

**The Grassland Fidelity Project:
New tools for evaluating grasslands and related grassy ecosystems
on National Parks in Southeastern United States**

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Cover painting by Philip Juras of a landscape in Mecklenburg County, North Carolina. His painting was inspired by the description of the historical Shuffletown Prairie near present-day Charlotte. Taken together with modern ecological inferences, these historical accounts are better informing ecological management and restoration initiatives across the southeastern grassland biome.

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EXECUTIVE SUMMARY

Loss of native grasslands is the single greatest conservation issue facing biodiversity in eastern North America. Rebuilding these forgotten ecosystems will require tremendous collaboration between ambitious organizations as the loss of southeastern grasslands is widespread, and unfortunately ongoing. While this grassland loss has been extensively documented, few resources have been developed to provide crucial and effective baseline data for the Southeast's biodiverse grassland ecosystems. In order to best facilitate a new regional approach to grassland restoration, we developed an important foundational resource: Conservation Lists of "workhorse" species targeted to specific alliances on each of 48 National Parks.

The Grassland Fidelity project was developed through a collaboration between the Southeastern Grasslands Institute (SGI) and North Carolina Botanical Garden (NCBG) as a new tool for ecologists and land managers. The data we assembled as part of this technical report can be used by NPS staff to better understand, document, monitor, restore, reconstruct, and manage grasslands across 48 National Parks in the Southeast Region. In this project, we had five primary goals:

1. Assign heliophily scores for southeastern plants to assess their fidelity to grassland-type ecosystems and their need for full sunlight to thrive and reproduce.
2. Use the U.S. National Vegetation Classification (USNVC, hereafter NVC) to develop lists of known and predicted types of grassland plant communities (alliances) for each park.
3. Use heliophily scores derived from expert opinion to develop lists of grassland-inhabiting species for NVC alliances present in parks.
4. For each grassland alliance of each park, create a Conservation List of "workhorse" plant species that can be used to guide or implement restoration and management of NPS grasslands. Conservation lists will include species high in conservatism as well as highly adapted to open, sunny conditions.
5. Develop a quick how-to-use guide to enable NPS staff to use the products of this project effectively, in concert with an ArcGIS web-application.

Assigning heliophily values was no small task. We assigned scores to 8,382 species and infraspecific taxa (e.g., subspecies), representing the entirety of the native and non-native plants occurring naturally across ten states in the southeastern United States from Kentucky and North Carolina southwards to Florida and Louisiana.

Lastly, we compiled the products of this project into an ArcGIS web-application that allows users to easily interact with the Conservation Lists, heliophily values, plant attributes, and alliances for each park. This includes the ability to query each National Park's grassland ecosystems (NVC alliances) and to create customized grassland species lists based upon a variety of monitoring, management, restoration, and reconstruction projects.

INTRODUCTION

The Southeastern Grassland Biome is a broadly defined region of diverse grassland habitats that spans large portions of the unglaciated Eastern United States east of the Great Plains (Fig. 1). This biome refers specifically to the 12 major grassland ecosystem types occurring across “The Biogeographic Southeast” (Noss et al. 2021a), which in pre-colonial times, would have constituted a significant portion of the regional habitat coverage. Grasslands, as adapted by previous authors (Coupland 1993, Frost 2006, Noss 2012, Veldman et al. 2015, Noss et al. 2021a) are defined by a specific set of criteria described below, and emphasize the importance of open conditions for sun-loving (heliophilic) plants:

Grasslands are ecosystems in which conservative sun-loving (heliophilic) plants such as graminoids (e.g., grasses, sedges, rushes) and forbs (e.g., asters, legumes) form a dominant and relatively continuous ground layer and constitute a high proportion of total plant cover, richness, or biomass, though patches of open bedrock, gravel, or sand may form sparsely vegetated or even non-vegetated inclusions. When heliophilic shrubs and trees are present, these typically form only a sparse or moderate canopy, with less than 50% of the canopy occupied, with less leaf cover than the nearly continuous herbaceous layer (Estes, Witsell, Weakley & Noss, in prep.).

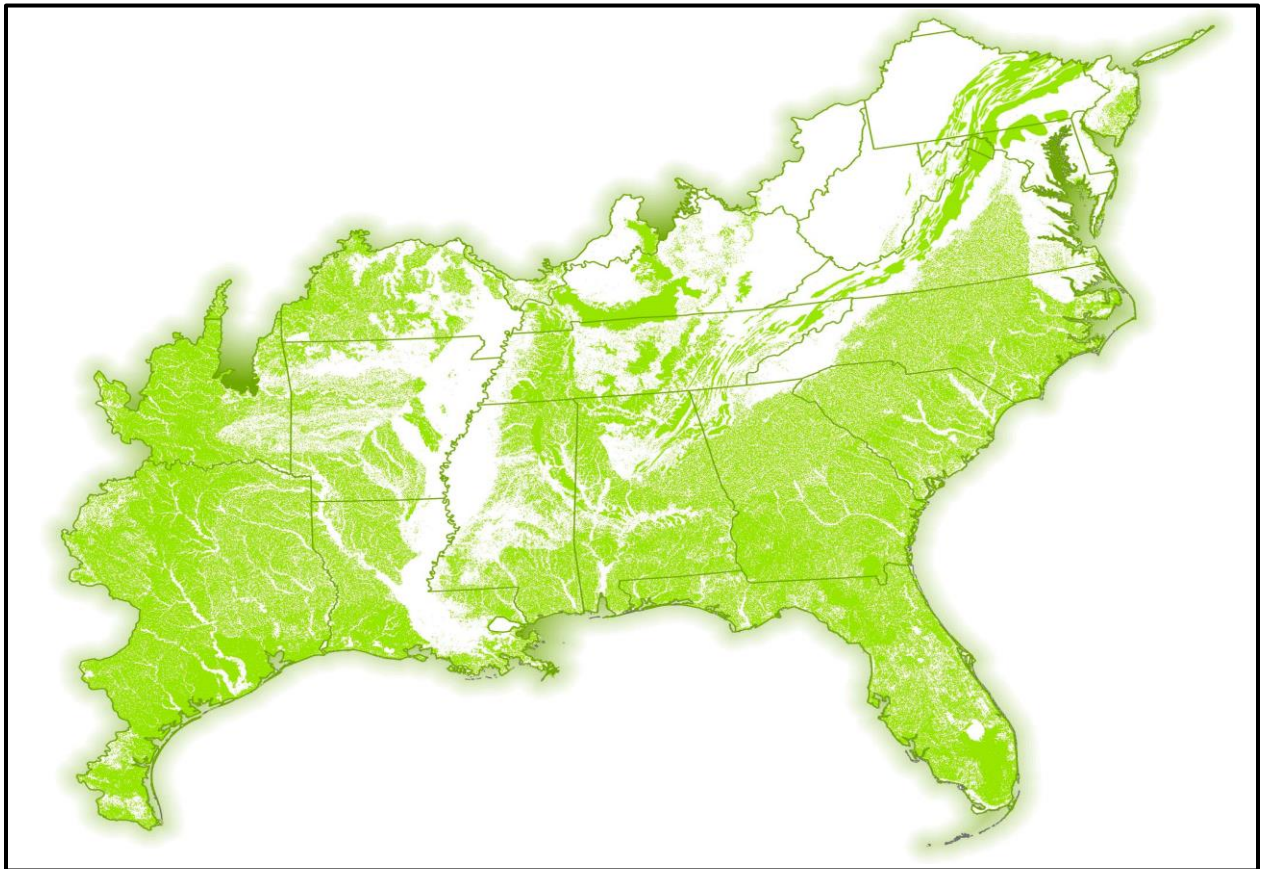


Fig. 1. The Southern Grassland Biome. Map showing the general distribution (in green) of grasslands and grassy ecosystems, which comprise the Southern Grassland Biome noted by E.O. Wilson (Noss 2012). Areas in green represent regions that included significant grassland and/or open woodland ecosystems historically; areas in white were likely historically dominated by non-grassy ecosystems (e.g., closed-canopy hardwood forests, forested wetlands, swamps). Map provisional, created by SGI and NatureServe.

The Southern Grassland Biome includes 12 major grassland ecosystem types

As is the case with species, diverse ecosystem types can be organized into a broadly-defined set of classes (Table 7; Fig. 2). Because of their varied form, Southeastern grasslands have been classified into 12 basic classes (Estes et al. 2016), which and at a finer scale, represent upwards of 118 ecological systems as defined by the NatureServe ecosystem classification system (Noss et al. 2021a, span an impressive array of ecological characteristics.



Fig. 2. The twelve major classes of grasslands within the Southern Grassland Biome.

Owing to its rich geological past, the grasslands of The Biogeographic Southeast occur across an impressive span of ecological conditions. For instance, grasslands are highly varied according to their parent material (underlying

geology), edaphic (soil) conditions such as moisture, organic content, and thickness, topographical relief and sun exposure (aspect), seasonality and annual precipitation levels, and historical and current disturbance regimes like fire and flooding. For instance, Florida Dry Prairies have been maintained by a combination of hyperseasonal climatic conditions as well as high fire frequency (in many cases burning annually). Conversely, some grassland types are maintained by extreme edaphic conditions, such as ultra-thin soils in barrens and outcrops (Fig. 2), or *non-fire* disturbance regimes such as periodic flooding in riverscours grasslands (Estes et al. 2023). Coastal grasslands, such as marshes and dunes, are often maintained by coarse, sandy soils (which limit the establishment of woody plants), high sun availability (which can create xeric growing conditions), and excessive salt concentrations, which can significantly limit plant diversity to a small suite of graminoid and herbaceous species. Savannas and woodlands, which have considerable representation across southeastern parks, are characterized by the presence of trees and sometimes shrubs above a grassy understory. While savannas tend to have sparser canopies and a denser ground-layer, woodlands still meet the necessary requirements of grassland classification, and require fire and/or grazing to maintain their structural integrity.

Components of grassland plant species

Grassland plant species have adapted in myriad ways to overcome the stressful, ever-changing conditions of their respective grassland habitats. For instance, in the frequent fire return intervals of the Florida Dry Prairie ecosystem, herbs, graminoids, and shrubs have all variously evolved to invest substantial energy into underground storage organs. Whether growing as dense, pin-cushion rosettes or geophytes with high root:shoot biomass ratios, these grassland species clearly demonstrate how plants have adapted to life in fire-prone hyperseasonal prairies (Orzell et al. 2024).

Historical southeastern grassland coverage dwarfs that of today

Put simply, the Biogeographic Southeast has a long legacy of landscape-level grassland coverage. The myth that the eastern United States was covered only in dense, climax forests counteracts historical evidence available from early European explorers and naturalists in North America. These limited, but vivid historical accounts reveal the extent of grassland coverage in eastern North America. For instance, early French explorers of North Carolina describe the Piedmont region as simply “Grande Savane.” This “big savanna,” while evident on early maps (Fig. 3) seem contrary to many 20th century ecologists who, perhaps biased by a more “forest-centric” view, instead acknowledged North American grasslands as small or isolated communities within a larger (closed-canopy) forest matrix (Quarterman 1950, DeSelm and Murdock 1993). Indeed, this would have applied to some grassland types, but assuming this applied to all grassland types ignores ample evidence from both past and present. As evidence continues to mount, we’re able to better understand aspects of historical grassland coverage. We now better understand the landscape-level extent of prairie coverage using pre-logging land survey data (Barone 2005) and modern weather models (Hanberry & Noss 2022); we are also better understanding how often, and in which seasons, fires tended to occur using tree-ring and fire-scar studies (Huffman & Platt 2014; Stambaugh et al. 2016), and lastly we now better comprehend grassland community stability over time using modern soil analyses (Krings et al. 2023). Detailed handwritten accounts from early 20th century botanists (e.g., John K. Small; Roland M. Harper) reveal botanical travels fraught with extensive wildfire smoke from landscape-level prairie fires. Roland M. Harper, perhaps ahead of his time in understanding fire ecology, was aware of the integral aspect of fire in maintaining grassy ecosystems, at a time when fire ecology was still grossly misunderstood and often inhibited (Harper 1911). Thus, the evidence is irrefutable. Grasslands, savannas, and woodlands were once a much greater component of the dominant vegetation in eastern North America.

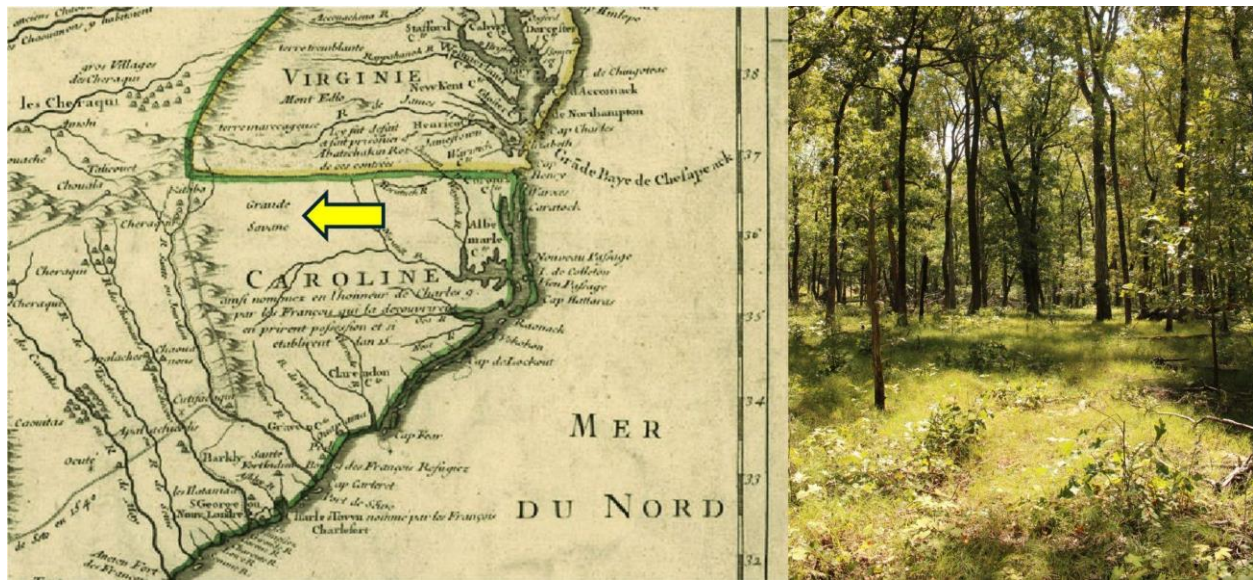


Fig. 3. French Map. Left: A map of Virginia and the Carolinas as seen by early French explorers in 1718. The large central region (left of yellow arrow) labeled as the “Grande Savane” region corresponds to the middle and upper Piedmont region of North Carolina. Map from Guillaume de L’Isle (1718). Right: is a modern-day Piedmont oak savanna in Uwharrie National Forest (picture by Scott Ward), which falls within the “Grande Savane” region mapped in 1718. See also Krings et al. (2023).

Historical grasslands were likely maintained by a different suite of ecological characteristics

Few have challenged the idea that closed-canopy forests covered extensive portions of the eastern US, particularly where ecological conditions favored this natural climax community type (e.g., rich mountain cove forests; old growth bottomlands and swamps). More revealing were the extensive regions of gently rolling hills, such as those present across the southeastern Piedmont ecoregion, that for years have been exposed to a combination of fire, drought, lightning strikes, and high winds that give equal chance to grassland ecosystem formation (see Fig. 4). Evidence of these ecological feedback mechanisms can be seen today in the management of natural areas, and yet historical interactions would be nearly impossible to recreate in modern times. For instance, Noss (2012) proposed the idea that historical site conditions, frequent landscape-level fires, and effects from the grazing of megaherbivores all variously interacted to determine the whereabouts and abundance of grassy ecosystems.

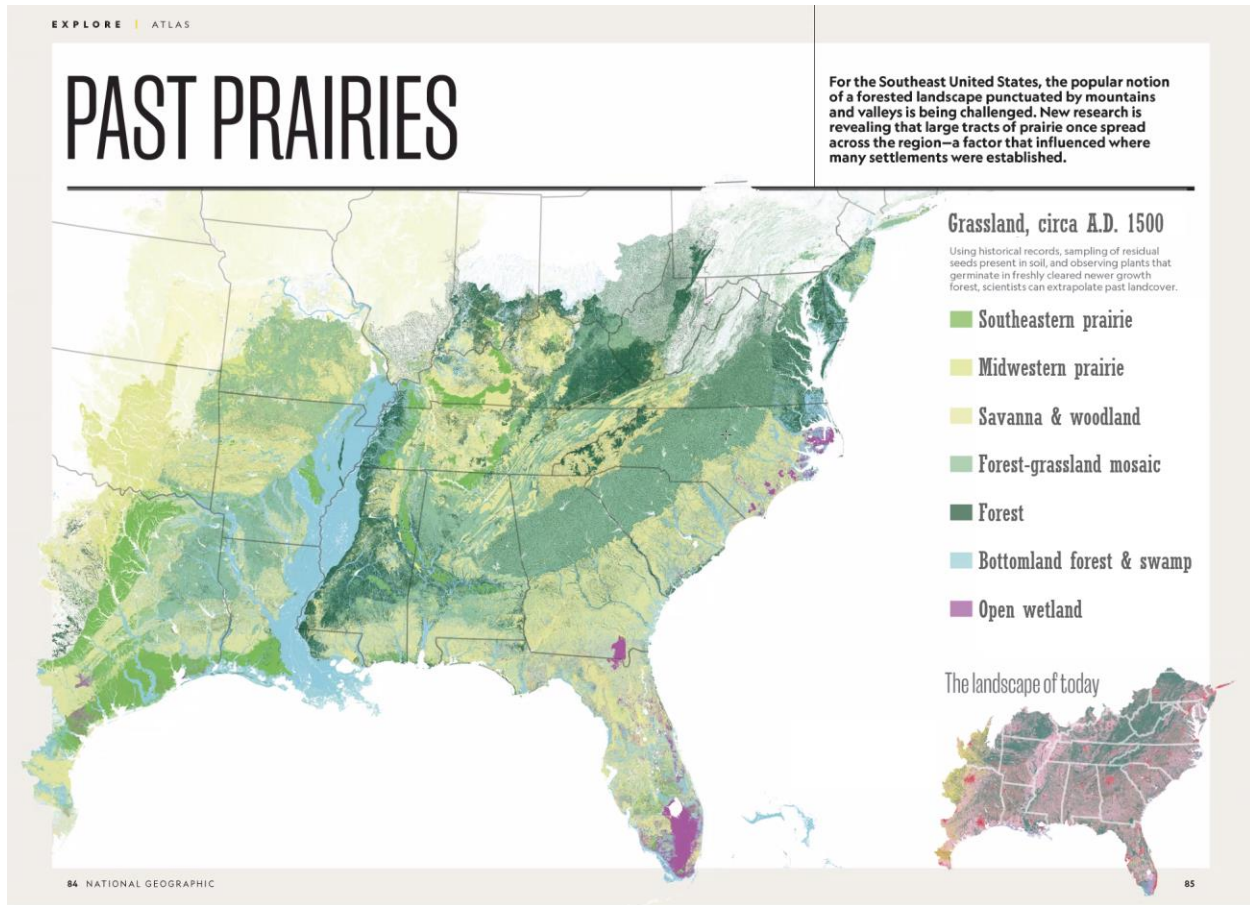


Fig. 4. Historical and current vegetation cover of the "Biogeographic Southeast," which includes E.O. Wilson's *Southeastern Grassland Biome*. Colors on maps correspond to historical estimates of grassland type cover; the map is currently in revision, but a final modified version will be published in *National Geographic* magazine. This map represents a collaboration among SGI, NatureServe, and National Geographic.

Furthermore, the accounts of large grassland mammals (e.g., American Bison) also support the idea of a grassland-woodland matrix landscape (Lawson 1709, Catesby 1771; also see Spooner et al. 2021), although our current understanding of this historical landscape is unsurprisingly limited after the bison's extirpation east of the Mississippi River in the early 1800's (Belue 1996) and subsequent collapse of grassy ecosystems. These historical accounts, along with inferences from modern evidence such as prairie disjunctions and modern landscape models have pulled these forgotten grasslands back into their much-deserved spotlight.

Historical grasslands can be restored

While the scientific and conservation communities continue to reconcile historical grassland evidence with modern ecological management, a major paradigm shift has occurred in our understanding of artificially-maintained forests (or simply "artificial forests") across the Southeast. For instance, new studies are shedding light on the potential of restoration, fire, and proper ecological management in restoring artificially closed forests to savannas rich with ground-layer diversity (Vander Yacht et al. 2020; see Fig. 5). These studies have clearly shown that formerly diverse grasslands can still persist in a landscape that has been heavily modified by humans and, desperate for sun, will respond positively (and often rapidly) to release from artificially closed canopies thanks, in part, to resilient seed- and bud banks.



Fig. 5. Oak savanna-woodland restoration (A is pre-treatment, B is post-treatment) at Catoosa WMA near Crossville, TN, USA. Merely thinning the overgrown (artificial forest) canopy and re-introducing fire caused a dramatic transformation in the formerly dormant, but now conspicuous ground-layer diversity, which includes many conservative grassland species. Photo by A. Vander Yacht from Vander Yacht et al. (2020).

Grassland conservation sits at a critical juncture as our awareness of their importance and historical abundance is precipitated by the continued loss of intact, old-growth grassland ecosystems (Veldman et al. 2015). As many understaffed land management agencies plan grassland restorations, they do not always have the capacity to publish on their restoration successes or failures. More alarming is the lack of scientific basis for such restoration techniques, as managers “fire from the hip” to pull highly degraded ecosystems back from the brink of forested collapse. Unsurprisingly, staff simply do not have time to restore and perform the rigorous research needed to simultaneously analyze and promote their findings. This unfortunately means that mere hearsay or informal reports serve as the basis for communication between various agencies within the larger southeastern ecological community, which may inadvertently lead to small-scale ecological successes but regional failures.

Key limitations and needs for improved southeastern grassland conservation

1. Improved maps

Using improved archival information, we need to develop a more scientifically-rigorous, ecological map of historical southeastern grassland types and coverage. This “new map of the Southeast” will revolutionize our understanding of the historical and current landscape coverage of grasslands across the eastern United States. Additionally, more precise historical mapping across the Southeast will allow ecologists to refine the U.S. National Vegetation Classification (NVC) system, which has long been the standard for southeastern plant community classification. This classification, while robust and standardized, may be potentially dismissive of nuanced grassland community types along the northern and western peripheral zones of the Biogeographic Southeast.

This work will help us to answer important questions, such as: Which grasslands were once more extensive across the Biogeographic Southeast and how dramatically have our grassy ecosystems changed? Which grassland types have been lost and what grasslands have the greatest conservation need? And, in which regions of the southeast is our knowledge of historical grassland cover most limited?

2. Improved grassland classification and awareness

In the initial phases of our project, our team noticed conspicuous omissions from the NVC classification system in both naming and classification. For example, many types of savanna ecosystems were, and still are, being recognized and named as “forests and woodlands” instead of as grasslands with trees. This ultimately inhibits regional and global grassland conservation, as awareness of their true structure, biodiversity, and landscape prevalence is minimized by forest-centric language and the myth of the forest as the dominant climax community type (see Veldman et al. 2015). Fortunately, an increased awareness of grasslands and savannas as ancient, old-growth ecosystems (Fill & Crandall 2024) continues to shed light on the many intricacies of these endemic-rich, fire-prone ecosystems.

Furthermore, modifications in the NVC are needed to accommodate potentially overlooked grassland community types across the Southeast and revise the classification for a broad range of grassland types. Some important questions from this research include: What additional light must be shed by the greater community of southeastern biologists to promote grassland conservation and awareness? Are recent efforts (Noss et al. 2021a) justified in the refinement of the original 45 NVC grassland types to 118 types, or are additional grassland types needing description? How can broad- and fine-scale grassland classifications be reconciled to address cooperative regional and global grassland conservation efforts?

3. Improved understanding of the connectivity between biodiversity and southeastern grassland ecosystems

While robust, the NVC system is also limited in its connectivity between individual species and ecosystem types. Meaning, we lack reliable information that crosswalks plant and animal species to their respective community types, as much of these connections live only in the minds of ecologists and not in a centralized database. For instance, it is well understood that wiregrass (*Aristida beyrichiana* and *A. stricta*) is a major component of longleaf pine habitats; however, the dominant grass changes considerably as one moves from the Carolinas, south through central Florida, and westward across the Gulf Coastal Plain. How do these dominant ground-layer species change throughout the broad range of southeastern pine savanna ecosystem types? Which grassland species should be employed in the restoration of a grassy ecosystem? Ultimately, this research will provide “expected” lists of plant species in any given grassland or grassy ecosystem type within the Biogeographic Southeast.

In 2021, Mark Frey (of NPS) began a dialogue with SGI in an effort to help NPS and its staff better understand its parks’ grassland plants and communities. From the above-mentioned needs, this communication then led to a collaboration among NPS, SGI, and NCBG. These important discussions and subsequent work agreements eventually led to the formation of the Grassland Fidelity project, in which five primary goals were established.

Goals of the Grassland Fidelity Project

1. Assign heliophily scores for southeastern plants to assess their fidelity to grassland-type ecosystems and their need for full sunlight to thrive and reproduce.
2. Use the U.S. National Vegetation Classification (USNVC) to develop lists of known and predicted types of grassland plant communities (alliances) for each park.
3. Use heliophily scores derived from expert opinion to develop lists of grassland-inhabiting species for NVC alliances present in parks.
4. For each grassland alliance of each park, create a Conservation List of “workhorse” plant species that can be used to guide or implement restoration and management of NPS grasslands. Conservation lists will include species high in conservatism as well as highly adapted to open, sunny conditions.
5. Develop a quick how-to-use guide to enable NPS staff to use the products of this project effectively, in concert with an ArcGIS web-application.

In this report, we first describe the context and lengthy groundwork needed to initiate this project conceptually. We describe the basis for a better understanding of regional grasslands and identify major gaps warranting research. Second, we provide rationale and background on the creation of the Grassland Fidelity Project and the methods used to crosswalk species to ecosystems. Lastly, we summarize the main findings from the development of our robust dataset and provide specific instructions on its use so that NPS staff may better understand, document, monitor, manage, restore, and reconstruct grasslands on National Park lands within the Biogeographic Southeast.

METHODS

The following were the steps involved in the implementation of this project, and each is explained individually below.

1. Extract existing documented species data for each NPS park
2. Produce a list of the grassland-related National Vegetation Classification alliances for each park
3. Establish “heliophily” scores for species in the southeastern U.S. region
4. Harvest additional species occurrence data
5. Perform nomenclatural cross-walking
6. Create lists of “workhorse species” for each grassland type as a set of key species for restoration and monitoring on each alliance
7. Generate targeted “conservation lists” for each grassland type in each park
8. Complete spreadsheet of morphological and ecological attributes (for the first set of parks only)
9. Provide summary of recommended best practices
10. Synthesize the conservation lists and documentation into a web portal

1. Extract existing documented species data for each NPS park

To extract floristic data for each park, we downloaded existing species data from the NPS IRMA portal (<https://irma.nps.gov/NPSpecies/>). We then aggregated each park’s list into a combined regional species list.

2. Produce a list of the grassland-related National Vegetation Classification alliances for each park

The list of alliances was generated in different ways for different parks, depending what data was available at that park. For the first set of parks, we had previously compiled a list of all known ecological (grassland) systems, which is a broader classification than alliances. This was an efficient starting point that led us then to consider and choose alliances related to these ecological systems. This step allowed us to incorporate broad regional data from recent grassland ecosystem classifications (Noss et al. 2021a), and also allowed a higher-level crosswalk to the National Vegetation Classification (USNVC 2022).

For parks without a list of ecological systems, we consulted earlier Vegetation Mapping projects archived in the NPS IRMA portal (<https://irma.nps.gov/>). Many types listed in those projects could be mapped onto existing NVC alliances to provide a starting point for these projects. Some types were no longer accepted but could be mapped onto NVC successors. Some types were too broad or informal to be of direct use in this project.

We then looked for additional alliances that might reasonably be expected to occur on each park. We searched the National Vegetation Classification (NVC) for the Biogeographic Southeast in order to identify grassland and grassland-related (e.g. open woodlands and open wetlands) vegetation types. We added alliances we considered probable based on personal field experience or alliances with potential for future restoration within a given park. Use of this systematic inventory and incorporation of EPA Level IV ecoregional data (US EPA 2013) identified gaps in the total alliance list per park given the potential for historical alliances to occur within park boundaries (even in heavily degraded ecosystems) as well as potentially omitted alliances that have been documented nearby. For instance, numerous smaller historical parks occur within the southeastern region, and while they often consist of (and are mapped) as cultivated vegetation (e.g., lawns, plantations), their historical ecological systems must be considered if park staff wish to implement modern grassland restoration within their respective parks. Furthermore, additional undescribed grassland types (or those previously unaccounted for) were also added into final park alliance lists, despite their omission from previous IRMA reports; this due to recent NVC classifications or revelations about undocumented community types. Many additional types warrant inclusion or re-classification, although this was not a primary aim of this project. In cases where we identified gaps in the NVC, it was necessary to create an SGI-placeholder alliance. For these, we assigned a provisional SGI alliance number (starting with “ASGI” instead of “A” for standard NVC alliances), provided a basic description and range statement, and we created a crosswalk back to the nearest equivalent alliance within the current NVC. Our intent of supplementing alliances was not to mirror or mimic the current NVC system, but instead to improve upon the system by recognizing gaps in regional ecosystem coverage and eventually implement into the NVC (Don Faber-Langendoen, pers. comm.; 2024). Further

communication and collaboration with the NVC editorial committee will help to solidify these new alliance types, and thus we felt their recognition was warranted for any future restoration goals within the NPS system.

Thus, given the dynamic historical, current, and future ecosystem management within National Parks, we incorporated multiple lines of evidence to assemble a region-wide alliance list mapped onto each park in the project scope. We did however, omit most community types dominated by non-native or ruderal taxa (although, see A2371). In compiling the final alliance list per park, there were 5 parks (ANJO, CARI, CHPI, NATC, TUPE) that were excluded. This was due primarily to the parks being too small or generally lacking any substantial natural vegetation cover. We were however, able to assign appropriate alliance and workhorse lists for other parks meeting these same criteria (e.g., DRTO, VICK, WRBR), although we were uncertain about the practicality of grassland restorations at these locations. In total, 48 of the initial list of 53 parks were included.

3. Develop “heliophily” scores for species in the southeastern U.S. region

The “heliophily” score was developed by the Southeastern Grasslands Institute and North Carolina Botanical Garden as a revolutionary tool for ecologists, land managers, and stewards. Heliophily serves as a measure of a plant’s affinity for sunlight. To create these values, we compiled a list of all southeastern plant species from the most recent database of the Flora of the Southeastern United States (FSUS, Weakley et al. 2022). This initial list contained all known native and non-native plant species occurring across the 25-state region of the flora, and included 10,719 taxa (species, subspecies, and varieties; Weakley and Southeastern Flora Team 2022). From this initial list, we then narrowed our focus to include only taxa pertaining to the states and state subregions of the 48 national parks included in analyses. This narrowed the initial list to 8,377 taxa.

We compiled a team of 7 botanists across the FSUS region who had expert field knowledge. This team then reviewed the total list of Southeastern plant species and manually assigned heliophily scores to all species in which they were familiar. Each reviewer scored a range of 500-4,000+ species, with multiple reviewers scoring the same species intentionally so that scores would not be limited to one person’s opinion where possible. We compiled 26,021 independent heliophily scores across all 8,377 species. We used the median score for each species as the final heliophily score (Appendix 3). The ranking system is similar to the coefficients of conservatism system, although ranked only from 1-9, with 1 representing species adapted to closed-canopy or densely shaded (e.g., cliff rockhouses) habitats and 9 representing species requiring fully-open habitats (Fig. 6).



Fig. 6. A rigorous system of scoring heliophily (“sun-lovingness”) was developed analogous to the scoring of Coefficients of Conservatism. In this system, each species receives a score from 1-9 to reflect its fidelity to open landscapes, with 9 being obligate open land species that need full sunlight and 1 being species adapted to shaded habitats.

Out of scope for this project, but a core part of the vision of Grassland Fidelity are Coefficients of Conservatism (C-values), developed by Swink & Wilhelm (1979) for remnant prairies in the Chicago region. These authors advocated for the use of C-values to better understand the likelihood of each plant species occurring within a remnant (undisturbed) prairie ecosystem. Since then, the C-value system and its associated metrics have been variously developed into the Floristic Quality Index (FQI), and offers a more dynamic approach to understanding floristic quality within sites and between sites (Wilhelm & Ladd 1988, Taft et al. 1997, Lopez & Fennessy 2002, Matthews 2003). Some plant species can thrive in areas of high human disturbance (i.e., “weedy”) and thus have a broad ecological amplitude; these species are scored low (1-3). Conversely, some plant species exist only in remnant or

refugial habitats (those unchanged by humans) and are thus scored high (9-10); these exist only in a narrow niche of high-quality, intact habitats. Species ranked between (4-8) are characterized as intermediate and can generally persist in ecosystems with some history or level of human disturbance.

In recent years, C-values have been published at state- or regional scales. For the Southeast region, C-value scores were obtained from a variety of state or regional sources, including datasets for wetland plant species (Gianopulos 2014) and for specific states, such as Arkansas (Witsell et al. 2024), Kansas (Freeman 2024), Missouri (Ladd & Thomas 2015), Virginia (DeBerry et al. 2021), and Tennessee and Kentucky (Shaw et al. 2023, Brothers & Shaw, in review) and within regions such as south Florida (Mortellaro 2012). Scores are also available on the Universal Floristic Quality Assessment Calculator website (Freyman et al. 2016). These values were then sometimes averaged across multiple states or regions and combined into our database as the average C-value across the FSUS region.

4. Harvest additional species occurrence data

In addition to foundational NPS and FSUS Data, we supplemented additional occurrence data from iNaturalist, Global Biodiversity Information Facility (GBIF), and SouthEast Regional Network of Expertise and Collections (SERNEC), and similarly consulted the Biodiversity of North America Program (BONAP, Kartesz 2014). All these sources except BONAP were compiled in large batch processes to aggregate many thousands of occurrences. Any additional occurrences on parks were added, except some that seemed unlikely or obviously planted. These data were crucial in augmenting and updating plant record occurrences, which ultimately enhances botanical resources available to park staff and visitors.

5. Nomenclatural cross-walking

Although an important foundation of taxonomy, changes to nomenclature pose a challenge to land managers and data scientists alike. They can even be daunting to taxonomists! Owing to the constant flux of plant names and synonyms, the FSUS database is the most up-to-date taxonomic authority for Southeastern plants and one of very few data sources with systematic species-concept mapping. This updated taxonomy provided us with the most efficient means of crosswalking the many synonyms for southeastern plant species across widely varying taxonomic sources and unifying into one accepted name as recognized in FSUS. Even with a robust source of synonyms, this is a daunting and often ambiguous process that requires some judgment about which species are reported. Where we couldn't be sure, we sometimes left multiple possible species as possibilities for occurring or being tied to an alliance. The resolution of taxa in different datasets did not always match, so we accepted partial matches such as a species level entity present on a park mapping onto a variety of the same species mapped onto an alliance for a park.

6. Create lists of “workhorse species” for each grassland type as a set of key species for restoration and monitoring on each alliance

The greatest challenge of our project was tying regional floristic data to NVC alliances. NVC alliances (along with “associations”) represent defined plant communities with a distinct floristic composition (the plant species present), as well as a uniform physiognomy (overall habitat structure), and habitat conditions (such as soils and bedrock); see page 177 in Jennings et al. (2009) for more information. These national classification schemes represent immense challenges for vegetation ecologists and botanists alike, as they attempt to capture the wide range of variation in natural plant communities across the US. Nonetheless, in a classification this broad, there are bound to be gaps in regional plant community types based upon a number of ecological characters. For instance, in central and southern Florida, longleaf pine (*Pinus palustris*) is relegated almost exclusively to upland, sandhill soils and fringes of dry prairies, whereas south Florida slash pine (*Pinus densa*) becomes the dominant pine of scrubby, mesic, and wet flatwoods. Thus, these regional variants often require subtle accommodation within either the same or different vegetation hierarchy. For example, see [Central Florida Slash Pine Flatwoods](#), a part of the larger [longleaf woodland alliance](#), instead of being classified within the [East Gulf Coastal Plain Wet Pine Open Woodland](#). This was, in large part, due to gaps in regional knowledge of alliances and park community mapping. Identification of key species on target alliances is essential, as land managers are more likely to manage habitats (alliances) and restore grassland types based upon the species integral to those alliance systems.

We first separated the entire NPS region into three geographic areas by project year (Fig. 7):

- Year 1. Interior Plateau, Appalachian, northern Piedmont
- Year 2. southern Piedmont and northern/western Coastal Plain
- Year 3. southern Coastal Plain

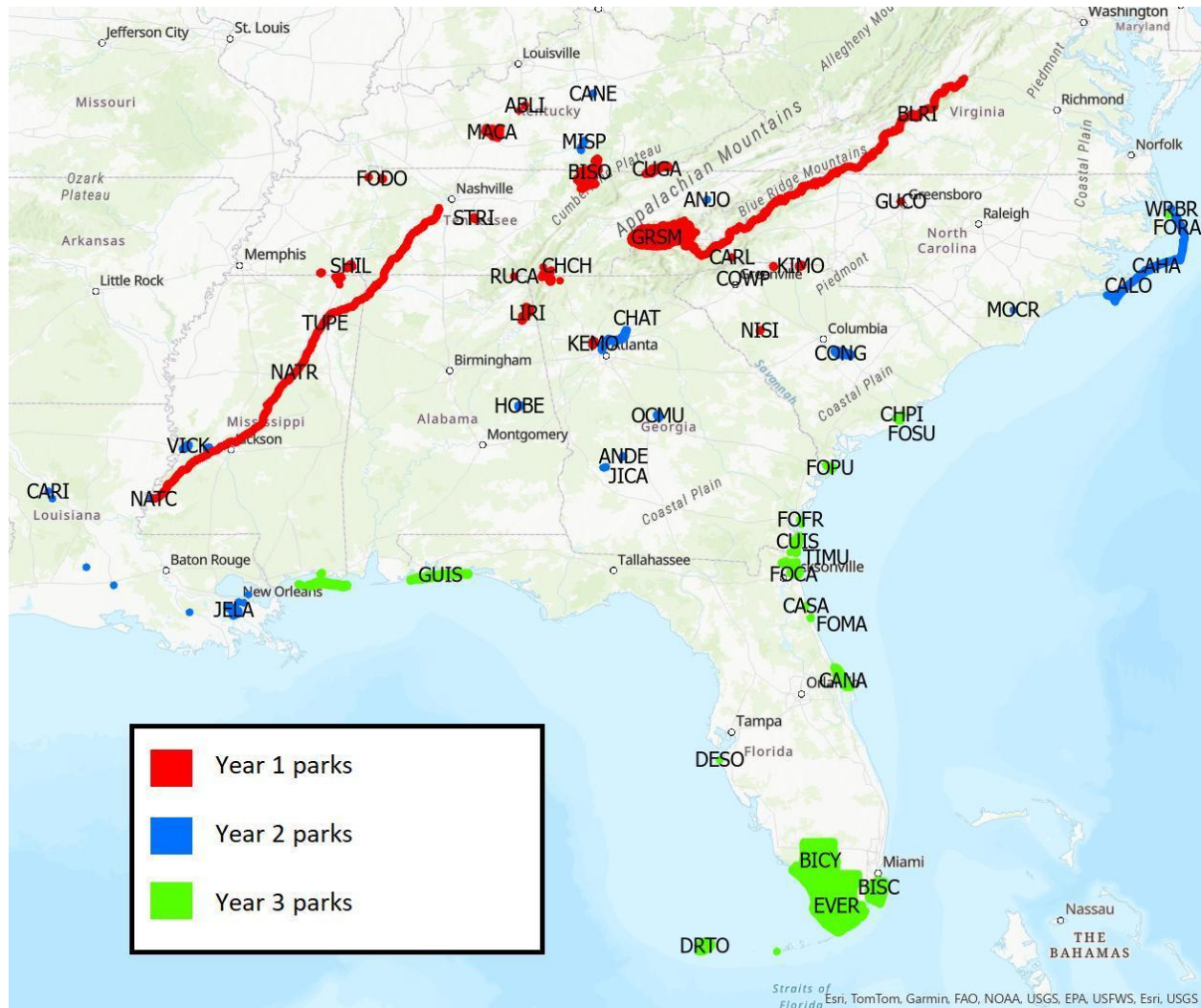


Fig. 7. Map of the Grassland Fidelity Project NPS Parks. Parks are mapped by year of project. SGI primarily assigned alliances for Year 1 parks; both teams assigned Year 2 park alliances; NCBG staff primarily assigned alliances for Year 3 parks.

Each region was assigned to our team's botanists most familiar with that region. Their task was to score each species that has some affinity to each alliance. We scored species not just as present or absent as some species are more integral to an alliance, while others are more peripheral or generalists that may occur there but occur nearly everywhere. The set of alliance affinity values is listed in Table 1.

For the first set of plots, we created an enormous matrix of 10,719 species as rows and 1,800 target types (alliances, groups, and associations) as columns. This created a daunting 20 million cell matrix to populate with affinity scores. Species were selected as workhorses based upon their primary roles as keystone or backbone species within a given grassland alliance (e.g., wiregrass in longleaf pine-wiregrass sandhills). Workhorses are geographically widespread and occur in numerous alliance types (e.g., *Schizachyrium scoparium*), or are limited to a geographically defined area and thus only represent specific alliances (e.g., *Schizachyrium rhizomatum* in peninsular FL). We then filtered our lists down to the workhorse species to complete this step.

In years 2 and 3, we made several modifications to the workflow. We focused exclusively on identifying workhorse species, as the other types of affinity scores did not advance the final product. In these latter two years, we focused on assigning each species to the alliances it best represents as workhorse species (if any). And we looked at each alliance and chose the species that seemed most critical to them. We then added a menu of species to further

consider by programmatically extracting species names from the NVC text fields that mention species names: Type Concept Summary, Floristics Summary, and Dynamics. We extracted species names from alliances as well as their children associations. We ordered these additional species by descending order of heliophily, cutting out species with low heliophily and only adding up to 50 additional species to consider. We reviewed the list of potential additions and accepted or removed species as seemed most appropriate for each type.

Table 1. Alliance affinity scores and definitions assigned to plant species for each National Vegetation Classification (NVC) alliance for each park in year 1 (and portions of year 2 and 3). The primary category assigned for each park were the “workhorse” species.	
Affinity Score	Definition (criteria for inclusion)
workhorse	These are the backbone or keystone species of a given ecosystem; they provide the greatest amount of coverage and structure in terms of biomass; they are key components to consider in rebuilding a particular grassland community type.
generalist	These are common to occasional species that are generally geographically widespread (region or statewide); species often occur in a variety of habitat types; frequencies are often low within a given habitat type.
incidental	These refer to taxa that may be present in grassland communities along the periphery or in select microhabitats embedded within, but otherwise primarily occur in non-grassland community types; their presence is often low in numbers and difficult to predict; they typically have a broad ecological amplitude and are merely peripheral in grasslands.
conservative	These are finicky species of low frequency and often, but not always, in relatively low abundance (i.e., often rare, but not necessarily); they tend to be of high conservation value and are often diagnostic or indicator species of particular remnant or refugial grassland habitats, but tend to lack the cover or biomass of workhorses; they often need certain ecological conditions of medium to high quality to survive or thrive and sometimes require specific disturbance regimes (e.g., frequent fire).
taxonomic issues to be resolved	These are taxa that have complex taxonomic issues due to their recent descriptions by science (or other ambiguities such as taxonomic splits or lumps); scrutiny is needed to assure that the right taxon is coded to the proper region and ecosystem
exotic	non-native species to that FSUS state-physiographic province

7. Generate targeted “conservation lists” for each grassland type in each park

We took the workhorse lists for each alliance and filtered those to species occurring on each target park, based on the species known to occur in the park from the previous steps. Using FSUS species distribution data, we also removed any species that were not listed as occurring natively in each state’s physiographic region (e.g., Piedmont, Coastal Plain of North Carolina), removing exotics and horticultural species for that park. This allowed us to create dynamic conservation lists for each target alliance on each park and removed many unlikely species due to the smaller size of many park floras compared to their respective state subregional floras.

We reviewed the conservation lists (showing park, alliance, and workhorse species) and scanned for issues where alliances had very few species, or for parks that had very few alliances to see if more species or targets might be plausible.

In addition to the rigorous data filtering described in the above steps, we then performed focused data QC on three alliances on each of 12 randomly chosen parks, where four botanists checked for any remaining issues with workhorse inclusion or omission, leading to many refinements described in our workflow. Species were initially considered for removal based upon our attributes data. For instance, many woody or less heliophytic (shade-tolerant) plant species were removed from final alliance workhorse lists as they did not fulfill criteria for grassland habitat types. Some woody plant species were also removed if they have been shown to be problematic within grasslands, especially those prone to fire suppression or exclusion (e.g., *Pinus taeda*) or otherwise can act as aggressive or

weedy natives (e.g., *Baccharis halimifolia*). While many of these species were removed entirely, some were retained within given regions or alliances if they were shown to be appropriate workhorses or particularly useful in a given ecosystem type. Other species were removed partially based upon hyper-regional knowledge of species distribution. These final conservation lists, exhaustively refined, are the most important deliverables from this project. Ultimately, park staff will benefit from this dynamic dataset as they aim for restoration targets using highly-specific workhorse species within targeted plant communities (alliances).

8. Complete spreadsheet of morphological and ecological attributes (for the first set of parks only)

For each species considered in the first year of this project, we assigned a set of attribute values that will be useful to habitat managers, stewards, restoration ecologists, and park staff (Table 2). Attribute values were categorical (e.g., growth form, moisture requirements), or ordinal/scale (e.g., Heliophily value, Avg C-value). The reasoning behind scoring of these given attributes relates primarily to their anticipated importance within restorations. For instance, a manager may want to consider using select shrub species of a given heliophily rank in heavily degraded or disturbed grassland remnants that require rapid establishment. These attribute data were assembled from various sources, primarily from expert opinion, but supplemented by consultation of various floristic manuals and taxonomic treatments, especially *Flora of North America* (1993+), SERNEC Portal (2023), and examination of herbarium specimens (see Reference(s) column).

For the last two years of the project, we omitted the attribute data from our proposal as we no longer had the team member responsible for traits on the project.

Table 2. List of attributes and attribute states for the 4,573 plant species scored for this project. Data population, according to the project agreement, was only completed for Year 1 parks but eventually would be ideally complete for all southeastern parks.		
Attributes (Characters)	Attribute States (Character States)	Reference(s)
Avg C-value	0-10	Arkansas (Witsell et al. 2024), Kansas (Freeman 2024), Missouri (Ladd & Thomas 2015), and Tennessee and Kentucky (Shaw et al. 2023, Brothers & Shaw, in review), south Florida (Mortellaro 2012)
Heliophily value	1-9	generated from expert opinion from this project
Native Status	Native, Exotic	FSUS (2022)
Growth Form	Tree, Shrub, Subshrub, Vine, Forb, Graminoid, Fern, Fern Ally, Thalloid	Flora of North America (1993+)
G Ranks	G1,G2, G3, G4, G5, GNR [combinations possible, definitions on NatureServe Explorer]	NatureServe (2025)
General Ecology	Aquatic, Mud Flat, Wet Woods, Terrestrial, Wetland, Epiphytic, Epipetric	Flora of North America (1993+)
Elevation Ranges (in 500 ft increments)	0-500; 500-1000; 1000-1500, 1500-2000, 2000-2500, 2500-3000, 3000-3500, 3500-4000, 4000-4500, 4500-5000, 5000-5500, 5500-6000, 6000-6500, 6500-7000 ft	Flora of North America (1993+) and expert opinion

Table 2. List of attributes and attribute states for the 4,573 plant species scored for this project. Data population, according to the project agreement, was only completed for Year 1 parks but eventually would be ideally complete for all southeastern parks.

Attributes (Characters)	Attribute States (Character States)	Reference(s)
Moisture Requirements	Hydric, Hydroxeric, Saturated, Inundated, Mesic, Xeric	generated from expert opinion for this project
Soil pH	Acidic, Circumneutral, Alkaline	generated from expert opinion for this project
Plant Duration	Annual, Biennial, Perennial	Flora of North America (1993+)
Plant Armed?	Yes, No	Flora of North America (1993+)
Woody or Herbaceous	Woody, Herbaceous	Flora of North America (1993+)
Leaf Duration	Deciduous, Evergreen, Tardily Deciduous, Absent	Flora of North America (1993+)
Reproductive Phenology (e.g., flowering month)	Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec	iNaturalist (2023+)
Fruit (type)	(many)	Flora of North America (1993+)
Flower Color	(many)	Flora of North America (1993+)

9. Provide summary of recommended best practices

In addition to the conservation lists, we also assembled a short summary with specific instructions on how to best use data from this project in the hopes that land stewards, biologists, ecologists, foresters, biological technicians, contractors and other park staff alike will be better able to monitor, manage, restore, reconstruct, and ultimately understand southeastern grasslands within and surrounding their park (see Appendix 1 for Grassland Fidelity Explorer version and Appendix 2 for Grassland Fidelity Spreadsheet version).

10. Synthesize the conservation lists and documentation into a web portal

Finally, we built a web portal to explore each park's grassland/open alliances and the workhorse species therein. The purpose of this web portal is to enable users to easily access data on grassland plant species and plant communities for each of the 48 national parks assessed. To access the web portal, use this web address:

<https://go.unc.edu/GrasslandFidelity>

RESULTS

We identified 132 alliances in the 48 parks studied in this project (Table 3), with 982 workhorse taxa. These workhorse species represent 12% of the state floras covered in our research (derivative state floras, FSUS 2022). The number of alliances per park varied from 1 to 35 (average = 8.4). Some larger parks, such as Congaree National Park, are mostly forested bottomlands, thus they have only limited grassy upland habitat.

Patterns across Parks

Table 3. List of the 48 National Parks included within the Grassland Fidelity Project. For each park, we also list how many species are included on the park-wide grassland plant species lists, the number of grassy alliances per park, and the number of workhorse species scored per park.

Park Name	Park Code	Number of Species on Parkwide Species List	Number of Grassy Alliances Per Park	Number of Workhorse Species Scored Per Park
Abraham Lincoln Birthplace	ABLI	703	10	148
Andersonville National Historic Site	ANDE	538	3	49
Big Cypress National Preserve	BICY	1323	16	160
Big South Fork National River and Recreation Area	BISO	1717	13	313
Biscayne National Park	BISC	624	3	25
Blue Ridge Parkway	BLRI	2577	35	446
Camp Nelson National Monument	CANE	37	3	7
Canaveral National Seashore	CANA	854	7	74
Cape Hatteras National Seashore	CAHA	1167	10	89
Cape Lookout National Seashore	CALO	696	10	80
Carl Sandburg Home NHS	CARL	637	10	118
Chattahoochee River National Recreational Area	CHAT	1097	6	156
Chickamauga & Chattanooga NMP	CHCH	1521	13	262
Congaree National Park	CONG	1051	3	47
Cowpens National Battlefield	COWP	583	11	97
Cumberland Gap National Historic Park	CUGA	1501	13	258
Cumberland Island National Seashore	CUIS	896	5	86
De Soto National Memorial	DESO	225	2	16
Dry Tortugas National Park	DRTO	15	1	11
Everglades National Park	EVER	1334	14	135
Fort Caroline National Memorial	FOCA	694	4	44
Fort Donelson National Battlefield	FODO	1289	7	243
Fort Frederica National Monument	FOFR	317	4	20
Fort Matanzas National Monument	FOMA	303	1	17
Fort Moultrie National Historical Park	FOMO	208	6	25
Fort Pulaski National Monument	FOPU	369	5	28
Fort Raleigh National Historic Site	FORA	299	1	11
Great Smoky Mountains National Park	GRSM	2020	25	353
Guilford's Courthouse NMP	GUCO	462	9	63
Gulf Islands National Seashore	GUIS	1327	10	111
Horseshoe Bend National Military Park	HOBE	491	5	81
Jean Lafitte National Historical Park and Preserve	JELA	645	4	48
Kennesaw Mountain National Battlefield	KEMO	896	12	126
Kings Mountain National Military Park	KIMO	1095	10	145
Little River Canyon National Preserve	LIRI	1260	10	214
Mammoth Cave National Park	MACA	1495	20	365
Mill Springs National Monument	MISP	232	2	111
Moores Creek National Battlefield	MOCR	737	1	18
Natchez Trace Parkway	NATR	1768	26	400
Ninety Six National Historic Park	NISI	519	8	81
Obed Wild & Scenic River	OBRI	1399	6	178
Ocmulgee National Monument	OCMU	594	3	40
Russell Cave National Monument	RUCA	883	11	154
Shiloh National Military Park	SHIL	1032	13	244

Table 3. List of the 48 National Parks included within the Grassland Fidelity Project. For each park, we also list how many species are included on the park-wide grassland plant species lists, the number of grassy alliances per park, and the number of workhorse species scored per park.

Park Name	Park Code	Number of Species on Parkwide Species List	Number of Grassy Alliances Per Park	Number of Workhorse Species Scored Per Park
Stones River National Battlefield	STRI	1119	9	212
Timucuan Ecological and Historic Preserve	TIMU	749	3	42
Vicksburg National Military Park	VICK	381	1	2
Wright Brothers National Memorial	WRBR	17	1	11

Most Frequent Alliances

The most frequently occurring grassland alliances identified from our project include canebrakes, Appalachian woodlands, and wet meadow and shrublands dominating mountain and interior parks, and salt marshes and dune grasslands dominating the coastal parks (Table 4). Three of the top 10 alliances were newly created alliances (e.g., ASGI118). 20 of the 48 parks had 10 or more alliances; 11 parks had 5-9 alliances, and 17 parks had 4 or fewer alliances (see Appendix 3), meaning more than half of parks (64.5%) had 5 or more alliances present.

Table 4: Most frequent alliance targets across National Parks

Alliances	Alliance Name	Count of Parks
A0795	<i>Arundinaria gigantea</i> Canebrake	22
A3269	<i>Pinus echinata</i> - <i>Pinus pungens</i> - <i>Quercus montana</i> Appalachian Woodland	13
A4497	<i>Spartina alterniflora</i> South Atlantic-Gulf Low Salt Marsh	12
A2346	<i>Spartina spartinae</i> - <i>Juncus roemerianus</i> High Salt Marsh	11
A2347	<i>Spartina patens</i> - <i>Spartina bakeri</i> - <i>Juncus roemerianus</i> Brackish Salt Marsh	11
ASGI118	Central & Southern Appalachian Acidic Wet Meadow & Shrubland	11
ASGI119	Central & Southern Appalachian Acidic Mesic Meadow & Shrubland	11
ASGI120	Central & Southern Appalachian Acidic Dry Meadow & Shrubland	11
A1199	<i>Uniola paniculata</i> - <i>Panicum amarum</i> Dune Grassland	11
A2345	<i>Batis maritima</i> - <i>Sarcocornia pacifica</i> - <i>Distichlis spicata</i> Salt Panne Marsh	8

Heliophily and C-value Ranges of Workhorse Species

We removed all species with heliophily values of 1-3 from the workhorse lists, as these are shade-requiring species. Approximately half of the workhorse species had heliophily values of 8 or 9 (505 out of 982, 51.4%; see Table 5). C-values ranged from 1 to 10, with the average being 5.6, with only 44 workhorses ranking at values of 9 or 10 (highly conservative or relictual species). C-values can vary across regions for a single species, and those with low values (Table 6) represent native species that may volunteer into sites on their own, but they do play a functional role in certain disturbed alliances.

Table 5: Count of workhorse species for each heliophily value

Heliophily	Count of Species
4	29
5	147
6	122
7	179
8	269
9	236

Table 6: Count of workhorse species for each C-value	
C-value	Count Taxa
unknown	63
1	16
2	36
3	59
4	137
5	175
6	194
7	179
8	79
9	28
10	16

Workhorse Species

Many characteristic workhorse species were crosswalked to alliances in this project, with grass species consistently being scored across major grassland types. Major grass workhorses include numerous species likely familiar to NPS staff and biologists, including Giant Cane (*Arundinaria gigantea*), Common Hairgrass (*Avenella flexuosa*), Silky Oat-Grass (*Danthonia sericea*), Saltgrass (*Distichlis spicata*), Seabeach Grass (*Panicum amarum*), Little Bluestem (*Schizachyrium scoparium*), Saltmeadow Cordgrass (*Spartina patens*), Gama Grass (*Tripsacum dactyloides*), and Sea Oats (*Uniola paniculata*), among many others (see Table 7). Other graminoids (sedges, rushes) also contributed substantially to final conservation lists, with characteristic species such as Black Needlerush (*Juncus roemerianus*), Sawgrass (*Cladium jamaicense*), Prickly Bog Sedge (*Carex atlantica*), Woolly Bulrush (*Scirpus cyperinus*), and Few-flowered Nutrush (*Scleria oligantha*) all occurring across a variety of ecoregional alliances for the Southeastern parks.

Table 7. The twelve major classes of grasslands within the Southern Grassland Biome with selected important species across alliances and parks. Note that some of these types can have very different composition based on underlying soil type or region. Some minor modifications were made to each species list for the 12 classes below to better depict species across ecoregions (for those classes occurring within both interior and coastal parks).

		
<u>Balds</u> <i>Avenella flexuosa</i> <i>Calamagrostis cainii</i> <i>Carex misera</i> <i>Danthonia compressa</i> <i>Schizachyrium scoparium</i> <i>Trichophorum cespitosum</i> <i>Aronia melanocarpa</i> <i>Danthonia sericea</i> <i>Houstonia serpyllifolia</i> <i>Hypericum densiflorum</i>	<u>Canebrakes</u> <i>Sambucus canadensis</i> <i>Passiflora incarnata</i> <i>Dioscorea villosa</i> <i>Arundinaria gigantea</i> <i>Elymus virginicus</i> <i>Oenothera biennis</i> <i>Valerianella radiata</i> <i>Chasmanthium latifolium</i> <i>Apios americana</i> <i>Clematis virginiana</i>	<u>Dunes</u> <i>Uniola paniculata</i> <i>Croton punctatus</i> <i>Iva imbricata</i> <i>Panicum amarum</i> <i>Hexasepalum teres</i> <i>Spartina patens</i> <i>Solidago mexicana</i> <i>Muhlenbergia sericea</i> <i>Heterotheca subaxillaris</i> <i>Sporobolus virginicus</i>
		
<u>Fens, Bogs, Seeps</u> <i>Juncus coriaceous</i> <i>Carex debilis</i> <i>Dichanthelium scoparium</i> <i>Rhynchospora capitellata</i> <i>Carex atlantica</i> <i>Osmundastrum cinnamomeum</i> <i>Xyris torta</i> <i>Oxypolis rigidior</i> <i>Solidago patula</i> <i>Osmunda spectabilis</i>	<u>Glades, Barrens, Outcrops</u> <i>Schizachyrium scoparium</i> <i>Dichanthelium depauperatum</i> <i>Agrostis perennans</i> <i>Aronia melanocarpa</i> <i>Andropogon ternarius</i> <i>Hypericum gentianoides</i> <i>Lobelia spicata</i> <i>Packera anonyma</i> <i>Avenella flexuosa</i> <i>Hypericum prolificum</i>	<u>Gravel & Sand Bars</u> <i>Justicia americana</i> <i>Boehmeria cylindrica</i> <i>Hypericum prolificum</i> <i>Swida obliqua</i> <i>Alnus serrulata</i> <i>Cephalanthus occidentalis</i> <i>Juncus repens</i> <i>Physocarpus opulifolius</i> <i>Swida amomum</i> <i>Chasmanthium latifolium</i>

		
<u>Freshwater Marshes</u> <i>Scirpus cyperinus</i> <i>Cephalanthus occidentalis</i> <i>Cyperus strigosus</i> <i>Typha latifolia</i> <i>Hymenachne hemitoma</i> <i>Schoenoplectus tabernaemontani</i> <i>Peltandra virginica</i> <i>Persicaria hydropiperoides</i> <i>Saururus cernuus</i> <i>Cladium jamaicense</i>	<u>Salt Marshes</u> <i>Borrichia frutescens</i> <i>Distichlis spicata</i> <i>Spartina alterniflora</i> <i>Juncus roemerianus</i> <i>Batis maritima</i> <i>Salicornia ambigua</i> <i>Spartina patens</i> <i>Limonium carolinianum</i> <i>Suaeda linearis</i> <i>Sporobolus virginicus</i>	<u>Meadows</u> <i>Sambucus canadensis</i> <i>Elymus virginicus</i> <i>Persicaria punctata</i> <i>Arundinaria gigantea</i> <i>Chasmanthium latifolium</i> <i>Dichanthelium clandestinum</i> <i>Packera anonyma</i> <i>Tridens flavus</i> <i>Cyperus strigosus</i> <i>Symphyotrichum lateriflorum</i>
		
<u>Prairies</u> <i>Helianthus angustifolius</i> <i>Schizachyrium scoparium</i> <i>Tridens flavus</i> <i>Tripsacum dactyloides</i> <i>Eutrochium fistulosum</i> <i>Lespedeza violacea</i> <i>Arundinaria gigantea</i> <i>Agrostis hyemalis</i> <i>Helianthus mollis</i> <i>Eupatorium rotundifolium</i>	<u>Riverscours</u> <i>Andropogon gerardi</i> <i>Schizachyrium scoparium</i> <i>Sorghastrum nutans</i> <i>Hypericum prolificum</i> <i>Amorpha fruticosa</i> <i>Cephalanthus occidentalis</i> <i>Swida amomum</i> <i>Chasmanthium latifolium</i> <i>Tripsacum dactyloides</i> <i>Liatris microcephala</i>	<u>Savanna-Woodlands</u> <i>Packera anonyma</i> <i>Schizachyrium scoparium</i> <i>Solidago nemoralis</i> <i>Pycnanthemum tenuifolium</i> <i>Helianthus divaricatus</i> <i>Lespedeza repens</i> <i>Sorghastrum nutans</i> <i>Liatris squarrulosa</i> <i>Pityopsis nervosa</i> <i>Scleria oligantha</i>

Spreadsheets

In Appendix 3, we have included 48 spreadsheets corresponding to each of the 48 parks analyzed for this project. On the first tab of each park's spreadsheet is the *Parkwide Species Lists*. The second tab is an *Alliance List* of target alliances in the park. The following tabs, one for each alliance on the park, are the *Conservation Lists* of the workhorse species for the alliance (see below).

Parkwide Species List

Below the park information of each park spreadsheet is a list of the known species of plants, including the family, scientific name and common name for each species of each park. Again, these parkwide species lists are from data available from a variety of sources (NPS reports, iNaturalist, SERNEC) to compile an entire working species list of plants from each park (see steps 1 and 4 in Methods). This differs from the workhorse lists (see below), which are the targeted grassland-specific lists recommended for restoration and monitoring. We also include important information regarding each park: including the park name, the state in which the park occurs, the EPA Level IV ecoregion(s) present and the subregion recognized by the Flora of the Southeastern U.S. (FSUS 2022).

Alliance List

This tab repeats the park information from the Parkwide Species then includes a list of the grassland or grassland-related vegetation alliances in that park. Each row represents an alliance, with Alliance Code (each including a link to alliance descriptions in the NatureServe Explorer), Alliance Status, broad Alliance Vegetation Class, and Alliance Name (Scientific).

Conservation Lists of Workhorse Species

Each tab after Alliance List represents the conservation list for an alliance (see Appendix 3; Fig. 10). The tab label corresponds to the NVC Alliance code, followed by “Species.” Additional information can be queried from the NVC Explorer, although much of the alliance information is repeated at the top of each park spreadsheet, including Alliance description, concept, dominant species, and other ecological information. This alliance information, conveniently located in each spreadsheet, will allow the users of these data to understand if the alliance is a good fit for their site (also see Fig. 8).

After the Parkwide Species, Species Attributes, and Alliance List finally sits each Alliance’s workhorse list. On each of these alliance tabs, the species name is listed (with a link to FSUS), its family name and common name. Next are some basic attributes for each workhorse species, including growth form (tree, shrub, forb, vine, graminoid, etc.), native status (only natives are selected for workhorses), heliophily score, Coefficient of Conservatism (C-value) within each respective region (with the average value denoted for species with multiple C-values across the entire Southeast), conservation status, and wetland indicator status. Next is a column that indicates whether the species is known to be commercially available (this data is currently in development, and thus currently incomplete). Following this information, the final column lists the alliance affinity (see Table 1, e.g. workhorse, conservative, generalist; inclusive for year 1 parks, incomplete for years 2 and 3). See each park’s species attributes tab for more Fig. 10 for a labeled spreadsheet example.

Attribute Spreadsheet

A separate tab of attribute data for the Year 1 parks lists attribute data, see Table 2 for details.

DISCUSSION

Grassland Fidelity patterns across southeastern parks

The Grassland Fidelity Project successfully identified 132 target National Vegetation Classification (NVC) grassland alliances for 48 National Parks in the Southeastern United States. While our research has shed light on the sometimes overlooked grasslands present in National Parks, the primary purpose of our findings are still thoroughly practical. The conservation and alliance lists, and related heliophily and conservatism scores provide both a quantitative and qualitative basis for more precise restoration, reconstruction, and monitoring goals within park grasslands and grassy ecosystems.

Particularly interesting to our team was the high frequency in occurrence of two alliances: A0795 (*Arundinaria gigantea* Canebrake) and A3269 (*Pinus echinata* - *Pinus pungens* - *Quercus montana* Appalachian Woodland Alliance), which were recorded across a total of 22 and 13 parks, respectively. While this reminds us of the scale of loss of unique grassland types like canebrakes, which are among the many ecosystems that have been all but eradicated from the southeastern landscape (Noss & Scott 1995, Noss 2012), or the wide scale conversion of open, grassy woodlands into artificially-closed forests, it also stresses the importance of increased awareness of grasslands and their management. Of course, many parks manage their grassy ecosystems with regular fire. Nonetheless, our

research helps to indicate the nature of habitat protection needs within parks. For instance, salt marsh community types have good representation in parks of the outer coastal plain (CAHA, CUIS), whereas other regionally important alliances are only minimally present (and thus preserved) within southeastern parks (e.g., A3305, Atlantic Coastal Plain Wet Longleaf Pine Savanna which is present only at Canaveral National Seashore and Moores Creek National Battlefield).

Unsurprising, however, was the dominance of heliophytes in our final conservation lists given the ultimate goal of our project, with 505 out of 982 workhorses (51.4%) falling into the highest heliophily categories of 8 and 9, meaning these are workhorses that need open conditions. Worth considering, though, are those workhorses scored as moderately heliophilic (4-7) as these may still be of particular importance for woodland and savanna restorations, or alliances with a sparse woody component. 20 parks have 10 or more alliances, often corresponding to some of the southeast's largest (e.g., Great Smoky Mountains; Big Cypress National Preserve) or "longest" National Parks (Blue Ridge Parkway; Natchez Trace Parkway), although see earlier comment (first paragraph of Results) about Congaree National Park. Alliance number per park should not be an indication of conservation priority, however, as major important grassland alliances are still identified for small parks or those with few total alliances. The high proportion of heliophilic plant species and grassland alliances recognized in this project, when considered with the span of ecoregions covered in the Southeastern network, places National Park land into the grassland conservation forefront.

A proposed Grassland Fidelity Index

The key attributes of species that were selected for the Conservation Lists in this project are heliophily (sun-lovingness or likelihood of a species occurring in an open, high-sun habitat) and conservatism (C-values). We propose in future work to combine these two elements into a Grassland Fidelity Index (GFI) score as an attribute of each plant species. The mechanism behind how this combination would best be accomplished will require further study, as will addressing the issue that conservatism scores vary by region.

We also envision a "mean Grassland Fidelity Index" (mean-GFI), similar to mean-C used to compare sites using FQI. A finalized mean-GFI will allow for standardized comparison between different restored grassland sites, as well as monitoring and assessment of the same site over time. Sites with the highest mean-GFI scores (i.e. greater concentrations of conservative heliophytes) are expected to represent intact grassland remnants, and in some cases, old-growth grasslands or savannas. Conversely, sites with the lowest mean-GFI scores are expected to be non-grasslands (such as forests, forested wetlands, etc.) or non-conservative habitats (ruderal, pastoral, weedy, etc.), although initial testing of the metric could better help to define these patterns. One direct use could be easily integrating GFI scores into plot-level monitoring data for NPS Inventory and Monitoring vegetation plots. From here, modifications to the GFI, such as cover-weighted mean-GFI, could help both NPS staff and our research team better understand which workhorses truly dominate their respective alliances. We view this project as fundamental to not only assessing restoration targets but also developing better public awareness and appreciation among Americans for grasslands in their backyards. More importantly, it will allow ecologists and land managers across different parks to compare and communicate restoration results. But, before digging further into implications for use, we provide some basic instructions for use (see Appendices 1 and 2), which will guide users to the many capabilities of our project.

Who stands to benefit from the Grassland Fidelity Data?

Results from our study can be used by a wide variety of interested parties, including NPS park staff, land stewards and managers, ecological researchers, and even the general public. These people and agencies can use our newly developed Grassland Fidelity datasets to better understand, document, monitor, manage, restore, and reconstruct grasslands on 48 National Parks in the Southeast Region, and can similarly inform work on neighboring public and private lands.

We believe that better comprehension of grassland restoration dynamics begins by communicating basic ecological information to National Parks staff with everyone from resource managers, burn bosses, and biologists benefiting from our short, targeted conservation (workhorse) lists. These lists were compiled to highlight the most appropriate native grassland species appropriate for the many grasslands visitors can experience at our parks. We also feel that

our data explorer helps to “demystify” aspects of botany, conservation, and grassland ecology, which we hope will be instrumental in helping those early in their study of park grasslands.

Many park visitors and park historian staff may also be interested in viewing historical aspects of National Parks through an ecological lens. For instance, what type of grasslands grew on the battlegrounds of Antietam, Fredericksburg, and Gettysburg? What would these areas have looked like centuries ago? While many parks unfortunately represent only remnants of their historical acreage, especially grassland remnants, we feel that the anticipated or expected alliances at a given park (using historical data like soils, and historical references like written accounts by early European explorers) will forge a better understanding of how these past grassland conditions have impacted conflicts, culture, and even current park conditions (like fuel loads or current dominant plant communities).

Lessons and challenges with Grassland Fidelity and community classification

Despite decades of important foundational work by the NVC in describing major species components of southeastern alliances, there were still challenges in our research in the crosswalking of workhorse species to alliances. After all, plants do not often aggregate into communities for the convenience of humans studying them. Botanists have long focused on the importance of regional “keystone” plant species in their local ecosystems (e.g., *Cladium jamaicense* in marl prairies of the Everglades), and while we were able to effectively “download” this nuanced information from our team of expert botanists, there still remain small holes in our collective knowledge. Furthermore, our fine focus on grassland types has allowed us to recognize potential NVC gaps and expand upon their robust classification system. For instance, we identified and developed 46 new ASGI provisional alliances during this project, which will help to highlight previously overlooked interior alliances, in addition to other ecoprovinces.

Choosing alliances

We understand that the documentation of National Park alliances is an on-going process, whether prior NVC relationships and alliance codes require recognition under new NVC classifications, or if new alliances (communities) are identified as present by each park’s staff, especially for rare habitats or regional community subtypes. We also realize that there were potential shortcomings in our crosswalking of older association names (retrieved from NPS reports) to their modern NVC alliance equivalents, as well as general challenges in objectively identifying grassland and grassy ecosystem alliances (although see below, Fig. 8). While we could not anticipate the full scope of community recognition across networks, we welcome feedback from NPS staff who have spent considerable time sampling their park’s plant communities.

Fig. 8. Key to Grassland Classes. Use the following key to find an appropriate grassland class for a particular site and its management goals. For restoration and especially reconstruction, some educated guesses as to the broad future conditions will (always) be necessary.

- 1 Upland communities – maintained as grasslands by processes other than wetland condition or riparian flooding.
- 2 Communities maintained as grasslands primarily by high elevation (usually over 4000 feet) coldness and periodic late and early season freezes, and secondarily by grazing, human clearing of woody vegetation, or fire..... **BALDS**
- 2 Communities maintained as grasslands primarily by one or more of: shallowness to rock or pannes, fire, droughtiness, soil “difficulty” (toxicity, shrink-swell-clay, etc.).
- 3 Maritime settings, influenced by coastal storms, unstable sands, salt spray..... **DUNES**
- 3 Non-maritime settings (rarely in the Coastal Plain, but then well away from the coast).
 - 4 Rock dominated ecosystems covering at least 100 m² and therefore lacking an overhead tree canopy, either with a high amount of bedrock or unconsolidated rock covering the site, or bedrock close to the ground surface and covered with shallow gravelly or marly soils mostly 5-20 cm deep or less with bedrock outcroppings more scattered; note forests or woodlands with scattered rock outcrops on the ground are grouped under “non rock dominated ecosystems”; grassland status dependent on the shallowness of soil (sometimes augmented by fire and droughtiness)..... **GLADES, BARRENS, OUTCROPS**

- 4 Non rock-dominated ecosystems, surface of the ground may have scattered isolated outcrops or even abundant outcrops, but these are not large enough to preclude the growth of trees or shrubs, individual rock outcrops or rock-dominated portions of site covering less than 100 m², soils mostly deep though sometimes with abundant rock fragments; grassland status not primarily caused by shallowness of soil to rock.
 - 5 Trees and shrubs typically with <10% canopy coverage, ground dominated by native grasses and forbs; soils usually fertile; topography flat to gently undulating plains..... **PRAIRIES**
 - 5 Trees covering 10-50% of the site otherwise ground dominated by native grasses, forbs, and shrubs; soils usually sandy or rocky; topography flat to rolling plains, wide basins or valleys, lower slopes of escarpments or hills..... **SAVANNA-WOODLANDS [in part; Upland]**
- 1 Wetland or riparian communities -- maintained as grasslands entirely or significantly by tidal or riparian flooding or by seepage or groundwater saturation.
 - 6 Coastal zone communities, maintained as grasslands by regular to rare, lunar- or wind-tidal inundation.
 - 7 Tidal waters salty..... **SALT MARSHES**
 - 7 Tidal waters fresh or oligohaline..... **FRESHWATER MARSHES [in part: Tidal]**
 - 6 Non-coastal communities, maintained as grasslands primarily by one or more of: non-tidal flooding, riverine flood-battering, or seasonal to permanent saturation.
 - 8 Graminoid component cane (*Arundinaria* spp.), in riparian or saturated situations.....**CANE BRAKES**
 - 8 Graminoid component primarily herbaceous.
 - 9 Non-riparian, in wetland situations that are isolated basins or groundwater/seepage fed.
 - 10 Seasonally to near-permanently flooded with ponded water (or indicators of standing water having been present during wetter seasons, such as line indicating high water mark, cracked mud), water 0.1-1.5 meters deep; grasses, sedges, rushes, forbs emerging out of standing water during wet seasons; shrubs and trees sparse, covering <30% of the site; landscape a low area in a lakeshore or a topographic depression or basin..... **FRESHWATER MARSHES [in part: Basin]**
 - 10 Standing water or indicators of standing water not present or if so, only 1-5 cm deep and limited to very small pools, soil saturated at least for certain seasons; trees and shrubs not emerging out of standing water; landscape flat or sloping.
 - 11 Woody component of shrubs or stunted trees; *Sphagnum* often common or even dominant; soils organic or mineral.....**FENS, BOGS, AND SEEPS**
 - 11 Woody component of trees and sometimes shrubs; *Sphagnum* absent or minor; soils usually mineral.....**SAVANNA-WOODLANDS [in part: Wetland]**
 - 9 Riparian grasslands created and maintained by riverine flooding or beaver-elevated hydrologies.
 - 12 Seasonally ponded wetlands in river corridors..**FRESHWATER MARSHES [in part: Riparian]**
 - 12 Temporarily or rarely ponded sites in river corridors.
 - 13 Saturated (at least seasonally) to shallowly and rarely ponded wetlands in river corridors.....**MEADOWS**
 - 13 Seasonally, temporarily, or rarely flooded sites in river corridors.
 - 14 Sites formed on deposits of sand, mud, silt, gravel, or mix of gravel and small cobble (most sediment particles <20 cm diameter), located along low-gradient streams or rivers, vegetation dominated by mostly annual weedy forb/grass species or saplings of short-lived tree species, sometimes with large areas that are unvegetated.....**GRAVEL AND SAND BARS**
 - 14 Sites formed over bedrock or jumbles of cobble or boulder (rock pieces >20 cm in diameter), located mostly along high-gradient streams or rivers or if not then located in bends where floodwaters flow against steep rocky riverbanks; vegetation dominated by mostly perennial, long-lived forb/grass species and long-lived stunted tree and shrub species.....**RIVERSCOURS**

Refining conservation lists

At each step along our data workflow and alliance crosswalk, we made iterative efforts to refine each alliance's final conservation (workhorse) list within each park. When first assigning workhorses, we realized certain alliances were relatively low in total workhorse species, and we thus supplemented these alliances with species listed within their respective NVC alliance descriptions. While this helped us to supplement alliances with few workhorse species, it subsequently added unnecessary species (such as woody plants, or species with shade-preference) to a broad level of alliance types across park networks. To finalize and refine the final conservation lists, we then implemented one final round of data QA/QC, where we considered the potential inclusion of shade-loving (not heliophytic) or woody plant species.

Of particular concern to our team of botanists was the inclusion of certain woody species on final conservation lists. Notoriously problematic species, such as *Liquidambar styraciflua* and *Diospyros virginiana*, were obvious targets for removal, as these native woody species pose problems for regular fire management in upland ecosystems. Similarly, we removed potentially aggressive shrubs and herbs from the final conservation lists, as propagation or seeding efforts should be placed on higher quality heliophytes and many weedy natives are likely to already be present along disturbed park fringes. This is one direct benefit of having C-values integrated into the Grassland Fidelity Explorer (see more below), which allows users of the Grassland Fidelity Explorer to filter for species with higher Coefficients of Conservatism. There are multiple instances; however, where park staff may employ the use of shrubs or trees as "nurse" plants in restorations occurring in severely degraded, sun-exposed, or edaphically-stressed habitats. In such cases, some targeted uses of woody plants may improve restoration success.

Best practices and challenges in implementing grassland restorations in National Parks

Managers and biologists across the southeastern National Parks have vastly different ecosystem management and restoration needs. The grassland habitats, elevations, fire regimes, seasonality, and even staff support varies drastically from Cape Hatteras to Obed and from Jean Lafitte to Mammoth Cave. A burn boss or fire effects crew in the Everglades will have an entirely different prerogative and set of restoration roadblocks than those in the Great Smokies. One concern that varies regionally is that certain species recognized by our team as critical components of conservation lists may not have commercial availability. Furthermore, in most cases native plant material that is commercially available will likely not represent locally-sourced genetic material (genotypes adapted to local conditions). In an ideal world, each park would have local genotype propagation facilities, but we understand that this may be an eventual and not immediate priority of restoration and biology staff. Prescribed fires, ecological management, visitor experience and interpretation, data management, resource planning, structural maintenance, and historical preservation; these are among the many demands of a modern National Park employee.

And so, there is no *one* universal strategy to restore or reconstruct grasslands. In fact, those sites requiring complete grassland reconstruction lack the basic ecological ingredients, such as a seed or bud bank, needed to transition from their highly degraded states. Both restorations and reconstructions will need to be supplemented with native seed, plugs, or other plantings and even smaller, historical parks may be interested in maintaining small areas with native grassy plantings as more attractive (and educational) alternatives to non-native, cultivated lawns.

The future of the Grassland Fidelity project and implications for use

While this is only the first step in the development and implementation of the Grassland Fidelity project, we hope that tailoring grassland ecosystem alliances and providing each type with simple but effective conservation lists is a major jumpstart for grassland-conservation efforts in National Parks. We also hope that the development of our easy-to-use, customized web interface for nearly 50 southeastern parks will encourage use among park staff that want to facilitate grassland restoration but may simply lack the time needed to research alliance and conservation lists due to their many other job responsibilities. This will cut out that all-too-familiar steep initial learning curve because our dataset synthesizes decades of botanical knowledge, grassland research, and plant community and field experience into a single, foundational resource. We are excited to develop these tools further alongside ambitious park staff and now will introduce the various aspects of the NPS Grassland Fidelity Explorer.

The NPS Grassland Fidelity Explorer

Using ArcGIS Experience Builder, we created the [NPS Grassland Fidelity Explorer](https://go.unc.edu/GrasslandFidelity). Click on the link or navigate to <https://go.unc.edu/GrasslandFidelity> to access. This contains the information in the spreadsheets (Appendix 3) but in an interactive format with additional features. Here are the steps to use the explorer (each step is illustrated in Fig. 9 below with the step number):

1. From the Park Code box in the upper left, select the park of interest (parks are listed by their acronyms and full names, [see here](#) for a full table of park codes with their full park names).
2. Next, browse the alliance list and click to select one from the table entitled “NVC Alliances Within Park.”
 - a. Filtering the alliance list by the 12 broad alliance class is a feature in progress.
 - b. Choosing an alliance can be challenging. The 12 broad grassland classes can be helpful to get to a single category. Is the site in dunes? Is it a rocky glade? The site’s expected hydrology will help determine if a wetter or drier alliance is chosen (see Fig. 2 and Table 7).
 - c. If you need help choosing a grassland class, see the key for the 12 classes described (Fig. 8).
3. For more information on alliance classification and descriptions, see directly below under “Alliance Information,” where alliance descriptions and supplemental information is listed. Here, users can explore the defining characteristics of each alliance, and also click on the link to NatureServe Explorer.
4. After you’ve selected an alliance, a conservation list of workhorse species will be shown in the upper right, with each workhorse listed alphabetically by scientific name. Click the link on the scientific name of a species to see all kinds of information about the species in the Flora of the Southeastern United States webapp. Click on the photo for a species to be directed to its iNaturalist page for information on citizen science observations. The number of matching species is shown in the top right of the screen, while each species’ common name and heliophily score is listed below each species’ photo.
5. Optional filters to narrow down the species shown in the conservation list:
 - a. Growth form: filter here to select Forbs, Graminoids, Shrubs, Subshrubs, Vines, Ferns, Fern Allies, or Trees
 - b. Heliophily: filter here to construct a workhorse list on specific heliophily scores (e.g., only those workhorses with the highest heliophily scores).
 - c. Commercial Availability: these data are provisional, but will filter for species with commercial availability in the nursery trade.

Fig. 9. Grassland Fidelity Explorer Screenshot. An example of the Grassland Fidelity Explorer showing 1. CANA (Canaveral National Seashore), 2. its list of available alliances and a selected alliance: A4497 (a Low Salt Marsh), 3. additional data from NatureServe about the selected alliance, 4. conservation list of workhorse species for this park and alliance, 5. Additional species filters: growth form, heliophily, and commercial availability.

Navigating the Spreadsheet for a Park

The process for navigating the spreadsheet data is similar to the Grassland Fidelity Explorer.

- Open the spreadsheet matching the Park Code box of the park of interest (parks are listed by their acronyms and full names, [see here](#) for a full table of park codes with their full park names).
 - If you like, you can browse the full list of species on the Parkwide species list tab.
- Next, browse the alliance list and note one or more alliance codes. Links to NatureServe Explorer are available for standard alliances by clicking the alliance code. Click on the corresponding tab marked “(Alliance Code) Species”
 - Choosing an alliance can be challenging. The 12 broad grassland classes can be helpful to get to a single category. Is the site in dunes? Is it a rocky glade? The site’s expected hydrology will help determine whether a wetter or drier alliance is chosen (see Fig. 2 and Table 7).
 - If you need help choosing a grassland class, see the key for the 12 classes described (Fig. 8).
- On the (Alliance Code)-Species tab, the full name of the alliance and links to NatureServe Explorer (where available) are at the top of the page. Key NatureServe descriptions are included below and to the right of the name and link.
- The conservation list of workhorse species is shown below the alliance information, with each workhorse listed alphabetically by scientific name. Click on a species to be directed to its Flora of the Southeastern United States (FSUS) page. Each species has additional information about it on its row: family, common name, growth form, native status, heliophily, C-values, conservation status, wetland status, commercial availability, and source for its inclusion.
 - Growth form: filter here to select Forbs, Graminoids, Shrubs, Subshrubs, Vines, Ferns, Fern Allies, or Trees
 - Heliophily: filter here to construct a workhorse list on specific heliophily scores (e.g., only those workhorses with the highest heliophily scores).
 - Commercial Availability: these data are provisional, but will filter for species with commercial availability in the nursery trade.

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Fig. 10. Screenshot of spreadsheet for one park, in this case Canaveral National Seashore (CANA). 1. Navigation to spreadsheet for park, 2. Alliance list (with links to NatureServe Explorer), 3. A conservation list of workhorse species for one alliance (here, a Low Salt Marsh Alliance A4497) with alliance information at top and a link to NatureServe Explorer, 4. the list of species, with scientific names linking to Flora of the Southeast (FSUS) and other species attributes, and 5. filters for all fields, with a few key fields highlighted.

LITERATURE CITED

- Barone, J.A. 2005. The historical distribution of prairies in the Jackson Prairie Belt and in western Mississippi. *Journal of the Mississippi Academy of Sciences*, 50(2), pp.144-149.
- Belue, T.F. 1996. *The long hunt: death of the buffalo east of the Mississippi*. Stackpole Books.
- Brothers, S. and J. Shaw. In review. [2025]. Assigning coefficients of conservatism to the vascular flora of Tennessee and Kentucky. *Castanea*.
- Campbell, J.J.N., DD. Taylor, M.E. Medley, & AC. Risk. 1991. Floristic and historical evidence of fire-maintained, grassy pine-oak “barrens” before settlement in southeastern Kentucky. Pages 359-375 in: SC. Nodvin and TA Waldrop (eds). *Fire and the Environment: Ecological and Cultural Perspectives*. Proceedings of an International Symposium. Southeastern Forest Experiment Station, Asheville, North Carolina.
- Catesby, M. 1771. *The natural history of Carolina, Florida and the Bahama islands*, vol I.
- Coupland, R.T. 1993. Overview of African grasslands. In: Coupland, R.T. (ed.), *Ecosystems of the world*. 8B. Natural grasslands. Eastern hemisphere and résumé, pp. 167–169. Elsevier, Amsterdam
- DeBerry, D., J. Thompson, Z. Bradford, D. Davis, J. Ludwig, R. Simmons, and T. Wieboldt. 2021. Coefficients of Conservatism (C-values) for the Flora of Virginia.
- DeSelm, H. R. & Murdock, N. 1993. Grass-dominated communities. In *Biodiversity of the Southeastern United States: Upland Terrestrial Communities* (eds W. H. Martin, S. G. Boyce and A. C. Echternacht), pp. 87–141. John Wiley & Sons, Hoboken
- Estes, D., Brock, M., Homoya, M., and Dattilo, A., 2016, A guide to the grasslands of the Mid-South: Clarksville, Tenn., Natural Resources Conservation Service, Tennessee Valley Authority, Austin Peay State University, and the Botanical Research Institute of Texas, 28 p.
- Estes, D., C. Tracey, E., Zimmerman, W. Knapp, J. Vanderhorst, J. Singhurst, and T. Witsell. 2023. Riverscours ecosystems of eastern unglaciated North America: A review. *Natural Areas Journal*, 43(3), pp.148-168.
- Estes, D., T. Witsell, A. Weakley & R. Noss, in prep. An updated definition of “grasslands” and related open ecosystems for the Biogeographic Southeast, U.S.A. Unpublished data.
- Fill, J. M., and R. M. Crandall. 2024. High survival promotes bunchgrass persistence in old-growth savannas under different fire regimes. *Ecosphere* 15:e70092.
- Flora of North America [Editorial Committee], eds. 1993+. *Flora of North America North of Mexico* [Online]. 25+ vols. New York and Oxford. <http://beta.floranorthamerica.org>. Accessed December 4, 2022.
- Freeman, C.C. 2024. Coefficients of Conservatism for Kansas vascular plants (2024) and selected life history attributes. Kansas Biological Survey, University of Kansas.
- Freyman, W.A., L.A. Masters, and S. Packard. 2016. The Universal Floristic Quality Assessment (FQA) Calculator: An online tool for ecological assessment and monitoring. *Methods Ecol. Evol.* 7: 380–383.
- Frost, C., 2006. History and future of the longleaf pine ecosystem. *The longleaf pine ecosystem: ecology, silviculture, and restoration*, 438: 9-42.
- GBIF.org 2023, GBIF Home Page. Available from: <https://www.gbif.org> [14 June 2023].

Gianopulos, K. 2014. Coefficient of Conservatism database development for wetland plants occurring in the Southeastern United States. North Carolina Dept. of Environment & Natural Resources, division of water resources: wetlands branch. Report to the EPA, region, 4.

Hanberry, B. B., and R. F. Noss. 2022. Locating potential historical fire-maintained grasslands of the eastern United States based on topography and wind speed. *Ecosphere* 13:e4098.

Harper, R.M., 1911. The relation of climax vegetation to islands and peninsulas. *Bulletin of the Torrey Botanical Club*, 38: 515-525.

Huffman, J. M., and W. J. Platt. 2014. Fire History of the Avon Park Air Force Range: Evidence from Tree-rings. Contract report submitted to Avon Park Air Force Range.

iNaturalist. Available from <https://www.inaturalist.org>. Accessed July 12, 2023.

Jennings, M. D., D. Faber-Langendoen, O. L. Loucks, R. K. Peet, and D. Roberts. 2009. Standards for associations and alliances of the U.S. National Vegetation Classification. *Ecological Monographs* 79:173–199.

Kartesz, J.T. 2014, and continuously updated. The Biota of North America Program (BONAP). Taxonomic Data Center. (<http://www.bonap.net/tdc>). Chapel Hill, N.C.

Krings, A., A.D., Szakacs, and E.G., Hyland. 2023. Remnants of the “Grande Savane?” insights from soil organic matter at two sites in the Deep River Triassic Basin of North Carolina. *Castanea*, 87:244-267.

L’Isle, G.D. 1718. Carte de la Louisiane et du cours du Mississipi i.e. Mississippi: Dressée sur un grand nombre de mémoires entr’autres sur ceux de Mr. le Maire. Paris: Chez l’auteur le Sr. Delisle sur le quay de l’horloge avec privilege du roy. Retrieved from the Library of Congress, <https://www.loc.gov/item/2001624908>

Ladd, D. and J.R. Thomas. 2015. Ecological checklist of the Missouri flora for Floristic Quality Assessment. *Phytoneuron* 2015-12: 1–274. Published 12 February 2015. ISSN 2153 733X

Lawson J. 1709. A new voyage to Carolina, London. <https://docsouth.unc.edu/nc/lawson/lawson.html>. Accessed 22 April 2025

Lopez, R. D., and M. Siobhan Fennessy. 2002. Testing the Floristic Quality Assessment Index as an Indicator of Wetland Condition. *Ecological Applications* 12:487–497.

Matthews, J. W. 2003. Assessment of the Floristic Quality Index for use in Illinois, USA, wetlands. *Natural Areas Journal* 23: 53-60.

Mortellaro, S., M. Barry, G. Gann, J. Zahina, S. Channon, C. Hilsenbeck, D. Scofield, G. Wilder, and G. Wilhelm. 2012. Coefficients of Conservatism Values and the Floristic Quality Index for the Vascular Plants of South Florida. *Southeastern Naturalist* 11:1–62.

National Park Service IRMA Portal (Integrated Resource Management Applications). Website. <https://irma.nps.gov> Accessed on July 20, 2023.

NatureServe. 2025. NatureServe Network Biodiversity Location Data accessed through NatureServe Explorer [web application]. NatureServe, Arlington, Virginia. Available <https://explorer.natureserve.org/>. (Accessed: April 20, 2025).

Noss, R. F. 2012. *Forgotten Grasslands of the South: Natural History and Conservation*. Island Press.

Noss, R. F., J. M. Cartwright, D. Estes, T. Witsell, G. Elliott, D. Adams, M. Albrecht, R. Boyles, P. Comer, C. Doffitt, D. Faber-Langendoen, J. Hill, W. C. Hunter, W. M. Knapp, M. E. Marshall, J. Singhurst, C. Tracey, J.

- Walck, and A. Weakley. 2021a. Science needs of southeastern grassland species of conservation concern: A framework for species status assessments. U.S. Geological Survey Open-File Report 2021-1047.
- Noss, R. F., J. M. Cartwright, D. Estes, T. Witsell, G. Elliott, D. Adams, M. Albrecht, R. Boyles, P. Comer, C. Doffitt, D. Faber-Langendoen, J. Hill, W. C. Hunter, W. M. Knapp, M. E. Marshall, J. Singhurst, C. Tracey, J. Walck, and A. Weakley. 2021b. Improving species status assessments under the U.S. Endangered Species Act and implications for multispecies conservation challenges worldwide. *Conservation Biology* 35:1715–1724.
- Noss, R.F. and J.M. Scott. 1995. *Endangered ecosystems of the United States: a preliminary assessment of loss and degradation* (Vol. 28). US Department of the Interior, National Biological Service.
- Orzell, S. L., M. Bitomský, E. L. Bridges, B. Budach, J. Klimešová, J. Martinková, Z. E. Reed, and S. J. Raynor. 2024. Florida's fiery subtropical grasslands: Growth forms, belowground organs, and post-fire recovery strategies. *Folia Geobotanica* 58:209–230.
- Quarterman, E. 1950. Major Plant Communities of Tennessee Cedar Glades. *Ecology* 31:234–254.
- SERNEC Data Portal. 2023. <http://www.sernecportal.org/index.php>. Accessed July 12, 2023.
- Shaw, J., D. Estes, B. Ruhfel, A.B. Morris, and T.R. Littlefield. 2023 [Tennessee-Kentucky Plant Atlas](#). [S.M. Landry and K.N. Campbell (original application development), [USF Water Institute](#), [University of South Florida](#)]. University of Tennessee at Chattanooga, Austin Peay State University, University of Michigan, Furman University, and Kentucky State Nature Preserves Commission.
- Spooner, J. K., R. K. Peet, M. P. Schafale, A. S. Weakley, and T. R. Wentworth. 2021. The Role of Fire in the Dynamics of Piedmont Vegetation. Pages 31–62 in C. H. Greenberg and B. Collins, editors. *Fire Ecology and Management: Past, Present, and Future of US Forested Ecosystems*. Springer International Publishing, Cham.
- Stambaugh, M. C., R. P. Guyette, J. M. Marschall, and D. C. Dey. 2016. Scale Dependence of Oak woodland Historical Fire Intervals: Contrasting the barrens of Tennessee and Cross timbers of Oklahoma, USA. *Fire Ecology* 12:65–84.
- Swink, F. and G. Wilhelm. 1979. *Plants of the Chicago region*. Revised and expanded edition with keys. The Morton Arboretum, Lisle, Illinois.
- Taft, J. B., G. S. Wilhelm, D. M. Ladd, and L. A. Masters. 1997. *Floristic Quality Assessment for Vegetation in Illinois: A method for Assessing Vegetation Integrity*. Illinois Native Plant Society.
- U.S. Environmental Protection Agency (EPA). 2013. Level III ecoregions of the continental United States: Corvallis, Oregon, U.S. EPA – National Health and Environmental Effects Research Laboratory, map scale 1:7,500,000, <https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states>.
- USNVC (United States National Vegetation Classification). 2022. Database Ver 2.032. 2022. Federal Geographic Data Committee, Vegetation Subcommittee. Washington D.C.
- Vander Yacht, A. L., P. D. Keyser, S. A. Barrioz, C. Kwit, M. C. Stambaugh, W. K. Clatterbuck, and R. Jacobs. 2020. Litter to glitter: promoting herbaceous groundcover and diversity in mid-southern USA oak forests using canopy disturbance and fire. *Fire Ecology* 16: 1-19.
- Veldman, J. W., E. Buisson, G. Durigan, G. W. Fernandes, S. Le Stradic, G. Mahy, D. Negreiros, G. E. Overbeck, R. G. Veldman, N. P. Zaloumis, F. E. Putz, and W. J. Bond. 2015. Toward an old-growth concept for grasslands, savannas, and woodlands. *Frontiers in Ecology and the Environment* 13:154–162.

Weakley, A.S., and Southeastern Flora Team. 2022. Flora of the southeastern United States (FSUS) Web App. University of North Carolina Herbarium, North Carolina Botanical Garden, Chapel Hill, U.S.A. fsus.ncbg.unc.edu. Accessed Nov 22, 2022.

Wilhelm, G. and Ladd, D., 1988, March. Natural area assessment in the Chicago region. In Transactions of the North American Wildlife and Natural Resources Conference. 53: 361-375.

Witsell, T., V.L. McDaniel, B.T. Baker, D.M. Zollner, G.L. De Jong, S.L. Hooks. 2024. Coefficients of conservatism for the vascular flora of Arkansas. *Phytoneuron* 2024-46: 1–99. Published 22 June 2024. ISSN 2153 733X.