Modeling Habitat Connectivity to Support State Wildlife Action Plans in the Mid-South

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Cover photo: Tombigbee National Forest, Ackerman Unit, Mississippi, by Toby Gray

Introduction

In 2000, Congress created the State and Tribal Wildlife Grants (SWG) program to address the need to conserve declining fish and wildlife species. In addition to providing critical funding to each U.S. state and territory to plan and implement conservation action, the program requires each state to develop a comprehensive wildlife conservation strategy, often currently referred to as a Wildlife Action Plan (WAP). Each plan must address particular "elements" including: identify the species of greatest conservation need (SGCN), identify the key habitats that support SGCN, identify threats to these species and habitats, describe proposed actions to address these threats, plan for monitoring the species, the habitats, and the effects of the actions, develop a procedure to review the WAP, and finally to engage and involve the public in the overall process.

Beginning in 2009, the U.S. Department of the Interior (DOI) initiated landscape-scale conservation efforts through the formation of Landscape Conservation Cooperatives (LCCs). This action expanded an initiative by the U.S, Fish and Wildlife Service to better integrate science and management to address landscape-scale disturbances. The LCCs partnered with other federal agencies and bureaus, states, tribes, NGOs, universities, and stakeholders to apply conservation science and management within geographically defined areas (U.S. Institute for Environmental Conflict Resolution, 2011).

The Gulf Coastal Plains and Ozarks (GCPO) LCC supported these efforts in states on the northern shore of the Gulf of Mexico and in the Ozark Highlands, an area referred to here as the "Mid-South." The GCPO LCC approached conservation design generally by summarizing species by Broadly Defined Habitats (BDHs), which were assessed in terms of measurable targets, or "endpoints," relating to vegetative structure and condition as well as landscape configuration and patch size. From 2014 – 2016, the GCPO LCC developed ecological assessments of the BDHs, using the best available spatial data to generate baseline accounts of how much and in what condition exist of nine BDH classes within five subgeographies: Ozark Highlands, East and West Gulf Coastal Plain, Mississippi Alluvial Valley, and Gulf Coast.

The quantitative, data-based products of the Ecological Assessments became data layer inputs to a regional geographical analysis that included partner activity, species presence, and landscape-scale threats summarized at the HUC12 watershed unit scale. The rankings of watersheds in terms of conservation opportunity constitutes the GCPO LCC Conservation Blueprint 1.0, which was incorporated into the Southeastern Conservation Adaptation Strategy (SECAS), a comprehensive effort to organize and coordinate multi-state, multi-agency wildlife conservation in the Southeastern United States.

This current project arises from an analysis of the limitations of Blueprint 1.0, specifically that overlapping or contradictory information about the presence/absence of individual BDH classes persists in the input layers as an artifact of their independent origins. This iteration uses a single base map of ecological systems, derived from LANDFIRE and

state-level sources, as a single, comprehensive, region-scale record of whether BDH classes exist in the landscape, and a standardized assessment of six desired condition metrics or endpoints: two landscape-scale configuration and patch size metrics, two site-scale metrics, and two variables addressing potential restoration status for land units currently in alternative land uses. This iteration also expands the geographical footprint of the Mid-South beyond the boundaries of the GCPO LCC, adds Mixed Forest and three of Southern Yellow Pine classes to the forested BDHs, and maps (but does not assess) additional habitat classes of Freshwater Marsh, Managed Forest, and Bottomland Barrens (freshwater sandbars mapped in the rivers of Oklahoma). The presence or absence of each habitat and the six condition variables are expressed in a bar code and a Condition Index score for each 30-meter grid cell (900 square meter land unit) in the 97 million ha (238 million acre) study area. Lastly, the project identifies potential connectivity corridors between core areas of desired habitat based on least-cost path analysis of subsets of core areas. These products constitute an improvement over Blueprint 1.0 by providing a standardized, comprehensive assessment of desired conditions over a larger area as a potential input layer to future iterations of the SECAS conservation planning product.

Background: GCPO LCC Ecological Assessments and Conservation Blueprint 1.0

The Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC) Conservation Blueprint 1.0 defined science priorities within a set of nine priority ecological systems, with landscape and species endpoints reflective of desired ecological states for each system. The ecological systems and species endpoints were established by the Cooperative's Integrated Science Agenda, which described the systems as Broadly Defined Habitats (BDH) associated with wildlife species identified by State Wildlife Action Plans as needing conservation action. The Science Agenda guided the process of developing individual ecological assessments for the systems by establishing desired landscape configuration and site condition endpoints based on species-habitat interactions. Each BDH was assessed separately, using distinct sets of input datasets. For terrestrial systems, assemblages of desired condition endpoints were summarized as Condition Index scores, mapped at the land unit (or grid cell in raster geospatial datasets) scale, with landscape configuration and patch size metrics prioritized over site-level metrics such as vegetation height, basal area, or percent canopy cover.

The ecological assessments identified the extent to which land units (grid cells in raster-based spatial data sets for terrestrial systems, stream segments or watersheds for aquatic systems) met each of the landscape endpoints to produce Condition Index Scores for land units. The Condition Index Scores were re-interpreted to produce a set of Management/Restoration Ranks (Restore, Enhance, Maintain) to guide conservation action. For example, a high-quality site in a low landscape configuration class would be ranked "Maintain," the highest Management Rank, whereas a low-quality site in high landscape configuration class (a higher raw Condition Index score) would fall in the lower Management Rank of "Enhance." The Conservation Blueprint 1.0 summarizes the

Management Ranks of land units, along with information about partner activity, species distribution, and threats to habitats, at the HUC12 watershed level. Aquatic systems were processed separately from terrestrial and wetland systems, then the information was combined in a map of Integrated Watershed Ranks (Figure 1).
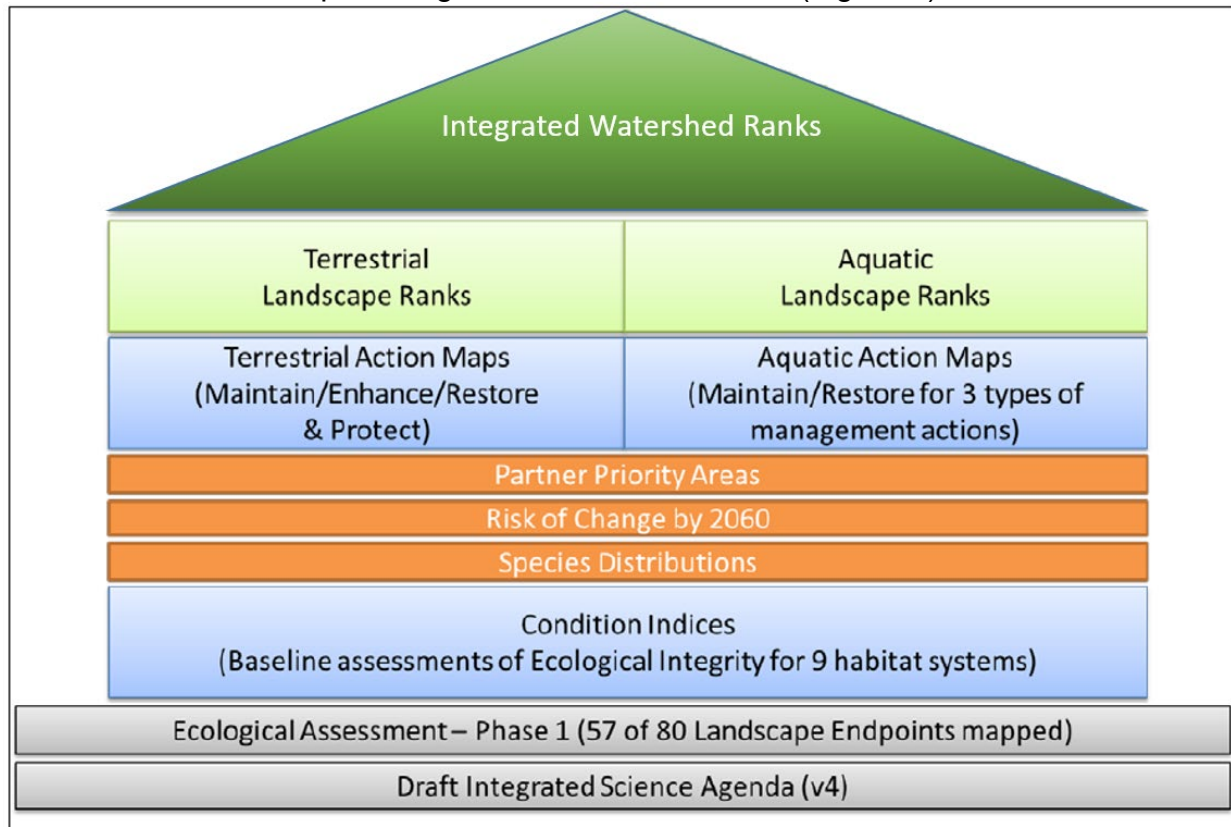
Figure 1: The basic structure of the Conservation Blueprint 1.0

The Integrated Watershed Ranks map assesses landscape quality from "Reference," describing a high-quality landscape with low conservation opportunity because landscape configuration and site condition goals are largely already met, through a set of Tiers of Conservation Opportunity, the lowest being Tier 4, the "lost causes" where restoration or conservation is prohibitively costly. The analysis argues that the greatest opportunities, the highest chance of gain for the least investment, is in improving Tier 2 or Tier 3 watersheds rather than Tier 1 watersheds (i.e., those at or close to "Reference" condition). The Integrated Watershed Ranks was used as an input layer in the Conservation Blueprint developed by the Southeast Conservation Adaptation Strategy, or SECAS.

Process: A connectivity assessment based on a revised integrated habitat condition index map

The Ecological Assessments that establish base layers for the GCPO LCC Conservation Blueprint 1.0 were developed independently according to the best information sources for each Broadly Defined Habitat (BDH). The individual terrestrial habitat maps use different source data and present results at different spatial scales.

This creates difficulty when generating integrated action or opportunity maps, since the inputs provide contradictory or overlapping information within the mapping units of the output. The Mid South Connectivity Mapping project improves an important input to the Conservation Blueprint by 1. Refining the list of Broadly Defined Habitats, 2. Integrating the BDH input layers into a comprehensive single map of all habitats, and 3. Standardizing the calculation of the Condition Index score by applying seven endpoints (presence or absence of habitat, two landscape configuration endpoints, two site condition endpoints, and two potential landscape endpoints) for a score range of 0 -14 across all terrestrial habitats.

This new data product combines all terrestrial systems into a single map with each 30 meter by 30 meter (900 square meter) mapping unit described in terms of potential habitat, existing habitat, and the presence or absence of four desired condition endpoints. The four endpoints include patch size, landscape scale configuration metrics, and site-level metrics such as basal area and percent overstory canopy for forested systems. For each land unit, a Condition Index score is generated by the contribution of endpoint scores, and a 13-digit bar code describes which endpoints contributed to the index score and whether the unit has the potential to become some other habitat type. The process is transparent, repeatable, and can be expanded to include more desired condition endpoints as data become available. A single spatial data product that integrates habitat information and standardizes the assessment of desired conditions greatly improves the ability to map cores of quality habitat and connectivity between cores. This report includes examples of habitat connectivity mapping through the process of iteratively generating cost distance maps for independent sets of core areas, summing the distance maps to identify corridors, and determining least cost paths through a cost map created by inverting the Condition Index scores.

Unified Mask: Integrating terrestrial broadly defined habitats into a single data layer

The Unified Mask is an integrated, comprehensive, regional map of existing Broadly Defined Habitats identified in the GCPO LCC Science Agenda. As mentioned above, this product improves the Broadly Defined Habitat and Condition Index inputs into the GCPO LCC Conservation Blueprint by combining all the information about terrestrial habitats into a single layer with no overlapping habitat. Other changes include the expanding of the footprint of the assessment and expanding and enhancing the list of assessed habitats.

An Expanded Study Area

We expanded our study area beyond the original GCPO LCC boundary by selecting those counties that border counties intersecting the boundary (i.e., going one county beyond). In areas of special interest to certain conservation partners, we selected additional counties. We chose to include the entire state of Louisiana, extending the assessed coastline westward to Galveston Bay. We then selected HUC12 watersheds intersecting these counties, added a 2km buffer to that, and edited the buffer to smooth out narrow eccentric incisions and isolated unselected islands (doughnut holes, an

unintended result created by the fact that watersheds have irregular shapes), creating a Study Area. The GCPO LCC boundary encompasses 73 million hectares (282 thousand square miles), and the Study Area is 24 million hectares (92 thousand square miles) larger at 97 million hectares (373 thousand square miles) (Figure 2).
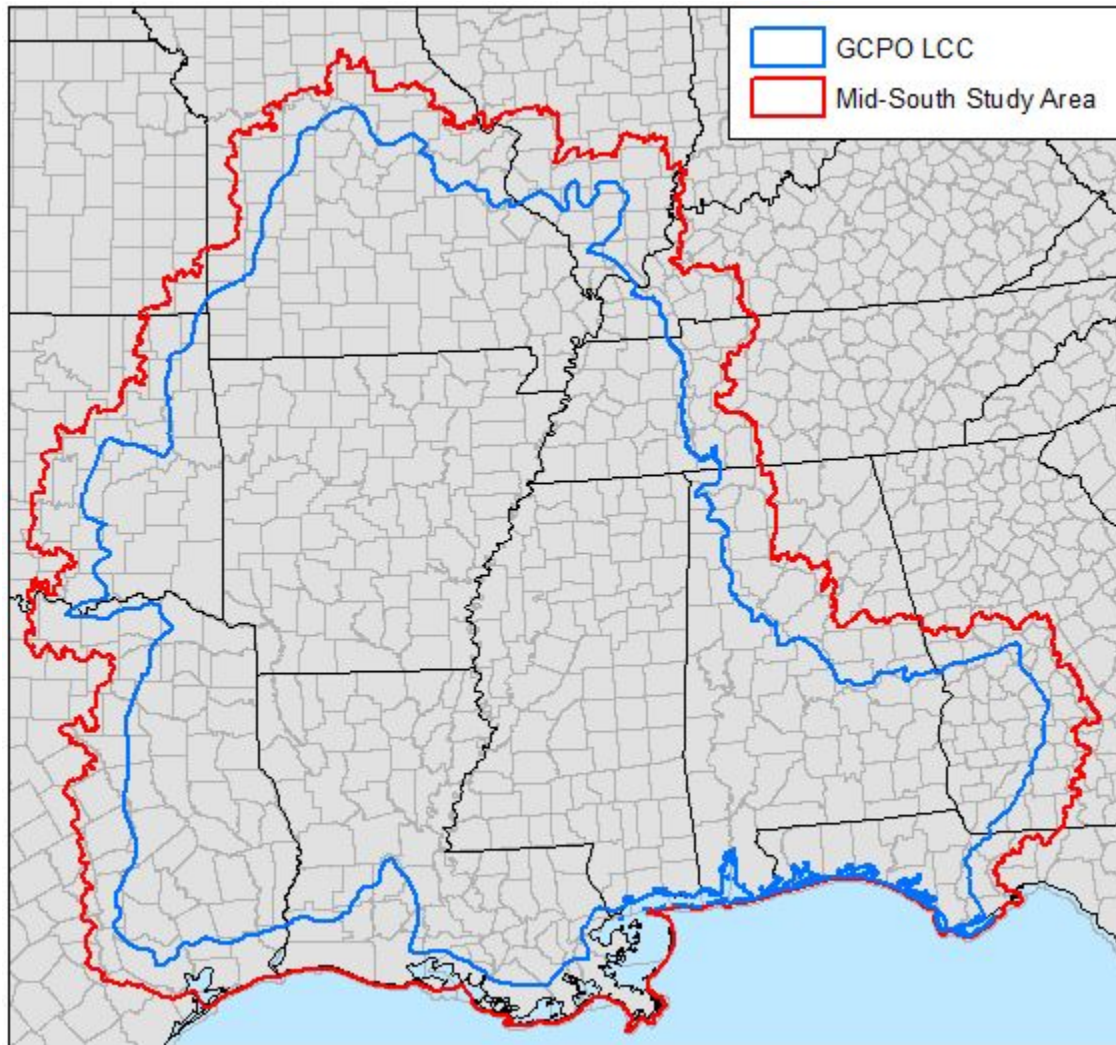
Figure 2: The Mid-South Study Area

A Refined Habitat List

The GCPO LCC identified six and assessed five terrestrial ecosystems in the Conservation Blueprint 1.0. Beaches and Dunes were described but not assessed due to lack of region-wide spatial data of sufficient fine scale resolution. The current project similarly describes and maps but does not assess beaches and dunes. The Ecological Assessments divided the Grassland-Prairie-Savanna system into general grassland (lands dominated by grass species) and grassland prairie (dominated by warm season native grasses and forbs) classes, a practice the Unified Mask repeats. Similarly, the Upland Hardwood Forest and Woodland class is mapped as separate Forest and

Woodland classes. The product presented here includes mapped glades in Arkansas and Missouri as part of the Woodland system using spatial data provided by the Central Hardwoods Joint Venture. Open Pine Woodlands and Savanna, treated as a single system in the Ecological Assessments, are here sub-divided into three Southern Open Pine Groupings following the recommendations of Nordman et al. (2016). We identified and mapped four additional targeted habitat types that do not appear in the GCPO LCC Science Agenda but which are described among the ecological systems of the input data layers and are considered of interest to partners in conservation: Bottomland Barrens (freshwater beaches and sand bars mapped by MoRAP in Oklahoma), Freshwater Marsh, Managed Forest, and Mixed Forest. Fifteen habitat types are described and mapped, of which nine (General Grassland and Grassland Prairie are distinct BDH classes in the map but are assessed as a single habitat, with prairie considered a more valued type) are assessed using desired condition endpoint metrics and ancillary datasets (Table 1).

Table 1: GCPO Terrestrial Habitats expanded and refined

GCPO Terrestrial Habitats mapped in 2017	Study Area Habitats mapped in 2018	Condition Assessed?
Beaches and Dunes	Beaches and Dunes	NO
Forested Wetlands	Forested Wetlands	YES
General Grassland	General Grassland	YES
Grassland Prairie	Grassland Prairie	YES
Open Pine Woodlands and Savanna	Longleaf Pine Flatwoods	YES
	Longleaf Pine Woodland	YES
	Shortleaf/Loblolly Pine Woodland	YES
Tidal Marsh	Tidal Marsh	YES
Upland Hardwood Woodland	Upland Hardwood Woodland	YES
	Glades	NO
Upland Hardwood Forest	Upland Hardwood Forest	YES
	Bottomland Barrens	NO
	Freshwater Marsh	NO
	Managed Forest	NO
	Mixed Forest	YES

Data Processing

We began with LANDFIRE Existing Vegetation (evt) (vintage April 2017, downloaded April 2018), translating the 281 classes described in the Study Area to the fifteen terrestrial Broadly Defined Habitats described in the 2018 update above plus an Other (non-habitat) class. In Texas the LANDFIRE evt data layer was replaced with Ecological Mapping Systems data from the Texas Parks and Wildlife Department. In Oklahoma, LANDFIRE evt classes were replaced with Ecological System Mapping data from

Missouri Resource Assessment Partnership (MoRAP). Those products were resampled from 10 to 30 meter resolution and translated to BDH classes. Similarly, in Florida, the evt classes were replaced with data from the Florida Cooperative Land Cover project, using the "STATE" classification rather than the more site-specific "SITE" classification. We then added the Map of Known Prairie Patches developed by GCPO LCC staff from multiple input sources, and a layer describing natural glades mapped in Missouri and Arkansas. The comprehensive translation of ecological system and land cover classes described in the input layers into the Broadly Defined Habitats of the Unified Mask is presented in Appendix I.
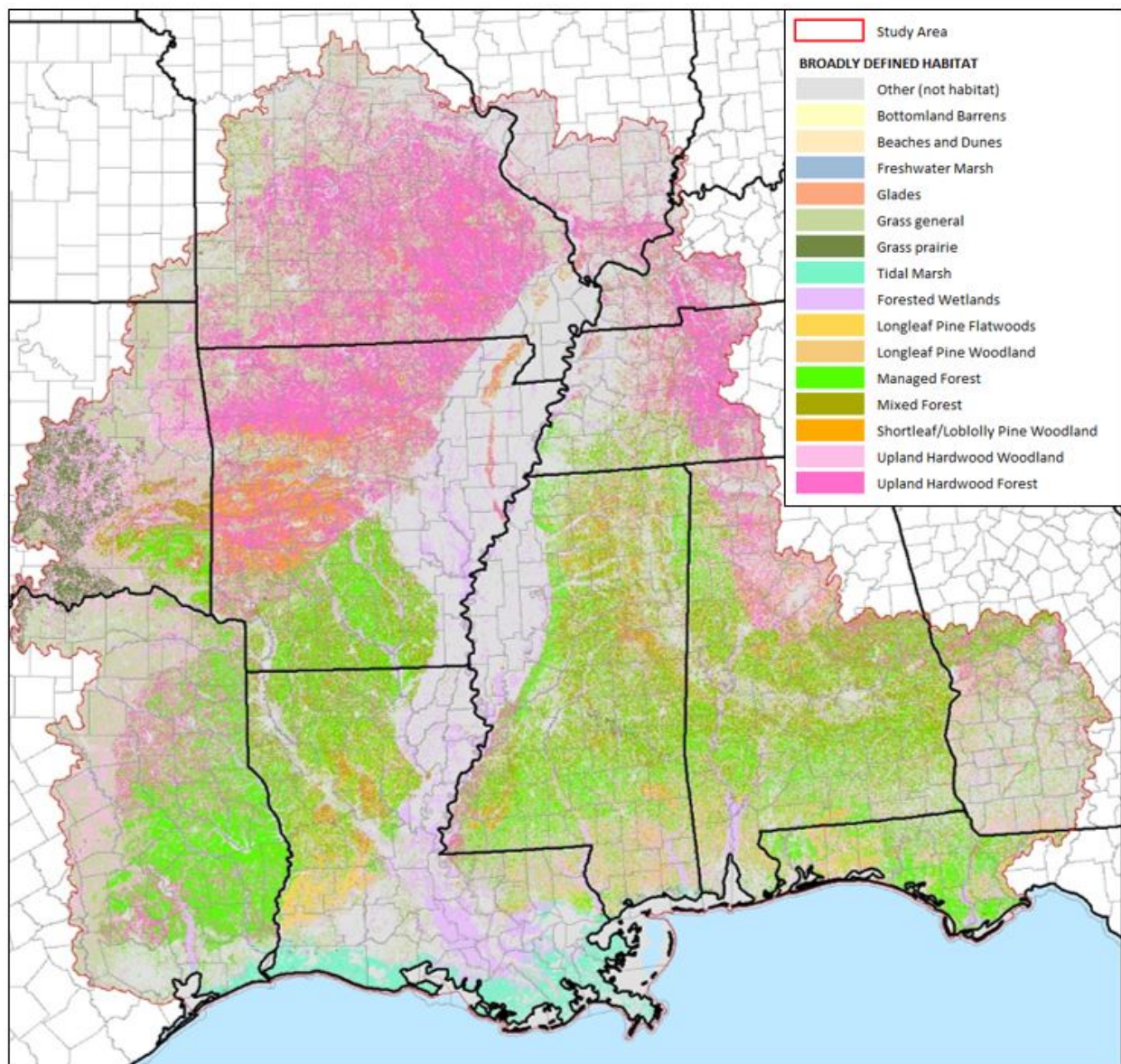
Results

Figure 3: Terrestrial Broadly Defined Habitats mapped in the Study Area

A comprehensive, unified map of terrestrial Broadly Defined Habitats shows that Managed Forest is a dominant forest type in the southern coastal plains and Upland Hardwood Forest is dominant in the highlands of the North. Habitat is sparse in the intensively farmed regions of the Grand Prairie of Arkansas, the Mississippi Alluvial Valley, the Doughty Plain of Southwest Georgia, the floodplain of the Red River in Louisiana, and in the urban centers of St. Louis, Memphis, Houston, and New Orleans (Figure 3).

Terrestrial Broadly Defined Habitats considered priorities for species of conservation concern cover 36.4 million ha (126.5 million acres), or 38% of the Study Area. Three additional classes of habitat, Grass General, Mixed Forest, and Managed Forest, considered of interest to conservation because of their potential for conversion to targeted habitat or management for targeted species, cover 33.2 million ha (82 million acres) or 34% of the area. All forest classes combined cover 51 million ha (12.5 million acres) or 53% of the total area (Table 2, Figure 4).

Table 2: Areal amounts of terrestrial Broadly Defined Habitats

Priority Habitat	Ha	Acres	Percent
Other (not habitat)	26,905,767	66,487,141	27.88
Bottomland Barrens	9,873	24,396	0.01
Beaches and Dunes	8,664	21,409	0.01
Freshwater Marsh	155,435	384,096	0.16
Glades	136,414	337,094	0.14
Grass general	16,040,049	39,636,742	16.62
Grass prairie	1,274,353	3,149,068	1.32
Tidal Marsh	1,358,239	3,356,358	1.41
Forested Wetlands	9,556,877	23,616,105	9.90
Longleaf Pine Flatwoods	675,000	1,668,000	0.70
Longleaf Pine Woodland	2,317,399	5,726,549	2.40
Managed Forest	10,655,691	26,331,396	11.04
Mixed Forest	6,499,255	16,060,381	6.73
Shortleaf/Loblolly Pine Woodland	1,521,471	3,759,724	1.58
Upland Hardwood Woodland	5,489,876	13,566,095	5.69
Upland Hardwood Forest	13,903,345	34,356,710	14.41
TOTAL	96,507,706	238,481,265	100.00
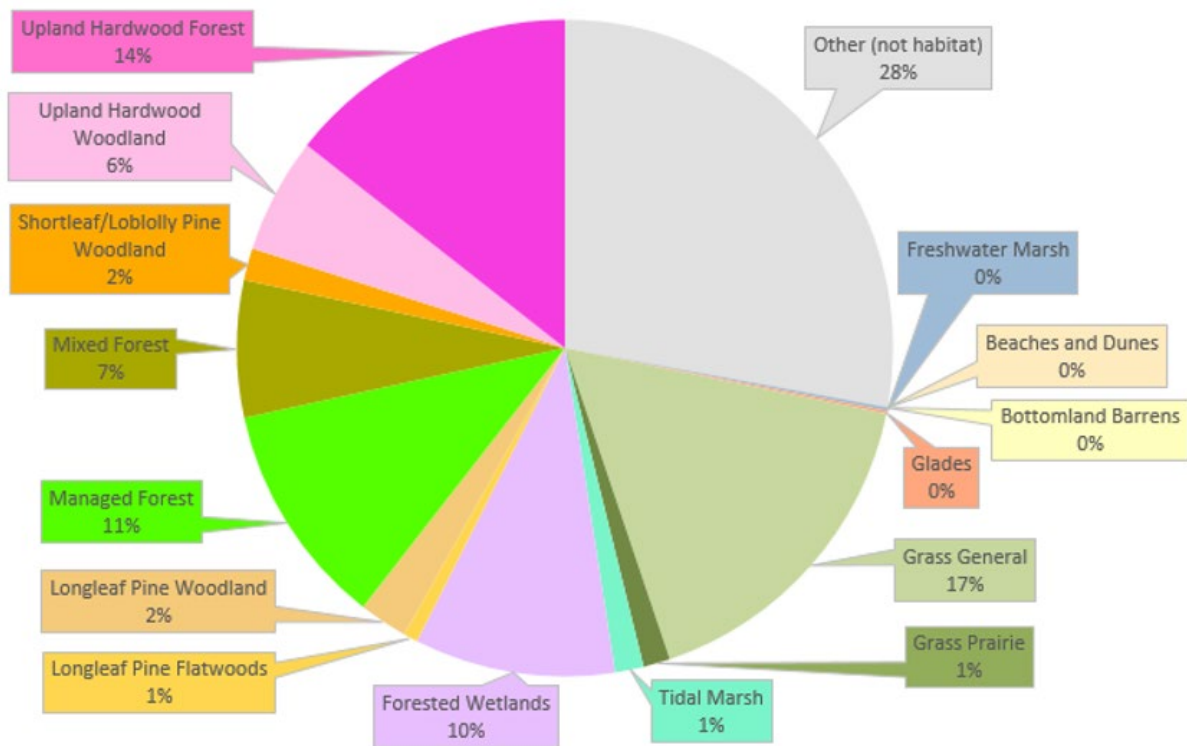
Figure 4: Pie Graph of areal amounts of habitat classes

Potential Habitats

Potential habitat was assessed using LANDFIRE's [Biophysical Settings] layer, which represents the vegetation that may have been dominant prior to European settlement. The 113 named ecological system classes in the study area were translated to the same BDH classes described in the Unified Mask, with three exceptions: we could find no equivalent in the Biophysical Settings classes for Bottomland Barrens, and General Grassland and Managed Forests are were not considered targeted potential habitats. We removed developed land and open water from consideration as potential habitat using a mask derived from [NLCD 2011 Land Cover (CONUS)]. Each BDH class was given a three-digit code to facilitate processing (Table 3). This code is used in the barcode descriptions that characterize the final product: the first three digits describe the existing habitat, the next three describe the potential habitat for each land unit (pixel). As a base-map input to the final set of products, a unified map of potential habitats is an improvement over the inputs to the GCPO LCC Conservation Blueprint 1.0, which mapped potential habitats independently, leading to overlapping and contradictory information across habitat classes (Figure 5).

Table 3: Potential and existing BDH classes represented by numerical values

Existing Habitat (BDH)	Code
Other (not habitat)	100
Bottomland Barrens*	101
Beaches and Dunes	110
Freshwater Marsh	120
Glades	121
Grass general*	122
Grass prairie	123
Tidal Marsh	124
Forested Wetlands	130
Longleaf Pine Flatwoods	131
Longleaf Pine Woodland	132
Managed Forest*	133
Mixed Forest	134
Shortleaf/Loblolly Pine Woodland	135
Upland Hardwood Woodland	137
Upland Hardwood Forest	138
*class not included in potential habitat map	
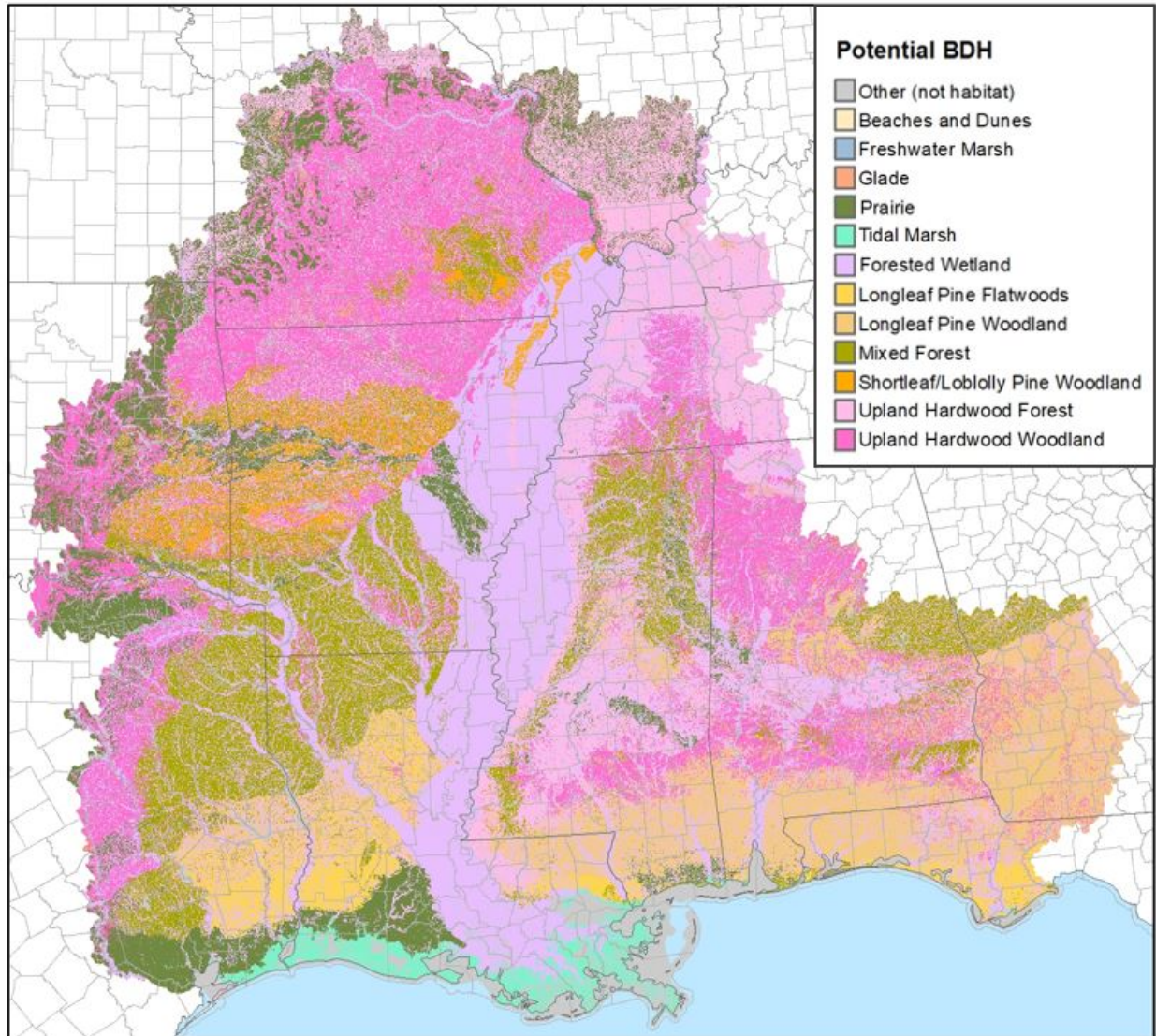
Figure 5: Potential Terrestrial Broadly Defined Habitats

Assessment of Desired Condition Endpoints

Landscape Conservation Design assumes that habitats supporting species of greatest conservation need can be described in terms of measurable endpoints describing optimal conditions for multiple species. Desired Condition Endpoints used in this project were adapted from the GCPO LCC ecological assessments of Broadly Defined Habitats in accordance with the evaluation of both endpoints and data used contained in the [State of the Gulf Coastal Plains and Ozarks 2017 Report,](#) which evaluated the landscape configuration and site condition endpoints presented in the Integrated Science Agenda and the datasets and information sources used in the ecological assessments. We generated a revised set of Condition Index values for our revised Unified Mask by first selecting endpoints and information sources deemed most relevant, reliable, and scientifically applicable. We standardized the process across habitats by assessing the same set of seven endpoints for each case:

1. Targeted ecological system (BDH class) is present: 3 points
2. Patch metric: 3 or 6 points
3. Landscape-level Configuration metric: 3 or 6 points
4. Site level endpoint (basal area for forested systems): 1 point
5. Site level endpoint (percent overstory canopy cover for forested systems): 1 point
6. Potential habitat, for land units not currently in a targeted habitat class: 1 point
7. Potential near habitat, a subset of potential habitat that is near existing habitat demonstrating certain landscape configuration characteristics: 1 point.

The maximum CI score is fourteen. Desired condition endpoint metrics and scores are summarized in Table 4.

Table 4: Endpoint metrics and condition index points assigned by BDH class

Field	EXIST	POTENT	MASK (A)	PATCH (B)	LANDSCAPE (C)	BASAL AREA (D)	CANOPY COVER (E)	POTENTIAL (F)	POTENTIAL NEAR (G)
	Broadly Defined Habitat Class	Potential Habitat Class (from LANDFIRE BpS)	Pixel describes the targeted BDH class	Pixel is part of a large patch	Pixel meets landscape-level patch and configuration criteria	Basal area range in square feet/acre (for forested classes) 1 point	For forested classes, % overstory canopy cover, 1 point	As indicated by LANDFIRE BioPhysical Settings	A subset of potential that is near a patch (1 point)
Forested Wetlands	130	130	3	2500 ha, 6	70% forest in 10,000 acre landscape, 3	BA 60 - 80	CC 60 - 90		Within 2500 meters of a forest patch >1250 ha
Grass prairie	122 General 123 Prairie	123	General 3	Prairie 6	Patch > 100 Acres 3	Grasslands burned at least once during the period 2006 - 2015	Grass height > 1 meter	1	Potential prairie within 1 km of a prairie patch of 100 acres or more
Longleaf Pine Flatwoods	131	131	3	600 acres of a variety of pine types, 6	< 3km to large patch, 3	BA 10 - 90	CC 15 - 75	1	Potential pine class within 3 km of an existing patch
Longleaf Pine Woodland	132	132	3	600 acres of a variety of pine types, 6	< 3km to large patch, 3	BA 15 - 90	CC 15 - 75	1	Potential pine class within 3 km of an existing patch
Mixed Forest	134	134	3	500 acres, 3	70% forest in 10km radius, 6	BA 50 - 90	CC 50 - 100	1	Potential pixels described as 70% forested within a 10 km radius
Shortleaf/ Loblolly Pine Woodland	135	135	3	600 acres of a variety of pine types, 6	< 3km to large patch, 3	BA 20 - 100	CC 15 - 85	1	Potential pine class within 3 km of an existing patch
Tidal Marsh	124	124	3	250 acres, 6	Moderate edge, 3	Interdigitation	Submerged Aquatic Vegetation	1	Within 567 meters of a tidal marsh patch of >250 acres.
Upland Hardwood Forest	138	138	3	3000 acres, 3	70% forested in a 10 km radius (77,630 acre landscape), 6	BA 80 - 100 AND proportion of oak hickory >70%	CC > 80	1	Potential UHF in a landscape that is 55% forested in a 10km radius
Upland Hardwood Woodland	137	137	3	3000 acres, 3	70% forested in a 10 km radius (77,630 acre landscape), 6	BA 30 - 80 AND proportion of oak-hickory >90%	CC 20 - 80	1	Potential UHW that is in a landscape that is 55% forested in a 10km radius

Standardizing the number of desired condition endpoints and the sequence in which they are reported allowed us to produce "bar code" descriptors for each 30-meter grid

cell in the project area. Slight differences exist in how these codes were generated for the set of maps that represent the individual Broadly Defined Habitat (BDH) classes and for the final Integrated Map of all habitats.

For the individual BDH maps, letters were used in the bar code to identify the habitat class, such as FW for Forested Wetlands, GR for Grasslands, etc. Potential habitat is screened to exclude existing developed land and open water but not other habitat classes. For example, for a potential grassland unit to be considered, the only requirement is that it not be an existing grassland, not be developed, and not be open water. It could currently belong to any other habitat class. A table of amounts of land in all possible potential vs. existing combinations is included in Appendix 2.

The Integrated Condition Index map uses numbers rather than letters to describe both the existing and potential habitats per unit. These make up the first six digits of the code. The next seven digits describe the presence or absence of conditions A, B, C…F described in Table 4. Considering an assessment of the relative conservation value of each possible potential vs. existing combination beyond the scope of the project, we chose to assess the CI scores for Potential and Potential near for only those potential classes that currently fall in the Other, not habitat class.

Neither method for evaluating potential habitats is ideal. The Other, not habitat class represents generally the costliest locations to explore for habitat restoration. On the other hand, inclusion of all potential habitat across the spectrum causes a confusion of overlapping information. Fifteen existing and eleven potential habitat classes create 161 combinations (see Appendix 2). A potential Grass Prairie currently in Upland Hardwood Woodland condition has different conservation action implications that one existing as Managed Forest. The implications are discussed in the Limitations and Future Directions section below.

An example of an Integrated Condition Index Map bar code and interpretation is shown in Figure 6. Note that in rare cases a potential habitat is named in the second three-digit segment but not acknowledged in the final two digits of the bar code. This is due to the fact that the National Land Cover Database (NLCD) data layer was used to mask developed land and open water for all potential habitats. The NLCD description of these classes broadly agrees with the input layers to the Unified Mask on these land cover classes, but the correspondence is not exact in all locations.
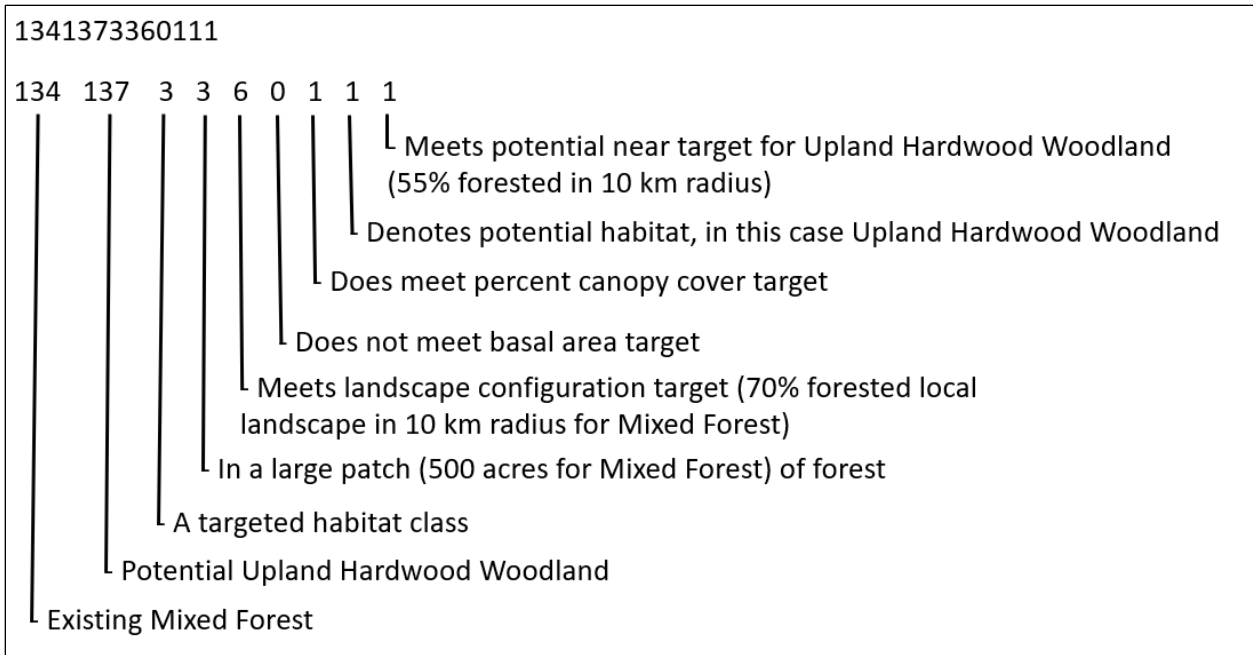
```
1341373360111

134  137  3  3  6  0  1  1  1
                           └ Meets potential near target for Upland Hardwood Woodland
                             (55% forested in 10 km radius)

                        └ Denotes potential habitat, in this case Upland Hardwood Woodland

                     └ Does meet percent canopy cover target

                  └ Does not meet basal area target

               └ Meets landscape configuration target (70% forested local
                 landscape in 10 km radius for Mixed Forest)

            └ In a large patch (500 acres for Mixed Forest) of forest

         └ A targeted habitat class

      └ Potential Upland Hardwood Woodland

   └ Existing Mixed Forest
```

Figure 6: Bar code descriptor for a typical Upland Hardwood Forest land unit

Condition Index Maps for Individual Broadly Defined Habitats

Ten of the fifteen Broadly Defined Habitats mapped were assessed and assigned per-pixel Condition Index (CI) scores according to desired condition endpoint metrics described above and information from ancillary datasets. The individual habitat CI maps consider potential habitat to be any area identified in the Potential Terrestrial Broadly Defined habitat maps that is not currently in the targeted habitat, not developed, and not open water. This allows areas to be considered potential habitat for one class while also existing as habitat in another class. For example, a potential Longleaf Pine Flatwoods grid cell may also be existing Mixed Forest. In other words, potential habitat grid cells do not overlap other classes of potential habitat grid cells, and existing habitat grid cells do not overlap other classes of existing habitat grid cells, but existing habitat grid cells of one class can and do overlap potential habitat grid cells of another class. Hectares of potential habitat classes mapped to differing existing classes are tabulated in Appendix 2. Ultimately all the individual habitat Condition Index maps were combined into an integrated Condition Index map, and for that product only those potential grid cells currently described as non-habitat were given a score. Note that in the Condition Index for Priority Habitats maps (below), scores of one or two represent mapped potential habitat and are colored blue, whereas scores of 3 – 14 represent mapped and assessed existing habitats and are colored orange (lowest) to green (highest).

Forested habitats

Desired landscape configuration endpoints for forested landscapes require classification of forested and non-forested land cover across large areas. In order to asses these conditions in the study area, we created two binary forest maps: one map of all forest types and one map of pine forest types.

General Forest/Non-Forest map

Three data sources were used to map forests for this project. Within the study area, but outside the Mississippi Alluvial Valley (MAV), we used forested habitats described by the Unified Mask: Forested Wetlands, Longleaf Pine Flatwood, Longleaf Pine Woodland, Managed Forest, Mixed Forest, Shortleaf/Loblolly Pine Woodland, and Upland Hardwood Forest and Woodland. Within the MAV we used a [forest layer](#) developed by the Lower Mississippi Valley Joint Venture (LMVJV). In order to assess landscape configuration metrics describing forested landscapes at scales of 10,000 acres (Forested Wetlands) and within 10 km diameter (Mixed Forest and Upland Hardwoods), we buffered the study area 10 km and used [NLCD 2011 Land Cover (CONUS)](#) to describe forest in the buffer. We combined the three data sources using the Mosaic to New Raster tool with LAST as the overlap operator and the input layers in order: NLCD, Unified Mask, LMVJV.

To assess patch size in the forest map we used the Region Group tool (in four directions) to define connectivity. This tool groups pixels wherever they share common sides but not corners. Pixel values are the same within groups but vary across groups, and patch size can be inferred by the pixel counts of the groups. Reclassifying on pixel count, we created new layers describing forest patches meeting the threshold for Forested Wetlands (27,788 pixels, 2500 Ha) and Upland Hardwoods (13,489 pixels, 3000 acres).

Forested Wetlands and Upland Hardwood Forest and Woodland use a measure of "forested landscape" as the second desired landscape configuration endpoint after patch size. Both systems use 70% as the threshold but the size of the local landscape differs. Upland Hardwood Forest and Woodland describes the local landscape as a 10 km radius, which is about 77,631 acres (31,416 ha). Forested Wetlands are associated with riparian zones and floodplains characterized by open land and agriculture and so use a smaller local landscape: 10,000 acres (4047 ha). To describe percent forest cover in these landscapes we used focal mean statistics on a version of the forest map that used 0 for non-forest and 1 for forest. A circle window radius of 333 pixels (10,000/30 = a 10,000 meter radius described in pixels) was used for Forested Wetlands, and a circle window radius of 120 pixels (roughly equivalent to 3589 meters, the radius of a circle with an area of 10,000 acres) was used for Forested Wetlands. In both versions, pixels with values >0.7 were retained to mask the habitat pixels meeting the desired condition.

Pine Forest Map

The three assessed pine habitat classes share the same desired landscape patch and configuration endpoints: 600-acre patch within 3 km of another patch. Pine classes are intermixed in the Unified Mask and in the source input layers. Pure stands of pine of a particular type are rare, restricting the assessment to these would fail to describe actual landscape level patch size and configuration. LANDFIRE maps vast areas of managed forest classes, particularly in the West Gulf Coastal Plain. We were unable to determine what threshold of activity or management intensity was used by LANDFIRE to determine whether a unit could be described as managed. A map of pine forest classes

including managed forest describes 37.84 million acres with 13.76 million acres in patches of 600 acres or more. Without managed forest, the Unified Mask describes 11.5 million acres with 1.9 million acres in patches of 600 acres or more. Our previous assessment of pine, based largely on data from the National GAP Land Cover Data Product, described 47.83 million acres of pine. We chose to include managed forest with the other three pine classes (Longleaf Pine Flatwoods, Longleaf Pine Woodland, and Shortleaf/Loblolly Pine Woodland) in our pine forest map. Landscapes described in pine patch and configuration endpoints are not as large as those in non-pine forest types, so land outside the study area (the buffer used in the general forest map) was not considered.

To assess the desired landscape patch and configuration endpoints, we first converted the raster data layer to polygons, calculated area, and created a new layer describing those over 600 acres. The proximity (3km to large patch) rule was used differently depending on patch size. Patches of 1-4 pixels (about a quarter acre to an acre) were considered as individual pixels and were assigned the configuration scores if they lay within the 3km buffer of the large patches. For patches of five pixels or more, but less than 600 acres, scores were given if any part of the patch was within 3 km of a large patch. For patches greater than 600 acres in size, the configuration score was only assigned for those within 3 km of another large patch. Those that are don't meet the threshold receive no points for being near themselves, although smaller patches do receive points for being near them.

Site-Level Endpoints: Basal Area and Canopy Cover

Landscape-level basal area data were obtained from the USFS Live tree species basal area of the contiguous United States (2000 – 2009) data product, which integrates vegetation phenology from MODIS imagery with extensive FIA field plot data of tree species basal area to map species distribution and basal area at 250 meter spatial resolution for the 48 conterminous U.S. states (Wilson et al. 2013). The layer was clipped to the Study Area boundary, projected to the common projection (Albers NAD 1983) of the project, and resampled to 30 meters. Desired ranges of basal area differ for each BDH class, so binary (in or out) layers describing each desired range were developed to contribute condition index and barcode information for each targeted system.

Landscape-level percent overstory canopy data were obtained from the NLCD 2011 USFS Tree Canopy analytical (CONUS) layer. This layer was clipped to the study area boundary and projected to the common projection. As with the basal area layer, individual binary layers expressing desired ranges of percent canopy cover were developed for each targeted system.

Forested Wetlands

Existing habitat: 9,555,662 ha (23,613,104 acres)
Potential habitat: 15,627,943 ha (38,618,383 acres)

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	2500 ha	6
Landscape Configuration	70% forested local landscape (10,000 acres)	3
Basal Area	60 - 80 square feet / acre	1
Canopy Cover	60 - 90 %	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Within 2500 meters of a forest patch >1250 ha	1

The Integrated Science Agenda described desired patch sizes for Forested Wetlands as 13 patches > 100,000 acres, 36 patches > 20,000 acres, and 52 patches > 10,000 acres. In the Blueprint 1.0 we chose to use a single metric of 2500 ha (6180 acres). We used the same endpoint for this project, deriving those patches from the Forest-non-forest layer through the Region Group tool as described above. The desired landscape configuration was derived by using focal statistics on the forest-non-forest layer as described above. Conservation Blueprint 1.0 used a basal area range of 60 – 70 square feet / acre and canopy cover of 60 – 70% as desired conditions for Forested Wetlands. We expanded these ranges to basal area 60 – 90 square feet / acre and canopy cover of 60 – 80% based on recommendations by the Lower Mississippi Valley Joint Venture (LMVJV Forest Resource Conservation Working Group, 2007). For the Potential Near metric, we targeted land units within 2500 meters of existing patches greater than 1250 ha in size, half the amount of the existing large patch target. Figure 7 shows the amount of land in each condition index level, and Figure 8 maps the distribution of CI scores in the landscape. With 15.6 million ha in the two potential habitat levels (CI = 1 or 2), Forested Wetland has the greatest capacity for restoration of all the habitat systems, although the vast majority is in the economically important agricultural landscapes of the Mississippi Alluvial Valley.

Figure 7: Hectares of Forested Wetlands by Condition Index and Management Label
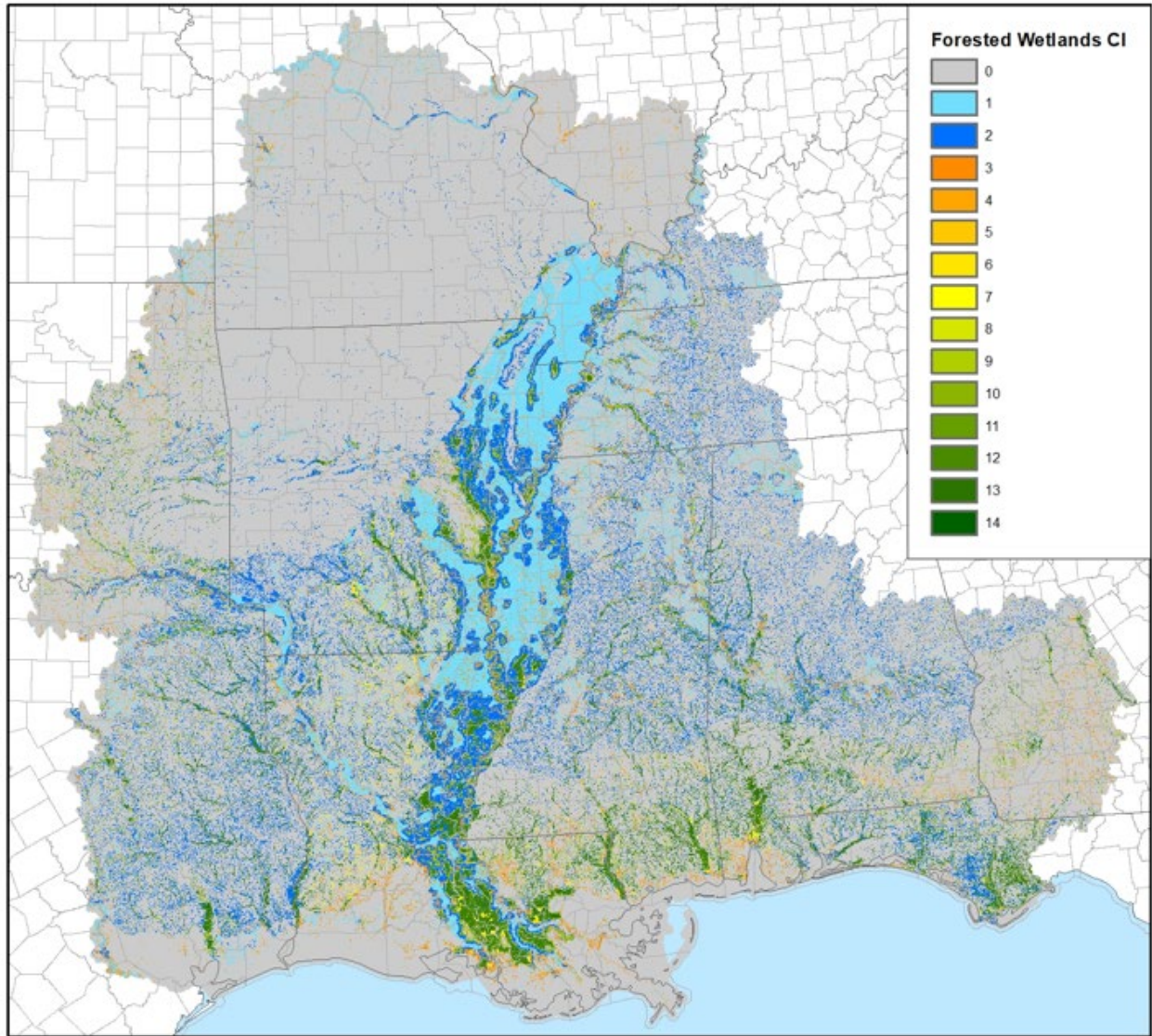
Figure 8: Condition Index map of Forested Wetlands

Mixed Forest

Existing habitat: 6,498,663 ha (16,058,919 acres)
Potential habitat: 8,274,427 ha (20,447,028 acres)

The Integrated Science Agenda did not describe Mixed Forest as a Broadly Defined Habitat, so this land cover type was not addressed in Blueprint 1.0. About 7% of the total area, or 32% of the total forested area, is described in the input layers to the Unified Mask as some form of mixed hardwood and conifer forest. Desired condition endpoints were obtained from Tom Foti, ecologist for the Arkansas Natural Heritage Commission. These endpoints are considered placeholders until species-habitat relations involving mixed forest are better understood.

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	500 acres	6
Landscape Configuration	70% forested local landscape (10 km radius)	3
Basal Area	50 - 90 square feet / acre	1
Canopy Cover	50 - 100%	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	70% forested local landscape (10 km radius)	1

Figure 9: Hectares of Mixed Forest by Condition Index and Management Label

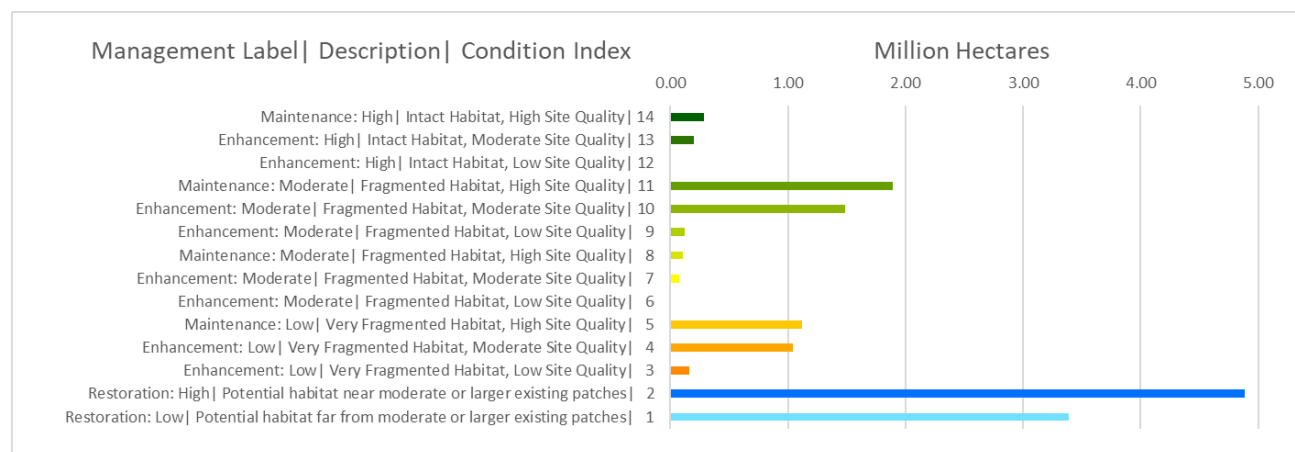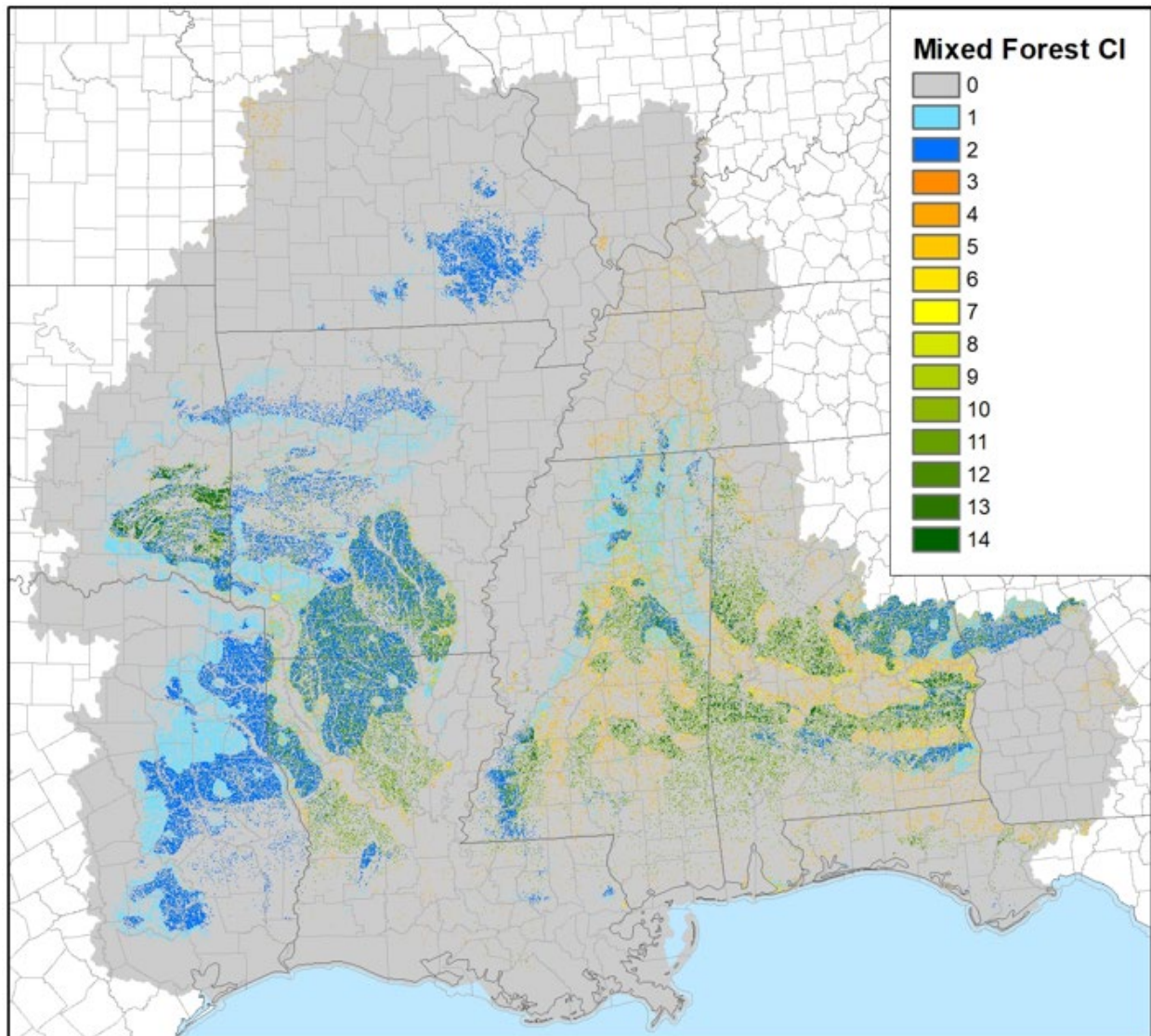*Figure 10: Mixed Forest Condition Index map*

Pine Systems

Existing habitat: 4,513,869 ha (11,154,273 acres)
Potential habitat: 10,139,283 ha (25,055,294 acres)

Pine Habitats were separated into three southern yellow pine groupings according to descriptions provided by Nordman et al. (2016). The total amount of 4.5 million ha (11.2 million acres) of existing pine forest was unexpectedly low. The GCPO LCC Ecological Assessment of Open Pine Woodland and Savanna used a base map derived from the National Gap Analysis Project (GAP) Land Cover Dataset to describe 47.8 million acres of pine forest. The current base map, derived from LANDFIRE, describes much more managed forest than the GAP layer. If we include the 10.7 million ha (26.3 million acres) of Managed Forest (Figure 11) in our pine forest map the total amount would be 15.2 million ha (37.5 million acres). We did not evaluate the condition of Managed Forest due to a lack of defined desired condition endpoints, but due to the fact that Managed Forest grid cells are greatly intermixed with those of pine and other forest classes in the Unified Mask raster dataset, we did include Managed Forest as an input into our map of general pine forest to be used when assessing patch size and landscape configuration endpoints for the three southern yellow pine classes.
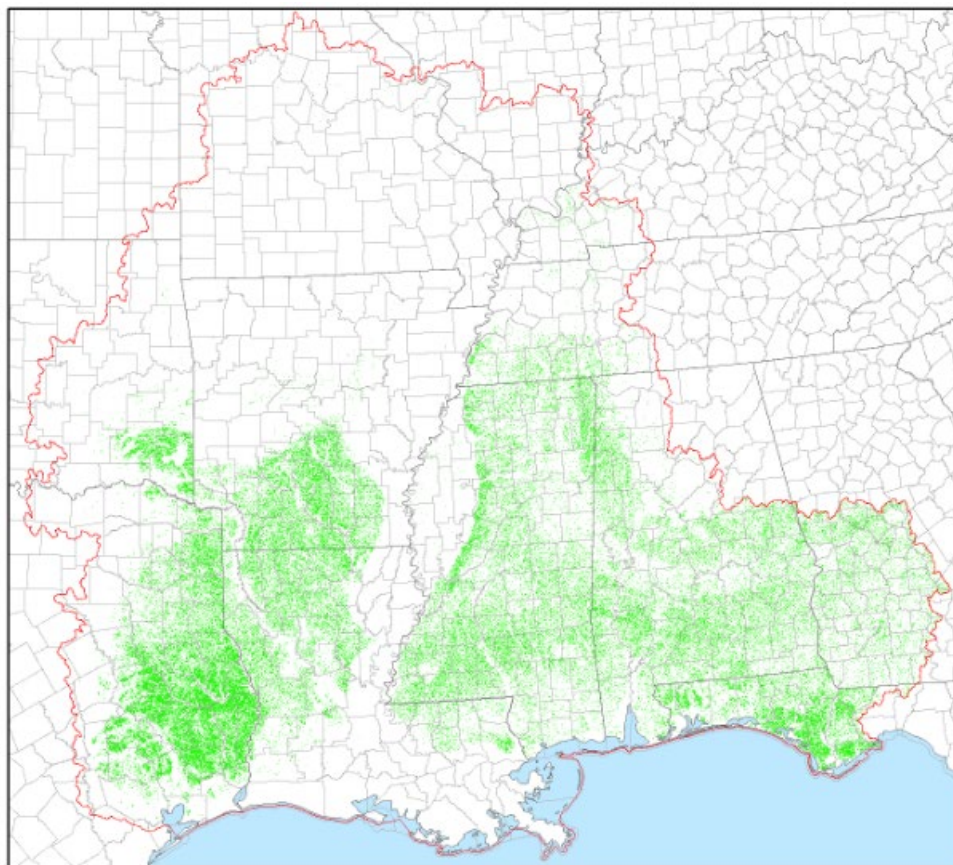
Figure 11: Managed Forest in the Unified Mask
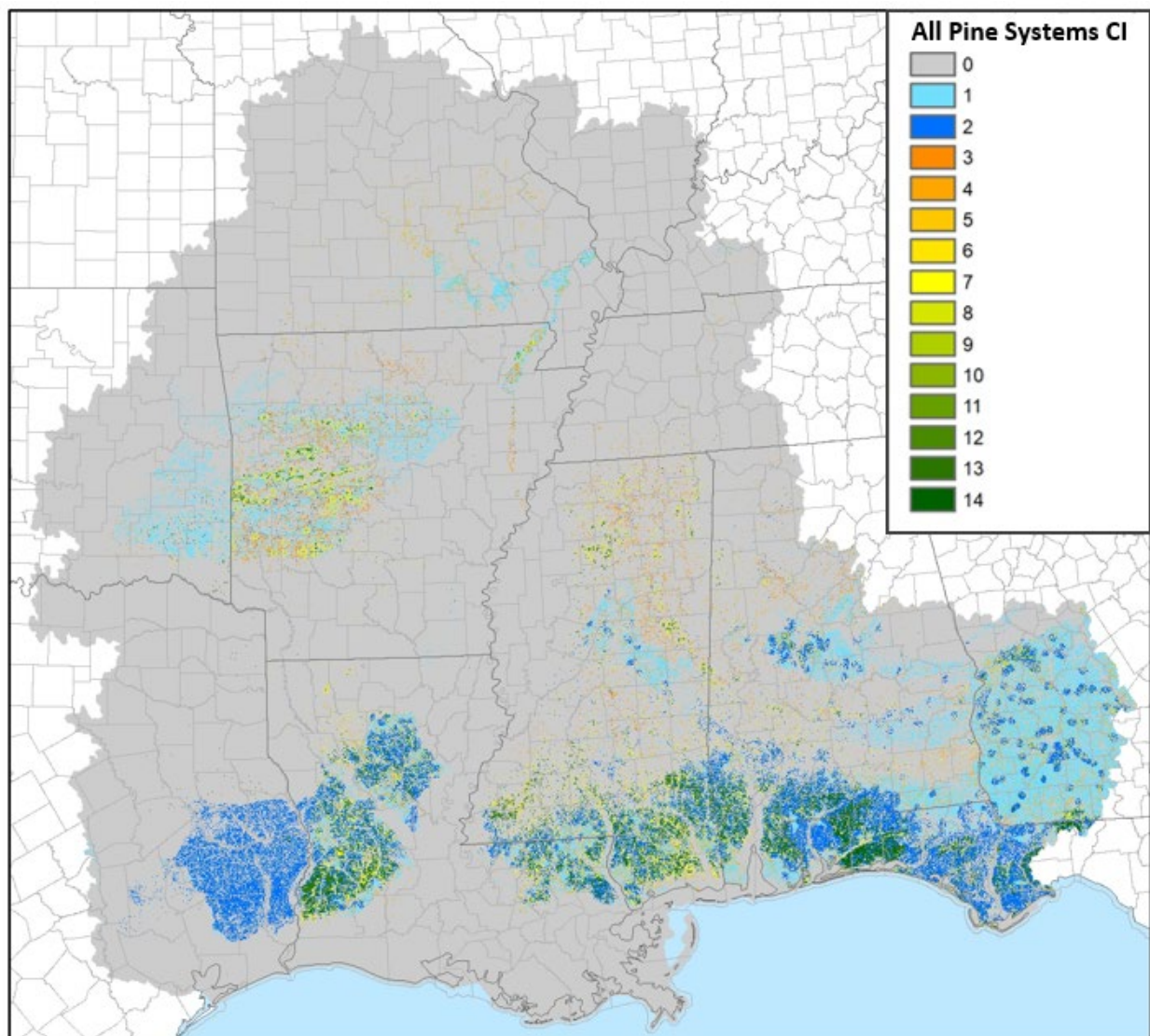
Figure 12: Combined Condition Index map for the three southern yellow pine groups

Longleaf Pine Flatwoods

Existing habitat: 674,925 ha (1,667,816 acres)
Potential habitat: 1,727,378 ha (4,268,543 acres)

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	600 acres (a variety of pine types)	6
Landscape Configuration	Less than 3km to large patch	3
Basal Area	10 - 90 square feet / acre	1
Canopy Cover	15 - 75 %	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Less than 3km to large patch	1

Figure 13: Hectares of Longleaf Pine Flatwood by Condition Index and Management Label
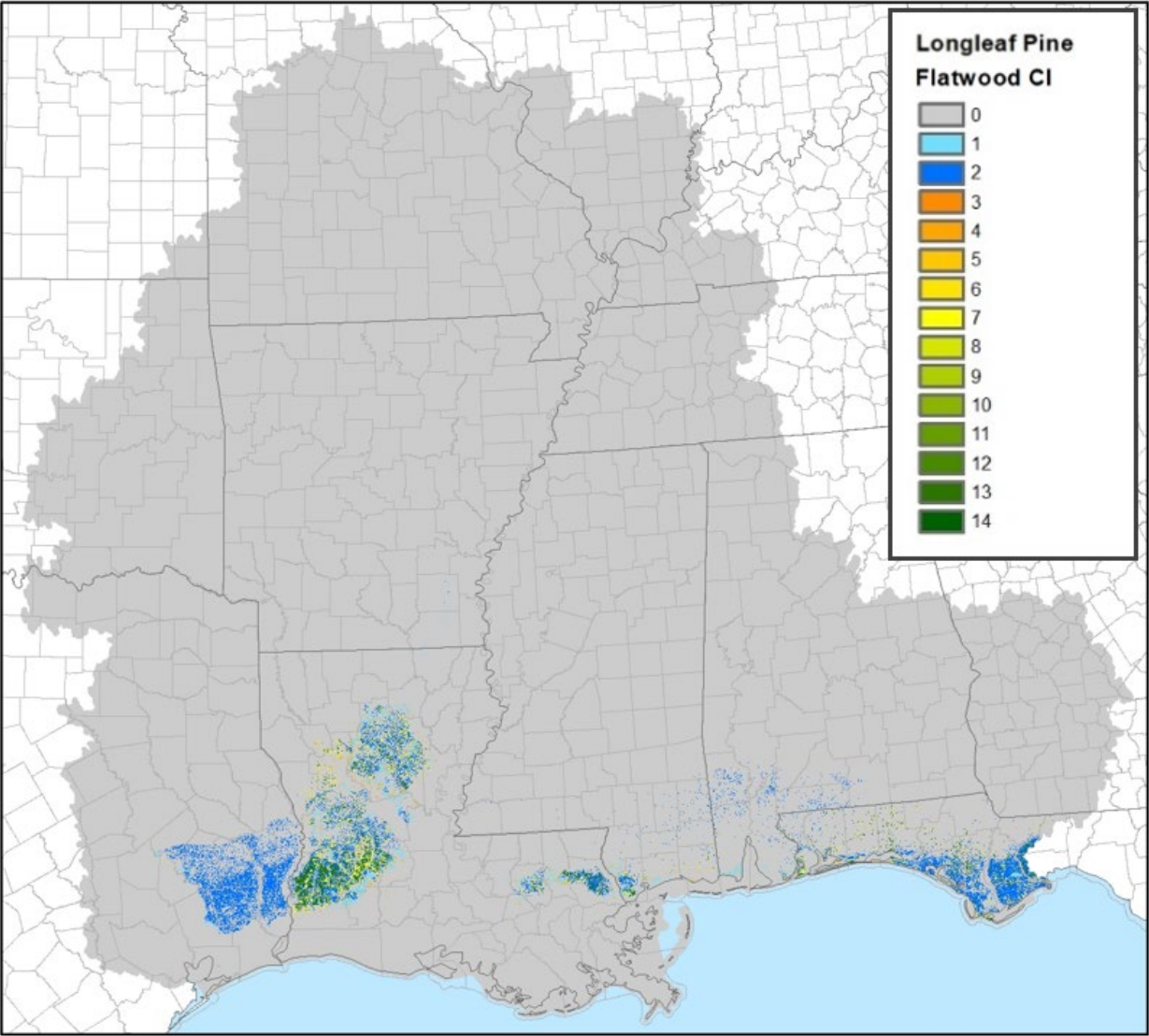
Figure 14: Longleaf Pine Flatwood Condition Index Map

Longleaf Pine Woodland

Existing habitat: 2,317,399 ha (5,726,549 acres)
Potential habitat: 6,202,626 ha (15,327,379 acres)

Desired Condtion	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	600 acres (a variety of pine types)	6
Landscape Configuration	Less than 3km to large patch	3
Basal Area	15 - 90 square feet / acre	1
Canopy Cover	15 - 75 %	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Less than 3km to large patch	1

Figure 15: Hectares of Longleaf Pine Woodland by Condition Index and Management Label

Figure 16: Longleaf Pine Woodland Condition Index Map

Shortleaf/Loblolly Pine Woodland

Existing habitat: 1,521,387 ha (3,759,516 acres)
Potential habitat: 1,361,879 ha (3,365,354 acres)

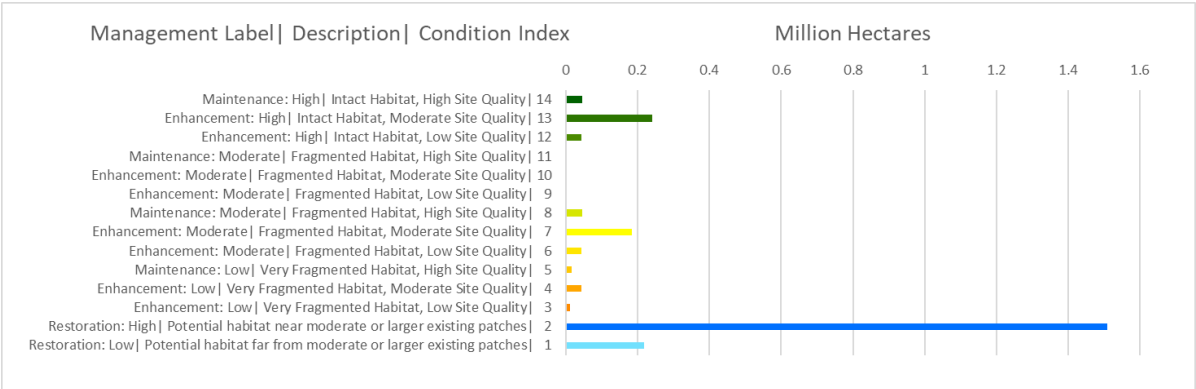| Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	600 acres (a variety of pine types)	6
Landscape Configuration	Less than 3km to large patch	3
Basal Area	20 - 100 square feet / acre	1
Canopy Cover	15 - 85 %	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Less than 3km to large patch	1

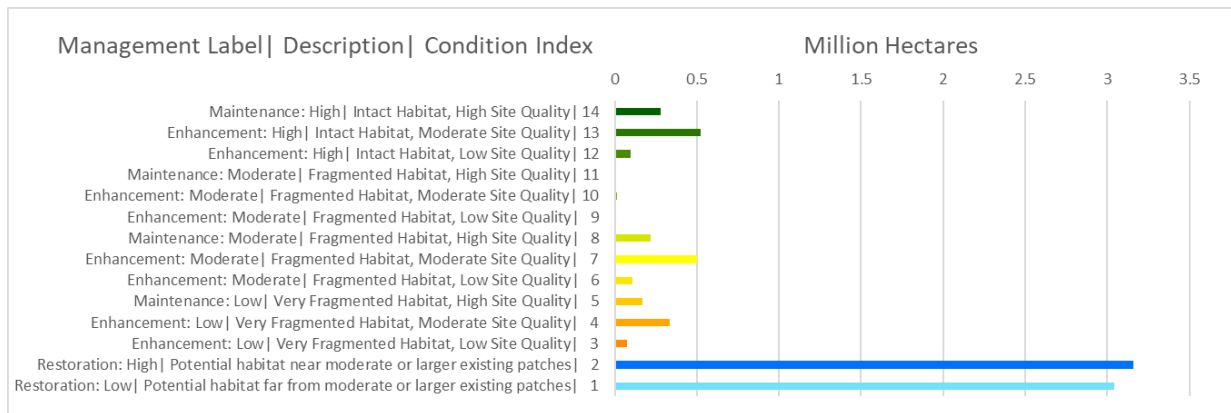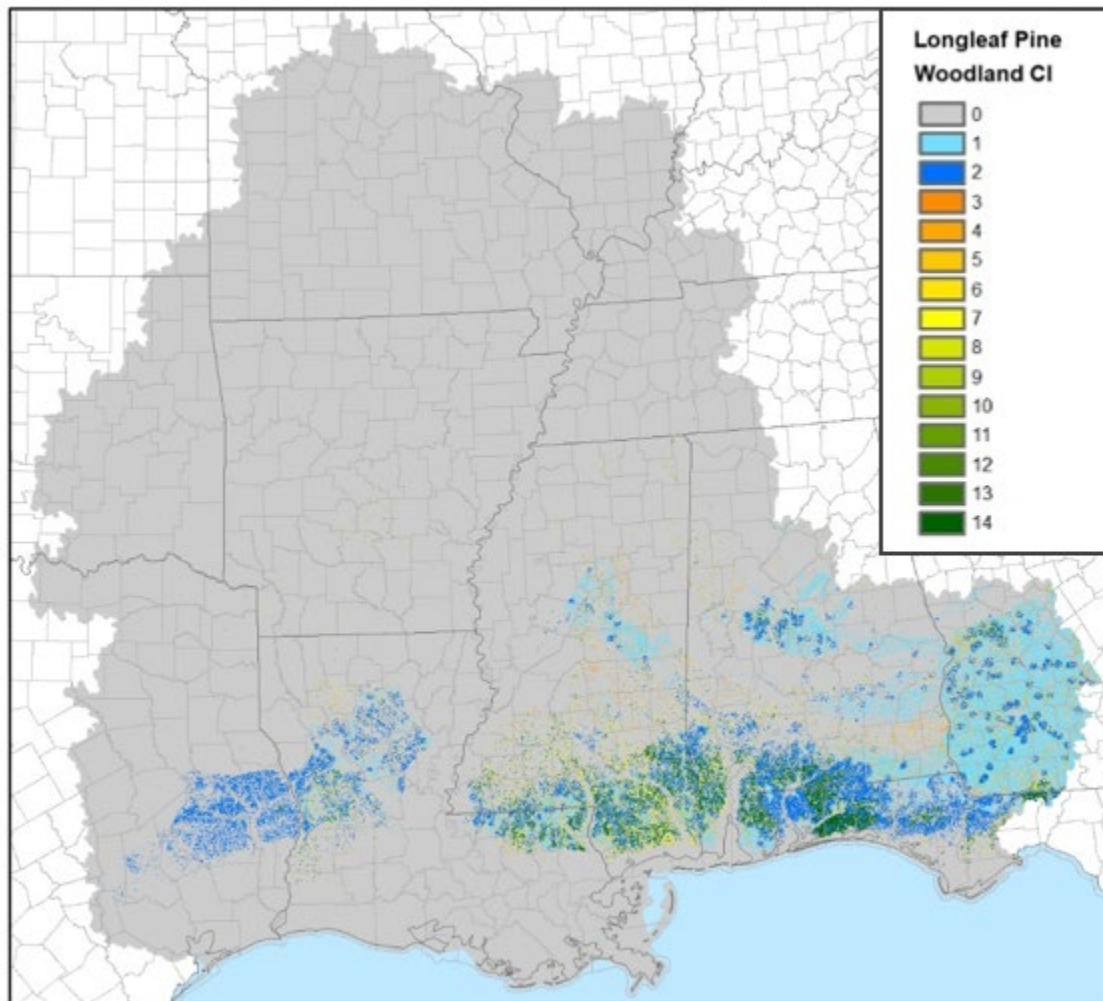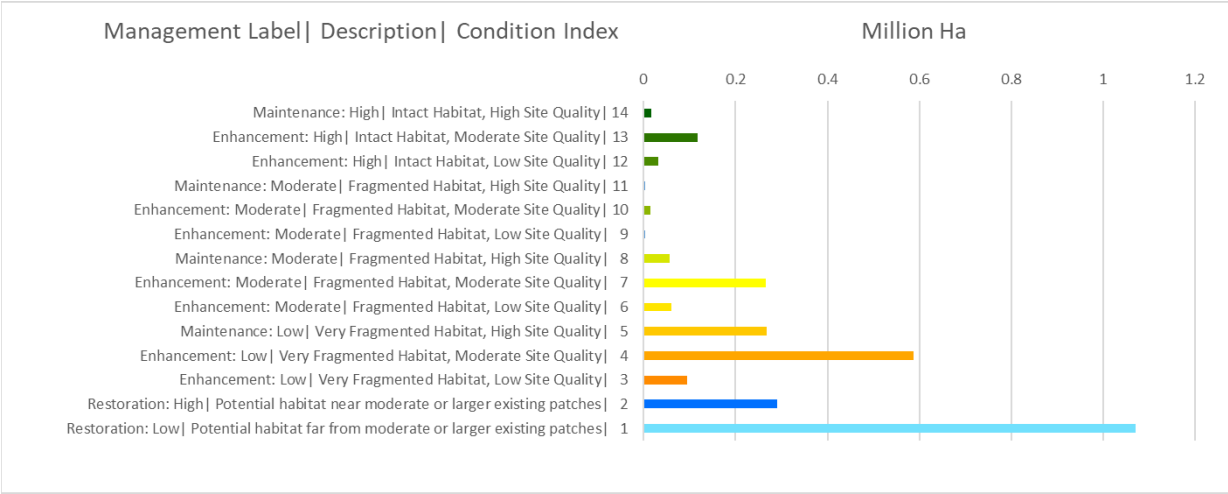*Figure 17: Hectares of Shortleaf/Loblolly Pine Woodland by Condition Index and Management Label*
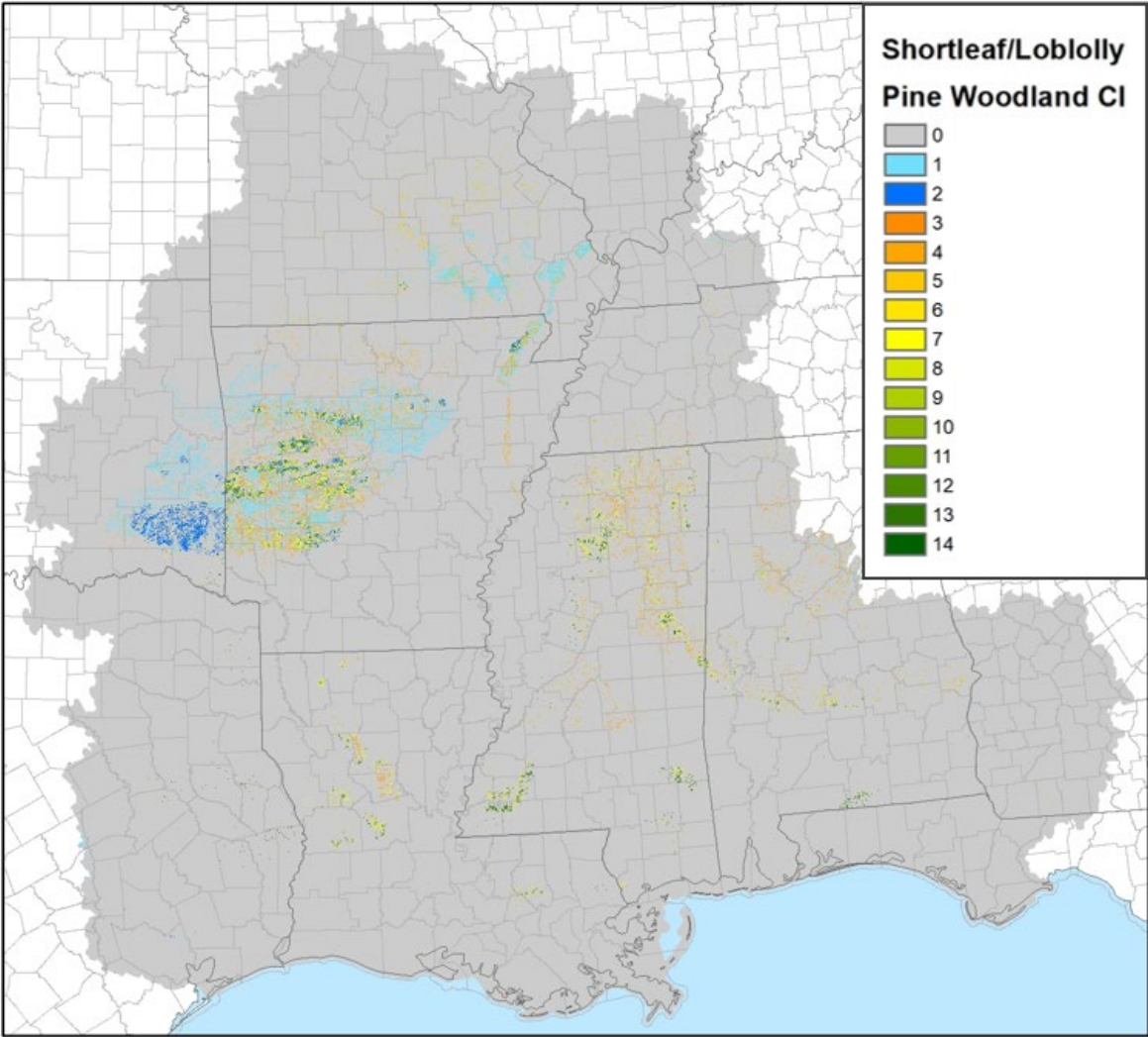
Figure 18: Shortleaf/Loblolly Pine Woodland Condition Index Map

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Upland Hardwood Forest and Woodland

Upland Hardwood Forest and Upland Hardwood Woodland were addressed as two separate classes with slightly different endpoints. These endpoints are unchanged from those used in the GCPO LCC Ecological Assessments and Blueprint 1.0. For these habitat classes, a percent oak-hickory component was included in the basal area endpoint. Maps describing percent oak-hickory per pixel were generated by dividing oak-hickory basal area values by total live tree basal area values according to the [USFS per-species and total live tree basal area data product](#) (Wilson et al. 2013). The Integrated Science Agenda does not provide total live tree basal area endpoint metrics for these habitats: we generated those ourselves. Condition index scores for basal area were assigned to pixels that met BOTH the basal area and percent oak-hickory targets. Land units described as Glades in the Unified Mask were considered Upland Hardwood Woodland and were assessed according to the desired condition metrics for that class.

Upland Hardwood Forest

Existing habitat: 13,903,345 ha (34,356,710 acres)
Potential habitat: 12,225,588 ha (30,210,788 acres)

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	3000 acres	6
Landscape Configuration	70% forested local landscape (10 km radius)	3
Basal Area	80 - 100 square feet / acre AND > 70% oak-hickory	1
Canopy Cover	> 80%	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	55% forested local landscape (10 km radius)	1
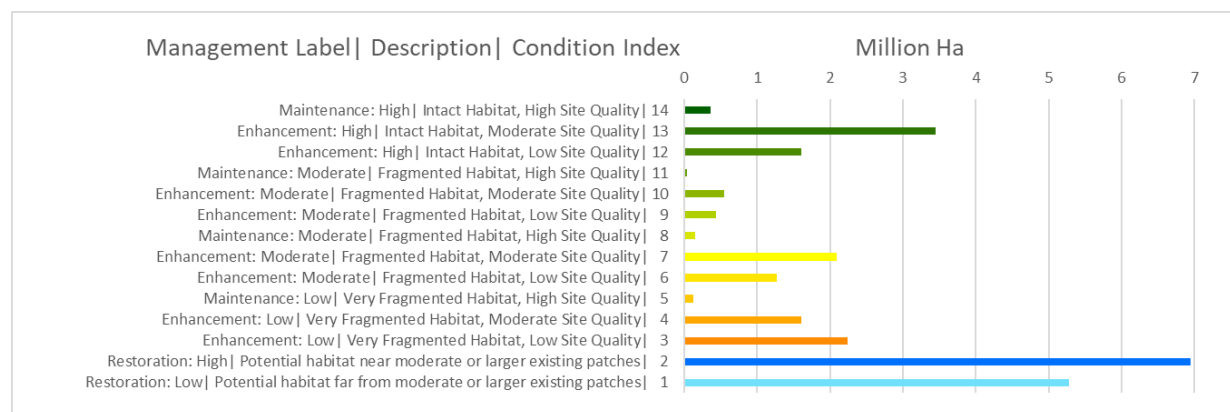
Figure 19: Hectares of Upland Hardwood Forest by Condition Index and Management Label
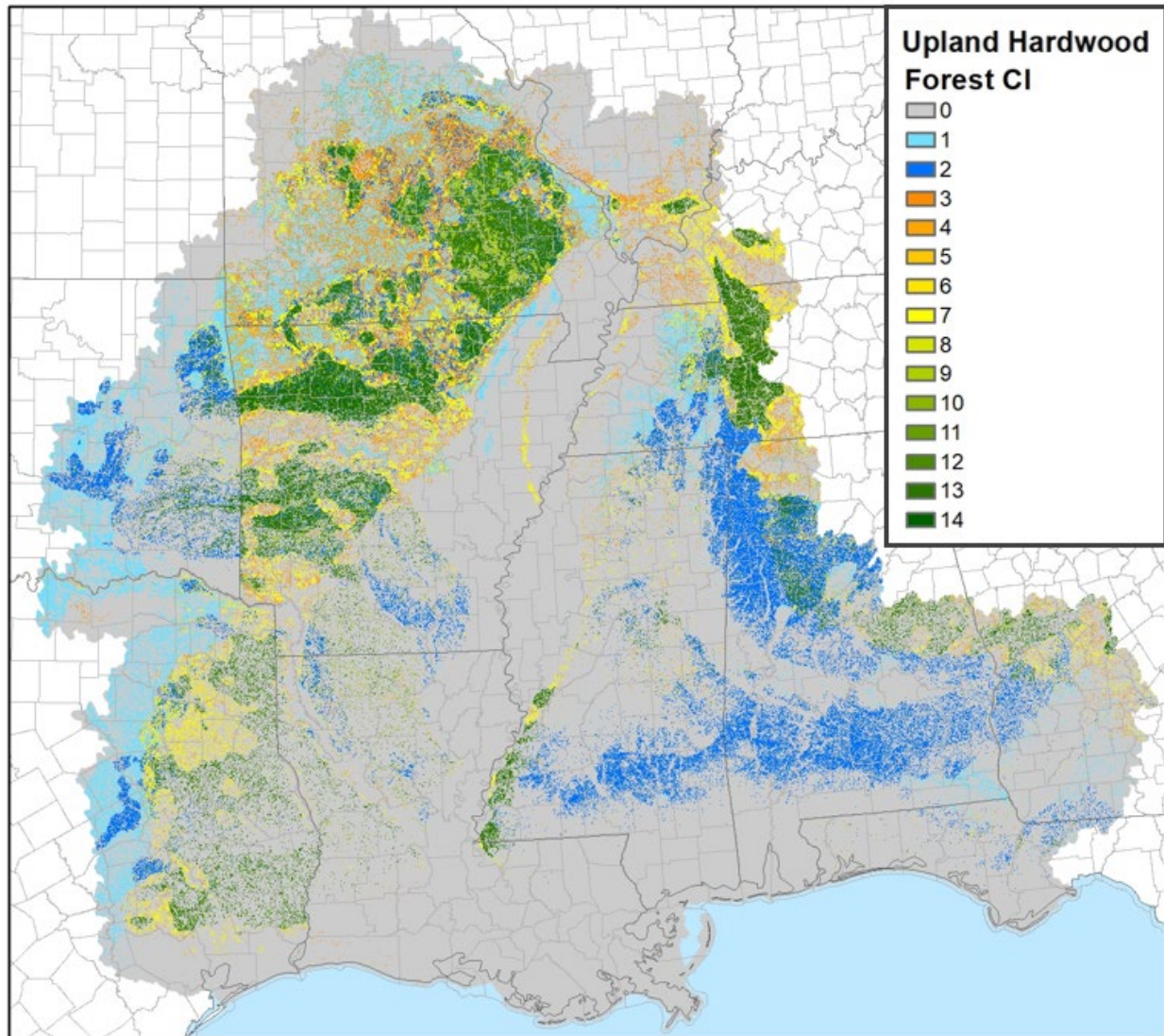
Figure 20: Upland Hardwood Forest Condition Index Map

Upland Hardwood Woodland

Existing habitat: 13,903,345 ha (34,356,710 acres)
Potential habitat: 12,225,588 ha (30,210,788 acres)

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	3000 acres	6
Landscape Configuration	70% forested local landscape (10 km radius)	3
Basal Area	30 - 80 square feet / acre AND > 90% oak-hickory	1
Canopy Cover	20 - 80 %	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	55% forested local landscape (10 km radius)	1
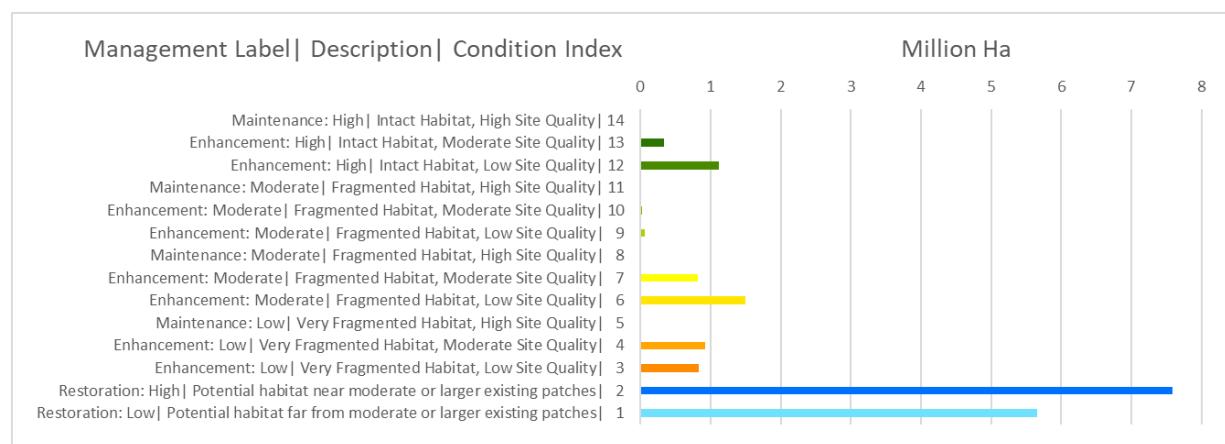
Figure 21: Hectares of Upland Hardwood Woodland by Condition Index and Management Label

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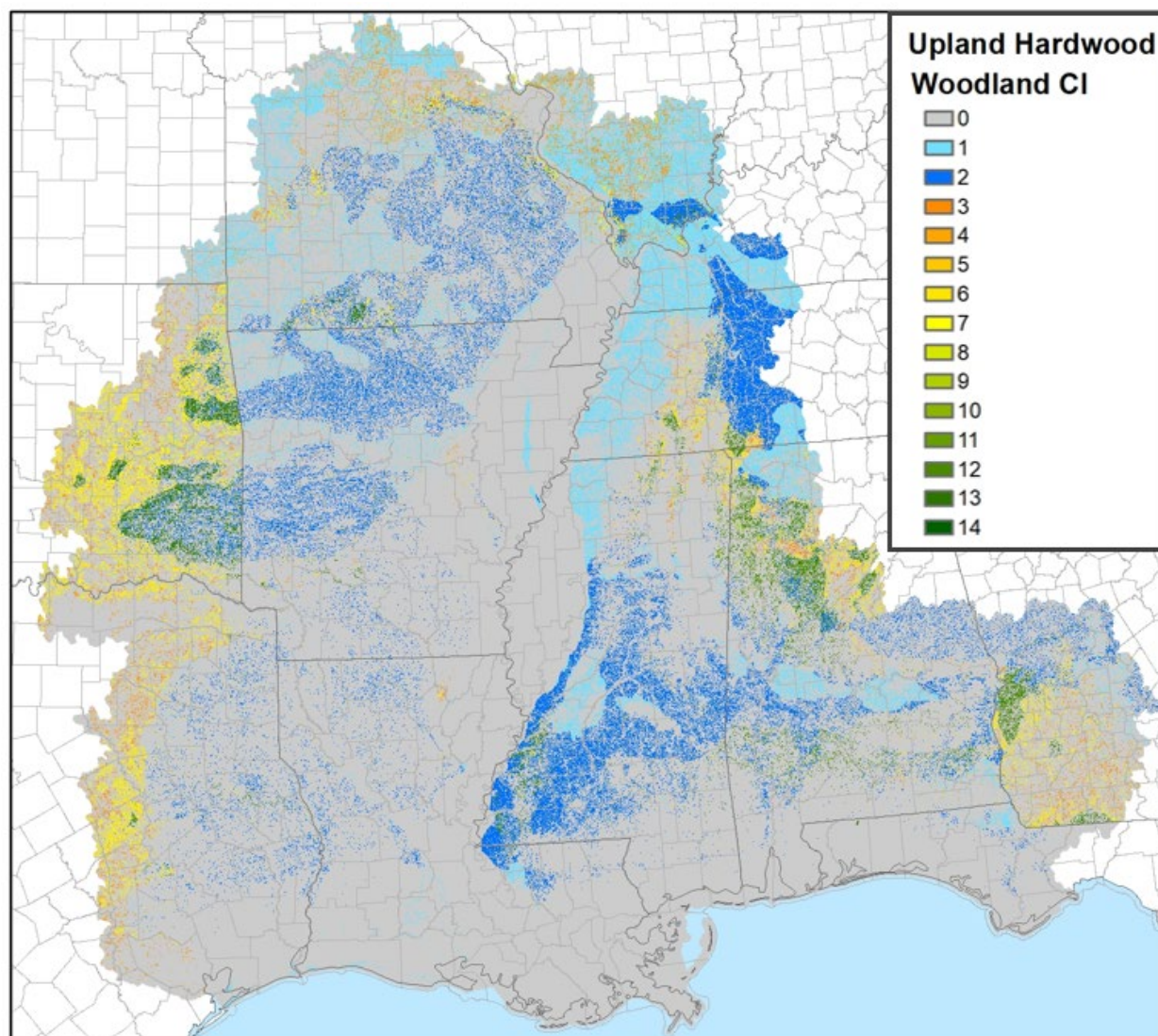
Figure 22: Upland Hardwood Woodland Condition Index Map

The Missouri-Oklahoma seam in both Forest and Woodland classes likely results from difficulty translating MoRAP (Oklahoma) and LANDFIRE (Missouri) classes of ecological systems and land cover to broadly defined habitats in a way that is consistent across the states. Upland Hardwood Forest exists in fairly large blocks in good condition in the Ozark Highlands, Ouachita Mountains, Cumberland Ridge, Southern Appalachian Mountains, and Southern Loess Hills. Upland Hardwood Forest is common but fragmented in the West Gulf Coastal Plain and quite rare in East Gulf Coastal Plain, which features great capacity for restoration (Figure 20). The Woodland class is much more rare in the landscape throughout the region. Potential for restoration is widespread except for in the Mississippi Alluvial Valley and Coastal areas (Figure 22).

Grassland
General Grassland: 16,039,603 ha (39,635,642 acres)
Prairie Grassland: 1,274,110 ha (3,148,468 acres)
Potential Prairie: 3,865,984 ha (9,553,275 acres)

Desired Condition	Metric	CI Score
General Grass	A land unit dominated by grass species	3
Grassland Prairie	Presence of warm season native grasses and forbs	6
Patch	Patch (general grass, prairie, or mix of both) > 100 Acres	3
Disturbance	Burned at least once during the period 2006 - 2015	1
Vegetation Height	> 1 meter	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Within 1 km of existing prairie patch > 100 acres	1

As with Conservation Blueprint 1.0 and the GCPO LCC ecological assessments, we replaced the 6-point value landscape configuration or patch metric for grasslands with an evaluation distinguishing natural prairie (dominated by native warm season grasses and forbs) from general grassland (any landscape dominated by grass, including pastures). The determination whether a grid cell is "general" or "prairie" is made during the generation of the Unified Mask. The ecological system descriptions of the input layers were carefully reviewed to determine which type is indicated. Then an overlay layer of known prairie patches in the region was applied.

For the patch endpoint (> 100 acres), a raster layer of all general and prairie types of grass was converted to polygon in order to calculate areas. Prairie and general classes are intermixed in the landscape, so a requirement that the entire patch consist of prairie classes only would have excluded large areas dominated by prairie conditions. Disturbance data was obtained from the Burned Area Essential Climate Variable data from USGS (Hawbaker et al. 2017). Any grid cell found described as having been burned at least once during the period 2006 – 2015 obtained the disturbance score. Scores for Vegetation Height were assigned by selecting the "herbaceous height > 1 meter" class from the Existing Vegetation Height data product from LANDFIRE (LANDFIREevh). Patches used for the Potential Near endpoint, unlike those for the patch endpoint, consisted of those > 100 acres of Grassland Prairie exclusively.

The most common existing BDH class for potential prairie pixels is Other, non-habitat, dominated by urban, developed, and agricultural uses, accounting for 3.3 million ha, or 43%. The second most common is Grassland General at 36%. This indicates that the major portion of land targeted for conversion to prairie is already in an herbaceous cover state. Grass General is a major component of the Mid-South, covering 17.3 million ha, or 18% of the total area. Ten percent of potential prairie land is currently covered by Upland Hardwood Forest and Woodland, the third most common cover. See Appendix 2 for more information about which current classes cover which potential classes.
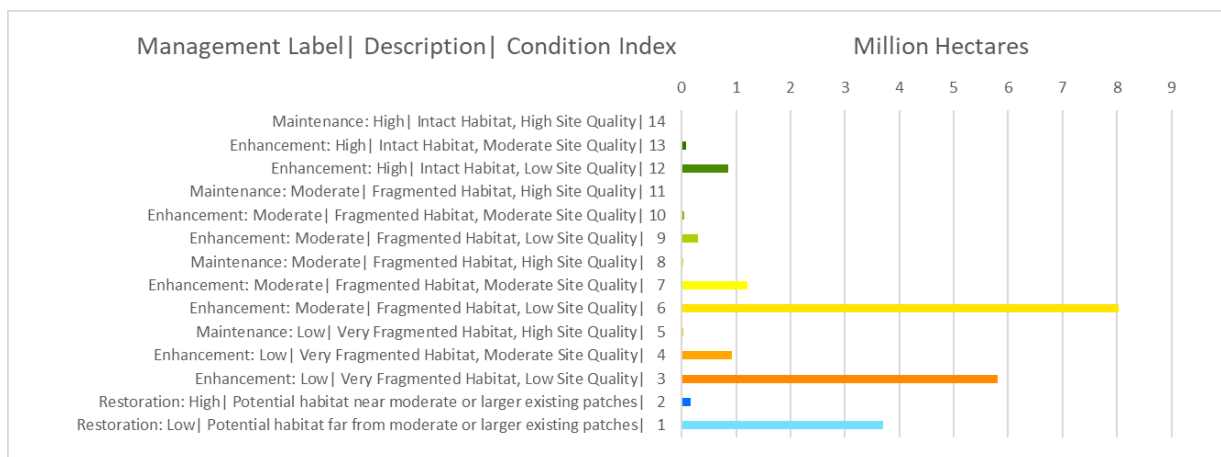
Figure 23: Hectares of Grassland by Condition Index and Management Label
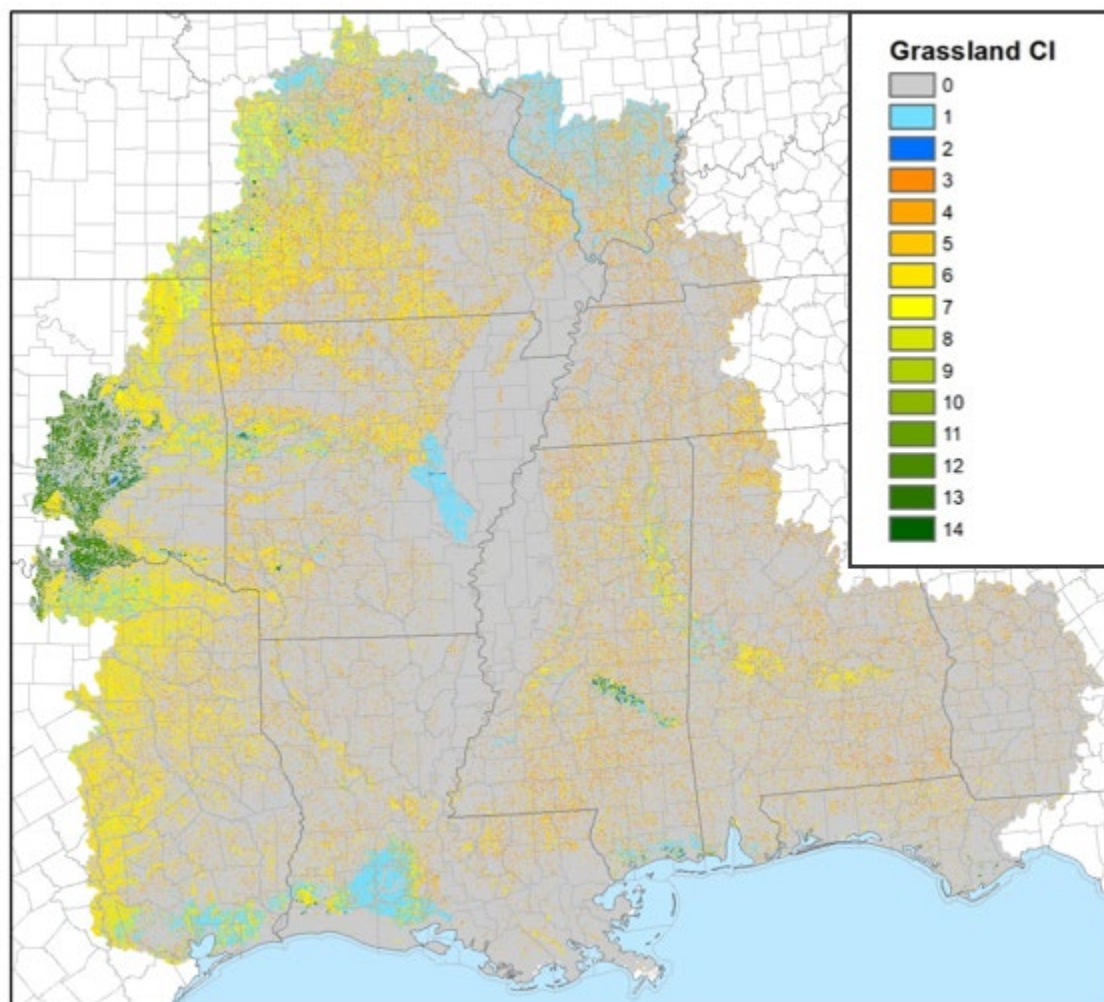
Figure 24: Grassland Condition Index Map. Scores of 3 – 8 represent General Grassland cover, 9 or more describes natural prairie conditions.

Ecological systems dominated by grass but not indicative of the presence of native warm season grasses and forbs that characterize prairie, our General Grassland class, are widely distributed in patches of various sizes across the study area with the exception of near-coastline areas and the Mississippi Alluvial Valley. Patches of true prairie are much smaller and less common, and most are not visible on a map of this size at this spatial scale. Most of the large prairie patches show at this scale lie in the Jackson Prairie Belt of Central Mississippi and the Semi-arid Prairie Region of Texas and Oklahoma. The MoRAP approach classified maps based on an extensive network of roadside points combined with remotely sensed imagery, so may be more reflective of conditions on the ground than the ecological system data from the LANDFIRE (Figure 24).

Tidal Marsh

Existing habitat: 1,355,323 ha (3,349,155 acres)
Potential habitat: 113,338 ha (280,070 acres)

Desired Condition	Metric	CI Score
Habitat Exists	Derived from Unified Mask	3
Patch Size	Greater than 250 acres	6
Moderate Edge	Divide perimeter by area: Select patches 1 SD above and below mean	3
Interdigitation	Combination of > 5 % saline, brackish, intermediate	1
Submerged Aquatic Vegetation	Marsh within 60 meters of SAV	1
Potential	Derived from LANDFIRE BioPhysical Settings	1
Potential Near	Within 567 meters of a patch > 250 acres. Distance = radius of a 250-acre circle	1

As described above in the section on the Unified Mask, this study increases dramatically the amount of North Gulf Coast shoreline assessed compared to the GCPO LCC Conservation Blueprint 1.0. This naturally increases the amount of Tidal Marsh assessed. The Blueprint 1.0 mapped Tidal Marsh using the USGS Marsh Type Delineation Project outside of Florida and the Florida Cooperative Land Cover Map in Florida. This project's Unified Mask, derived from LANDFIRE Existing Vegetation Type (evt) outside Florida, describes a Tidal Marsh footprint similar to that of the USGS product, although it may overestimate in some locations (Figure 25).
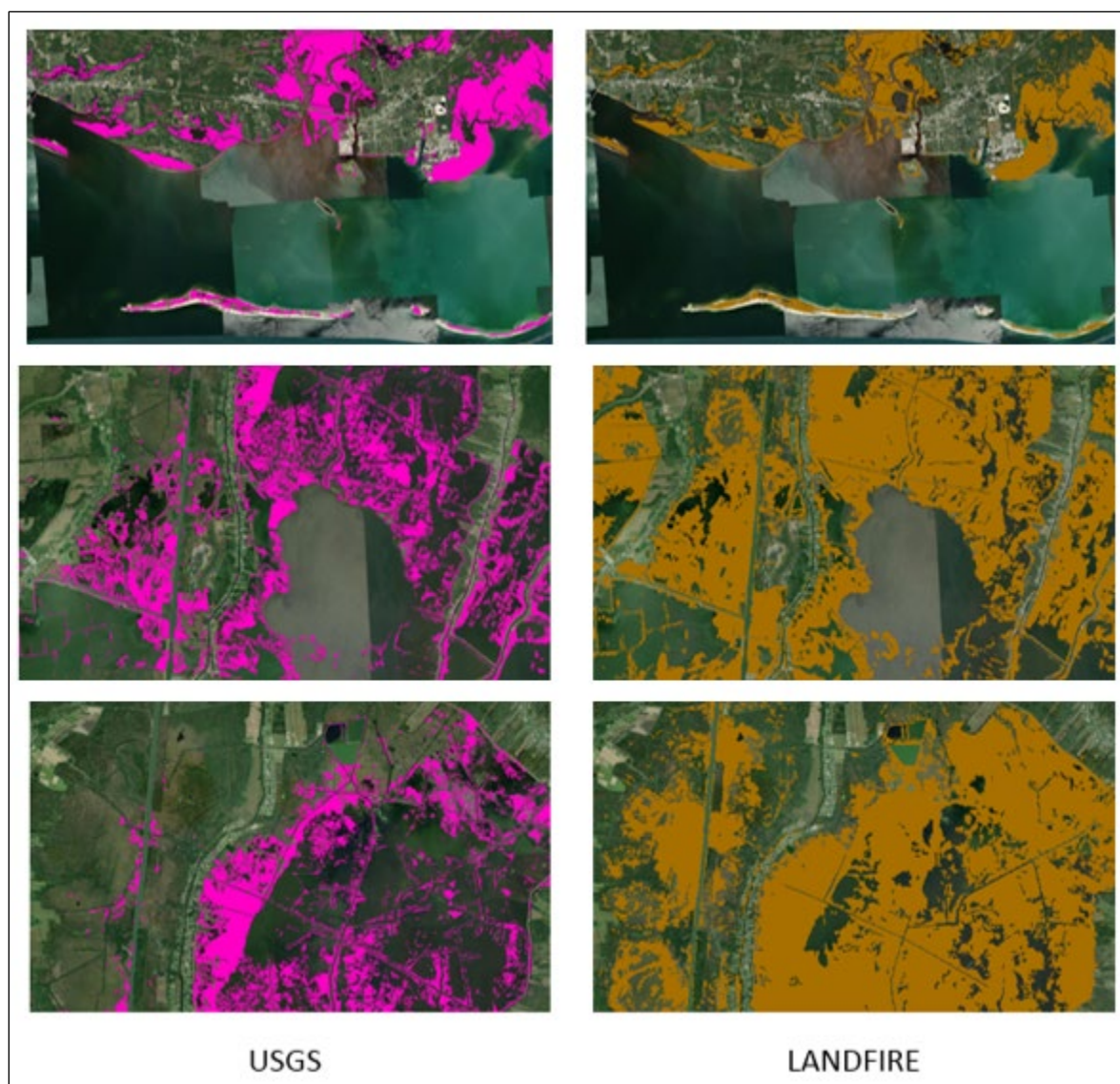
Figure 25: Tidal Marsh mapped by USGS (input to Blueprint 1.0) and as mapped by LANDFIRE evt (input to the current project).

Desired condition endpoint values are unchanged from Blueprint 1.0. The Condition Index scoring here does not follow the same pattern as the other systems because the endpoints lack a true measurable landscape configuration metric. For Tidal Marsh, moderate edge takes the place held by the landscape configuration metric in the standardized scoring and bar code pattern.

Describing Tidal Marsh Patches

The GCPO LCC Integrated Science Agenda describes > 70% vegetation cover and < 20% open water as a desired condition endpoint for Tidal Marsh. In order to include open water in the patches, we used a combination of "eliminate polygon parts," "dissolve," and converting to raster and back to polygon. The resulting map describes 137,393 patches totaling 1,405,924 ha (3,474,113 acres). We used zonal statistics on a

binary (0,1) raster layer of tidal marsh patches and open water and found that all but three (99.99%) of the patches met the vegetation and open water thresholds. We chose not to use this endpoint in the calculation of the condition index score since it does not add information about the spatial distribution and configuration of the desired condition. Small patches are far more common than large patches, but large patches account for the vast majority of area. With the large patch threshold at 250 acres, we found 136,391 small patches totaling 135,700 ha (335,320 acres) and 1002 large patches totaling 1,266,178 ha (3,128,793 acres).

Moderate Edge

Edge density was calculated per patch by dividing perimeter by area and multiplying the result by 10,000. We selected patches one standard deviation above and below mean edge density to represent patches with moderate edge. We ignored patches < 5 acres in size. The highest edge density values are associated with the smallest, most serpentine patches (Figures 26 and 27).
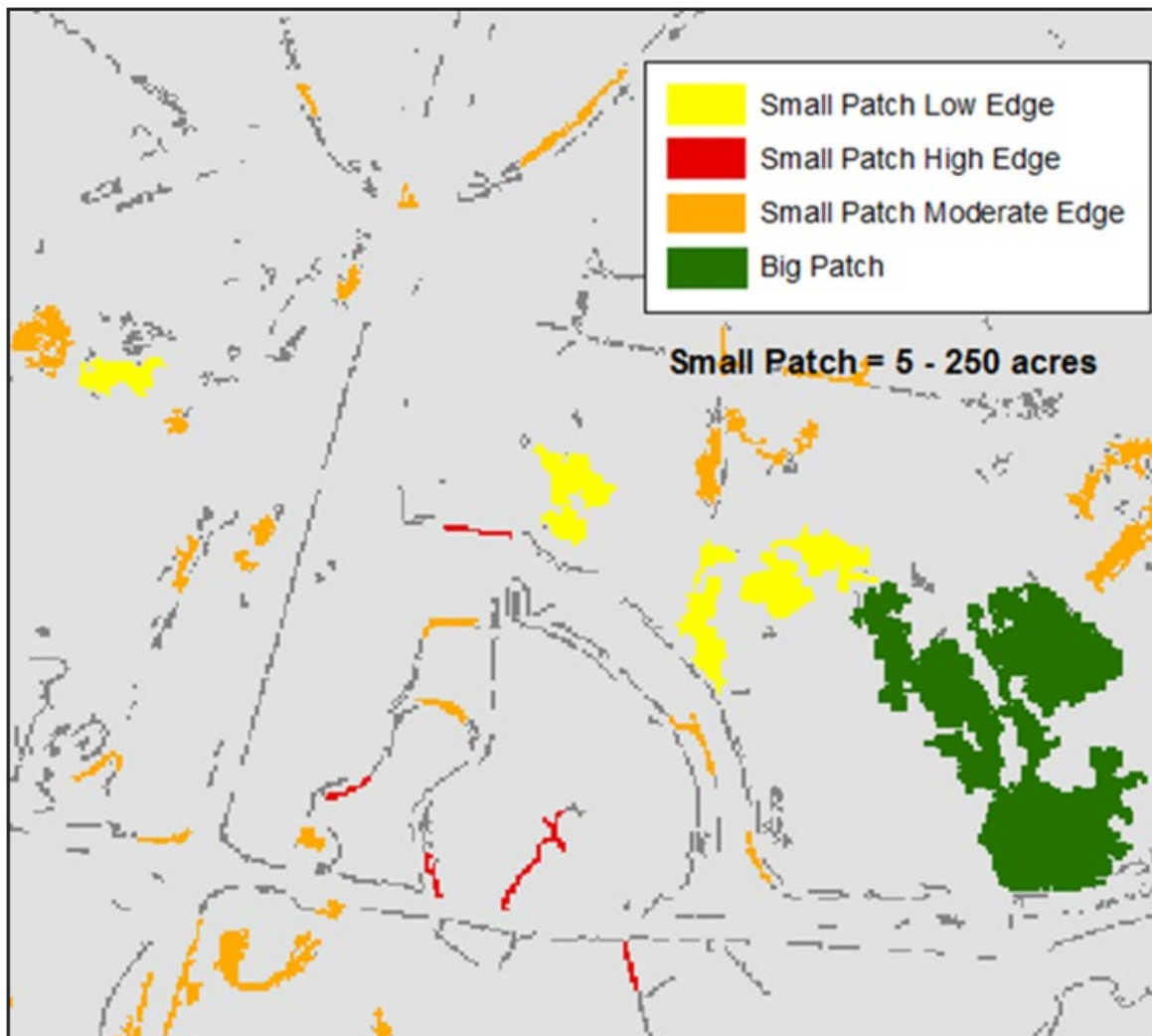
Figure 26: Small patches of Tidal Marsh classified as having low, moderate, and high edge density
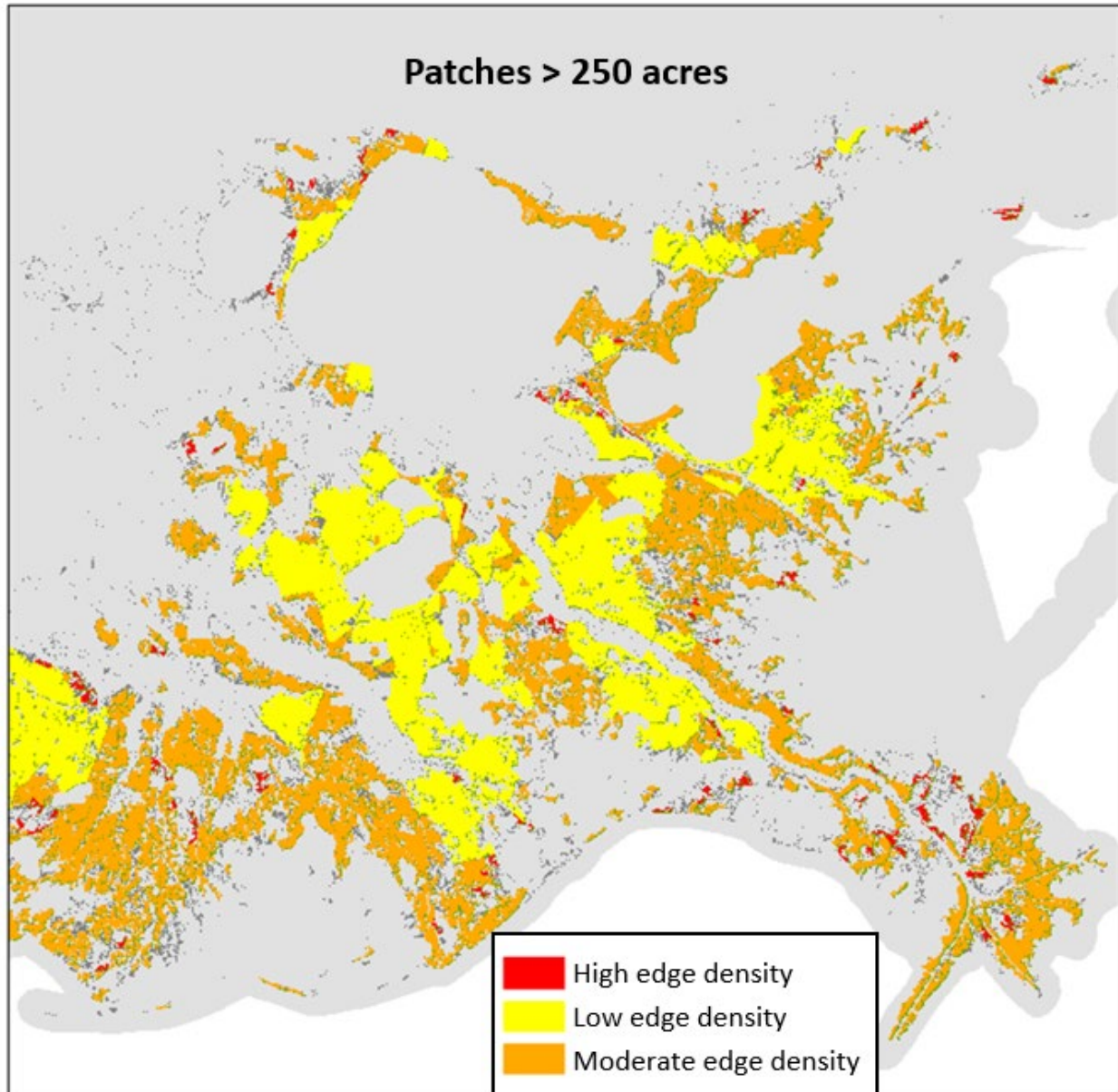
Figure 27: Large Patches of Tidal Marsh classified as having low, moderate, and high edge density

Interdigitation of Marsh Types

As with Conservation Bluepoint 1.0, we used the USGS Marsh Type Delineation Project layer and the Tabulate Area tool to identify all marsh patches having > 5% coverage for the three marsh types: Intermediate, Brackish, and Saline. We tabulated areas for all marsh patches, but for the Condition Index process used only those patches in the large (> 250 acres) category. Unfortunately, the USGS source data omits Florida.
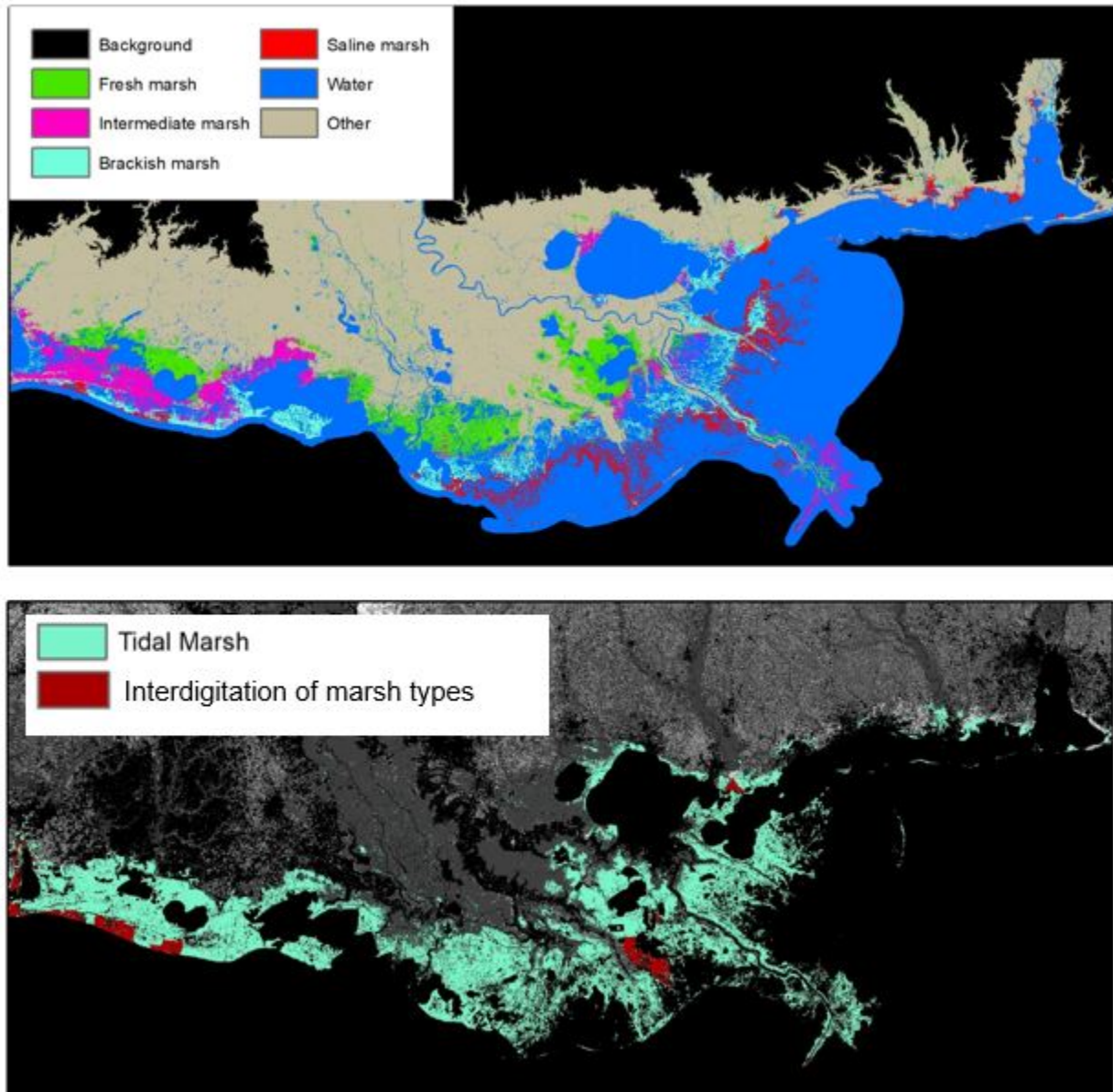
Figure 28: Marsh salinity classes mapped by the USFS Marsh Type Delineation Project (top) and marsh patches having >5% of each type (bottom)

Among the small (5-250 acre) patches, interdigitation of types was indicated in only 50 out of 8737 patches, accounting for 2120 acres, or 0.01% of the area. Among the large patches, interdigitation was indicated in 33 of 976 patches constituting 151,767 acres, or 5% of the total area.

Submerged Aquatic Vegetation (SAV)

Submerged Aquatic Vegetation was mapped using the Seagrasses in the continental United States as of March 2015 data layer from NOAA (Office of Coastal Management, 2019), and Submerged aquatic vegetation and environmental data for coastal areas from Texas through Alabama 2013 – 2015 from USGS (La Peyre et al. 2017). The USGS data were tabulated in a csv file. To map SAV, we selected records (rows) for

which 'SAVCov_A' values were greater than 50, then created a point file from the latitude and longitude information in these records. The point file was converted to a 30m raster and combined with the NOAA Continental 2015 layer. Since SAV occurs in open water and Tidal Marsh is mapped for this project as a terrestrial habitat, we assigned the CI scores to proximal grid cells by applying a Euclidean distance to the SAV cells and identifying Tidal Marsh grid cells within 60 meters (two pixels) of the SAV occurrence (Figure 29). This process indicated the existence of SAV in proximity to 5531 acres of tidal marsh, about 0.002% of the total area of tidal marsh.

□ ☑ rastercalc70
■ 0
■ 3   Tidal Marsh
□ 100   SAV + 60 meters Euclidean
□ 103   Intersect of Tidal Marsh and SAV
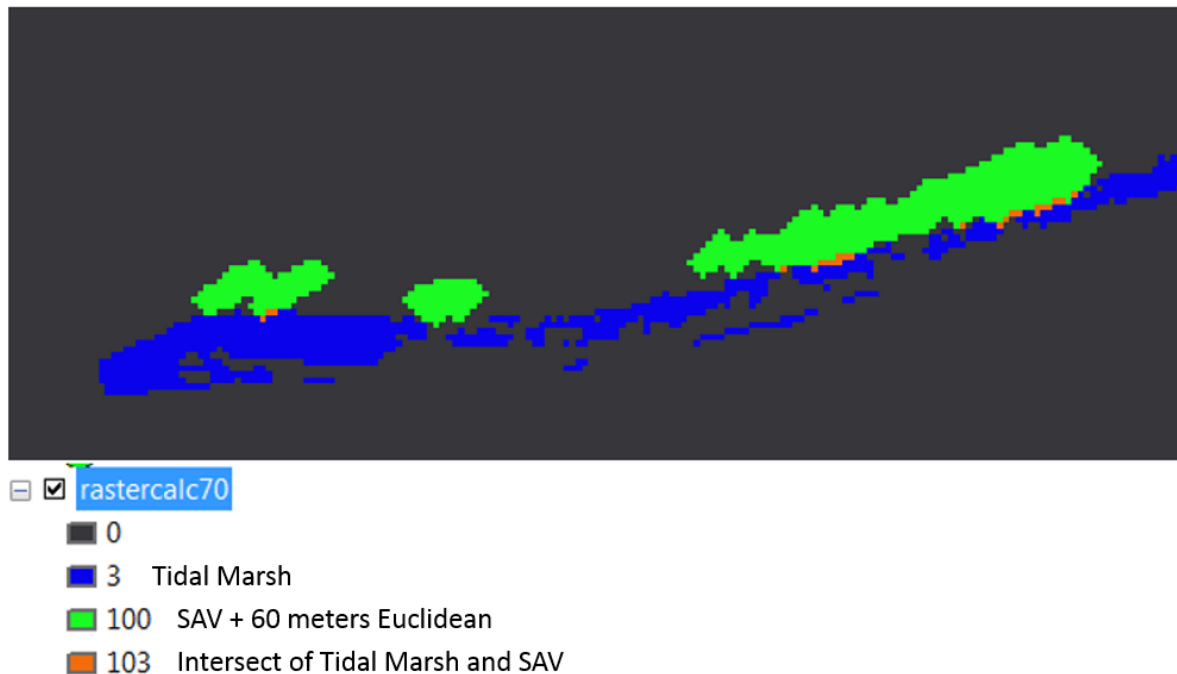
Figure 29: Euclidean distance (60 meters) used on SAV grid cells to associate Tidal Marsh grid cells with SAV.
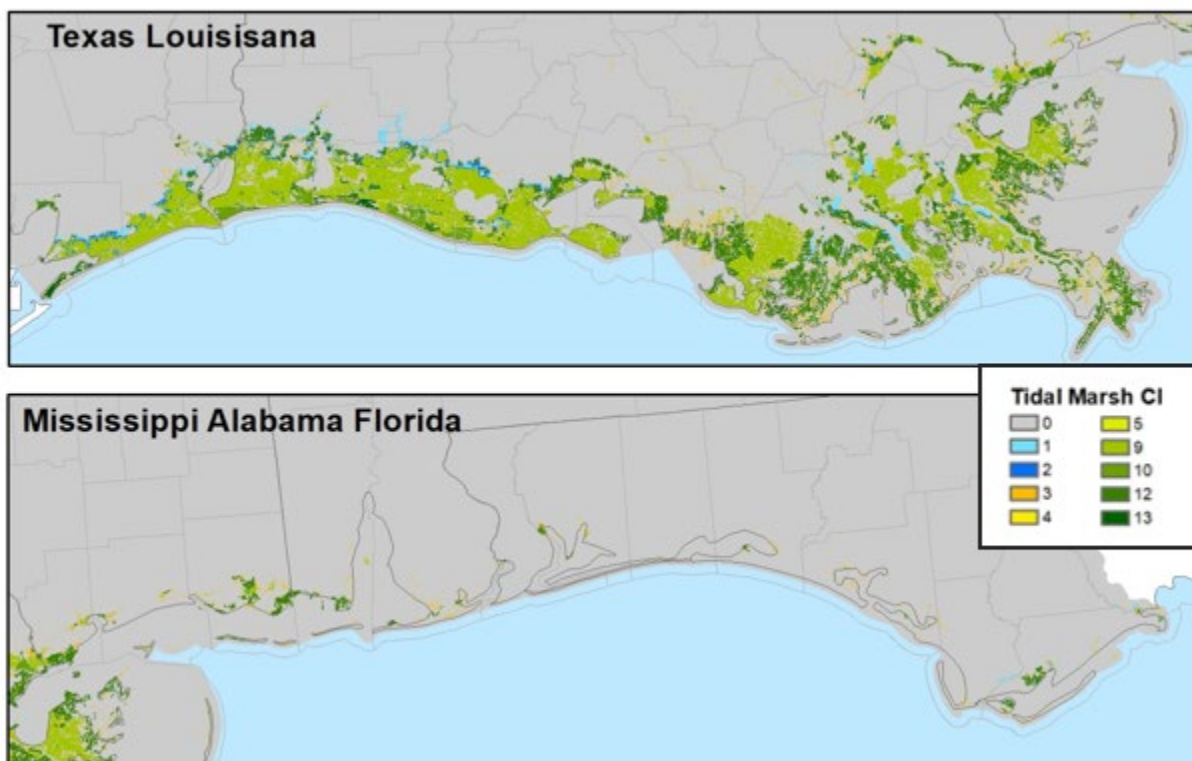
Figure 30: Tidal Marsh Condition Index Map
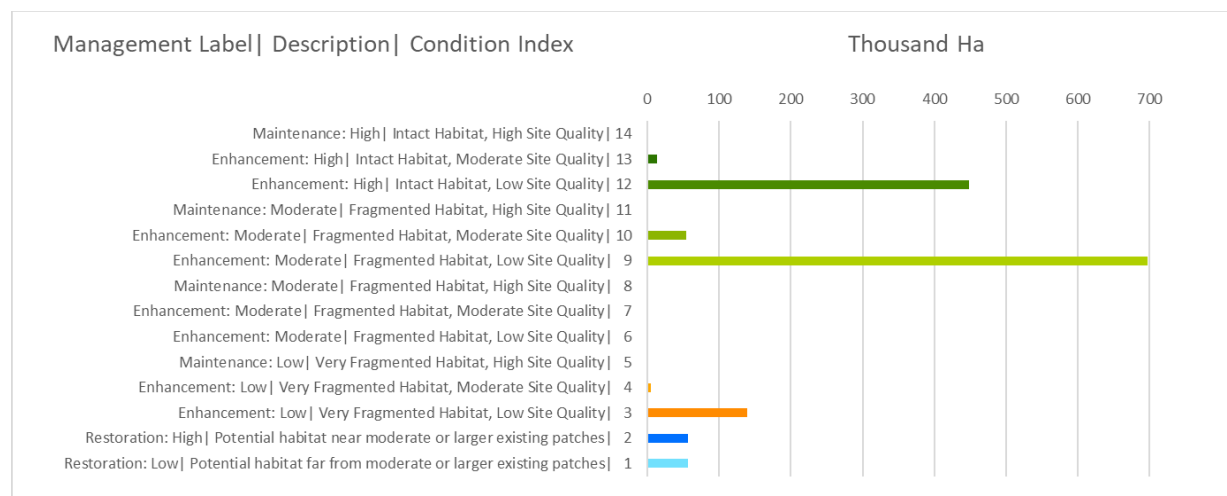
Figure 31: Hectares of Tidal Marsh by Condition Index and Management Label

Combining Habitat Maps into an Integrated, Comprehensive Map

The Integrated Condition Index Map combines the nine individual Broadly Defined Habitat maps into a single surface with a standardized bar code descriptor and Condition Index score for each grid cell.

Data Processing

The Integrated Condition Index Map was created by combining the Unified Mask, The Potential Habitat Map, and seven other layers, each composed of a single column (A, B, C…G) in table 4 (Assessment of Desired Condition Endpoints section, page 13) representing that condition for all nine assessed habitats. For example, column A assigns a 0 or 3 based on whether a targeted habitat exists for that unit. We created column A rasters for all nine habitats and combined them. We did the same with the other six columns. Since the "combine" tool only works on integers, we replaced the letter combinations describing the habitats with the numerical values from the input maps. The final combine operation joined the existing, potential, and seven endpoint layers into one. The barcode was concatenated in a new field. Summing Condition Index scores in a new field required an if, else script to sum columns F and G (potential and potential near) for those in existing class 100 Other (not habitat) only, for all other classes sum A…E. The final steps were to delete the fields used to generate bar code and CI scores and to join back to the attribute table the class names of existing and potential BDH classes.

Results

The Integrated Condition Index Map indicates that 68.7 million ha (74 % of the total area) as one of the targeted, mapped BDH classes. Of that, 31% (21.6 million ha) is in the poorest condition, with a score of 3 indicating no desired condition targets met. 32% (21.9 million ha) scores 9 or higher, indicating at least one of the patch or landscape configuration targets have been met, perhaps the greatest potential return on resource allocation for conservation. The remaining 37 % of the mapped habitat is described as being in between, with scores ranging from 4 – 8 (Table 5, Figures 32 and 33).

Table 5: Amount of land at each level of the Condition Index in the Integrated Map

CI Score	Acres	Ha
0	22,037,886	8,918,209
1	26,773,518	10,834,607
2	12,334,684	4,991,554
3	53,359,496	21,593,321
4	15,580,462	6,305,043
5	4,460,971	1,805,249
6	27,551,342	11,149,374
7	13,038,208	5,276,253
8	1,568,884	634,890
9	7,264,449	2,939,750
10	7,596,866	3,074,271
11	4,958,765	2,006,694
12	15,403,100	6,233,269
13	16,158,614	6,539,008
14	2,733,538	1,106,198
TOTAL	230,820,785	93,407,692
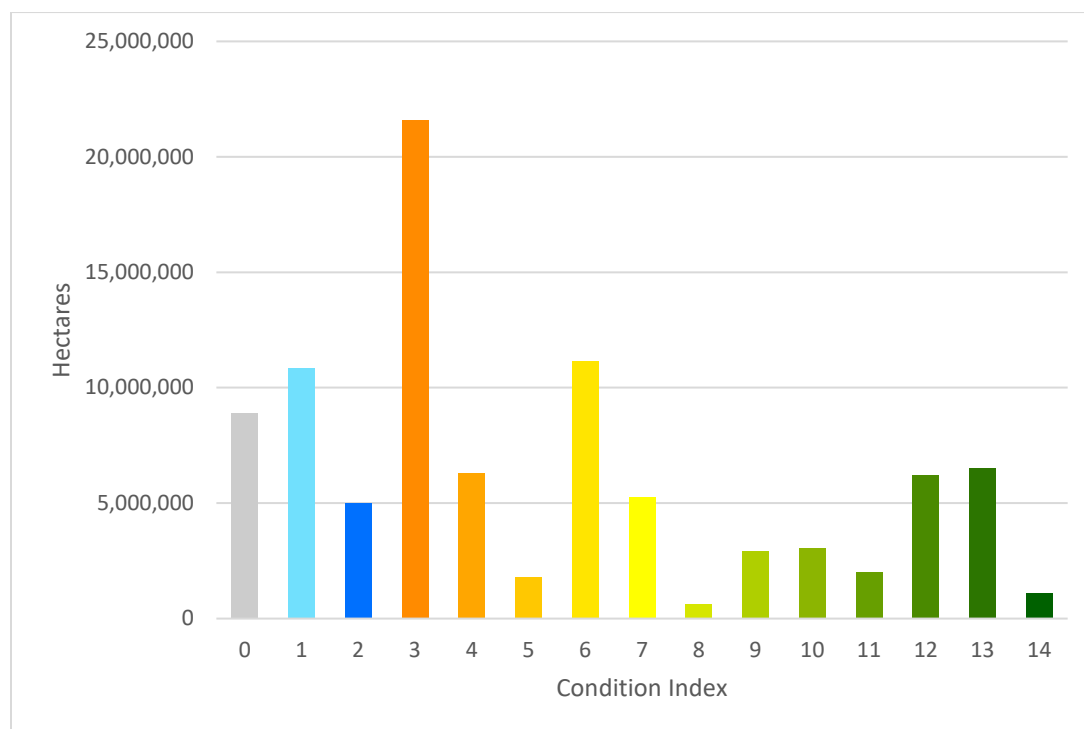
Figure 32: Bar graph of Hectares described at each Condition Index level
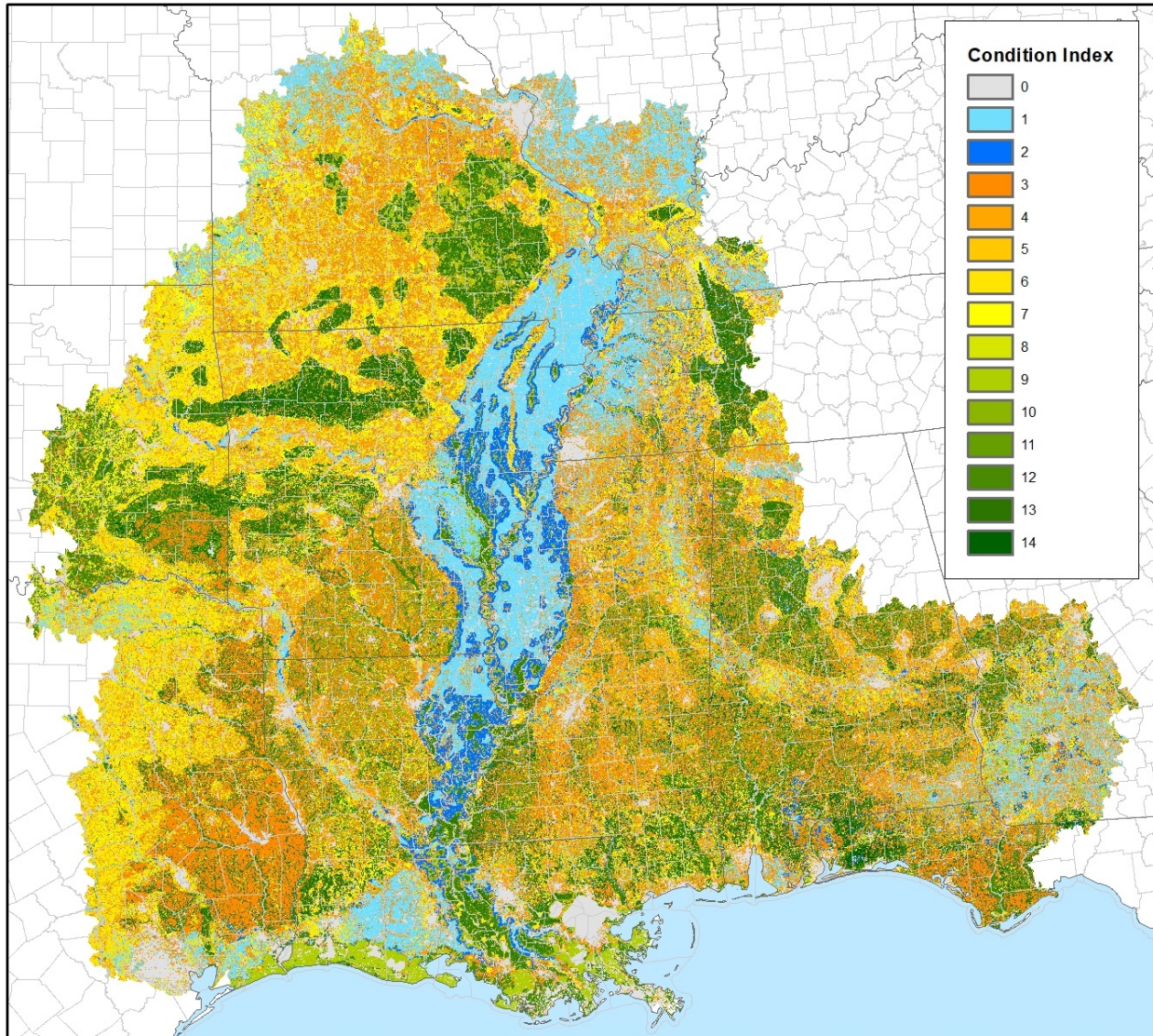
Figure 33: Integrated Condition Index Map

Potential for Connectivity Modeling

Resources in the landscape are distributed in patches, and animals move among patches to acquire the resources needed to live or to supplement existing resources with those in additional patches. Landscape connectivity is the degree to which the landscape facilitates or impedes movement among resource patches, and it is derived from both distance between patches and the biophysical nature of the route(s) (Taylor et al. 1993). Landscape conservation design approaches have incorporated increasingly sophisticated models of connectivity in recent decades. These models attempt to predict or describe gene flow and the movement or dispersal of organisms based on information about features in the landscape. Types of connectivity models, in increasing level of detail provided and data required, can be described as **structural**, depending mainly on physical attributes of the landscape and incorporating minimal information about the distribution and patterns of movement of focal species, **potential**, combining records of species occurrence and known dispersal capabilities with physical attributes

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of the landscape, and **actual** connectivity, the most labor-intensive, based on observed movement pathways (Calabrese and Fagan 2004). The connectivity modeled here would be considered structural: the data inputs describe the physical landscape, while the targets for desired habitat conditions and landscape patch size and configuration for specific Broadly Defined Habitat classes are based on expert judgement about the needs and movements of focal wildlife species.

The Appalachian Landscape Conservation Cooperative identified conservation priority areas (regional and local cores) by combining a synthesis of multi-scaled conservation targets and conservation design elements in the Marxan spatial optimization software program to solve the minimal set problem of achieving all conservation goals simultaneously for minimum cost. They modeled connectivity for the optimal 25% of the geography using the circuit-theory based software gflow (Leonard et al. 2017). Circuit-theory based connectivity views the landscape as a circuit board and landscape features, rendered as pixels in a raster data layer, as resisters. A common approach is to estimate the net movement probabilities (or flow) as "current density" confronted with effective resistance in the landscape, enabling pairwise measures of isolation between populations or sites (Dickson et al. 2019). The South Atlantic Landscape Conservation Cooperative identified potential hubs, or core areas, in their Conservation Blueprint chiefly by identifying areas ranked in the top 10% of their ecosystem integrity score according to Zonation software outpoints, along with inputs from TNC Secured Lands Database and the TNC Resilient Land Project. Their corridor analysis used Linkage Mapper, a set of open-source Python scripts shared in an ArcGIS toolbox, to map corridors between hubs. Their inland corridor layer consists of the top 20% of the corridor surface output, which corresponds to 5% of the South Atlantic inland area not already covered by high, medium, or low priority pixels (South Atlantic Landscape Conservation Cooperative 2017). Linkage Mapper is closely associated with Circuitscape, a widely-used application of circuit theory to conservation corridor mapping (McRae et al. 2016).

Circuit theory models of connectivity are analogous to random walkers, or wildlife species prone to explore the landscape with little knowledge of the pattern of resource distribution, whereas least-cost methods, based on perfect knowledge of the landscape, mimic the movement patterns of those species who know their landscape well. For example, circuit theory models better predict juvenile wolverine dispersal paths and cost-distance paths better predict elk migration patterns (McClure et al. 2016). This reflects the habits of juvenile wolverines as exploratory movers and elk as following routes established over generations (McRae et al. 2016). Descriptions of circuit theory models sometimes depict least-cost path approaches as being restricted to the single, one-cell wide solution (McRae et al. 2008, McCrae et al. 2016). However, a least-cost approach can identify wider corridors by summing multiple cost distance maps (ArcGIS Desktop 2019).

Data Processing

Corridors connecting areas of best-quality habitat were identified by selecting watersheds with highest average condition index values, merging watersheds to create

polygons patches, grouping patches by size (very small, small, medium, large), creating cost distance surfaces for each group of patches, and summing the cost distance surfaces.

Identifying core areas

In order to distribute core areas across the entire study area, we selected HUC12 units with highest average Condition Index within subgeographies based on EPA Level III ecoregions. Since this project expands the boundary used in GCPO LCC Conservation Blueprint 1.0, the five original subgeographies do not adequately describe the landscape. In order to include the added physiographic regions (e. g. Temperate Prairies in the west and the Southern Appalachian Mountains in the east), we combined the 21 EPA level III ecoregions in the study area to a revised set of ten subegeorgaphies that correspond generally to the GCPO LCC subgeographies plus the additional areas. HUC12 basins intersecting the ten subgeographies were selected and some basins were "traded" between subgeographies in order to enhance spatial compactness, fill holes, and eliminate isolated basins (Figure 34).
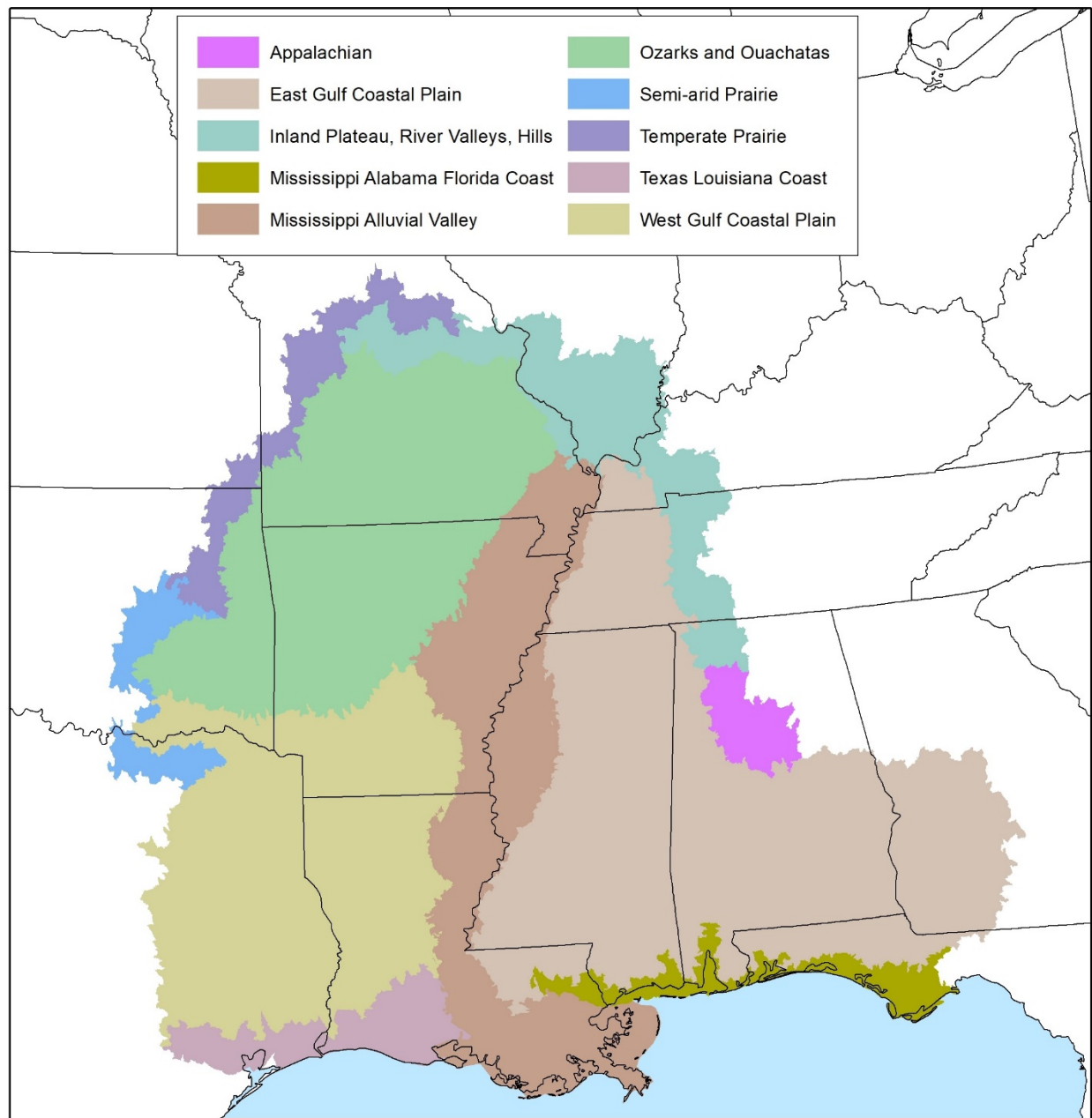
Figure 34: Subgeographies of the study area based on combinations of EPA Level III Ecoregions

Core areas within subgeographies were created by selecting the top ten percent of HUC12 basins based on Condition Index scores (Figure 35). Watersheds with average Condition Index in the top ten percent of each subgeography were dissolved to create core area polygons. The 194 resulting polygons were classified into four groups based on size: ten largest, twenty next largest, seventy next largest, and the ninety-four smallest.
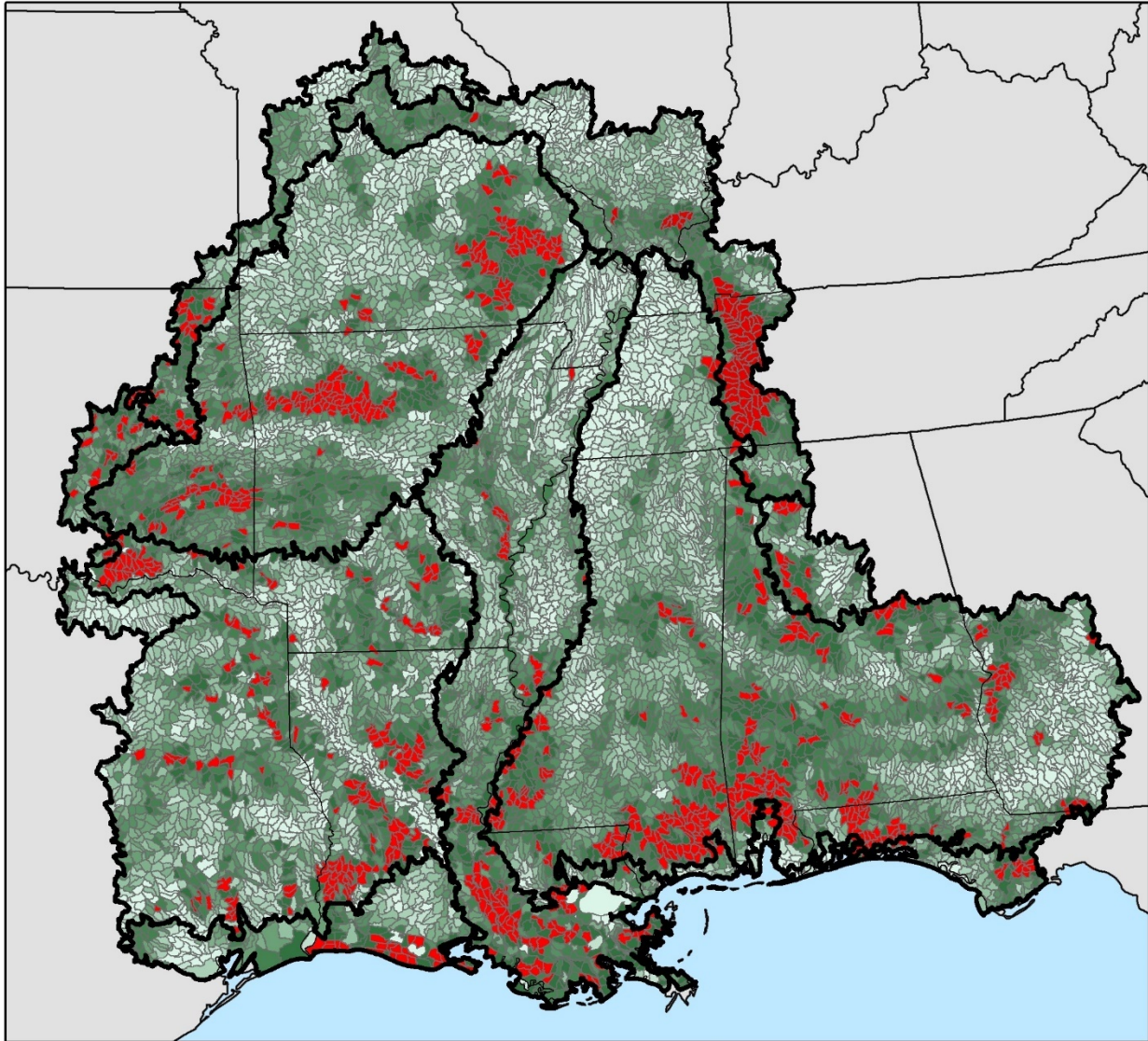
Figure 35: Condition Index scores were averaged within watersheds: darker green indicates higher average condition index. The top ten percent of watersheds within each subgeography (red) were selected as core areas.

Identifying corridors connecting cores

Least-cost paths and corridors linking core areas were modeled by creating cost distance and back link rasters for each of the four classes (top ten, next twenty, next seventy, bottom ninety-four) of core area polygons. Each set of cores was treated as a region, and the cost distance map describes the cost of moving through the landscape from each grid cell in the most economical cell-by-cell route. Some pre-processing steps were needed before applying least cost operations to the Condition Index raster:

1. Aggregate to coarser scale. Least cost path operations in a desktop environment are computationally labor intensive. We aggregated by a factor of 20, averaging Condition Index values in the original 30-meter grid cells to an output map at 600-meter resolution.

2. Truncate the Index values to reduce data dimensionality and increase processing efficiency. The aggregate tool output is calculated to six decimal places, an unnecessary level of precision which causes problems with tabulating and classifying the data. The original Condition Index integer range of 0 – 14 is too coarse for mapping subtle changes in landscape quality, so we multiplied grid cell values by 100 before truncating. For example, a value of 4.2675 in the output of the aggregation becomes 426 after multiplying by 100 and truncating. Least cost processes are multiplicative and therefore invalidated by zero values in the grid cells. To ensure that no zero values persisted in the grid, we increased each grid cell value by one, expressing Condition Index in a new range of 1 – 1401.
3. Invert the Index values, a step necessary whenever high value is to be associated with least cost. The formula $1402 - x$ provides a flipped set of integer values where 1 is expressed as 1401, 1401 as 1, and 701 as 701.
4. Increase the penalty for crossing non-habitat areas. The Condition Index uses a value of zero to indicate non-habitat. Aggregated (600 meter) grid cells with an average condition index less than one indicate density of non-habitat classes of land cover, such as developed land or intensive agriculture. These correspond to values of 1301 – 1401 after the conversion process described above. To increase the penalty for moving through non-habitat areas, we reclassified the value grid so that all values greater than 1300 equal 3000.

The raster value surface output of these steps was used to generate cost distance maps for each of the four sets of core areas (Figure 36). The set of four cost distance maps were summed to suggest potential corridors based on physical attributes in the landscape (Figure 37).
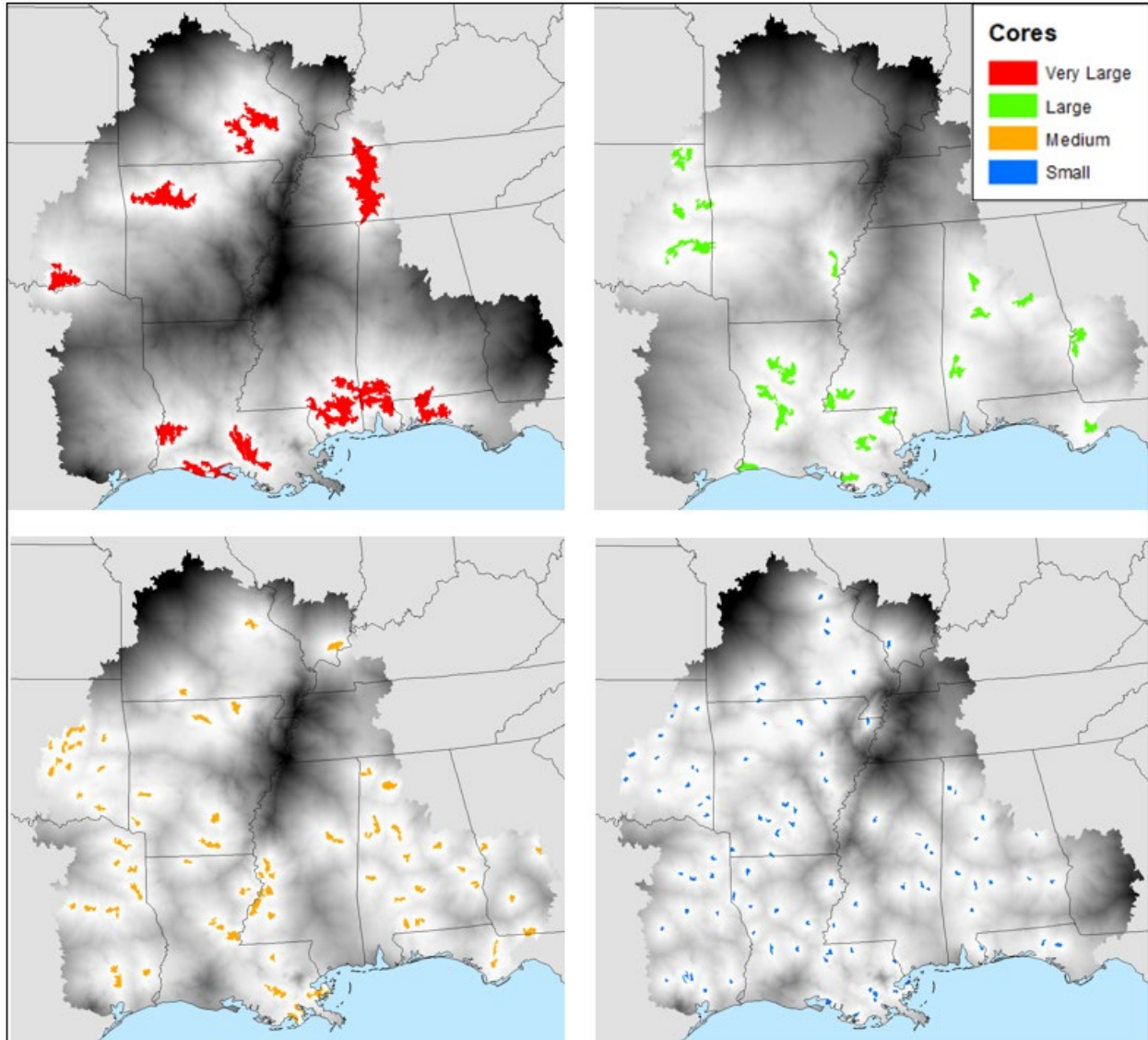
Figure 36: Cost distance maps for each of the four sets of core areas

The corridors were refined and enhanced by calculating least cost paths from each set of cores to each of the others, a process that, although not a pairwise comparison, links every core to one neighbor in each category by way of least cost path (Figure 37). For example, for each of the ten largest cores, a path is created to a single feature polygon in each of the other three classes by way of the path that accumulates the least cost (the highest quality habitat). The process repeats for the twenty next largest, the seventy medium-sized, and the ninety-four smallest cores. Although this process links every core to a neighbor, the linkages are primarily across the size classes. The process fails to describe some important linkages within classes, a limitation that would be addressed by a more sophisticated analysis.
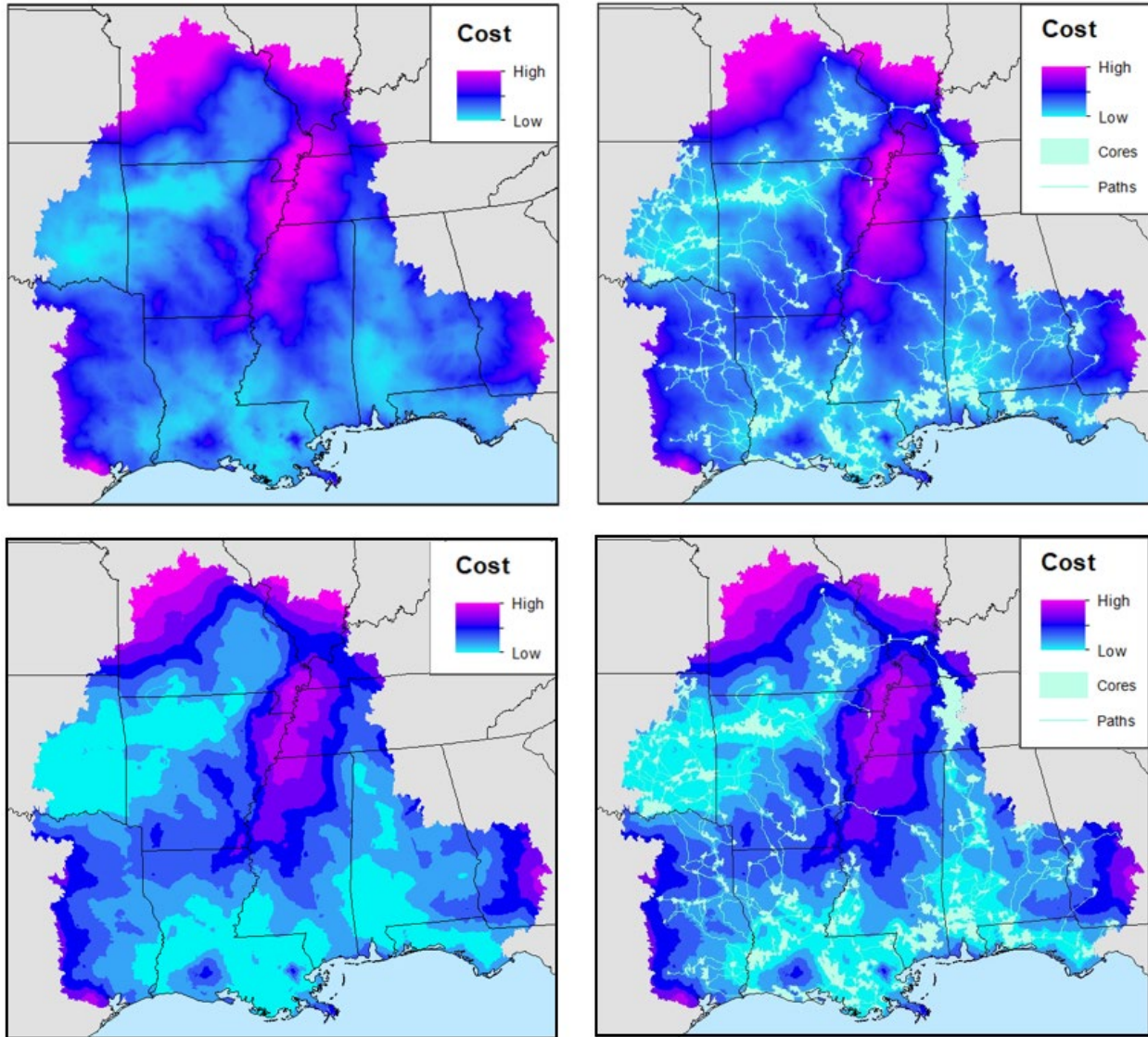
Figure 37: Potential corridors indicated by summing cost distance maps of inverted Condition Index values. Top row uses a color stretch, bottom row uses Jenk's breaks seven classes. Maps on right have core areas and network of paths added.

Limitations and Future Directions

Potential
This project uses the LANDFIRE Biophysical Settings data product to provide information about potential for habitat restoration in the landscape. The Individual Broadly Defined Habitat maps acknowledge the value (that is, assigns a score of 1 to a unit of potential habitat and an additional value of 1 for those within a certain distance of existing habitat meeting certain patch size and/or landscape configuration metrics) of *all* potential landscapes provided they are not currently in the existing targeted habitat, a developed class, or open water. The Integrated Condition Index map acknowledges (using the bar code descriptor) the presence of mismatches between potential and existing habitats within land units but assigns the Condition Index score only to those lands currently not in any targeted habitat class, that is, class 100, Other (non-habitat). A future direction would be to prioritize restoration for each targeted habitat according to current conditions. For example, an existing Shortleaf/Loblolly Pine Woodland described as potential Mixed Forest should probably be maintained or enhanced as the less common habitat it currently is, whereas an existing unit of Mixed Forest demonstrating potential for Shortleaf/Loblolly Pine Woodland should be considered an opportunity to expand the range of the declining open pine class through restoration. The tabulation of total hectares in each potential vs. existing mismatch in Appendix 2 could guide the prioritization of restoration potential based on existing conditions in the landscape.

Grassland
Grass-dominated landscapes are fairly common in the Mid-south, while natural prairies are extremely rare. While natural stands of native warm-season grasses and forbs are a conservation priority, general grasslands (lacking the floristic diversity but providing similar though temporally variable structure) also hold some benefit for wildlife. This project used a set of polygons describing known, mapped prairies in addition to inputs from ecological system classification maps from LANDFORE, MoRAP and Florida CLC to map grasses, parsing them into general and prairie types. Native prairies and general grasslands are spectrally similar and difficult to parse when developing classified ecological system maps from remote sensing imagery inputs. Classified ecological system and land cover maps tend to depict grassy openings as mixed natural and general grassland types. Mapping on a pixel-by-pixel basis, as this project does, creates a limitation by ignoring potential patches. A future iteration of this project might apply a threshold approach to account for intermixing of prairie and general grassland pixels in patches instead of assessing the types entirely separately. For example, the 100-acre patch size endpoint could apply to patches that are >70% natural prairie. For those 50 – 70% prairie, a larger patch, perhaps 500 acres, might be required, and a larger still, perhaps 1000 acres, for grasslands < 50% prairie. The GCPO LCC Ecological Assessment of Grasslands indicated that all land cover and ecological system mapping products mix general and prairie grass classes within patches of known prairie, and that, of the available products, while none are perfect, LANDFIRE evt does the best job of recognizing prairie classes and of avoiding the error of describing agricultural classes (Figure 38).
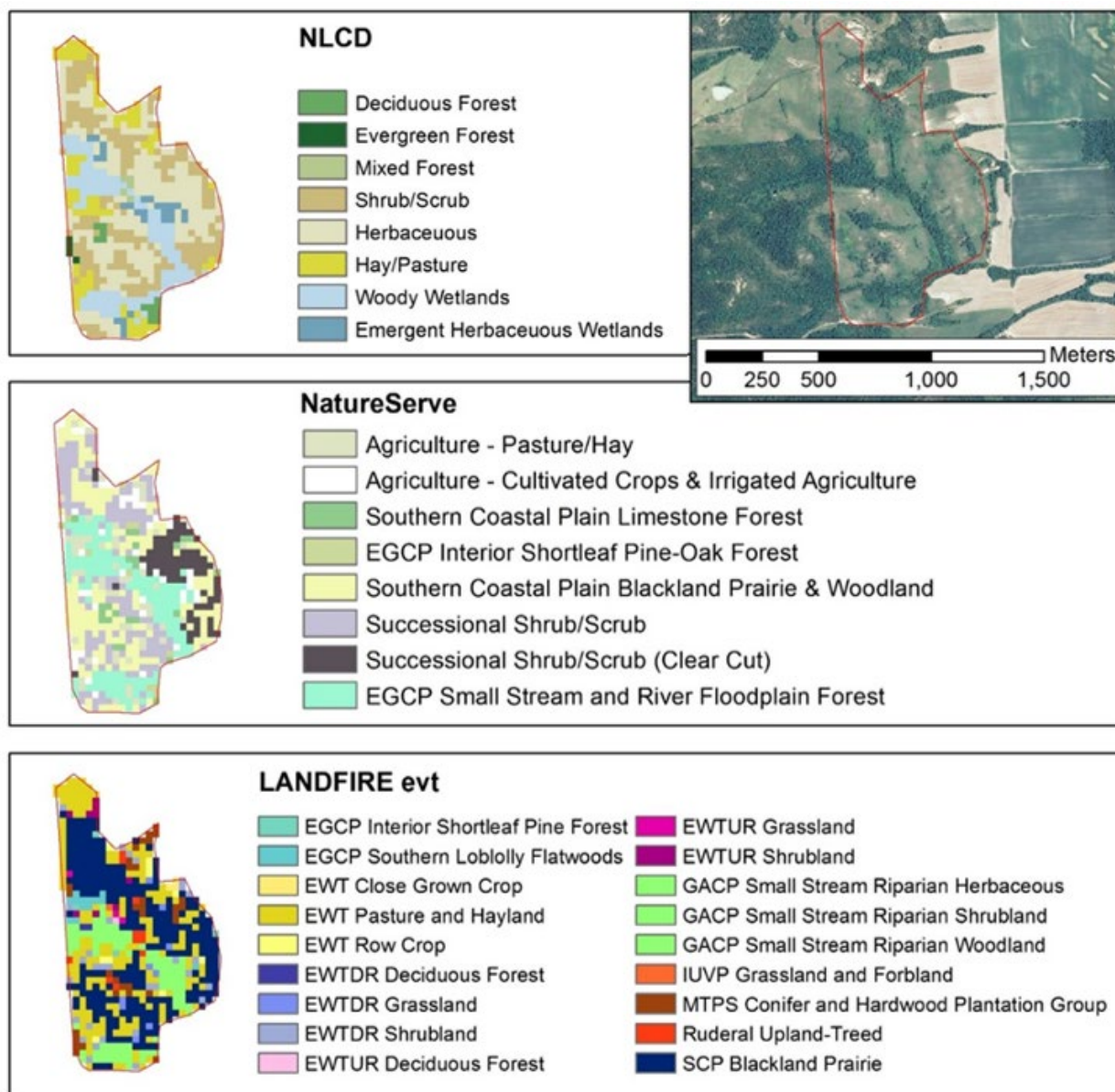
Figure 38: Pulliam Prairie in Chickasaw County, Mississippi. All land cover and ecological system mapping products mix general herbaceous classes with natural prairie classes within known natural prairie patches, with LANDFIRE evt generally identifying a greater portion of natural prairie classes in these areas. Note: EGCP = East Gulf Coastal Plain; EWT = Eastern Warm Temperate; EWTDR = Eastern Warm Temperate Developed Ruderal; GACP = Gulf and Atlantic Coastal Plain; IUVP = Introduced Upland Vegetation Perennial; MTPS = Managed Tree Plantation Southeast; SCP = Southern Coastal Plain

Not all habitat classes assessed

We were unable to devise a strategy for incorporating aquatic habitats into our analysis in the time frame of the project. Assessment of glade habitats would be improved by developing measurable desired condition endpoints for that class. This project mapped glades separately but used the endpoints for upland hardwood woodland to generate Condition Index scores for those units. Similarly, endpoints for Managed Forest based

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on literature and expert opinion would improve assessments of those landscapes. Condition and Configuration for all broadly defined habitats should be continually reviewed. We have the least confidence in the assessment metrics used for Mixed Forest. Those were developed for Arkansas but were applied across the entire study area, and although they were developed following a similar methodology to Nordman et al. (2016) they have not yet undergone broad peer-review. Beaches and Dunes were omitted due lack of spatial data rather than lack of measurable endpoints. We anticipate updating the Beaches and Dunes assessment in the very near future with information from a recently completed Northern Gulf Coast dune mapping project.

Connectivity

Summing cost distance map surfaces between four classes of core areas provides a broad, landscape-level description of where potential corridors might exist, based on broad knowledge of species-habitat interactions and physical characteristics of the landscape. This process is limited by the fact that it doesn't consider potential corridors between all cores in a pairwise fashion, as would be the case in a circuit-theory based analysis. Since the process doesn't explicitly address connections between cores *within* core size classes, such connections, where indicated, are incidental. The limitation is particularly noticeable in the classes of smaller core size because they are made up of more individual units. A future direction, outside of alternative software, would be to split the total set of core areas into a larger number of classes each containing fewer individuals, resulting in more paths created. This process is also limited by a lack of consideration of core areas outside the study area. The product could be improved by incorporating core areas and corridors identified by neighboring Landscape Conservation Cooperatives and by the Southeastern Conservation Adaptation Strategy (SECAS).

Conclusion

This set of spatial data products refines and improves the Conservation Blueprint 1.0 product developed by the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative. The principal improvement is the elimination of spatially contradictory information about the distribution of habitat for targeted wildlife species across the landscape. Each of the ecological assessments for terrestrial broadly defined habitats was reproduced using a single integrated map based on ecological systems and measurable landscape attributes. For each terrestrial broadly defined habitat, an independent assessment was produced using two large landscape targets, two measures of habitat condition, and two measures of potential to generate a condition index score, standardized to range from 0 – 14 across all habitat types. Each individual habitat assessment data layer includes a bar code descriptor field that explains which measures contributed to the index for each cell in the grid. These individual condition index layers were combined into a unified assessment of all habitat types in a single map. A simple analysis of potential corridors linking core areas of highest quality habitat was produced by identifying core areas, splitting core areas into classes based on size, creating cost distance surface grids for each class, and linking each individual patch in each class to its least cost "nearest" neighbor from each of the other three classes. All

the spatial data products for this project can be found at the home page for the project on the USGS SciencBase website: https://www.sciencebase.gov/catalog/item/5ccb0cfce4b09b8c0b780433 . This assessment of terrestrial connectivity intersects significant portions of twelve states: Missouri, Illinois, Kentucky, Oklahoma, Arkansas, Tennessee, Texas, Louisiana, Mississippi, Alabama, Georgia, and Florida, and may provide important information for review of their Wildlife Action Plans. The Condition Index scores have been incorporated into a 2019 project developing draft Conservation Opportunity Areas for the state of Arkansas. Products from this project have potential to be a key input into the next iteration of the Southeastern Conservation Adaptation Strategy (SECAS) regional assessment of lands and waters having high conservation value.

Appendix 1: Crosswalks of ecological systems and land cover maps to Broadly Defined Habitats

1A: LANDFIRE Existing Vegetation Type (evt)

LANDFIRE Value	LANDFIRE Name	BDH Name
3408	Alabama Ketona Glade and Woodland	Glade
3317	Allegheny-Cumberland Dry Oak Forest and Woodland	Upland Hardwood Woodland
3415	Arkansas Valley Prairie and Woodland	Grass Prairie
3459	Atlantic Coastal Plain Clay-Based Carolina Bay Wetland	Forested Wetland
3346	Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland	Longleaf Pine Woodland
3468	Atlantic Coastal Plain Streamhead Seepage Swamp-Pocosin-Baygall	Forested Wetland
3347	Atlantic Coastal Plain Upland Longleaf Pine Woodland	Longleaf Pine Woodland
3294	Barren	Other (not habitat)
3413	Bluegrass Savanna and Woodland	Upland Hardwood Woodland
3338	Central and South Texas Coastal Fringe Forest and Woodland	Upland Hardwood Woodland
3320	Central and Southern Appalachian Montane Oak Forest	Upland Hardwood Forest
3437	Central and Upper Texas Coast Dune and Coastal Grassland	Beaches and Dunes
3463	Central Appalachian Dry Oak Forest	Upland Hardwood Forest
3369	Central Appalachian Dry Pine Forest	Shortleaf/Loblolly Pine Woodland
3453	Central Florida Pine Flatwoods	Longleaf Pine Flatwoods
3471	Central Interior and Appalachian Floodplain Forest	Forested Wetland
3274	Central Interior and Appalachian Floodplain Herbaceous	Grass General
3275	Central Interior and Appalachian Floodplain Shrubland	Forested Wetland
3493	Central Interior and Appalachian Herbaceous Wetlands	Freshwater Marsh
3472	Central Interior and Appalachian Riparian Forest	Forested Wetland
3300	Central Interior and Appalachian Riparian Herbaceous	Grass General
3319	Central Interior and Appalachian Riparian Shrubland	Forested Wetland
3283	Central Interior and Appalachian Shrub Wetlands	Freshwater Marsh
3497	Central Interior and Appalachian Sparsely Vegetated Systems	Freshwater Marsh

3479	Central Interior and Appalachian Swamp Forest	Forested Wetland
3280	Central Interior and Appalachian Swamp Shrubland	Forested Wetland
3291	Central Interior Highlands Calcareous Glade and Barrens Herbaceous	Glade
3401	Central Interior Highlands Calcareous Glade and Barrens Woodland	Upland Hardwood Woodland
3363	Central Interior Highlands Dry Acidic Glade and Barrens	Glade
3132	Central Mixedgrass Prairie Grassland	Grass Prairie
3421	Central Tallgrass Prairie	Grass Prairie
3308	Crosstimbers Oak Forest and Woodland	Upland Hardwood Woodland
3322	Crowley's Ridge Mesic Loess Slope Forest	Upland Hardwood Forest
3510	Crowley's Ridge Sand Forest	Shortleaf/Loblolly Pine Woodland
3398	Cumberland Sandstone Glade and Barrens	Glade
3298	Developed-High Intensity	Other (not habitat)
3296	Developed-Low Intensity	Other (not habitat)
3297	Developed-Medium Intensity	Other (not habitat)
3299	Developed-Roads	Other (not habitat)
3435	East Gulf Coastal Plain Dune and Coastal Grassland	Beaches and Dunes
3527	East Gulf Coastal Plain Interior Oak Forest	Upland Hardwood Forest
3372	East Gulf Coastal Plain Interior Shortleaf Pine Forest	Shortleaf/Loblolly Pine Woodland
3546	East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest	Mixed Forest
3349	East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	Longleaf Pine Woodland
3433	East Gulf Coastal Plain Jackson Prairie	Grass Prairie
3568	East Gulf Coastal Plain Jackson Prairie Woodland	Grass Prairie
3380	East Gulf Coastal Plain Maritime Forest	Mixed Forest
3454	East Gulf Coastal Plain Near-Coast Pine Flatwoods	Longleaf Pine Flatwoods
3307	East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	Upland Hardwood Woodland
3327	East Gulf Coastal Plain Northern Loess Bluff Forest	Upland Hardwood Forest
3306	East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland	Upland Hardwood Forest
3325	East Gulf Coastal Plain Northern Mesic Hardwood Slope Forest	Upland Hardwood Forest
3485	East Gulf Coastal Plain Savanna and Wet Prairie	Grass Prairie
3588	East Gulf Coastal Plain Southern Hardwood Flatwoods	Upland Hardwood Forest
3455	East Gulf Coastal Plain Southern Loblolly Flatwoods	Shortleaf/Loblolly Pine Woodland
3589	East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	Mixed Forest

3329	East Gulf Coastal Plain Southern Loess Bluff Forest	Upland Hardwood Forest
3577	East Gulf Coastal Plain Wet Prairie Grassland	Freshwater Marsh
3578	East Gulf Coastal Plain Wet Prairie Shrubland	Freshwater Marsh
3358	East-Central Texas Plains Pine Forest and Woodland	Shortleaf/Loblolly Pine Woodland
3519	East-Central Texas Plains Post Oak Savanna and Woodland	Upland Hardwood Woodland
3979	Eastern Cool Temperate Aquaculture	Other (not habitat)
3972	Eastern Cool Temperate Bush fruit and berries	Other (not habitat)
3975	Eastern Cool Temperate Close Grown Crop	Other (not habitat)
3930	Eastern Cool Temperate Developed Ruderal Deciduous Forest	Other (not habitat)
3931	Eastern Cool Temperate Developed Ruderal Evergreen Forest	Other (not habitat)
3934	Eastern Cool Temperate Developed Ruderal Grassland	Other (not habitat)
3932	Eastern Cool Temperate Developed Ruderal Mixed Forest	Other (not habitat)
3933	Eastern Cool Temperate Developed Ruderal Shrubland	Other (not habitat)
3976	Eastern Cool Temperate Fallow/Idle Cropland	Other (not habitat)
3970	Eastern Cool Temperate Orchard	Other (not habitat)
3977	Eastern Cool Temperate Pasture and Hayland	Grass General
3974	Eastern Cool Temperate Row Crop	Other (not habitat)
3973	Eastern Cool Temperate Row Crop - Close Grown Crop	Other (not habitat)
3950	Eastern Cool Temperate Undeveloped Ruderal Deciduous Forest	Upland Hardwood Forest
3951	Eastern Cool Temperate Undeveloped Ruderal Evergreen Forest	Shortleaf/Loblolly Pine Woodland
3954	Eastern Cool Temperate Undeveloped Ruderal Grassland	Grass General
3952	Eastern Cool Temperate Undeveloped Ruderal Mixed Forest	Mixed Forest
3953	Eastern Cool Temperate Undeveloped Ruderal Shrubland	Mixed Forest
3905	Eastern Cool Temperate Urban Deciduous Forest	Other (not habitat)
3906	Eastern Cool Temperate Urban Evergreen Forest	Other (not habitat)
3908	Eastern Cool Temperate Urban Herbaceous	Other (not habitat)
3907	Eastern Cool Temperate Urban Mixed Forest	Other (not habitat)
3909	Eastern Cool Temperate Urban Shrubland	Other (not habitat)
3971	Eastern Cool Temperate Vineyard	Other (not habitat)
3978	Eastern Cool Temperate Wheat	Other (not habitat)
3273	Eastern Great Plains Floodplain Herbaceous	Grass General
3469	Eastern Great Plains Floodplain Woodland	Forested Wetlands
3488	Eastern Great Plains Wet Meadow-Prairie-Marsh	Freshwater Marsh

3375	Eastern Serpentine Woodland	Glades
3999	Eastern Warm Temperate Aquaculture	Other (not habitat)
3992	Eastern Warm Temperate Bush fruit and berries	Other (not habitat)
3995	Eastern Warm Temperate Close Grown Crop	Other (not habitat)
3935	Eastern Warm Temperate Developed Ruderal Deciduous Forest	Other (not habitat)
3936	Eastern Warm Temperate Developed Ruderal Evergreen Forest	Other (not habitat)
3939	Eastern Warm Temperate Developed Ruderal Grassland	Other (not habitat)
3937	Eastern Warm Temperate Developed Ruderal Mixed Forest	Other (not habitat)
3938	Eastern Warm Temperate Developed Ruderal Shrubland	Other (not habitat)
3996	Eastern Warm Temperate Fallow/Idle Cropland	Other (not habitat)
3990	Eastern Warm Temperate Orchard	Managed Forest
3997	Eastern Warm Temperate Pasture and Hayland	Grass General
3994	Eastern Warm Temperate Row Crop	Other (not habitat)
3993	Eastern Warm Temperate Row Crop - Close Grown Crop	Other (not habitat)
3955	Eastern Warm Temperate Undeveloped Ruderal Deciduous Forest	Upland Hardwood Forest
3956	Eastern Warm Temperate Undeveloped Ruderal Evergreen Forest	Shortleaf/Loblolly Pine Woodland
3959	Eastern Warm Temperate Undeveloped Ruderal Grassland	Grass General
3957	Eastern Warm Temperate Undeveloped Ruderal Mixed Forest	Mixed Forest
3958	Eastern Warm Temperate Undeveloped Ruderal Shrubland	Mixed Forest
3915	Eastern Warm Temperate Urban Urban Deciduous Forest	Other (not habitat)
3916	Eastern Warm Temperate Urban Urban Evergreen Forest	Other (not habitat)
3918	Eastern Warm Temperate Urban Urban Herbaceous	Other (not habitat)
3917	Eastern Warm Temperate Urban Urban Mixed Forest	Other (not habitat)
3919	Eastern Warm Temperate Urban Urban Shrubland	Other (not habitat)
3991	Eastern Warm Temperate Vineyard	Other (not habitat)
3998	Eastern Warm Temperate Wheat	Other (not habitat)
3523	Edwards Plateau Dry-Mesic Slope Forest and Woodland	Upland Hardwood Woodland
3383	Edwards Plateau Limestone Woodland	Upland Hardwood Woodland
3356	Florida Longleaf Pine Sandhill	Longleaf Pine Woodland
3387	Florida Peninsula Inland Scrub Shrubland	Upland Hardwood Forest
3489	Floridian Highlands Freshwater Marsh Herbaceous	Freshwater Marsh

3579	Floridian Highlands Freshwater Marsh Shrubland	Freshwater Marsh
3473	Gulf and Atlantic Coastal Plain Floodplain Forest	Forested Wetlands
3332	Gulf and Atlantic Coastal Plain Floodplain Herbaceous	Grass General
3359	Gulf and Atlantic Coastal Plain Floodplain Shrubland	Forested Wetlands
3573	Gulf and Atlantic Coastal Plain Small Stream Riparian Herbaceous	Grass General
3574	Gulf and Atlantic Coastal Plain Small Stream Riparian Shrubland	Forested Wetlands
3474	Gulf and Atlantic Coastal Plain Small Stream Riparian Woodland	Forested Wetlands
3498	Gulf and Atlantic Coastal Plain Sparsely Vegetated Systems	Beaches and Dunes
3480	Gulf and Atlantic Coastal Plain Swamp Systems	Forested Wetland
3396	Gulf and Atlantic Coastal Plain Tidal Marsh Herbaceous	Tidal Marsh
3490	Gulf and Atlantic Coastal Plain Tidal Marsh Shrubland	Tidal Marsh
3182	Introduced Upland Vegetation-Perennial Grassland and Forbland	Other (not habitat)
3187	Introduced Upland Vegetation-Treed	Other (not habitat)
3538	Introduced Wetland Vegetation-Herbaceous	Other (not habitat)
3536	Introduced Wetland Vegetation-Tree	Other (not habitat)
3381	Lower Mississippi River Dune Woodland and Forest	Upland Hardwood Woodland
3513	Lower Mississippi River Flatwoods	Forested Wetland
3534	Managed Tree Plantation-Northern and Central Hardwood and Conifer Plantation Group	Managed Forest
3535	Managed Tree Plantation-Southeast Conifer and Hardwood Plantation Group	Managed Forest
3384	Mississippi Delta Maritime Forest	Forested Wetland
3509	Mississippi River Alluvial Plain Dry-Mesic Loess Slope Forest	Upland Hardwood Forest
3553	Mixed Loblolly-Slash Pine	Shortleaf/Loblolly Pine Woodland
3539	Modified/Managed Northern Tallgrass Grassland	Other (not habitat)
3287	Modified/Managed Northern Tallgrass Shrubland	Other (not habitat)
3540	Modified/Managed Southern Tallgrass Grassland	Other (not habitat)
3564	Modified/Managed Southern Tallgrass Shrubland	Other (not habitat)
3397	Nashville Basin Limestone Glade and Woodland	Glades
3313	North-Central Interior Beech-Maple Forest	Upland Hardwood Forest
3311	North-Central Interior Dry Oak Forest and Woodland	Upland Hardwood Woodland
3310	North-Central Interior Dry-Mesic Oak Forest and Woodland	Upland Hardwood Woodland
3314	North-Central Interior Maple-Basswood Forest	Upland Hardwood Forest

3394	North-Central Interior Oak Savanna	Upland Hardwood Woodland
3412	North-Central Interior Sand and Gravel Tallgrass Prairie	Grass Prairie
3518	North-Central Interior Wet Flatwoods	Upland Hardwood Woodland
3290	North-Central Oak Barrens Herbaceous	Upland Hardwood Woodland
3395	North-Central Oak Barrens Woodland	Upland Hardwood Woodland
3292	Open Water	Open Water
3312	Ouachita Montane Oak Forest	Upland Hardwood Forest
3364	Ozark-Ouachita Dry Oak Woodland	Upland Hardwood Woodland
3304	Ozark-Ouachita Dry-Mesic Oak Forest	Upland Hardwood Forest
3334	Ozark-Ouachita Mesic Hardwood Forest	Upland Hardwood Forest
3582	Ozark-Ouachita Oak Forest and Woodland	Upland Hardwood Forest
3367	Ozark-Ouachita Shortleaf Pine Forest and Woodland	Shortleaf/Loblolly Pine Woodland
3507	Ozark-Ouachita Shortleaf Pine-Bluestem Woodland	Shortleaf/Loblolly Pine Woodland
3583	Ozark-Ouachita Shortleaf Pine-Oak Forest and Woodland	Mixed Forest
3418	Pennyroyal Karst Plain Prairie and Barrens	Grass Prairie
3551	Pinus elliottii Saturated Temperate Woodland Alliance	Longleaf Pine Woodland
3552	Pinus palustris-Pinus elliottii Forest Alliance	Longleaf Pine Woodland
3550	Pinus taeda Forest Alliance	Shortleaf/Loblolly Pine Woodland
3295	Quarries-Strip Mines-Gravel Pits	Other (not habitat)
3195	Recently Burned-Herb and Grass Cover	Grass General
3191	Recently Logged-Herb and Grass Cover	Managed Forest
3192	Recently Logged-Shrub Cover	Mixed Forest
3532	Ruderal Forest-Northern and Central Hardwood and Conifer	Mixed Forest
3533	Ruderal Forest-Southeast Hardwood and Conifer	Mixed Forest
3531	Ruderal Upland Forest	Upland Hardwood Forest
3529	Ruderal Upland Herbaceous	Grass General
3528	Ruderal Upland Shrubland	Upland Hardwood Forest
3194	Ruderal Upland-Treed	Mixed Forest
3321	South-Central Interior Mesophytic Forest	Upland Hardwood Forest
3326	South-Central Interior/Upper Coastal Plain Flatwoods	Forested Wetland
3457	South-Central Interior/Upper Coastal Plain Wet Flatwoods	Upland Hardwood Woodland
3423	Southeastern Great Plains Tallgrass Prairie	Grass Prairie
3351	Southeastern Interior Longleaf Pine Woodland	Longleaf Pine Woodland

3353	Southern Appalachian Low-Elevation Pine Forest	Shortleaf/Loblolly Pine Woodland
3352	Southern Appalachian Montane Pine Forest and Woodland	Shortleaf/Loblolly Pine Woodland
3315	Southern Appalachian Oak Forest	Upland Hardwood Forest
3335	Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	Upland Hardwood Forest
3343	Southern Atlantic Coastal Plain Mesic Hardwood Forest	Upland Hardwood Forest
3450	Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods	Longleaf Pine Flatwoods
3430	Southern Coastal Plain Blackland Prairie	Grass Prairie
3567	Southern Coastal Plain Blackland Prairie Woodland	Grass Prairie
3330	Southern Coastal Plain Dry Upland Hardwood Forest	Upland Hardwood Woodland
3328	Southern Coastal Plain Limestone Forest	Mixed Forest
3357	Southern Coastal Plain Mesic Slope Forest	Mixed Forest
3570	Southern Coastal Plain Nonriverine Cypress Dome Herbaceous	Freshwater Marsh
3460	Southern Coastal Plain Nonriverine Cypress Dome Woodland	Forested Wetland
3571	Southern Coastal Plain Seepage Swamp and Baygall Shrubland	Forested Wetland
3461	Southern Coastal Plain Seepage Swamp and Baygall Woodland	Forested Wetland
3305	Southern Interior Low Plateau Dry-Mesic Oak Forest	Upland Hardwood Forest
3406	Southern Piedmont Dry Oak Forest	Upland Hardwood Forest
3448	Southern Piedmont Dry Oak-Pine Forest	Mixed Forest
3368	Southern Piedmont Dry Pine Forest	Mixed Forest
3316	Southern Piedmont Mesic Forest	Upland Hardwood Forest
3419	Southern Ridge and Valley Patch Prairie	Grass Prairie
3376	Southern Ridge and Valley/Cumberland Dry Calcareous Forest	Upland Hardwood Woodland
3392	Tamaulipan Calcareous Thornscrub	Upland Hardwood Woodland
3560	Tamaulipan Mesquite Upland Shrub	Upland Hardwood Woodland
3391	Tamaulipan Mesquite Upland Tree	Upland Hardwood Woodland
3390	Tamaulipan Mixed Deciduous Thornscrub	Upland Hardwood Woodland
3562	Tamaulipan Riparian Shrubland	Forested Wetland
3438	Tamaulipan Savanna Grassland	Grass Prairie
3422	Texas Blackland Tallgrass Prairie	Grass Prairie
3486	Texas Saline Coastal Prairie	Grass Prairie
3434	Texas-Louisiana Coastal Prairie	Grass Prairie

3403	West Gulf Coastal Plain Catahoula Barrens	Grass Prairie
3339	West Gulf Coastal Plain Chenier and Upper Texas Coastal Fringe Forest and Woodland	Upland Hardwood Forest
3590	West Gulf Coastal Plain Hardwood Flatwoods	Upland Hardwood Forest
3584	West Gulf Coastal Plain Hardwood Forest	Upland Hardwood Forest
3323	West Gulf Coastal Plain Mesic Hardwood Forest	Upland Hardwood Forest
3405	West Gulf Coastal Plain Nepheline Syenite Glade	Glade
3506	West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods	Upland Hardwood Woodland
3428	West Gulf Coastal Plain Northern Calcareous Prairie	Grass Prairie
3458	West Gulf Coastal Plain Pine Flatwoods	Mixed Forest
3371	West Gulf Coastal Plain Pine Forest	Mixed Forest
3591	West Gulf Coastal Plain Pine-Hardwood Flatwoods	Mixed Forest
3585	West Gulf Coastal Plain Pine-Hardwood Forest	Mixed Forest
3587	West Gulf Coastal Plain Sandhill Oak and Shortleaf Pine Forest and Woodland	Mixed Forest
3586	West Gulf Coastal Plain Sandhill Oak Forest and Woodland	Upland Hardwood Forest
3378	West Gulf Coastal Plain Sandhill Shortleaf Pine Forest and Woodland	Shortleaf/Loblolly Pine Woodland
3462	West Gulf Coastal Plain Seepage Swamp and Baygall	Forested Wetland
3429	West Gulf Coastal Plain Southern Calcareous Prairie	Grass Prairie
3348	West Gulf Coastal Plain Upland Longleaf Pine Forest and Woodland	Longleaf Pine Woodland
3451	West Gulf Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	Longleaf Pine Flatwoods
3965	Western Cool Temperate Close Grown Crop	Other (not habitat)
3920	Western Cool Temperate Developed Ruderal Deciduous Forest	Other (not habitat)
3921	Western Cool Temperate Developed Ruderal Evergreen Forest	Other (not habitat)
3924	Western Cool Temperate Developed Ruderal Grassland	Other (not habitat)
3922	Western Cool Temperate Developed Ruderal Mixed Forest	Other (not habitat)
3923	Western Cool Temperate Developed Ruderal Shrubland	Other (not habitat)
3966	Western Cool Temperate Fallow/Idle Cropland	Other (not habitat)
3960	Western Cool Temperate Orchard	Managed Forest
3967	Western Cool Temperate Pasture and Hayland	Grass General
3964	Western Cool Temperate Row Crop	Other (not habitat)
3963	Western Cool Temperate Row Crop - Close Grown Crop	Other (not habitat)
3940	Western Cool Temperate Undeveloped Ruderal Deciduous Forest	Upland Hardwood Forest

3944	Western Cool Temperate Undeveloped Ruderal Grassland	Grass General
3900	Western Cool Temperate Urban Deciduous Forest	Other (not habitat)
3901	Western Cool Temperate Urban Evergreen Forest	Other (not habitat)
3903	Western Cool Temperate Urban Herbaceous	Other (not habitat)
3902	Western Cool Temperate Urban Mixed Forest	Other (not habitat)
3904	Western Cool Temperate Urban Shrubland	Other (not habitat)
3968	Western Cool Temperate Wheat	Other (not habitat)
3495	Western Great Plains Depressional Wetland Systems	Freshwater Marsh
3162	Western Great Plains Floodplain Forest and Woodland	Forested Wetland
3254	Western Great Plains Floodplain Herbaceous	Grass General
3253	Western Great Plains Floodplain Shrubland	Forested Wetland
3204	Western Great Plains Mesquite Shrubland	Upland Hardwood Woodland
3148	Western Great Plains Sand Prairie Grassland	Grass Prairie
3212	Western Great Plains Sandhill Grassland	Grass General
3149	Western Great Plains Shortgrass Prairie	Grass Prairie
3385	Western Great Plains Wooded Draw and Ravine	Forested Wetland
3416	Western Highland Rim Prairie and Barrens	Grass Prairie
3989	Western Warm Temperate Aquaculture	Other (not habitat)
3985	Western Warm Temperate Close Grown Crop	Other (not habitat)
3925	Western Warm Temperate Developed Ruderal Deciduous Forest	Other (not habitat)
3926	Western Warm Temperate Developed Ruderal Evergreen Forest	Other (not habitat)
3929	Western Warm Temperate Developed Ruderal Grassland	Other (not habitat)
3927	Western Warm Temperate Developed Ruderal Mixed Forest	Other (not habitat)
3928	Western Warm Temperate Developed Ruderal Shrubland	Other (not habitat)
3986	Western Warm Temperate Fallow/Idle Cropland	Other (not habitat)
3980	Western Warm Temperate Orchard	Managed Forest
3987	Western Warm Temperate Pasture and Hayland	Grass General
3984	Western Warm Temperate Row Crop	Other (not habitat)
3983	Western Warm Temperate Row Crop - Close Grown Crop	Other (not habitat)
3910	Western Warm Temperate Urban Deciduous Forest	Other (not habitat)
3911	Western Warm Temperate Urban Evergreen Forest	Other (not habitat)
3913	Western Warm Temperate Urban Herbaceous	Other (not habitat)
3912	Western Warm Temperate Urban Mixed Forest	Other (not habitat)
3914	Western Warm Temperate Urban Shrubland	Other (not habitat)
3988	Western Warm Temperate Wheat	Other (not habitat)

1B: Texas Ecological Systems

Texas Value	Texas Name	BDH Name
6100	Active Sand Dune	Beaches and Dunes
9000	Barren	Other (not habitat)
207	Blackland Prairie: Disturbance or Tame Grassland	Grass General
1824	Central Texas: Floodplain Baldcypress Swamp	Forested Wetlands
1806	Central Texas: Floodplain Deciduous Shrubland	Forested Wetlands
1801	Central Texas: Floodplain Evergreen Forest	Mixed Forest
1805	Central Texas: Floodplain Evergreen Shrubland	Mixed Forest
1803	Central Texas: Floodplain Hardwood - Evergreen Forest	Mixed Forest
1804	Central Texas: Floodplain Hardwood Forest	Forested Wetlands
1807	Central Texas: Floodplain Herbaceous Vegetation	Grass General
1802	Central Texas: Floodplain Live Oak Forest	Forested Wetlands
1814	Central Texas: Floodplain Seasonally Flooded Hardwood Forest	Forested Wetlands
1906	Central Texas: Riparian Deciduous Shrubland	Forested Wetlands
1901	Central Texas: Riparian Evergreen Forest	Forested Wetlands
1905	Central Texas: Riparian Evergreen Shrubland	Forested Wetlands
1903	Central Texas: Riparian Hardwood - Evergreen Forest	Forested Wetlands
1904	Central Texas: Riparian Hardwood Forest	Forested Wetlands
1907	Central Texas: Riparian Herbaceous Vegetation	Grass General
1902	Central Texas: Riparian Live Oak Forest	Forested Wetlands
5807	Chenier Plain: Fresh and Intermediate Tidal Marsh	Tidal Marsh
5806	Chenier Plain: Fresh and Intermediate Tidal Shrub Wetland	Tidal Marsh
5504	Chenier Plain: Hardwood Fringe Forest	Forested Wetlands
5502	Chenier Plain: Live Oak Fringe Forest	Forested Wetlands
5503	Chenier Plain: Mixed Live Oak - Deciduous Hardwood Fringe Forest	Forested Wetlands
5717	Chenier Plain: Salt and Brackish High Tidal Marsh	Tidal Marsh
5716	Chenier Plain: Salt and Brackish High Tidal Shrub Wetland	Tidal Marsh
5707	Chenier Plain: Salt and Brackish Low Tidal Marsh	Tidal Marsh
5706	Chenier Plain: Salt and Brackish Low Tidal Shrub Wetland	Tidal Marsh
6307	Coastal and Sandsheet: Deep Sand Grassland	Grass General
6507	Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	Tidal Marsh
6402	Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	Forested Wetlands

6306	Coastal and Sandsheet: Deep Sand Shrubland	Other (not habitat)
6100	Coastal: Beach	Beaches and Dunes
5617	Coastal: Salt and Brackish High Tidal Marsh	Tidal Marsh
5616	Coastal: Salt and Brackish High Tidal Shrub Wetland	Tidal Marsh
5607	Coastal: Salt and Brackish Low Tidal Marsh	Tidal Marsh
5600	Coastal: Tidal Flat	Tidal Marsh
4724	Columbia Bottomlands: Baldcypress Swamp	Forested Wetlands
4706	Columbia Bottomlands: Deciduous Shrubland	Forested Wetlands
4705	Columbia Bottomlands: Evergreen Shrubland	Forested Wetlands
4707	Columbia Bottomlands: Grassland	Grass General
4704	Columbia Bottomlands: Hardwood Forest and Woodland	Forested Wetlands
4717	Columbia Bottomlands: Herbaceous Wetland	Freshwater Marsh
4702	Columbia Bottomlands: Live Oak Forest and Woodland	Upland Hardwood Forest
4703	Columbia Bottomlands: Mixed Evergreen - Hardwood Forest and Woodland	Forested Wetlands
4716	Columbia Bottomlands: Riparian Deciduous Shrubland	Forested Wetlands
4715	Columbia Bottomlands: Riparian Evergreen Shrubland	Upland Hardwood Forest
4727	Columbia Bottomlands: Riparian Grassland	Grass General
4714	Columbia Bottomlands: Riparian Hardwood Forest and Woodland	Upland Hardwood Forest
4737	Columbia Bottomlands: Riparian Herbaceous Wetland	Freshwater Marsh
4712	Columbia Bottomlands: Riparian Live Oak Forest and Woodland	Forested Wetlands
523	Crosstimbers: Hardwood - Juniper Slope Forest	Upland Hardwood Forest
521	Crosstimbers: Juniper Slope Forest	Mixed Forest
502	Crosstimbers: Live Oak Forest and Woodland	Upland Hardwood Woodland
524	Crosstimbers: Oak - Hardwood Slope Forest	Upland Hardwood Forest
503	Crosstimbers: Post Oak - Juniper Woodland	Upland Hardwood Woodland
504	Crosstimbers: Post Oak Woodland	Upland Hardwood Woodland
534	Crosstimbers: Sandyland Oak Woodland	Upland Hardwood Woodland
507	Crosstimbers: Savanna Grassland	Gras Prairie
1101	Edwards Plateau: Ashe Juniper Motte and Woodland	Mixed Forest
1205	Edwards Plateau: Ashe Juniper-Live Oak Shrubland	Mixed Forest
1225	Edwards Plateau: Ashe Juniper-Live Oak Slope Shrubland	Mixed Forest
1103	Edwards Plateau: Deciduous Oak - Evergreen Motte and Woodland	Mixed Forest
1102	Edwards Plateau: Live Oak Motte and Woodland	Mixed Forest
902	Edwards Plateau: Live Oak Slope Forest	Mixed Forest
903	Edwards Plateau: Oak - Ashe Juniper Slope Forest	Mixed Forest

1104	Edwards Plateau: Oak - Hardwood Motte and Woodland	Upland Hardwood Forest
904	Edwards Plateau: Oak - Hardwood Slope Forest	Upland Hardwood Forest
1107	Edwards Plateau: Savanna Grassland	Grass General
1226	Edwards Plateau: Shin Oak Slope Shrubland	Mixed Forest
2007	Grand Prairie: Tallgrass Prairie	Grass General
9317	Grass Farm	Other (not habitat)
5207	Gulf Coast: Coastal Prairie	Grass General
5307	Gulf Coast: Coastal Prairie Pondshore	Freshwater Marsh
5004	Gulf Coast: Near-Coast Baldcypress Swamp	Forested Wetlands
2207	Gulf Coast: Salty Prairie	Tidal Marsh
2206	Gulf Coast: Salty Prairie Shrubland	Other (not habitat)
9505	Invasive: Evergreen Shrubland	Other (not habitat)
9007	Marsh	Freshwater Marsh
9002	Mud Flat	Freshwater Marsh
9116	Native Invasive: Baccharis Shrubland	Other (not habitat)
9107	Native Invasive: Common Reed	Other (not habitat)
9126	Native Invasive: Deciduous Shrubland	Other (not habitat)
9104	Native Invasive: Deciduous Woodland	Other (not habitat)
9124	Native Invasive: Huisache Woodland or Shrubland	Other (not habitat)
9105	Native Invasive: Juniper Shrubland	Other (not habitat)
9101	Native Invasive: Juniper Woodland	Other (not habitat)
9106	Native Invasive: Mesquite Shrubland	Other (not habitat)
9214	Non-Native Invasive: Chinese Tallow Forest	Other (not habitat)
9205	Non-native Invasive: Rose Shrubland	Other (not habitat)
9204	Non-native Invasive: Saltcedar Shrubland	Other (not habitat)
9600	Open Water	Other (not habitat)
9301	Pine Plantation > 3 meters tall	Managed Forest
9305	Pine Plantation 1 to 3 meters tall	Managed Forest
4924	Pineywoods: Bottomland Baldcypress Swamp	Forested Wetlands
4906	Pineywoods: Bottomland Deciduous Successional Shrubland	Forested Wetlands
4905	Pineywoods: Bottomland Evergreen Successional Shrubland	Forested Wetlands
4907	Pineywoods: Bottomland Herbaceous Wetland	Freshwater Marsh
4914	Pineywoods: Bottomland Seasonally Flooded Hardwood Forest	Forested Wetlands
4904	Pineywoods: Bottomland Temporarily Flooded Hardwood Forest	Forested Wetlands
4902	Pineywoods: Bottomland Temporarily Flooded Live Oak Forest	Forested Wetlands
4903	Pineywoods: Bottomland Temporarily Flooded Mixed Pine - Hardwood Forest	Forested Wetlands
4917	Pineywoods: Bottomland Wet Prairie	Grass General

4307	Pineywoods: Catahoula Herbaceous Barrens	Glades
4305	Pineywoods: Catahoula Woodland or Shrubland Barrens	Glades
9197	Pineywoods: Disturbance or Tame Grassland	Grass General
3013	Pineywoods: Dry Pine - Hardwood Forest or Plantation	Managed Forest
3011	Pineywoods: Dry Pine Forest or Plantation	Managed Forest
3014	Pineywoods: Dry Upland Hardwood Forest	Upland Hardwood Woodland
4004	Pineywoods: Hardwood Flatwoods	Upland Hardwood Forest
3507	Pineywoods: Herbaceous Flatwoods Pond	Freshwater Marsh
2307	Pineywoods: Herbaceous Seepage Bog	Freshwater Marsh
4003	Pineywoods: Longleaf or Loblolly Pine - Hardwood Flatwoods or Plantation	Managed Forest
4001	Pineywoods: Longleaf or Loblolly Pine Flatwoods or Plantation	Managed Forest
12005	Pineywoods: Longleaf Pine Woodland	Longleaf Pine Woodland
3304	Pineywoods: Northern Mesic Hardwood Forest	Upland Hardwood Forest
3303	Pineywoods: Northern Mesic Pine - Hardwood Forest	Mixed Forest
3003	Pineywoods: Pine - Hardwood Forest or Plantation	Managed Forest
3001	Pineywoods: Pine Forest or Plantation	Managed Forest
4207	Pineywoods: Saline Glade	Glades
3207	Pineywoods: Sandhill Grassland or Shrubland	Grass General
3203	Pineywoods: Sandhill Oak - Pine Woodland	Mixed Forest
3204	Pineywoods: Sandhill Oak Woodland	Upland Hardwood Woodland
3201	Pineywoods: Sandhill Pine Woodland	Shortleaf/Loblolly Pine Woodland
3604	Pineywoods: Seepage Swamp and Baygall	Forested Wetlands
4824	Pineywoods: Small Stream and Riparian Baldcypress Swamp	Forested Wetlands
4806	Pineywoods: Small Stream and Riparian Deciduous Successional Shrubland	Forested Wetlands
4805	Pineywoods: Small Stream and Riparian Evergreen Successional Shrubland	Mixed Forest
4807	Pineywoods: Small Stream and Riparian Herbaceous Wetland	Freshwater Marsh
4802	Pineywoods: Small Stream and Riparian Live Oak Temporarily Flooded Forest	Forested Wetlands
4814	Pineywoods: Small Stream and Riparian Seasonally Flooded Hardwood Forest	Forested Wetlands
4804	Pineywoods: Small Stream and Riparian Temporarily Flooded Hardwood Forest	Forested Wetlands
4803	Pineywoods: Small Stream and Riparian Temporarily Flooded Mixed Forest	Forested Wetlands
4817	Pineywoods: Small Stream and Riparian Wet Prairie	Grass General
4407	Pineywoods: Southern Calcareous Mixedgrass Prairie	Grass General

3404	Pineywoods: Southern Mesic Hardwood Forest	Upland Hardwood Forest
3403	Pineywoods: Southern Mesic Pine - Hardwood Forest	Mixed Forest
3004	Pineywoods: Upland Hardwood Forest	Upland Hardwood Forest
4107	Pineywoods: Weches Herbaceous Glade	Glades
4106	Pineywoods: Weches Shrub Glade	Glades
3704	Pineywoods: Wet Hardwood Flatwoods	Forested Wetlands
602	Post Oak Savanna: Live Oak Motte and Woodland	Upland Hardwood Woodland
624	Post Oak Savanna: Oak - Hardwood Slope Forest	Upland Hardwood Forest
623	Post Oak Savanna: Oak - Redcedar Slope Forest	Mixed Forest
603	Post Oak Savanna: Post Oak - Redcedar Motte and Woodland	Upland Hardwood Woodland
613	Post Oak Savanna: Post Oak - Yaupon Motte and Woodland	Upland Hardwood Woodland
604	Post Oak Savanna: Post Oak Motte and Woodland	Upland Hardwood Woodland
621	Post Oak Savanna: Redcedar Slope Forest	Mixed Forest
707	Post Oak Savanna: Sandyland Grassland	Gras Prairie
706	Post Oak Savanna: Sandyland Woodland and Shrubland	Upland Hardwood Woodland
607	Post Oak Savanna: Savanna Grassland	Grass General
5106	Red River: Floodplain Deciduous Shrubland	Forested Wetlands
5105	Red River: Floodplain Evergreen Shrubland	Forested Wetlands
5103	Red River: Floodplain Hardwood - Evergreen Forest	Forested Wetlands
5104	Red River: Floodplain Hardwood Forest	Forested Wetlands
5107	Red River: Floodplain Herbaceous Wetland	Freshwater Marsh
5114	Red River: Floodplain Seasonally Flooded Hardwood Forest	Forested Wetlands
5117	Red River: Floodplain Wet Prairie	Grass General
9307	Row Crops	Other (not habitat)
9004	Swamp	Forested Wetlands
6000	Upper Gulf Coast: Beach	Beaches and Dunes
9410	Urban High Intensity	Other (not habitat)
9411	Urban Low Intensity	Other (not habitat)

1C: Oklahoma Ecological Systems

OK Value	OK Name	BDH Name
1205	Arbuckle: Ashe Juniper Shrubland	Mixed Forest
1101	Arbuckle: Ashe Juniper Woodland	Mixed Forest
1206	Arbuckle: Deciduous Shrubland	Mixed Forest
901	Arbuckle: Juniper Slope Forest	Mixed Forest
903	Arbuckle: Oak - Juniper Slope Forest	Mixed Forest

1103	Arbuckle: Oak - Juniper Woodland	Mixed Forest
904	Arbuckle: Oak Slope Forest	Upland Hardwood Forest
1114	Arbuckle: Oak Woodland	Upland Hardwood Woodland
1107	Arbuckle: Prairie/Pasture	Grass General
14407	Arkansas Valley: Prairie/Pasture	Grass General
14417	Arkansas Valley: Sandy Prairie/Pasture	Grass General
9000	Barren	Other (not habitat)
207	Blackland: Pasture/Prairie	Grass Prairie
525	Crosstimbers: Eastern Redcedar Slope Woodland and Shrubland	Upland Hardwood Woodland
515	Crosstimbers: Eastern Redcedar Woodland and Shrubland	Upland Hardwood Woodland
507	Crosstimbers: Pasture/Prairie	Grass Prairie
504	Crosstimbers: Post Oak - Blackjack Oak Forest and Woodland	Upland Hardwood Woodland
524	Crosstimbers: Post Oak - Blackjack Oak Slope Forest	Upland Hardwood Forest
503	Crosstimbers: Post Oak - Eastern Redcedar Forest and Woodland	Upland Hardwood Woodland
523	Crosstimbers: Post Oak - Eastern Redcedar Slope Forest	Upland Hardwood Forest
534	Crosstimbers: Sandyland Post Oak - Blackjack Oak Forest and Woodland	Upland Hardwood Woodland
526	Crosstimbers: Sandyland Shrubland and Grassland	Upland Hardwood Woodland
506	Crosstimbers: Young Post Oak - Blackjack Oak Woodland	Upland Hardwood Woodland
9327	Disturbed Soil Pasture	Grass General
14717	Eastern Great Plains: Herbaceous Wetland	Freshwater Marsh
2007	Grand Prairie: Prairie/Pasture	Grass General
9600	Open Water	Other (not habitat)
2027	Osage Plains: Tallgrass Prairie/Pasture	Grass General
13103	Ozark-Ouachita: Dry Mixed Oak - Evergreen Woodland	Mixed Forest
13104	Ozark-Ouachita: Dry Oak Woodland	Upland Hardwood Woodland
13106	Ozark-Ouachita: Dry Oak Woodland Young Regrowth	Upland Hardwood Woodland
13003	Ozark-Ouachita: Dry-Mesic Mixed Oak - Evergreen Forest	Mixed Forest
13004	Ozark-Ouachita: Dry-Mesic Oak Forest	Upland Hardwood Forest
13006	Ozark-Ouachita: Dry-Mesic Oak Woodland Young Regrowth	Upland Hardwood Woodland
13706	Ozark-Ouachita: Montane Stunted Oak Woodland	Upland Hardwood Woodland
9117	Ozark-Ouachita: Pasture/Prairie	Grass General
13500	Ozark-Ouachita: Riparian Barrens	Bottomland Barrens
13506	Ozark-Ouachita: Riparian Deciduous Shrubland and Young Woodland	Upland Hardwood Woodland

13515	Ozark-Ouachita: Riparian Evergreen Woodland and Shrubland	Shortleaf/Loblolly Pine Woodland
13504	Ozark-Ouachita: Riparian Hardwood Woodland	Upland Hardwood Woodland
13517	Ozark-Ouachita: Riparian Herbaceous Wetland	Freshwater Marsh
13503	Ozark-Ouachita: Riparian Mixed Evergreen - Hardwood Woodland	Shortleaf/Loblolly Pine Woodland
13403	Ozark-Ouachita: Shortleaf Pine - Oak Forest	Mixed Forest
9301	Pine Plantation	Managed Forest
9305	Pine Plantation - 1 - 3 meters	Managed Forest
607	Post Oak Savanna: Pasture/Grassland	Grass Prairie
613	Post Oak Savanna: Post Oak - Eastern Redcedar Sandyland Woodland	Upland Hardwood Woodland
603	Post Oak Savanna: Post Oak - Eastern Redcedar Woodland	Upland Hardwood Woodland
614	Post Oak Savanna: Post Oak Sandyland Woodland	Upland Hardwood Woodland
604	Post Oak Savanna: Post Oak Woodland	Upland Hardwood Woodland
617	Post Oak Savanna: Sandyland Shrubland and Grassland	Upland Hardwood Woodland
606	Post Oak Savanna: Young Woodland Regrowth	Upland Hardwood Woodland
9412	Quarry	Other (not habitat)
9307	Row Crops	Other (not habitat)
9206	Ruderal Deciduous Shrubland and Young Woodland	Upland Hardwood Woodland
9104	Ruderal Deciduous Woodland	Upland Hardwood Woodland
9115	Ruderal Eastern Redcedar Woodland and Shrubland	Upland Hardwood Woodland
9103	Ruderal Mixed Deciduous - Eastern Redcedar Woodland	Upland Hardwood Woodland
14800	South Central Interior: Bottomland Barrens	Bottomland Barrens
14815	South Central Interior: Bottomland Eastern Redcedar Woodland and Shrubland	Mixed Forest
14804	South Central Interior: Bottomland Hardwood Forest	Forested Wetlands
14817	South Central Interior: Bottomland Herbaceous Wetland	Freshwater Marsh
14803	South Central Interior: Bottomland Mixed Evergreen - Hardwood Forest	Mixed Forest
14806	South Central Interior: Bottomland Shrubland and Young Woodland	Forested Wetlands
15100	South Central Interior: Riparian Barrens	Bottomland Barrens
15115	South Central Interior: Riparian Eastern Redcedar Woodland and Shrubland	Mixed Forest
15104	South Central Interior: Riparian Hardwood Woodland	Forested Wetlands
15117	South Central Interior: Riparian Herbaceous Wetland	Freshwater Marsh
15103	South Central Interior: Riparian Mixed Evergreen - Hardwood Woodland	Mixed Forest
15106	South Central Interior: Riparian Shrubland and Young Woodland	Forested Wetlands
1800	Southeastern Great Plains: Bottomland Barrens	Bottomland Barrens

1815	Southeastern Great Plains: Bottomland Eastern Redcedar Woodland and Shrubland	Forested Wetlands
1804	Southeastern Great Plains: Bottomland Hardwood Forest	Forested Wetlands
1817	Southeastern Great Plains: Bottomland Herbaceous Wetland	Freshwater Marsh
1803	Southeastern Great Plains: Bottomland Mixed Evergreen - Hardwood Forest	Forested Wetlands
1806	Southeastern Great Plains: Bottomland Shrubland and Young Woodland	Forested Wetlands
1900	Southeastern Great Plains: Riparian Barrens	Bottomland Barrens
1915	Southeastern Great Plains: Riparian Eastern Redcedar Woodland and Shrubland	Forested Wetlands
1904	Southeastern Great Plains: Riparian Hardwood Woodland	Forested Wetlands
1917	Southeastern Great Plains: Riparian Herbaceous Wetland	Freshwater Marsh
1903	Southeastern Great Plains: Riparian Mixed Evergreen - Hardwood Woodland	Forested Wetlands
1906	Southeastern Great Plains: Riparian Shrubland and Young Woodland	Forested Wetlands
9410	Urban High Intensity	Other (not habitat)
9411	Urban Low Intensity	Other (not habitat)
3014	West Gulf Coastal Plain: Dry Upland Hardwood Forest	Upland Hardwood Woodland
4900	West Gulf Coastal Plain: Large River Bottomland Barrens	Bottomland Barrens
4906	West Gulf Coastal Plain: Large River Bottomland Deciduous Shrubland	Forested Wetlands
4915	West Gulf Coastal Plain: Large River Bottomland Evergreen Woodland and Shrubland	Mixed Forest
4904	West Gulf Coastal Plain: Large River Bottomland Hardwood Forest	Forested Wetlands
4917	West Gulf Coastal Plain: Large River Bottomland Herbaceous Wetland	Freshwater Marsh
4903	West Gulf Coastal Plain: Large River Bottomland Mixed Hardwood - Evergreen Forest	Mixed Forest
4914	West Gulf Coastal Plain: Large River Bottomland Seasonally Flooded Hardwood Forest	Forested Wetlands
14307	West Gulf Coastal Plain: Northern Calcareous Prairie/Pasture	Grass General
9197	West Gulf Coastal Plain: Pasture	Grass General
3003	West Gulf Coastal Plain: Pine - Hardwood Forest	Mixed Forest
3001	West Gulf Coastal Plain: Pine Forest	Shortleaf/Loblolly Pine Woodland
3204	West Gulf Coastal Plain: Sandhill Oak Woodland	Upland Hardwood Woodland
3201	West Gulf Coastal Plain: Sandhill Shortleaf Pine Woodland	Shortleaf/Loblolly Pine Woodland

4800	West Gulf Coastal Plain: Small Stream Barrens	Bottomland Barrens
4806	West Gulf Coastal Plain: Small Stream Deciduous Shrubland	Forested Wetlands
4815	West Gulf Coastal Plain: Small Stream Evergreen Woodland and Shrubland	Shortleaf/Loblolly Pine Woodland
4804	West Gulf Coastal Plain: Small Stream Hardwood Woodland	Forested Wetlands
4817	West Gulf Coastal Plain: Small Stream Herbaceous Wetland	Freshwater Marsh
4803	West Gulf Coastal Plain: Small Stream Mixed Pine - Hardwood Woodland	Forested Wetlands
4814	West Gulf Coastal Plain: Small Stream Seasonally Flooded Hardwood Woodland	Forested Wetlands
3006	West Gulf Coastal Plains: Young Upland Hardwood Woodland Regrowth	Upland Hardwood Woodland

1D: Florida Cooperative Land Cover

FL Value	FL Name	BDH Name
1110	Upland Hardwood Forest	Upland Hardwood Forest
1120	Mesic Hammock	Upland Hardwood Forest
1140	Slope Forest	Upland Hardwood Forest
1150	Xeric Hammock	Upland Hardwood Forest
1200	High Pine and Scrub	Mixed Forest
1210	Scrub	Other (not habitat)
1213	Sand Pine Scrub	Mixed Forest
1214	Coastal Scrub	Other (not habitat)
1231	Upland Pine	Longleaf Pine Woodland
1240	Sandhill	Longleaf Pine Woodland
1310	Dry Flatwoods	Longleaf Pine Flatwoods
1311	Mesic Flatwoods	Longleaf Pine Flatwoods
1312	Scrubby Flatwoods	Longleaf Pine Flatwoods
1340	Palmetto Prairie	Other (not habitat)
1400	Mixed Hardwood-Coniferous	Mixed Forest
1500	Shrub and Brushland	Other (not habitat)
1600	Coastal Uplands	Beaches and Dunes
1640	Coastal Strand	Beaches and Dunes
1650	Maritime Hammock	Mixed Forest
1670	Sand Beach (Dry)	Beaches and Dunes
1700	Barren and Outcrop Communities	Glades
1720	Upland Glade	Glades
1800	Cultural - Terrestrial	Other (not habitat)
1821	Low Intensity Urban	Other (not habitat)
1822	High Intensity Urban	Other (not habitat)
1830	Rural	Other (not habitat)
1840	Transportation	Other (not habitat)
1850	Communication	Other (not habitat)
1860	Utilities	Other (not habitat)
1870	Extractive	Other (not habitat)
1880	Bare Soil/Clear Cut	Other (not habitat)
2100	Freshwater Non-Forested Wetlands	Freshwater Marsh
2110	Prairies and Bogs	Grass general
2120	Marshes	Freshwater Marsh
2121	Isolated Freshwater Marsh	Freshwater Marsh
2123	Floodplain Marsh	Freshwater Marsh
2200	Freshwater Forested Wetlands	Forested Wetlands
2210	Cypress/Tupelo(incl Cy/Tu mixed)	Forested Wetlands
2211	Cypress	Forested Wetlands
2213	Isolated Freshwater Swamp	Forested Wetlands

2215	Floodplain Swamp	Forested Wetlands
2220	Other Coniferous Wetlands	Forested Wetlands
2221	Wet Flatwoods	Forested Wetlands
2230	Other Hardwood Wetlands	Forested Wetlands
2231	Baygall	Forested Wetlands
2232	Hydric Hammock	Forested Wetlands
2300	Non-vegetated Wetland	Other (not habitat)
2400	Cultural - Palustrine	Other (not habitat)
3000	Lacustrine	Other (not habitat)
3100	Natural Lakes and Ponds	Other (not habitat)
3200	Cultural - Lacustrine	Other (not habitat)
4000	Riverine	Other (not habitat)
4100	Natural Rivers and Streams	Other (not habitat)
4200	Cultural - Riverine	Other (not habitat)
5000	Estuarine	Other (not habitat)
5220	Tidal Flat	Other (not habitat)
5240	Salt Marsh	Tidal Marsh
5250	Mangrove Swamp	Other (not habitat)
6000	Marine	Other (not habitat)
9100	Unconsolidated Substrate	Other (not habitat)
18331	Cropland/Pasture	Other (not habitat)
18332	Orchards/Groves	Other (not habitat)
18333	Tree Plantations	Managed Forest
18334	Vineyard and Nurseries	Other (not habitat)
18335	Other Agriculture	Other (not habitat)
22131	Dome Swamp	Forested Wetlands
22132	Basin Swamp	Forested Wetlands
183313	Improved Pasture	Grass general

Appendix 2: Pivot table of hectares of potential and existing terrestrial Broadly Defined Habitats

POTENTIAL HABITAT

EXISTING	Beaches and Dunes	Forested Wetland	Freshwater Marsh	Glades	Prairie	Longleaf Pine Flatwoods	Longleaf Pine Woodland	Mixed Forest	Other (not habitat)	Shortleaf Loblolly Pine Woodland	Tidal Marsh	Upland Hardwood Forest	Upland Hardwood Woodland	Grand Total	Mis-matched
Beaches and Dunes	489	370		469		327	138	414	4,060		69	41	19	6409	5920
Bottomland Barrens		1,984	3		605			30	6,664	5	13	103	461	9871	N/A
Forested Wetlands	53	8,178,857	806	1,800	189,417	226,418	157,920	160,876	30,878	4,965	10,203	275,025	317,447	9,554,664	1,375,807
Freshwater Marsh	29	61,011	244	12	36,480	9,113	2,628	2,415	24,218	121	6,337	4,585	8,130	155,322	155,078
Glades	56	7,602	3	20,252	9,263	17	380	6,050	43	932		35,747	56,117	136,407	116,154
Grass general		2,733,961	2,661	30,383	2,883,597	227,978	1,005,413	1,796,411	33,255	340,629	32,565	2,658,346	4,290,115	16,035,372	N/A
Grass prairie	8	116,395	78	469	569,784	14,679	7,562	39,366	4,009	5,407	5,095	54,277	456,110	1,273,239	703,455
Longleaf Pine Flatwoods	197	166,362	313		16,205	434,604	28,007	16,287	508		362	5,150	6,789	674,784	240,179
Longleaf Pine Woodland	26	69,521	79	243	52,567	70,712	1,691,321	84,489	234	225	34	213,421	134,300	2,317,172	625,851
Managed Forest	19	1,793,857	406	1,724	184,218	811,348	1,985,816	2,857,471	6,829	88,310	956	1,342,926	1,581,303	10,655,182	N/A
Mixed Forest	56	1,434,250	268	11,705	152,623	137,123	688,739	1,529,308	1,027	131,272	80	1,189,908	1,222,171	6,498,530	4,969,223
Other (not habitat)	1,694	8,941,962	10,584	33,501	3,337,590	293,983	2,233,466	1,154,639	3,145,627	155,405	108,219	3,452,695	2,281,486	25,150,850	22,005,223
Shortleaf Loblolly Pine Woodland	1	87,023	8		56,394	21,174	58,174	459,454	35	228,002	2	313,888	295,766	1,521,387	1,293,385
Tidal Marsh	141	37,350	97		4,162	3,550	10	523	4,586		1,248,093	18,340	8	1,316,860	68,767
Upland Hardwood Forest	5	1,114,740	339	14,729	322,551	121,622	276,483	2,157,182	7,499	622,452	4,881	4,702,877	4,556,095	13,901,455	9,198,578
Upland Hardwood Woodland	0	410,333	637	65,197	443,886	1,045	458,540	432,071	10,069	123,210	2	723,374	2,819,505	5,487,870	2,668,365
Grand Total	2,775	25,155,580	16,997	181,482	8,259,354	2,373,694	8,594,600	10,696,983	3,279,541	1,700,934	1,416,910	14,990,702	18,025,821	94,695,374	
Mis-matched	2,286	16,976,723	16,753	161,230	7,689,570	1,939,090	6,903,279	9,167,675	133,914	1,472,933	168,817	10,287,825	15,206,317		
% potential not realized	82	67	99	89	93	82	80	86	4	87	12	69	84		

Note: "Mis-matched" *column* describes hectares of existing habitat classes with potential to be in some other class, obtained by subtracting the number of hectares of matching existing and potential from the Grand Total for that row. "Mis-matched" *row* describes hectares of potential habitat classes in some other existing class, obtained by subtracting the number of hectares of matching existing and potential from the Grand Total for that column.

(Appendix II continued)

By far, the single existing class occupying the greatest area of potential habitat is the Other (non-habitat) class, dominated by agricultural, urban, and developed land, which accounts for 22 million acres of potential habitat. Grass General, which has no potential habitat match, covers sixteen million hectares, including 2.9 million ha of prairie, 1.6 million ha of pine, and seven million ha of upland hardwood forest and woodland. The potential habitat with the greatest loss is freshwater marsh with 99% converted to other types and only 244 ha mapped. This result will change when land cover in Southwest Louisiana is updated with a recently acquired data layer that distinguishes marsh types. Ninety-three percent of potential prairie is shown to be in some other habitat type. Some discrepancies between existing and potential classes are the result of possible errors in the mapping process. For example, over a million acres of potential forested wetland mapped as upland hardwood forest stands out as unusual. These may have been mistakenly identified from the source layers: LANDFIRE evt classes 3323 West Gulf Coastal Plain Mesic Hardwood Forest, 3321 South-Central Interior Mesophytic Forest, and 3305 Southern Interior Low Plateau Dry-Mesic Oak Forest, all mapped to Upland Hardwood Forest, should perhaps be re-evaluated.

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