with a mean of over 2,600 per site. In general, sites in the Ridge and Valley were larger than those in the Interior Plateau in terms of average site size (686 m^2 vs. 318 m^2), average number of flowering spikes (3,356 vs. 1,625), and average number of ramets (4,209 vs. 2,671). The growth form tended to be more clumped (i.e., more ramets per clump) in the Interior Plateau than in the Ridge and Valley where the growth form is more “lawn like” (9.4 ramets/clump vs. 4.1 ramets/clump. This may reflect the fact that *X. tennesseensis* sites in the Interior Plateau

had a denser canopy cover than sites in the Ridge and Valley. Counterintuitively, the average number of seedlings found per site was higher (931 vs. 202) in the Interior Plateau.

INTRODUCTION

Tennessee yellow-eyed grass (*Xyris tennesseensis* Kral) is a rare perennial monocot of the family Xyridaceae (Alabama Natural Heritage Section 1992; Patrick et. al. 1995; Nordman et al. 1998). First described by Kral (1978), it is known from only 38 current and historical populations (41 occurrences) scattered among Alabama, Georgia and Tennessee (Alabama Natural Heritage Program 1998; Georgia Natural Heritage Program 1998; Tennessee Division of Natural Heritage 1998). Contrasted with the other 20+ taxa of this genus in the Southeastern U.S. (see Kral 1979), *X. tennesseensis* has relatively specialized habitat requirements. Whereas most *Xyris* in the Southeast either require or tolerate the acidic "boggy/mucky" soils of the Coastal Plain, *X. tennesseensis* is limited almost exclusively to slightly alkaline or circum-neutral, gravelly-sandy substrata in rocky calcareous regions of the Ridge and Valley or Interior Low Plateaus physiographic provinces.

Xyris tennesseensis was proposed and approved for Federal listing as an endangered species in 1991 (United States Fish & Wildlife Service 1991a and 1991b). NatureServe provides a conservation ranking of G2 and S1 (AL, GA, TN) for this species. NatureServe conservation rankings for individual species are based upon state Natural Heritage Program data and reflect the quantity or abundance of the species (number of populations and population sizes), as well as the quality of individual sites/populations, and an assessment of threat. The alpha portion of the alpha-numeric rank reflects the scale/jurisdiction of the rank (G = global or entire range; S = subnational or state level). The numeric portion reflects the combined degree of rarity and threat, with a smaller number indicating a more rare and “at-risk” species (1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, 5 = demonstrably secure) (NatureServe 2008).

Despite its federally endangered and imperiled status, little is known about the ecological features of this species. This knowledge void is problematic for managers, as it prevents them from fully understanding the ecological context in which effective management tactics can be designed and implemented. Compounding this problem is the lack of a centralized depository for population status and habitat-related information. Information pertinent to these populations and their habitats is currently scattered among a number of agencies and jurisdictions (Federal, State and County). Agencies specifically important to this effort included: the state Natural Heritage Programs (NHP) of AL, GA, and TN; the Natural Resources Conservation Service (NRCS); the U.S. Geological Survey (USGS); and the U.S. Fish and Wildlife Service (USFWS).

The objectives of this project were to provide information about the population status and habitat features of this species. A special effort was made to assemble as much pertinent information as possible from the disparate sources and jurisdictions mentioned above to produce a comprehensive summary of *X. tennesseensis* information. Specific objectives were to:

1) Describe the habitat features of as many of the extant populations of this species as possible, and

2) Describe the population status of the above extant populations, including information on population size and demography. This information was collected to provide a basis for long-term monitoring of these populations.

METHODS

Habitat Description of Xyris tennesseensis

Distribution

The known distribution of *X. tennesseensis*, both current and historic, was garnered from the records of various Federal and state conservation agencies (i.e., USFWS and state NHPs) and from early status reports by Kral (1990), Allison (1993), and Garland (1996). All sites where landowner access was granted were surveyed for current population status. Frequent contact was maintained with the AL, GA and TN Natural Heritage Programs during the course of this project to stay abreast of new population/site discoveries. New population/site discoveries resulting from this study were updated in the appropriate conservation records. Nine populations discovered after the field phase of this study (i.e., after Nov. 1999) are not included. All data and results are organized and presented using an ecoregion format based upon Griffith et al. (1998 and 2001). The ecoregion concept with intellectual foundations in both geology and ecology is increasingly important to environmental assessment and management (Loveland and Merchant 2004). Ecoregion formulation includes physiographic, geologic, edaphic, climatic, and floristic elements. These elements of the two principal ecoregions in which *X. tennesseensis* is known to occur (i.e., Interior Plateau and Ridge and Valley) are described herein.

The concepts of ecoregions and physiographic provinces can be confusing as they are overlapping in some respects. Physiography is concerned primarily with geology, topography, and landforms, whereas ecoregionalization blends geological considerations with ecological ones and is, therefore, a more "inclusive" concept. Both constructs employ a hierarchical structure and delineate similar boundaries while utilizing similar nomenclature. For example, the geographic location and boundaries of the Interior Plateau ecoregion coincide very closely with those of the Interior Low Plateaus physiographic province. There are some differences between the two regarding the inter-digitation of boundaries or inclusions of neighboring ecoregions and physiographic provinces, but these are truly minor. The similarity of the two concepts suggests that geologic and topographic conditions dictate hydrologic and edaphic structure/formation, which in turn drive ecologic and floristic composition.

Physiography, Geology, and Hydrology

The physiography and geology of known *X. tennesseensis* habitats were compiled using physiographic, geologic and hydrologic maps and publications from various Federal and state geologic/land use agencies (i.e., USGS, state Geological Surveys, and NRCS). Classic and definitive physiographic texts, such as those by Fenneman (1938), Hunt (1967) and Quarterman and Powell (1978), were also consulted.

Soil Associations and Analysis

When available, USDA county soil surveys and maps were used to determine the soil associations of known *X. tennesseensis* populations. Soil information for unmapped (traditionally less agriculturally important) counties (i.e., Bibb Co., AL; Bartow Co., GA; and Lewis Co., TN) was obtained through personal communication with soil scientists.

A special field survey of *X. tennesseensis* sites in Bibb County was arranged with a resource soil scientist to determine if undescribed and unmapped soil inclusions were present within the boundaries of those populations.

Soil analysis used soil samples collected from each of the 19 populations (23 occurrences) surveyed for this report. Populations with multiple occurrences (i.e., sub-populations) were sampled at least once per occurrence. Extensive occurrences, or those presenting noticeably different sub-habitat types, were sub-divided and sub-sampled (i.e., one soil sample per sub-habitat type). The Mosteller Springs, GA site was sub-divided into four distinct sections for the purposes of soil sampling. The Lloyd's Chapel Swale, and Red Bay Hwy, AL sites were sub-divided into two sections each. Each sample consisted of soil cores (0-10 cm in depth) taken from at least five different representative areas of the population and combined into a single sample for analysis. Samples were analyzed by the Auburn University Soil Testing Laboratory.

Each soil sample was analyzed for a number of characteristics, including soil texture, pH, organic matter, total nitrogen, and 16 other elements. Soil texture (particle size) was determined using 40 g of soil and the Bouyoucos Style Hydrometer Method. Soil pH (of a 1:1 soil:H_2O mixture) was determined using 20 g of soil with a Fisher-Dual Electrode System with both a fast-flow reverse sleeve reference electrode and a glass body indicating electrode. Organic matter was determined by dry combustion with a LECO WR-12 carbon analyzer and employing a 1.9x correction factor. The organic matter determination required a variable amount of soil (0.1-0.5 g). Total nitrogen was determined using a LECO CHN 2000 nitrogen analyzer and 0.8 g of soil. Additionally, 5 g of soil were double acid extracted and the extract analyzed for Al, B, Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, P, Pb, and Zn using an inductively-coupled argon plasma spectrometer (Jarrell-Ash ICAP 9000) (Odom and Kone 1997).

Climate/Exposure

The macroclimate for *X. tennesseensis* habitats was determined from Alabama Agricultural Experiment Station and NOAA weather data. Efforts were made to obtain climate data from reporting weather stations located near *X. tennesseensis* sites. Local or microclimate variables (i.e., slope, aspect and shading level) were measured/estimated in the field as part of this study. The site-specific habitat features affecting microclimate were determined using an Abney Level and magnetic compass, respectively. The relative degree of shading provided by canopy and perimeter species was subjectively determined and assigned a value using a four-tiered scale based on percentage of shrub/tree canopy cover: (1) Significantly Shaded (> 75%), (2) Moderately Shaded (51% - 75%), (3) Partially Open (26%- 50%), and (4) Mostly Open (≤ 25%).

Floral Associates

Floral associates of *X. tennesseensis* were determined by field surveys of the local seep/spring/fen/streambank microsites and surrounding habitats. Additional information critical to this effort was obtained from habitat descriptions by Kral (1990) and United States Fish & Wildlife Service (1994a, b) and floral lists provided by Shea (2000). Floral associates (including species and genera) were grouped according to frequency of association (i.e., common, intermediate, and infrequent). Common associates were species and genera found in at least 75% of the surveyed *X. tennesseensis* populations. Intermediate associates were those located in 50-74% of the surveyed populations.

Infrequent associates appeared in fewer than 50% of the surveyed populations. Trees, shrubs and herbs of the adjacent ecotone were placed into the infrequent associate category. Common and intermediate associates are organized and presented here using an ecoregion theme. Infrequent associates were combined into a single list without ecoregion distinction.

Population Size and Demography of Xyris tennesseensis

A complete census of reproductive scapes and spikes was made of the 19 populations (23 occurrences) of *X. tennesseensis* surveyed for this study. It is important to note that the number of officially recognized populations does not necessarily equate to the number of physical site occurrences. Use of the term "occurrence" indicates a known presence (extant or historical) of a group of similar organisms. Occurrences located closely enough to one another to have a reasonable opportunity for genetic exchange (given a host of biotic and abiotic factors, such as intervening topography and floral communities, or hydrologic connectivity, or lack thereof, etc.) may be combined or "mapped" as a single population by state Natural Heritage Programs (Alabama Natural Heritage Program 2008; Georgia Natural Heritage Program 2008; and Tennessee Division of Natural Heritage 2008). For example, one complex of sites in Tennessee (Little Grinder's Creek) contains six occurrences, but only three populations. Another single population in Alabama (Little Schultz Creek) contains two occurrences.

Each population/occurrence was also sampled for several population parameters: clump size (i.e., numbers of ramets/clump), ramet reproductive status (i.e., reproductive vs. vegetative), ramet reproductive effort (numbers of spikes/reproductive ramet) and numbers of seedlings. In cases of small populations/occurrences (i.e., Little Grinder's

Creek – Hick Hill Br., TN; Floodplain and Champion Boundary, TN; Petit Cr./Wofford's Crossroards, GA), a complete census of these parameters was made. In other cases, a subsample of the population/occurrence was made and values to represent the entire population/occurrence were estimated based on the results of the subsample. Population parameter data were combined with the reproductive spike census data to develop estimates of total population size and demographic composition for each population/occurrence. An example of this is: (Spikes/Population) × (Reproductive Ramets/Spikes) × (Clumps/Reproductive Ramets) = Clumps/Population.

The spike census was performed by counting all of the current season's visible spikes, regardless of size or blooming status, during the flowering period of *X. tennesseensis* (August-September). The process was aided by the use of hand tally counters. Efforts at thoroughness included inspecting the "interior" of each clump near the ground for hidden or newly emerging scapes. However, the necessity to minimize the impact of the survey to the populations and habitats prevented aggressively approaching and handling plants in especially fragile and sensitive areas (i.e., Mosteller Springs, GA; Langford Branch, TN; and Twin Falls Hollow, TN).

Demographic sampling employed a mixed subjective/random method. Two sampling transects per site were subjectively placed in an effort to maximize *X. tennesseensis* participation. An exception to this was the very large Mosteller Springs, GA population that required four transects. Transects varied in length from 5 m to 20 m. The subjective placement and variable lengths of transects were necessary given the irregular layout/design of the sites and the sometimes "spotty" distribution of *X. tennesseensis* clumps within a site. Each transect was sampled with five randomly assigned 0.1 m^2 plots using a 0.2 m × 0.5 m quadrat. In some cases, the sensitivity of the habitat (Mosteller Springs, GA; Langford Branch, TN; and Twin Falls Hollow, TN) mandated that transects and plots be located only on the periphery of the populations, resulting in additional subjectivity to the sampling exercise.

The decision was made to use the term "ramet" to describe the individual plants/shoots within a *X. tennesseensis* clump. This was done in part to satisfy conventions of previous studies (Nordman 1999) and also as recognition of the clonal nature of *X. tennesseensis*. A ramet is defined here as a physiologically independent member of a genet.

Use of the term ramet, however, is not without its limitations. While it may be true that individuals within a clump are physiologically independent, assigning genetic lineage to them is problematic. *Xyris tennesseensis* is a perennial that, when mature, is typically cespitose with few to many individuals producing an abundance of scapes. It reproduces both by seed and by production of lateral buds from the axils of crown leaves. Seeds are small (0.5-0.6 mm) and the lack of wind dispersal features allows a disproportionate amount of the seed rain to fall directly into and around the parent clump. As clumps increase in size over time, it is difficult to determine if an individual represents a sexual or an asexual addition. Another difficulty is created when a mass or "lump" of seeds (perhaps still contained in fruits of a spike that has fallen to the ground) is dispersed together in one location. In this case, the resulting mature clump would contain almost all genetically different individuals (i.e., not a genet and, therefore, not technically ramets). Nevertheless, ramet is the most convenient term available to describe the situation with *X. tennesseensis* in the field.

Site size (area) was also measured for each population/occurrence. It was a liberal measure that not only included the area currently occupied by each *X. tennesseensis* population, but also areas adjacent to populations and between clumps that represented likely *X. tennesseensis* habitat. Consequently, site sizes may appear larger than expected, and the calculated density values lower than expected.

RESULTS/DISCUSSION

Habitat Description of Xyris tennesseensis

Distribution

The known current and historic distribution of *X. tennesseensis* is restricted to the states of Alabama, Georgia, and Tennessee, almost exclusively within the Interior Plateau (IP) and Ridge and Valley (RV) level III ecoregions as presented by Griffith et al. (1998 and 2001). Further refinement of the level III ecoregions, into level IV ecoregions, places *X. tennesseensis* populations in the Western Highland Rim (WHR) of the Interior Plateau ecoregion, as well as the Southern Limestone/Dolomite Valleys and Low Rolling Hills (SLDV), and the Southern Shale Valleys (SSV) of the Ridge and Valley ecoregion (Fig. 1a, b). Several *X. tennesseensis* occurrences in the RV ecoregion are also near boundaries with the level IV ecoregion, Southern Sandstone Ridges (SSR) ecoregion. Due to the extensive use of acronymns in this chapter regarding physiographic areas and ecoregions, a comprehensive summary of them is provided for reader convenience (Table 1).

Three exceptions to the Interior Plateau and Ridge and Valley distributional paradigm involve one population surveyed for this study (Red Bay Highway-Franklin

Co., AL), and two that were not (Pine Log Springs-Bartow Co., GA, and unnamed site-Wilcox Co., AL). The Red Bay Highway site (to be discussed in depth later) is found within the Transition Hills (TH) (level IV) of the Southeastern Plains (SEP) (level III) ecoregion. Its location is very near a border with the IP ecoregion, with which it shares many features. The Pine Log Springs situation is similar in that it is technically located in the Southern Metasedimentary Mountains (level IV) of the Piedmont (level III) ecoregion, but is very near a border with the RV ecoregion and is similar in many respects to it, as well. The unnamed Wilcox Co. site is in the Southern Hilly Gulf Coastal Plain (level IV) of the SEP ecoregion, but was reported only once and never has been relocated. Some concern as to the validity of the record exists (Schotz, pers. comm.).

The tally of all known current and historic populations (Tables 2 and 3) stands at 37 (41 occurrences) (Alabama Natural Heritage Program 2008; Georgia Natural Heritage Program 2008; and Tennessee Division of Natural Heritage 2008). This includes five populations considered extirpated or of unknown status (Unnamed-Wilcox Co. and Ryan Church/Quarry, AL; Oak Flat Seep, GA; and Spring Branch Seep and Little Swan Creek, TN), and four of unknown status, due primarily to lack of landowner-permitted access (Wesley Chapel Spring, AL; Barnsley Gardens and Deep Springs, GA, and Sandy Mitchell Hollow, TN), leaving 28 populations considered extant. A status of "unknown" is conferred upon very small populations observed either infrequently or with a lapse of more than three years since the last observation.

The majority of the 28 extant populations occur in the RV ecoregion (Fig. 1a, b). An inventory by ecoregion of the populations considered extant shows the RV ecoregion with 16 populations, the IP ecoregion with 11, and the SEP ecoregion with one (Tables 2 and 3). An inventory by state indicates 11 populations in Tennessee, ten in Alabama, and seven in Georgia. In Tennessee, all populations are confined to a single county (Lewis). In Alabama, four populations each are located in Bibb and Calhoun Counties, with one located in each of Franklin and Shelby Counties. Georgia has six populations in Bartow County and one in Floyd County. Of the 28 populations considered extant, 19 were surveyed and sampled for this report.

Physiography, Geology, and Hydrology

Ridge and Valley Ecoregion

The current range of *X. tennesseensis* is confined to the Interior Low Plateaus (ILP) and Ridge and Valley (RV) physiographic provinces (Fenneman 1938; Quarterman and Powell 1978). The RV physiographic province stretches northeasterly along the entire length of the Appalachian Highlands for 1900 km from central Alabama to the lower Hudson Valley in New York. It is one of seven physiographic provinces comprising the Appalachian Highlands major physiographic division. It is bordered by the New England, Adirondack, and St. Lawrence Valley physiographic provinces on the north, and the Coastal Plain (CP) physiographic province on the south. To the east and west are the Blue Ridge and Appalachian Plateaus (AP) physiographic provinces, respectively. The Blue Ridge (and Piedmont) are referred to as the "Older Appalachians," and are mostly composed of highly deformed and resistant igneous and metamorphic rock. By comparison, the AP and RV, both considered the "Newer Appalachians" contain mostly sedimentary rock (Fenneman 1938; Hunt 1967). The Appalachian Highlands of today occupy an area that during the Paleozoic Era included the eastern edge of the ancient continent, Laurentia (the continental core of present day North America), and the shallow inland seas to the west (Roberts 1996).

The Appalachian Highlands owe their existence to a series of three orogenies, spanning most of the Paleozoic Era. The first two orogenies were directly related to the building of the Older Appalachians. A third and final orogeny resulted in the formation of the Newer Appalachians. The orogenies, especially the third, spawned massive mountains on the continental edge (Roberts 1996). Persistent and prolonged erosion of these highlands delivered huge amounts of sediment (nearly 12 km in depth) westward and southward to the shallow inland sea. The sea supported marine organisms giving rise to thick limestone deposits (Fenneman 1938). Through the process of chemical substitution of Mg^{2+} for Ca^{2+} some limestone was transformed to dolostone, a term for sedimentary rock used to avoid confusion with the mineral, dolomite (Bates and Jackson 1980). During the third orogeny, the sea became shallow enough due to sediment accumulation to support swamps. This organic debris resulted in coal seams becoming interbedded with other sedimentary rock layers. In its early stages, the final orogeny compressed and folded these layers of sedimentary rock into various anticlinoria and synclinoria. As orogeny progressed, layer-parallel compression resulted in extensive thrust faults (horizontal faults beneath thin “sheets” of rock) (Roberts 1996).

The RV physiographic province is subdivided into a number of sub-provinces (sections) and sub-sub-provinces (districts). The southern portion of the RV is formally divided into the Southern Ridge and Valley (SRV) section in Georgia, and the Alabama Ridge and Valley (ARV) section in Alabama. The Alabama Ridge and Valley section is further divided into seven districts, with the Cahaba Valley (CAV) district containing the

Bibb County populations and the Coosa Valley (COV) district containing the Calhoun County populations of *X. tennesseensis*. The Southern Ridge and Valley is composed of three districts, with the Great Valley (GV) district containing the Bartow and Floyd County populations (Sapp and Emplaincourt 1975; Clark and Zisa 1976) (Table 4). An example of a hierarchical physiographic province system is given below.

Division	Appalachian Highlands Physiographic Division
Province	Ridge and Valley Physiographic Province
Section	AL Ridge and Valley Physiographic Section
District	Cahaba Valley Physiographic District

The RV physiographic province can be considered a series of valley floors with long narrow mountain ridges of uniform height trending from southwest to northeast. Most large streams and tributaries have a tendency to flow in this direction, down-cutting the soft valley floors and avoiding the harder ridges. The larger rivers that flow transversely across the region were formed at an earlier stage. The major sub-basins containing *X. tennesseensis* habitat in the RV are drained by the Cahaba, Coosa, Etowah and Coosawattee Rivers (United States Soil Conservation Service 1984; United States Soil Conservation Service 1995; McFadden and Landers 2000) (Table 5). The average elevation of most valley floors is approx. 100–750 meters above sea level (a.s.l.), with an average relief of 150–450 m between ridge top and valley floor. Whereas the terms “Ridge” and “Valley” aptly describe the general lay of the land, both landscape types are not usually equally present. Depending on the given physiographic district, either type may dominate (Fenneman 1938). Of the ten named physiographic districts in the RV physiographic province of Georgia and Alabama, four are predominantly ridges and five are predominantly valleys (Ridge**:** Coosa Ridges, Weisner Ridges, Cahaba Ridges, Armuchee Ridges; Valley**:** Coosa Valley, Cahaba Valley, Birmingham-Big Canoe Valley, Chickamauga Valley, and Great Valley).

It is the valley districts that are favored by *X. tennesseensis*, with the COV, CAV and GV districts containing all the known populations. Valley districts are essentially broad valleys, bordered by steep ridges, with only moderate and occasional topographic relief. The harder, more resistant sedimentary rock (i.e., quartzite, sandstone, conglomerate, and/or chert) tends to form the ridges, with softer, weaker sedimentary rock (i.e., limestone, dolostone and shale) forming the valley floors. In many cases, the calcitic and dolomitic components of cherty limestone/dolostone once present on the valley floors and at the foot of slopes have dissolved, leaving only cherty residuum (Hunt 1967; Roberts 1996).

Bedrock geology underlying *X. tennesseensis* seep/spring/stream habitat in the valley districts is principally middle Cambrian to lower Ordovician limestones and dolostones (Table 4). Specifically, the bedrock is as follows: 1) COV – three dolostone formations (Chepultepec, Copper Ridge and Ketona); 2) CAV – four dolostone formations (i.e. Brierfield, Chepultepec, Copper Ridge, and Ketona) and two limestone formations (Longview and Newala); 3) GV – two shale and sandstone formations (Conasauga and Rome) (Butts 1946; Warman and Causey 1962; Lawton and Marsalis 1976; Raymond et al. 1988; Szabo et al. 1988). Although the formations of the GV may seem to violate the calcareous pattern, both the Conasauga and Rome Formations are frequently interbedded locally with thin layers of limestone, and occasionally, dolostone (Butts and Gildersbee 1948).

The structural geology of the valley districts is partly characterized by the presence of major thrust faults (e.g., Jacksonville Fault, Helena Fault, Talladega-Cartersville Fault, and Rome Fault) (Lawton and Marsalis 1976; Szabo et al. 1988). The combination of faults and various layered strata provides an ample distribution system for groundwater. Seeps and springs are frequently found in areas of contact between different strata, especially at the foot of slopes. Here, groundwater and seepage flow filter vertically through porous strata (e.g., highly fractured/jointed quartzite or sandstone), until reaching a non-porous layer (limestone, dolostone, calcareous shales and siltstones) and travelling horizontally to emerge as a seep or spring (Stout & Associates and Reisz Engineering 1989).

Interior Plateau Ecoregion

The ILP physiographic province also supports *X. tennesseensis*. A relatively small physiographic province, it is centered in central Tennessee and Kentucky, and expands to include extreme southern Illinois, Indiana and Ohio, and the northwestern corner of Alabama (Quarterman and Powell 1978). The ILP is one of three physiographic provinces comprising the Central Plains major physiographic division. It is bordered by the Appalachian Plateau (AP) physiographic province to the east and south, the Coastal Plain (CP) and Ozark Plateaus physiographic provinces to the west, and the Central Lowland physiographic province to the north. The rock of the ILP physiographic province is almost all sedimentary, owing to the vast erosional and organismal deposits in the same shallow inland sea of the Paleozoic Era that figured so prominently in the creation of the RV physiographic province(Fenneman 1938, Hunt 1967).

Although the RV and ILP physiographic provinces share much of the same span of geologic history, intense folding and faulting of the RV resulted in gradually sloping synclinal basins and anticlinal arches further inland. Topographically, the ILP is "cuesta-form" (i.e., consisting of a series of low plateaus and escarpments) with a mix of highly dissected uplands, steep slopes, deep-cutting stream channels and alluvial basins and plains (Fenneman 1938). Structurally, the Cincinnati Arch is the major feature of the province. It is a broad anticline running from northern Alabama to Lake Erie formed on the back of two structural domes: the Nashville Dome and the Jessamine (Lexington) Dome. Early cycle(s) of erosion base-leveled (flattened) most of the domes forming the Highland Rim Peneplain. Subsequent cycle(s) of erosion differentially wore down the softer Ordovician strata in the core of the domes, forming a topographic basin. The Nashville Dome, composed of older Ordovician limestone and encircled by the plateau escarpments of younger Mississippian sandstone, conglomerate and shale, is known as the Central Basin. The higher plateaus sloping away from the escarpments constitute the Highland Rim (Roberts 1996).

The Highland Rim is one of four physiographic sections within the ILP. It is sub-divided into twelve districts, with the Western Highland Rim district (WHR) containing the Lewis County, TN *X. tennesseensis* populations, and the Moulton Valley (MV) district containing the Franklin County, AL populations (Quarterman and Powell 1978). In the past, the assignment of land area in northwestern Alabama to a particular physiographic province has proven problematic. The difficulty stems from the convergence and commingling of AP, ILP, and CP formations and sediments. The problem is especially pronounced south of the Tennessee River near the Alabama-Mississippi border in Colbert, Franklin, and Marion Counties. Not only is there a blending/blurring of boundaries, but the commingling is frequently manifested as "islands" or outliers. The Red Bay Highway (RBH) population in Franklin County lies in such a contested area.

A thorough review of relevant maps, texts, and "expert" opinion suggests that the Red Bay Highway population might best be considered to lie within the MV physiographic district of the ILP physiographic province. This is despite the fact that strict adherence to an ecoregional concept locates it within the Southeastern Plains (SEP) ecoregion, which is an approximate analog of the Coastal Plain physiographic province. The difference is explained by the extension of the MV physiographic district westward along extensions of the Moulton Valley along creeks, etc. The IP ecoregion includes the Moulton Valley in the Eastern Highland Rim (EHR) ecoregion (level IV), but the westward extensions along creeks are included in the Transition Hills (TH) of the SEP ecoregion.

An examination of the Physiographic Regions Map of Alabama (Geological Survey of Alabama @ 1: 500,000) locates the RBH population within the western MV of the ILP physiographic province near the border of a CP physiographic province outlier (Fall Line Hills district). It shows an indefinite/irregular western border of the MV near the Mississippi state line. Superimposition of State Route 247 (Red Bay Highway) onto the Geologic Map of Franklin County (@ approx. 1: 62,500) indicates that the section of highway near the population likely straddles the contact between the CP deposits of the

Cretaceous Tuscaloosa Group and the ILP deposits of Mississippian Bangor Limestone. Fenneman (1938) recognized the ambiguous nature of the province boundaries in this area and used an escarpment on the northern edge of the Warrior Basin as an arbitrary southern limit of the ILP. This would place the population in the CP physiographic province. However, Fenneman admitted that "while such areas may properly belong in the CP physiographic province, they are not CP (in character)." Kral, aware of the problem, has treated the area differently in two separate reports. Kral (1983) which postdates the discovery of this population, makes no mention of any populations in the CP. Later, Kral (1990) positions the population in the CP physiographic province, but near AP physiographic province and ILP physiographic province (MV) outliers. Quarterman and Powell (1978), the most definitive treatment of the ILP, provides a broad-scale map (without landmarks) suggesting that the population would lie west of the western boundary of the MV (i.e., in the CP). However, the written description of the MV is "a vale developed on Bangor Limestone… [whose] western boundary is at the edge of sediments of Cretaceous Age…" This would allow for a highly dissected, and multi-fingered extension of the MV boundary westward towards Mississippi along several creeks (including Cedar Creek, the local watershed of the RBH population), a result consistent with the Physiographic Regions Map of Alabama. For the purposes of this chapter, the RBH site of the MV physiographic district will be discussed along with sites found in the WHR physiographic district, as part of the ILP physiographic province.

The WHR district, perhaps the largest district in the ILP physiographic province, is situated almost entirely in central Tennessee. It is a greatly dissected upland plateau topographically presenting itself as a region of ridges and valleys. Elevations range from

100-300 m a.s.l. with an average topographic relief of 100+ m. There are numerous deeply entrenched meandering streams providing much of the dissected character (Safford 1869; Fenneman 1938). The major sub-basins containing *X. tennesseensis* habitat in the ILP physiographic province are drained by Bear Creek and the Lower Duck River (Hart 2000). Karst topography is also present (i.e. caverns, sinks, springs, etc.), although to a lesser extent than is found in other sections of the Highland Rim. Seeps and springs, both here and in the MV, are found at or near the contact between differing strata similar to that found in the RV physiographic province (Fenneman 1938; Roberts 1996).

The bedrock geology beneath *X. tennesseensis* habitat is mostly upper Devonian to Mississippian shales, chert, and silicastone, all with varying calcitic/dolomitic content. However, some older Silurian and Ordovician limestones are found in the more severely carved valleys and drains. Specifically, the Fort Payne Formation and Chattanooga Shale are found along the ridges and most slopes, with Fernvale Limestone and Leiper's Formation at the toe of some slopes and along the more deeply cut streams (Miller et al. 1966; Brasfield et al. 2000). Here, as with *X. tennesseensis* habitat in the RV physiographic province, there is adherence to a calcareous theme. The majority of the carbonate component of the Ft. Payne Formation is contained within its lower silicastone facies (as opposed to upper cherty facies), and can be significant locally (Colvin and Marcher 1964; Wilson et al. 1965). The Leiper's Formation is principally calcarenite, a type of limestone containing at least 50% consolidated detrital calcareous sand (Bates and Jackson 1980).

The MV district is the southernmost portion of the ILP. It is a narrow valley running east/west for 80 km through northwestern/north central Alabama. It is essentially a limestone vale between two sandstone and sandstone/conglomerate cuestas. The range in elevation is from 150-250 meters a.s.l. with 30-75 m of topographic relief. Several fingers of the limestone extend westward from the MV proper along streams that drain and cut the landscape (as per the RBH discussion). Most streams flow in a north to northwesterly direction. Some karst topography is present in the valley area (Quarterman and Powell 1978).

The bedrock geology underlying *X. tennesseensis* habitat is Mississippian limestone and sandstone. Nearby, the limestone and sandstone may be overlain by undifferentiated deposits of Cretaceous sand/clay/gravel. Specifically, Bangor Limestone is found on valley floors and exposed on selected slopes and outcrops. The sand/clay/gravel mix of the Tuscaloosa Group can be found covering most of the ridge tops, especially where the sediments of the upper Fall Line Hills district of the CP physiographic province intergrade with those of the MV district. The gravel component of the Tuscaloosa group is frequently a chert or limestone (Peace 1963; Szabo et al.1988).

Soil Associations and Analysis

Ridge and Valley Ecoregion

The valley district soils of *X. tennesseensis* habitat are varied. However, whether of calcareous seeps, springy meadows, or along the banks, bars, and terraces of streams, these soils share certain hydric features. In the Southern Limestone/Dolomite Valleys and Low Rolling Hills (SLDV), and Southern Shale Valleys (SSV) of Alabama, the soils of the larger mapped soil series include the Iuka fine-sandy loam, slopes 0-2%, and the Bibb sandy loam, slopes 0-2%. Both are Entisols formed in loamy/sandy alluvium with depths to bedrock mapped > 1.5 meters. Specifically, the Iuka is a Coarse-loamy, siliceous, active, acid, thermic Aquic Udifluvent, and the Bibb is a Coarse-loamy, siliceous, active, acid, thermic Typic Fluvaquent. Mantachie and Minter soils may also be present or involved (Soil Stat Lab 1999; Soil Survey Staff 1999) (Table 5). The two other dominant soil series near *X. tennesseensis* populations include the Lee silt loam, 0-2% slopes, and the Lobelville silt loam and cherty silt loams, slopes 0-2%. Both are Inceptisols formed in loamy, gravelly alluvium, with depths to bedrock > 1.2 meters. In the case of the Lee series, the alluvium is derived from cherty limestones and calcareous shales. Specifically, Lee soil is a Fine-loamy, siliceous, semi-active, nonacid, thermic Fluvaquentic Endoaquept, and the Lobelville is a Fine-loamy, siliceous, active thermic Fluvaquentic Dystrudept. Minvale, Bodine (formerly Clarksville), and Fullerton soils exist just upslope (Harlin et al. 1961; Soil Stat Lab 1999; Soil Survey Staff 1999) (Table 5).

A requested soil survey of four *X. tennesseensis* sites in Bibb Co., AL, by a USDA soil scientist (Johnson, 2000) indicated that *X. tennesseensis* colonies frequently exist on small "specialized" pockets of soil. Soil surveys delineate, by necessity, soil units at a particular scale. Mapping soils using a minimum size criterion (e.g., 1-2 ha) inevitably misses or ignores small "micro-sites" or "pockets" of differing soil types, termed "inclusions." *Xyris tennesseensis* habitats along perennial and ephemeral stream courses in the SLDV and SSV ecoregions tend to be shallow, recently formed in sandy or loamy substrates, underlain by limestone/dolostone, and overlain by gravelly chert. Most sites are small, irregularly shaped, and "spotty" in distribution. The Bibb Co. survey not only determined that *X. tennesseensis* occurs on unmapped inclusions, but also identified these inclusions as two previously undescribed, and hence, unnamed soil types: a thermic, lithic Psammaquent, and a coarse-loamy, siliceous, thermic mollic Fluvaquent (Table 5). It is likely that many *X. tennesseensis* colonies occur on unmapped inclusions.

The SLDV and SSV ecoregions in Georgia support *X. tennesseensis* on at least five different soil types. They are as follows: 1) Chewacla silt loam, slopes 0-2%; 2) Cedarbluff silt loam, slopes 0-2%; 3) Cartecay loam, slopes 0-2%; 4) Tupelo silt loam, slopes 0-3%; and 5) Wehadkee fine sandy loam, slopes 0-2%. Inceptisols, Entisols, Ultisols and Alfisols are all represented with average depths to bedrock > 1.5 m. These soils formed in alluvium, most from carbonate parent material. Specifically, the Chewacla is a Fine-loamy, mixed, active, thermic Fluvaquentic Dystrudept; the Cedarbluff is a Fine-loamy, siliceous, thermic Fragiaquic Paleudult; the Cartecay is a Coarse-loamy, mixed, semi-active, nonacid, thermic Aquic Udifluvent; the Tupelo is a Fine, mixed, semi-active, thermic Aquic Hapludalf; and the Wehadkee is a Fine-loamy, mixed, active, nonacid, thermic Fluvaquentic Endoaquept (Tate et al. 1978; Soil Stat Lab 1999; Soil Survey Staff 1999; Griner 2000).

The "typical" or dominant Southeastern U.S. soil is a historically cultivated, highly leached and weathered Ultisol with base saturation < 35% (Brady and Weil 1996). As shown in this chapter, most *X. tennesseensis* habitat soils in the RV and IP ecoregions are not Ultisols, but probably entosolic inclusions in a variety of hydric or near hydric soils. However, contrasting these soils with the general features of Ultisols can prove illustrative, if only to establish relative uniqueness of substrate and scarcity of *X. tennesseensis* habitat.

Textural analysis of RV ecoregion soils indicated a range of particle sizes from sand to loam (clay 2.5 – 20%), with most sites either a sandy loam or loamy sand (Table

6). Organic matter content has a range of 1.4 – 15.3% and averages about 6%. This is consistent with relatively young alluvial soils of small drains and seeps (Table 6).

In general, results from elemental and reaction analysis of *X. tennesseensis* habitat soils were unremarkable with the exception of pH, Ca, and Mg (Table 6). The average pH range of a Southeastern Ultisol is 5.0–6.0 (Grunewald 2004). Mean pH of *X. tennesseensis* habitat soil in the RV ecoregion was 6.69, with a range of 6.07 to 7.36. The presence of large numbers of base forming cations is responsible for the relatively high soil reactivity (slightly alkaline pH) (Brady and Weil 1996). Average Ca and Mg concentrations of a Southeastern Ultisol ranged from 90-250 ppm and 15-35 ppm, respectively (Adams et al. 1994). Analysis of *X. tennesseensis* habitat soil in the RV ecoregion revealed an average Ca level of 1784 ppm and a range of 427-4228 ppm. Similar analysis for Mg showed an average level of 349 ppm, with a range of 97–1156 ppm (Table 6).

The substantial Ca and Mg soil fractions can be attributed to the calcitic and dolomitic contributions of parent material. Of particular interest is the proportionate abundance of Ca to Mg. Relatively low Ca/Mg ratios (mostly 3.5-5) bear testament to the significant dolomitic deposits within the RV ecoregion. Chilingar (1957) developed a classification scheme of calcareous rocks based on Ca/Mg ratios, and ordered along a limestone-dolostone continuum: Magnesian Dolomite Ca/Mg Ratio (1.0-1.5); Dolomite (1.51-1.7); Slightly Calcitic Dolomite (1.71-2.0); Calcitic Dolomite (2.01-3.5); Highly Dolomitic Limestone (3.51-16); Dolomitic Limestone (16.1-60); Magnesian Limestone (60.1-105); Calcitic Limestone (> 105). The especially low value of 3.18 for the Alligator Glades West site probably results from the presence of unusually pure and Mg rich Ketona Dolomite (Raymond et al. 1988). The high concentrations of base-forming cations are responsible for the relatively high soil reactivity (slightly alkaline pH). Micronutrient and trace element analyses were essentially unremarkable. Complete results for these are available in Table 7.

Interior Plateau Ecoregion

In the WHR ecoregion, the soil along the deeply incised drains and the limestone/dolostone fens comprising *X. tennesseensis* habitat is the Biffle-Sulphura-Rock Outcrop Association (Brasfield et al. 2000). Biffle gravelly silt loam, an Ultisol on 30-60% slopes, is the soil series associated with toe slopes and the cherty residuum/colluvial mix found on small ledges and banks of streams. It is a Fine-loamy, siliceous, thermic Typic Hapludult. Depth to bedrock is 1-1.5 m. Lee soils, described for the RV ecoregion, may also be found in this area. The Sulphura channery silts/clays and loams, 30-60% slopes, are formed in residuum of inter-bedded siltstone, limestone and shale. These Inceptisols, typical of the fens and seeps further upslope, are loamy-skeletal, siliceous, semi-active, thermic, Typic Dystrudepts. Depth to bedrock is 0.5 – 1.0 m (Soil Stat Lab 1999; Soil Survey Staff 1999). Of course, as was true with the soils of the RV ecoregion, the small area of substrate beneath an actual *X. tennesseensis* colony may represent an inclusion that differs in some way(s) from the larger mapped soil unit(s).

Soils of the western MV physiographic district within the Transition Hills (TH) of the SEP ecoregion, are an amalgamation of SEP and IP ecoregion sediments. This is consistent with the commingling of physiographic provinces and geologic parent materials described earlier. The soil of the only known *X. tennesseensis* population in the SEP ecoregion is the Flomaton (formerly Guin) gravelly loamy sand, slopes 2-40%.

It is an Ultisol formed on upland marine (CP) sediments. The Flomaton soil is a Sandy-skeletal, siliceous, thermic Psammentic Paleudult. Depth to bedrock is > 1.5 m. Other SEP ecoregion soils associated with it, or present locally, include the Savannah and Saffell series. The influence of the IP ecoregion is seen in the nearby presence, and perhaps inclusion, of the Colbert, Rock-land (sandstone) and Rock-land (limestone) soils. Colbert soil developed in residuum weathered from clayey limestone and calcareous shale. Rock-land types consist of outcrops, boulders, and rock fragments covering at least 30% of the ground surface. The soil between the rock is a plastic, sticky silty clay mixed with sandy colluvium derived from higher limestone/sandstone soils (Sherard et al. 1965; Soil Stat Lab 1999; Soil Survey Staff 1999).

Textural analysis of IP ecoregion soils showed that all are either sandy loams or loamy sands. The RBH site in the TH has the highest clay fraction of all sites (mean of 25%) and very nearly qualifies as a clay loam. Clay loams are frequently associated with the sticky, plastic clays of the Colbert and Rock-land soils (Sherard et al. 1965; Soil Stat Lab 1999; Soil Survey Staff 1999) (Table 5).

Organic matter content averaged about 18% for the province as a whole and ranged from 1.7% to 32.2% (Table 6). However, the organic matter of *X. tennesseensis* habitat soils in the WHR fluctuated around 22% while the organic matter of the TH was approximately 2%. The difference reflects the inorganic, mineral-slick nature of the Red Bay Highway site (Table 6).

The mean pH for the entire IP ecoregion was 7.12 with a range of 6.54 –7.75 (Table 6). The mean pH of the *X. tennesseensis* habitat soil for the SEP ecoregion was noticeably higher at 7.79 (Table 6). The relatively high pH for the TH suggests the local presence of Bangor Limestone and supports the contention that the Red Bay Hwy site is an IP ecoregion outlier.

Xyris tennesseensis habitat soils in the IP ecoregion are similar to those found in the RV ecoregion with regards to their relatively high levels of Ca and Mg, although the average Ca level in the IP is over 3× that found in the RV ecoregion (Table 5). Mean Ca and Mg concentrations for the entire IP ecoregion were 6165 ppm and 614 ppm, respectively. Mean Ca and Mg levels for the SEP were 4643 ppm and 106 ppm, respectively. Comparison of Ca and Mg concentrations between the WHR of the IP ecoregion and the TH of the SEP ecoregion showed substantial differences. While the mean Ca concentration was very high for *X. tennesseensis* habitat soils in both the WHR (6165 ppm) and TH (4643 ppm), the mean Mg concentration varied considerably. In the WHR, the mean Mg concentration was 614 ppm with a range of 408-924 ppm, yielding a Ca/Mg ratio of 10.1. However, the mean Mg concentration in the TH was a relatively low 106 ppm with a range of 87-125 ppm, yielding a Ca/Mg ratio of 43.8. Lower Ca levels and lower Ca/Mg ratios in the SEP ecoregion than in the IP ecoregion suggest a decreased abundance of limestone and a relative absence of dolomite, consistent with the known geology. Difference between the soils of the WHR and MV physiographic districts suggests an increasing degree of influence by the soils of the CP.

Elemental analysis detected relatively high levels of P in the *X. tennesseensis* habitat soils of the IP ecoregion, approximately six-fold the levels found in the RV ecoregion (43.6 ppm vs. 7.3 ppm). The increase in P was especially pronounced in the WHR with an average content of about 53 ppm and a range of 15.6–116.7 ppm (Table 6). Since farming and grazing operations are locally scant, a likely cause of the elevated P levels would be the presence of “brown” and “blue” phosphate. Brown phosphate, tricalcium phosphate $Ca_3(PO_4)_2$ residuum formed from weathered limestone (primarily Leiper’s Formation), and blue phosphate, embedded phosphate and phosphate nodules within portions of Chattanooga Shale, are significant enough in the region to support limited mining (Cathcart 1980).

Climate and Exposure

Ridge and Valley Ecoregion

Several classification systems exist for macroclimate in the United States: the Köppen (Ackerman 1941), Thornthwaite (1948), and Borchert (1950) systems. The specific classifications of *X. tennesseensis* habitat by system is as follows: Thornthwaite type B_2 B'_3 b'_3 r (or B_3 B'_2 b'_4 r); Köppen type Cfa; and Borchert type II.

In general, the macroclimate of the RV and IP ecoregions in the Southeastern United States may be considered a moderately humid, mesothermal climate with adequate monthly rainfall during most years. Winters are wet and generally mild, whereas summers are wetter and more sunny. Summers can be hot, but the overall climate is without a distinctly dry season (relative to classically arid areas) (Baskin and Baskin 1999).

The area is also considered to possess moderate thermal efficiency (Thornthwaite 1948). Thermal efficiency evaluates the water necessary for plant growth/survival against water availability (precipitation and soil moisture storage). It focuses on the phenomenon of evapotranspiration, considering not only temperature but also how day length and growing season length vary with latitude. Although growing season length in *X. tennesseensis* habitat is relatively long (180-220 days/year between first and last frosts) (National Climatic Data Center 1998), approximately 48-56% of the annual evapotranspiration occurs during the months of summer (25% of the year) (Thornthwaite 1948). Consequently, while there is no distinct dry season, there are hot, dry periods in summer where plant water need exceeds that available.

Periods of water deficiency are, of course, less frequent and pronounced in the microclimates of hydric systems. The springs, seeps, fens and streambanks of *X. tennesseensis* habitat supply additional surface and ground water that supplements precipitation. However, even this may prove inadequate in unusually dry years for those *X. tennesseensis* populations relying on ephemeral or intermittent water sources. This was the case in 2000 when water sources failed for the following Alabama populations: Red Bay Highway (seeps/borrow ditch), Alligator Glades West (ephemeral seep/stream), and Lloyd's Chapel Swale (spring(s)/runoff). These populations suffered an 80-95% decline in observable flowering spikes and clumps between the 1998/1999 sampling dates and 2000 (Moffett 2000). The period 1997-99 was slightly warmer (+ 0.49^{o}C Max; + 1.22^{o}C Min) and noticeably drier (- 19.78 cm) (Agricultural Weather Information Service, Inc. 2000a and 2000b; Auburn University, Mesonet Automated Weather Station Data 2000a; National Climatic Data Center 2000a) than the 30-Year average (Owenby and Ezell 1992a and 1992b) (Table 8).

Site slopes were relatively constant while aspects were highly variable (Table 8). Slopes ranged between 1-15%, although a 2-3% slope was most common. Aspects occurred in all directions with no identifiable pattern.

Interior Plateau Ecoregion

In general, the period 1997-99 was both warmer (+ 1.04^{o}C Max; + 1.38^{o}C Min) and drier (- 25.58 cm) (Auburn University, Mesonet Automated Weather Station Data 2000b; National Climatic Data Center 2000b) than the 30-Year average for the entire ILP province (Owenby and Ezell 1992c), although precipitation levels in the WHR and MV districts were markedly different from one another. While the TH was much drier (- 53.65 cm) than the 30-Year average, the WHR actually showed a slight increase in precipitation (+ 2.5 cm) (Table 8). This resulted, in part, from a few large thunderstorm events in Lewis County during 1998. Several of these produced severe flooding events, one of which destroyed the Little Swan Creek, TN population (Nordman, pers. comm.). For the purposes of climatic analysis, the RBH site in the TH of the SEP ecoregion is included with the IP ecoregion.

Site slopes and aspects were both highly variable. Slopes ranged from 1-50%. Aspects included most directions, although a general westward orientation (including SW and NW) was most common (Table 8).

<u>Floral Associates</u>

Ridge and Valley Physiographic Province

Xyris tennesseensis habitat in the RV ecoregion is predominantly a calcareous, gravelly/cherty, spring/seep complex adjacent to or associated with perennial or ephemeral streams (although there are examples of wet meadows/pastures, roadside ditches/rights-of-way (ROWs), and artificial impoundments). The frequent floral associate species (observed in > 75% of the surveyed sites) of *X. tennesseensis* included *Juncus brachycephalus* (Englem.) Buch, *Ludwigia microcarpa* Michx., *Microstegium vimineum* (Trin.) A. Camus, and *Arthraxon hispidus* (Thunb.) Makino (Tables 10a, b, c). *Juncus brachycephalus* is considered a *X. tennesseensis* “marker species” (Kral 1990) throughout the range of *X. tennesseensis* (i.e., in both the RV and IP ecoregions). *Ludwigia microcarpa* is a very reliable *X. tennesseensis* indicator as well, occurring in 11 of the 12 populations surveyed in the RV. *Microstegium vimineum* and *A. hispidus* are two highly successful, non-native invasive species occupying many wetlands in the Southeastern United States (Invasive 2006), including *X. tennesseensis* habitat.

There were also a number of other plants associated with *X. tennesseensis* (Tables 10a, b, c). Frequent floral associate genera (composed of several species) were *Carex*, *Cyperus*, *Eupatorium*, *Juncus* (other than *J. brachycephalus*) and *Rhynchospora*. Intermediate floral associate species (found in 50%-75% of the surveyed sites) were *Fuirena squarrosa* Michx., *Helenium autumnale* L., *Hypericum interior* Small, *Mecardonia acuminata* (Walter) Small, *Mitreola petiolata* (J. F. Gmel.) Torrey & A. Gray, and *Rhynchospora capitellata* (Michx.) Vahl. *Hypericum interior* is considered a marker species for Georgia sites (Kral 1990). A list of infrequent floral associate species (identified in < 50% of the surveyed sites) for both the RV and IP ecoregions combined is provided in Table 11.

Interior Plateau Ecoregion

Xyris tennesseensis habitat in the IP ecoregion is similar to that found in the RV ecoregion, but generally has steeper slopes with shallower soil and a more fen-like appearance. Frequent floral associate species were *Amphicarpaea bracteata* (L.) Fernald, *H. autumnale, J. brachycephalus, M. vimineum, Oxypolis rigidor* (L.) Raf., *Parnassia grandifolia* DC., *Phlox glaberrima* L., and *Rudbeckia fulgida* var. *umbrosa* (C. L. Boynt. & Beadle) Cronq. *Juncus brachycephalus* and *M. vimineum* were the only frequent common floral associates found to be shared by the RV and ILP. Both *P. grandifolia* and *R. fulgida* var. *umbrosa* are marker species in Tennessee (Kral 1990). Frequent floral associate genera were *Carex, Cyperus, Eupatorium, Juncus, Rhynchospora,* and *Scirpus*. *Rhynchospora capitellata* was the only species found that met the intermediate floral associate criterion, although there were many infrequent floral associates (Table 11). For the purposes of floristic analysis, sites in the TH of the SEP ecoregion are included with the IP ecoregion.

Population Size and Demography of Xyris tennesseensis

Ridge and Valley Ecoregion

The combined populations of the RV ecoregion contain 3-6 times more *X. tennesseensis* (depending on the measure) than the combined populations of the IP ecoregion (Table 12). This is despite the fact that three populations were not surveyed in the RV ecoregion (Wesley Chapel Spring, AL; Deep Springs, GA; and Barnsley Gardens, GA), but only two IP ecoregion populations (Sandy Mitchell Hollow, TN; and Spring Branch Seep, TN) were excluded from the survey (Table 2).

Single site sizes ranged from small (35 m^2 - Clear Creek Spring, GA) to a very large (2,920 m^2 Mosteller Springs, GA), with an average size of approximately 690 m^2 (Table 12). If one considers the Little Schultz Creek complex of occurrences in its entirety, it would be the largest site, as it stretches for ca. 1.6 km along the creek and encompasses ca. 6,000 m^2. However, given the sparse density of *X. tennesseensis* plants over most of the stream course, this view would grossly overestimate the area of that site and it was, therefore, removed from the "site size" calculations. The number of reproductive spikes per occurrence varied from a low of 38 (The Sinks, AL) to a high of 20,878 (Mosteller Springs, GA), with a mean of 3,356 per occurrence for the RV ecoregion. The number of total clumps per occurrence varied from a low of 22 (Petit Creek/Wofford's Crossroads, GA) to 5,739 (Mosteller Springs, GA), with an ecoregion mean of 1,078. Resulting densities ranged from 0.02 to 6.78 clumps/m^2. Mosteller Springs, GA was by far the largest occurrence in both the RV and IP ecoregions. It was nearly twice as large as the next largest occurrence, Lloyd's Chapel Swale, AL (20,878 vs. 11,370 reproductive spikes).

Most of the *X. tennesseensis* clumps contained predominantly reproductive (as opposed to vegetative) ramets. Reproductive ramets are defined here as those sporting at least one reproductive scape or spike in any stage of development. Reproductive ramets as a percentage of total ramets in the population ranged from 24.05% (The Sinks, AL) to 95.55% (Firing Fan Creek, AL), with a mean of 60.18% for the entire RV ecoregion (Table 13). Occurrences with the lowest percentages of reproductive ramets tended to correspond to those receiving the most shade (Table 9). The four sites receiving significant or moderate amounts of shade had only 24.05%, 27.44%, 30.54% and 48.09% of their ramets reproductive. This is contrasted with 50.00%, 72.03%, 81.85%, 86.30%, and 95.55% of total ramets reproductive for the five sites receiving almost no shade (classed as mostly open in Table 13).

Mean number of spikes per reproductive ramet ranged from 1.00 (The Sinks, AL) to 1.92 (Firing Fan Creek, AL), with a mean of 1.31 for the ecoregion as a whole (Table 12b). Although one spike per ramet is most common, it may be as great as five spikes per ramet in mature clumps in brightly lit areas. The mean number of spikes per reproductive clump varied from 1.73 (Little Schultz Creek – upper, AL) to 7.00 (Petit Creek/Wofford's Crossroads, GA), with a mean of 4.19 for the total RV ecoregion.

Estimated numbers of seedlings were highly variable, ranging from 0 to 7,815 per site (Table 12). Predictably, Mosteller Springs (the largest site with the most plants) had the greatest number. However, it is interesting to note that four Alabama sites had fewer than 200 seedlings each (Alligator Glades West, Little Schultz Cr. – upper, The Sinks, and Burning Ground Seep); and another four sites had no seedlings at all (Firing Fan Creek, AL; Clear Creek Spring, GA; Interstate Hypericum Springs, GA; and Petit Cr./Wofford's Crossroads, GA).

Interior Plateau Ecoregion

Site sizes ranged from a diminutive 1m^2 (Little Grinder's Creek – Hick Hill Br., TN) to a large 1,260 m^2 (Twin Falls Hollow, TN), with a mean size of approximately 257 m^2 (Table 12). The number of reproductive spikes per occurrence varied from a low of 32 (Little Grinder's Creek-Hick Hill Br., TN) to a high of 8,741 (Twin Falls Hollow, TN), with an ecoregion mean of 1,571. The number of total clumps per occurrence varied from a low of 11 (Little Grinder's Creek – Hick Hill Br., TN) to a high of 603 (Twin Falls Hollow, TN), with a mean of 215 for the whole ecoregion. The resulting densities ranged from 0.48 to 11.00 clumps/m^2. Twin Falls Hollow, TN was the largest occurrence in the ILP, being four times as large as its nearest competitor, Little Grinder's Creek – Hick Hill Br/LGC Confluence, TN (8,741 vs. 2,105 reproductive spikes).

As was the case in the RV ecoregion, most of the ramets in *X. tennesseensis* clumps were predominantly reproductive (Table 13). Reproductive ramets, as a percent of total ramets in the population, were remarkably similar to the RV, ranging from 24.15% (Little Grinder's Creek – Hick Hill Br/LGC Confluence, TN) to 78.92% (Little Grinder's Creek – Nix Branch, TN), with a mean of 57.1% for the entire IP ecoregion.

Occurrences with the lowest percentages of reproductive ramets also tended to correspond to those receiving most shade (Table 9). In the most heavily shaded site (Little Grinder's Creek –Confluence, TN) only 25.14% of the ramets were reproductive, compared to 68.15% at the least shaded site (Red Bay Highway).

Mean number of spikes per reproductive ramet ranged from 1.00 (Little Grinder's Creek- Hick Hill Br/LGC Confluence, TN) to 1.52 (Little Grinder's Creek – Floodplain, TN), with a mean of 1.2 for the whole IP ecoregion. The mean number of spikes per reproductive clump varied from 2.57 (Little Grinder's Creek – Waterfall, TN) to 16.57 (Twin Falls Hollow, TN), with an ecoregion mean of 6.1.

Estimated numbers of seedlings in the IP ecoregion were as highly variable as in the RV ecoregion, ranging from 0 to 1,013 (Table 12). The site with the greatest shading and the least percentage of reproductive ramets (Little Grinder's Creek – Hick Hill Br./LGC Confluence, TN) also contained the greatest number of seedlings. At four Tennessee sites (Langford Branch, Little Grinder's Creek Floodplain, Little Grinder's Creek -Champion Boundary, and Twin Falls Hollow) no seedlings were found.

The sole site in the TH of the SEP ecoregion (Red Bay Highway) has a site size of 870 m^2 and 740 clumps, yielding a clump density of 0.86 clumps/m^2, less than most sites in the IP ecoregion. The flowering spike total of 2,117 compares moderately to those of the IP ecoregion. With 68.2% of all ramets reproductive, 1.3 spikes per reproductive ramet, and 3.8 spikes per reproductive clump, it falls within the low to moderate ranges for those reproductive measures when compared to sites in the IP ecoregion.

CONCLUSIONS

Results of the status survey of 19 *Xyris tennesseensis* populations have shown it to be a truly rare and threatened plants. Its limited distribution, habitat specificity, small site sizes, and small number and sizes of populations all support its status as federally endangered, as well as its NatureServe conservation rankings of G2 and S1 (AL, GA, TN). Habitat characterizations generated from this effort should prove helpful in locating additional populations and managing/protecting those currently known.

Xyris tennesseensis sites were characterized according to their physiography, geology, hydrology, edaphic features and chemistry, floristic composition, and climate/exposure. Although restricted to the Interior Low Plateaus and Ridge and Valley physiographic provinces, *X. tennesseensis* was not found uniformly throughout. Despite the name Ridge and Valley, *X. tennessensis* is found only within the valley portions of this province (Cahaba Valley, Coosa Valley, and Great Valley). In the Interior Low Plateau it is likewise found in the Moulton Valley, or on toe-slopes within the Western Highland Rim. It is not an inhabitant of ridges or steep slopes.

Geologically, *X. tennesseensis* sites are associated with various calcareous parent materials and formations. These are principally limestones, dolostones, calcareous shales, or some undifferentiated combination. In the IP ecoregion, these are primarily cherty limestones of the Ft. Payne Formation, or Chattanooga Shales containing calcareous deposits. In the RV ecoregion, *X. tennesseensis* can be found in areas containing various limestones (Longview and Newala), dolostones (Brierfield, Chepultepec, Copper Ridge, and Ketona), and numerous shales and calcareous combinations.

Hydrologic characterization shows almost all *X. tennesseensis* populations along, or at the headwaters of, small streams or in seep/fen complexes associated with small streams. Most streams (or associated complexes) qualify as first order, with a few being second order and third order. In Georgia, all populations are associated with first order streams. In Alabama, all populations are associated with first order streams, except those along Little Schultz Creek (second order), and the very small population, The Sinks, located along Six Mile Creek (third order). Tennessee offers the most exceptions with several of the Little Grinder's Creek populations located along a second order portion of Little Grinder's Creek, and the Autney Hollow population located at the confluence of two first order streams. Two populations, now considered extirpated, existed historically along a third order section of Little Swan Creek.

Edaphically, the most interesting feature is the relative obscurity of the soils supporting *X. tennesseensis*. The soils are all considered hydric sandy loams, but are uncommon, isolated, and small enough in size to have gone unnamed and unmapped by the Natural Resources Conservation Service, and exist as small inclusions within larger mapped soil series (typically of the orders Ultisol and Inceptisol). These soils also contain high levels of both Ca and Mg, with mean values of 3,300 ppm and 400 ppm, respectively. This is 15-20× greater than average levels of Ca (170 ppm) and Mg (25 ppm) found in typical southeastern U.S. Ultisols. The presence of these high levels of basic cations contributes to the mean circumneutral soil pH of *X. tennesseensis* sites (6.9), which is also much greater than the pH of a typical southeastern U.S. Ultisol (5.5).

Floristic analysis of *X. tennesseensis* sites uncovered several plant species faithful enough in their co-occurrence to warrant being considered frequent floral associates or “marker species.” Frequent floral associates in the IP ecoregion were *Amphicarpaea bracteata*, *Helenium autumnale*, *Juncus brachycephalus*, *Microstegium vimineum*, *Oxypolis rigidor*, *Parnassia grandifolia*, *Phlox glaberrima*, and *Rudbeckia fulgida* var. *umbrosa*. In the RV ecoregion, *J. brachycephalus*, *Ludwigia microcarpa*, *M. vimineum*, and *Arthraxon hispidus* were frequent floral associates, with *Hypericum interior* considered a marker species in Georgia. *Juncus brachycephalus* and *M. vimineum* were the only two frequent floral associates shared by both ecoregions.Climatically, *X. tennesseensis* sites experience mild wet winters and warm wet summers with occasional droughts, but no distinct dry season. During the course of this survey (1998-1999) temperatures were near normal, but preciptation was ca. 20-54 cm below the 30-Year average. In general, slope/aspect/exposure analysis indicated gentle (1-5%) slopes overall (occasionally steeper in the IP ecoregion), no discernible patterns of aspect, and sites that varied from mostly open to mostly shaded. It was observed that sites characterized as mostly open contained greater percentages of reproductive ramets.

Site size measurements, flowering spikes censuses and demographic sampling of *X. tennesseensis* populations indicated great variation among populations. Mean site size was ca. 500 m^2 with a range of 1-2,290 m^2 (the unusually long riparian corridor along Little Schultz Creek that was sparsely and irregularly populated with *X. tennesseensis* was removed from the calculation of these values so as not to skew the results). The average site size in the RV ecoregion was approximately 2× larger than the mean of sites found in the IP ecoregion (686 m^2 vs. 318 m^2) (Note that means and ranges for the IP ecoregion include the Red Bay Highway outlier site). Numbers of flowering spikes at individual sites varied from 32 to 20,878 with a mean of 2,635. Populations in the RV ecoregion contained nearly twice the mean number of flowering spikes as those populations in the IP ecoregion (3,355 vs. 1,625). Ramet numbers were also highly variable and ranged from 40 to 25,182 with a mean of 3,540 per site. Once again, populations in the RV ecoregion contained on average nearly twice the number of ramets found in the IP ecoregion (4,209 vs. 2,671). Seedling numbers were no exception to the overall pattern of variability and RV ecoregion numerical superiority. Numbers of seedlings ranged from 0 to 7,815 with a mean of 614 per site. The mean number of seedlings per site was almost 5× greater in the RV ecoregion than in the IP ecoregion (931 vs. 202).

Upon reflection, with 28 sites considered extant and with over 81,000 ramets, 63,000 flowering spikes, and 14,000 seedlings identified as a result of this survey, it might be tempting to conclude that *X. tennesseensis,* while rare compared to most other plant species, is still not imminently threatened with extinction. However, it needs to be pointed out that, in my opinion, only a few of the known *X. tennesseensis* sites and populations can be considered large, robust and stable. In the IP ecoregion, the Twin Falls Hollow, TN population is such a site, as is the complex of sites/populations associated with Little Grinder's Creek, although individually many of these are quite small and/or compromised by shading and competition. The recently discovered Dry Branch, TN complex of sites (not part of this survey) may prove to be the largest and "best" *X. tennesseensis* site yet. In the RV ecoregion, the largest and most valuable population from a conservation perspective is that of Mosteller Springs, GA (the largest single contiguous site anywhere), because other Georgia sites are relatively small or compromised in some manner. In Alabama, the best sites are those associated with the military installations in Calhoun, Co. (Ft. McClellan, Pelham Range, and Anniston Army Depot), but the largest site there, Lloyd's Chapel Swale, has been in a state of decline for several years. The intent of this conclusion is to dispel any sense of complacency regarding the status of *X. tennesseensis*, and to encourage the conservation community to redouble its efforts to locate new populations and aggressively manage the ones that are known, especially on public lands.

Table 1. List of ecoregions and physiographic areas, with their abbreviations as they appear in the chapter regarding the 1998-99 USFWS status survey of *X. tennesseensis* sites and populations. Their listing here is primarily alphabetical, and secondarily hierarchical (according to their respective schemes).

Ecoregion (Level III)	**Ecoregion (Level IV)**	**Abbreviation**
Interior Plateau		IP
	Western Highland Rim	WHR
Ridge and Valley		RV
	Southern Limestone/Dolomite Valleys and Low Rolling Hills	SLDV
	Southern Shale Valleys	SSV
	Southern Sandstone Ridges	SSR
Southeastern Plains		SEP
	Southern Hilly Gulf Coastal Plain	SHGC
	Transition Hills	TH

Physiographic Province	**Physiographic Section**	**Physiographic District**	**Abbreviation**
Appalachian Plateaus			AP
Coastal Plain			CP
Interior Low Plateaus			ILP
	Highland Rim		HR
		Western Highland Rim	WHR
		Moulton Valley	MV
Ridge and Valley			RV
	Alabama Ridge and Valley		ARV
		Cahaba Valley	CAV
		Coosa Valley	COV
	Southern Ridge and Valley		SRV
		Great Valley	GV

Table 2. List of known *X. tennesseensis* occurrences not surveyed/sampled for the 1998-99 USFWS status report, with reason provided.

Site Names	State Natural Heritage Program E.O. Code Reference #	Reason Not Surveyed/Sampled
INTERIOR PLATEAU ECOREGION		
TENNESSEE		
Lewis County		
Dry Branch - confluence	014*TN	Discovered after time of survey
Dry Branch - plane crash	015*TN	Discovered after time of survey
Dry Branch - headwaters	016*TN	Discovered after time of survey
Dry Branch - county line	018*TN	Discovered after time of survey
Dry Branch - tributary seep	019*TN	Discovered after time of survey
Little Swan Creek	002*TN	Considered Extirpated
Sandy Mitchell Hollow	003*TN	Landowner permission denied
Spring Branch Seep	012*TN	Existence known only from 1945 specimen
PIEDMONT ECOREGION		
GEORGIA		
Bartow County		
Pine Log Springs	009*GA	Landowner permission denied
RIDGE and VALLEY ECOREGION		
ALABAMA		
Bibb County		
Alligator Glades East	013*AL	Discovered after time of survey
Wesley Chapel Spring	008*AL	Status Unknown - only a few vegetative ramets present
Shelby County		
Ryan Church/Quarry	not mapped	Considered Extirpated
Ebeneezer Swamp	011*AL	Discovered after time of survey
GEORGIA		
Bartow County		
Barnsley Gardens	008*GA	Landowner permission denied
Soggy Bottom Fen	010*GA	Discovered after time of survey
Gordon County		
Oak Flat Seep/Oakman	002*GA	Considered Extirpated
Whitfield County		
Deep Springs	004*GA	Landowner permission denied
SOUTHEASTERN PLAINS ECOREGION		
ALABAMA		
Wilcox County		
Unnamed Site	not mapped	Considered Extirpated

Table 3. List of known *X. tennesseensis* occurrences surveyed/sampled for the 1998-99 USFWS status report. Site abbreviations to be used throughout the remainder of the chapter are also provided.

Site Names	State Natural Heritage Program E.O. Code Reference #	Site Abbreviations
INTERIOR PLATEAUS ECOREGION		**IP Ecoregion**
TENNESSEE		**TN**
Lewis County		**Lewis Co.**
Autney Hollow	004*TN	AH
Langford Branch[1]	001*TN	LB
Little Grinders Creek - Nix Branch, Hicks Hill Branch, & Little Grinders Creek Confluence	007*TN	LGC-NHC
Little Grinders Creek - Waterfall	013*TN	LGC-WF
Little Grinder's Creek- Floodplain & Champion Boundary	010*TN	LGC-FCB
Twin Falls Hollow	005*TN	TFH
RIDGE and VALLEY ECOREGION		**RV Ecoregion**
ALABAMA		**AL**
Bibb County		**Bibb Co.**
Alligator Glades West	006*AL	AGW
Little Schultz Creek	007*AL	LSC
The Sinks	009*AL	TS
Calhoun County		**Calhoun Co.**
Burning Ground Seep	010*AL	BGS
Firing Fan Creek	012*AL	FFC
Lloyd's Chapel Swale	003*AL	LChS
Willett Springs	002*AL	WS
GEORGIA		**GA**
Bartow County		**Bartow Co.**
Clear Creek Spring	007*GA	CCS
Interstate Hypericum Springs	001*GA	IHS
Mosteller Springs	003*GA	MS
Petit Creek/Wofford's Crossroads Swale	006*GA	PC/WCS
Floyd County		**Floyd Co.**
Mull Farm Pond	005*GA	MFP
SOUTHEASTERN PLAINS ECOREGION		**SEP Ecoregion**
ALABAMA		**AL**
Franklin County		**Franklin Co.**
Red Bay Hwy	001*AL	RBH

[1] Langford Branch - Considered the Type Locality for *X. tennesseensis* by Kral (1978)

Table 4. List of physiographic sections, physiographic districts, and geologic formations underlying *X. tennesseensis* sites surveyed during the 1998-99 USFWS status survey.

	Sites	Physiographic Section	Physiographic District	Lithodemic Units or Geologic Formations [1]
<u>IP Ecoregion</u>				
TN	**Lewis Co.**			
	AH	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale
	LB	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale
	LGC-NHC	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale (Fernvale/Leipers Formation)
	LGC-WF	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale (Fernvale/Leipers Formation)
	LGC-CB	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale
	TFH	Highland Rim	Western Rim	Fort Payne Formation/Chattanooga Shale
<u>RV Ecoregion</u>				
AL	**Bibb Co.**			
	AGW	AL Ridge & Valley	Cahaba Valley	Ketona Dolomite
	LSC	AL Ridge & Valley	Cahaba Valley	Brierfield, Chepultepec and Copper Ridge Dolomites
	TS	AL Ridge & Valley	Cahaba Valley	Longview Limestone and Newala Limestone
	Calhoun Co.			
	BGS	AL Ridge & Valley	Coosa Valley	Chepultepec, Copper Ridge, and Ketona Dolomites Undifferentiated
	FFC	AL Ridge & Valley	Coosa Valley	Chepultepec, Copper Ridge, and Ketona Dolomites Undifferentiated
	LChS	AL Ridge & Valley	Coosa Valley	Chepultepec, Copper Ridge, and Ketona Dolomites Undifferentiated
	WS	AL Ridge & Valley	Coosa Valley	Chepultepec, Copper Ridge, and Ketona Dolomites Undifferentiated
GA	**Bartow Co.**			
	CCS	S. Ridge & Valley	Great Valley	Conasauga Middle - Limestone Unit & Lower - Shale/Sandstone Unit
	IHS	S. Ridge & Valley	Great Valley	Rome Formation
	MS	S. Ridge & Valley	Great Valley	Conasauga Upper - Limestone/Shale Unit
	PC/WCS	S. Ridge & Valley	Great Valley	Conasauga Lower - Dolostone Unit
	Floyd Co.			
	MFP	S. Ridge & Valley	Great Valley	Conasauga Upper - Limestone/Shale Unit
<u>SEP Ecoregion</u>				
AL	**Franklin Co.**			
	RBH	Highland Rim	Moulton Valley	Bangor Limestone/Gordo Formation

[1] Geologic Formations - names in parentheses indicate a geologic formation or type present in the area, but to a lesser extent.

Table 5. List of major soil associations found near *X. tennesseensis* occurrences that were surveyed during the 1998-99 USFWS status survey. Watershed information (i.e., HUCs) and primary water sources also provided.

	Sites	Soil Series [1]	Immediate Water Source	Hydrologic Units [5] Sub-Basin	Sub-Watershed
IP Ecoregion					
TN	**Lewis Co.** [2]	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seep/Perennial Stream Complex	Lower Duck River	Big Swan Creek - upper
	AH	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seeps	Lower Duck River	Big Swan Creek - upper
	LB	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seep/Perennial Stream Complexes	Lower Duck River	Big Swan Creek - upper
	LGC-NHC	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seep/Per./Ephml. Stream Complexes	Lower Duck River	Big Swan Creek - upper
	LGC-WF	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seep/Perennial Stream Complex	Lower Duck River	Big Swan Creek - upper
	LGC-CB	Biffle-Sulphura-Rock Outcrop Assn (Lee)	Seeps	Lower Duck River	Big Swan Creek - upper
	TFH				
RV Ecoregion					
AL	**Bibb Co.** [3]				
	AGW	Unnamed loamy siliceous, thermic mollic fluvaquent	Seep/Ephemeral Stream Complex	Cahaba River	Little Cahaba River
	LSC	Unnamed thermic, lithic psammaquent	Spring/Seep/Per.Stream Complex	Cahaba River	Sandy Cr.-Cahaba River
	TS	Unknown	Spring/Seep/Per.Stream Complex	Cahaba River	Six Mile Creek
	Calhoun Co.				
	BGS	Lee (Lobelville, Bodine, and Fullerton)	Seep/Perennial Stream Complex	Middle Coosa River	Lower Cane Creek
	FFC	Lee (Minvale, Bodine, and Fullerton)	Stream	Middle Coosa River	Upper Cane Creek
	LChS	Lobelville (Bodine, and Fullerton)	Seep/Ephemeral Stream Complex	Middle Coosa River	Upper Cane Creek
	WS	Clarksville (Bodine, and Fullerton)	Spring Impoundment/Pond	Middle Coosa River	Lower Cane Creek
GA	**Bartow Co.** [4]				
	CCS	Wedhadkee	Seep/Ephemeral Stream Complex	Etowah River	Etowah River - Two Run Cr.
	IHS	Tupelo (Wedhadkee)	Seep/Perennial Stream Complex	Etowah River	Etowah River - Petit Creek
	MS	Cartecay (Wedhadkee)	Spring/Seep/ Per. Stream Complex	Coosawattee River	Pine Log Creek
	PC/WCS	Cedarbluff (Wedhadkee)	Seeps	Etowah River	Etowah River - Petit Creek
	Floyd Co.				
	MFP	Chewacla	Seep/Spring Impoundment/Pond	Upper Coosa River	Coosa River - upper
SEP Ecoregion					
AL	**Franklin Co.**				
	RBH	Flomaton (Savannah, Saffell and Colbert)	Seeps/Borrow Ditch	Bear Creek	Upper Cedar Creek

[1] Soil Series - names in parentheses indicate a similar series that may be found in the same area, but to a lesser extent.

[2] Lewis Co., TN - Soil Survey not published for this county. Soil info and descriptions provided by Debbie Brasfield, USDA-NRCS Soil Srvy. Proj. Leader, Lewis Co.

[3] Bibb Co., AL - Soil Survey not published for this county. Soil info and descriptions provided by Ken Johnson, USDA-NRCS, Resource Soil Scientist. The descriptions were derived by sampling the *X.tennesseensis* habitat for "inclusions", normally too small to be mapped by a standard soil survey.

[4] Bartow Co., GA - Soil Survey not published for this county. Soil info and descriptions provided by Carol Griner, USDA-NRCS, State Communications Technician.

[5] Hydrologic Units - Sub-Basins mapped to 8-digit HUCs; Sub-watersheds mapped to12 digit HUCs

Table 6. Results of soil tests completed during the 1998-99 USFWS status survey of *X. tennesseensis* populations. Results include concentrations of macro and secondary nutrients, (ppm - except for N%), % organic matter, particle size, texture and pH. ND = Not Detectable using these methods.

IP Ecoregion	Sites	N (%)	P	K	Ca	Mg	Ca/Mg Ratio	Organic Matter %	Particle Size: Sand %	Particle Size: Silt %	Particle Size: Clay %	Textural Class	pH
TN	**Lewis Co.**												
	AH	0.73	22.92	43.2	3603.27	462.53	7.79	23.1	78.75	16.25	5	Loamy Sand	6.54
	LB	0.4	57.03	75.73	4083.37	407.58	10.02	11.7	51.25	43.75	5	Sandy Loam	6.86
	LGC -Nix Br [1]	0.5	15.58	87.49	4808.6	436.8	11.01	16.2	71.25	28.75	ND	Loamy Sand	7.75
	LGC - Confluence [1]	1.1	105.22	308.9	8753.98	923.89	9.48	32.2	N/A	N/A	N/A	N/A	7.3
	LGC - Waterfall [1]	0.77	36.38	93.57	6791.48	681.83	9.96	23.2	76.25	21.25	2.5	Loamy Sand	6.81
	LGC - Floodplain [1]	0.97	46.91	127.53	9038.47	884.1	10.22	25.4	N/A	N/A	N/A	N/A	7.64
	LGC - CB	1	24.51	113.02	5595.81	515.4	10.86	19.2	85	10	5	Loamy Sand	7.12
	TFH	0.83	116.74	108.17	6648.62	598.64	11.11	21.7	75	17.5	7.5	Sandy Loam	6.93
	MEAN	0.79	53.16	119.70	6165.45	613.85	10.06	21.59	72.92	22.92	5.00		7.12
RV Ecoregion													
AL	**Bibb Co.**												
	AGW	0.31	10.8	34.4	3672.9	1155.7	3.18	14.9	82	17	0	Loamy Sand	6.8
	LSC - upper [1]	0.07	5.93	17.75	901.03	249.61	3.61	2.5	88.75	3.75	7.5	Sand	7.09
	LSC - lower [1]	0.08	8.78	29.28	3506.79	660.09	5.31	4.4	80	12.5	7.5	Loamy Sand	7.5
	TS	0.06	4.6	39.66	908.9	220.69	4.12	1.8	88.75	3.75	7.5	Sand	6.58
	Calhoun Co.												
	BGS	0.09	3.5	19.6	599.4	147.5	4.06	1.9	70	20	10	Sandy Loam	6.54
	FFC	0.13	7.75	43.03	858	236.62	3.63	2.9	56.25	38.75	5	Sandy Loam	7.01
	LChS - Pelham Range [1]	0.06	3.7	17.9	716.8	179.2	4.00	1.4	35	50	15	Silt Loam	6.2
	LChS - Co. R-O-W [1]	0.13	2.4	10.6	447.2	96.7	4.62	2.3	56	34	10	Sandy Loam	6.45
	WS	0.16	4.35	45.14	1199.85	331.55	3.62	4.5	41	39	20	Loam	6.59
GA	**Bartow Co.**												
	CCS	0.38	9.87	72.89	2811.68	160.8	17.49	9.5	43.75	51.25	5	Silt Loam	6.07
	IHS	0.14	7.07	55.28	1990.79	327	6.09	4.2	56.25	36.25	7.5	Sandy Loam	7.36
	MS - upper seep [1]	0.65	8.52	71.64	2140.8	481.72	4.44	6	77.5	17.5	5	Loamy Sand	6.81
	MS - lower mill pond [1]	0.37	7.83	51.98	1842.33	397.13	4.64	7.7	57.5	35	7.5	Sandy Loam	6.19
	MS - water wheel run [1]	0.17	8.13	53.47	1070.62	273.73	3.91	4.1	60	35	5	Sandy Loam	6.77
	MS - streamside [1]	0.12	9.12	54.85	987.81	216.51	4.56	3.6	86.25	11.25	2.5	Sand	7
	PC/WCS	0.37	13.82	132.51	2438.05	417.51	5.84	11	66.25	28.75	5	Sandy Loam	6.33
	Floyd County												
	MFP	0.75	7.53	124.09	4228.45	371.92	11.37	15.3	N/A	N/A	N/A	N/A	6.37
	MEAN	0.24	7.28	51.42	1783.61	348.47	5.56	5.76	65.33	27.11	7.50		6.69
SEP Ecoregion													
AL	**Franklin Co**												
	RBH - Seep [1]	0.02	2.58	38.14	5825.21	87.17	66.83	1.7	48.75	28.75	22.5	Loam	7.95
	RBH - Borrow Ditch [1]	0.03	8.07	63.87	3461.44	125.46	27.59	2.4	36.25	36.25	27.5	Clay Loam	7.62
	MEAN	0.03	5.33	51.01	4643.33	106.32	47.21	2.05	42.50	32.50	25.00		7.79

[1] Several populations or sites, incl. Little Grinders Cr., Little Schultz Cr., Lloyd's Chapel Swale, Mosteller Mill, and Red Bay Hwy had habitat either so large or diverse as to require sub-sampling.

Table 7. Results of soil tests for micronutrients and trace elements as part of the 1998-99 USFWS status survey of *X. tennesseensis* populations.
Concentrations in ppm. ND = Not Detectable using these methods.

IP Ecoregion	Sites	Al	B	Ba	Co	Cr	Cu	Fe	Mn	Mo	Na	Pb	Zn
TN	**Lewis Co.**												
	AH	226.69	1.14	8.81	0.26	1.06	ND	73.51	29.77	0.48	39.4	1.32	10.35
	LB	216.14	1.46	3.56	0.4	0.94	ND	89.85	27.5	0.42	48.8	2.33	6.31
	LGC -Nix Br [1]	80.57	1.82	7.21	0.52	1.89	ND	18.11	153.42	0.31	48.65	0.88	5.7
	LGC - Confluence[1]	98.06	3.5	10.8	0.48	2.31	ND	39.73	63.15	0.52	126.9	1.32	15.66
	LGC - WF	179.1	2.49	11.13	0.42	1.78	ND	82.7	52.33	0.46	55.13	1.37	12.85
	LGC - Floodplain[1]	126.4	3.97	11.07	0.53	2.22	ND	55.95	50.94	0.51	90.96	1.56	11.66
	LGC - Champion Bdry[1]	242.65	2.23	12.78	1.24	2.12	ND	108.11	171.49	0.48	53.01	1.59	9.99
	TFH	126.77	2.78	4.99	0.49	1.48	ND	49.85	43.61	0.46	91.86	1.71	19.51
	MEAN	162.05	2.42	8.79	0.54	1.73	ND	64.73	74.03	0.46	69.34	1.51	11.50
RV Ecoregion													
AL	**Bibb Co.**												
	AGW	26.1	3.8	9.8	0.1	1.1	ND	13.7	47.9	0.2	19.4	0.7	1.6
	LSC - upper[1]	77.42	0.6	5.18	0.79	1.15	1.63	100.16	123.35	0.25	11.25	0.81	0.97
	LSC - lower[1]	113.47	0.99	4.15	0.82	1.71	0.13	38.4	137.65	0.46	26.41	0.86	1.26
	TS	73.57	0.64	4.55	0.59	0.66	0.11	121	68.19	0.21	18	0.25	1.82
	Calhoun Co.												
	BGS	100.6	0.5	3.9	0.6	0.5	4.3	50.4	68.7	0.2	2.9	4.6	14.3
	FFC	149.73	0.85	4.66	2.08	2.68	2.72	157.73	354.06	0.43	11.9	1.21	4.46
	LChS - Pelham Range[1]	98.2	0.5	5.4	0.4	0.6	1.3	67.8	41.2	0.1	8.5	2.2	2.5
	LChS - Co. R-O-W[1]	109.2	0.3	5	0.3	0.4	0.6	57.6	34.8	0.1	2.8	1.3	1.1
	WS	96.83	0.8	3.88	0.7	0.75	1.13	82.35	70.98	0.06	21.47	1.04	5.1
GA	**Bartow Co.**												
	CCS	172.41	1.02	4.52	1.11	1.3	ND	144.64	91.21	0.4	49.67	1.8	5.88
	IHS	76.03	1.56	3.34	1.59	3.27	ND	250.14	475.38	0.46	26.44	1.21	4.14
	MS - upper seep[1]	186.03	1.11	6.5	1.28	1.51	ND	109.32	144.81	0.34	35.79	1.18	12.27
	MS - lower mill pond [1]	194.94	1.1	5.34	1.25	1.32	ND	154.59	93	0.47	36.77	1.47	10.3
	MS - water wheel run[1]	130.77	0.69	5.75	0.92	0.95	ND	121.22	93.11	0.38	30.77	1.62	1.8
	MS - streamside[1]	97.13	0.7	5.67	0.7	1.08	ND	157.88	95	0.33	25.75	1.35	6.02
	PC/WCS	76.03	1.56	3.34	1.59	3.27	ND	159.01	65.31	0.46	46.73	1.77	4.14
	Floyd County												
	MFP	131.72	1.37	3.81	0.87	1.5	ND	36.63	136.36	0.3	108.2	0.66	2.34
	MEAN	112.36	1.06	4.99	0.92	1.40	1.49	107.21	125.94	0.30	28.40	1.41	4.71
SEP Ecoregion													
AL	**Franklin Co**												
	RBH - seep[1]	47.46	0.43	4.24	1.7	1.38	ND	14.73	118.95	0.17	42.05	0.52	0.05
	RBH - borrow ditch[1]	92.27	0.63	5.29	2.03	1.12	ND	100.41	104.84	0.18	55.06	0.77	9.72
	MEAN	69.87	0.53	4.77	1.87	1.25	ND	57.57	111.90	0.18	48.56	0.65	4.89

[1] Several sites, incl. Little Grinders Cr., Little Schultz Cr., Lloyd's Chapel Swale, Mosteller Mill, and Red Bay Hwy had habitat either so large or diverse as to require dividing the site for subsampling.

Table 8. Temperature and precipitation for *X. tennesseensis* sites surveyed as part of the 1998-99 USFWS status survey. Included are mean maximum and minimum annual temperatures, 30-Year average temperatures, and the differences between them. Values for sites in the same county used the same National Oceanographic and Atmospheric Administration (NOAA) reporting stations.

	Temperature						Precipitation		
					Difference				
Sites	**Annual Avg. °C (97-99)**		**30-Year Avg. °C**		**(columns 2-4)**	**(columns 3-5)**			**Difference**
IP Ecoregion	**MAX**	**MIN**	**MAX**	**MIN**	**MAX**	**MIN**	**Annual in cm (97-99)**	**30-Year Avg. in cm**	**(columns 8 - 9)**
TN									
Lewis Co.									
All sites	22.34	7.71	21.28	6.78	1.06	0.93	144	141.5	2.5
RV Ecoregion									
AL									
Bibb Co.									
All Sites	24.17	10.02	23.22	10.61	0.95	-0.59	147.29	149.73	-2.44
Calhoun Co.									
All Sites	23.33	11.89	23	11.72	0.33	0.17	125.2	134.3	-9.1
GA									
Bartow Co.									
All Sites	22.78	10.34	22.28	9.11	0.50	1.23	83.59	121.3	-37.71
Floyd Co.									
MFP	22.37	10.26	21.67	8.44	0.70	1.82	123.1	140.5	-17.4
MEAN	23.16	10.63	22.54	9.97	0.62	0.66	119.80	136.46	-16.66
SEP Ecoregion									
AL									
Franklin County [1]									
RBH	23.07	11.17	22.33	10.67	0.74	0.5	139.37	141.91	-2.54

[1] Franklin County - NCDC and NOAA, Tupelo WSO ARPT First Order Station (Lee County, MS). Closer Cooperative stations had missing data for the period.

[2] Lewis County - NCDC and NOAA, Linden II Cooperative Station (Perry County). Closer Cooperative stations had missing data for the period.

[3] Bibb County - NCDC and NOAA, Centreville 6 SW Cooperative Station (Bibb County, AL).

[4] Calhoun County - AWIS and NOAA, Anniston FAA ARPT First Order Station (Calhoun County, AL).

[5] Bartow County - NCDC and NOAA, Cartersville Station (Bartow County, GA).

[6] Floyd County - AWIS and NOAA, Rome Station (Floyd County, GA).

Note: Temperature and Precipitation data for each county/weather station were counted only once in the determination of physiographic province means.

Table 9. Elements of exposure (slope, aspect, and subjective shading level) for all *X. tennesseensis* sites surveyed as part of the 1998-99 USFWS status survey.

IP Ecoregion	Sites	Dist to Weather Station	Slope 1	Aspect 2	Shading Level
TN	**Lewis Co.**				
	AH	36	10%	W/SW	2
	LB	44	12-14%	NW	3
	LGC- Nix Br.[4]	40	1-2%	S/SE	3
	LGC- Hick Hill Br.[4]	40	1-2%	W/NW	2
	LGC - Confluence[4]	40	50%	S	1
	LGC - Waterfall[4]	40	25%	W/SW	3
	LGC - Floodplain[4]	40	12%	E	2
	LGC - Champion Boundary[4]	40	15%	W/NW	2
	TFH	44	20-25%	W/NW	3
	MEAN	40.44	16.20%		2.33
RV Ecoregion					
AL	**Bibb Co.**				
	AGW	24	2-3%	N/NW and S/SE	3
	LSC - upper[4]	16	2-3%	SW and NE	2
	LSC - lower[4]	16	2-3%	SW, NE, S/SE and N/NW	2
	TS	20	1-5%	SW and NE	1
	Calhoun Co.				
	BGS	20	1-2%	N/NE	4
	FFC	16	1-2%	E and W	4
	LChS	16	1%	E/SE	4
	WS	20	1-5%	All directions except N	3
GA	**Bartow Co.**				
	CCS	12	1-2%	SE	4
	IHS	8	10-15%	SE and NW	2
	MS	20	3-5%	E (mainly), and N,N/NE	3
	PC/WCS	12	5%	SW	4
	Floyd Co.				
	MFP	16	1-5%	All Directions	4
	MEAN	16.62	3.30%		3.08
SEP Ecoregion					
AL	**Franklin Co.**				
	RBH	80	10-15%	SE	4
	MEAN	80	12.5		4

[1] Slope -Typically measured from the "top" of a population down to a major defining feature (I.e. road, stream, etc.). The length of the overall slope may contain numerous small flat steps or terraces (i.e., microsites) inhabited by *X. tennesseensis,* thus the overall slope of the site may exceed that of a particular microsite.
the overall slope of the site may greatly exceed that of a particular microsite.

[2] Aspect - May include multiple directions if a population borders more than one side of a stream or pond.

[3] Shading Level - Subjective - (1) Significantly Shaded, (2) Moderately Shaded, (3) Partially Open, (4) Mostly Open.

[4] Several sites/populations, including Little Grinders Cr.and Little Schultz Cr. were diverse enough to require subsampling

Table 10a. Principal floral associates of *X. tennesseensis* and their frequency across *X. tennesseensis* sites and populations during the 1998-99 USFWS status survey. An "X" indicates presence in a population

IP Ecoregion		*Amphicarpaea*	*Arthraxon*		*Mitreola*			*Fuirena*
TN	**Sites**	*bracteata*	*hispidus*	*Carex* spp.[2]	*sessilifolia*	*Cyperus* spp.[3]	*Eupatorium* spp.[6]	*squarrosa*
	Lewis Co.							
	AH	X	X	X				X
	LB	X		X	X	X		
	LGC-Nix Br.	X		X		X	X	
	LGC-Hick Hill Br.							
	LGC-Confluence			X		X		X
	LGC-WF			X		X	X	
	LGC-Floodplain			X				
	LGC-Champion Bndry			X				
	TFH	X		X	X		X	
	Status[1]	common	infrequent	common	infrequent	common	common	infrequent
RV Ecoregion								
AL	**Bibb Co.**							
	AGW			X	X	X	X	
	LSC - upper		X	X		X	X	X
	LSC - lower		X				X	X
	TS				X	X	X	
	Calhoun Co.							
	BGS		X	X		X	X	
	FFC		X	X	X	X	X	
	LChS		X		X	X	X	X
	WS		X		X	X	X	X
GA	**Bartow Co.**							
	CCS			X	X	X		
	IHS			X	X	X	X	
	MS		X	X	X	X	X	X
	PC/WCS		X			X	X	
	Floyd Co.							
	MFP		X	X		X	X	X
SEP Ecoregion	Status[1]	**N/A**	common	common	intermediate	common	common	intermediate
AL	**Franklin Co.**							
	RBH		X	X	X	X	X	X

[1] Status -Common - floral associates present in > 75% of populations surveyed (i.e., 4 out of 5 IP; 9 out of 12 RV; not applicable in SE PL.).

-Intermediate - floral associates present in 50-75% of populations surveyed (i.e., 3 out of 5 ILP; 6-8 out of 12 RV; not applicable in SE PL.).

-Infrequent - floral associates present in < 50% of populations surveyed (i.e. 2 or fewer in ILP; 5 or fewer in RV; not applicable in SE PL.).

Note: Only associates of *X. tennesseensis* microhabitats were categorized. Plants of surrounding habitats and ecotones were combined into the infrequent category.

[2] *Carex* spp. - includes *C. granularis, C. hystericina, C. iria, C. laevivaginata, C. leptalea, C. lurida,* and *C. vulpinoidea.* No single species occurs in 9 or more pops.

[3] *Cyperus* spp. - includes *C. diandrus, C. erythrorhizos, C. flavescens, C. rivularis,* and *C. strigosus.* No single species occurs in 9 or more populations.

[4] *Eupatorium* spp. - includes *E. capillifolium, E. coelestinum, E. fistulosum, E. hyssopifolium, E. perfoliatum,* and *E. serotinum*. No single species occurs in 9 or more pops.

Table 10b. Principal floral associates of *X. tennesseensis* and their frequency across *X. tennesseensis* sites and populations during the 1998-1999 USFWS status survey. An "X" indicates presence in a population

	Sites	*Helenium autumnale*	*Hypericum interior*	*Juncus* spp.[2]	*Juncus brachycephalus*	*Ludwigia microcarpa*	*Mecardonia acuminata*	*Microstegium vimineum*
IP Ecoregion								
TN	**Lewis Co.**							
	AH	X	X	X	X		X	X
	LB	X	X	X	X	X		X
	LGC-Nix Br.			X	X			X
	LGC -Hick Hill Br.				X			X
	LGC-Confluence			X				
	LGC-WF			X	X			X
	LGC-Floodplain			X	X			X
	LGC-Champion Bndry			X	X			X
	TFH	X		X	X	X	X	
	Status[1]	common	infrequent	common	common	infrequent	infrequent	common
RV Ecoregion								
AL	**Bibb Co.**							
	AGW	X	X	X	X	X		
	LSC - upper	X	X	X	X	X	X	X
	LSC - lower	X	X	X	X	X	X	X
	TS		X	X				X
	Calhoun Co.							
	BGS	X	X	X	X	X	X	X
	FFC	X	X	X	X	X	X	X
	LChS	X		X	X	X	X	X
	WS	X		X	X	X		X
GA	**Bartow Co.**							
	CCS		X	X	X	X		X
	IHS		X	X	X	X	X	X
	MS	X	X	X	X	X	X	X
	PC/WCS		X	X		X		X
	Floyd Co.							
	MFP			X	X	X		X
SEP Ecoregion	Status[1]	intermediate	common	common	common	common	intermediate	common
AL	**Franklin Co.**							
	RBH	X		X	X	X	X	X

[1] Status -Common - floral associates present in > 75% of populations surveyed (i.e., 4 out of 5 IP; 9 out of 12 RV; not applicable in SE PL.).

-Intermediate - floral associates present in 50-75% of populations surveyed (i.e., 3 out of 5 ILP; 6-8 out of 12 RV; not applicable in SE PL.).

-Infrequent - floral associates present in < 50% of populations surveyed (i.e. 2 or fewer in ILP; 5 or fewer in RV; not applicable in SE PL.).

Note: Only associates of *X. tennesseensis* microhabitats were categorized. Plants of surrounding habitats and ecotones were combined into the infrequent category.

[2] *Juncus* spp. (other than *J. brachycephalus*) - includes *J. acuminatus, J. brachycarpus, J. coriaceous, J. debilis, J. diffusissimus,* and *J. effusus.* No single species occurs in 10 or more populations.

Table 10c. Principal floral associates of *X. tennesseensis* and their frequency across *X. tennesseensis* sites and populations during the 1998-99 USFWS status survey. An "X" indicates presence in a population

IP Ecoregion	Sites	*Oxypolis rigidor*	*Parnassia grandifolia*	*Phlox glaberrima*	*Rhyncohspora capitellata*	*Rhynchospora* spp.[2]	*Rudbeckia fulgida* var. *umbrosa*	*Scirpus* spp.[3]
TN	**Lewis Co.**							
	AH	X	X	X	X	X	X	X
	LB	X	X	X	X	X	X	X
	LGC-Nix Br.	X	X			X	X	X
	LGC -Hick Hill Br.		X				X	
	LGC-Confluence			X			X	
	LGC-WF		X				X	
	LGC-Floodplain	X	X				X	
	LGC-Champion Bndry	X	X				X	
	TFH	X		X	X	X	X	X
	Status[1]	common	common	common	intermediate	common	common	common
RV Ecoregion								
AL	**Bibb Co.**							
	AGW				X	X	X	
	LSC - upper		X		X			
	LSC - lower	X			X	X		
	TS					X		
	Calhoun Co.							
	BGS					X		
	FFC	X				X		
	LChS					X		
	WS					X	X	
GA	**Bartow Co.**							
	CCS	X			X	X		X
	IHS	X			X	X	X	X
	MS	X			X	X	X	X
	PC/WCS							
	Floyd Co.							
	MFP					X		
	Status[1]	infrequent	infrequent	N/A	intermediate	common	infrequent	infrequent
SEP Ecoregion								
AL	**Franklin Co.**							
	RBH					X	X	X

[1] Status -Common - floral associates present in > 75% of populations surveyed (i.e., 4 out of 5 IP; 9 out of 12 RV; not applicable in SE PL.).

-Intermediate - floral associates present in 50-75% of populations surveyed (i.e., 3 out of 5 ILP; 6-8 out of 12 RV; not applicable in SE PL.).

-Infrequent - floral associates present in < 50% of populations surveyed (i.e. 2 or fewer in ILP; 5 or fewer in RV; not applicable in SE PL.).

Note: Only associates of *X. tennesseensis* microhabitats were categorized. Plants of surrounding habitats and ecotones were combined into the infrequent category.

[2] *Rhyncospora* spp. (other than *R. capitellata*) - includes *R. caduca, R. mixta, and R. thornei.* No single species occurs in 9 or more populations.

[3] *Scirpus* spp. - includes *S. atrovirens, S. cyperinus, S. polyphyllus,* and *S. validus.* No single species occurs in 9 or more populations.

Table 11. Infrequent Associates of *X. tennesseensis* combined for both RV and IP ecoregions. Infrequent associates occur in less than 50% of all the surveyed *X. tennesseensis* habitats. The list includes herbs and shrubs of the *X. tennesseensis* seeps, springs, fens, and streambanks, and upland/ecotonal trees, shrubs and herbs. It was compiled using: 1) project field data, 2) USFWS Recovery Plan Appendix (United States Fish and Wildlife Service 1994), 3) Species Status Report (Kral 1990), and 4) field notes (Shea 2000).

Acer leucoderme Small
Acer rubrum L.
Acer saccharum Marsh.
Acorus americanus (Raf.) Raf.
Agalinis purpurea (L.) Pennell
Alisma subcordatum Raf.
Alnus serrulata (Aiton) Willd.
Ammania sp.
Andropogon virginicus L.
Andropogon glomeratus (Walt.) B.S.P.
Apocynum sp.
Apios americana Medik.
Asplenium sp.
Aster spp.
Barbarea sp.
Bidens cernua L.
Bidens frondosa L.
Bidens tripartita L.
Bignonia capreolata L.
Boehmeria cylindrica (L.) Sw.
Callitriche heterophylla Pursh.
Cardamine bulbosa
(Schreb. Ex Muhl.) Brittons, Sterns & Poggenb.
Cardamine pennsylvanica Muhl. ex Willd.
Carpinus caroliniana Walter
Carya alba (L.) Nutt.
Carya pallida (Ashe) Engl. & Graebn.
Celtis sp.
Cephalanthus occidentalis L.
Cercis Canadensis L.
Chamaecrista fasciculata (Michx.) Greene
Cheilanthes sp.
Chelone glabra L.
Cirsium muticum Michx.
Cornus amomum Mill.
Corylus sp.
Croton alabamensis E.A. Sm. ex Chpm
Cryptotaenia sp.
Decumaria barbara L.
Desmodium sp.
Dichanthelium scoparium (Lam.) *Gould*
Diodia virginiana L.
Diospyros virginiana L.
Dulichium arundinaceum (L.) Britton
Echinochloa sp.
Eclipta prostrata (L.) L.
Eleocharis obtusa (Willd.) Schult.
Epilobium coloratum Biehler
Fimbrystylis autumnalis (L.) Roemer & Schult.
Fimbrystylis miliacea (L.) Vahl
Forestiera ligustrina (Michx.) Poir.
Fraxinus americana L.
Fraxinus pennsylvanica Marsh.
Galium obtusum Bigelow
Glyceria striata (Lam.) A.S. Hitchc.
Gratiola ramosa Walter
Hamamelis virginiana L.
Hibiscus moscheutos L.
Hydrocotyle sp.
Hypericum frondosum Michx.
Hypericum gymnanthum Engelm. & A. Gray
Hypericum mutilum L.
Impatiens capensis Meerb.
Jamesianthus alabamensis S.F. Blake & Sherff
Juniperus virginiana L.
Justicia americana (L.) Vahl
Kyllinga pumila Michx.
Lactuca floridana (L.) Gaertn.
Leersia virginica Willd.
Leucospora multifida (Michx.) Nutt.
Lindera benzoin (L.) Blume
Liquidambar styraciflua L.
Lobelia cardinalis L.
Lobelia puberula Michx.
Lobelia siphilitica L.
Ludwigia alata Elliot
Ludwigia alternifolia L.
Ludwigia decurrens Walter
Ludwigia palustris (L.) Elliot
Lycopus rubellus Moench
Lycopus virginicus L.
Lysimachia ciliata L.
Lysimachia lanceolata Walter
Lysimachia quadriflora Sims
Lythrum alatum Pursh.
Magnolia virginiana L.
Marshallia mohrii Beadle & F.E. Boynt.
Marshallia trinervia Walter (Trel.)
Mentha x. piperata L.
Mikania scandens L. (Willd.)
Mimulus alatus Aiton

Table 11. Infrequent Associates of *X. tennesseensis* combined for both RV and IP ecoregions (cont).

Mimulus ringens L.
Minuartia patula (Michx.) Mattf.
Muhlenbergia sylvatica (Torr.) Torr. Ex A. Gray
Myrica cerifera (L.) Small
Nasturtium officinale W.T. Aiton
Onoclea sensibilis L.
Osmunda regalis L.
Ostrya virginiana (Mill.) *K. Koch*
Panicum anceps Michx.
Panicum dichotomum L.
Panicum flexile (Gattinger) Scribn.
Paspalum dilatatum Poir.
Pellaea sp.
Penstemon sp.
Phlox amplifolia Britton
Pilea pumila (L.) A. Gray
Pinus echinata Mill.
Pinus taeda L.
Pinus virginiana Mill.
Platanus occidentalis L.
Pluchea camphorata (L.) DC
Poa sp.
Polygala boykinii Nutt.
Polygonum cespitosum Blume
Polygonum hydropiperoides Michx.
Polygonum pensylvanicum L.
Polygonum punctatum Elliot
Polygonum sagittatum L.
Polygonum virginianum L.
Potamogeton foliosus Raf.
Prunella vulgaris L.
Pycnanthemum tenuifolium Schrad.
Quercus alba L.
Quercus austrina Small
Quercus falcata Michx.
Quercus muhlenbergii Engelm.
Quercus nigra L.
Quercus phellos L.
Quercus shumardii Buckley
Quercus stellata Wangenh.
Quercus velutina Lam.
Ratibida pinnata (Vent.) Barnhart
Rhexia mariana L.
Rhexia virginica L.
Rhus aromatica Aiton
Rhus copallinum L.
Rhynchospora colorata (L.) H. Pfeiffer
Rorippa sp.
Rosa palustris Marsh.
Rotala ramosior (L.) Koehne
Rudbeckia laciniata L.
Rudbeckia triloba L.
Rudbeckia heliopsidis Torr. & A. Gray
Ruellia sp.
Rumex conglomerates Murray
Rumex obtusifolius L.
Sabal minor (Jacq.) Pers.
Sabatia angularis (L.) Pursh.
Sagittaria sp.
Salix caroliniana Michx.
Salix nigra Marsh.
Saururus cernuus L.
Schedonorus phoenix (Scop.) Holub
Scleria verticellata Muhl. ex Willd.
Scutellaria lateriflora L.
Sedum pulchellum Michx.
Selaginella apoda (L.) Spring
Silphium asteriscus L.
Silphium terebinthinaceum Jacq.
Solidago patula Muhl. ex Willd.
Solidago rugosa Mill.
Sparganium americanum Nutt.
Sporobolus junceus (P. Beauv.) Kunth
Symphyotrichum racemosum
(Elliot) G.L. Nesom
Thelypteris palustris Schott
Thelypteris noveboracensis (L.) Nieuwl.
Trichostema brachiatum L.
Tridens flavus (L.) Hitchc.
Ulmus alata Michx.
Ulmus rubra Muhl.
Vaccinium sp.
Verbesina alternifolia (L.) Britton ex Kearney
Verbesina virginica L.
Vernonia gigantean (Walter) Trel.
Vernonia missurica Raf.
Veronica anagallis-aquatica L.
Xyris difformis Chapman var. *difformis* Chapman
Xyris jupicai Rich.
Xyris torta Sm.
Zizia aurea (L.) W.D.J. Koch

Table 12. Results of flowering spike censuses and clump/ramet/seedling sampling at *X. tennesseensis* sites during 1998-99 USFWS status survey.

						Population Measures				
IP Ecoregion	**Sites**	**% Pop/ Size Sampled**	**Site [C,1] Size (m^2)**	**Reproductive [C] Spikes**	**Density [E] ($Clumps/m^2$)**	**Total [E] Veg. Clumps**	**Total [E] Rep. Clumps**	**Total [E] Clumps**	**Total [E] Veg. Ramets**	**Total [E] Rep. Ramets**
TN	**Lewis Co.**									
	AH	31.7%	260	733	1.12	66	225	291	742	619
	LB	11.6%	545	1,231	0.55	17	284	301	594	1,093
	LGC-Nix Br.[2]	53.0%	30	589	5.03	8	143	151	109	408
	LGC - Hick Hill Br.[2]	100.0%	1	32	11.00	2	9	11	14	26
	LGC- Confluence[2]	8.9%	85	2,105	3.05	79	180	259	6,236	2,094
	LGC-WF[2]	24.6%	100	533	2.73	65	208	273	460	492
	LGC-Floodplain[2]	100.0%	10	87	2.00	1	19	20	59	73
	LGC-Champion Bndry[2]	100.0%	20	86	1.10	1	21	22	62	81
	TFH	4.0%	1,260	8,741	0.48	75	528	603	3,290	7,987
	Sub-total for IP	N/A	2,311	14,137	N/A	314	1,617	1,931	11,566	12,873
	Mean for IP	48.2%	256.8	1570.8	3.0	34.9	179.7	214.6	1285.1	1430.3
RV Ecoregion										
AL	**Bibb Co.**									
	AGW	11.8%	40	1,332	6.78	25	246	271	721	1,069
	LSC - upper[2]	28.2%	355	294	1.36	312	170	482	662	291
	LCS - middle[2]	N/A	2,600	80	0.06	N/A	N/A	150	N/A	N/A
	LSC - lower[2]	8.3%	3,000	2,137	0.60	840	960	1,800	2,281	2,113
	TS	100.0%	350	38	0.15	36	15	51	120	38
	Calhoun Co.									
	BGS	8.2%	330	3,415	4.45	450	1020	1,470	826	2,127
	FFC	27.3%	235	1,173	1.29	4	300	304	29	623
	LChS	5.2%	2,325	11,370	1.07	428	2060	2,488	1,166	7,347
	WS	19.8%	160	2,637	3.66	66	519	585	1,331	2,103
GA	**Bartow Co.**									
	CCS	77.2%	35	684	3.71	10	120	130	131	473
	IHS	12.2%	225	1,230	4.38	568	423	985	3,123	1,181
	MS	5.3%	2,920	20,878	1.97	1359	4380	5,739	8,249	16,933
	PC/WCS	100.0%	960	119	0.02	5	17	22	104	104
	Floyd Co.									
	MFP	10.9%	300	1,594	2.03	92	516	608	286	1,290
	Sub-total for RV	N/A	13,835	46,981	N/A	4195	10746	15,085	19,029	35,692
	Mean for RV	31.9%	988.2	3355.8	2.3	322.7	826.6	1077.5	1463.8	2745.5
SEP Ecoregion										
AL	**Franklin Co.**									
	RBH	18.7%	870.00	2,117.00	0.86	192	556	748	722	1,545
	Total (IP + RV + SE PL)	N/A	17,016	63,235	N/A	4,701	12,919	17,764	31,317	50,110
	Mean (IP + RV + SE PL)	37.7%	709.0	2634.8	2.5	204.4	561.7	740.2	1361.6	2178.7

Codes: [C] = Census/measurement data; [E] = Extrapolations using sample data

[1] Site Size - includes all "potential/likely" *X. tennesseensis* habitat in the general proximity of existing clumps/colonies, whether or not occupied by *X. tennesseensis*.

[2] Two sites (Little Grinders Cr. and Little Schultz Cr.) had habitat either so large or diverse as to require dividing the site for subsampling

Table 13. Population descriptions for *X. tennesseensis* populations surveyed during the 1998-99 USFWS status survey.

IP Ecoregion	Sites	% Ramets Reproductive	Descriptive Relationships: Mean Ramets per Clump	Descriptive Relationships: Mean Spikes per Rep. Ramet	Mean Spikes per Rep. Clump
TN	**Lewis Co.**				
	AH	45.5%	4.7	1.2	3.3
	LB	64.8%	5.6	1.2	4.3
	LGC-Nix Br.[1]	78.9%	3.4	1.4	4.1
	LGC - Hick Hill Br.[1]	65.0%	3.6	1.2	3.6
	LGC- Confluence[1]	25.1%	32.2	1.0	11.7
	LGC-WF[1]	51.7%	3.5	1.1	2.6
	LGC-Floodplain[1]	55.3%	6.6	1.5	4.5
	LGC-Champion Bndry[1]	56.6%	6.5	1.1	4.1
	TFH	70.8%	18.7	1.1	16.6
	Mean for IP	57.1%	9.4	1.2	6.1
RV Ecoregion					
AL	**Bibb Co.**				
	AGW	59.7%	6.6	1.2	5.4
	LSC - upper[1]	30.5%	2.0	1.0	1.7
	LSC - lower[1]	48.1%	2.4	1.0	2.2
	TS	24.1%	3.1	1.0	2.5
	Calhoun Co.				
	BGS	72.0%	2.0	1.6	4.5
	FFC	95.6%	2.1	1.9	3.9
	LChS	86.3%	3.4	1.7	5.5
	WS	61.2%	5.9	1.3	5.1
GA	**Bartow Co.**				
	CCS	78.3%	4.6	1.5	5.7
	IHS	27.4%	4.4	1.0	2.9
	MS	67.2%	4.4	1.2	4.8
	PC/WCS	50.0%	9.5	1.2	7.0
	Floyd Co.				
	MFP	81.9%	2.6	1.3	3.1
	Mean for RV	60.2%	4.1	1.3	4.2
SEP Ecoregion					
AL	**Franklin Co.**				
	RBH	68.2%	3.0	1.4	3.8
	Total (IP + RV + SE PL)	N/A	N/A	N/A	N/A
	Mean (IP + RV + SE PL)	59.3%	6.1	1.3	4.9

[1] Two sites (Little Grinders Cr. and Little Schultz Cr.) had habitat either so large or diverse as to require division of the site for subsampling

Figure 1a. Map of historic and extant populations of *Xyris tennesseensis*. Approximate locations of sites/populations indicated by the [hatched symbol] polygon. Base map combines Level IV Ecoregions for TN (Griffith et al. 1998) and AL/GA (Griffith et al. 2001). Legend is in Fig. 1b.

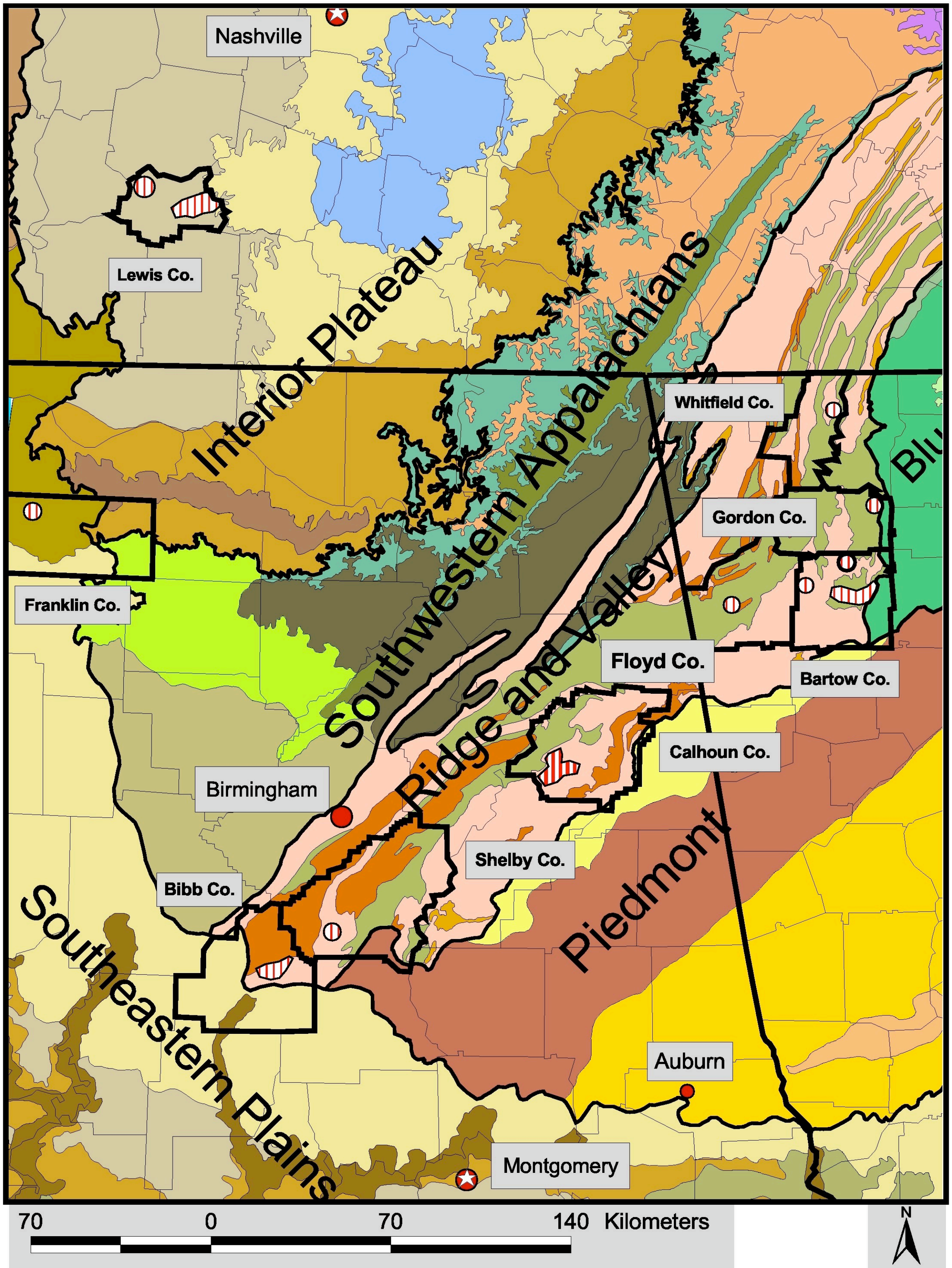
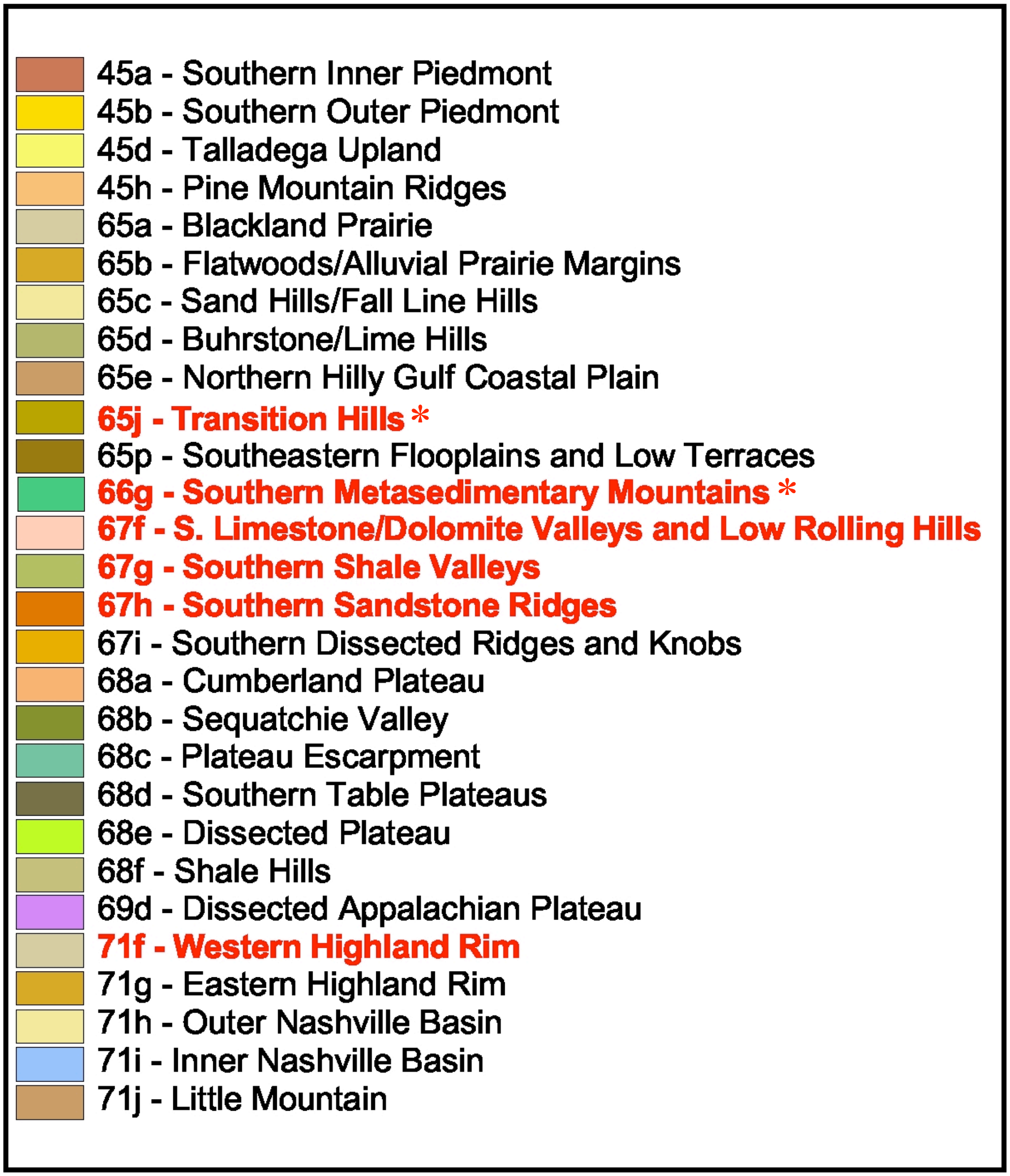


Figure 1b. Legend of map (Fig. 1a) showing *X. tennesseensis* population locations. Level III Ecoregion designations are as follows: (45) Piedmont; (65) Southeastern Plains; (66) Blue Ridge; (67) Ridge and Valley; (68) Southwestern Appalachians; (69) Central Appalachians; and (71) Interior Plateau. Level IV Ecoregion designations are given by the entire numeric-alpha code. Level IV Ecoregions shown in red comprise the known range of this species. *Xyris tennesseensis* populations in two ecoregions, labeled with an asterisk, are in complicated geologic settings and/or in ecoregion border situations, and technically violate the Ridge and Valley and Interior Plateau paradigm.



III. MANAGEMENT OF *XYRIS TENNESSEENSIS* (TENNESSEE YELLOW-EYED GRASS), A FEDERALLY ENDANGERED PLANT SPECIES

ABSTRACT

A three-year study was conducted to determine effects of cutting of shrubs that were shading a population of *X. tennesseensis* Kral. Shrubs were cut to ground level on small plots and *Xyris* flowering, ramet numbers (a ramet is defined as a leaf-producing stem) and seedling numbers were monitored during three post-treatment seasons. Floral visitation was also documented to determine if shrub cutting increased the likelihood of floral visits by insects that might pollinate flowers. In addition, the seed bank of the site was quantified. Shrub cutting significantly increased flowering of *Xyris* on the site, and also significantly increased seedling production, but no significant increase in total *Xyris* numbers was found. Floral visits were significantly more frequent to *Xyris* flowers located on cut plots. There was no *Xyris* seed bank. I conclude that cutting shrubs can stimulate *Xyris* reproduction and propose a management plan to implement cutting on a 12-year rotation on this site. This rotation is designed to boost *Xyris* reproduction without seriously compromising the unique associated flora of this seepage site.

Key words: endangered species, pollination biology, plant-plant competition, plant succession, wetland management, *Xyris tennesseensis*, seed bank.

INTRODUCTION

Plant conservation in the southeastern United States is a vital undertaking, but frought with numerous challenges. This exceptionally biodiverse region (Stein et al. 2002) is also one of the most populous and rapidly developing (U.S. Census Bureau 2000). The southeastern U.S., with only 24.8% of the total surface area of the United States (U.S. Census Bureau 1990), supports a disproportionately high portion of the nation's human population (36%) (U.S. Census Bureau 2000) and native vascular and nonvascular flora (44.8%) (NatureServe 2008). Of the ca. 24,300 national taxa, nearly 11,000 are represented in the southeast (NatureServe 2008), with 11 states ranked in the top 20 nationally for species richness (Stein et al. 2002). Inevitably, however, the intersection between high levels of species richness and human population has put many taxa at risk of serious decline or extinction, with eight states ranked in the top 20 nationally for plant taxa at risk (Stein et al. 2002). The situation for many plant taxa is dire and active management of rare plant habitat is an important component of a conservation strategy (California Native Plant Society 2008; Center for Plant Conservation 2008; New England Wildflower Society 2008).

Tennessee yellow-eyed grass (*Xyris tennesseensis*) is a rare species known from a handful of populations scattered among Tennessee, Georgia, and Alabama (U.S. Fish & Wildlife Service 1994a). Despite its status as a federally endangered plant (U.S. Fish & Wildlife Service 1991a, b), little is known about the ecological features of this species. Anecdotal reports and observations by Kral (1983) indicate that it may respond well to occasional disturbance that keeps sites relatively open. My research on *X. tennesseensis* indicates that flower production and (perhaps) seedling recruitment are most extensive in locations that are relatively sunny and lack an overstory of shrub or tree canopies. However, southeastern vegetation usually undergoes succession in which a climax community of trees develops unless some disturbance (fire, windthrow, disease, etc.) prevents this from occurring (Lewis et al. 1981; Thompson and Degraf 2001). Natural successional processes, then, must be set back periodically if populations of *X. tennesseensis* are to remain vigorous and healthy.

Protection of federally endangered plant species is often problematic when those species occur on privately owned land. This makes protection of federally endangered species even more important when they occur on government-owned land, because government-owned sites are more likely to be protected over the long term than privately owned sites. Recent survey work with *Xyris tennesseensis* (Ch. II) shows it to be a good example of this phenomenon. Of the 38 populations (41 occurrences) known, including both those extant and those considered extirpated, only 6 (16%) are at least partly on government-owned land. Three additional sites, one in protected private ownership (Ebeneezer Swamp Ecological Preserve – Univ. of Montevallo), another under quasi-governmental influence (Red Bay Highway – Alabama Dept. of Transportation Rights-of-Way), and a third under governmental management (Pine Log Springs Wildlife Management Area - Georgia Dept. of Natural Resources lease), have varying degrees of protection. Even with the inclusion of these three additional sites, only 24% (9 out of 38) of the *X. tennesseensis* populations have any form of protection or degree of public influence over their fate. The I-75/US 411 population in Bartow Co, Georgia, mapped as "Interstate Hypericum Springs" by the Georgia Natural Heritage Program (1998), occurs on federal highway right-of-way (i.e., public property) and, therefore, represents an opportunity to ensure proper management and stewardship for *X. tennesseensis* on at least one site.

The I-75/US 411 population extends about 10-15 m in length and about 4-6 m in width on either side of a cement drainage culvert (which has silted in and contains considerable aquatic vegetation, giving the appearance of a somewhat natural stream). The population is being heavily impacted by the thick and aggressive growth of the shrub *Hypericum interior* Small. It should be noted that uncertainty/disagreement exists among taxonomic authorities regarding the narrow-leaved form of this species. Some authorities consider it either a variety of *H. densiflorum* Pursh. (Weakley 2008), or choose not to recognize it at all (R. Kral, pers. comm.). This 1.5-2 m high shrub thicket formed a perimeter around the entire *Xyris tennesseensis* population and about 50% of the population was currently completely shaded by an overstory of *Hypericum*. The remaining 50% was at least partly shaded by this shrub. The portion of the *Xyris* population in the densest part of the thicket was 100% vegetative (i.e., no flowering stalks were produced in either 1998 or 1999).

Clearly, any long-term management plan for this population must include management of these shrubs. Given the site's proximity to the interstate and a number of businesses, fire probably is not a feasible management tool. However, "mechanical management" (i.e., cutting) of the *Hypericum* could be accomplished and would likely benefit this *Xyris* population. A conservation strategy for *X. tennesseensis* was developed by Hogan (1996) suggesting possible benefits of practices that create or maintain early successional habitat (including overstory removal). Unfortunately, it was based upon generalities and assumptions of best management practices (BMPs) and responsible stewardship notions as they might apply to any obligate wetland, heliophytic herb. To date I know of no scientific data that would allow me to predict with certainty the result of this action.

This research was designed to document the effects of a specific management treatment on this *X. tennesseensis* population in northwestern Georgia. The research had two primary objectives:

1) to determine the likely impact of shrub overstory removal on this population. Observation of this population suggested that some management activity was urgently needed for the *X. tennesseensis* population on this site, as succession had changed, and is changing the site in ways unfavorable to *X. tennesseensis*, and,
2) to provide management information for other *X. tennesseensis* populations in similar need of management decisions.

METHODS

Xyris *Response Study*

We used this situation as an opportunity to determine the effect of *Hypericum* overstory removal on the *Xyris tennesseensis* population. Test plots (labeled *Xyris*-present) were established to compare and contrast two scenarios: 1) *Xyris* present with the *Hypericum* left (control treatment); and 2) *Xyris* present with the *Hypericum* removed (Fig. 1). We also included two other treatments to see if *Hypericum* removal might allow expansion of the *Xyris* population. Plots (labeled *Xyris*-absent) at the margin of the current *Xyris* population were either untreated or had the *Hypericum* removed, and then were monitored for *Xyris*. This treatment was designed to determine if dormant rootstocks of *Xyris* were stimulated to grow by removal of the shading *Hypericum*, or if expansion of the current population might occur due to establishment of seedlings.

The design of the *Hypericum* removal experiment involved 7 pairs of treatment plots (5.75 m × 3.0 m) located on either side of a culverted stream (Fig. 1). Four pairs of treatment plots were recognized as containing *X. tennesseensis* (labeled X1, X2, X3, and X4), with three pairs lacking any *X. tennesseensis* (labeled A1, A2, and A3). The exact locations of pairs of plots were determined in an effort to pair locations with similar numbers and distributions of *Xyris* individuals. This explains the gaps that occur between some of the treatment plots shown in Figure 1. Each treatment plot in a pair of plots had one of two treatments randomly assigned to it. One plot had all the living woody plant material (primarily *H. interior*) removed from it (labeled Cut), the other plot was left "as is" and served as a control (labeled Uncut). Within each treatment plot is a smaller assessment plot (1.5 m × 5.0 m) from which data were collected (Fig. 2). Each assessment plot was further subdivided into a series of five subplots (1.5 m × 1.0 m), labeled A, B, C, D, and E in Figure 2. A moisture and light gradient existed from the stream up the bank and into the *Hypericum* thicket. The A subplots were located closest to the stream (and so had greatest light and moisture levels) whereas the E subplots were located farthest from the stream, deep in the *Hypericum* thicket (and so had the least moisture and light levels). The subplot design provided of a convenient framework for subsampling of ramets, seedlings, soil, and floral visitors.

Hypericum and other woody plants in the removal plots were manually removed by cutting them at their bases with lopping shears or a chain saw. Removal occurred during the dormant season for *Xyris* (January 2001) to minimize negative impact of this activity on *Xyris*. There was no follow-up use of herbicides on the cut stumps (i.e., "cut and paint"). Although the effect on woody competition would have been enhanced above that of cutting alone, the use of herbicides (even if judiciously and carefully applied directly to target stumps) is an inappropriate activity given the commingling of shrubs with an extremely rare, federally endangered species.

Several types of data were collected from the assessment plot of each treatment plot in early August of each year of the study. I counted the number of *Xyris* flowering spikes produced and estimated percent *Xyris* cover in each assessment plot. I also collected data on ramet numbers in the B subplot of every assessment plot. A ramet was defined as an apparent leaf-producing stem. The B subplot was selected because it generally contained the largest number of *Xyris* plants in all the experimental plots. This variable is an attempt to measure vegetative proliferation that, because of the lawn-like growth in dense *Xyris* patches, is very difficult to reliably determine. Reproductive success was also documented for the B subplots by careful examination for seedlings. Additionally, I collected data on cover of other plant species by estimating total non-*Xyris* cover in each treatment plot during our August data collection trips. This was especially important because shrub stumps were not herbicide-treated after cutting and so shrubs quickly began to re-grow.

Data were analyzed in several ways, depending on the particular variables involved. Spike counts in each treatment plot for post-treatment years (2001, 2002, 2003) were compared to pre-treatment (2000) counts by calculating the percent change in spikes. Data for ramet and seedling numbers in B subplots were used to generate percent change values in a fashion similar to that for spikes. All three variables (% change spike counts, % change ramet counts, and % change seedling counts) were analyzed by repeated measures mixed model factorial Analysis of Variance (ANOVA) to determine the effects of time, treatment, and the time × treatment interaction on each variable. Repeated measure Multivariate Analysis of Variance (MANOVA) was employed in situations where a violation of the assumption of sphericity occurred (Pallant 2001). The relationship between the percent change in *Xyris* spike numbers for all years and the percent change in non-*Xyris* cover in each plot for all years was analyzed using a Pearson Correlation. All statistical analyses were performed using SPSS 15.0 and followed approaches outlined in Pallant (2001) and Shannon (2001).

Xyris *Annual Flowering Spike Census*

In addition to the flowering spike counts recorded in the assessment plots as part of the *Xyris* response study, all flowering spikes were counted for the site during each year of the study (2000, 2001, 2002, and 2003). This included spikes in the treatment plots that were outside of the smaller assessment plots and spikes outside the treatment plots as well. Flowering spike census data for the entire site were also collected in 1999 during the course of a USFWS-funded population status survey of all known extant *X. tennesseensis*. Spike counts are a standard field technique used for *X. tennesseensis* site/population surveys by state Natural Heritage Programs (Georgia Natural Heritage Program 1998).

Species List for Site

A list of all plant species in the immediate vicinity of the study area (i.e., extending ca. 5 m beyond the boundaries of the study area) was compiled from observations during the period 1999-2003 and from results of the seed bank study.

Seed Bank Study

Determinations of both the size of the *X. tennesseensis* seed bank and the species composition of the total seed bank were made. Circular soil cores, 7.5 cm in diameter and 5 cm deep (221 cm^3 total soil volume), were collected on 18 August 2000. I did not collect soil deeper than 5 cm because: 1) *Xyris* seeds are very small and can only germinate if very close to the soil surface (Baskin and Baskin 2003), and 2) it is probable that most *Xyris* seeds recently shed by the plants in the population are located in the uppermost soil layer. In an effort to minimize contamination by living rootstocks, soil cores were collected from an un-vegetated area of a subplot as near to its center as possible. Soil from subplots A and B were combined into a single sample labeled "Front" with soil from subplots D and E treated similarly and labeled "Rear." Front and rear areas (Fig. 2) differ in that front areas are nearer the stream, less shaded by *H. interior*, and contain more *X. tennesseensis*. Subplot C was excluded from the experiment in an effort to keep the sample design balanced. This generated a total of 28 samples (7 plot pairs × 2 treatments each × 2 samples per treatment). The protocol of collecting two samples (i.e., front and rear) per plot was developed as a compromise, allowing an analysis of a potential *Xyris* seedbank at environmental extremes while reducing the total number of samples collected.

Each soil sample was air dried for two days and then gently crumbled on top of sterile potting mix in a 15.24 cm diameter plastic houseplant overflow tray (with drainage holes added). The potting mix, retail Jungle Growth®, was autoclaved at 121° C for 40 minutes before use to ensure it lacked viable seeds. The soil trays were then placed in a greenhouse at the Patterson Greenhouse Complex at Auburn University, Lee County, Alabama. Seven control trays (sterile potting mix only) were placed among the soil sample trays to detect any greenhouse propagule contamination. All trays were watered daily and efforts were made to maintain night and day temperatures at 15.5° and 21°C, respectively. In the warmest parts of the summer months, however, daytime readings in excess of 30°C sometimes occurred. Unexpected repair and maintenance problems in February 2001 necessitated closing the Patterson facility and relocating the project to a Plant Science Research Center greenhouse, also at Auburn University. Temperature fluctuation at this facility was more controlled, with maxima rarely exceeding 25°C. The seedbank study was conducted for 36 months (through August 2003).

Efforts were made to identify each seedling to species level. This required that seedlings be allowed to reach a sufficient size or stage of floral development where reliable identification was possible. In most cases, seedlings matured in place, although the sheer size of some developing plants required transplanting to a separate pot where development could occur without negatively impacting (i.e., shading, crowding, etc.) the remaining seeds/seedlings. After identification, all seedlings not transplanted to separate pots, were removed from the soil sample trays and discarded.

Floral Visitor Study

Clearing treatment plots dramatically changed the vegetative cover of those areas. I wanted to determine if floral visitation was influenced by the clearing treatments. I hypothesized that removal of shrubs and increased flower spike production would increase the visitation rate of insects to *Xyris* flowers in the cut plots.

To document visitation rate, the number of open flowers was counted in the B subplot of a pair of plots (cut and uncut). Then, for 10 minutes, the number of visits to the open flowers present in each B subplot was counted. A "visit" was defined as the landing of an insect on a *Xyris* flower. Each type (presumed species) of insect was assigned a field name based on its appearance and morphology. One observer counted the number of visits by each species of insect to the flowers in the B subplot of one member of a pair of treatment plots during a 10-minute census period. At the same time, another observer counted visits to the flowers in the B subplot of the other member of that treatment plot pair. Observers were switched between treatment types so that any observer bias would be spread among treatments.

It was logistically possible to conduct two censuses for each pair of treated plots during each day spent in the field. *Xyris* flowers survive for but a single day, and have a very constant and narrow period of anthesis. Flowers begin opening around 11:30 am (some variability is associated with cloud cover) and remain open until ca. 1:30 pm. Visits per flower for each census period were averaged to calculate the mean number of visits per flower for each subplot on each day. Data were collected for each of three days and, because flower production and weather conditions varied between days, data from each day were considered replicates in our statistical analysis. Visitors were assigned field names during data collection and the more common visitors were collected to allow more precise identification. Specimens were submitted to the Systematic Entomology Laboratory of the USDA Agricultural Research Service at the Smithsonian Institution in Washington, D.C., for expert identification.

Data were analyzed by a repeated measures mixed model factorial ANOVA (with two treatment levels and seven insect visitor categories). Census data were summarized as number of visits per flower for seven major floral visitors: *Lasioglossum zephyrum*, *Ocyptamus fuscipennis*, *Toxomerus geminatus*, *T. boscii*, *Agapostemon* sp., *Bombus* sp., and Other. The Other category contained visits by taxa for which relatively few visits (<1% of the total) were observed. The ANOVA was designed primarily to allow us to determine the effect of treatment and of visitor type on number of flower visits over time.

RESULTS

Xyris *Response Study*

Analysis of the percent change in spikes over time showed a significant violation of the sphericity assumption (Mauchley's test, $P = 0.023$), so that we proceeded using a repeated measures Multivariate Analysis of Variance (MANOVA) using Wilk's Lambda. Both time and treatment significantly affected percent change in spike production, and the interaction term was also significant (Table 1). Other terms in the analysis were not significant (Table 1).

Of these results, those most pertinent to the objectives of the study are the significant treatment and treatment × time portions of the analysis. The cut treatment resulted in enhanced spike production in every year, relative to values for the uncut plots (Table 2). The treatment × time interaction was explored by follow-up ANOVAs for each year. These showed a significant treatment effect for the first and second years post-treatment ($F_{1,28} = 8.43$, $P = 0.007$ and $F_{1,28} = 6.72$, $P = 0.015$, respectively) but a non-significant effect for the third year post-treatment ($F_{2,12} = 1.63$, $P = 0.21$). Thus, the significant stimulation of spike production lasted only through 2002, as flowering spike levels returned to near pre-treatment levels by 2003 (Table 2).

The ephemeral nature of the treatment effect may have been due to the rapid recovery of vegetation in the cut plots. The cut *Hypericum* stumps re-sprouted so that by 2003 there were several large brushy clumps of *Hypericum* covering much of the ground surface in each treatment plot. An increase in the cover of graminoid and herbaceous plants other than *Xyris* in the treatment plots was observed. These features may explain the decline in *Xyris* spike production documented in the two years (2002 and 2003) following the initially large increase in 2001 (Table 2). A correlation analysis was conducted to determine if this explanation was supported by our data. The percent change in *Xyris* spike numbers for all years was analyzed relative to the percent change in non-*Xyris* cover in each plot for all years using a Pearson Correlation analysis. Results showed a significant negative correlation between the variables ($r = -0.56$, $P < 0.001$) and that variation in the non-*Xyris* cover variable explained 31% of the variation of the *Xyris* spike production variable (Fig. 3).

Ramet data showed no significant effect of any factor. There was no sphericity violation (Mauchley's test, $P = 0.78$) and the ANOVA showed no significant effect of time ($F_{2,12} = 2.03$, $P = 0.173$), treatment ($F_{1,6} = 2.01$, $P = 0.206$), or time × treatment ($F_{2,12} = 0.86$, $P = 0.446$) on the change in ramet numbers relative to those counted in 2000. Despite this, there was a trend in the data for the change in ramet numbers to be greater in the cut plots (Table 2). Due to large variation in the data and the small sample size, the statistical power of our analysis was low, and so it is worthwhile to point out this trend as perhaps indicating an effect that a larger study would have been able to statistically confirm.

Seedling data showed a significant treatment effect. The sphericity assumption was not violated (Mauchley's test, $P = 0.386$) and the ANOVA showed that time and the time × treatment interaction were not significant ($F_{2,12} = 2.07$, $P = 0.169$ and $F_{2,12} = 1.31$, $P = 0.306$, respectively). However, treatment was significant ($F_{1,6} = 7.47$, $P = 0.034$) and mean percent change in seedling numbers showed consistently more seedlings in the cut plots during each post-treatment year (Table 2). Follow up ANOVAs indicated a significant treatment effect for the second year ($F_{1,6} = 6.084$, $P = 0.049$), but non-significant effects for the first and third years ($F_{1,6} = 2.19$, $P = 0.190$, and $F_{1,6} = 4.13$, $P = 0.088$, respectively). Overall, the average increase in seedling numbers during the three post-treatment years was ca. 2,400% in cut plots and 200% in uncut plots. The large values for percent change in Table 2 reflect the very few seedlings encountered during our pre-treatment census in 2000. It should also be noted that seedling production was very localized in the B subplots, usually occurring in openings of the plant cover on exposed mineral soil associated with a seepage area. Because seedlings are very small and were not marked or monitored individually, it is not known if any became established and thus became new recruits into the population.

In the *Xyris*-absent plots (i.e., located on the margins of the population with little or no obvious *Xyris* initially present) there was very little observed rootstock/ramet proliferation, and no seedling recruitment, over the course of the study. The only cut *Xyris*-absent plot to experience a flowering spike was in A3 (southwest corner of the population/site) where a total of 8 flowering spikes were produced on approximately five ramets during the period 2001-03. There was also a small clump (≈ 5 ramets) discovered in the A1 Uncut plot (northwest corner of the population/site) that produced four flowering spikes in 2000, but never flowered again (although the ramets persisted through the end of the study).

Xyris *Annual Flowering Spike Census*

Total number of censused flowering spikes varied during the course of the study from a low of 1,188 in 2000 to a high of 3,746 during 2001. The low corresponds to the pre-treatment year and the high reflects the dramatic first-year response to clearing/thinning. Flowering spike levels returned to pre-treatment levels (i.e., 1999 and 2000) by 2003 (Fig. 4).

Species List for Site

The species list for the site is provided in Table 3. Many of these species are typical wetland plants or associates of *X. tennesseensis* as documented by surveys of other localities (Boyd et al. 2000).

Seed Bank Study

The total count of species germinated from the seed bank soil samples was 47 (Table 4). A total of 4,045 seeds germinated during the 36-month seed bank study, yielding a germinated seed density of 32,726 seeds/m^2 (28 samples × 44.2 cm^2/sample = 0.124 m^2 total soil core surface area). No seedlings of *X. tennesseensis* were found, indicating that there is no *Xyris* seed bank on this site. Most of the species in the seed bank are typical for this type of site. For example, the large number of seedlings of *Juncus* and Cyperaceae species is expected for a moist seep habitat.

Floral Visitor Study

Xyris flowers were visited by a number of insect species (Table 5). However, the vast majority of visits (86%) were made by the bee *Lasioglossum zephyrum* and the fly

Ocyptamus fuscipennis. Two other fly species, both in the genus *Toxomerus*, contributed another 11% of floral visits. Other fly species, bee species and even a butterfly species occasionally visited flowers, but all of their visits combined comprise less than 3% of the total visits recorded (Table 5).

The effect of treatment and time differed with respect to floral visitation. As there was no violation of the sphericity assumption (Mauchley's test, $P = 0.077$), I proceeded with the ANOVA approach. Because of the complexity of this analysis, I will summarize the results in Table 6. The significance of the time factor in the analysis indicates that visitation numbers varied between years, but that result may be due to larger-scale fluctuations in conditions during the days on which we censused visits in each year. The significant treatment result shows that treatments resulted in significant variation in insect visitation to *Xyris* flowers. When expressed as visits per bloom cycle (*Xyris* blooms for roughly two hours during each day), the mean visitation rate for flowers in the cut plots was 11.2 (SE = 1.2) visits per flower whereas for the uncut plots it was 7.5 (SE = 1.1) visits per flower.

The frequency of individual visitor species (Table 5) illustrates that some species were much more frequent floral visitors than others; the statistical significance of this is reflected in Table 6. Other significant results, for time × species and the 3-way interaction, indicate that visitor species varied in their frequency of visits in complex ways that cannot be explained easily with the data available. Our observations of visitor behavior indicate that different visitors may have different effects on *Xyris* pollination. Bees visited flowers to collect pollen and probably serve as effective pollinators. Flies often visited flowers to consume pollen, frequently while hovering. This activity pattern casts doubt on the effectiveness of flies on pollination of *X. tennesseensis* flowers.

DISCUSSION

Early successional habitats (communities dominated by shrubs, graminoids and forbs) are maintained naturally by a variety of disturbance regimes/events that retard or set back successional forces. Thompson and Degraf (2001) discuss the maintenance of most successional communities in the eastern U.S. as requiring periodic disturbance, although some successional communities tend to be more stable than others and "resist" succession. These are described as very hydric sites that are saturated or covered with water for long periods during the growing season (e.g., shrub wetlands) and xeric or shallow-soiled sites (e.g., barrens and glades), with most other communities that fall within these extremes experiencing more rapid succession.

Removal, exclusion, and reduction of disturbance events/forces from natural communities allow succession to proceed unabated. Open-canopy wetlands (including calcareous seep and fen systems), unless disrupted by fire, beaver activity, grazing, or periodic wet years, will experience an invasion of woody vegetation and transition into a closed canopy wetland system, unsuitable for many species (Murdock 2004; Natural Resources Conservation Service 2006). Fire suppression, both active and passive (Bragg and Hulbert 1976; Briggs et al. 2002), extirpation of beavers (Thompson and Degraf 2001), and abandonment of historical farm and pastureland (Litvaitis et al. 1993; Trani et al. 2001) have encouraged succession and the loss of many early successional habitats. An assessment by Noss (1995) of the status of ecosystems in the U.S. identified 41 ecosystems that have declined in area by more than 98%, with the greatest losses occurring in the South, Northeast, Midwest, and California. Although primarily due to land development, fire suppression has contributed substantially to this decline (Thompson and Degraf 2001). Fire frequency in wetlands is less than in upland systems, nevertheless, fire suppression is a threat to wetland/fen communities by encouraging the encroachment of woody vegetation with an accompanying increase in shading and drying (i.e., enhanced transpiration) (Nature Conservancy 2008) and changes in soil nutrient levels and pH (Bekele et al. 2006).

In the absence of naturally occurring disturbance regimes, the use of anthropogenic methods to mimic these events may be necessary to retard successional forces. Numerous habitat management techniques have been used to reduce competition and counter succession. These include prescribed fire and mechanical methods, such as chaining, cabling, scalping, disk/plow tillage, and chainsaw felling, as well as herbicide application (Yoakum et al. 1980). The efficacy of "management-disturbance," particularly single applications, is questionable. Research has demonstrated a dependency of disturbance success on a host of factors, including species life history, plant age class, post-disturbance weather, seasonality of disturbance application, and the intensity and frequency of disturbance (Owens et al. 2007). Prescribed fire is a preferred management tool for systems where fire was historically the predominant disturbance factor (Lewis et al. 1981). However, since logistical, legal, and liability concerns frequently render the use of this technique impractical (Thompson and Degraf 2001), manual/mechanical techniques of woody competition removal are frequently favored by land managers. Utilization of manual techniques can be found in settings as varied as calcareous prairies of Louisiana (Hyatt 1999), bog-turtle inhabited fens of New Jersey (New Jersey Division of Fish and Wildlife 2008), tallgrass prairies in Illinois (United States Forest Service 1997), and lakeshore fens of western Switzerland (Güsewald and Le Nédic 2004).

The *Xyris* response study showed that cutting overstory *Hypericum* significantly stimulated flower spike production. This stimulatory effect lasted two years but, by the third year, recovery of the *Hypericum* and an increase in other herbaceous species appeared to suppress the *Xyris* population once more. The rapid return of woody competition due to coppice sprouting was not unexpected given the lack of herbicide application to cut surfaces (DiTomaso 1997). However, the rapid, and more importantly, overwhelming response of graminoids and forbs was unexpected.

The *Xyris* response study also showed a significant increase in seedling production but not in ramet numbers. The increase in seedlings was greater in years 2 and 3, suggesting a lag between flower production and seedling production in the plots. However, despite the significant increase in seedling production, it is not known whether seedlings survived to become established plants. I found no significant increase in ramet numbers in the B subplots over time, although the analysis was hampered by low sample size and extensive variation in the dataset.

There was no evidence of a *Xyris* seed bank on this site. This conflicts with greenhouse studies performed by Baskin and Baskin (2003) which indicated a small persistent seedbank for *X. tennesseensis*. The discrepancy may be the result of different methodologies used, with their samples being lifted as intact as possible from the ground, immediately fitted into flats and not disturbed, while ours were air-dried for two days and then crumbled over autoclaved soil. Or perhaps, the lack of a demonstrated seed bank at the Interstate Hypericum Springs site reflects high levels of granivory, destructive frugivory, or seed parasitism. *Xyris* spike heads have been documented as a top-10 food item of wild turkey (*Meleagris gallopavo*) in various habitats in Florida (Schemnitz 1956). Additionally, the presence of both cotton rats (*Sigmodon hispidus*) and damaged flowering scapes (i.e., spike heads missing and only partial scapes visible) were observed on multiple occasions in years during and after the study (Moffett, pers obs.).

From a management perspective, this implies that any additional seedling establishment on cleared sites will come from seeds produced after sites are cleared. Given the lack of any *Xyris* growth or recruitment in the *Xyris* Absent plots, there appears to be no benefit to the *Xyris* population of clearing areas outside the major population boundary. No suppressed plants or seed bank was found that would allow significant population expansion in areas outside the *Xyris*-containing seeps. Baskin and Baskin (2003) also found the germinated seedlings to be extremely short-lived (i.e. most survived less than a month). While not specifically related to the results presented in this chapter, this finding, if applicable to seed germination/survival *in situ*, could present additional problems for recovery of this species.

Floral visits per flower were significantly increased in the cut plots. This may be due to the more open habitat, the greater density of flowering spikes, or other features that differed between cut and un-cut plots. Unfortunately, the importance of floral visitors to the population biology of *Xyris* is unclear. Boyd et al. (2000) found that seed set was greatest for flowers that were outcrossed, but that seed germinability was greatest for flowers that were self-pollinated. They also reported that *Xyris* seed set was relatively large for flowers that were enclosed in bags, so that this species apparently does not require floral visitors to set seed. North American xyrids possess no nectaries and the pollen reward is slight, and may rely primarily on pollination by wind or selfing (Kral 2000). This would be consistent with Boyd et al. (2000), but would contradict Walker-Larsen and Harder (2000) who maintain that the presence of functional staminodes in the Xyridaceae (and certain genera in the allied Commelinaceae) mimics large amounts of pollen and may stimulate bees to perform pollen-collecting activities. At least one insect, a solitary bee *Lasioglossom zephyrum* (Smith), has been shown to aggressively collect pollen by initiating pre-mature anthesis (i.e. removing the sheath-like sepal surrounding the bud) in an effort to gain first access to floral rewards (Wall et al. 2002). Since this activity occurs pre-anthesis, the staminodes would be unavailable to attract pollinators at this point, but they still might serve to stimulate the bee once they become visible.

It seems likely from our research that floral visitors play some role in genetic exchange among *Xyris* flowers within a population. Small populations of plants frequently suffer from limited genetic exchange (Frankham et al. 2002) and have been shown to have lower genetic diversity and increased homozygosity in many cases (Ouberg et al. 2006). Pollinator behavior may have a substantial influence on gene flow within and among plant populations (Goddell et al. 1997) and, to this end, increased floral visitation as shown in our research may improve the fitness of a *Xyris* population.

Additionally, *Xyris* may actually benefit in the long run from its association with *Hypericum*, as opposed to suffering from it. The impetus for this study was the observation that 50% of the *Xyris* population was shaded by a *Hypericum* thicket and that nearly all of the shaded *Xyris* was purely vegetative. However, it bears mentioning that while persisting only vegetatively, it persisted nonetheless. In fact, the *Xyris* persisted rather robustly, and there was an observed dearth of other graminoid and forb competitors. It may well be that the *Hypericum* provides refuge from the thick/aggressive graminoid and forb growth that outcompetes *Xyris* individuals. *Hypericum* could allow *Xyris* to persist until such time that a naturally occurring disturbance (i.e. fire, scouring flood, rockslide, etc.) creates suitable microsites nearby. In this regard, *Hypericum* may function somewhat analogously to a nurse plant by providing refuge to individuals of another species, although the term nurse plant *sensu strictu* refers to the facilitation of seedling survival (Castro et al. 2002).

MANAGEMENT IMPLICATIONS

General Management Recommendations

Management recommendations for the *Xyris tennesseensis* population on this site are based on the following: 1) the results of this study; 2) the results of a similar study involving graminoid and herbaceous competition on Pelham Range in Anniston, AL; 3) personal observations of J. Mincy Moffett at approximately 85% of all known *Xyris tennesseensis* sites; and 4) a desire to provide an effective, yet "low-impact" management strategy with respect to *Xyris* and its calcareous seep/fen associates (particularly *Hypericum interior*).

Removing woody competition is necessary to set back the natural processes of succession. Alone, however, it is insufficient to promote the continued existence, or expansion, of the *Xyris* population on this site. While the existing *Xyris* plants are quick to exploit the reduction in woody competition, the effect is short-lived as graminoids and herbs rapidly recruit into the area and begin to outcompete *Xyris*. Consequently, in order for *Xyris* to persist in a given area, it must have access to additional suitable microsites for seedling recruitment and ramet proliferation. A suitable microsite is considered to be a sunny, continually wet, disturbed/exposed patch of mineral soil. The effect over time is for individual patches of *Xyris* to flow or move "amoeba-like" into suitable microsites and away from increased competition across the overall site, reminiscent of classic fugitive species metapopulation dynamics (Hanski and Zhang 1993).

As mentioned in the discussion above, *Xyris* may actually benefit from its association with *Hypericum*. Therefore, there is reason to be judicious in the management of *Hypericum*, suggesting the need for a "periodic thinning" or "pruning" rather than a "total removal" approach. Other woody species, however, have not shown a potential benefit to *Xyris*, and should not be accorded the same leniency.

It should also be remembered that *Xyris* is just one of a number of rare or unusual plants that inhabit these rare calcareous seep/fen habitats. Others include *Carex hystericina, Hypericum interior, Juncus brachycephalus, Lysimachia quadriflora, Ludwigia microcarpa, Mecardonia acuminata, Mitreola petiolata, Rhynchospora thornei,* and *Rudbeckia fulgida*. Although not protected under federal law, every effort should be made to minimize the impact of site management on this special habitat and *Xyris*' numerous floral associates.

Specific Management Recommendations

The management strategy should consist of a three-pronged approach: 1) *Hypericum* management; 2) other woody species management; and 3) *Xyris* management. The dense stands or thickets of *Hypericum* need to be reduced, but in a manner that will allow them to provide refuge from competition for portions of the *Xyris* population. To aid this effort, the site should be divided into 4 management zones (A, B, C, and D) (Fig. 5). These zones are all approximately the same size (≈ 35-40m^2) and are designed to incorporate areas of current *Xyris* growth. There were a very small number of *Xyris* plants found in the *Xyris*-Absent plots, and were almost certainly pre-existing individuals that we did not notice during our initial surveys of these densely vegetated plots and do not represent new recruitment. Thus, we have no evidence that suppressed *Xyris* individuals or a seed bank exist that would justify clearing of areas outside of the boundaries of the *Xyris* population of this site.

Hypericum management should consist of manually cutting back the shrubs to just above the ground. This should ideally be performed in late winter while plants are still dormant, but at a time when any growth resulting from a stimulatory effect of the pruning would have a better chance of avoiding a hard freeze. There should be no herbicide treatment to any part of the *Hypericum* so that they will be able to re-grow. *Hypericum* management should be performed once every three years in each management zone, creating a 12-year rotation for the entire site (Table 7).

Management of the other woody species and *Xyris* should be an annual event. Once a year during very late summer (mid-September), a survey of the entire site (i.e., all management zones) should occur. Any non-*Hypericum* woody plant should be cut to the ground or uprooted (if size permits). We judge this to be a relatively minor task, since our experience over the three years of this study has been the recruitment of very few non-*Hypericum* woody individuals into the study plots (i.e., five or six *Acer rubrum* and *Salix nigra)*.

Xyris management should occur at the same time as management of the other woody species (mid-September). It should consist of the creation of four (one per management zone) small exposed patches of mineral soil next to, but not on top of, existing patches of *Xyris*, after which seeds from nearby mature *Xyris* spikes can be hand-sown into these patches. Patches may be created by vigorously scratching the ground using a heavy garden or utility rake, and may vary in size from 0.25 m^2 (0.5 m × 0.5 m) to 0.0625 m^2 (0.25 m × 0.25 m). The idea is to keep them small so as not to encourage erosion on the seep slopes, and to only disturb as much soil as is necessary to remove the graminoids, herbs, and organic matter/debris. Care should be taken to alter the microsite topography as little as possible. Hand sowing of seeds is accomplished by manually removing the spikes and then crushing or "hand-rolling" them between the palms while holding them above the patches. This activity will be adequate to force the fruits from the bracts and the seeds from the fruits. Each patch should be seeded with 20 spikes which should provide somewhere between 10,000 and 40,000 total seeds (10-20 fruits per spike; 50-100 seeds per fruit). The patches should be subjectively placed from year to year so they are "spread out" within a management zone (i.e., not adjacent to last year's patch). This management activity will require someone on site with the ability to correctly identify *Xyris* and delineate its occurrence (i.e., patches/clumps) within the management plot. The purpose of these *Xyris* management plots is to encourage recruitment of new seedlings into the population of each management site. Since we have observed seedlings primarily on patches of moist soil, and since the cutting of the *Hypericum* will stimulate growth of other herbaceous plants, this technique will provide the opportunity for *Xyris* seedling establishment and the recruitment of new plants into the population. A limited pilot study using this approach of direct-sowing by hand was conducted in at the Lloyd's Chapel Swale site on Pelham Range in Anniston, AL, with successful results.

Delineation of Management Area and Plots

The overall management area should include all areas of the study site with active or recently active seeps and some *Xyris* present nearby. On the north side of the culvert, the management area would encompass the study plot areas formerly labeled X1(Cut)/(Uncut), X2(Cut)/(Uncut), and areas in-between and; on the south side it would include the study plot areas X3(Cut)/(Uncut), X4(Cut)/(Uncut) and areas in-between. However, the management area would only extend 4 m upslope from the culvert, as opposed to 5.75 m (the depth of the study plots). Areas above 4 m are outside the area of influence of the seeps and do not possess the appropriate hydrology for the establishment or maintenance of a *Xyris* population. The management area north of the culvert would be divided into two management plots, labeled A and B; the area south of the culvert would likewise be divided into two plots, labeled C and D. Figure 5 shows the appropriate boundaries of the four proposed management plots.

It should be mentioned that there are a couple of small areas on the western edge of the population that are outside of the seep complex and support a few (5-10) ramets of *Xyris*. They exist along (or near) a south-flowing spring run that flows into the culvert at approximately the A1 (Uncut)/(Cut) experimental plot border. We believe that this area, while containing adequate moisture, *Hypericum* and *Xyris*, is fundamentally different from the seepy slopes. It has deeper, muckier soils, and is much wetter. The A1 (Cut) plot rebounded rapidly after clearing with an almost jungle-like growth of *Carex* spp., *Juncus* spp., *Lonicera japonica, Ludwigia alterniflora, Mikania scandens, Solidago* spp., *Rubus* sp., and other assorted herbs and vines. It would undoubtedly prove a daunting management task to keep that area of the site free from competing vegetation. Therefore, we recommend excluding it from the management area.

Table 1. Results of MANOVA analysis (using Wilk's Lambda) of changes in flowering spike numbers in cut plots at Interstate Hypericum Springs, Bartow Co., GA. Changes in numbers of flowering spikes were evaluated between treatment groups and across time annually from 2000 (pre-treatment) through 2003 (post-treatment). A significant violation of the sphericity assumption (Mauchley's Test) dictated the abandonment of the repeated measures mixed model factorial ANOVA approach.

Factor	F-value	Degrees of freedom	P-value
Time	7.29	2, 27	0.003
Treatment	3.13	3, 26	0.043
Subplot	1.08	12, 84	0.394
Time × treatment	3.51	2, 27	0.044
Time × subplot	0.57	8, 56	0.800
Subplot × treatment	1.35	12, 84	0.205
Time × subplot × treatment	1.37	8, 56	0.233

Table 2. Mean percent change in values of three response variables (spikes, ramets, and seedlings) by treatment (cut and uncut) from the habitat restoration, *Xyris* response study at Interstate Hypericum Springs, Bartow, Co., GA. Standard errors are given in parentheses. Asterisks indicate a significant treatment effect between pairs of means for cut and uncut plots. N = 8

		Response Variables		
Year	**Treatment**	**Spikes**	**Ramets**	**Seedlings**
2001 vs. 2000	**Cut**	235% (69%)*	16% (13%)	1,100% (720%)
	Uncut	19% (13%)*	3.75% (19%)	27% (94%)
2002 vs. 2000	**Cut**	138% (51%)*	17% (17%)	3,250% (1,240%)*
	Uncut	18% (16%)*	-21% (21%)	168% (155%)*
2003 vs. 2000	**Cut**	1% (15%)	6% (20%)	2,963% (1,242%)
	Uncut	-19% (6%)	-33% (15%)	409% (188%)

Table 3. Site plant species list from Interstate Hypericum Springs, Bartow, Co., GA.

Family	**Species name**	**Common name**
Aceraceae	*Acer rubrum* L.	Red Maple
Aizoaceae	*Mollugo verticillata* L.	Carpetweed
Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	Poison-Ivy
Asteraceae	*Aster dumosus* L.	Bushy Aster
	Cirsium sp.	Thistle
	Conyza canadensis (L.) Cronq.	Horseweed
	Eclipta prostrata (L.) L.	Eclipta
	Erechtites hieraciifolia (L.) Raf. ex DC	Fireweed
	Erigeron quercifolius Lam.	Oakleaved Fleabane
	Eupatorium capillifolium (Lam.) Small	Dogfennel
	Eupatorium perfoliatum L.	Boneset
	Eupatorium mohrii Greene	Throughwort
	Eupatorium serotinum Michx.	Late Boneset
	Gamochaeta purpurea (L.) Cabrera	Purple Cudweed
	Leucanthemum vulgare Lam.	Oxeye daisy
	Packera anonyma (Alph. Wood). W.A. Weber & A. Löve	Ragwort
	Pseudognaphalium obtusifolium (L.) Hillard & B.L. Burtt	Fragrant Cudweed
	Helianthus angustifolius L.	Swamp Sunflower
	Mikania scandens (L.) Willd.	Climbing Hempweed
	Rudbeckia fulgida Ait.	Black-eyed Susan

Table 3. Study site plant species list Interstate Hypericum Springs, Bartow, Co., GA. (cont.).

Asteraceae	*Solidago gigantea* Ait.	Giant Goldenrod
	Solidago patula Muhl. ex Willd	Goldenrod
	Sonchus asper (L) Hill	Spiny Sowthistle
	Vernonia angustifolia Michx.	Ironweed
Brassicaceae	*Cardamine hirsuta* L.	Bitter Cress
	Nasturtium officinale W.T. Aiton	Water Cress
Campanulaceae	*Lobelia amoena* Michx.	Lobelia
	Lobelia puberula Michx.	Downy Lobelia
	Triodanis biflora (Ruiz & Pav.) Greene	Venus' Looking Glass
Caprifoliaceae	*Lonicera japonica* Thunb.	Japanese Honeysuckle
	Sambucus nigra L. ssp. *canadensis* (L.) R. Bolli	Elderberry
Clusiaceae	*Hypericum interior* Small	St. John's-Wort
	Hypericum mutilum L.	St. John's-Wort
Cyperaceae	*Carex granularis* Muhl. ex Willd	Sedge
	Carex hystericina Muhl. ex Willd	Sedge
	Carex lurida Wahlenb.	Sedge
	Carex vulpinoidea Michx.	Sedge
	Cyperus flavescens L.	Flatsedge
	Cyperus strigosus L.	Flatsedge
	Eleocharis obtusa (Willd.) Schult.	Spike rush

Table 3. Study site plant species list from Interstate Hypericum Springs, Bartow, Co., GA. (cont.).

Cyperaceae	*Fimbristylis autumnalis* (L.) Roemer & J.A. Schultes	Fringe Rush
	Fimbristylis millacea (L.) Vahl	Fringe Rush
	Rhynchospora caduca Ell.	Beak Rush
	Rhynchospora capillacea Torr.	Beak-Rush
	Rhynchospora glomerata (L.) Vahl	Beak-Rush
	Rhynchospora thornei Kral	Beak-Rush
	Scleria verticillata Muhl. ex Willd	Nut-Rush
Fabaceae	*Chamaecrista fasciculata* (Michx.) Greene	Partridge Pea
	Lespedeza cuneata (Dum. Cours.) G. Don	Lespedeza
Gentianaceae	*Sabatia angularis* (L.) Pursh.	Marsh Pink
	Sabatia quadrangula Wilbur	Marsh Pink
Haloragaceae	*Myriophyllum spicatum* L.	Eurasian Water-Milfoil
Juncaceae	*Juncus coriaceus* Mackenzie	Bog Rush
	Juncus marginatus Rostk.	Bog Rush
	Juncus brachycephalus (Engelm.) Buch.	Bog Rush
Lemnaceae	*Lemna* sp.	Duckweed
Loganiaceae	*Mitreola petiolata* (J.F. Gmel.) Torrey & A. Gray	Mitrewort
Lythraceae	*Rotala ramosior* (L.) Koehne	Toothcup
Onagraceae	*Ludwigia alternifolia* L.	Seed-Box

Table 3. Study site plant species list from Interstate Hypericum Springs, Bartow, Co., GA. (cont.).

Onagraceae	*Ludwigia microcarpa* Michx.	Evening Primrose
	Ludwigia palustris (L.) Elliott	Floating Primrose
Pinaceae	*Pinus taeda* L.	Loblolly Pine
Platanaceae	*Platanus occidentalis* L.	Sycamore
Poaceae	*Andropogon glomeratus* (Walt.) B.S.P.	Bushy Bluestem
	Andropogon virginicus L.	Broomsedge
	Arthraxon hispidus (Thunb.) Makino	Small Carpgrass
	Festuca spp.	Fescue
	Glyceria striata (Lam.) A.S. Hitch.	Manna Grass
	Leersia virginica Willd.	Cutgrass
	Microstegium vimineum (Trin.) A. Camus	Nepalese Browntop
	Panicum spretum (Schult.) Freckmann	Panic Grass
Polygonaceae	*Polygonum hydropiper* L.	Smartweed
	Polygonum pensylvanicum L.	Pinkweed
	Polygonum setaceum Baldw.	Smartweed
	Rumex crispus L.	Dock
Primulaceae	*Lysimachia quadriflora* Sims.	Bog Loosestrife
	Samolus parviflorus Raf.	Water Pimpernel
Ranunculaceae	*Clematis virginiana* L.	Virgin's Bower
Rosaceae	*Prunus serotina* Ehrh.	Black Cherry
	Rubus trivialis Michx.	Blackberry/Dewberry

Table 3. Study site plant species list from Interstate Hypericum Springs, Bartow, Co., GA. (cont.).

Rubiaceae	*Galium tinctorium* (L.) Scop.	Bedstraw
	Galium hispidulum Michx.	Fleshy-fruit Bedstraw
Salicaceae	*Salix nigra* Marsh.	Black Willow
Scrophulariaceae	*Mecardonia acuminata* (Walt.) Small	Mecardonia
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	False Nettle
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia Creeper
	Vitis cinerea (Englem.) Englem. ex Millard	Pigeon Grape
	Vitis rotundifolia Michx.	Muscadine

Table 4. Plant species germinating from the seed bank study soil cores taken from Interstate Hypericum Springs, Bartow Co., GA. The percent seedlings column reflects that species' percentage of the 4045 seedlings that germinated. National Wetland Inventory status is provided using the following codes based on percentage of a species' natural occurrences found in wetlands: OBL (Obligate ≥ 99%); FACW (Facultative Wetland = 67% - 98%); FAC (Facultative = 34% - 66%); FACU (Facultative Upland = 1% - 33%); UPL (Upland < 1%); modifiers (+) and (-), indicate the higher and lower ends of ranges, respectively.

Family	**Species**	**Wetland Code (USFWS)**	**Percent Seedlings**
Aizoaceae	*Mollugo verticillata* L.	FAC	0.12%
Asteraceae	*Aster dumosus* L.	FAC	0.12%
	Conyza canadensis (L.) Cronq.	UPL	0.07%
	Eclipta prostrata (L.) L.	FACW-	0.20%
	Erechtites hieraciifolia (L.) Raf. ex DC	FAC-	0.17%
	Erigeron quercifolius Lam.	FAC+	0.05%
	Eupatorium capillifolium (Lam.) Small	FACU	0.05%
	Eupatorium mohrii Greene	FACW-	0.05%
	Eupatorium serotinum Michx.	FAC	0.10%
	Gamochaeta purpurea (L.) Cabrera	UPL	0.10%
	Pseudognaphalium obtusifolium (L.) Hillard & B.L. Burtt	No ranking	0.32%
	Helianthus angustifolius L.	FAC+	0.02%

Table 4. Plant species germinating from the seed bank study soil cores (cont.).

	Mikania scandens (L.) Willd.	FACW+	0.82%
	Rudbeckia fulgida Ait.	FAC+	0.20%
	Solidago gigantea Ait.	FACW	0.20%
	Sonchus asper (L.) Hill.	FAC+	0.05%
	Vernonia angustifolia Michx.	FACU-	0.05%
Brassicaceae	*Cardamine hirsuta* L.	FAC	0.02%
Campanulaceae	*Lobelia puberula* Michx.	FACW-	0.10%
Clusiaceae	*Hypericum interior* Small	FACW-	11.42%
Cyperaceae	*Carex granularis* Muhl. ex Willd.	FACW	3.46%
	Carex hystericina Muhl. ex. Willd.	OBL	0.22%
	Carex vulpinoidea Michx.	OBL	0.25%
	Cyperus strigosus L.	FACW+	0.10%
	Fimbristylis autumnalis (L.) Roemer & J.A. Schultes	OBL	0.10%
	Rhynchospora caduca Ell.	OBL	0.42%
	Rhynchospora capillacea Torr.	OBL	0.02%
	Rhynchospora thornei Kral	No ranking	0.07%
	Scleria verticillata Muhl. ex. Willd.	OBL	0.10%
Juncaceae	*Juncus coriaceus* Mackenzie	FACW	71.17%
	Juncus marginatus Rostk.	FACW	0.30%
	Juncus brachycephalus (Engelm.) Buch.	OBL	1.33%
Loganiaceae	*Mitreola petiolata* (J.F. Gmel.) Torrey & A. Gray	FACW+	0.07%

Table 4. Plant species germinating from the seed bank study soil cores (cont.).

Onagraceae	*Ludwigia alternifolia* L.	OBL	0.02%
	Ludwigia microcarpa Michx.	OBL	4.13%
Poaceae	*Andropogon glomeratus* (Walt.) B.S.P.	FACW+	0.22%
	Festuca spp.	No ranking	0.02%
	Glyceria striata (Lam.) A.S. Hitchc.	OBL	0.30%
	Leersia virginica Willd.	FACW	0.25%
	Panicum spretum (Schult.) Freckmann	No ranking	0.05%
Polygonaceae	*Rumex crispus* L.	FAC	0.02%
Primulaceae	*Lysimachia quadriflora* Sims.	OBL	0.30%
	Samolus parviflorus Raf.	OBL	0.25%
Rosaceae	*Rubus trivalis* Michx.	No ranking	1.53%
Rubiaceae	*Galium tinctorium* (L.) Scop.	FACW	0.25%
	Galium hispidulum Michx.	No ranking	0.02%
Scrophulariaceae	*Mecardonia acuminata* (Walt.) Small	FACW	0.42%
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	FACW+	0.35%

Table 5. Frequency of visits by all floral visitor taxa to *Xyris* flowers in both cut and uncut plots during all years (2001-2003) of the habitat restoration study at Interstate Hypericum Springs, Bartow Co., GA.

Order: Family (if known)	**Taxon (or field name if no specimen collected)**	**Percent of all visits**
Hymenoptera: Halictidae	*Lasioglosssum zephyrum*	60.65%
Diptera: Syrphidae	*Ocyptamus fuscipennis*	25.25%
Diptera: Syrphidae	*Toxomerus geminatus*	7.85%
Diptera: Syrphidae	*Toxomerus boscii*	3.34%
Hymenoptera: Halictidae	*Agapostemon* sp.	1.43%
Hymenoptera: Bombidae	*Bombus* sp.	0.56%
Diptera: Syrphidae	Large syrphid	0.35%
Diptera: Unknown	Golden fly	0.3%
Hymenoptera: Unknown	Large black bee	0.04%
Diptera: Unknown	Small black fly	0.04%
Coleoptera: Curculionidae	Weevil	0.09%
Lepidoptera: Hesperiidae	Skipper	0.09%

Table 6. Results of statistical analysis floral visitation data from the 3-year study at Interstate Hypericum Springs, Bartow Co., GA. The analysis was a repeated measures mixed model 2 × 7 factorial ANOVA.

Factor	F-value	Degrees of freedom	P-value
Time	11.5	2, 644	<0.001
Treatment	4.91	1, 322	0.027
Visitor species	31.5	6, 322	<0.001
Time × treatment	0.492	2, 644	0.618
Time × visitor species	10.4	12, 644	<0.001
Treatment × visitor species	0.849	6, 322	0.533
Time × treatment × visitor species	3.85	12, 644	<0.001

Table 7. Management schedule for the *X. tennesseensis* population at the Interstate Hypericum Springs site, Cartersville, GA

Year	Month	Management Activity
2004	March (mid)	1) Initial Management Area and Plot Delineation 2) *Hypericum* Management (Plot A)
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2005	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2006	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2007	March (mid)	*Hypericum* Management (Plot B)
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2008	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2009	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2010	March (mid)	*Hypericum* Management (Plot C)
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management

Table 7. Management schedule for the *X. tennesseensis* population at the Interstate Hypericum Springs site, Cartersville, GA (cont.).

2011	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2012	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2013	March (mid)	*Hypericum* Management (Plot D)
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2014	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2015	March (mid)	No Management Activity
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management
2016	March (mid)	REPEAT Management Rotation *Hypericum* Management (Plot A)
	September (mid)	1) Other Woody Species Management 2) *Xyris* Management

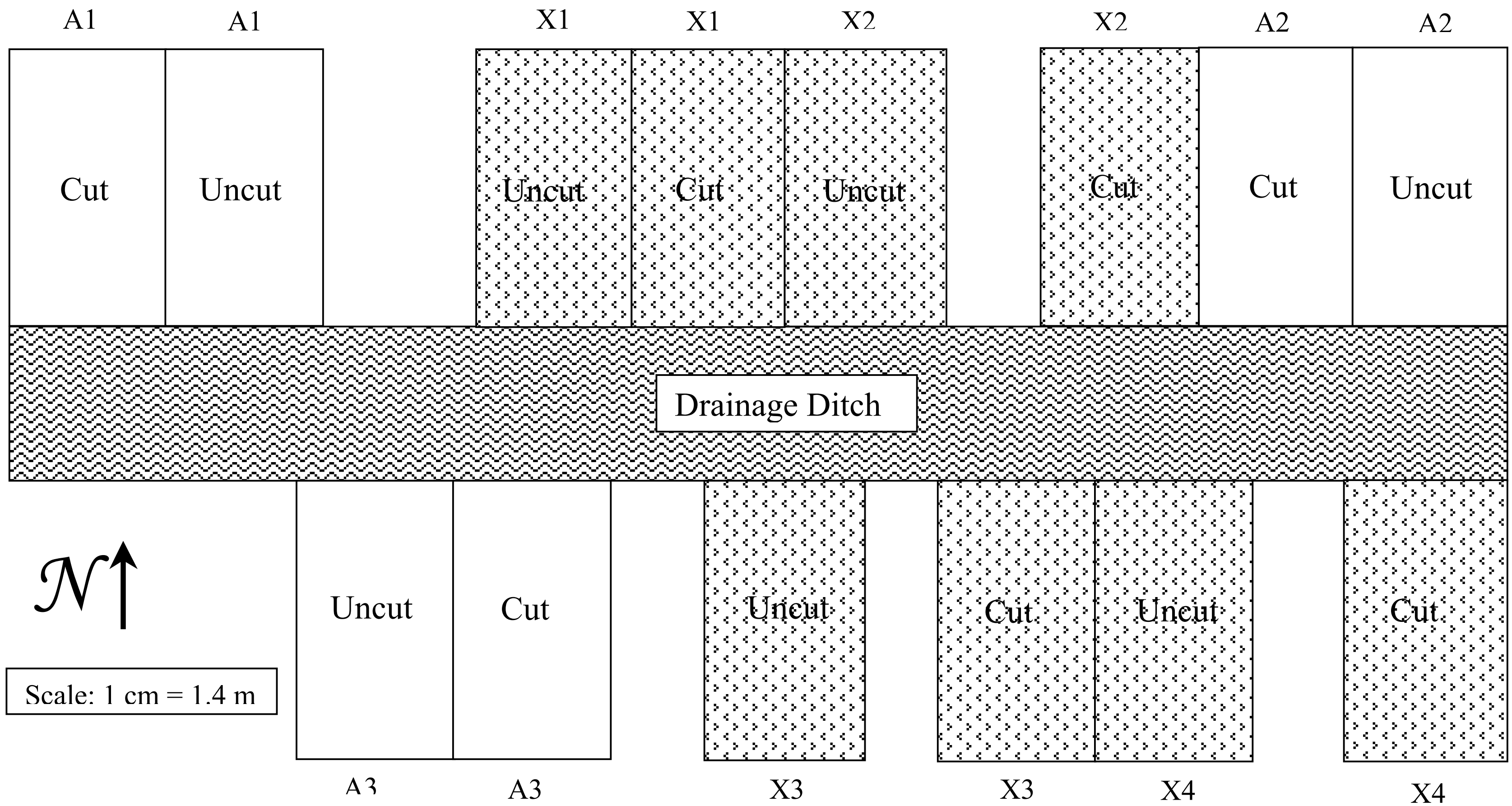


Figure 1. Plot map of the *X. tennesseensis* management study at the Interstate Hypericum Springs site, Cartersville, GA. Study plots with codes beginning with "X" had *Xyris* present at the beginning of the study period. Study plots with codes beginning with "A" were absent any identifiable *Xyris*. Study plots are in pairs with respect to the two treatments (i.e., cut and uncut). Cut plots had all woody stems cut to ground level. Uncut plots received no treatment. Overall, there were four pairs of *Xyris*-present plots (X1, X2, X3, and X4), and three pairs of *Xyris*-absent plots (A1, A2, and A3).

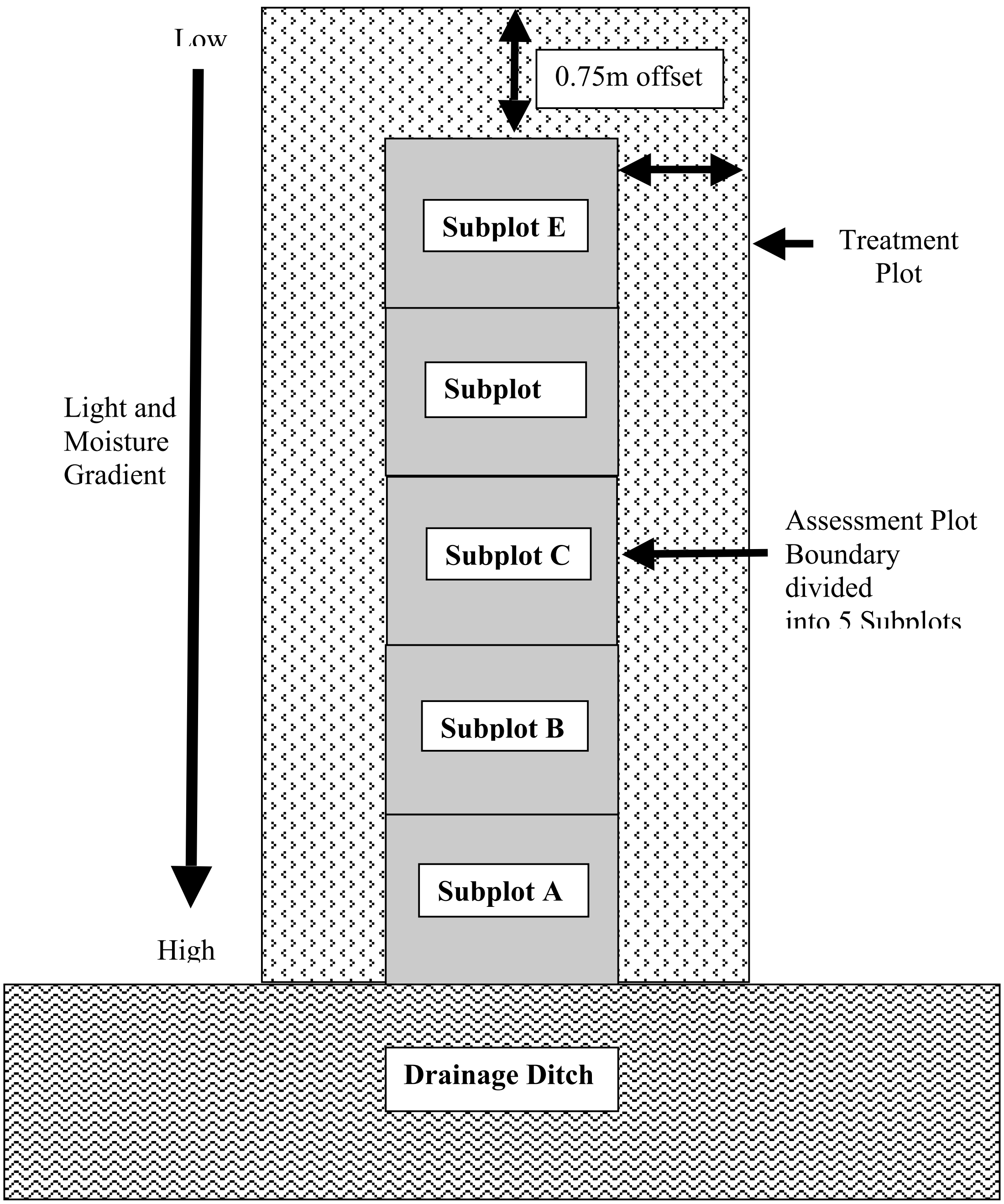


Figure 2. Treatment plot map showing subplots. Each treatment plot is 3.0 m × 5.75 m in size. The assessment plot from which data were collected is 1.5 m × 5.0 m in size. The subplots are arranged along a light and moisture gradient that extends from the relatively dry and shaded area (i.e., *Hypericum* thicket) area near subplot E to the wetter and more open area near subplot A (i.e., drainage ditch).

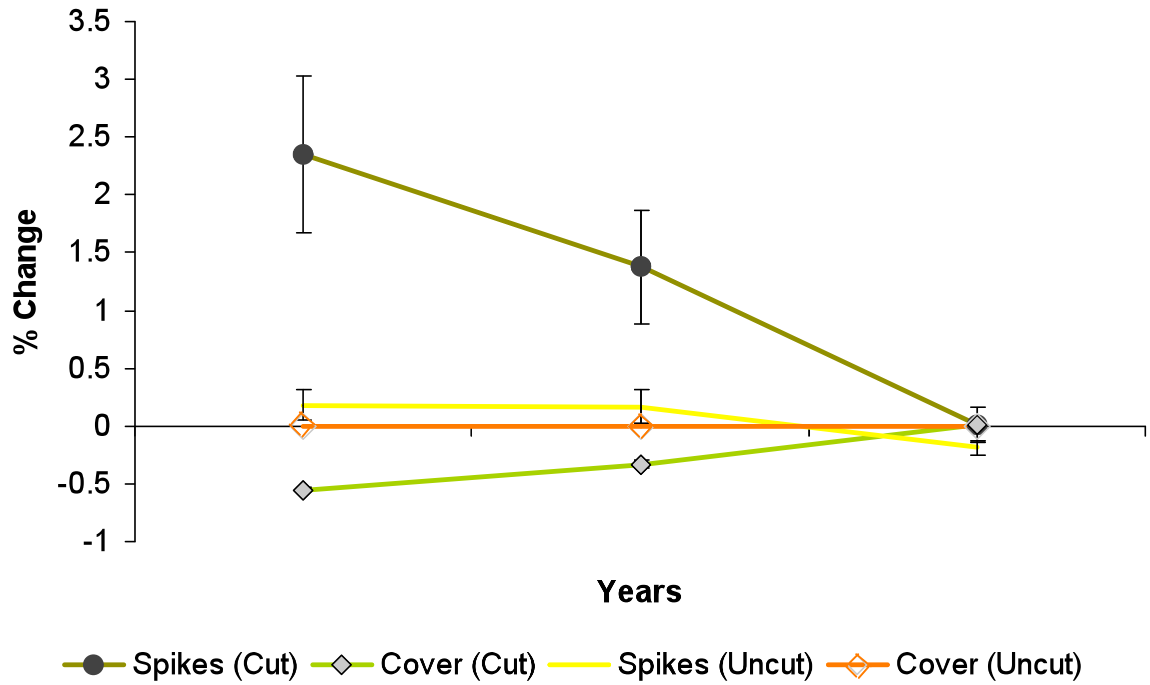


Figure 3. Graph showing inverse relationship between the percent change in number o flowering spikes and the percent change in non-*Xyris* cover at Interstate Hypericum Springs, Bartow Co., GA. for the three years following treatments. Year 1 represents tl change from 2000 to 2001, Year 2 represents 2000 to 2002, and Year 3 represents 200(to 2003. For uncut plots, the standard errors for spikes and cover was ≤ 0.03% and erro bars are not visible at the scale of the figure.

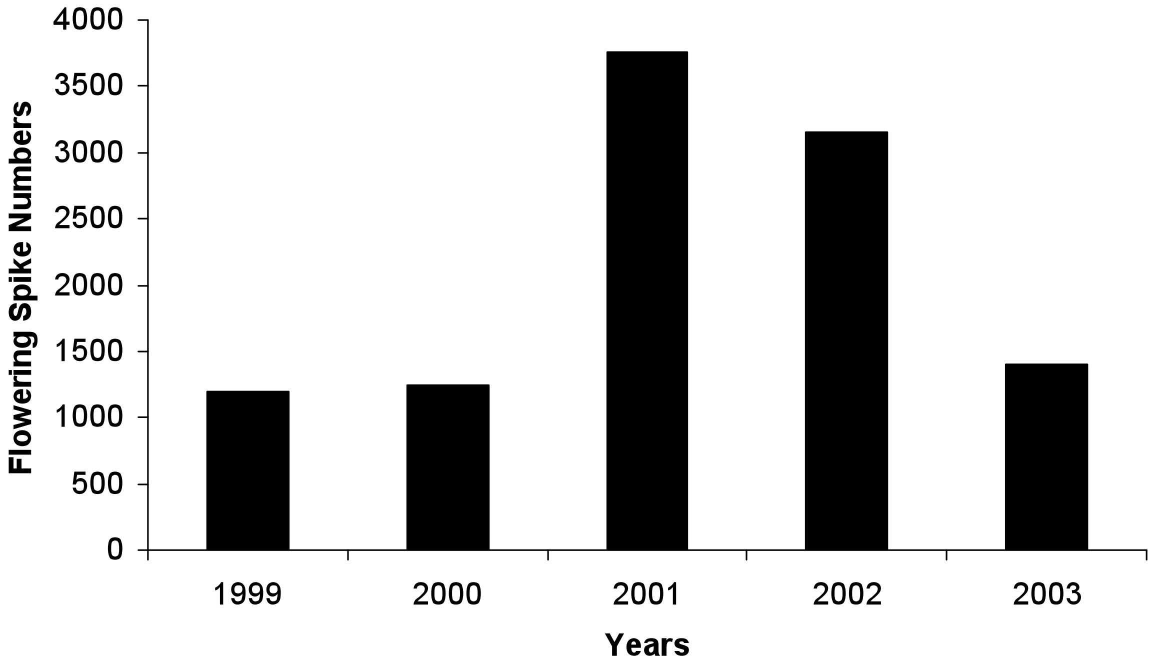


Figure 4. Results of annual flowering spike censuses for the entire Interstate Hypericum Springs, Bartow Co., GA population/site. Totals include those spikes located outside the assessment and treatment plots. Pre-treatment numbers of flowering spikes are reflected in the 1999 and 2000 censuses.

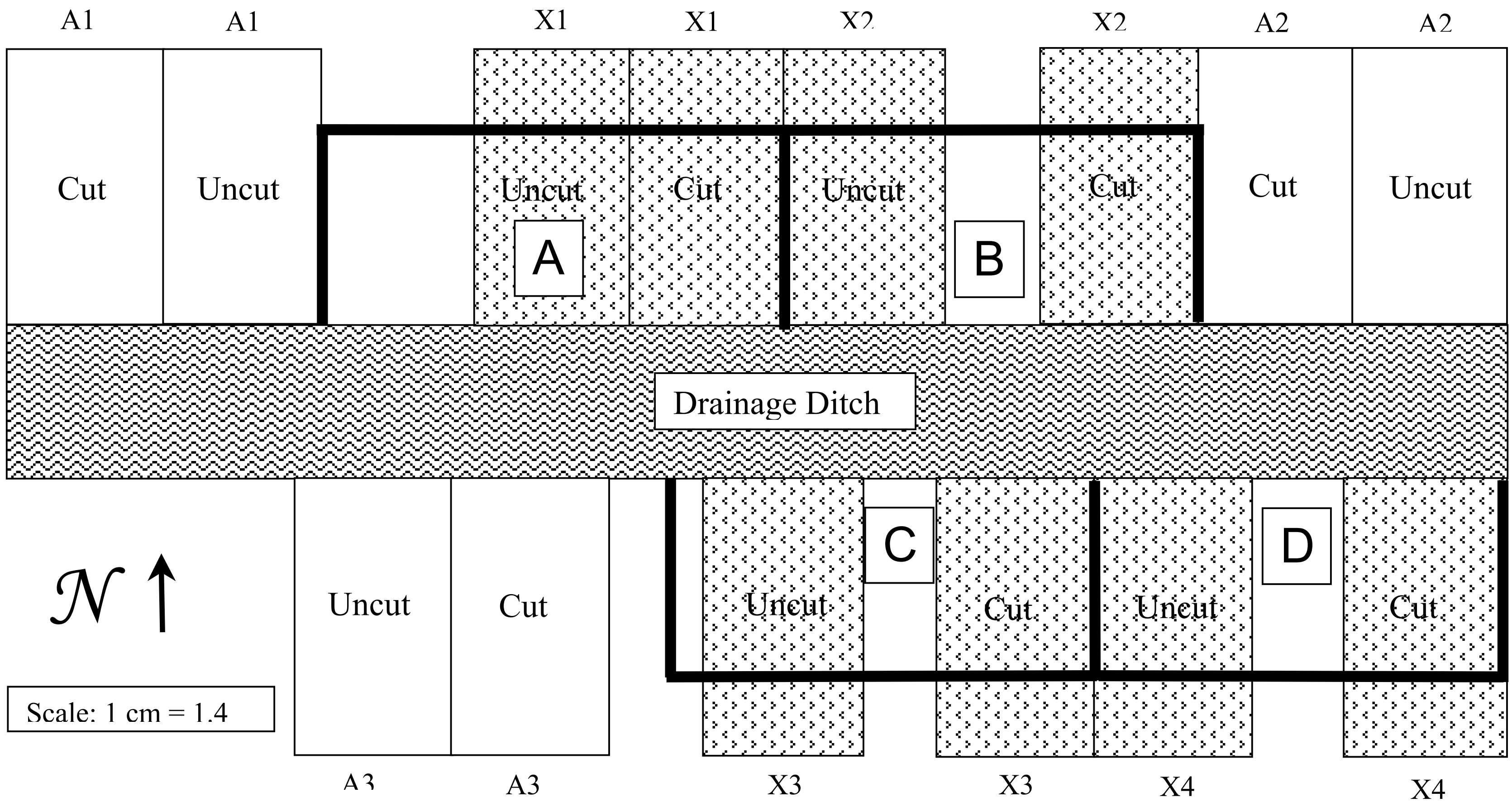


Figure 5. Map of the proposed Management Zones overlain on plot map of the *X. tennesseensis* management study at the Interstate Hypericum Springs site, Bartow Co., GA. Management Zones are delineated A, B, C, and D, and are all ca. 35-40 m^2 in area.

IV. *XYRIS SPATHIFOLIA*: A NEW XYRID FROM THE KETONA DOLOMITE - LIMESTONE GLADES OF ALABAMA

ABSTRACT

A distinctive new *Xyris* has been found in a single small (<0.01 ha) calcareous dolomitic (Ketona Limestone) fen in Bibb County, Alabama. The novelty is growing alongside the rare federally endangered xyrid, *X. tennesseensis*, but is uniformly distinct from it. I distinguish this putative new taxon from the latter, giving it species rank based upon observations of field-collected material, flowering spike censuses, laboratory studies, greenhouse common garden trials, and herbarium surveys. The fen occurs within an area known as the Ketona Glades, an extreme southerly section of the Ridge and Valley Ecoregion containing unusually pure (Mg > 1,100 ppm), exposed dolomitic outcrops. Annual censuses of flowering spike numbers, conducted during 1999 – 2005, showed a dramatic decline for both sympatric xyrids beginning in 2000. The decline, most likely the result of two consecutive years of severe drought (1999 and 2000), was followed by a gradual recovery in numbers of the new *Xyris* in subsequent years when more normal levels of precipitation returned. This recovery was not shared by *Xyris tennesseensis*. A chromosome count of the novel taxon was inconclusive, although evidence suggested a haploid level of n = 9, which is consistent with known chromosome

levels of other North American *Xyris*. Morphometric analysis of the two taxa, using 3-year-old plants grown in a greenhouse common garden setting, showed significant differences between them for nine morphological characters. Examination of national, regional, and local herbarium records supported the novel status of the new taxon. The new species, *X. spathifolia* Kral & Moffett is herein described, figured, and discussed as to its relationship with *X. tennesseensis*.

INTRODUCTION

Despite the pervasive notion that cataloging of the vascular plant flora of North America is complete, new species continue to be discovered. Frequently, these discoveries occur in spatial or temporal clusters, resulting in the revelation of a botanical "hot spot," as in the case with the Ketona Glades of Bibb County, Alabama (Ertter 2000). During the last 10-12 years, nine vascular plant taxa new to science (including the one described herein) have been identified from this area, as well as seven state records (including some regional disjuncts) and more than 60 taxa of conservation concern (Allison and Stevens 2001). With a total flora of over 420 species occurring within an area of ca. 125 ha (Alabama Water Watch 2002), it is one of the most botanically diverse areas in the eastern United States (Allison and Stevens 2001).

During a 1999 field survey of populations of the rare and endangered *Xyris tennesseensis* Kral in the Ketona Glades, a markedly different xyrid was found admixed with the former in a small, intermittent seep over Ketona Limestone at the headwaters of a tributary to Alligator Creek (*M. Moffett*, s.n., 7 August 1999). On the date of the discovery, approximately 900 flowering spikes of the novelty were tallied. They arose from about 200 clumps comprising nearly 1,100 ramets (defined here as a single, apparently physiologically independent *Xyris* unit, capable of flowering at maturity). Individuals of the putative new xyrid showed consistent differences from *X. tennesseensis* across the mixed population during the seven-year investigative period (1999-2005). In addition, 3-year-old, seed-grown, greenhouse plants also maintained consistent differences between the two taxa collected from this site. The objectives of this chapter, are to: 1) describe the habitat and floral community of the site where these two taxa co-occur; 2) perform a mineral, chemical, and particle size analysis of the fen soils and contrast them to the surrounding glade soils; 3) present annual census results of flowering spike numbers during the investigative period for both *X. tennesseensis* and the new taxon (*X. spathifolia*), and evaluate any differences in their respective recoveries from a population decline in 2000; 4) observe and report any differences in chromosome number between the two taxa; 5) perform a morphometric analysis of the two xyrids, using plants grown in a standard setting (i.e., "common garden"); 6) examine and annotate various local, regional and national herbarium records with respect to this new taxon; and 7) describe this distinctive taxon using field-collected material.

As mentioned in the prefatory paragraph, this plant, thus far known only from the type locality, was relatively abundant at this site when it was discovered. However, severe drought during the summers of 1999 and 2000 decimated the population. The drastically reduced population size and fluctuating local climate have limited the collection of additional voucher material.

METHODS

Study Site

Location

The site of this mixed *Xyris* population, containing the novel xyrid, is a fen/seep complex at the headwaters of Alligator Creek within an area mapped as "Alligator Glades West" by the Alabama Natural Heritage Program (Alabama Natural Heritage Program 1998) and referred to as "Enchanted Glade" by Allison and Stevens (2001). The seep area is very small, ca. 24 m^2 (3 m × 8 m) in size. It is located 1.7 km N of Bulldog Bend (Little Cahaba River) in Bibb County, Alabama (Lat. 33° 04'; Long. 87° 01'). Alligator Glades West is one of ca. 45 such sites comprising the Bibb County Ketona Glades (Fig. 1) and contains the sole known population of this new taxon. Extensive searches made along Alligator Creek, and of the six glades (and their ecotones) in Bibb County known to contain *X. tennesseensis,* have yielded no other populations.

Ecoregion/Geologic/Hydrologic Description

The ecoregion description of this site is presented at Level III and Level IV detail as provided by Griffith et al. (2001). The area is also described in a physiographic province format using Sapp and Emplaincourt (1975). Geologic formations and hydrologic unit descriptions are based upon Szabo (1988) and the National Hydrography Dataset (Alabama Cooperative Extension System 2008), respectively.

Soils

Analysis of soil properties and chemistry was performed using soil core material (0-10 cm in depth) taken from at least five different representative areas of the population and combined into a single sample for analysis. Soil testing was performed by the Auburn University Soil Testing Laboratory. The sample was analyzed for soil texture, pH, percent organic matter, total nitrogen, and 16 other elements. Soil texture (particle size) was determined using 40 g of soil and the Bouyoucos Style Hydrometer Method. Soil pH (of a 1:1 soil/H_2O mixture) was determined using 20 g of soil with a Fisher-Dual Electrode System with both a fast-flow reverse sleeve reference electrode, and a glass body indicating electrode. Organic matter was determined by dry combustion with a LECO WR-12 carbon analyzer and total nitrogen was determined using a LECO CHN 2000 nitrogen analyzer. Additionally, 5 g of soil were double-acid extracted and the extract analyzed for Al, B, Ba, Ca, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, P, Pb, and Zn using an inductively-coupled argon plasma spectrometer (Jarrell-Ash ICAP 9000) (Odom and Kone 1997). Cation exchange capacity was calculated using the Mehlich-1 method (Mehlich 1953).

Climate

Average annual and eight-month (March-October) "growing season" temperature and precipitation levels for the period 1998 – 2005 were obtained from National Oceanic and Atmospheric Administration records from weather stations closest to the field site (National Climatic Data Center 2006). The nearest stations, West Blocton (COOP/WBAN 018809/99999) and Centreville 6 SW stations (COOP/WBAN 011525/99999), are located ca. 12 km WNW and ca. 25 km SSW of the field site, respectively. Precipitation and temperature data were available from the Centreville 6 SW station, while only precipitation data were available from the West Blocton station (although unavailable for 2004). Given the highly localized and "spotty" nature of rainfall, the precipitation levels presented here are means of the values from the two stations. Departures are based on a weighted 30-Year Average, using the updated value from 2002.

Vegetative Community

The relationship of the fen plant community to surrounding plant communities can be modeled as a series of two concentric rings surrounding a center. The outermost ring represents the dominant dry-mesic oak/pine/hickory matrix, with the middle ring representing the highly specialized and much less common Ketona Glades community. The center represents the fen community, the least common locally (in terms of areal extent) of these communities (Fig. 2). Descriptions of plant communities for fen, surrounding glades, and the ecotone between them, use personal observations from field visits over several years and a variety of seasons. Species are listed as dominant or "typical" on the basis of their frequency and/or aspect dominance. In the case of graminoid/herbaceous components of the fen proper, species are also considered in light of their frequency of association with *X. tennesseensis* at other sites throughout its tri-state range (AL, GA, and TN).

Annual Flowering Spike Census Comparison

An annual census of flowering spikes of both *X. tennesseensis* and *X. spathifolia* was performed in mid-August during each year from 1999-2005. Spike counts are a standard field technique used for *X. tennesseensis* site/population surveys by state Natural Heritage Programs (Georgia Natural Heritage Program 1998). Tallies were accomplished using hand-held counters. Care was taken to include all spikes while avoiding double-counting; a critical task given the number of diminutive, newly-emerged, spikes frequently obscured by foliar portions of a plant.

During the unusually dry years of 1999 and 2000, which respectively were 15.1% and 28.3% below the 30-Year Average for precipitation, the seep failed continuously for 18 months. This was associated with considerable mortality for the herbaceous plant community, including both species of *Xyris*. Flowering populations of *X. tennesseensis* and *X. spathifolia* declined to the lowest levels observed during the course of the study in 2000. As more favorable levels of precipitation returned during the subsequent five-year period, population levels began to recover. Differences in recovery success between the species were evaluated statistically using the Wilcoxon signed-rank test. Recovery success was defined as the percent increase in flowering spikes in subsequent years above the "low" observed during the 2000 census. This non-parametric test was selected as an alternative to a paired-samples t-test in order to address problems involving normality and sample size. All statistical analyses used SPSS 15.0 software and followed approaches provided in Pallant (2001) and Shannon and Davenport (2000).

Common Garden Experiment

The common garden experiment initially developed from an attempt to prevent the extinction of this interesting new taxon. During the severe summer drought of 2000, following the severe drought in late summer and fall of 1999, there was concern regarding the future viability of this sole known population of *X. spathifolia*. In August 2000, as a hedge against possible future extirpation, a mature fruiting spike was collected from each of the 13 surviving clumps sporting at least two such spikes. A mature fruiting spike also was collected from 13 of the surviving 21 flowering clumps of *X. tennesseensis*. Spikes were stored in separate brown paper sacks in an unheated outdoor shed in Opelika, Lee County, AL.

In February 2001, seeds from each spike were sown onto a 60:40 mixture of Pro-Mix (Premier Horticulture, Dorval, Canada) and sand in separate 15.2 cm diameter (6-inch) clay pots and grown in a heated/evaporatively-cooled greenhouse at the Auburn University Plant Science Research Center (PSRC). Approximately 50-100 seeds germinated in each pot by June. Plants were thinned to about 10 per pot during the second year, and their parental identity was carefully maintained. Seedlings removed from pots (and hence the experiment) were grown commingled in flat trays in a separate part of the greenhouse. Annual greenhouse temperatures typically range from ca. 18.3 – 29.4 °C, per PSRC records. During the growing season (March to October), the average daily photosynthetic photon irradiance at bench level (adjusted for 60% shade cloth) ranged from 3 mol m^{-2} d^{-1} to 15 mol m^{-2} d^{-1}, on overcast and sunny days, respectively (Elkins and Wallace 2000). Plants were fertilized every two weeks with liquid 20-20-20 (N-P-K) during the growing season. During the subsequent three years, the seedlings matured and reproduced vegetatively, generating clumps of ca. 30-40 ramets and 30-60 flowering spikes per pot by the summer of 2003.

During the summer of 2004, we realized that what began as a "rescue propagation" could provide data for a limited morphometric analysis of the principal characters distinguishing these syntopic xyrids. The 3-year-old plants of known parentage grown from seed in a common environment constituted a "common garden" experiment. Sample size was N = 25; 12 pots of *X. spathifolia* and 13 pots of *X. tennesseensis*.

The nine morphological characters selected for measurement are aspects of the new taxon that, in the field, appeared most obviously different from *X. tennesseensis*, and were also easily quantifiable. The characters are: leaf length, leaf width, plant height, spike length, lateral sepal length, petal length, anther length, stamen length, and seed length. In all cases, measurements were taken at the widest (or longest) part of a structure along the appropriate axis. With regard to plant height, the longest or "tallest" plant structure for each ramet was measured. This was usually a measure of maximum scape length, although in some cases the structure of greatest length was a leaf. Flower petal length was measured from base of claw to blade apex. Stamens were measured from the point of basal fixation with the anther to the lowest point of basal adnation to the corolla. Seeds were measured along the major axis (i.e., tip to tip). Data were not collected on several other important characters used in North American *Xyris* species classification because of the high similarity of the two taxa for these characters. Excluded characters included: keel features of the lateral sepal, position of the lateral sepal relative to the bracts (i.e., inserted/exserted), color and texture of the leaf sheath, and the presence/absence of a mealy (farinose) seed coating.

Samples were generated by first numbering all reproductive ramets in a pot, and then randomly selecting five ramets from each pot. Sample values for each pot were created by averaging the values recorded from the five randomly selected ramets. Since most of the plants resulting from the original propagation did not flower and produce seeds until summer/fall 2003, it is certain that most ramets selected for measurement in this experiment were the result of asexual, vegetative reproduction. Thus, each sample represented a mean of the progeny of a single distinct, field-identified clump.

Samples for different characters were developed using different approaches. Measurements of leaf length and width were gathered from the four outermost leaves of each selected ramet. Spike lengths were obtained using all spikes from a selected ramet. Measurements of floral structures were recorded from the single open flower on each spike (it is usually the case with *Xyris* that only one flower opens each day per spike). For seed length measurements, all mature capsules were identified on each spike and numbered. One capsule was randomly selected from each spike and then five seeds were subjectively chosen from each capsule for measurement. Plant height measurements involved but a single value for each ramet. Length measurements for petals, sepals, stamens, anthers, and seed length were made using a light microscope with a stage micrometer.

Differences in the nine character means for the two taxa were statistically analyzed using the Student's t-test, except when data violated normality assumptions and were not subsequently improved using either square root or logarithmic transformations. This was the case involving seed size, where the non-parametric Mann-Whitney U-test was employed. Normality was assessed using the Kolmogrov-Smirnov and Wilk-Shapiro tests. Homogeneity of variance assumptions were evaluated using Levene's test, with Levene's correction applied to violations. Effect sizes for t-tests are expressed as eta^2

values, and for the Mann Whitney-U test by an effect size correlation ($r_{\gamma\lambda}$) using Cohen's D. Statistical software utilized was SPSS 16.0. Analysis adhered to procedures found in Pallant (2001) and Shannon and Davenport (2000).

Chromosome Counts

Chromosome counts were performed using a squash preparation with acetocarmine staining similar to methods of Beeks (1956) and Snow (1963). Flower buds were collected from numerous flowering spikes and fixed in FAA [90 mL ethanol (50%):5 mL formaldehyde (37%):5 mL glacial acetic acid] for 24 hr and then transferred for future storage to 70% ethanol at 4°C. Anthers were removed from the buds and pollen mother cells (PMCs) were prepared for examination by 12 hr (overnight) staining in 1% acetocarmine stain enhanced with 0.5% ferric chloride mordant [1/1 volume ratio].

Immediately prior to squashing, PMCs were removed from the stain, placed on a slide and macerated with a dissecting probe in 45% glacial acetic acid for approximately 2 minutes, with the excess liquid drawn off. They were then double-stained using a drop of acetocarmine (w/mordant) under gentle heat (hotplate) for approximately 3 minutes, and the excess liquid again drawn off. A drop of Hoyer's Solution [50 mL distilled H_2O, 30 gm gum Arabic, 200 gm chloral hydrate, and 16 mL glycerin] was applied to help clear the cytoplasm and facilitate permanent mounting. The PMCs were then squashed with a coverslip. Preparations were viewed under a compound light microscope at magnifications of 400× and 1000× (oil emersion).

Review of Herbarium Records

Xyris specimens from numerous state, regional, and national herbaria were reviewed and annotated as part of this project. Taxa selected for the review process were either part of the *X. difformis* "complex" **(**Kral 1978) or known to occur syntopically with *X. tennesseensis*. The *X. difformis* complex comprises *X. difformis* (varieties *curtissii*, *difformis,* and *floridana*), *X. tennesseensis*, and *X. torta*. *Xyris jupicai* is not considered a member of this complex (Kral 1978), but does co-occur with *X. tennesseensis* at a few locations. Only those specimens collected from Alabama, Georgia and Tennessee (the tri-state range of *X. tennesseensis*) were examined. The purpose of this investigation was to determine if specimens of *X. spathifolia* had been collected previously under a different name, thereby providing not only additional specimens for study, but also expanding the known range of the new taxon. Approximately 900 specimens of *X. difformis, X. jupicai, X. tennesseensis* and *X. torta* were examined from vascular plant collections at Auburn University [AUA], Duke University [DUKE], Harvard University [GH], Jacksonville State University [JSU] at Jacksonville AL, Jacksonville State University [JSU] at Anniston Museum of Natural History (Anniston, AL), Missouri Botanical Garden [MO], New York Botanical Garden [NY], Smithsonian Institute [US], Troy University [TROY], University of Alabama-Florence [UNAF], University of North Alabama-Huntsville [HALA], University of Alabama-Tuscaloosa [UNA], University of Florida [FLAS], University of Georgia [GA], University of Michigan [MICH], University of North Carolina [NCU], University of Tennessee [TENN] and Vanderbilt University [VDB] at Botanical Research Institute of Texas [BRIT]. Herbarium acronyms follow Index Herbariorum (Holmgren and Holmgren 1998).

RESULTS

Study Site

Ecoregion/Geologic/Hydrologic Description

The Ketona Glades are located at the southern edge of the Southern Limestone/Dolomite Valleys and Low Rolling Hills Level IV Ecoregion within the broader scale Ridge and Valley Level III Ecoregion (Griffith et al. 2001). They can also be alternatively placed within the Cahaba Valley Physiographic District (subsection) of the Ridge and Valley Physiographic Province (Sapp and Emplaincourt 1975). The Ketona Glades area is diverse physiographically and ecologically, as demonstrated by its relative proximity to several other ecoregions: approximately 8 km north of the Fall Line Hills (Level IV) of the Southeastern Plains (Level III); 25 km southeast of the Shale Hills (Level IV) of the Southwestern Appalachians (Level III); and 40 km west of the Southern Inner Piedmont (Level IV) of the Piedmont (Level III).

The Ketona Formation underlies both the Ketona Glades and the isolated fen. Ketona Glades are similar to the "xeric limestone prairie" type defined by Lawless et al. (2006), but best referred to as a Ketona Glade as defined by Allison and Stevens (2001). The Ketona Formation is dolomitic limestone $CaMg(CO_3)_2$ of remarkable purity with a relatively low Ca/Mg ratio (1.2:1) (Rheams 1992). Dolomite is most often formed from the replacement in limestone of Ca by Mg and the degree of the replacement determines its classification using the Chilingar (1957) system. With nearly equal Ca and Mg, Ketona dolomite can be classified as a magnesian dolomite. Although both limestone and dolomite erode relatively quickly in geologic time, dolomite is the “harder” and less erodable of the two using the Mohs Scale of Mineral Hardness (American Federation of Mineralogical Societies 2006).

The *X. spathifolia* population is situated within a seep/fen complex associated with an intermittent stream that feeds Alligator Creek (a first order stream), and thence the Little Cahaba River. The 12-digit Hydrologic Unit Code (HUC) for Alligator Creek is 031502020404 with 8-, 10-, and 12-digit HUC basin names of Cahaba River (8), Little Cahaba River (10), and Little Cahaba River (12), respectively (Alabama Cooperative Extension System 2008). The fen is surrounded by a small xeric dolomitic prairie/glade, mentioned in the preceding paragraph. The term fen is applied here in a very general sense to indicate a wetland with at least a periodic connection to a groundwater or flowing water source, and a circumneutral to basic soil/water pH. This is in contrast to an isolated hydric system with only a rainwater source creating acidic pH conditions (i.e., minerotrophic vs. ombrotrophic). However, the lack of an apparent perennial surface water inlet/outlet would define this site as an isolated wetland, of type Southern Piedmont/Ridge and Valley Upland Depressional Swamp, using NatureServe (2005b) methodology for classifying ecological systems. It would also, therefore, qualify as an isolated or non-jurisdictional wetland under Section 404 of the Clean Water Act (NatureServe 2005a).

Soil

Ketona Glades are droughty habitats that experience relatively high levels of insolation, are composed of shallow, circum-neutral soils (i.e. pH 7.4 – 7.6) with occasional rock outcrops, and support primarily a forb and graminoid vegetation community (Allison and Stevens 2001). Fens or seepy areas associated with the glades represent "hydric inclusions" of microhabitat within the already specialized xeric glade habitat. It is only near these wetland inclusions that an obligate wetland species, such as *X. tennesseensis* (U.S. Fish and Wildlife Service 1988), could survive in the sub-xeric glades. A soil description and classification, generated by the USDA - Natural Resources Conservation Service following a field visit to the site in April 2001, indicated an unnamed and unmapped entisolic inclusion. It is best classified as a thermic, lithic psammaquent; a sandy loam with a very thin O horizon, a thin friable A Horizon, no B Horizon, a structureless C Horizon, and depth to bedrock of about 10-20 cm (Ken Johnson, USDA, pers. comm.).

Soil testing results are presented below and are evaluated qualitatively in terms of Adams et al. (1994). Principal results found a circum-neutral pH of 6.8, and relatively high CEC of 27.1 meq/100g. Macronutrient levels were 0.31% N, a medium-high level of P (10.8 ppm), and a low-medium level of K (34.4 ppm). Secondary nutrient levels included a high level of Ca (3673 ppm), and a very high level of Mg (1156 ppm), yielding a Ca/Mg ratio of 3.2:1. Particle size analysis indicated a loamy-sand, with relatively high (14.9%) organic matter. Complete results of soil analysis are provided in Table 1.

The hydric fen soil of Alligator Glades differs from both ultisols, the dominant soil order of the southeastern U.S., and the alfisols/mollisols that are the primary soil orders of xeric limestone prairies and glades (Lawless et al. 2006). The fen soil is deeper with a higher organic fraction (14.9%) than alfisols, mollisols, or ultisols, which have representative soil organic matter levels ranging from 2-4% (Brady 1990). The pH of the fen (6.8) is intermediate between the 7.4-7.6 range for Ketona Glades soils (Allison and Stevens 2001) and the 5.0-5.8 range for typical ultisols (Grunwald 2008). This intermediate position is consistent with the presence of humic acids (by-products of organic matter decomposition), mitigated to some extent by an increase in CEC (provided by the organic matter) and the subsequent sequestration of basic cations from the weathering of nearby dolomitic parent material. Another effect of high levels of soil organic matter in the fen is an elevated CEC value (27.1 meq/100), exceeding the typical CEC range (8-12 meq/100g) for loamy-sand textured soils (Brady and Weil 1999). The fen soil's lower levels of certain nutrients (Ca, K, P, Zn) compared to the Ketona Glades soils may be the result of leaching associated with flowing water. Table 2 provides a comparison of Ketona Glades "glade-proper" soil and Alligator Glades fen soil using eight measures provided in Allison and Stevens (2001).

Climate

Broad scale climate classification of the Ketona Glades can be described using several traditional approaches. Application of the Thornwaithe (1931) system indicates a climate type of (B_2 B'_3 b'_4 r), corresponding to a humid, mesothermal climate with little or no moisture deficiency in any season, and a summer concentration of thermal efficiency of approximately 50%. Corresponding classifications include the Cfa type climate regime of the Köppen system (Ackerman 1941), and a Type II regime using Borchert (1950).

From 1998-2005, the extent of the study period plus a prior year, temperature averages were near normal and precipitation averaged slightly less than the 30-Year Average for the Alligator Glades vicinity. Average annual and "growing season" (March-October) mean temperatures were 17.1°C and 21.2°C, respectively. These represent departures of less than 0.2% from the 30-Year Averages. Average annual total precipitation was 145.1 cm, while growing season total precipitation was 93.1 cm, reflecting departures from the 30-Year average of –4.0% and –3.2%, respectively. Rainfall totals for the first drought year of 1999 were 17.2% below the 30-Year Average for the growing season and 15.1% below for the full year. The drought worsened in 2000, as precipitation fell short of the 30-Year average by 32.8% and 28.3%, respectively, for the growing season and full year. Complete temperature and precipitation data are provided in Table 3.

Vegetative Community

The plant community of the fen and adjacent ecotone differ from those of the surrounding higher, more xeric and shallow-soiled glades. The fen is a mosaic of open and shrubby patches, while the glades generally present an open-aspect habitat with little or no canopy cover, except along ecotonal areas with the hydric fen and surrounding dry-mesic oak/pine/hickory forest (much of which has been converted to loblolly pine plantation).

The glade community is dominated by grasses and forbs. Dominant grasses were *Andropogon virginicus* L. and *Schizachyrium scoparium* (Michx.) Nash. Frequently encountered forbs were *Agalinis purpurea* (L.) Pennell, *Allium canadense* L. var. *mobilense* (Regel) M. Owenby, *Amsonia ciliata* Walt. var. *tenuifolia* (Raf.) Woods, *Callirhoë alcaeoides* (Michx.) Gray, *Cnidoscolus stimulosus* (Michx.) Engelm & Gray, *Hypoxis hirsuta* (L.) Coville, *Liatris cylindracea* Michx., *Linum sulcatum* Riddell var. *sulcatum*, *Lobelia spicata* Lam., *Minuartia patula* (Michx.) Mattf., *Nothoscordum bivalve* (L.) Britt, *Polygala boykinii* Nutt., *Rudbeckia triloba* var. *pinnatiloba* Torr. & Gray, *Salvia azurea* Lam., *Schoenolirion croceum* (Michx.) Wood, *Scleria verticillata* Muhl. ex Willd., *Solidago ulmifolia* Muhl. ex Willd., *Sporobolus junceus* (Michx.) Kunth., *Tetragonotheca helianthoides* L. and *Yucca filamentosa* L. Characteristic species also include two newly described species, *Coreopsis grandiflora* Hogg ex Sweet var. *inclinata* J. Allison and *Erigeron strigosus* Muhl. ex Willd. var. *dolomiticola* J. Allison. Of particular conservation interest is the presence of the federally threatened aster, *Marshallia mohrii* Beadle & F.E. Boynt.

The ecotonal community is dominated by woody trees, shrubs and vines. The perimeter of the fen is dominated by *Pinus taeda* L., *Quercus muehlenbergii* Engelm., *Q. nigra* L., and *Ulmus rubra* Muhl. Sub-canopy composition is principally that of *Acer leucoderme* Small, *Cercis canadensis* L., *Cornus florida* L., *Diospyros virginiana* L., *Frangula caroliniana* (Walt.) Gray, *Juniperus virginiana* L. and *Ostrya virginiana* (P. Mill.) K. Koch. Prominent lianas include *Berchemia scandens* (Hill) K. Koch, *Bignonia capreolata* L., *Parthenocissus quinquefolia* (L.) Planch, *Toxicodendron radicans* (L.)

Kuntze and *Vitis rotundifolia* Michx. The ecotonal shrub layer consists of *Croton alabamensis* E.A. Sm. ex Chapman var. *alabamensis*, *Forestiera ligustrina* (Michx.) Poir., *Morella cerifera* (L.) Small and *Viburnum rufidulum* Raf.

The deeper-soiled interior of the hydric fen contains a different suite of plants from those of the ecotone and possesses a graminoid/herbaceous community that is remarkably similar to other *X. tennesseensis* sites throughout its range. Shrubs present include *Sabal minor* (Jacq.) Pers. and *Viburnum nudum* L., along with a frequent associate of *X. tennessensis,* the shrubby St. John's-wort, *Hypericum interior* Small. Characteristic graminoids and forbs include *Juncus brachycephalus* (Engelm.) Buch. and *Ludwigia microcarpa* Michx., both frequent associates of *X. tennesseensis*. Several moderately frequent associates are also found here, such as *Mitreola petiolata* (J.F. Gmel.) Torrey & A. Gray, *Fuirena squarossa* Michx., *Helenium autumnale* L., *Mecardonia acuminata* (Walt.) Small var. *acuminata*, *Rhynchospora capitellata* (Michx.) Vahl. and the rare (NatureServe conservation ranking of G3/S1) *R. thornei* Kral. Additional infrequent associates present include *Carex granularis* Muhl. ex Willd., *Cyperus erythrorhizos* Muhl., *Kyllinga pumila* Michx., *Lobelia puberula* Michx., *Rhynchospora colorata* (L.) H. Pfeiffer and *Rudbeckia fulgida* Aiton var. *umbrosa* (C.L. Boynton & Beadle) Cronq., along with a state rare orchid (NatureServe conservation ranking of G4/S2), *Ponthieva racemosa* (Walt.) C. Mohr.

Annual Flowering Spike Census

The number of ramets and flowering spikes of both species of *Xyris* decreased dramatically during the study period, the result of a two-year drought during the summer and fall 1999 and throughout 2000 (Table 4). Flowering spikes of *X. spathifolia* decreased 98% (from 889 to 22) during this period while those of *X. tennesseensis* decreased 94% (from 443 to 28). More normal levels of precipitation in the five subsequent years from 2001 through 2005 (Table 3) coincided with an increase of *X. spathifolia* to nearly 500 flowering spikes as of the 2005 census. Flowering spikes of *X. tennesseensis*, however, never returned to pre-drought levels. Although the population reached 82 flowering spikes in 2004, it declined again to 28 in 2005 (Table 4). Comparison of recovery success between the two species (N = 5) using the Wilcoxon signed-rank test indicated a significant difference (Z = -2.023; P = 0.043). Recovery success percentages for *X. spathifolia* (range: 41% to 2,309%) were substantially greater than for *X. tennesseensis* (range: –11% to 193%) for each of the five post-drought years (Table 4).

Common Garden Experiment

Analysis of morphological characters from greenhouse grown plants in a common garden setting revealed significant differences in all nine size-related traits. In all cases, measurements for *X. tennesseensis* specimens were significantly larger than those for *X. spathifolia* (Table 5). Significance values ranged from < 0.001 to 0.03, with effect sizes indicating that 39-93% of the variance in each character was explained by taxon assignment alone. Table 6 provides a qualitative assessment of character state differences bwtween the two taxa based on vouchered herbarium specimens and field collected material.

Chromosome Counts

Attempts to stain and isolate PMC chromosomes were not fully successful, thus the resulting chromosome counts were generally inconclusive. In 32 of the 36 trials, the chromosomes either failed to properly take up stain or to separate post-staining. Initial problems involving staining were addressed with use of a mordant ($FeCl_3$) and by increasing the time of the first staining (in the double-staining process) from one to twelve hours. Difficulties with isolation, however, persisted and were never adequately overcome.

Although inconclusive, results from four of the trials did suggest nine distinctly stained and separated chromosomal units or "masses" within single PMCs. The stage of meiosis was most likely late prophase or early metaphase, although it was unclear if the stained chromosomes were products of meiosis I or II.

Review of Herbarium Records

Review of approximately 900 specimens of *X. difformis, X. jupicai, X. tennesseensis* and *X. torta* from 19 national, regional and state herbaria located only a single record fitting the concept of *X. spathifolia,* collected by James R. Allison in 1993 from Alligator Glades West, the sole known extant site of this new taxon.

Taxonomic Description

Xyris spathifolia Kral & Moffett, sp. nov. TYPE: U.S.A. Alabama. Bibb Co., Alligator Glades West, small seep over Ketona Dolomite, N on Co. Rd. 65, 2 km past Bulldog Bend Bridge, thence 1.6 km E on gated gravel logging road, and then 0.15 km S by foot; headwaters W branch of Alligator Creek, 7 August 1999, M. Moffett, s.n.

(holotype, VDB: paratype, same location, R. Kral & M. Moffett 90103, VDB). Other specimens examined - Alabama: Bibb Co., 1.2 mi N.W. of mouth of Alligator Cr. (0.55 mi WSW of Alligator Cr.), 5 September 1993, *James R. Allison* 7963 (AUA).

Herba caespitosa: basis leviter pilosa, caulis brevis aut in innovationibus elongates, usque ad 1 cm longis. Folia erecta vel ascendentia, torta, flexuosa, vaginis scaporum longiora; vaginae a basin ecarinatae, sursum carinatae, valde costatae, maximam parte valde rugulos-papillosae aut papillosae, rufobrunneolae at subroseolae, in laminas gradatim contractae, elingulatae; laminae compressae, auguste lineari, 1--2 mm latae, pallidae olivaceae, margine leviter incrassate, papillosa; apices incurvati, obtuse-acuti, leviter incrassate, paginae longitudine prominente, papillosae. Vaginae scaporum pro parta maxima apertae, laminis brevibus. Scapi flexuosi et torti, anguste lineari, ca. 1 mm latae, apices versus valde (3--)4--5-costati, cortis valde tuberculato-papillosis, intervallis profunde sulcatis vel concavis aut fere planis, leviter aut prominente papillosis. Spicae multiflorae, ovoideae, 5--8 mm longae, obtusae. Bracteae erectae, laxe spiraliter imbricatae, firmae, rigidae, cum areis dorsalis; bracteae steriles vulgo 4, pari inferiori carinati, 2.5--3 mm, in fertiles gradatim transientes; bracteae fertiles late obovatae vel suborbiculatae, 4.5--5 mm, convexae, matricibus nitidis, pallide vel profunde brunneolis, nitidis, ad apicem late rotundatae, areis dorsalibus ovatis, granulato-papillosis, viridulis. Sepala lateralia libera, oblanceolata, 4--4.5 mm, acuta; ala carinali lata, a basi ad medium integra, ad apicum versus leviter lacerata. Laminae petalorum obovatae, ca. 3.5 mm, luteolae, apice valde erosae. Staminodia bibrachiata, brachiis longipenicillatis. Stamina ca. 1 mm longa, antheris late oblongis, ca. 0.5 mm longis, profunde auriculatis et emarginatis, filamentis crassis, ca. 0.6 mm longis. Capsula ellipsoideo-cylindrica, placenta parietalis. Semina late ellipsoideo vel anguste ovoidea, ca 0.5 mm longa, opaca vel leviter translucida aut farinosa, irregulariter lineate.

Perennial, cespitose, 15--40(--50) cm tall, roots fibrous. Stems short, or present as slender, ascending, rhizome-like bases on innovations (result of burying of clump by sediment). Leaves ascending to erect, 15--30 cm long, soft, sheaths often fully as long as blade or longer, gradually widening from keeled apex to convex base, proximally multi-costate, smooth, pale tan to brown, upsheath with tints of red or pink, progressively increasingly rugulose and papillate, densely so and green distally, margins pale, scarious, gradually narrowed to blade (this often most of its length infolding distal leaf of innovation); blade linear, mostly 1--2 mm wide, slightly to very twisted, flattened, margins proximally to medially strongly papillose, toward apex smooth or nearly so; apex narrowed, excentrically acute, its incurved tip incrassate, blunt, smooth; surfaces densely pale-granular-papillose and interruptedly rugulose proximally, progressively smoother up-blade. Scape sheaths shorter than principal leaves, mostly open, short-bladed. Scapes erect or ascending, narrowly linear, ca. 1 mm thick, twisted, pale green, proximally subterete with (mostly) 5--8 papillate costae, the intervals smooth or nearly so, distally sharply unequally angulate-ribbed, with up to 5(--7) costae making the angles, 2-3 most raised, all densely papillate-tuberculate, the intervals sulcate to broadly concave, slightly to very papillose or papillose-rugulose in short lines. Spikes ovoid to ellipsoidal or lance-ovoid, 5--8 mm, blunt, several flowered, bracts in flat spiral, loosely imbricate, the proximal 2-3 sterile, narrowly ovate-triangular, 2.5--3 mm, keeled, the fertile ones broadly obovate, 4.5--5 mm, convex, apex broadly rounded, entire, aging erose, surface a lustrous rich brown with a green, ovate, subapical, granular dorsal area. Lateral sepals free, equilateral, oblanceolate (viewed from side), ca. 4--4.5 mm, acute, the thin keel entire proximally, progressively widening and shallowly ascending-lacerate distally. Petals distinct, blades obovate (measured from claw apex), ca. 3.5 mm, apically erose; staminodia bibrachiate, staminodial hairs pencillate, slightly clavate. Capsule ellipsoid-cylindric, 2--2.5 mm, placentation 3-parietal; seeds broadly ellipsoid to narrowly ovoid, ca. 0.5 mm, apiculate, with 8-10 ribs/side, slightly farinose.

The epithet "spathifolia" is based on a peculiar morphology of lower leaves of innovations. These are spathe-like, their margins conduplicate and enfolding inner leaves. Plates for both *X. spathifolia* and *X. tennesseensis* are found in Figures 3 and 4, respectively.

Identification Key (*X. tennesseensis* sympatric xyrids, incl. *X. difformis* complex)

1. Keel of lateral sepals usually firm, papillate, ciliate, ciliolate, or fimbriate, or in various combinations of these…………………………………………..…*Xyris torta*
1. Keel of lateral sepals scarious, lacerate to (rarely) nearly entire.
    2. Leaf sheaths or sheath base light green, straw-colored, or dull brown…………………………………………………...…*Xyris jupicai*
    2. Leaf sheaths or sheath base with red, pink, or purple tints, or glossy brown or red-brown.
        3. Seeds opaque or mealy

4. Base of mature plant bulbous

   5. A generally larger plant 30--70 cm in height; leaf sheaths and blade surfaces mostly smooth or just slightly papillate along keels and edges; scapes with 2 ridges somewhat flattened and wing-like distally, all papillate at edges; stem base lacks rhizome……...
   ……………………………………………*Xyris tennesseensis*

   5. A generally smaller plant 15--40 cm; leaf sheaths and blade surfaces papillate; scapes sharply 5--7 angled distally, ridges densely papillate-tuberculate; stem base possesses what may be short ascending rhizomes…………………..…….*Xyris spathifolia*

4. Base of mature plant not bulbous……….*Xyris difformis* var. *floridana*

3. Seeds translucent

   6. Leaves and scapes (except for edges and ribs) smooth; scape somewhat to much widened distally; 2 ribs comparably wider, making wings smooth or papillate……………...…*Xyris difformis* var. *difformis*

   6. Leaves and scapes variously papillate or minutely scabrous; scapes not much widened distally; ribs all equally prominent, somewhat scabrous……………………………...…*Xyris difformis* var. *curtissii*

DISCUSSION

The results support the status of *X. spathifolia* as a new taxon. Observations of material in the field revealed consistent differences in various character states relating to size (Table 6). This was supported by morphological analysis of greenhouse-grown material (Table 5) that showed statistically significant differences in these characters as well. Analysis of recovery success using flowering spike census data (Table 4) showed a statistically significant difference between the two taxa, and is likely reflective of an underlying genetic difference. Moreover, the examination of herbarium records uncovered only a single previously collected specimen conforming to *X. spathifolia* (from the same glade: Alligator Glades West), supporting its status as a unique and previously undescribed taxon.

The question of what rank to assign this novelty is intriguing. Certainly, careful attention should be given to the plant at its sole known location, as well as searching for it in other calcareous fens of the area. Of particular interest is the fact that, prior to this discovery, only *Xyris tennesseensis* of North American xyrids has been known to occupy fen-like habitats. One would be tempted to consider the new morphology a simple anomaly, perhaps a reaction to extreme habitat by *X. tennesseensis,* were it not for the presence of both taxa commingled at a single site which, nonetheless, are easily distinguished on the basis of a suite of characters.

Differences in several character states between *X. spathifolia* and *X. tennesseensis* were observed and maintained throughout the 3-year common garden study. The differences were manifest primarily in terms of leaf and scape surface features (i.e., ridges, wings, papillae) and size of individual characters, as well as overall plant size. There was also a tendency for some of the *X. spathifolia* specimens to possess small lateral ascending offshoots reminiscent of rudimentary rhizomes, a feature not known from other North American xyrids. The differences exhibited by the new taxon are of a nature and degree that are consistent with species status distinctions recognized for this genus (Kral 1966, Kral 2000).

Cytogenetic analysis of chromosome number in *Xyris* is difficult (Benko-Iseppon and Wanderly 2002) and in this case inconclusive. However there was some evidence of a haploid complement n = 9, which would be consistent with all other North American xyrids (Lewis 1961, Kral 1966, Kral 2000). While not offering support for taxonomic distinction, it is certainly possible that genetic differences between *X. tennesseensis* and *X. spathifolia* occur at a level other than chromosome number (e.g. individual base pairs).

If the new xyrid taxon is to be considered a species, then some discussion of speciation seems appropriate. All types of speciation require some event restricting or limiting gene flow between groups (e.g., geographic separation, random genetic mutation that allows for adaptation to a new environment/habitat, polyploidy), that facilitates an accumulation of differences between groups until such time that the changes cause reproductive isolation and the groups are no longer capable of interbreeding (Coyne and Orr 2004). These common aspects of speciation are convenient and provide a general framework for the understanding of speciation, but it must be acknowledged that the species concept and mechanisms of speciation involving plants are eminently more complex and problematic than for animals (Stebbins 1993).

Sympatric, allopatric, parapatric, and peripatric speciation types are not all equally likely explanations for the emergence of the incipient species, *X. spathifolia.* Sympatric speciation, while rare biologically, is well represented in the plant kingdom, as plants are given to developing multiple sets of chromosomes (polyploidy), creating reproductive isolation (Otto and Whitton 2000). However, given the specific lack of evidence for a chromosome number other than n = 9 here, there is no basis for proposing polyploidy as a mechanism initiating sympatric speciation. Allopatric speciation, requiring geographic separation, is equally nonsensical if the ancestral "parent" is considered to be *X. tennesseensis*, since both species are syntopic and co-occupy an extremely small area (< 0.01 ha). Parapatric speciation, variations in reproductive frequency along an environmental, behavioral or temporal gradient, also seems very unlikely given the syntopic nature of these two xyrids. Furthermore, it was observed by the author that the blooming phenology of both xyrids was similar, with daily anthesis from ca. 11:00 am to 2:00 pm from mid-July thru mid-September, indicating no temporal barriers for reproductive interaction. Peripatric speciation, however, does present a possible explanation for speciation. This special form of allopatric speciation is plausible if one considers an ancestor other than *X. tennesseensis*. *Xyris difformis*, sympatric with *X. tennesseensis* and known from Bibb Co., AL, is a potential candidate. It is possible that a few propagules of *X. difformis*, representing only a fraction of the species' genome, colonized the Alligator Glade West community long enough ago to have "drifted" to the point of speciation. Gene-level molecular comparisons may be a way to test this hypothesis.

Statistical analysis of the recovery success of the two xyrids following the two-year period of extreme drought indicated that *X. spathifolia* more quickly returned to pre-drought levels of flowering abundance than did *X. tennesseensis*. This not only supports an argument for taxonomic distinctiveness, but may also inform the speciation discussion. If the working assumption is that *X. tennesseensis* is the progenitor of the new taxon, it may be that a genetic mutation at a molecular level conferred greater “fitness” on a portion of the *X. tennesseensis* population, rendering it better able to survive and reproduce in the high Mg soils (Allison and Stevens 2001) and drought – prone environment of the Ketona Glades. In this instance, there may not be a reproductive isolating mechanism yet established, so hybrids and back-crosses between *X. tennesseensis* and the new group (i.e., *X. spathifolia*) may be on-going. However, if the new group is truly better adapted to the local environment, then we may be witnessing the gradual “replacement” of *X. tennesseensis* with *X. spathifolia* at this site.

Conservation Considerations

The Ketona Glades, a botanical hotspot, have provided eight new plant taxa representing five plant families to science in the last decade (Allison and Stevens 2001). Their recent discovery after centuries of plant exploration in the eastern U.S., coupled with the geologic/edaphic uniqueness of the area, argue for their genuine rarity and conservation significance. The conservation status of these species (Table 7), as provided by NatureServe (2008), lists six of the eight taxa as critically imperiled or imperiled globally, with all eight taxa considered imperiled or critically imperiled at a subnational/state level (S1 or S2).

In addition to rarity, however, conservation rankings require an assessment of threat. In general, species inhabiting isolated non-alluvial wetlands experience greater threats than those inhabiting larger “connected” systems (Weakley and Schafale 1994).

Primary threats to *X. tennesseensis* include conversion of habitat to agriculture, quarrying, road widening/maintenance (including herbicide use), forestry practices, lowering of the water table, and natural succession (Kral 1983; Kral 1990; U.S. Fish & Wildlife Service 1994a). Although not well understood, the early and persistent successional nature of isolated wetlands suggests the presence of frequent disturbance forces (Virginia Department of Conservation and Recreation 2006). While it is likely that small patch habitats ebb and flow across the landscape over time, the forces that create new suitable habitat or maintain them indefinitely are important to the colonization and perpetuation of many species. Small wetlands in the southeastern U.S. have likely been maintained by some combination of fire (Frost 1995; Kirkman 1995; Folkerts 1997; Kirkman et al. 1999) and hydrologic fluctuations (MacRoberts and MacRoberts 1993; Folkerts 1997), topo-edaphic factors (Kirkman et al. 2000), and various stochastic events, such as rock slides, windthrow, insect/pathogen damage, drought, ice-storms, etc. (U.S. Department of Agriculture 1994). Activities that reduce or eliminate natural disturbance or fluctuation regimes, such as fire suppression or water table lowering, may increase the rate of natural succession.

Considering the documented rarity of *X. spathifolia*, its association with and similarity to *X. tennesseensis*, and the specific threats associated with its single known extant site, a strong argument can be made for a "high" conservation ranking. This sole isolated site is located within a loblolly pine plantation where fire suppression is practiced, thereby encouraging severe woody tree and shrub encroachment. The overstocked plantings along (and within) the intermittent stream course are capable of drastically reducing groundwater levels within the fen (Jackson et al. 2005). Moreover, this site lacks formal legal protection (i.e., it is privately owned with no conservation easements/covenants in place). Thus it would seem to satisfy the requirements of both extreme rarity and threat necessary to justify a G1/S1 ranking. The rarity and threat to this species would support its status as the xyrid of greatest conservation concern in North America (north of Mexico). The currently recognized *Xyris* species of greatest conservation concern is *X. tennesseensis* (G2/S1 in Al, GA, and TN). It also has status and receives protection under the federal Endangered Species Act of 1973, under state law in Georgia through the Georgia Wildflower Preservation Act of 1973 (Georgia Dept. of Natural Resources 2008), and under state law in Tennessee through the Rare Plant Protection and Conservation Act of 1985 (Crabtree 2008). Alabama does not currently protect rare plants under state law, a fact that only contributes to the precarious situation facing the sole known population of *X. spathifolia*.

Table 1. Results of various chemical, mineral, and particle size analyses of Alligator Glades seep soil performed by the Auburn University Soil Testing Laboratory.

Macronutrients					
N	P	K			
0.31%	10.8 ppm	34.4 ppm			
Secondary Nutrients					
Ca	Mg	Ca/Mg			
3673 ppm	1156 ppm	3.2:1			
Micronutrients					
Al	B	Ba	Co	Cr	Cu
26.1 ppm	3.8	3.8 ppm	0.1 ppm	1.1 ppm	0.0 ppm
Fe	Mn	Mo	Na	Pb	Zn
13.7 ppm	47.9 ppm	0.2 ppm	19.4 ppm	0.7 ppm	1.6 ppm
pH, CEC, and Organic Matter					
pH	CEC	O.M.			
6.8	27.1 meq/100g	14.9%			
Particle Size Analysis					
Sand	Silt	Clay			
82%	17%	1%			

Table 2. Comparison of selected soil chemistry measures from the fen soil sampled in this study and from Ketona Glades "glade" soils. Ketona Glades soil means presented here are based upon values from four Bibb County, AL glade sites as reported by Allison and Stevens (2001).

Site	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Ca/Mg Ratio	Zn (ppm)	Mn (ppm)
Fen Soil	6.8	10.8	34.4	3673	1156	3.2:1	1.6	47.9
Glade Soils mean	7.5	30.5	83.3	6887	999	6.9:1	3	33

Table 3. Average annual and eight-month (March-October) temperature and precipitation levels for the period 1998 – 2005 at the Alligator Glades site. Departures are based on an adjusted 30 Year Average. Temperature data provided by the NOAA weather station Centreville 6 SW (COOP/WBAN 011525/99999), approx. 25 km SSW of field site. Precipitation data are the mean of data from the above station and the West Blocton station (COOP/WBAN 018809/99999), ca. 12 km WNW of field site.

3a. Temperature

	Growing Months (Mar-Oct)			Full Year (12 mos)		
	Avg. Temp.	Depart. From 30-Yr. Avg.		Avg. Temp.	Depart. From 30-Yr. Avg.	
Years	(°C)	(°C)	(%)	(°C)	(°C)	(%)
1998	21.6	0.4	1.9	17.8	0.7	4.4
1999	20.9	-0.2	-1.2	17.2	0.2	1.1
2000	21.5	0.3	1.5	17.0	0.0	0.1
2001	20.2	-1.0	-4.7	16.7	-0.4	-2.1
2002	22.0	0.8	4.0	17.3	0.3	1.6
2003	20.9	-0.3	-1.3	16.6	-0.4	-2.5
2004	21.7	0.5	2.3	17.3	0.2	1.4
2005	20.5	-0.7	-3.2	16.7	-0.4	-2.2
Avg.	21.2	0.0	-0.1	17.1	0.0	0.2

3b. Precipitation

	Growing Months (Mar-Oct)			Full Year (12 mos)		
	Avg. Pcp.	Depart. from 30-Yr. Avg.		Avg. Pcp.	Depart. From 30-Yr. Avg.	
Years	(cm)	(cm)	(%)	(cm)	(cm)	(%)
1998	90.2	-5.9	-6.1	162.6	11.4	7.6
1999	79.6	-16.5	-17.2	128.3	-22.9	-15.1
2000	64.6	-31.5	-32.8	108.5	-42.7	-28.3
2001	111.0	14.8	15.4	161.0	9.8	6.5
2002	82.7	-13.5	-14.0	137.3	-13.9	-9.2
2003	103.7	7.5	7.8	147.3	-3.9	-2.6
2004	89.0	-7.2	-7.5	147.2	-4.0	-2.7
2005	124.0	27.9	29.0	168.9	17.7	11.7
Avg.	93.1	-3.1	-3.2	145.1	-6.1	-4.0

Table 4. Results of the annual census of flowering spikes, and the recovery success of *X. tennesseensis* (*X. tn*.) and *X. spathifolia* (*X. spt*.) at the Alligator Glades site. Censuses were completed during mid-to-late August in each year from 1999-2005. Recovery success reflects the percent change in flowering spikes in subsequent years above the level in year 2000, and is given in parentheses.

Taxa	1999	2000	2001	2002	2003	2004	2005
X. spt.	889	22	31 (41%)	65 (195%)	320 (1,355%)	493 (2,141%)	530 (2,309%)
X. tn.	443	28	26 (-7%)	49 (75%)	65 (132%)	82 (193%)	25 (-11%)

Table 5. Comparison (mean ± SE) of nine different character states between *X. spathifolia* and *X. tennesseensis* as evaluated in the common garden experiment. Independent samples t-tests were used for the first eight characters. The Mann-Whitney U test was used for the ninth character (seed size). Homogeneity of variance violations and subsequent Levene's corrections are indicated by asterisks. Degrees-of-freedom values departing from 23 ($N_1 + N_2 - 2$) result from these corrections. A significance threshold of $\alpha = 0.05$ was used. Effect sizes for t-tests and Mann-Whitney U tests are given by eta^2 and effect size correlation ($r_{\gamma\lambda}$) using Cohen's D, respectively.

Character	***X. spath.*** **(N = 12) (mean ± S.E.)**	***X. tenn.*** **(N = 13) (mean ± S.E.)**	**d.f.**	**Test Statistic**	**Sig.**	**Effect Size**
Leaf length (cm)	24.1 ± 1.57	48.9 ± 2.3	20.8	-8.87 *	<0.001	0.774
Leaf width (mm)	1.51 ± 0.16	6.98 ± 0.69	13.3	-7.77 *	<0.001	0.733
Plant height (cm)	27.5 ± 3.54	48.6 ± 3.83	23	-4.05	0.001	0.413
Spike length (mm)	6.75 ± 0.42	13.0 ± 0.67	19.8	-7.93 *	<0.001	0.732
Petal length (mm)	3.46 ± 0.03	4.44 ± 0.04	22.2	-17.5 *	<0.001	0.930
Sepal length (mm)	4.27 ± 0.06	4.77 ± 0.07	23	-5.59	<0.001	0.575
Stamen length (mm)	1.01 ± 0.02	2.14 ± 0.06	15.7	-17.1 *	<0.001	0.926
Anther length (mm)	0.55 ± 0.02	1.74 ± 0.07	13.8	-17.1 *	<0.001	0.927
Seed length (mm)	0.52 ± 0.01	0.55 ± 0.01	22.7	-2.18	0.03	0.39

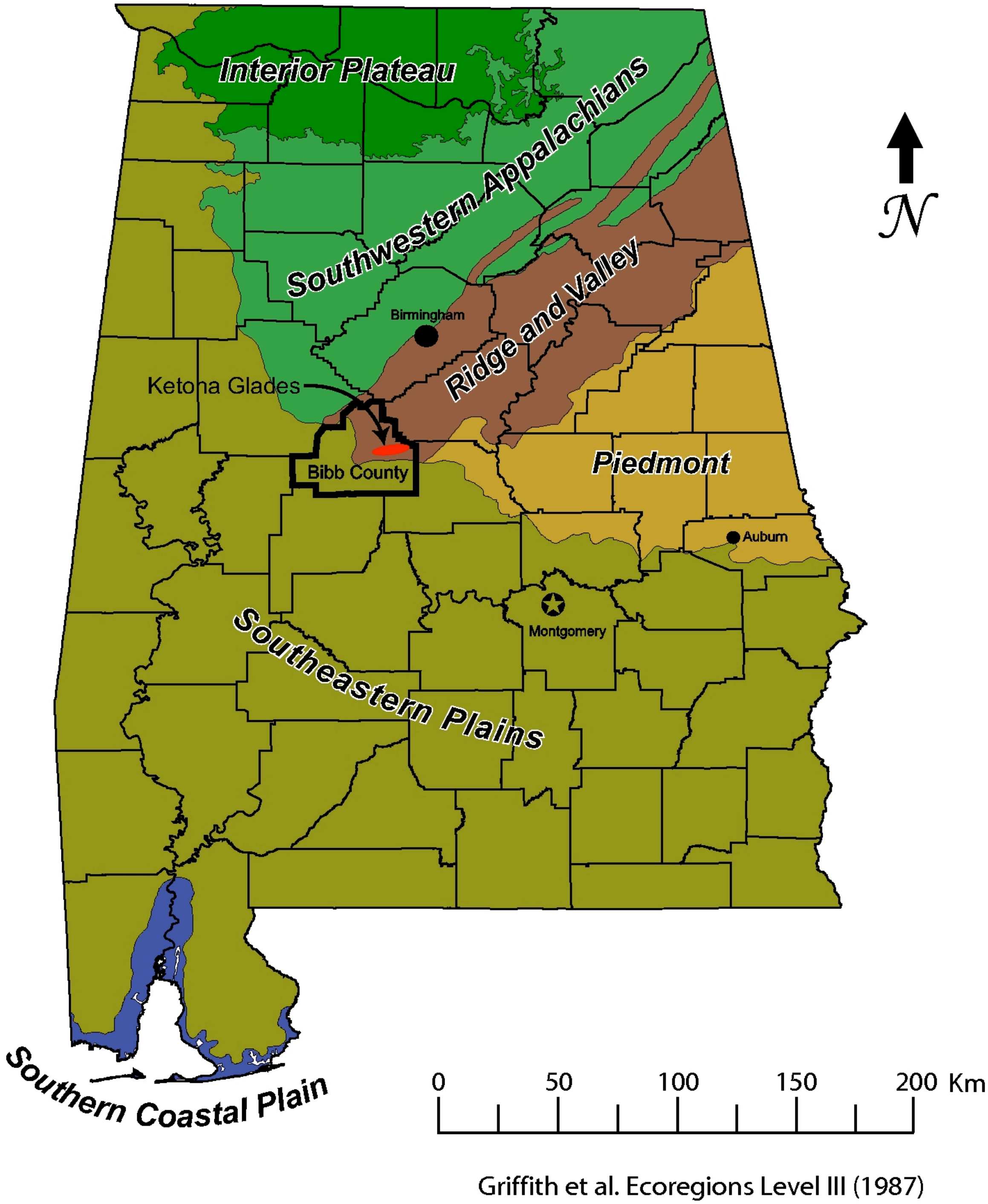
Table 6. Comparison of selected morphological features between *X. spathifolia* and *X. tennesseensis* from herbarium material. *Xyris spathifolia* specimens (type and isotype material) are vouchered at BRIT, Ft. Worth, TX. Analysis provided by Robert Kral.

Character State	*Xyris spathifolia*	*Xyris tennesseensis*
Plant height	15--40(--50) cm	30--70(--85) cm
Stem base	May be short-ascending-rhizomatous (ascending lateral offshoots)	Lacks rhizomes
Principal leaves (length x width)	15--30 cm × 1--2 mm	40--60 cm × 4--10 mm
Leaf surfaces	Sheath papillate medially and distally, blade edges papillate, proximal surfaces papillate	Sheath smooth or finely papillate, sheath keel sometimes papillate, blade edges mostly smooth, surfaces smooth
Scapes	Subterete and multicostate proximally, ca. 1 mm wide distally, sharply 5--7 angled isodiametric, ridges densely papillate-tuberculate, some sharply raised, intervals sulcate or deeply concave, papillate	Subterete and multicostate proximally, 2--3 mm wide distally, often compressed, 3--5 ridged, with 2 ridges flattened and wing-like, all papillate at edges, intervals smooth, level to shallowly concave
Spikes	Ovoid to ellipsoidal or lanceovoid, 5--8 mm	Ovoid, 10--15 mm
Lateral sepals	4.0--4.5 mm long, lanciform, keel ascending-lacerate apically	4.5--5.0 mm long, lanciform, keel ascending-lacerate apically
Petal blades	Obovate, ca. 3.5 mm	Obovate, ca. 4.5 mm
Stamens	1--1.1 mm long, anthers 0.5--0.6 mm	2--2.4 mm long, anthers 1.5--2 mm
Seeds	Ellipsoidal, ca. 0.5 mm, slightly farinose	Ovoid to broadly ellipsoidal, ca. 0.5--0.6 mm, slightly to very farinose

Table 7. NatureServe conservation status of eight new plant taxa described from the Ketona Glades, Bibb Co. (Allison and Steven 2001). G and S ranks of 1 or 2 convey substantial rarity and risk.

Family	Taxon	G-rank	S-rank	Federal Status	State Status
Asteraceae	*Coreopsis grandiflora* var. *inclinata*	G5T2	S2	None	None
	Erigeron strigosus var. *dolomiticola*	G5T2?	S2?	None	None
	Liatris oligocephala	G1	S1	None	None
	Silphium glutinosum	G2	S2	None	None
Boraginaceae	*Onosmodium decipens*	G2	S2	None	None
Fabaceae	*Dalea cahaba*	G2	S2	None	None
Loganiaceae	*Spigelia gentianoides* var. *alabamensis*	G1T1	S1	Endangered	None
Scrophulariaceae	*Castilleja kraliana*	G2	S2	None	None
Asteraceae	*Coreopsis grandiflora* var. *inclinata*	G5T2	S2	None	None

Figure 1. Map showing the location of the Ketona Glades at the extreme southwestern edge of the Ridge and Valley ecoregion, in Bibb Co., AL.



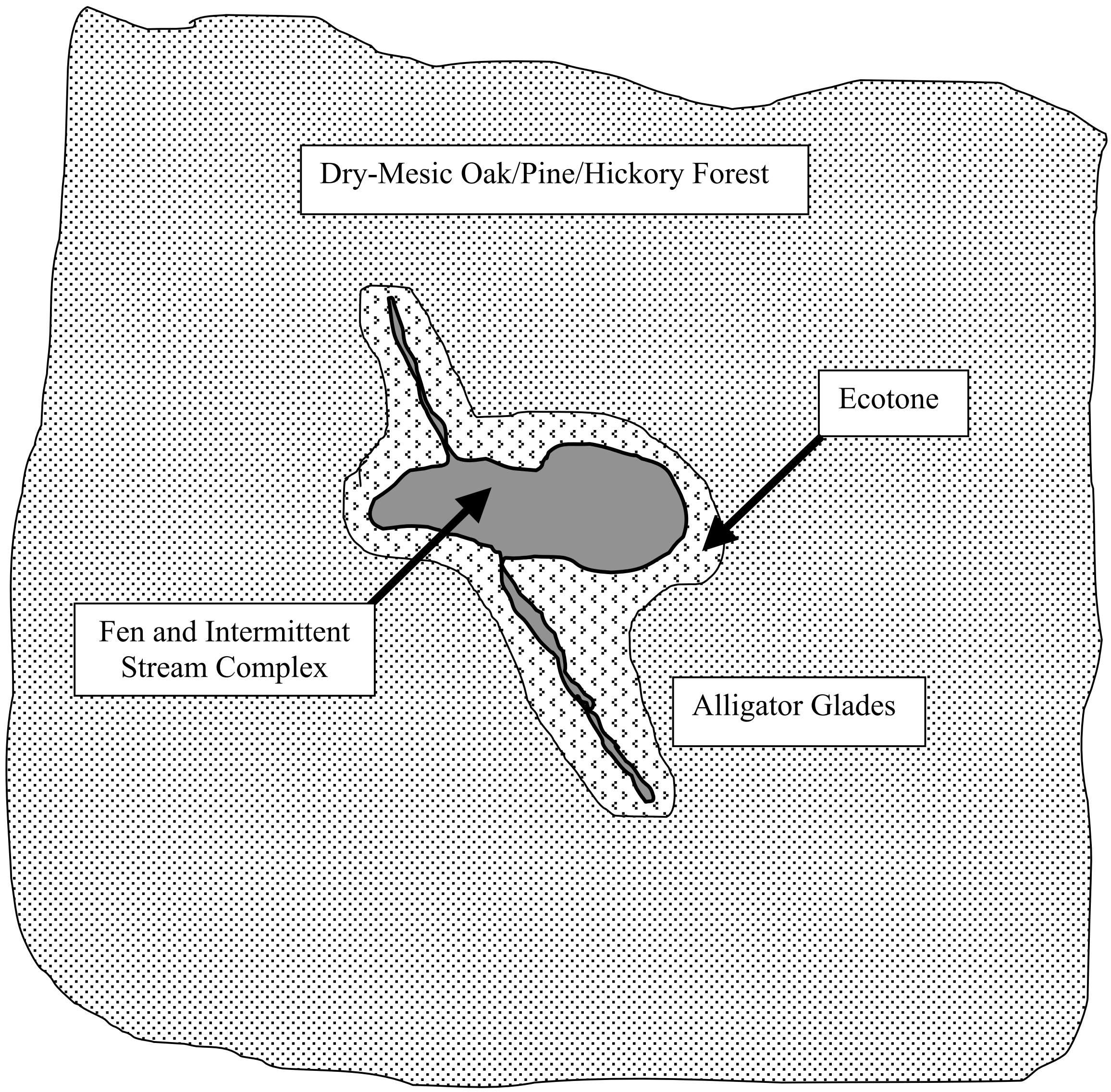


Figure 2. Idealized drawing illustrating the placement of the hydric fen within the sub-xeric Alligator Glades (part of the larger Ketona Glades). Alligator Glades is further shown within the dominant, dry-mesic, oak/pine/hickory forest matrix. The ecotonal zone is also displayed.

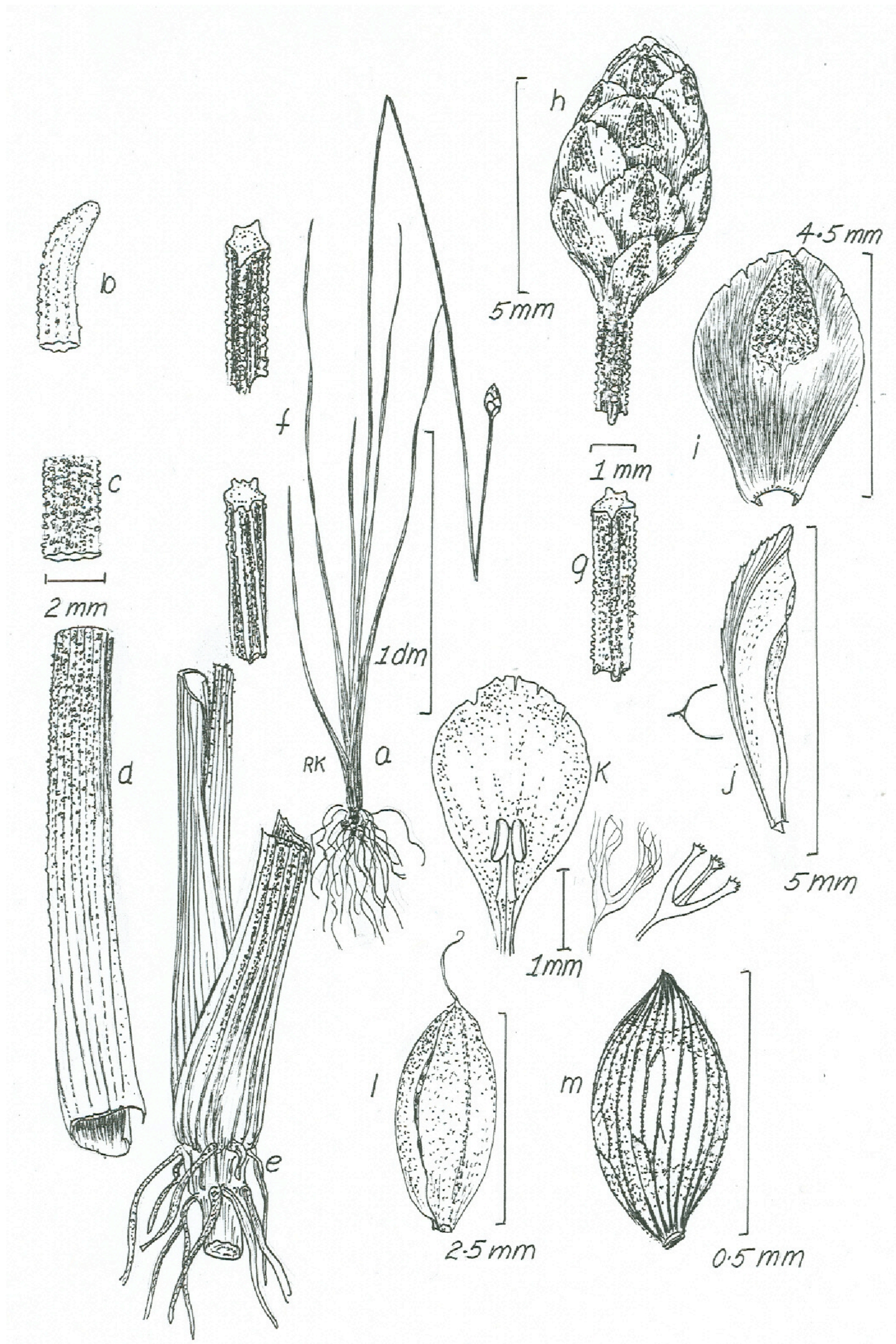


Figure 3. *Xyris spathifolia* (from the type).--a. Habitat sketch.--b. Leaf tip.--c. Sector of leaf midblade. --d. Leaf sheath.--e. Base of innovation.--f. Sectors of lower (below) and middle (above) scape.--g. Sector of distal part of of scape.--h. Spike. i. Fertile bract.--j. Lateral sepal.--k. Petal blade and anther (left), staminodium and style branches (right).--l. Capsule.--m. Seed. Prepared by Robert Kral.

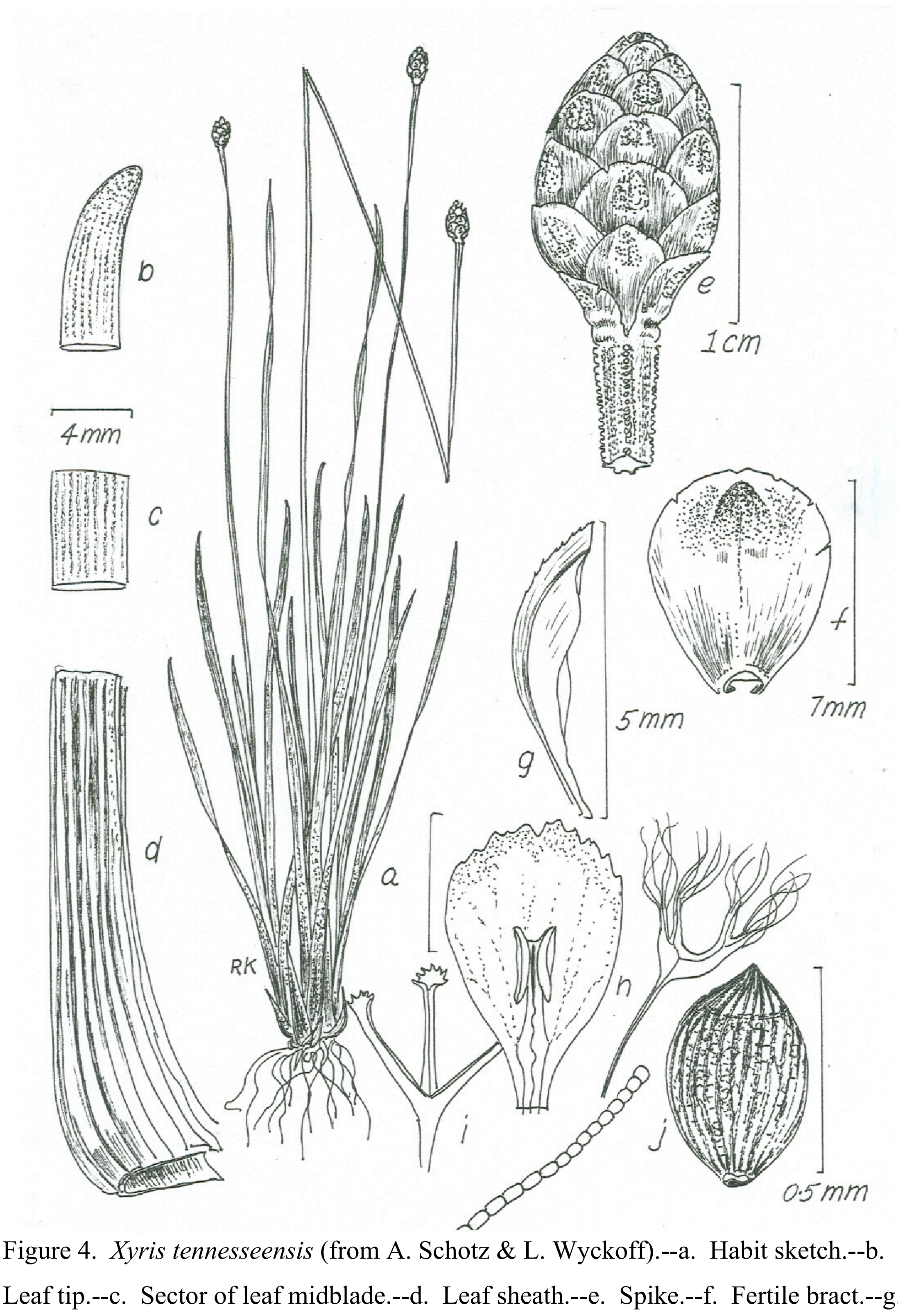


Figure 4. *Xyris tennesseensis* (from A. Schotz & L. Wyckoff).--a. Habit sketch.--b. Leaf tip.--c. Sector of leaf midblade.--d. Leaf sheath.--e. Spike.--f. Fertile bract.--g. Lateral sepal.--h. Petal blade, stamen (left); staminodium, enlarged view of beard hair (right).--i. Stylar apex.--j. Seed. Prepared by Robert Kral.

V. CONCLUSIONS

Xyris tennesseensis is a rare plant restricted to a highly specialized habitat and known from a small number of sites within a limited geographic range. Its rarity and affinity for unusual wetland habitat have placed it at substantial risk for extinction (NatureServe 2008). Conservation efforts focusing not only on acquisition and legal protection of extant populations, but also on the management of populations, will likely be required to sustain this species in the future *in situ*. The unusual character of *X. tennesseensis* microhabitat and its association with the floristically remarkable Ketona Glades of Bibb Co., AL has produced a new species of *Xyris*, known from but a single site, and appearing to be the rarest xyrid in North America north of Mexico.

Habitat analysis, census, demographic sampling, and status survey (Ch. II) confirmed the rarity of *X. tennesseensis* and highly specialized nature of its habitat, as well as its tenuous existence. A habitat summary of the 19 *X. tennesseensis* populations surveyed showed small microsite inclusions within larger wetland or forested systems. The average site size for a population across all ecoregions was quite small at ca. 500 m^2 (about a 22 m × 22 m plot, to offer some perspective). In fact, 13 of the 19 populations exist on less than 400 m^2 of habitat (this figure makes an adjustment for the unusually long riparian corridor population associated with the Little Schulz Creek population complex). All soils supporting populations of *X.*

tennesseensis had relatively very high levels of Ca and Mg, and consequently a relatively high pH, when compared to typical ultisols of the southeastern U.S. (Adams et al. 1994; Brady and Weil 1996; Grunewald 2004). The average Ca, Mg, and pH levels across all *X. tennesseensis* sites were 3,294 ppm, 409 ppm, and 6.9, respectively, compared to ultisol "normal" ranges of Ca, Mg, and pH of 90-250 ppm, 15-35 ppm, and 5-6, respectively. Flowering spike censuses and demographic sampling of all sites found a total of over 81,000 ramets, 63,000 flowering spikes, and 14,000 seedlings. This is ca. 3,500 ramets, 2,600 flowering spikes, and 600 seedlings per site. The means are misleading, however, as three very large robust sites account for 55% of the total ramets, 65% of total flowering spikes, and 68% of total seedlings. These three sites, Lloyd Chapel Swale, AL; Mosteller Springs, GA; and Twin Falls Hollow, TN all qualify as exceptional in the opinion of the author. Another four sites qualify as good: Little Grinders Creek (Nix Br./Hick Hill Br./Confluence), TN; Little Schultz Creek, AL; Burning Ground Seep, AL; and Willett Springs, AL.

Xyris tennesseensis responds favorably to woody plant competition reduction, although the effect is short-lived (Ch. III). Manual removal of the shrub, *Hypericum interior*, and a limited number of other woody species, from a *X. tennesseensis* population in Bartow, Co., GA had an almost immediate effect on reproductive output, as measured by numbers of flowering spikes. In the growing season of the year following the removal of the woody competition, numbers of flowering spikes of *X. tennesseensis* significantly increased three-fold, but decreased in the second year, and by the third year had returned to pre-treatment levels. The return to pre-treatment levels was correlated with an increase in non-*Xyris* vegetative cover, and appeared particularly related to the robust growth of herbs and graminoids. The implication is that *X. tennesseensis* is not a strong competitor with other herbs and may require some management (other than woody encroachment control) to maintain a site in an early-successional state appropriate for *X. tennesseensis*. I also suggested that the relationship between *X. tennesseensis* and *H. interior* may be a favorable one, similar in nature to that of a "nurse plant." Woody plant cutting significantly increased floral visitation and, perhaps, overall levels of successful pollination and outcrossing. The cutting treatment also had a significant effect on seedling production, although survival of the seedlings into adults was not studied. Thus, woody plant cutting seems a valuable component of a management strategy for *X. tennesseensis* populations, especially where prescribed fire is not an option.

The Ketona Glades of Bibb Co., AL, are considered a botanical hotspot, not only for the southeast, but in the entire United States as well (Ertter 2000; Alabama Water Watch 2002). Within the last decade nine plant taxa (including the one described in Ch. IV) have been described from this unique edaphic and floristic area (Allison and Stevens 2001). In addition to the nine new taxa, this area of only 125 ha supports over 420 species, 60 taxa of conservation concern, and numerous state records (Allison and Stevens 2001; Alabama Water Watch 2002). One such species of conservation concern is *X. tennesseensis*. During the habitat analysis and population survey of *X. tennesseensis sites* detailed in Ch. II, a small unfamiliar xyrid was found growing alongside *X. tennesseensis* in a very small isolated fen community within the Ketona Glades. Examination of field collected material, extensive herbarium searches, and results of a common garden study using 3-year-old seed-grown plants indicated this was a new species, previously unknown to science (Ch. IV). *Xyris spathifolia*, the proposed name of the new taxon, differs from *X. tennesseensis* in terms of overall plant and plant character size, leaf and scape surface features, and lower leaf morphology. In general *X. spathifolia* is smaller vegetatively (by about 50% in leaf size and overall plant height), smaller reproductively (by about 10% to 50% depending on the individual character), has a greater number of and more pronounced papillate/tuberculate protuberances on scape and leaf surfaces, and has extreme enfolding or "spathing" of inner leaves by the outer lower leaves. Given its single known population, despite extensive searches in the immediate area, this species of *Xyris* will now replace *X. tennesseensis* as the rarest and most threatened xyrid in North America, north of Mexico. It is hoped that this new taxon can receive rapid conservation protection by the U.S. Fish and Wildlife Service, due to its single very small population, and threats from pine plantation activity/management surrounding it.

Both *X. tennesseensis* and *X. spathifolia* are rare, obligate wetland, perennial plant species with a high degree of specificity for uncommon habitat. As such, they are at substantial risk of extinction. This is especially true of *X. spathifolia* known from but a single privately-owned site. As the southeastern U.S. continues to grow and develop in terms of population and infrastrusture, the risks to native flora will only compound and intensify, and the need for conservation actions will become paramount.

There are several conservation efforts currently underway directed at *X. tennesseensis*. One of the most important involves updating the state Natural Heritage Program element occurrence records with current status and census information. Additionally, in Georgia, the state Department of Natural Resources (DNR) is actively searching for new populations. Living material (from GA ecotypes) will be safeguarded *ex situ* by various member gardens of the Georgia Plant Conservation Alliance (GPCA). Georgia DNR and the GPCA are also collaborating on the establishment of new populations in suitable habitat as part of an *in situ* conservation program for the species.

The situation involving *X. spathifolia* is obviously dire given its single population. Currently, there is some living material remaining from the common garden study that will be safeguarded at GPCA member institutions and the Auburn University Donald E. Davis Arboretum. Visits to obtain *X. spathifolia* seed from the Alligator Glades West site, in order to to bolster the existing *ex situ* collections, will be made in August/September of this year (2008). Efforts will also be made to work cooperatively with the new property owners of the Alligator Glades West site, Forest Investment Associates, to better manage the site for the benefit of both xyrids.

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