Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna and Flatwoods

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Ecological Integrity Assessment

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A. INTRODUCTION

A.1. ECOLOGICAL SYSTEM DESCRIPTION

A.1.1. Classification Summary

CES203.265 Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna and Flatwoods

Primary Division: Gulf and Atlantic Coastal Plain (203)
Land Cover Class: Woody Wetland
Spatial Scale & Pattern: Matrix
Required Classifiers: Natural/Semi-natural; Vegetated (>10% vasc.)
Diagnostic Classifiers: Forest and Woodland (Treed); Short Disturbance Interval; Needle-Leaved Tree

Concept Summary: This system of wet *Pinus palustris*-dominated savannas and flatwoods ranges from southern Virginia to southern South Carolina. It was once one of the most extensive systems in the coastward part of its range. Examples and associations share the common features of wet, seasonally saturated, mineral soils and exposure to frequent fire. They occur on a wide range of soil textures, which is an important factor in distinguishing different associations. The vegetation is naturally dominated by *Pinus palustris* or, less frequently, other wetland pines. There is a dense ground cover of herbs and low shrubs; grasses dominate but there is often a large diversity of other herbs. Frequent, low-intensity fire is the dominant natural ecological force.

Range: This system ranges from southern Virginia to southern South Carolina. To the south, the equivalent system is Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods (CES203.536), the range of which includes Georgia.
Divisions: 203:C
TNC Ecoregions: 57:C
Subnations: NC, SC, VA

A.1.2. Environment

Climate
The entire range of this system has a warm humid climate, with mild winters, hot summers, and rainfall well distributed through the year.

Geomorphology and Soils
The system occurs in areas of low topographic relief, generally on broad interfluvial areas but occasionally on higher river terraces. Local sites may be featureless flats or can range

from local highs (low ridges in peatlands) to local lows (swales in drier uplands) in relict coastal, fluvial, or aeolian landforms. Soils can range in texture from coarse sands to loams to clays. Soils are generally acidic and infertile, but variation in fertility associated with soil texture differences is believed to be an important factor differentiating associations.

Hydrology
Soils are seasonally saturated by high regional water tables or less often by perched water tables, but rarely have appreciable surface water. Rainfall and sheet flow are the main sources of water. All examples of this system show vegetational evidence of wetness, but not all are treated as jurisdictional wetlands.

Elevation and Topography
Examples occur in the flat topography of the Coastal Plain, with occasional small patches in flat areas within the higher relief of the Sandhills region. All examples are below 1000 feet elevation, and elevation is not a significant factor.

A.1.3. Vegetation & Ecosystem

Vegetation
The natural vegetation structure is largely two-layered, consisting of a patchy open pine canopy and a dense herbaceous layer. Shrubs are mostly short and sparsely distributed among the herbs. Understory size trees are largely limited to patches of young pine in canopy gaps. Examples altered by lack of fire have more shrubs and understory hardwoods, and correspondingly less herb cover.

Each association has its characteristic herb layer composition, but all have herb layers dominated by one or more characteristic savanna grasses. The most typical grasses include *Aristida stricta*, *Ctenium aromaticum*, *Sporobolus pinetorum*, *Schizachyrium scoparium*, *Andropogon* spp., *Sporobolus teretifolius*, and *Muhlenbergia expansa*. Most savanna associations have a large suite of other characteristic herbs. These associations have some of the highest fine-scale plant species richness values found anywhere in the world. A few associations do not have high species richness, but are still dominated by one of the characteristic grasses and a small number of other herbs.

Longleaf pine is the most typical dominant tree and often the only canopy tree species. Some examples are dominated or codominated by pond pine (*Pinus serotina*). It is unclear if this is natural in all cases, but it is regarded as natural at least in the wetter associations. Longleaf reproduces in canopy gaps, forming small even-aged patches. The overall canopy structure is a fine mosaic of these patches, producing a many-aged stand in aggregate. Homogenization of the patch structure and age structure is a common alteration, as is loss of the older trees.

Biogeochemistry

In natural circumstances, much or most above-ground nutrient release is by fire rather than by decomposition. The dominant plants produce litter that is high in carbon and slow to decompose. In the absence of fire, litter accumulates and a thick duff layer forms on the soil surface.

Productivity
Productivity is fairly low, presumably because of nutrient limitations. Productivity is temporarily increased by fire.

Animals
Relatively little is known about most of the component animal species. Lepidoptera, which include a number of species endemic to this system or to specific associations within it, are believed to depend on a metapopulation structure. Those that cannot hide from fire also depend on unburned patches to recolonize burned areas. The same is also true for some grasshopper species, and potentially of many other insects.

Red-cockaded woodpeckers, a prominent species in this system, depend on old living pine trees to construct their nest cavities. Nest cavities are an important limiting resource for populations. This species also depends on the natural vegetation structure of tall trees and grassy ground cover with little understory. If a hardwood midstory develops, as often occurs with lack of fire, the birds abandon their nest cavities. Increased nest predation and usurping of nests by pileated woodpeckers occur with altered vegetation structure. Red-cockaded woodpeckers are believed to play somewhat of a keystone role because unoccupied nest cavities are used by a variety of other animals.

Fox squirrels (*Sciurus niger*) are believed to play somewhat of a keystone role in Pine Savannas. They feed on longleaf pine seeds and seed caches may plant many seeds. They also feed on subterranean fruiting bodies of fungi that form mycorrhizae with the longleaf pines, helping to disperse their spores. Fox squirrels are well adapted to the natural vegetation structure of Pine Savannas, but apparently suffer detrimental competition with gray squirrels when the structure is altered.

A.1.3. Dynamics

Fire
Fire is the most important ecological process for this system. Estimates for the presettlement fire regime range from 1 to 5 years. Natural fires are low to moderate intensity surface fires. The dominant herbaceous vegetation and leaf litter is highly flammable and slow to decompose. Many of the live herbaceous and shrub species are also flammable. The most abundant dominant grass, wiregrass, becomes flammable within a couple of hours after a rain. Virtually all component plants are resilient to this kind of fire, either surviving it or resprouting rapidly from underground parts. At least some insects, however, are not resilient to fire and must recolonize from unburned refugia.

Weather
Wind throw and lightning strikes are major causes of death in longleaf pine trees, though fires and insects are also a major cause. Longleaf pines are more tolerant of wind than most trees, and even moderate hurricanes often produce only limited canopy gaps.

Population Dynamics
Most of the plants in this system, both trees and herbs, are long-lived and conservative. Because most plants are resilient to the prevailing natural disturbances, turnover of individuals is slow. They recover readily from top-killing, spreading vegetatively to fill small empty spaces, but they do not readily invade larger disturbed areas. Mechanical disturbance severe enough to kill root system often leaves long-lasting damage. A suite of widespread weedy plants invades disturbed areas and may have a seed bank. Weedy vegetation is less flammable, and affects fire behavior, altering ecological dynamics.

Longleaf pine is long-lived and slow to mature. Trees are capable of living over 400 years (Platt and Rathburn (1993). Trees are relatively slow to mature, and may require 80 years to produce substantial amounts of seed. Cone production begins late and continues to increase as the tree ages, with trees 15 inches dbh producing twice as many cones as those 12 inches dbh, and 19 inch dbh trees doubling cone production again (Boyer and White 1990). Seed production varies widely from year to year, with mast years occurring every three years or more. Seedlings require mineral soil to germinate. Most successful seedling establishment occurs only with the coincidence of fire and mast years.

Many insect populations appear to depend on a metapopulation structure. Local populations may be reduced or locally eliminated by fires and reoccupy habitat by recolonization from unburned habitat patches (Hall, et al. 2000).

A.1.4. Landscape Spatial Summary

Nearby upland longleaf pine systems are tightly linked ecologically, sharing many species of plants and animals, including red-cockaded woodpeckers and fox squirrels. Other natural systems, such as pocosins or swamps, are less strongly linked but provide additional habitat and dispersal routes for some species. The landscape surrounding this system is also important for its effect on fire behavior.

The transition of pine savanna systems to wetter systems (savanna ecotone) is an important zone for the biodiversity of the system and is a particularly dynamic area for ecological processes. It is also extremely sensitive to disruption of fire regimes and is often mechanically disturbed. The transition to drier systems is not as well studied, but sometimes includes species not found in the interior of either system.

A.1.5. Size

As in most communities, large size improves ecological integrity and significance by supporting larger populations of component species. Large size occurrences are more

buffered from patch disturbances and fluctuations in populations. Very small sizes are detrimental because fires may not achieve their characteristic behavior and because a number of species may be absent or present in non-viable small populations. Small occurrences are unlikely to support populations of the more sparsely distributed species. No threshold is known at which there are more rapid changes with reduced size.

Some important animal species, including red-cockaded woodpecker and fox squirrel, require large areas; though both of these species can also occur in upland longleaf pine, so their presence depends on a combination of occurrences size and landscape context. Wider ranging species such as black bear and bobcats are habitat generalists whose presence depends more on landscape context.

Pine Savannas once covered extensive areas in the range of this system. Most remaining occurrences are artificially reduced in size. Though some consist of naturally bounded small patches, most would have occurred within 2 km of other patches which no longer exist.

A.2. ECOLOGICAL INTEGRITY

A.2.1. Threats

Fire Regime Alteration
Absence of fire beyond the natural range of return intervals results in both rapid and long term deterioration of vegetation. Communities show evidence of deterioration after only a few years without fire. Flowering ceases for many plants, shrubs and understory trees become larger and denser, and species richness declines as increased woody cover and litter buildup suppress the herb layer. These changes are readily reversible for several years, but eventually become irreversible. Without fire, longleaf pine regeneration largely ceases except in mechanically disturbed areas. Understory hardwoods may eventually reach the canopy, and pond pine (*Pinus serotina*) becomes more abundant. The final result of long term fire suppression in most pine savannas is dense shrubby vegetation that resembles a pocosin, but some may become hardwood forests.

Fire fighting activities may cause more direct impacts on the system. Soil disturbed by fire plow lines is generally occupied by weeds and seldom recovers to natural savanna herbaceous vegetation. Fire plow lines are often cut in parallel sets, and often disturb the wet edges of savannas where some species are concentrated.

Hydrological Alteration
Because of the low relief and substantial role of rainfall and inhibited drainage, this system is less susceptible to hydrologic alteration from the surrounding landscape than many wetlands. However, effective ditching within or adjacent to an occurrence are reasonably believed to reduce wetness. Intensive regional drainage will also affect hydrology. Reduced wetness can result in upland species invading the system, but is less significant than absence of fire.

Land Use
Timber management is the most common land use that alters remnants of this system. Conversion to pine plantation generally is accompanied by bedding and chemical treatments that largely destroy the natural system. However, plantations that are flat planted, and rarely bedded plantations, can sometimes retain significant savanna herbaceous and be recognized as examples of this system in fair condition. Clearcutting without planting often results in herbaceous layer damage and soil disturbance in the wet soils, and regeneration of longleaf pine often fails. A modified form of shelterwood cutting has proven successful for natural regeneration (Boyer and White 1990). All forms of even-aged timber management homogenize the natural patch structure and age structure of the canopy and eliminate the old trees upon which red-cockaded woodpecker depend. Small patch selection and thinning more mimic natural processes and alter the system primarily in reducing the number of old trees and potential ground disturbance by logging equipment.

Pine straw raking is sometimes practiced in pine savannas, though it is more common in upland longleaf pine systems. Pine straw raking results in mechanical damage to the herbaceous layer, sometimes severe. At typical raking intervals, the communities are unable to recover, and damage accumulates. Disturbance of the soil sometimes also occurs. In addition, raked areas are seldom burned and are thus deprived of the ecological benefits of fire. Herbicides are often used to kill shrubs and hardwood trees to facilitate raking. The effect of these herbicides on the large number of herbaceous species is not well known.

Nutrient enrichment
While seldom practiced other than in pine plantations that already have little natural character left, fertilization is detrimental to pine savannas. Species richness is substantially decreased.

Exotics
At present, no exotic plants are significant threats to this system. Slash pine (*Pinus elliottii*) is often planted outside its native range, and may locally reproduce in savannas. Cogon grass (*Imperata cylindrica*) is detrimental in longleaf pine systems farther south and may become a future problem in the range of this system. Imported fire ants are present in many savannas, and are suspected of eliminating or reducing populations of a broad range of ground-dwelling fauna, but this is not well documented.

Fragmentation
As in most ecological systems, isolation from other examples can be expected to make occurrences more susceptible to loss of species populations and to inbreeding within populations. Insects dependent on metapopulations are particularly susceptible. Isolation from other natural systems eliminates wide-ranging habitat generalist animals that may play significant roles in this system.

A.2.2. Justification of Metrics

Landscape Context
Context is addressed at the scale of the immediate borders of the occurrence, and at the large landscape scale. Because of the open structure of pine savannas, typical edge effects such as light levels, wind, or abundance of nest parasites and predators probably are unimportant. However, intact edges indicate intact ecotones between vegetation types, a particularly important component of pine savannas. Juxtaposition of different habitat types is believed to be important for some animal species.

The larger landscape context is addressed as the patch size and nature of other systems to which the occurrence is connected. Other longleaf pine systems share many species and are particularly good contributors to integrity of pine savannas. Other natural communities share fewer species but are sources of wide-ranging habitat generalist species that would not be able to survive in the relatively small patches of pine savanna alone. It is assumed that any connection that allows these species to readily move between the pine savanna and the other habitats will provide this benefit, and that size of the overall landscape habitat is more important than variation in degree of connection or in how close most of that area is to the occurrence [sentence is unclear]. It may be appropriate in the future to split this into separate metrics for area of connected longleaf pine systems and area of other connected natural systems.

Biotic Condition
Biotic condition includes separate measures for canopy and field layer. The field layer, particularly the herb layer, contains most of the species richness, and is also crucial for ecosystem dynamics because of its role in fire behavior. Because most of the plants are highly conservative, the herb layer is not readily replaceable if lost. Herb layer condition integrates history of fire, mechanical disturbance, and shading by woody plants, among other factors. Other vegetation measures (shrub layer, understory, canopy tree regeneration) can also indicate alteration of community condition, but the long term effect is more readily indicated by the herb layer.

The canopy is the largest portion of the biomass of the system, the most important structural component for many vertebrates, and a major source of fuel (pine needles). It is frequently altered. Composition, age structure, and horizontal structure are all crucial aspects of canopy condition that can vary independently and are rated separately.

Exotic species are not documented as a major threat at present, but may become so in the future. A separate metric for exotic species damage is included, but it is expected to vary much.

Abiotic Condition
One of the important abiotic factors, fire, interacts so strongly with the biota that it is better addressed by evaluation of biotic condition. The remaining crucial abiotic factors

that are subject to alteration are hydrology and soil chemistry. Both potentially affect species composition and richness as well as ecosystem processes. Both are difficult to measure and have a substantial range of natural variation that is not well known. They are therefore evaluated based on evidence of alteration to natural conditions rather than by direct measures.

Size

Among pine savannas, larger size corresponds to greater expected viability for all component species and to the ability to support a larger number of component species. However, the benefit of increased size varies with community condition. Many plants are present in high densities when communities are in good condition but sparse or absent when they are degraded. Many insects depend on the abundance of a single host plant species. Many vertebrates are dependent on vegetation structure, which changes with condition. Two size rating metrics are used to account for this variation. Area in best condition indicates how much area is in the condition indicated by the condition rating. This is the area that contributes the most to integrity of the system and viability of its species. Total area indicates amount of habitat available to less sensitive species, some of which require more habitat area than more sensitive species.

A.2.3. Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 1. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some tiers are not doable at Tier 1 (i.e., they require a ground visit). The focus for this System is primarily on a Tier 2 approach.

For each measure a rating metric is developed, scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric is provided in section B. Each metric is rated, and then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition (with sub-ratings for the Herbaceous Layer and the Canopy Layer), Abiotic Condition, and Size.

Table 1. Overall Set of Metrics for the **Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna and Flatwoods System.** Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shaded metrics are core metrics, unshaded are supplementary metrics.

Category	**Key Ecological Attribute**	**Indicators/Metrics**	**Tier**
LANDSCAPE CONTEXT	Edge Effect	Edge ratio of natural/non-natural habitat (buffer)	1, 2, 3
	Connectivity	Size and connectivity of compatible natural systems.	1, 2, 3
BIOTIC CONDITION	Field Layer Condition	Abundance of characteristic savanna grasses	2, (3)
		Herbaceous layer diversity/composition	2, (3)
		Longleaf Pine regeneration *[Metric may be developed in the future]*.	
	Canopy Condition	Canopy composition	(1), 2, 3
		Canopy patch structure	(1), 2, 3
		Trees size/age	(1), 2, 3
	Exotics	Presence and abundance of exotics	2, 3
	Animals	Status of *Picoides borealis* and *Sciurus niger*	3
		Status of Lepidoptera community	3
ABIOTIC CONDITION	Hydrology	Evidence of hydrological alteration	(1), 2, 3
	Soil Chemistry	Absence of artificial nutrient enrichment	
SIZE	Size	Total area of system occurrence	1, 2, 3
		Area of system occurrence in best Biotic and Abiotic Condition class	2, 3

Table 2. Overall Set of Metrics for the Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna and Flatwoods System and their ratings. All metrics are core. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive.

Category	**Key Ecological Attribute**	**Indicator/ Metric**	**Tier**	***Metric Rating Criteria***			
				A Excellent	**B Good**	**C Fair**	**D Poor**
LAND-SCAPE CONTEXT	Edge Effect	Intactness of edge	1, 2, 3	System is bordered by natural communities at least 100 meters wide in at least fair condition over 50% or more of its boundary	System is bordered by natural communities at least 100 meters wide in at least fair condition over 25-50% of its boundary.	System is bordered by natural communities at least 100 meters wide in at least fair condition over 5-25% of its boundary.	System is bordered by developed land, agriculture, pine plantation, or degraded natural systems, or isolated by barriers over 95% or more of its boundary.
	Connec-tivity	Size and connectivity of compatible natural systems.	1, 2, 3	System is connected to at least 1000 acres of other longleaf pine systems, or 5000 acres of other natural systems, in at least fair condition.	System is connected to at least 100 acres of other longleaf pine systems, or to 500 acres of other natural systems, in at least fair condition.	System is connected to other longleaf pine systems of less than 100 acres and connected to less than 500 acres of other natural systems.	System is isolated from other longleaf pine systems in at least fair condition, and is connected to less than 500 acres of other natural systems.
BIOTIC CONDI-TION	Field Layer Condition	Abundance of characteristic savanna grasses	2, (3)	Characteristic savanna grasses moderate to dense (generally averaging three or more clumps per square meter)	Characteristic savanna grasses reduced somewhat from natural density but still abundant and well distributed (generally averaging at least one or two clumps per square meters).	Characteristic savanna grasses at much reduced density overall but still present at least in numerous parts of the occurrence (averaging less than 1 clump per square meter, or less than 10% of the area at natural density).	Characteristic savanna grasses absent or present only as sparsely scattered clumps

Category	Key Ecological Attribute	Indicator/ Metric	Tier	*Metric Rating Criteria*			
				A Excellent	**B Good**	**C Fair**	**D Poor**
		Herbaceous layer diversity/composition	2, (3)	Herb diversity high and composition appropriate for community type. Litter layer not dense.	Herb diversity reduced somewhat relative to natural levels (herbs not just in suppressed vegetative condition due to short term absence of fire). Litter layer moderately dense.	Characteristic herb diversity much reduced. Savanna graminoids that respond to disturbance (*Andropogon* spp., *Dichanthelium* spp., *Rhynchospora* spp.) or weedy forbs may be present at increased densities.	Overall richness of characteristic species greatly reduced. Savanna graminoids that respond to disturbance or weedy forbs may be present at increased densities, or may be the dominant herbs, or herbs may be largely absent.
		Longleaf Pine regeneration		Longleaf pine appears to be reproducing successfully: moderate densities of seedlings occupy canopy gaps within two mast year cycles. Seedlings leave the grass stage after an appropriate number of years.		Longleaf pine is reproducing at reduced levels. Only sparse seedlings are present in canopy gaps even after repeated mast years, OR seedlings are abundant but do not leave the grass stage after a number of years.	Longleaf pine regeneration is failing, with no seedlings in canopy gaps even after repeated mast years.
	Canopy Condition	Canopy composition	(1), 2, 3	*Pinus palustris* and *Pinus serotina* make up 95% or more of the canopy.	*Pinus palustris* and *Pinus serotina* make up 50% or more of the canopy	*Pinus palustris* and *Pinus serotina* make up 10-50% of the canopy, with most of the rest being other pines.	*Pinus palustris* and *Pinus serotina* make up less than 10% of the canopy, or compose up to 50% but the rest is hardwoods, OR canopy is very sparse or absent.

Category	Key Ecological Attribute	Indicator/ Metric	Tier	*Metric Rating Criteria*			
				A Excellent	**B Good**	**C Fair**	**D Poor**
		Canopy patch structure	(1), 2, 3	Canopy a mosaic of small patches of different ages, including old trees and canopy gaps with young regeneration. Overall density moderate (average tree cover generally 30-70%), though individual patches may be denser.	Canopy largely homogeneous in age, but with some gaps containing regeneration or some variation in tree sizes AND overall density moderate (30-70% tree cover).	Canopy homogeneous in density and age, AND extremely dense.	Canopy extremely sparse or absent.
		Trees size/age	(1), 2, 3	Canopy size trees averaging 30 cm dbh or more, with more than a few old trees (over 35 cm dbh or over 200 years old).	Canopy trees averaging 30 cm dbh or more but essentially without old trees, OR canopy trees averaging 25-30 cm dbh but old trees common.	Canopy trees averaging 25-30 cm dbh and old trees essentially absent OR average canopy trees smaller but old trees common.	Essentially no old trees present AND average tree size smaller than 25 cm.
	Exotics	Presence and abundance of exotics	2, 3	No invasive exotic plant or animal species present.	Invasive exotic species present locally in small numbers.	Invasive exotic species widespread in the community but not dense.	Invasive exotic plant species widespread and dense, reducing native plant density.
	Animals	Status of *Picoides borealis* and *Sciurus niger*	3	Both *Picoides* and *Sciurus* present at approximately natural abundance.	Both species present but at least one at unnaturally low densities.	One species present.	Both species absent.

Category	Key Ecological Attribute	Indicator/ Metric	Tier	*Metric Rating Criteria*			
				A Excellent	**B Good**	**C Fair**	**D Poor**
		Status of Lepidoptera community	3	Characteristic butterfly and moth species present at close to natural levels of abundance and species richness.	Characteristic butterfly and moth species present but at somewhat reduced levels of abundance and species richness.	Some characteristic butterfly and moth species present but at significantly reduced levels of abundance and species richness. Only habitat generalist or weedy species abundant.	Few or no butterflies and moths present.
ABIOTIC CONDI-TION	Hydrology	Evidence of hydrological alteration	(1), 2, 3	No evidence of effective artificial alteration of hydrology: ditches are absent, old, or not tied in to effective drainage; ground surface is not substantially altered.	Evidence of mild alteration of hydrology: ditches that are tied in to drainage networks are present at low density BUT ground surface is not substantially altered (as by bedding or pervasive fire plow lines).	Evidence of moderate alteration of hydrology: site is bedded or pervaded by numerous fire plow lines BUT ditches are absent or present only at low density.	Site is intensively altered by a dense network of ditches or by bedding combined with ditches.
	Soil Chemistry	Absence of artificial nutrient enrichment		No artificial nutrient addition.	Minimal artificial nutrient addition.	Artificial nutrient addition calibrated to match loss from artificial action such as pine straw harvesting.	Excessive or uncontrolled artificial addition of nutrients.
SIZE	Size	Total area of system occurrence	1, 2, 3	100 acres or more	30-100 acres	2- 30 acres	Less than 2 acres

Category	Key Ecological Attribute	Indicator/ Metric	Tier	*Metric Rating Criteria*			
				A Excellent	**B Good**	**C Fair**	**D Poor**
		Area of system occurrence in best Biotic and Abiotic Condition class	2, 3	100 acres or more	30-100 acres	2- 30 acres	Less than 2 acres

A.3. SCORECARD PROTOCOLS

Combination table approach: In this approach, the combinations of individual ratings for each measure are assessed to create an overall rating for the category. Every possible combination of ratings for the measures is specified and the overall rating is specified. For example, if one measure is ranked A, and the other B, the combination table will tell you whether the combined rating is A or B. The combination table allows for ecological judgment as to how the measures might interact. If more than three factors need to be combined, the fourth factor is used as modifier to the result based on the other three. This is indicated in the caption for the table.

At this time, roll-ups are provided for each of the four categories, but the four categories themselves are not rolled up into an overall Ecological Integrity Index.

A.3.1. Landscape Context Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the combination table (Table 3) to roll up the two metrics into an overall Landscape Context rating.

Table 3. Landscape context combination table. The combination table explicitly "translates" each combination of measure ratings from Table 2 into a combined letter score.

	Edge Effect			
Connectivity	**A**	**B**	**C**	**D**
A	**A**	**A**	**B**	**C**
B	**B**	**B**	**C**	**C**
C	**B**	**C**	**C**	**D**
D	**D**	**D**	**D**	**D**

Rationale for combination tables: Connectivity receives more weight than edge effect. The two are partially interchangeable, allowing a high score in one to partially compensate for a low score in the other. Several combinations are very unlikely to occur, but are included in the table for completeness. If an occurrence has little or no other

natural communities bordering it, it is possible but very unlikely to have a strong biological connection to any other natural lands. This makes several other fair to poor combinations very unlikely.

A.3.2. Biotic Condition Rating Protocol

Rate all measures according to the specs. Then use the combination rule tables (Tables 4, 5) to reach an herbaceous layer score and canopy score. Then use the final combination rule with the herbaceous layer score, canopy score, and exotic species score to reach an overall biotic condition rating (Table 6).

Rationale for Scoring and Combination tables

Herbaceous layer sub-rating: Abundance of characteristic grasses and herb layer diversity are both crucial characteristics of pine savanna systems. A system cannot be in excellent condition unless both are excellent, so only a combination of A and A combines to an A. In general, the lower of the two ratings determine the combined rating, but much higher ratings on one factor are allowed to compensate to a limited degree for a low rating on the other. Thus, occurrences with excellent characteristics for one factor may be regarded as good despite only fair characteristics on the other.

Canopy layer sub-rating: Canopy composition is crucial to canopy condition. Other species of pines can play some, but not all, of the ecological role of longleaf pine, and hardwoods alter several ecological functions. Because the D rating for canopy composition includes appreciable amounts of hardwoods, good size/age and patch structure have almost no ability to compensate for this deficiency. Because the C rating includes appreciable amounts of other pines, it has less drastic effect on the combined score. Interpretation of canopy composition interacts strongly with tree size/age; large trees are of little to no benefit if they are hardwoods and of only limited benefit if they are other pines.

Tree size/age is given intermediate weight between canopy composition and canopy patch structure because it is more irreplaceable than patch structure. Gaps can be created quickly and relatively easily from a homogeneous canopy; however, true heterogeneous structure takes a long time to restore, so its presence raises the score of a site with fair tree size/age. Some combinations of size/age and patch structure are logically impossible. Forests cannot have heterogeneous patch structure with trees of different ages if all the trees are young.

Biotic condition rating: Both canopy layer condition and herb layer condition are crucial to excellent vegetation condition. Therefore, only the combination of A x A is scored as an overall A. While not ecologically interchangeable, different combinations of canopy and herb layer condition can be treated as intermediate overall condition. Because the herb layer is more irreplaceable than the canopy and harbors most of the species diversity in the communities; the herb layer score is given more weight in these combinations.

Exotic plant rating: Finally, exotic plant invasion is a measure that is somewhat but not completely redundant with herb layer condition. It is kept as a separate measure, but for the combination approach, only affects the combined score when it is extremely high (D rating). Because dense exotic plants detract from natural condition and represent a future threat whatever the density or diversity of the herb layer, this measure has considerable weight, lowering the combined score by one level for all combinations in which it is poor.

Table 4. Herbaceous Layer sub-rating combination table. The combination table explicitly "translates" each combination of measure ratings from Table 2 into a combined letter score.

		Herb layer diversity		
Abundance of characteristic grasses	**A**	**B**	**C**	**D**
A	**A**	**B**	**B**	**C**
B	**B**	**B**	**C**	**D**
C	**B**	**C**	**C**	**D**
D	**C***	**D**	**D**	**D**

Table 5. Canopy Layer sub-rating combination table. The combination table explicitly "translates" each combination of measure ratings from Table 2 into a combined letter score.

		Tree size/age		
Canopy patch structure	**A**	**B**	**C**	**D**
	Canopy composition			
A	**A: A** **B: B** **C: B** **D: C**	**A: B** **B : B** **C: C** **D: D**	**A: B** **B: B** **C: C** **D: D**	**Will not occur.**
B	**A: A** **B: B** **C: C** **D: D**	**A: B** **B: C** **C: C** **D: D**	**A: C** **B: C** **C: D** **D: D**	**A: C** **B: C** **C: C** **D: D**
C	**A: B** **B: B** **C: C** **D: D**	**A: B** **B: B** **C: C** **D: D**	**A: C** **B: C** **C: D** **D: D**	**A: C** **B: C** **C: C** **D: D**
D	**D**	**D**	**D**	**D**

Table 6. Combination table for overall biotic condition scoring based on herb layer and canopy layer sub-ratings from Tables 4 and 5. Using the combination approach, if presence and abundance of exotics score = D, reduce the score from this table by one grade (e.g. from B to C).

		Canopy score		
Herb layer score	**A**	**B**	**C**	**D**
A	**A**	**B**	**B**	**C**
B	**B**	**B**	**B**	**C**
C	**B**	**C**	**C**	**D**
D	**C**	**D**	**D**	**D**

A.3.3 Abiotic Condition Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the combination table (Table 7) to roll up the two metrics into an overall Abiotic Condition rating.

Abiotic Combination Table and Scoring Rationale: Each measure has a similar weight, but the two are not interchangeable. The combined rating is driven by the minimum value.

Table 9. Abiotic Condition combination table. The combination table explicitly translates each combination of measure ratings from Table 2 into a combined letter score.

		Hydrological condition		
Soil nutrient status	**A**	**B**	**C**	**D**
A	**A**	**B**	**C**	**D**
B	**B**	**B**	**C**	**D**
C	**C**	**C**	**C**	**D**
D	**D**	**D**	**D**	**D**

A.3.4 Size Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the combination table (Table 11) to roll up the two metrics into an overall Size rating.

Size Combination Table Rationale:

Because the high quality area is able to support more species and larger populations of the more sensitive species, the size of the high quality area is the primary size measure. However, having large additional areas in poorer condition may compensate to some degree if the high quality area is small.

Table 11. Size combination table. The combination table explicitly "translates" each combination of measure ratings from Table 2 into a combined letter score.

	Size of high quality area			
Total system size	**A**	**B**	**C**	**D**
A	**A**	**B**	**B**	**C**
B	**Will not occur.**	**B**	**C**	**C**
C	**Will not occur.**	**Will not occur.**	**C**	**D**
D	**Will not occur.**	**Will not occur.**	**Will not occur.**	**D**

B. DOCUMENTATION FOR METRICS

B. 1. LANDSCAPE CONTEXT METRICS

B.1.1. Intactness of edge

Definition: This metric addresses the extent of alteration to the immediate surroundings of the system occurrence, expressed as a percentage of the edge which is bordered by other natural system types. In multi-patch occurrences, it addresses the sum of edges of all patches.

Background: This metric is one of two that measure the effect of the area surrounding the system occurrences. It indicates the integrity of transition zones (ecotones) with adjacent systems and the ability of the adjacent systems to interact. This system interacts with adjacent systems through animal movement, and potentially through fire spread or sheltering and plant seed dispersal. Water and nutrient movement may also occur but is believed to be relatively minor because of low gradients and slow flow. Different systems naturally border pine savannas; upland longleaf pine, pocosins, and swamps are most common, but small patch systems may also be embedded. The most intensive interaction is likely with upland longleaf pine systems, through which fire can readily spread and which share important species; however, all adjacent systems will share some species and affect natural fire behavior. The ecotone between pine savannas and adjacent systems is widely recognized as being of particular biodiversity significance because some species are concentrated in it.

Rationale for Selection of the Variable: Interaction with adjacent systems through animal movement, seed dispersal, and fire spread is an important aspect of ecological function in this system. Detrimental edge effects in the form of altered biotic interactions are possible at artificial edges. Because of the open vegetation structure of savannas, physical effects of forest edge are unlikely to be important. However, seed rain of weedy

or uncharacteristic plants is likely, and increased populations of uncharacteristic animals may also occur. The ratio of natural to unnatural habitat is a simple measure of the effect of the immediate vicinity on these functions.

Measurement Protocol: This metric is evaluated by measuring or estimating the amount of edge of system patches and measuring or estimating the amount of adjacent cover that is natural systems in at least fair condition. To avoid ineffectively small natural fringes, adjacent natural systems should be at least 100m wide. Agriculture, cultural vegetation, plantations, developed areas, 4-lane highways, heavily traveled 2-lane highways, and degraded natural systems are counted as unnatural habitat. [All natural systems that would rate at least C on the condition portion of their occurrence rank are treated as natural edges.]

Tier 1 protocol for this metric consists of a remote sensing-based measure, using aerial photo interpretation or a land cover map, to determine adjacent systems within a 100 m buffer.
Tier 2 protocol for this metric consists of field observation combined with aerial photo interpretation to determine adjacent systems within a 100 m buffer, and an estimate of the fraction of natural systems within that buffer.
Tied 3 protocol for this metric consists of field assessment and measurement of amounts of edge bordered by each system [not developed].

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
System is bordered by natural communities at least 100 meters wide in at least fair condition over 50% or more of its boundary	System is bordered by natural communities at least 100 meters wide in at least fair condition over 25-50% of its boundary.	System is bordered by natural communities at least 100 meters wide in at least fair condition over 5-25% of its boundary.	System is bordered by developed land, agriculture, pine plantation, or degraded natural systems, or isolated by barriers over 95% or more of its boundary.

Scaling Rationale: No data are known to suggest that there is anything other than a steady loss of integrity as more of the ecotones are lost and more of the adjacent areas are altered. The thresholds chosen are arbitrary.

Confidence that reasonable logic and/or data support the index: Medium. Further research may reveal more appropriate thresholds in the scale. Further research may suggest value in weighting surrounding condition by the compatibility of different conditions.

B.1.2. Size and connectivity of compatible natural systems

Definition: This metric addresses the connection of the pine savanna occurrence to other natural systems. It simultaneously combines three aspects of connectivity: size of the connected natural landscape, what systems are present in the connected landscape, and what condition the connected systems are in.

Background: This metric is one of two that measure the effect of the area surrounding the system occurrences. While it accounts for areas immediately adjacent to the occurrence, it also includes the effect of areas that are farther away but still connected.

Rationale for Selection of the Variable: This system interacts with connected systems through animal movement, and potentially through fire spread or sheltering and plant seed dispersal. Some interactions are primarily with immediately adjacent areas, while others, particularly animal movement and seed dispersal, may occur from a larger area if it is connected to the system occurrence. The most intense interaction is with upland longleaf pine systems, which shares many species; however, all connected systems will share some species and contribute to the ecological function of the occurrence. It is assumed that the most important influence on a pine savanna by its connected landscape is what species the landscape supports. Therefore, the size, condition, and system type of the connected area are more important than how close it is to the occurrence or, beyond a minimum, how tight the connection is. This metric is intended to address this benefit in a general way, recognizing that much greater complexity is possible.

Measurement Protocol: This metric is evaluated by assessing the amount and condition of connected upland longleaf pine systems and of other connected natural systems. For tier 1 and 2 evaluations, the condition assessment is rough, using a drive-by look or aerial photography interpretation. For tier 3, the connected habitat patches should be evaluated by integrity assessment protocols for those systems. Connection means geographic continuity, with no barriers and no more than the width of a two-lane road or creek separating the systems. Barriers are substantial barriers to natural processes or species movement, including developed areas, four-lane highways with substantial traffic and no passages for terrestrial animals, and agricultural fields.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
System is connected to at least 1000 acres of other longleaf pine systems, or 5000 acres of other natural systems, in at least fair condition.	System is connected to at least 100 acres of other longleaf pine systems, or to 500 acres of other natural systems, in at least fair condition.	System is connected to other longleaf pine systems of less than 100 acres and connected to less than 500 acres of other natural systems.	System is isolated from other longleaf pine systems in at least fair condition, and is connected to less than 500 acres of other natural systems.

Data: N/A

Scaling Rationale: Large areas of connected upland longleaf pine systems in good condition contribute the most to function of the system occurrence, supporting some of the same characteristic species, increasing the viability of those species that require large areas, and allowing for metapopulation dynamics for many species. Smaller areas of connected longleaf pine systems, poorer quality longleaf pine systems, and large areas of other natural systems benefit ecological function but to a lesser degree.

Confidence that reasonable logic and/or data support the index: Medium. There is a need for further thought about the benefit of connected semi-natural areas such as pine plantations, and to resolve this metric with the separation rules in the OCCURRENCEspecs.

B.2. BIOTIC CONDITION METRICS

B.2.1. Abundance of characteristic savanna grasses

Definition: This metric indicates the abundance of the dominant grasses relative to natural condition. Characteristic savanna grasses are *Aristida stricta, Ctenium aromaticum, Sporobolus pinetorum, Schizachyrium scoparium, Andropogon* spp., *Sporobolus teretifolius,* and *Muhlenbergia expansa.*

Background: This metric is one aspect of the biotic condition of specific occurrences of wetland or terrestrial ecological systems. The dominant grasses are both a very important part of vegetation structure and an important driver of ecological dynamics through their effect on fire behavior. Their abundance also is a good indicator of absence of severe alteration of various kinds. Most of the characteristic savanna grasses are highly conservative; they spread vegetatively into small open spaces but do not readily re-establish in larger areas where they have been lost. The characteristic grasses are readily reduced in density or lost through mechanical disturbance or heavy shading resulting from lack of fire, the two most common alterations of pine savannas. Because different

associations within this system have different characteristic grasses, assessment must be made relative to what is appropriate for the specific occurrence at hand. Interpretation of some grass species, particularly *Schizachyrium scoparium* and *Andropogon spp.* may differ from one occurrence to another, as they may replace other characteristic grasses in some associations but be the natural dominant in others.

Rationale for Selection of the Variable: Density of grass clumps was selected rather than the more commonly measured vegetative cover because it is expected to be less variable. Cover changes quickly after a fire. Grass clumps that have been reduced in size by shading or litter burial can often expand rapidly. New grass clumps are believed to rarely be established, and grass clumps are lost only with long shading or with severe mechanical disturbance. The density of grass clumps is therefore a better measure of potential future grass cover than is current grass cover.

Measurement Protocol: This metric, at present, must be evaluated by an ocular estimate of whether grass clump density is at an appropriate level relative to the association that is present. No true reference data on densities are yet available. The densities list are rough rules of thumb. When appropriate reference data on density can be collected, the tier 3 metric will be a quantitative plot measure and the tier 2 metric a plotless ocular estimate.

The species of grasses must also be evaluated relative to the appropriate composition for the association at hand. In particular, large amounts of *Andropogon* spp. or *Schizachyrium scoparium* in associations naturally dominated by *Aristida stricta* indicates alteration and should lead to a lower rating. Conversely, associations outside of the range of *Aristida stricta* may naturally be dominated by these species and should be given a high rating. The presence of other weedy graminoids such as *Rhynchospora* spp. or *Dichanthelium* spp. may serve as an indication that high *Andropogon* or *Schizachyrium* abundance is a result of disturbance.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Characteristic savanna grasses moderate to dense (generally averaging three or more clumps per square meter).	Characteristic savanna grasses reduced somewhat from natural density but still abundant and well distributed (generally averaging at least one or two clumps per square meters).	Characteristic savanna grasses at much reduced density overall but still present at least in numerous parts of the occurrence (averaging less than 1 clump per square meter, or less than 10% of the area at natural density).	Characteristic savanna grasses absent or present only as sparsely scattered clumps

Data: While extensive data exist for cover, clump density data are insufficient to set precise thresholds at this time. Clewell (1989) found *Aristida beyrichiana* densities averaged 4.8 clumps/square meter in "bogs" and 4.6 in flatwoods (the South Atlantic Coastal Plain Longeaf Pine Savanna system), and noted that the standard errors were low, but the full range of natural variability is not known. Schafale roughly counted 4 to 6 clumps of *Aristida* stricta per square meter in one site. Values may be different for other grass species, and may be different for this system than for the South Atlantic system.

Scaling Rationale: These ratings are based on best scientific judgment, based on rough ideas of natural values.

Confidence that reasonable logic and/or data support the index: High for logic. Data for quantitative rating are lacking.

B.2.2. Herbaceous layer diversity/composition

Definition: This metric assesses the biotic condition of the herbaceous layer in terms of species richness and particular species present. Species composition and richness vary substantially among pine savanna associations, so this metric should be re-evaluated in reference to the particular association.

Background: This metric is one aspect of the biotic condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The herbaceous layer is the most important stratum in pine savannas; it contains the vast majority of the plant species and is the densest stratum under natural conditions. Most of the herbaceous species are very conservative, and are not readily recovered once truly lost. The extremely high fine-scale species richness is one of the most notable features of most pine savanna associations. Plots of 625 square meters have been measured with 70-84 vascular plant species (Walker and Peet 1983). However, the natural range of variation is not well known. Species richness is somewhat patchy on a fine scale, and sites will need to be evaluated over their extent. A number of specialist insects depend on single or small sets of species.

Measurement Protocol: This metric consists of evaluating the species present and overall species richness relative to reference condition for the specific association. The tier 2 metric consists of listing all the species present in the site. The tier 3 metric consists of a statistically valid set of sample plots for the site. Once the association has been identified, data may be compared to the Carolina Vegetation Survey (CVS) or other plot-based data for species and species richness values (CVS unpublished). However, the evaluator should use judgment because it is not known if the CVS data represent the full range of natural variation for these values. The evaluator will also need to account for

the length of time since fire. Some herb species become hard to identify, let alone find, in the absence of fire. If the area burns before too long, these species reappear, apparently from vegetative material. After too long without fire, species are lost and do not readily return even with a return of fire. Therefore, number of species seen should be evaluated against the numbers that are likely to be recognizable at the time of the survey. Inappropriate species are generally recognizable as weedy species that respond to mechanical disturbance, species that increase in the absence of fire, or invasive exotics (But see the caution about the dominant grasses under B 2.1).

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Herb diversity high and composition appropriate for community type	Herb diversity reduced somewhat relative to natural levels (herbs not just in suppressed vegetative condition due to short term absence of fire).	Herb diversity much reduced. Savanna graminoids that respond to disturbance (*Andropogon* spp., *Dichanthelium* spp., *Rhynchospora* spp.) or weedy forbs may be present at increased densities.	Overall richness of characteristic species greatly reduced. Savanna graminoids that respond to disturbance or weedy forbs may be present at increased densities, or may be the dominant herbs, or herbs may be largely absent.

Data: While extensive data from the Carolina Vegetation Survey exist for species composition and richness in most of the associations, it is not known whether these data represent the full natural range of values for each association (Carolina Vegetation Survey unpublished). They should therefore be interpreted with caution.

Scaling Rationale: These ratings are based on best scientific judgment. A more precise quantitative scale is possible. The following observations help explain the ratings for this metric:

Excellent: If fire has not occurred for several years, many species may be vegetative and require careful searching to find. If fire has not occurred in many years, herbaceous diversity is likely to be reduced.

Good: Herb diversity may be reduced when there is either low-intensity ground disturbance or absence of fire for 7-15 years. The herb diversity is reduced somewhat relative to natural levels (herbs not just in suppressed vegetative condition due to short term absence of fire). Conservative savanna grasses may or may not still be abundant.

Fair: Great reductions in herb diversity generally occur when most of the surface has either been covered with dense litter, dense shrubs, or heavily shaded for many years, or a significant fraction has been severely disturbed. The often happens after more than 15 years without fire, or with logging or other vehicle traffic when soils are wet.

Poor. This generally occurs when most of the ground surface has been covered with dense litter or heavy shade for decades, or when most of it has had severe mechanical disturbance. This is common with bedding, past cultivation, past dense plantations, and long fire suppression.

Confidence that reasonable logic and/or data support the index: High for logic. Data for quantitative ratings are close to adequate but have not been fully evaluated.

B.2.A Longleaf pine regeneration (non-core metric)

Definition: This metric assesses the success of regeneration of *Pinus palustris*, the canopy dominant.

Background: This metric is not a core metric. It was suggested by reviewers and has been included as a supplemental metric. It potentially provides additional indication of biological integrity that indicates the interaction between field layer and canopy and integrates a number of factors, including presence of canopy gaps, fire regime, soil disturbance, and seed source. It is ultimately crucial for long term survival of the system. Natural longleaf pine regeneration is irregular. Abundant regeneration depends on a conjunction of large seed crop and fire to prepare the seedbed. Longleaf pines mature late, and must be large to produce many seeds. Seeding is irregular, with mast years every 2 to 7 years. Seedlings are vulnerable to destruction by fire in their first year, again when they are growing rapidly and are 0.5-2 meters tall (bolting from the grass stage). The absence of new seedlings in any given year is common, but absence of any seedlings or saplings in canopy gaps and absence of new seedlings after mast years that produced seedlings in nearby stands is an indication of problems.

Rationale for Selection of the Variable: It is unclear if this variable is needed. The main factors that affect longleaf pine regeneration are addressed in other metrics. However, problems with it can potentially be addressed separately from other factors.

Measurement Protocol: For tier 2, the abundance of longleaf pine seedlings in canopy gaps is estimated and compared to the observer's experience of appropriate levels. For tier 3, the density of seedlings is counted in plots.

Data: Unknown. Data on seedling densities may be available. State transition modelling may indicate what proportion of a stand should be in canopy gaps with regeneration.

Scaling Rationale: The thresholds are only roughly defined. The irregular distribution of seedlings makes overall density or abundance measures difficult. The scale focuses on canopy gaps where regeneration should be present, and evaluates density of seedlings and their success at growing up. Appropriate number of gaps is not addressed at this time. The limited knowledge does not justify using all four rating classes.

Confidence that reasonable logic and/or data support the index: Low. The irregular nature of longleaf pine reproduction makes this index difficult to assess in single measurements.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Longleaf pine appears to be reproducing successfully: moderate densities of seedlings occupy canopy gaps within two mast year cycles. Seedlings leave the grass stage after an appropriate number of years.		Longleaf pine is reproducing at reduced levels. Only sparse seedlings are present in canopy gaps even after repeated mast years, OR seedlings are abundant but do not leave the grass stage after a number of years.	Longleaf pine regeneration is failing, with no seedlings in canopy gaps even after repeated mast years.

B.2.3. Canopy composition

Definition: This metric assesses the species composition of the canopy.

Background: This metric is one aspect of the biotic condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: After the herb layer, the canopy is the most important stratum in pine savannas. The canopy is often altered by logging, and lack of fire over long periods can also affect it. The canopy is generally composed exclusively of *Pinus palustris* or of a mix of *Pinus serotina* and *Pinus palustris*, occasionally solely of *Pinus serotina*.

Measurement Protocol: This metric consists of evaluating the species abundance of different tree species in the canopy. Cover is recommended as the standard measure, but basal area will generally give similar results, and density of larger stems is also likely to be similar. Tier 2 metric consists of an ocular estimate of relative cover over the whole site. Tier 3 metric consists of ocular cover estimate or basal area measurement in a set of plots that is statistically valid for the site.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Pinus palustris and *Pinus serotina* make up 95% or more of the canopy.	*Pinus palustris* and *Pinus serotina* make up 50% or more of the canopy	*Pinus palustris* and *Pinus serotina* make up 10-50% of the canopy, with most of the rest of pines.	*Pinus palustris* and *Pinus serotina* make up less than 10% of the canopy, or compose up to 50% but the rest is hardwoods.

Data: While extensive data (Peet and Allard 1993, Carolina Vegetation Survey unpubl.) exist for canopy composition in existing stands, the widespread alteration of canopies in pine savannas make it uncertain how well these data represent natural reference condition.

Scaling Rationale: No data are known to indicate appropriate thresholds. The thresholds used are somewhat arbitrary. Other pine species will serve some of the same functions as the characteristic pines, and therefore are treated as less of an alteration than hardwoods. Extensive published and unpublished literature indicates that *Pinus palustris* is usually strongly dominant or is the sole species present in natural stands (Platt 1999). Extensive observations show *Pinus serotina* to often be abundant or codominant in pine savannas that are not otherwise highly altered. The natural range of *Pinus serotina* within longleaf pine savannas is not well known. It is treated as an appropriate canopy species.

Confidence that reasonable logic and/or data support the index: High for logic. Quantitative data exist, but need further review to assess how well they represent natural reference condition. Because the natural role of *Pinus serotina* in these systems is not well known, this protocol may overestimate the condition where it is abundant.

B.2.4. Canopy patch structure

Definition: This metric assesses the biotic condition of the canopy in terms of horizontal patch structure and density.

Background: This metric is one aspect of the biotic condition of specific occurrences of wetland or terrestrial ecological systems. Pine savannas naturally existed as fine-scale mosaics of even-aged patches regenerated in canopy gaps, with a very open density on average.

Rationale for Selection of the Variable: After the herbaceous layer, the canopy is the most important stratum in pine savannas. The patch structure is an important reflection of tree dynamics and for creating heterogeneity within the community. The patch structure is often homogenized by disturbance such as logging.

Measurement Protocol: This metric consists of evaluating the horizontal structure of the canopy relative to the reference condition of fine-scale heterogeneity in density and tree age. The Tier 2 protocol is an ocular evaluation of variation in tree age and density, estimating overall canopy cover, abundance of canopy gaps with regeneration, and number of different age patches represented. A more precise, quantitative tier 3 metric may potentially be developed, but lack of reference sites in natural condition currently limits its precision.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Canopy a mosaic of small patches of different ages, including old trees and canopy gaps containing regeneration. Overall density moderate (average tree cover generally 30-70%), though individual patches may be denser.	Canopy largely homogeneous in age, but with some gaps containing regeneration or some variation in tree sizes AND overall density moderate (30-70% tree cover	Canopy homogeneous in density and age, AND extremely dense.	Canopy extremely sparse or absent.

Data: While extensive data (Peet and Allard 1993, Carolina Vegetation Survey unpublished) exist for canopy density in 1/10 ha plots, more extensive spatial data are needed to evaluate canopy heterogeneity. Given the widespread canopy alteration in pine savannas, it is also unclear how well these data represent the natural reference condition. They should therefore be interpreted with caution. Although it is a different, related system type, the data on spatial patterns at the Wade Tract (Platt et al. 1988, Platt and Rathburn 1993) are believed to be the best reference for natural structure in this system. Evaluation of Carolina Vegetation Survey data relative to optimal herb layers may give additional calibration, as may state-transition modeling being done for Fire Regime Condition Class and Landfire programs (ref needed).

Scaling Rationale: These ratings are based on best scientific judgment. A more precise quantitative scale is possible but data may not be sufficiently representative and have not been fully analyzed. The rating categories are based on common states for canopies in existing sites, and account for both how closely they match the natural state and how readily they can return to the natural state. Thus, dense canopies, where gap formation may create structure quickly, are rated higher than very sparse canopies that will require growth of many more trees to create structure.

Excellent: This is the old-growth condition that prevailed over most of the natural landscape.

Good: This is modified from natural condition, but contains many of its characteristics at reduced levels. Moderate density allows herbaceous vegetation to persist, and present

of some gaps allows at least some regeneration. It generally occurs in older second-growth stands but may occur in young-mature stands that have had natural disturbance or selective cutting.

Fair: This is significantly modified and lacks most of the functions associated with heterogeneity. However, more natural structure can begin to develop by thinning of the dense canopy. This generally occurs following clearcutting with successful regeneration. It often accompanies poor canopy composition.

Poor: This is significantly modified and lacks most of the functions associated with the canopy. Development of a more natural structure will take establishment of a new stand of trees and the passage of much time.

Confidence that reasonable logic and/or data support the index: High for logic. Appropriate data for quantitative ratings may not exist.

B.2.5. Tree size/age

Definition: This metric assesses the abundance of large old trees in the canopy.

Background: This metric is one aspect of the biotic condition of the canopy. Pine savannas exist naturally as multi-aged stands, with trees capable of living to 400+ years old.

Rationale for Selection of the Variable: After the herbaceous layer, the canopy is the most important stratum in pine savannas. Old trees are an important component of the canopy; they are often absent or reduced in abundance because of logging, and are impossible to replace quickly if lost. Longleaf pines produce seed at a later age than most pines, and trees at least 80 years old or 12 inches dbh (Boyer and White 1990) are necessary to have an adequate supply of viable seed for reproduction in canopy gaps. The seed crop is also a major food source for *Sciurus niger*. Large, old trees with red heart rot are needed by *Picoides borealis* to excavate nest cavities.

Measurement Protocol: This metric is evaluated by measuring average tree diameters and noting the size and abundance of the largest trees, over 35 cm dbh. For tier 2, measurements of several trees estimated to be of average size are used. For tier 3, any statistically valid sampling method may be used. Because of the patchy nature of natural pine savanna canopies, care will be needed to measure the whole stand with some kind of distributed plot or transect sample or complete tally. Single plots cannot be expected to be adequate, and likely will give results less accurate than an ocular estimate. Quantitative thresholds of number of large trees per hectare need to be developed.

Tree size and age are believed to be reasonably well correlated in most sites, but in the more extremely wet occurrences old trees may be stunted. If appropriate, trees may be

aged by coring, and numbers of trees over 200 years old using instead of trees over 35 cm dbh.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Canopy size trees averaging 30 cm dbh or more, with more than a few old trees (over 35 cm dbh or over 200 years old).	Canopy trees averaging 30 cm dbh or more but essentially without old trees, OR canopy trees averaging 25-30 cm dbh but old trees common.	Canopy trees averaging 25-30 cm dbh and old trees essentially absent OR average canopy trees smaller but old trees common.	Essentially no old trees present AND average tree size smaller than 25 cm.

Data: While extensive data on 1/10 hectare plots exist for pine savannas (Peet and Allard 1993, Carolina Vegetation Survey unpub.), more extensive spatial data are needed to evaluate stand age structure. Given the extensive canopy alteration in pine savanna, it is also unclear how well these data represent the natural reference condition. They should therefore be interpreted with caution. Although it is a different, related system type, the data on ages and sizes at the Wade Tract (Platt et al. 1988, Platt and Rathburn 1993) are believed to be the best reference for natural structure in this system. Evaluation of state transition modeling being done for Fire Regime Condition Class and Landfire programs may provide additional insight into appropriate reference condition.

Scaling Rationale: The scale is based on extensive experience with ocular estimates and literature values for other related systems. Further analysis and measurement is needed to establish a more precise quantitative scale. The rating categories are based on common states for canopies in existing sites.

Confidence that reasonable logic and/or data support the index: High for logic. Appropriate data for quantitative rating may not exist.

B.2.B. Status of *Picoides borealis* and *Sciurus niger* (non-core metric)

Definition: This metric assesses the status of two area-sensitive vertebrates that are important parts of the system.

Background: These species are among the best known of vertebrates in this system. Both depend on vegetation structure and on the presence of older pine trees.

Rationale for Selection of the Variable: It is unclear if this metric is needed. The most important factors that these species respond to are covered by vegetation condition metrics. However, direct assessment of their status may prove a more sensitive indicator of biological condition.

Measurement Protocol: Abundance of both species is measured by appropriate census methods. Indirect indicators are potentially usable for both. Longleaf pine cones stripped of their scales is regarded as evidence of fox squirrel presence, though it is unclear how it relates to their abundance. Red-cockaded woodpecker cavity trees are readily visible and it is generally clear if they are occupied, without seeing the birds. Determination of successful breeding would be more laborious. Because of its federal listing status, red-cockaded woodpeckers are periodically censused on some public lands.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Both *Picoides* and *Sciurus* present at approximately natural abundance.	Both species present but at least one at unnaturally low densities.	One species present.	Both species absent.

Data: Extensive guidelines have been prepared for management of red-cockaded woodpeckers. Appropriate densities in typical habitat have been studied. Some research has been done on fox squirrel demography and habitat needs (Peter Weigl, Wake Forest University), which potentially could give more quantitative indicators.

Scaling Rationale: The thresholds at present are rough, and depend on the observer's judgement. Further research may lead to more quantitative thresholds.

Confidence that reasonable logic and/or data support the index: Low. This index needs further consideration, both for what it would indicate and for how it can best be measured.

B.2.C Status of Lepidoptera community (non-core metric or tier 3 only)

Definition: This metric assesses the status of butterflies and moths, a group that is known to be diverse in pine savannas and to be particularly sensitive to management as well as to community condition.

Background: A diverse set of Lepidoptera are characteristic of pine savanna systems. Many are tied to specific host plants and occur only in pine savanna systems, or in pine savanna plus upland longleaf pine systems. Lepidoptera spend most of the year as eggs and larvae. They are vulnerable to fire, and many must recolonize burned patches from nearby unburned areas. They are harmed by both inadequate burning and by too-frequent burning, as well as by burning at the wrong season or burning too large an area at once (Hall, et al. 1999; Hall, et al. 2000). Many Lepidoptera are believed to exist as metapopulations. They therefore depend on landscape configuration as well as on-site conditions.

Rationale for Selection of the Variable: The status of Lepidoptera is not well reflected by any of the other metrics. Lepidoptera are believed to reflect the status of the larger invertebrate community, which is an important part of the biota and ecosystem of pine

savannas. This metric is designated as non-core solely because of the difficulty of obtaining data.

Measurement Protocol: Lepidoptera species present and rough abundances (catch per unit effort) are determined by black-light trapping and netting of day-flying species. Species data are compared to expected or previously measured data to determine rating. Appropriate means of comparison need to be developed. With further research, this measurement may potentially be replaced by a more targeted measurement of selected indicator species.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Characteristic butterfly and moth species present at close to natural levels of abundance and species richness	Characteristic butterfly and moth species present but at somewhat reduced levels of abundance and species richness	Some characteristic butterfly and moth species present but at significantly reduced levels of abundance and species richness. Only habitat generalist or weedy species abundant.	Few or no butterflies and moths present.

Data: Studies of Lepidoptera in pine savannas (Hall, Sullivan, and Schweitzer 1999; Hall and Schweitzer 1993) may provide a basis for appropriate species and abundances, but more data will likely be needed to characterize all the different associations and the determine the natural range of variation.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High for inclusion of the index. Medium to low for the specific measures and thresholds.

B.3. ABIOTIC CONDITION METRICS

B.3.1. Hydrology

Definition: This metric assesses the degree of alteration to natural hydrology.

Background: This metric is one aspect of the abiotic condition of the system. Pine Savannas are naturally seasonally saturated, but hydrology is one of the most frequently altered abiotic factors.

Rationale for Selection of the Variable: Hydrologic alteration has important effects on ecological system integrity. Hydrology is hard and costly to measure directly, and the natural range of variability is not well known. Therefore, this variable focuses on the presence of stressors that typically alter hydrology. Accurate assessment of hydrologic

condition requires field examination and professional judgment. The effectiveness of alterations such as ditches varies depending on the age, what they are tied in to, and whether they are cleared and maintained. No simple relationship exists between number of ditches and degree of hydrologic alteration. Bedding also varies with height of beds and how they are oriented relative to the water table and the direction of natural water flow.

Measurement Protocol: The measure is evaluated by examining the occurrence for ditches, bedding, and other artificial alterations of hydrology and estimating their effectiveness. The surrounding area may also need to be examined for the presence of ditches that would affect the occurrence.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No evidence of effective artificial alteration of hydrology: ditches are absent, old, or not tied in to effective drainage; ground surface is not substantially altered.	Evidence of mild alteration of hydrology: ditches that are tied in to drainage networks are present at low density BUT ground surface is not substantially altered (as by bedding or pervasive fire plow lines).	Evidence of moderate alteration of hydrology: site is bedded or pervaded by numerous fire plow lines BUT ditches are absent or present only at low density.	Site is intensively altered by a dense network of ditches or by bedding combined with ditches.

Data: Ground water well data may exist for several individual Pine Savanna sites. Sufficient data to define the range of natural variation in water tables do not exist. No simple quantitative measure of the degree of alteration caused by ditches or bedding is known.

Scaling Rationale: In the absence of quantitative data, the scale is based on guidelines for professional judgment.

Confidence that reasonable logic and/or data support the index: High confidence for logic, but data are lacking.

B.3.2. Nutrient Enrichment

Definition: This metric assesses the degree of alteration to natural soil fertility.

Background: This metric is one aspect of the abiotic condition of the system. Pine Savannas are naturally nutrient-poor, and nutrient limitation is believed to be key to their species richness and other aspects of their character.

Rationale for Selection of the Variable: Experiments have shown nutrient enrichment to be detrimental to species richness and species composition. Different associations vary in nutrient content of the soil, so the emphasis is on artificial alteration of soils.

Measurement Protocol: The measure is evaluated by determining if nutrients have been added to the site, generally by deliberate fertilization or application of sewage. This generally requires some knowledge of past land management, and cannot be reliably observed in the field.

Metric Rating:

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No artificial nutrient addition.	Minimal artificial nutrient addition.	Artificial nutrient addition calibrated to match loss from artificial action such as pine straw harvesting.	Excessive or uncontrolled artificial addition of nutrients.

Data: Carolina Vegetation Survey data include soil nutrient analysis for numerous plots, which may represent close to the natural range of variability in soil chemistry. No definitive means is known to determine from field observations that a site has been fertilized. Development of ranges to evaluate chemical analysis is possible, but may require more data collection.

Scaling Rationale: In the absence of detailed analysis of soil nutrient data, this scale focuses on knowledge of land management history.

Confidence that reasonable logic and/or data support the index: Nutrient status is an important factor. The difficulty in determining whether nutrients have been added may make this measure problematic. Fertilization of Pine Savannas is generally accompanied by other activities that degraded them, so this measure may seldom vary except in the poorer examples. But the nutrient metric may be too problematic to use because at this point one has to know that it had been fertilized, which is only observable when it's being applied. And the effects, while potentially serious, can be hard to sort out from the effects of fire suppression. Perhaps this metric is only effective at tier 3, where one could (theoretically) do chemical analysis and compare it to the natural ranges for each association or soil type.

B.4. SIZE METRICS

B.4.1. Size of high quality area

Definition: This metric assesses the size of the area to which the highest condition rating applies.

Background: For occurrences that are heterogeneous with regard to condition, this metric indicates the size of area which is in the best condition class. For homogeneous occurrences, this will be the same as the total system size, but for heterogeneous occurrences it may be smaller.

Existing Pine Savanna association occurrences in North Carolina range from isolated patches less than 1 acre to complexes up to about 1600 acres. Most system occurrences contain only a single association, but some of the largest complexes may contain several associations. Existing system occurrences are believed to range up to 2000 acres. Median sizes for remaining viable occurrences of the different associations in North Carolina range from 25 to 100 acres. Occurrences in other states are likely to have a similar range of size.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Because the combined rating for the occurrence is based on a combination of size and condition, the size of the high quality area, the area corresponding to the condition rating, is the most important size measure. However, having large additional areas in poorer condition may compensate to some degree.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area within the occurrence that meets the criteria for the best condition rating score given to the occurrence, the most intact area within the overall occurrence.

Measure	Definition	Tier	A Excellent	B Good	C Fair	D Poor
Size of high quality area	Area of system in best condition class (see rollup of condition metrics)	2, 3	100 acres or more	30-100 acres	2- 30 acres	Less than 2 acres

Data: Plot data collected by the Carolina Vegetation Survey could potentially be analyzed to check the scaling of this measure by comparing plant species occurrence to

size of high quality area. However, the number of different sites represented may not be sufficient to provide meaningful correlations. More limited data on animal occurrences may be used for similar analysis of the effect of size on animal species richness. Likely no data exist that would address the effect of size on other ecological functions.

Scaling Rationale: The present scale is based on the range of sizes of remaining occurrences in North Carolina and professional judgment about thresholds (North Carolina Natural Heritage Program element occurrence database). The range of sizes is expected to be similar throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High. Existing data may be appropriate for testing and refining the index, but this analysis has not been done.

B.4.2. Total size of system occurrence

Definition: This metric assesses the total size of all areas included in the occurrence or stand, i.e., all stands or patches that are close enough together to fall within the same occurrence.

Background: Size (area) of the occurrence has a large effect on the internal heterogeneity and diversity of an occurrence. To define the area, rules are needed to specify when two or more patches or stands are close enough together to belong to the same occurrence.

Rationale for Selection of the Variable: Most ecological function is proportional to size of occurrences, and some is disproportionately related to large occurrences. Some ecological functions occur only, or at much greater levels, in areas in good condition, while other ecological functions may occur even in relatively poor or degraded areas. Some species are specific to habitat in the best condition while others are more tolerant of degraded examples. Other ecological functions may occur in poorer quality areas, but only at a much reduced frequency/intensity, and some species may occur there but only at low density. Poorer areas thus contribute to the ecological significance of occurrences, but to a lesser degree than areas in better condition.

Measurement Protocol: This metric is evaluated by measuring or estimating the total area of the occurrence.

Measure	Definition	Tier	A Excellent	B Good	C Fair	D Poor
Total system size	Total area of system within separation distance	1, 2, 3	100 acres or more	30-100 acres	2- 30 acres	Less than 2 acres

Data: Plot data collected by the Carolina Vegetation Survey could potentially be analyzed to check the scaling of this measure by comparing plant species occurrence to size of occurrence. However, the number of different sites represented may not be sufficient to provide meaningful correlations. More limited data on animal occurrences may be used for similar analysis of the effect of size on animal species richness. Likely no data exist that would address the effect of size on other ecological functions.

Scaling Rationale: The scale is based at present on the range of sizes of occurrences in North Carolina (North Carolina Natural Heritage program element occurrence database) and professional judgment about thresholds. The range of sizes is expected to apply throughout the range of the system. The scale could be improved by basing it on the correlation of species presence/richness with size values.

Confidence that reasonable logic and/or data support the index: High. Existing data may be appropriate for testing and refining the index, but this analysis has not been done.

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