West Gulf Coastal Plain Flatwoods Pond Ecological System

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ECOLOGICAL INTEGRITY ASSESSMENT

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A. INTRODUCTION

A.1. ECOLOGICAL SYSTEM DESCRIPTION

A.1.1. Classification Summary

CES203.547 West Gulf Coastal Plain Flatwoods Pond

Primary Division: Gulf and Atlantic Coastal Plain (203)
Land Cover Class: Woody Wetland
Spatial Scale & Pattern: Small patch
Required Classifiers: Natural/Semi-natural; Vegetated (>10% vasc.)
Diagnostic Classifiers: Depressional; Graminoid

Concept Summary: This system represents predominately graminoid-dominated flatwoods ponds of the West Gulf Coastal Plain of eastern Texas and western Louisiana. These ponds are generally circular or elliptical, flat-bottomed depressions on flat terraces in the Outer Coastal Plain. The slowly permeable soils trap local runoff and precipitation resulting in higher water tables than surrounding areas. Water depth may be 3-5 feet in the winter and even deeper toward the center of some examples (Bridges 1988, Bridges and Orzell 1989a). Examples range from shallow to several meters in depth; the large and deeper examples may exhibit distinct vegetation zonation. Most examples have a layer of tall wetland grasses and sedges above a layer of semi-aquatic herbs. Many lack a significant woody layer due in part to periodic fires originating in the pine savanna matrix. However, scattered, often stunted *Nyssa biflora* and stems of *Cephalanthus occidentalis* may be present. The following species are characteristic of this type: *Eriocaulon compressum, Xyris fimbriata, Eleocharis equisetoides, Eleocharis quadrangulata*, as well as two additional species, *Carex verrucosa* and *Rhynchospora cephalantha*, which are more frequent in other pond types. Some other species frequently found in this type include *Eriocaulon compressum, Rhynchospora corniculata, Panicum hemitomon, Ludwigia sphaerocarpa, Xyris laxifolia var. iridifolia (= Xyris iridifolia)*, and *Sagittaria graminea*. Other herbaceous species may include *Gratiola brevifolia, Hydrolea ovata, Proserpinaca pectinata, Pluchea rosea, Ludwigia pilosa, Bacopa caroliniana, Xyris* sp., and *Rhynchospora capitellata*.

Range: West Gulf Coastal Plain of eastern Texas and western Louisiana.
Divisions: 203:C
TNC Ecoregions: 31:?, 40:C, 41:C
Subnations: LA, TX

A.1.2. Environment

Climate, Hydrology and Geomorphology
Elevation and topography: Elevation ranges from 25 to 100 m. The outer Coastal Plain (Flatwoods) of the West Gulf Coastal Plain is nearly level to gently sloping and has a low local relief.

Climate: *Average annual precipitation*-1,175 to 1,400 mm, increasing from west to east. Precipitation is evenly distributed throughout the year but is slightly greater in the east during winter. *Average annual temperature*-19 to 21 C. *Average freeze-free period* -260 to 280 days. The Gulf Coast enjoys a climate uncharacteristic of its latitude, which typically hosts warm, arid, and semi-arid climates. The Gulf of Mexico, Caribbean Sea, and Atlantic Ocean substantially influence the region's climate. The region enjoys mild winters thanks to Gulf of Mexico waters, which moderate winter temperatures. Occasionally, however, these mild winters are punctuated by cold air masses reaching far south from the northern Pacific or the Arctic, bringing low temperatures and freezing conditions. This situation arises when the midlatitudinal jet stream that governs the tracks of storm systems shifts from a more east-west direction into north-south meanders, allowing cold air and winter storms to penetrate southern regions. Summers in the region tend to be hot and humid.

The Gulf and the Atlantic are also major sources of moisture, resulting in greater rainfall than typical for the latitude. A variety of processes bring rainfall to the region, including storm fronts in the winter and spring, and thunderstorms and tropical storms in the summer and fall. Hurricanes and tropical storms, which bring much-needed moisture and can also cause severe flooding, wind damage, and shoreline erosion, occur regularly in late summer and fall.

Water: Rainfall, perennial streams, and ground water provide an abundance of water. Most of the soils must be drained for optimum growth of general farm crops.

Soils: Most of the soils have a water table near the surface during at least part of the year. The dominant soils are Udalfs. They are deep and medium textured or moderately coarse textured. These soils have a thermic temperature regime, a udic moisture regime, siliceous mineralogy, and a weak fragipan or plinthite. Somewhat poorly drained Fragiudalfs (Splendora series), moderately well drained Paleudalfs (Segno and Hockley series), and poorly drained Ochraqualfs (Sorter and Acadia series) are dominant in Texas. Poorly drained Glossaqualfs (Caddo series) and Paleudults (Beauregard series) are dominant in Louisiana. Poorly drained Glossaqualfs (Waller, Wrightsville, Guyton, Aldine, and Ozan series) are in depressions. The entire area is underlain by unconsolidated sediments. (http://soilphysics.okstate.edu/S257/south/mlra/152b.htm).

In Jasper and Newton counties, Texas, the flatwoods ponds are most often included within areas mapped as Evadale soils (fine, mixed, thermic, typic Glossaqualfs) or complexes including this soil type, and may also be included in areas labeled as the Jasco silt loam (coarse-silty, siliceous, thermic, typic Fragiaqualfs). At the western limit of their range, near the boundary with coastal prairies, the ponds are mapped as Waller Loam, depressional (fine-loamy, siliceous, thermic, Typic Glossaqualfs) or Gessner loam (coarse-loamy, siliceous, thermic, Typic Glossaqualfs) (Bridges 1988).

Hydrology

The Flatwoods ponds are characterized by a fluctuating water table, from winter seasonal highs of 0.3 to 1.6 meters deep, to summer lows from 0.3 meters below the surface to 0.3 meters above the surface. Water collects from local rainfall and runoff from very small watersheds, with no input from streamflow and little or no outflow. The slowly permeable soils and natural depression position results in a persisting high water table for long periods after rain, particularly when evaporation is low, usually with continuous water from November through April or May (Bridges 1988, Bridges and Orzell 1989).

A.1.3. Vegetation and Ecosystem

Vegetation composition

Plant species dominance varies greatly depending upon water depth and the spread of colonial, rhizomatous species, and may also be related to geographic isolation of individual ponds and variations in local fire regimes. Each association has its own distinctive composition, and they may occur as distinct zones or as more of a mosaic. Most examples have zones (or a mosaic) of taller wetland grasses, shorter grasses, herbs, and graminoids (including at least some annuals) and a zone of semi-aquatic herbs. Scattered woody plants, especially *Nyssa biflora*, may be present. In some instances woody stems may develop sufficient density to be classified as woodlands. The density of woody stems may depend on length of time since the last fire.

Following severe mechanical disturbance, a suite of widespread weedy plants may invade the disturbed areas (or may originate from a seed bank). This weedy vegetation is typically less flammable, and affects fire behavior, altering the ecological dynamics of the system.

A.1.4. Dynamics

Fire
Fire is a important ecological process for this system, in that fires which originate in adjacent forested vegetation types will "burn through" the pond under the right set of conditions. This may (depending on moisture and fire intensity) have the effect of "re-setting the clock" in the pond, killing the above-ground portions of at least some of the woody vegetation, and even burning up some of the accumulated organic matter in some cases.

A.1.5. Landscape

Most of this area is in farms, and about three-fourths is forest, principally pine and pine-hardwood. Much of the forest acreage is owned by large corporations, and lumber and pulpwood are the chief products. Cleared areas are used mostly for pasture, but some are used for crops. Rice, grain sorghum, corn, and soybeans are commonly grown. Many small subdivisions are being developed throughout the area. (http://soilphysics.okstate.edu/S257/south/mlra/152b.htm).

These ponds are subject to local draining and removal of vegetation. They may also be affected by hydrological alteration of the landscape. If adjacent pine flatwoods, oak-pine forests, or other natural vegetation is replaced with managed plantation pine (and hydrology is not severely altered through ditching and draining), examples may survive in the short-term, but their chances for long-term viability may be limited.

A.2. ECOLOGICAL INTEGRITY METRICS

A.2.1. Threats

Hydrological Alteration
The controlling factor for these ponds is the fluctuating water table, which varies 1 to 1.5 meters over long seasonal periods (Bridges and Orzell 1989). If this water table is disrupted (becoming either more uniformly wet or more uniformly dry) the ecological dynamics of the pond will be affected.

Disruption of fire regime/fire suppression conditions in surrounding vegetation matrix
Maintenance of the natural vegetation of the Pond requires periodic fire to reduce the height and vigor of woody plants (trees and shrubs). Invasion of these plants can inhibit the dominance of the characteristic herbaceous flora.

Vegetation alteration
The most likely vegetation alteration would be the establishment of a pine plantation (*Pinus elliottii, Pinus taeda*) throughout the pond. This would disrupt the natural vegetation patterns, and destroy the typical plant cover, and establish a greater woody plant cover, which would prevent herbaceous plants from thriving.

Nutrient enrichment
More information is needed on the nutrient cycles in West Gulf Coastal Plain Flatwoods Ponds, but it is assumed that these are relatively nutrient poor ecological systems. They are characterized by seasonally flooded hydric soils. Adjacent and upstream land uses all have the potential to contribute excess nutrients into these areas. Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species. Altered hydrology can disrupt nutrient cycles, especially through increased aerobic decomposition under drier conditions.

Exotics
Non-native plants or animals can have substantial impacts to depression ponds. Non-native plants can increase dramatically under the right conditions and essentially dominate an area previously dominated by native species. This can generate secondary effects on animals (particularly invertebrates) that depend on native plant species for forage, cover, or propagation. Non-native plants which can be problems in this system include Japanese Climbing Fern (*Lygodium japonicum)*, Chinaberry (*Melia azerderach*), Japanese Honeysuckle (*Lonicera japonica*), Ardisia (*Ardisia crenata*), Chinese Privet (*Ligustrum sinense),* Popcorn Tree *(Tradiaca sebifera)* and other Category I invasive plants (FLEPPC 2005). Non-native animals could include feral hogs (*Sus scrufa)*, Imported fire ants *(Solenopsis invicta*), and Armadillo (*Dasypus novemcinctus*). These animals are important predators of native amphibians and invertebrates. Feral hogs also disturb the ground/herb/seedling layer and can promote both weedy native plants and invasive exotic plants.

Fragmentation
Human land uses, primarily in adjacent and upland areas, can fragment the landscape and thereby reduce connectivity between depression ponds and between the depressional and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Roads, bridges, and development can also fragment these areas and impact their integrity.

A.2.2. Justification of Metrics

Measures include:

- Landscape condition indicators that account for connection between the pond(s) and the matrix vegetation areas.
- Landscape condition indicators that account for the size and intactness of the adjacent matrix vegetation communities.
- Biotic condition indicators of species composition, species diversity, and vegetation structure.
- Evidence of any hydrologic alteration and other disruptions of physical conditions in and around the ponds.
- Impacts on nutrient status, which could affect species diversity (some rare or "conservative" species compete better in lower nutrient conditions).

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 can be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 metrics are assessed using ground sampling, but may only require 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.

The Scorecard (see Tables 1 and 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

Core metrics are shaded gray in Tables 1 and 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

Supplementary metrics are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 and 3.

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, then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size.

Table 1. Overall Set of Metrics for the West Gulf Coastal Plain Flatwoods Pond System (CES203.547) Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

Category	Indicators/Metrics	Definition	Tier
LANDSCAPE CONTEXT	Adjacent Land Use	Land Use Coefficient Score	1
	Connectivity	Size and connectivity of adjacent natural systems.	1
	Buffer (Edge Ratio)	Buffer (Edge ratio of native and non-native habitat within 100 m radius)	1
	Fire-maintained landscape	Area of contiguous fire-maintained landscape within 1 km.	1
BIOTIC CONDITION	Native Plant Species	Percent cover of native plant species	2, (3)
	Invasive Plant species	Percent cover of invasive plant species	2, (3)
	Percent Cover of Intolerant Species	Percent cover of intolerant (conservative) plant species (the lists of intolerant species and their values need to be determined).	2, (3)
ABIOTIC CONDITION	Evidence of Hydrologic Alterations	Visual evidence of hydrological alteration	(1), 2, 3
	Water Table Depth	Depth to water table in cm.	2,3
	Nutrient Enrichment (C:N, C:P)	Absence of artificial nutrient enrichment	3
	Nutrient Enrichment (C:N, C:P)	Absence of artificial nutrient enrichment	3
SIZE	Absolute Size	Total area of system occurrence (pond or complex of ponds	1, 2, 3

Table 2. Overall Set of Metrics for the West Gulf Coastal Plain Flatwoods Pond System (CES203.547), showing the ratings for each metric Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

Category	Essential Ecological Attribute	Indicators/Metrics	Definition	Tier	Metric Rating Criteria			
					A Excellent	B Good	C Fair	D Poor
LAND-SCAPE CONTEXT	Landscape Composition	Adjacent Land Use	Ratio of Human-dominated uses adjacent to the wetland	1 (2)	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Connectivity	Size and connectivity of compatible natural systems	1 (2)	Example is surrounded by at least 90% native and unaltered landscape with very little to no urban development or agriculture, and little to no industrial forestry. No unnatural barriers present. Connectivity of adjacent systems allows natural ecological processes, (e.g., fire and species migrations) to occur.	The surrounding landscape is composed of at least 75% natural or semi-natural vegetation, with little urban development within or adjacent to the occurrence. Adjacent systems surrounding occurrence retain much connectivity. Few non-natural barriers present.	The adjacent systems surrounding the occurrence are fragmented by alteration with limited connectivity. Surrounding landscape is a mosaic of agricultural or semi-developed areas with >50% natural or semi-natural vegetation. Some non-natural barriers are present. Significant disturbance, but easily restorable.	There is major human-caused alteration of surrounding landscape. Adjacent systems surrounding occurrence are mostly converted to agricultural or urban uses. Connectivity of adjacent landscape is severely hampered.
		Buffer (Edge Ratio)	Buffer (Edge ratio of native and non-native habitat within 100 m radius)	1 (2)	System (pond or group of ponds) is bordered by natural communities in at least good condition over 80% or more of its boundary	System is bordered by natural communities in at least fair condition over 30-80% of its boundary.	System is bordered by natural communities over 5-30% of its boundary.	System is completely surrounded by developed land, agriculture, pine plantation, or degraded natural systems, or isolated by barriers.

Category	Essential Ecological Attribute	Indicators/Metrics	Definition	Tier	Metric Rating Criteria			
					A Excellent	**B Good**	**C Fair**	**D Poor**
		Area of contiguous fire-maintained landscape		2	[to be developed]	[to be developed]	[to be developed]	[to be developed]
BIOTIC CONDI-TION	Community Composition	Native Plant Species	Percent cover of native plant species	2, (3)	Percent of total vegetative cover in the occurrence composed of native plant species is greater than 90%.	Percent of total vegetative cover in the occurrence composed of native plant species is between 75 and 90%.	Percent of total vegetative cover in the occurrence composed of native plant species is between 45 and 75%.	Percent of total vegetative cover in the occurrence composed of native plant species is less than 45%.
		Invasive Plant species	Percent cover of invasive plant species	2, (3)	Percent of total vegetative cover composed of invasive exotic plant species is less than 2%.	Percent of total vegetative cover composed of invasive exotic plant species is between 2 and 10%.	Percent of total vegetative cover composed of invasive exotic plant species is between 10 and 30%.	Percent of total vegetative cover composed of invasive exotic plant species is greater than 30%.
		Percent cover of Intolerant Species	Percent cover of intolerant (conservative) plant species (the lists of intolerant species and their values need to be determined).	2, (3)	Percent of total vegetative cover composed of intolerant plant species is greater than 10%.	Percent of total vegetative cover composed of intolerant plant species is between 5% and 10%.	Percent of total vegetative cover composed of intolerant plant species is between 2% and 5%.	Percent of total vegetative cover composed of intolerant plant species is less than 2%.

Category	Essential Ecological Attribute	Indicators/Metrics	Definition	Tier	Metric Rating Criteria			
					A Excellent	B Good	C Fair	D Poor
ABIOTIC CONDI-TION	Hydrology	Evidence of Hydrologic Alteration	Visual evidence of hydrological alteration	(1), 2, 3	No evidence of effective artificial alteration of hydrology (neither depletion nor enhancement): ditches or impoundments are absent or not apparent; ground surface is not substantially altered.	Evidence of mild alteration of hydrology: ditches or impoundments that are old, ineffective, or not connected to effective drainage ditches and 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. Pond hydrology is fundamentally altered and would require extensive restoration.
		Water Table Depth	Depth to water table	2,3	Water Table depth during site visit (mid-July through August) = 0-20 cm	Water Table depth during site visit (mid-July through August) = 20-30 cm	Water Table depth during site visit (mid-July through August) = 30-40 cm	Water Table depth during site visit (mid-July through August) = > 40 cm
	Chemical / Physical Processes	Nutrient Enrichment (C:N)	Absence of artificial nutrient enrichment	3	No artificial nutrient addition	Minimal artificial nutrient addition.	Moderate artificial nutrient enrichment	Excessive or uncontrolled artificial addition of nutrients.
		Nutrient Enrichment (C:P)	Absence of artificial nutrient enrichment	3	No artificial nutrient addition	Minimal artificial nutrient addition.	Moderate artificial nutrient enrichment	Excessive or uncontrolled artificial addition of nutrients.
SIZE	Size	Absolute Size	Total area of system occurrence (pond or complex of ponds	1, 2, 3	Very large (> 4 ha [10 ac])	Large (4-1 ha [10-2.5 ac])	Moderate (1-0.2 ha [2.5-0.25 ac])	Small (< 0.1 ha [0.25 ac])

A.3. SCORECARD PROTOCOLS

A point-based approach is used to roll up the metrics into Category scores. Points are assigned for each rating level (A, B, C, D) within a measure. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score, but this approach has not yet been developed for this system.

It is not always possible to develop a four grade rating system for each metric, because we lack sufficient detail on how the metric changes or what the thresholds might be. In some cases, the ratings may combine A and B. The point scoring approach is A/B = 5, C=3, D = 1.

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

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

A.3.1. Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to roll up the metrics into an overall Landscape Context Rating.

<u>Rationale for scoring table:</u> All measures are scored and weighted equally.

Table 3. Landscape Context Metrics and Ratings for this System. Scores for the ratings are show in each cell.

Measure	**Tier**	**A**	**B**	**C**	**D**	**Weight**	**Score** (weight x rating)
Adjacent Land Use	1	5	4	3	1	0.33	
Connectivity	1	5	4	3	1	0.33	
Buffer (Edge Ratio)	1	5	4	3	1	0.33	
Landscape Context Rating A=4.5 - 5.0 B=3.5 - 4.4 C=2.5 - 3.4 D=1.0 – 2.4							**Total = sum of N scores**

A.3.2. Biotic Condition Rating Protocol

Rate the Biotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring:

If a formal Vegetation Index of Biotic Integrity is developed across the range of this System based on rigorous Tier 3 indicators (e.g., DeKeyser et al. 2003, Mack et al. 2004), then this table will be upgraded, and the rating of Biotic Condition = the VIBI rating.

Table 4. Biotic Condition Rating Calculations. Scores for the ratings are shown in each cell.

Measure	**Tier**	**A**	**B**	**C**	**D**	**Weight***	**Score**
Native Plant Species	2	5	4	3	1	0.33 (0.5)	
Invasive Plant species	2	5	4	3	1	0.33(0.5)	
Percent Cover of Intolerant Species (under development)	3	5	4	3	1	0.33 (N/A)	
Biotic Condition Rating A=4.5 - 5.0 B=3.5 - 4.4 C=2.5 - 3.4 D=1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric for percent cover of intolerant species is not available.

A.3.3. Abiotic Condition Rating Protocol

Rate the Abiotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) to roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: All measures are scored and weighted equally.

Table 5. Abiotic Condition Rating Calculations. Scores for the ratings are shown in each cell.

Measure	**Tier**	**A**	**B**	**C**	**D**	**Weight***	**Score** (weight x rating)
Hydrology	2	5	4	3	1	0.33	
Nutrient Enrichment (C:N)						0.165	
Nutrient Enrichment (C:P)	2	5	4	3	1	0.165	
Water Table Depth	3	5	4	3	1	0.33	

Measure	Tier	A	B	C	D	Weight*	Score (weight x rating)
Abiotic Condition Rating A=4.5 - 5.0 B=3.5 - 4.4 C=2.5 - 3.4 D=1.0 – 2.4							**Total = sum of N scores**

A.3.4. Size Rating Protocol

Rate the size measure according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metric into an overall Size rating.

Rationale for Scoring:

Table 6. Size Rating Calculations.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Size	The current size of the wetland	1	5	4	3	1	1.0)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total =**

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

B. DOCUMENTATION FOR METRICS

B.1. LANDSCAPE CONTEXT METRICS

B.1.1. Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses adjacent to the wetland. The intensity of human uses may be an suitable metric for the disturbance gradient that results from increasing human use of landscapes (Brown and Vivas 2003).

Each land use type occurring in the 100 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target wetland (Hauer et al. 2002, as modified).

Background: The intensity of human dominated land uses in a landscape affect ecological processes of natural communities. The more intense the activity, the greater the effect on ecological processes. Most landscapes are composed of patches of developed land and patches of "wildlands" (e.g. natural ecological systems), or undeveloped lands that remain within a developed landscape mosaic (Brown and Vivas 2003). This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems.

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 100 m of the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge. To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m under each Land Use type and then plug in the corresponding coefficient (Table 1; the coefficients in this table are derived from Hauer et al. (2002)) with some manipulation to account for regional application) into the following equation:

Sub-land use score = ∑ LU x PC⁄100

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the wetland edge, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 1. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. [2002] with modifications)

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Hayed	0.3
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.4
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., light recreation and grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with nonnative or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002; with modifications).

Confidence that reasonable logic and/or data support the index: Medium.

B.1.2. Size and connectivity of compatible natural systems

Definition: This metric addresses the connection of the flatwoods pond system occurrence to other natural systems. It combines two aspects of connectivity: the size of the connected natural landscape and what systems are present in the connected landscape. Both determine the benefit that a flatwoods pond occurrence gains from its connected natural landscape.

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. For wider ranging animals, the total size of connected habitat will determine what species are present. The most intense interaction is with upland of flatwoods forest and woodland systems, which shares many species; however, all connected systems will share some species and contribute to the ecological function of the occurrence.

Measurement Protocol: This metric is evaluated by assessing the amount and condition of connected upland longleaf pine, oak-pine, and/or flatwoods systems, the total area of connected natural systems, and whether the other systems are adjacent or connected through other natural areas. 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.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Example is surrounded by at least 90% native and unaltered landscape with very little to no urban development or agriculture, and little to no industrial forestry. No unnatural barriers present. Connectivity of adjacent systems allows natural ecological processes, (e.g., fire and species migrations) to occur.	The surrounding landscape is composed of at least 75% natural or semi-natural vegetation, with little urban development within or adjacent to the occurrence. Adjacent systems surrounding occurrence retain much connectivity. Few non-natural barriers present.	The adjacent systems surrounding the occurrence are fragmented by alteration with limited connectivity. Surrounding landscape is a mosaic of agricultural or semi-developed areas with >50% natural or semi-natural vegetation. Some non-natural barriers are present. Significant disturbance, but easily restorable.	There is major human-caused alteration of surrounding landscape. Adjacent systems surrounding occurrence are mostly converted to agricultural or urban uses. Connectivity of adjacent landscape is severely hampered.

B.1.3. Area of Contiguous Fire-Maintained Landscape

Area of Contiguous Fire-Maintained Landscape). This variable represents the area of fire-maintained supplemental landscape contiguous to and including the flatwoods occurrence: supplemental landscape includes fire-maintained areas of both Wet Pine Flats and uplands. Other types of habitat (nonsavanna) are not included in the area estimates because, at this time, there are no known animal species that require both Wet Pine Flats and supplemental habitat of a different type. (See V*LANDSCP* protocol in Rheinhardt et al. 2002)

To determine the area, the boundary of contiguous fire-maintained habitat should be delineated from recent (< 5 years old), high resolution, aerial photography (Figure 23). All fire-maintained Wet Pine Flats and upland pine savannas or oak-pine forests should be included within delineated boundaries, but any discontinuities in fire-maintained habitat wider than 50 m (150 ft) should be excluded, as well as all bedded areas. Subtract any area of dissimilar cover (fire-excluded habitat, development, highways, etc.) enveloped by the contiguous boundary from the total area delineated if the discontinuity exceeds 1 ha (2.5 acres) in size. Include the area of the flatwoods occurrence if it is a fire-maintained savanna. Area can be determined by digitizing fire-maintained landscape or by overlaying a dot grid matrix. (See V*LANDSCP* protocol in Rheinhardt et al. 2002).

More research is needed to develop the metrics.

B.1.4. Edge Ratio of Natural/non-natural Habitat (Buffer)

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. 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. The most intensive interaction is likely with upland longleaf pine, pine-oak, and/or flatwoods 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.

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 flatwoods ponds, 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 EO rank specs 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 (pond or group of ponds) is bordered by natural communities in at least good condition over 80% or more of its boundary	System is bordered by natural communities in at least fair condition over 30-80% of its boundary.	System is bordered by natural communities over 5-30% of its boundary.	System is completely surrounded by developed land, agriculture, pine plantation, or degraded natural systems, or isolated by barriers.

Scaling Rationale: No data are known to suggest that there is anything other than a steady loss of integrity as more adjacent areas are altered. The thresholds chosen are arbitrary. [Should the Edge Effect go to zero?, (i.e. “system is completely surrounded by developed land” or should it go to <5%?]

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.2 BIOTIC CONDITION METRICS

B.2.1. Percent Cover of Native Plant Species

Definition: This metric indicates the degree to which the pond area supports the natural range of cover by native plants, as opposed to exotic plants (the cover of which is a separate measure),

Background: This metric is one aspect of the condition of specific occurrences of any vegetated terrestrial ecological systems.

Rationale for Selection of the Variable: Productivity and spatial and temporal heterogeneity are underlying factors which strongly influence species diversity due to their affect on resource abundance and niche diversity (Vannote et al. 1980, Gregory et al. 1991; Manley and Schlesinger 2001). Although human disturbance can cause an increase in diversity, that dominance shift is often associated with an increase in the amount of non-native species. Thus, the expected range of species richness of native plants in an area is assumed to be indicative of the natural range of variation in the environmental factors which control productivity and spatial heterogeneity in riparian shrublands. As native plant richness decreases, it is assumed that the underlying factors controlling diversity, mainly productivity and spatial heterogeneity, have been altered either from nutrient enrichment, invasive and/or non-native species, or other human-induced disturbances.

Measurement Protocol: Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system, making sure that each microhabitat is surveyed, and make a comprehensive species list. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. The 10 cover classes identified in Peet et al. (1998) are recommended (trace [solitary/few], 0.1-1%, 1-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, > 95%) but any cover class system can be used as long as they same system remains consistent when comparing data with time or a different site. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by totaling the number of native species, dividing by the total number and multiplying x 100 : These values are then compared to Table 4 to determine the metric status in the scorecard.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Percent of total vegetative cover in the occurrence composed of native plant species is greater than 90%.	Percent of total vegetative cover in the occurrence composed of native plant species is between 75 and 90%.	Percent of total vegetative cover in the occurrence composed of native plant species is between 45 and 75%.	Percent of total vegetative cover in the occurrence composed of native plant species is less than 45%.

Data: N/A

Scaling Rationale: The criteria are based on and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Confidence that reasonable logic and/or data support the index: High

B.2.2. Percent Cover of Invasive Plant Species

Definition: Percent of total vegetative cover of the pond system which is composed of invasive, exotic plants.

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

Rationale for Selection of the Variable: Non-native species or native increasers can displace other native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). Wetlands dominated by non-native, invasive species typically support fewer native animals (Zedler and Kercher 2004). For example, marshes are susceptible to invasion by many non-native species including narrowleaf cattail (*Typha angustifolia*), purple loosestrife (*Lythrum salicaria*), barnyard grass (*Echinochloa crus-galli*), and reed canary grass (*Phalaris arundinacea*). Pasture grasses such as Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis gigantea*), and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*) may be invade the peripheral margins of marshes. One source for information on exotic invasive plant species of the Southeastern United States and their control is Miller (2003). More specific information is needed on the specific invasive exotics that can affect flatwoods ponds

Measurement Protocol: Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire wetland and make a qualitative ocular estimate of the total cover of each invasive species growing in the wetland. This is typically a very easy task in marshes, since invasive species tend to develop monocultures in disturbed marshes. The 10 cover classes identified in Peet et al. (1998) are recommended (trace [solitary/few], 0.1-1%, 1-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, > 95%) but any cover class system can be used as long as they same system remains consistent when comparing data with time or different site. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Mack 2004; Peet et al. 1998).

The metric is calculated by dividing the total cover of invasive species by the total vegetative cover of all species and multiplying by 100.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Percent of total vegetative cover composed of invasive exotic plant species is less than 2%.	Percent of total vegetative cover composed of invasive exotic plant species is between 2 and 10%.	Percent of total vegetative cover composed of invasive exotic plant species is between 10 and 30%.	Percent of total vegetative cover composed of invasive exotic plant species is greater than 30%.

Data: N/A

Scaling Rationale: The criteria are based on and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Confidence that reasonable logic and/or data support the index: High

B.2.3. Percent cover of Intolerant Species

The use of some kind of floristic quality assessment in evaluating wetland quality requires that a ranking system be developed for the plant species of interest that evaluates them as to their relative tolerance/intolerance of disturbance. This is also referred to as a "coefficient of conservatism" (Swink and Wilhelm 1994). These indices have not been developed for the southeastern Coastal Plains, but they have been tested in some other areas. This is a need which should be fulfilled.

For example, in Minnesota wetlands, increasing levels of impairment resulted in fewer intolerant plant species, such as iris (*Iris* sp.), slender riccia (*Riccia fluitans*), and common bladderwort (*Utricularia macrorhiza*), and increased coverage of tolerant species, such as reed canarygrass (*Phalaris arundinacea*), duckweed (*Lemna* sp.), and cattail (*Typha* sp.) (Gernes and Helgen 1999). Intolerant species may be among the first to be decimated after perturbation and the last to recolonize after normal conditions have returned (Karr et al. 1986). Endangered or threatened species should not automatically be considered intolerants, because their low numbers may be due to factors other than human disturbance. Trends (increases or decreases) in distribution or abundance from historical data can be examined to help assign attributes to these taxa. Tolerance rankings may also be based on factors that indicate the ecological conservatism of taxa (those taxa adapted to a specific narrow range of biotic and abiotic factors) (Wilhelm and Ladd 1988, Andreas and Lichvar 1995). However, because of a lack of information for many wetland taxa, empirical, rather than theoretical, approaches may be necessary or preferred to establish tolerance rankings. For example, taxa that are represented in the least impaired sites and tend to disappear in the most impaired sites would be empirically defined as intolerant. Similarly, taxa that tend to increase in disturbed sites would be defined as tolerant (Gernes and Helgen 1999). The mere presence of intolerant taxa is a strong indicator of good biological condition. The relative abundance of these taxa, in contrast, is often difficult to estimate accurately without extensive and costly sampling efforts (Karr and Chu 1999).

Therefore, intolerant taxa should be represented simply as the number of intolerant species per unit sample effort. In contrast to intolerant taxa, the presence alone of tolerant taxa says little about biological condition, because tolerant groups inhabit a wide range of places and conditions. However, note that many wetland organisms can tolerate the stressful levels produced by a variety of natural environmental disturbances (Wissinger 1997, Euliss et al. 1999, Higgins and Merritt 1999), and care should be taken to base tolerance designations on human disturbances and not natural ones. Tolerance attributes should be expressed as the percentage of tolerant individuals from either a single species or a grouping of highly tolerant species.

Note that if a high number of tolerant or intolerant species is included in the composition of attributes, the usefulness of those attributes will be diminished. In general, it is recommended that only about 10% (no fewer than 5% or no more than 15%) of taxa in a region should be classed as intolerant or tolerant (US EPA 2002d).

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

Metric Rating

Excellent	Good	Fair	Poor
Percent of total vegetative cover composed of intolerant plant species is greater than 10%.	Percent of total vegetative cover composed of intolerant plant species is between 5% and 10%.	Percent of total vegetative cover composed of intolerant plant species is between 2% and 5%.	Percent of total vegetative cover composed of intolerant plant species is less than 2%.

Data: N/A

Scaling Rationale: The criteria are based on and best scientific judgment. These are very tentative hypotheses as they have not been validated with quantitative data. A tolerance/intolerance scale does not yet exist for the characteristic plant species of this ecological system, but this could be developed.

Confidence that reasonable logic and/or data support the index: Low. The general rationale for the use of the metric is high, but a formal metric, such as FQI values, are lacking and the threshold values need testing.

B.3 ABIOTIC CONDITION METRICS

B.3.1. Hydrology

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
No evidence of effective artificial alteration of hydrology (neither depletion nor enhancement): ditches or impoundments are absent or not apparent; ground surface is not substantially altered.	Evidence of mild alteration of hydrology: ditches or impoundments that are old, ineffective, or not connected to effective drainage ditches and 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. Pond hydrology is fundamentally altered and would require extensive restoration.

B.3.2. Water Table Depth

Definition: This metric estimates water table depth based on a single site visit in mid-July or August and is a metric of hydrological integrity of the wetland. This season is the time of year when water is less likely to be above the soil surface, although it may persist in the deepest portions of the wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland ecological systems. It would be assumed that for a flatwoods pond to have intact ecological functioning, the depth to the water table must not be too great, even in the driest parts of the year.

Rationale for Selection of the Variable: Water table fluctuations are probably the most important factor affecting examples of this system (Bridges and Orzell 1989a). Water collects in these depressions after rainfall events, and tends to be deepest during the winter time when precipitation is concentrated (although other factors may also be important, such as the amount of evapotranspiration). Standing water may be evident from approximately November through May, and sporadically afterwards.

Measurement Protocol: This metric is measured by obtaining soil cores with a soil auger, determining the point of contact with the water table by visual observation of soil wetness. (The actual digging of soil pits in the wetland should not be necessary). One should ensure that soil sampling locations represent the edge as well as interior of the wetland. If quantitative vegetation data are being collected, sample locations should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil samples would be taken within each of the intensive modules (See section B.2.1 for further information regarding plot establishment). The distance between the soil surface and water level equals depth to water table.

This metric should only be used during site visits made in mid-July through August. Consideration of annual precipitation and its deviation from long-term averages from the closest weather station are needed to assess the reliability of this metric. During years of average precipitation, this metric is a reliable rapid metric of the integrity of groundwater levels in the pond system.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Water Table depth during site visit (mid-July through August) = 0-20 cm	Water Table depth during site visit (mid-July through August) = 20-30 cm	Water Table depth during site visit (mid-July through August) = 30-40 cm	Water Table depth during site visit (mid-July through August) = > 40 cm

Scaling Rationale: For western wetland systems (e.g. Rocky Mountain Subalpine-Montane Fen), similar metric criteria are based on Cooper (1990), Woods (2001; and Chimner Cooper (2003), and best scientific judgment. In this system, water tables within or near 30 cm of the soil surface have been shown to sustain peat integrity, while water tables below 35 cm begin to decompose resulting in a loss of peat integrity and subsequent change in biotic composition. More research is needed to determine if these values are most appropriate for West Gulf Coastal Plain Flatwoods Ponds.

Confidence that reasonable logic and/or data support the index: Low/Medium

B.3.3. Nutrient Enrichment (C:N)

Definition: The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess N in the system (compared to reference standard). Increasing leaf N decreases the C:N ratio and indicates nitrogen enrichment.

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

Rationale for Selection of the Variable: Nitrogen enrichment causes vegetation to increase uptake and storage of nitrogen in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Nitrogen is typically measured by dry combustion using a CHN analyzer. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory, such as CSU's Soil, Water, and Plant Testing Laboratory, for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:N ratios need to be established in undisturbed wetlands. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

Confidence that reasonable logic and/or data support the index: Medium/High.

B.3.4. Nutrient Enrichment (C:P)

Definition: The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess P in the system (compared to reference standard). Increasing leaf P decreases the C:P ratio and indicates phosphorous enrichment.

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

Rationale for Selection of the Variable: Phosphorous enrichment causes vegetation to increase uptake and storage of phosphorous in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002a, 2002b). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002a, 2002b). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002a, 2002b). See U.S. EPA (2002a, 2002b) for additional information.

Phosphorous is typically measured by spectrophotometry in acid (H_2SO_4-H_2O_2) digests. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory, such as CSU's Soil, Water, and Plant Testing Laboratory, for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:P ratios need to be established in undisturbed wetlands. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

Confidence that reasonable logic and/or data support the index: Medium/High.

B.4 SIZE METRICS

B.4.1. Size

Definition: Absolute size is the current size of the wetland.

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

Rationale for Selection of the Variable: Absolute size is pertinent to ecological integrity if the surrounding landscape is impacted by human-induced disturbances. When the surrounding landscape is impacted and has the potential to affect the wetland, larger sized wetlands are able to buffer against these impacts better than smaller sized wetlands due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. However, when the landscape is unimpacted (i.e. has an "Excellent" rating), then absolute size has little impact on ecological integrity since there are no adjacent impacts to buffer. Of course, larger wetlands tend to have more diversity (MacArthur and Wilson 1967), however this is a metric more pertinent to functional or conservation value than ecological integrity. Thus, absolute size is included as a metric but is only considered in the overall ecological integrity rank if the landscape is impacted. Regardless, absolute size provides important information to conservation planners and land managers.

Measurement Protocol: Absolute size can be measured easily in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Absolute size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified for delineating the boundaries of the wetland ecological system type.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Very large (> 4 ha [10 ac])	Large (4-1 ha [10-2.5 ac])	Moderate (1-0.2 ha [2.5-0.25 ac])	Small (< 0.1 ha [0.25 ac])

Data: N/A

Confidence that reasonable logic and/or data support the index: Medium/High.

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APPENDIX A: FIELD FORM REQUIREMENTS

[To be developed]