MISSISSIPPI ALLUVIAL VALLEY

The GCPO LCC subgeographic construct for the Mississippi Alluvial Valley (MAV) was developed with guidance from the Geomatics Working Group primarily from the geographic extent for the MAV Bird Conservation Region (BCR 26) (North American Bird Conservation Initiative [NABCI]). An exception is the southern portion of BCR 26, which was removed and incorporated into the GCPO LCC's Gulf Coast subgeographic construct for operational effectiveness. The MAV BCR is comprised primarily of Mississippi River alluvial floodplain and formerly held one of the largest expanses of bottomland hardwood forest in North America. It is also one of the most impeded systems on the continent, with altered hydrology from a vast network of protection levees and most naturally occurring bottomland forests long ago converted to agriculture across the majority of the MAV area (NABCI BCR 26).

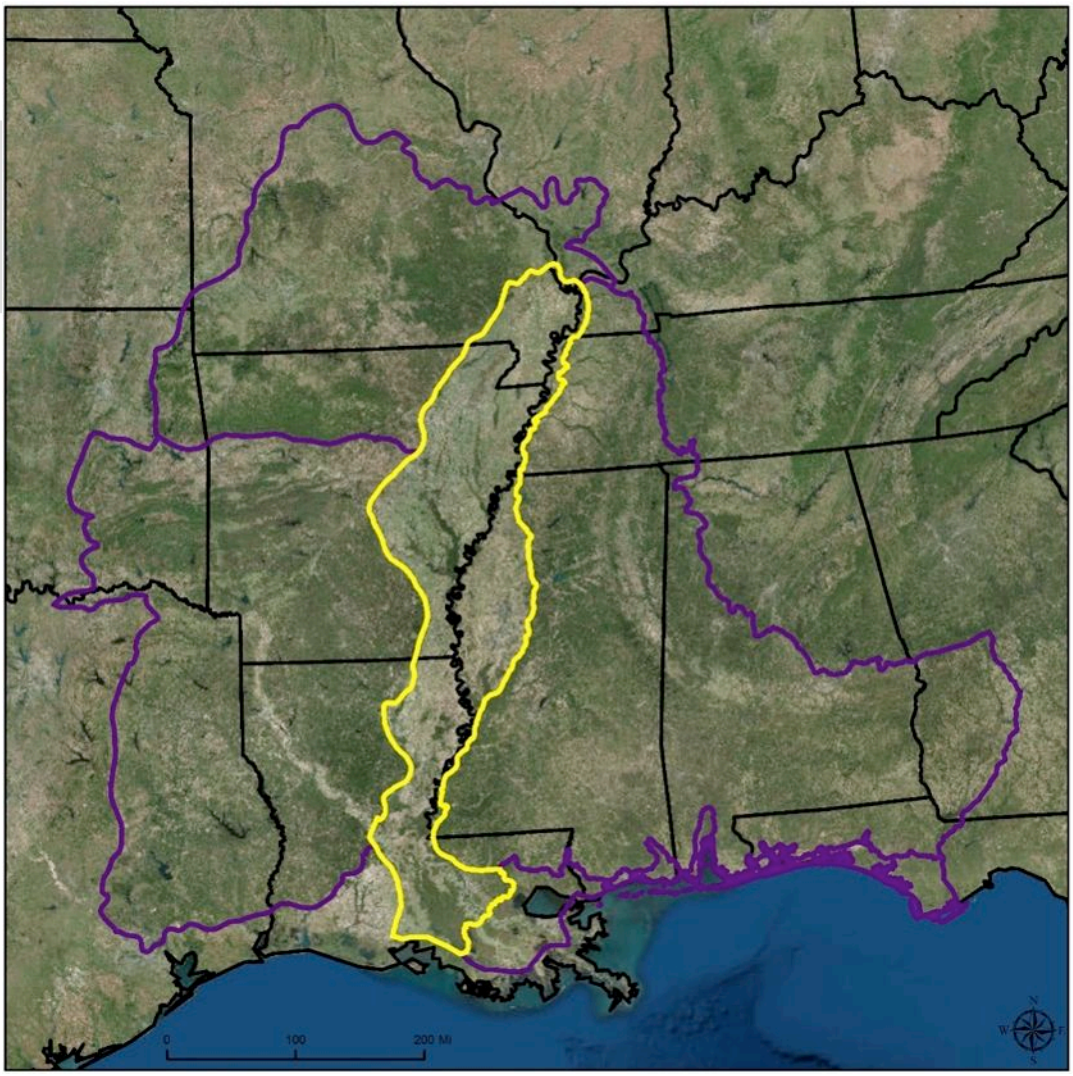

Figure #. The Mississippi Alluvial Valley subgeographic construct (outlined in yellow) of the Gulf Coastal Plains and Ozarks LCC.

Introduction to Forested Wetlands of the Mississippi Alluvial Valley

The bottomland, or "forested wetland" system, was selected from the NatureServe/U.S. Fish and Wildlife Service series of "Broadly Defined Habitats" as the initial terrestrial ecological

system of focus for the MAV subgeography in the GCPO LCC Integrated Science Agenda (ISA). In the MAV, forested wetland systems include alluvial bottomland hardwoods in the Mississippi River low and high floodplain, and alluvial bottomland hardwoods (overcup-oak dominated) and alluvial cypress-tupelo forests of the Mississippi River bottomland depression from the southern tip of Illinois through Mississippi and southern Louisiana. Also included are the lower Mississippi River flatwoods and riparian forests in the MAV. These systems support several species of conservation concern prioritized in the ISA as representative of a healthy forested wetland, including the Louisiana black bear (*Ursus americanus luteolus*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), swallow-tailed kite (*Elanoides forficatus*), red-headed woodpecker (*Melanerpes erythrocephalus*), and Swainson's (*Limnothlypis swainsonii*), Kentucky (*Geothlypis formosa*), and hooded (*Setophaga citrina*) warblers during some or all parts of their annual cycle. Desired ecological states for MAV forested wetlands are generally described in the ISA as "*local landscapes that are extensively forested with large contiguous patches of forest with a naturally diverse canopy containing a floristic diversity within the midstory and understory"* (LMVJV Forest Resource Conservation Working Group, 2007).

As in all ISA priority systems, desired ecological states are defined within general categories of landscape attributes related to habitat amount, configuration, condition, and temporal consideration. For MAV forested wetlands, desired ecological states are primarily derived from the document entitled "Restoration, Management, and Monitoring of Forest Resources in the Mississippi Alluvial Valley: Recommendations for Enhancing Wildlife Habitat" (LMVJV Forest Resource Conservation Working Group 2007). The ISA defined the desired ecological state for forested wetland habitat that is managed to meet targets of basal area, canopy cover, species composition and other metrics describing appropriate forest condition and configuration for priority wildlife species as a total amount of 3.7 million acres with 35-50% of all bottomland forest stands meeting the targeted structural conditions outlined below at a given point in time. This target was defined based on the Partners In Flight (PIF) MAV Bird Conservation Plan (Twedt et al. 1999) and its estimated requirement of 3.7 million acres of forested wetland to sustain a source population of breeding songbirds. For clarity and simplicity we performed initial assessments of condition and configuration separately, and then where possible combined configuration and condition characteristics into a Condition Index Value to better summarize forested wetland amount as it relates to desired conditions for priority wildlife species. Included below is the relevant section from Appendix 1 of the GCPO LCC Integrated Science Agenda outlining the desired conditions for forested wetlands in the MAV.

MISSISSIPPI ALLUVIAL VALLEY

Forested Wetlands (Source: LMVJV Forest Resource Conservation Working Group, 2007)

General description of desired ecological state: *Local landscapes that are extensively forested with large contiguous patches of forest with a naturally diverse canopy containing a floristic diversity within the midstory and understory.*

Amount: 3.7 M acres

Configuration: Local landscapes (≥10,000 ac) extensively (70-100%) forested
Large contiguous patches of forest

- 13 patches >100,000 ac
- 36 patches >20,000 ac
- 52 patches >10,000 ac

Condition: Structure (Mature forest)

- Overstory Canopy Cover: 60-70%

- Midstory Cover: 25-40%
- Understory Cover: 25-40%
- Basal Area: 60-70 ft^2/ac
- Tree Stocking: 60-70%
- Large (≥26" dbh) snags: 0.2/ac

Composition

- Diverse tree species composition
- Occurrence of cane and overstory vines

Water quantity

- Flow patterns mimicking natural hydrology

Temporal considerations:

- An appropriate distribution of successional stages, with <10% of local landscape in early successional stage at any given time

Delineating forest cover in the GCPO geography

Ecological function of forested wetland systems is presumed to be positively related to the amount and configuration of all forest habitat in a landscape, such that interspersion of upland forest systems in forested wetland will better support priority species and ecological integrity of the system. We approached the assessment of MAV and GCPO forested wetland systems by first examining all forest cover in the landscape. For assessment of forest cover we used a combination of remote sensing products including 2011 National Land Cover Database (NLCD) forest classes (Jin et al. 2013) and the forthcoming 2011 MAV forest classification layer produced by the Lower Mississippi Valley Joint Venture (LMVJV; Mitchell et al. *In Review*). We used NLCD as the primary data source when assessing forests outside the GCPO LCC MAV subgeography, and the LMVJV forest classification as the primary data source for forest assessment within the MAV.

NLCD was developed using 2011 Landsat TM imagery, with forest classes including only areas with trees exceeding 5 m (16 ft) in height and where trees compose at least 20% of the total vegetation cover (Jin et al. 2013). We first clipped the 2011 NLCD to a 10 km buffer around the GCPO LCC geographic boundary, then resampled the data from 30 m resolution to 250 m resolution using a nearest neighbor algorithm. We resampled to 250 m to allow the forest classification to serve as a "mask" for assessing other forested wetland configuration and condition data developed at a 250 m resolution from MODIS satellite imagery (see sections below). Once data were at 250 m resolution we then reclassified the data to extract NLCD Deciduous Forest (41), Evergreen Forest (42), Mixed Forest (43), and Woody Wetlands (90)) classes as a single forest value.

We next assessed the LMVJV forest classification data for the MAV, using 2011 Landsat-based classification supplemented with known reforestation patches and aggregated across 90 m breaks (Mitchell et al. *In Review*). To produce this product Mitchell et al. used 11 cloud free Landsat 5 TM scenes from Oct-Nov 2011 in combination with ancillary data, then used object-based image analysis to segment out classify forests and other landcover features. This analysis was supplemented with spatial data on regenerating forest planted under the U.S. Department of Agriculture Wetland Reserve Program (now part of the Agricultural Conservation Enhancement Program), Conservation Reserve Program, and other conservation easement lands. We converted vector polygon data to a 30 m resolution then resampled up to 250 m

resolution raster using a nearest neighbor algorithm. We clipped this layer to the GCPO LCC MAV subgeography boundary. We then mosaicked the LMVJV forest classification to 2011 NLCD forest classes using LMVJV forest as the primary operator, resulting in a 250 m resolution forest "mask" that combined the two datasets within the GCPO (**Table FW.1**).

Table FW.1. Estimated acreage per GCPO subgeography of forest derived from National Land Cover Dataset forest classes (deciduous forest, mixed forest, evergreen forest, forested wetlands) mosaicked with the Lower Mississippi Valley Joint Venture forest classification for the Mississippi Alluvial Valley.

	Acres forest mask per GCPO subgeography
Mississippi Alluvial Valley	**9,185,486**
East Gulf Coastal Plain	34,365,330
West Gulf Coastal Plain	30,480,610
Ozark Highlands	19,448,550
Gulf Coast	2,917,463
Gulf Coastal Plains and Ozarks (full extent)	96,397,439

Delineating forested wetlands in the GCPO geography

Using the forest mask defined above, our next objective was to delineate forested wetlands from within that forested landscape. We evaluated four options to delineating forested wetlands outlined below. Note we did not explore a delineation based on National Wetlands Inventory forested wetland/scrub wetland classes due to limitations in data availability in the western portions of the GCPO LCC geography.

Alternative 1: Inundation frequency-based delineation

We first evaluated the recently developed GCPO LCC floodplain inundation frequency (IF) dataset as a mechanism for delineating forested wetlands. The IF dataset uses atmospherically-corrected reflectance data available in Landsat 5 and 7 imagery Climate Data Records from 1983-2011 (December-March) to develop an index of inundation extent in the GCPO geography (Allen *in press*). Classification was done using Landsat band 5, where pixels with spectral signatures <500, or 501-1200 with NDVI <0.42 and slope <10% were classified as wet. Relative inundation frequency was calculated based on a per-pixel index of proportion of Landsat scenes in which each pixel was classified to a wet condition. Each 30 m pixel in the GCPO geography was classified based on the proportion of inundation (0-1) over time, with 1 indicating 100% of scenes classified the pixel as wet. We resampled the IF dataset to a 250 m resolution using a nearest neighbor algorithm, then reclassified to extract IF data >0.1 (i.e., pixels were wet >10% of the time over the time period). We then extracted the forest classification mask from above through the IF dataset to pull out forested wetlands as forests that were inundated during the winter at least 10% of the time over the last 28 years.

Alternative 2: 2011 NLCD woody wetlands

We next evaluated 2011 National Land Cover Database (NLCD) woody wetlands classification (Value =90) as a basis for assessment of forested wetlands within the MAV and GCPO geography. NLCD woody wetlands are defined as "areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water" (Jin et al. 2013). We selected NLCD over other wetland data sources such as the freshwater-forested and shrub-wetland classes in the National Wetlands Inventory (NWI) (USFWS 2014) because of lacking comprehensive availability of NWI data within the GCPO geography. We first resampled the 30 m resolution 2011 NLCD layer to a 250 m resolution using a nearest neighbor algorithm, then reclassified the resampled data to eliminate all values except woody wetlands. We then extracted the data through the forest classification mask to provide a consistent dataset for comparison with the other options.

Alternative 3: GAP Analysis Program

For the third option we evaluated the GAP Analysis Program National GAP Land Cover data layer (US Geological Survey, Gap Analysis Program, 2011) as a potential basis for assessment of forested wetlands. GAP data provides a 30 m resolution hierarchical classification of landcover, with classification to NatureServe ecological classification system defined by plant associations and alliances occupying similar landforms and edaphic features in particular geographies (Comer et al. 2003). Ecological classifications in the GAP land cover product were classified using CART decision tree methods at a state-level using 1999-2000 Landsat TM imagery in combination with ancillary landform and vegetation index data. Landfire land cover products were crosswalked to the national GAP data layer in states lacking a state or regional GAP effort, including Arkansas, Louisiana, Texas, Oklahoma, and Missouri in the GCPO geography. We first resampled the GAP data layer to 250 m resolution using a nearest neighbor algorithm. We then used the reclassify function in ArcGIS to extract 43 forested wetland classes defined in the USFWS/NatureServe broadly-defined habitat specification for forested wetland systems in the GCPO geography, and supplemented with other classes where we felt appropriate classes may have been excluded from BDH consideration (**Table FW.2**). We then extracted the GAP forested wetland classes through the 2011 forest mask to account for any potential losses that may have happened in the decade since GAP was developed and provide a consistent comparison to the other forested wetland options.

Table FW.2. GAP Analysis Program forested wetland land cover classes by acreage in the GCPO geography as defined by the USFWS/NatureServe guide to broadly-defined habitats and supplemented as needed.

GAP Ecological System	Acres
East Gulf Coastal Plain Small Stream and River Floodplain Forest	4,680,514
West Gulf Coastal Plain Small Stream and River Forest	3,278,630
Mississippi River Floodplain and Riparian Forest	3,078,138
East Gulf Coastal Plain Large River Floodplain Forest - Forest Modifier	2,028,790
Southern Coastal Plain Blackwater River Floodplain Forest	1,823,578
Mississippi River Low Floodplain (Bottomland) Forest	1,292,705
West Gulf Coastal Plain Large River Floodplain Forest	1,101,987
Gulf and Atlantic Coastal Plain Swamp Systems	959,544
Central Interior and Appalachian Floodplain Systems	426,315
Lower Mississippi River Flatwoods	251,234
Red River Large Floodplain Forest	161,944
Southern Coastal Plain Nonriverine Cypress Dome	138,263
Southern Coastal Plain Nonriverine Basin Swamp	135,906
Mississippi River Riparian Forest	135,236

Mississippi River Bottomland Depression	124,872
West Gulf Coastal Plain Nonriverine Wet Hardwood Flatwoods	120,699
Central Interior and Appalachian Riparian Systems	98,803
Southern Coastal Plain Hydric Hammock	96,358
Lower Mississippi River Bottomland Depressions - Forest Modifier	82,839
Western Great Plains Floodplain Systems	66,433
South-Central Interior Small Stream and Riparian	55,768
East Gulf Coastal Plain Tidal Wooded Swamp	47,641
South-Central Interior Large Floodplain - Forest Modifier	46,509
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	23,059
Southeastern Great Plains Floodplain Forest	21,920
Southern Piedmont Small Floodplain and Riparian Forest	21,842
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak Dominated Modifier	21,786
South-Central Interior Large Floodplain	21,590
North-Central Interior Wet Flatwoods	7,223
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/ Nyssa Modifier	4,390
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	4,105
Ozark-Ouachita Riparian	3,218
West Gulf Coastal Plain Seepage Swamp and Baygall	2,702
North-Central Interior and Appalachian Rich Swamp	2,078
Southern Coastal Plain Seepage Swamp and Baygall	1,855
Cumberland Riverscour	1,144
Atlantic Coastal Plain Clay-Based Carolina Bay Forested Wetland	896
Southern Piedmont Large Floodplain Forest - Forest Modifier	636
Western Great Plains Wooded Draw and Ravine	574
Atlantic Coastal Plain Peatland Pocosin	327
West Gulf Coastal Plain Near-Coast Large River Swamp	265
Southeastern Great Plains Riparian Forest	178
Tamaulipan Riparian Systems	6

Alternative 4: Composite approach

We compared products of alternatives 1-3 by calculating acreages and examining each alternative against aerial imagery. Alternatives 1-3 provided widely varying estimates of acreage, with the IF approach (alternative 1) appearing to produce the most conservative and NLCD approach (alternative 2) producing the most liberal estimates of forested wetland acres (**Table FW.3**). Assessment against aerial imagery also revealed substantial differences in spatial distribution in forested wetland classification among the 3 alternatives with no layer clearly improving upon the other. After extensive consideration the apparent best approach was to use areas of agreement across layers as a basis for forested wetlands in the GCPO geography. We used map algebra to create two composite layers for evaluation. One being the more conservative analysis where all 3 layers were required to be in agreement, and the second a more liberal analysis requiring only 2 layers be in agreement to be deemed a forested wetland pixel. Being restrictive to only areas where all 3 data layers were in agreement resulted in estimates much lower than the conservative IF-based alternative, and spatial distribution failing to capture large areas of forested wetland.

However, when compared against aerial imagery it was evident that restricting forested wetland analysis to areas where 2 or more data layers were in agreement was a better option. In this approach we overlaid the GAP, NLCD, and IF- derived forested wetland datasets, each with an associated score of 1, then used map algebra to calculate a composite score, and reclassified all pixels summing to 2 or 3 as forested wetland pixels. Note there is potential for compounding

errors in this composite approach, but comparisons against aerial imagery far surpassed any of the alternative approaches independently. Using this composite approach of 2 or more layer agreement, we estimate 4.6 million acres of forested wetlands exist in the MAV subgeography, and 12.9 million acres in the entire GCPO geography exists in any condition (**Table FW.3**).

We used the composite forested wetland layer throughout the remaining assessment below as a baseline forested wetland mask in which each target landscape endpoint was assessed (**Figure FW.1**). In the final section of this report we summarize acreage of forested wetlands estimated to be in or near the desired ecological state as defined by the GCPO science agenda.

Table FW3. Estimate acreage comparisons for forested wetlands in the GCPO subgeographies as defined in alternatives 1-4 described above.

	Acres forested wetland				
	IF >10%	**GAP/Landfire**	**NLCD woody wetland**	**GAP+NLCD+IF (3 agreement)**	**GAP+NLCD+IF (>2 agreement)**
Mississippi Alluvial Valley	**3,454,716**	**4,517,561**	**5,295,387**	**1,783,034**	**4,634,766**
East Gulf Coastal Plain	1,582,863	5,795,481	6,643,206	778,783	3,756,848
West Gulf Coastal Plain	1,458,585	3,716,462	5,578,600	622,643	3,010,544
Ozark Highlands	645,578	149,900	246,395	24,093	111,197
Gulf Coast	589,763	1,411,696	2,234,541	504,496	1,392,314
Gulf Coastal Plains and Ozarks (full extent)	7,731,504	15,591,100	19,998,128	3,713,049	12,905,669

Figure FW.1. GCPO forested wetland composite based from overlays of forests with inundation frequency >10%, NLCD woody wetland class, and GAP forested wetland classes. This product represents where 2 or more data layers indicated forested wetland per pixel, and was used as the forested wetland mask throughout the remainder of the assessment.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Composite GCPO LCC Forested Wetlands (NLCD/IF/GAP) -GCPO geography (raster)
- GCPO LCC Floodplain Inundation Frequency (raster)

Technical References

Allen, Y. *In press.* Landscape scale assessment of floodplain inundation frequency using Landsat imagery. River Research and Applications.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U. S. Terrestrial Systems. Arlington, Virginia: NatureServe.

Jin, S., L. Yang, P. Danielson, C. Homer, J. Fry, and G. Xian. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment 132: 159 - 175.

LMVJV Forest Resource Conservation Working Group. 2007. Restoration, management, and monitoring of forest resources in the Mississippi Alluvial Valley: recommendations for enhancing wildlife habitat. R. Wilson, K. Ribbeck, S. King, and D. Twedt, editors. Lower Mississippi Valley Joint Venture.

Mitchell, M., R. R. Wilson, D. J. Twedt, A. E. Mini. *In review.* Object-based forest classification to facility landscape-scale conservation in the Mississippi Alluvial Valley.

U.S. Fish and Wildlife Service [USFWS]. 2014. National Wetlands Inventory. <http://www.fws.gov/wetlands/index.html> Accessed 23 May 2014.

Twedt, D., D. Pashley, C. Hunter, A. Mueller, C. Brown, and B. Ford. 1999. Partners in Flight Bird Conservation Plan for the Mississippi Alluvial Valley (Physiographic Area #05). Version 1.0. Partners In Flight. < http://www.partnersinflight.org/bcps/plan/MAV_plan.html>

US Geological Survey, Gap Analysis Program (GAP). May 2011. National Land Cover, Version 2. < http://gapanalysis.usgs.gov/gaplandcover/data/ > accessed 24 September 2014.

Ecological System: **Forested Wetlands**

Landscape Attribute: *Configuration*

Desired Landscape Endpoint: Local landscapes (≥10,000 ac) extensively forested (70-100% forested)

Management of forested wetland systems in the MAV must be approached at different scales and with forest configuration in mind, as different species occupying forested wetlands will respond in different ways to forest patch size and configuration in addition to site-level differences in forest condition. Desired forest stand conditions in MAV bottomlands suggest forested wetland species needs will be better met in "local landscapes (≥10,000 ac) that are extensively (70-100%) forested" in a matrix of large blocks of contiguous forest (bottomland and upland) and closely associated smaller forest fragments" (LMVJV Forest Resource Conservation Working Group 2007). Forested wetland species are assumed to respond to the forest in its entirety, thus the hypothesis is that forested wetland patches situated in a large forest block would promote wildlife populations better than isolated forested wetlands in an inhospitable landscape matrix.

Data Sources and Processing Methods

Under the premise that species will respond more favorably to forested wetland patches in a larger, predominantly forested matrix, we sought to assess the entirety of the forested landscape by using the 250 m resolution mosaic of 2011 National Land Cover Database (NLCD) forest classifications (Jin et al. 2013) and the LMVJV Mississippi Alluvial Valley 2011 forest classification layer (Mitchell et al. in review) described earlier. We conducted a neighborhood analysis using a 10,440 ac rectangular moving window (26x26 - 250m^2 pixels) to calculate mean forest cover across the "local" landscape. We then reclassified neighborhood analysis outputs, assigning pixels with mean values ≥0.7 a value of 1 and all other values a 0, then calculated forested acreage within the MAV and other GCPO subgeographies based on the number of forested pixels ≥0.7 within the geographic extent. We constructed percent forested area by dividing acreage of extensive forest cover by total acreage within each geographic extent.

Summary of Findings

Our analysis suggests over 3.5 million acres (14%) of the MAV consists of extensively forested land with ≥70% forest cover when assessed across a ~10,000 ac local landscape (**Table FW.4**). The MAV exhibits the least extensively forested subgeography, with the remaining subgeographies ranging between 21-35% of local landscapes considered extensively forested. At this scale, areas of extensive forest cover include forested wetlands of the Atchafalaya Basin, areas within and surrounding White and Cache River National Wildlife Refuges in Arkansas, Delta National Forest in Mississippi and several other land holdings throughout areas of the MAV (**Figure FW.2**).

Table FW.4. Acreage of extensive forest cover (>70%) present in local (≥10,000 ac) landscapes and percent of total landscape area with extensive forest cover in the Mississippi Alluvial Valley and other LCC subgeographies calculated from the mosaic of 2011 Lower Mississippi Valley Joint Venture MAV forest classification and 2011 National Land Cover Database (NLCD) (deciduous, evergreen and mixed forest and woody wetlands classifications).

Geographic extent	Acres	% total area
Mississippi Alluvial Valley	**3,520,353**	**14%**
East Gulf Coastal Plain	12,764,430	21%
West Gulf Coastal Plain	16,182,380	31%
Ozark Highlands	11,624,030	35%
Gulf Coast	1,621,365	27%
Gulf Coastal Plains and Ozarks (full extent)	45,712,555	25%

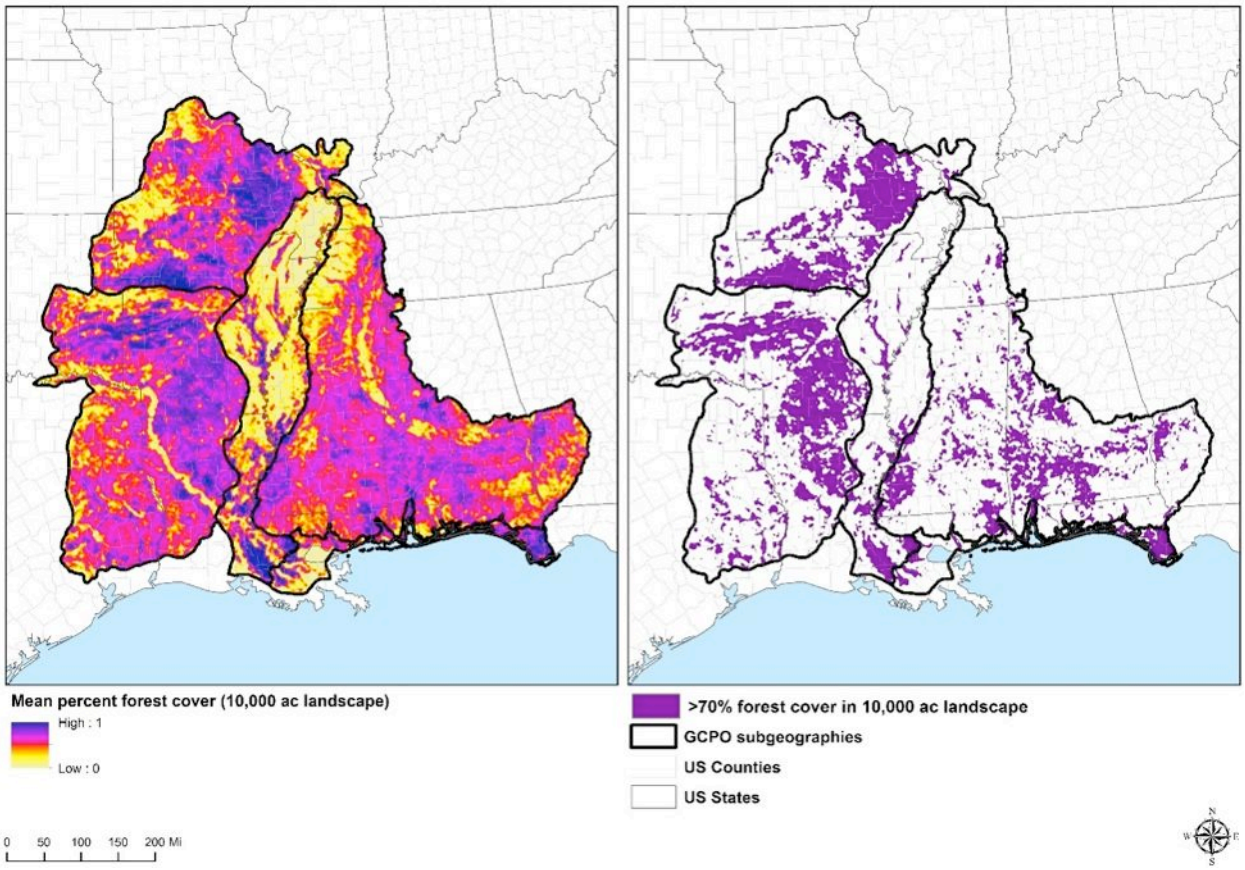

Figure FW.2. Areas of extensive (>70%) forest cover within local ((≥10,000 ac) landscapes in each GCPO subgeography derived from the mosaic of 2011 NLCD forest classes and 2011 LMVJV MAV forest classification.

Future Directions and Limitations

Wildlife habitat objectives in MAV forested wetland systems include targeting "local landscapes of >10,000 acre that are extensively forested in a matrix of large blocks and closely associated smaller fragments" (LMVJV Forest Resource Conservation Working Group 2007). From within the extensively forested area it is hypothesized that 35-50% of that forest area should meet desired structural targets (e.g., basal area, canopy cover, etc.) at any given point in time to meet wildlife habitat objectives in the MAV. This assessment component provides the coarse (10,000 ac) baseline information of extensive forested areas in the MAV and GCPO. We assume NLCD

and LMVJV forest classification are accurate in delineating forest (Wickham et al. 2013, Mitchell et al. in review). We also acknowledge that a large moving window such as demonstrated here may be problematic when evaluating long and linear forested wetland configurations which are prevalent features of the landscape in the MAV subgeography. We also assume 10,000 acre is representative of a local landscape for priority species outlined in the draft Integrated Science Agenda. It is likely that a 10,000 acre landscape will be sufficient for several priority species and may be much larger than necessary for species exhibiting limited dispersal and small home range sizes. However, some species like Louisiana Black Bear and other bird species may respond to a greater scale than 10,000 acres during parts of their annual cycle. The subsequent assessment of draft Science Agenda species endpoints as they relate to habitat characteristics will provide insight on the variability of species perception of "local" landscape.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Extensive (>70%) Forest Cover in 10,000 ac (raster)

Technical References

Jin, S., L. Yang, P. Danielson, C. Homer, J. Fry, and G. Xian. 2013. A comprehensive change detection method for updating the National Land Cover Database to circa 2011. Remote Sensing of Environment 132:159-175.

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Wickham, J. D., S. V. Stehman, L. Gass, J. Dewitz, J. A. Fry, T. G. Wade. 2013. Accuracy assessment of NLCD 2006 land cover and impervious surface. Remote Sensing of Environment 130:294-304.

Chapter 2: Configuration, large contiguous patches of forest

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Configuration*

Desired Landscape Endpoint: Large contiguous patches of forest

- 13 patches > 100,000 ac
- 36 patches > 20,000 ac
- 52 patches > 10,000 ac

Maintaining the premise that species respond with greater favor to forested wetlands in a larger forested matrix, this ISA endpoint relates to size of forest patches within which the forested wetland system resides. Similar to the forest composition endpoint above, the patch size endpoint was also derived from the PIF MAV Bird Conservation Plan and targeted toward breeding songbird objectives: 101 total forest patches with 13 patches >100,000 acres, 36 patches >20,000 acres, and 52 patches >10,000 acres in size. These objectives assume silvicolous birds were reliant on forest cores of >5,200 acres for sustainable populations (Twedt et al. 1999), with overlapping needs by other priority species such as black bear and Rafinesque's big-eared bats (*Corynorhinus rafinesquii*).

Data Sources and Processing Methods

We again assessed the entirety of the forested landscape using the 250 m resolution mosaic of 2011 LMVJV forest classification combined with 2011 National Land Cover Database (NLCD) forest classifications described above. However the objective here was to assess of number and size of patches of contiguous forest land meeting criteria for Integrated Science Agenda target acreage in the MAV. To assess patch size we first clipped the forest classification raster layer to a 10 km buffer around the GCPO geography, then converted pixels to non-simplified polygons. We then ran an aggregate polygon function in ArcGIS, aggregating all polygons within 250 m (i.e., grouping adjacent and diagonal pixels into a single polygon). To restrict our assessment to solely patches within the MAV subgeography we first clipped forest patches down to the MAV boundary, then recalculated acreage of aggregated polygons and selected out contiguous forest patches within the >100,000, >20,000, and >10,000 acres. We did not assess forest patches outside of the MAV for this section of the assessment due to complexities in patch delineation in the heavily-forested matrix in the East and West Gulf Coastal Plain, Ozark Highland, and Gulf Coast subgeographies. However patches >10,000 ac across the entire GCPO geography were included in the assessment compiling all endpoints into a Condition Index Value for use in the GCPO LCC Conservation Blueprint.

Summary of Findings

Using these methods we estimated the MAV subgeography to have 11 existing patches of "contiguous" (i.e., within 250 m) forest cover >100,000 acres in size, with the largest single patch found in the Atchafalaya Basin (~1.03 million acres) in southern Louisiana and presumably comprised primarily of forested wetlands (**Table FW.5**). A second large forest patch (~996,000 acres) can be found in the eastern Arkansas, primarily comprised of lands within and adjacent to the White and Cache River National Wildlife Refuges (**Figure FW.3**). Of the 4.6 million acres of forest land estimated in > 100,000 acre patches, 998,214 acres (22%) is currently protected conservation lands under state, federal or non-profit jurisdiction according to the GAP Analysis Project Protected Areas Database (GAP status 1-3).

We estimated the MAV to have 31 forest patches 20,000 to 100,000 acres in size, with 7 of those patches ~ 50,000 acres. This sums to a total of 42 patches >20,000 acres in the MAV. Of the 1.2 million acres of forest land estimated in patches between 20,000 and 100,000 acres in size about 21% is currently protected conservation lands (**Table FW.5**). We estimated 35 additional forest patches from 10,000 to 20,000 acres in size within the MAV, with about 16% of the 469,778 acre of forest land in this patch size range found in existing protected areas (**Table FW.5**).

The cumulative number of forest patches >10,000 acres is therefore 77, with an estimated total of 6.32 million acres forested (wetland and upland) land in patches >10,000 acres. Our estimates of large forest patches in the MAV are greater than an assessment based from 1992

thematic imagery, which found 6 patches of forest cover >100,000 ac (Twedt and Loesch 1999). However patch delineation outputs depend greatly on resolution and patch aggregation technique, which differed in this assessment from Twedt and Loesch 1999). Though the present estimate of contiguous forest patches >100,000, falls short of the target of 13 patches outlined in the ISA, estimated numbers of forest patches >10,000 (n=77) and >20,000 (n=42) acres surpass suggested ISA targets and proximity of large forest patches provide ample potential for targeted corridor management to connect patches.

Table FW.5. Estimated number of forested patches, and cumulative acres (total and protected) within each forest patch size range in the Mississippi Alluvial Valley subgeography of the GCPO LCC calculated from the mosaic of Lower Mississippi Valley Joint Venture 2011 forest classification and 2011 National Land Cover Database (NLCD) forest classes.

Patch size range (acres)	Observed no. patches	Target no. patches	Cumulative patch acres	Cumulative patch acres protected
10,000 – 20,000	35	52	469,778	76,235
20,000 – 100,000	31	36	1,237,990	261,805
> 100,000	11	13	4,608,245	998,214

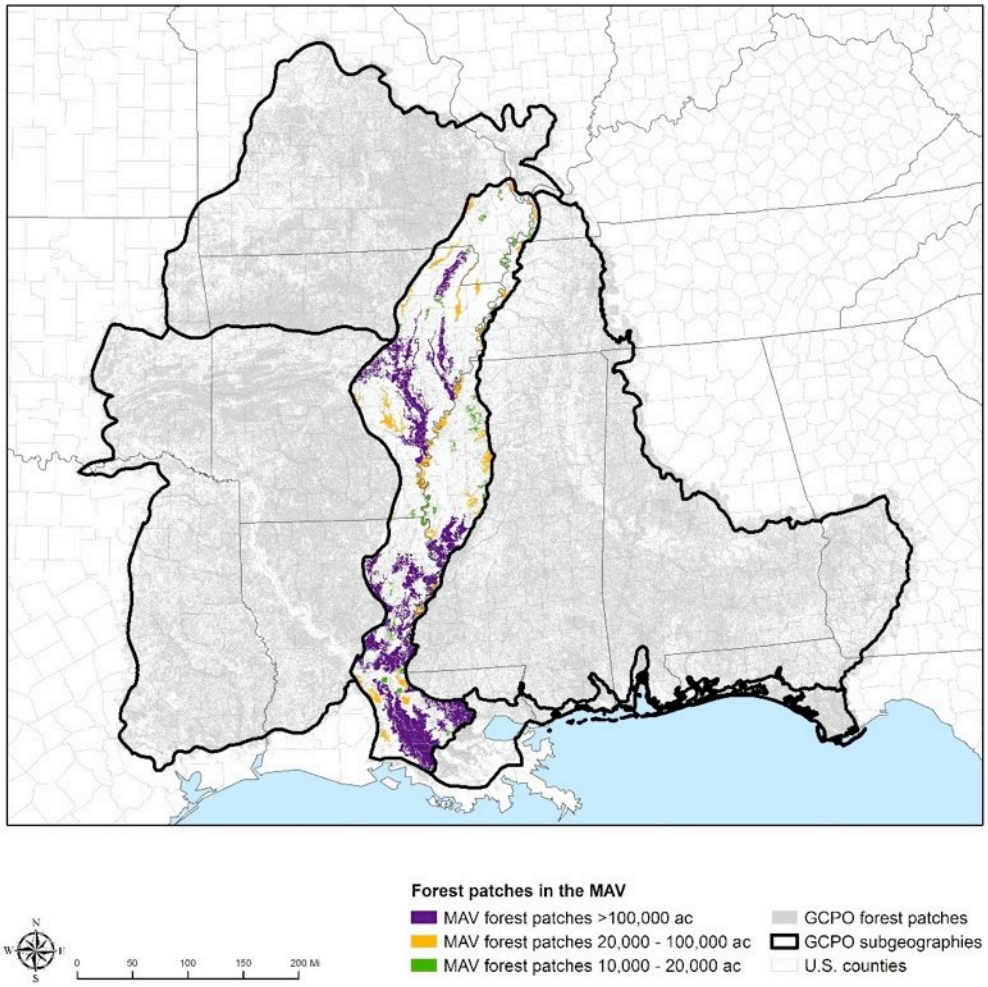

Figure FW.3. Forest patches from 10,000-20,000 acres, 20,000-100,000 acres, and >100,000 acres based on a mosaic of LMVJV forest classification and NLCD 2011 forest classes in the Mississippi Alluvial Valley subgeography of the GCPO LCC geography.

Future Directions and Limitations

Delineation of forest patches through large-scale remote sensing techniques appeared to be successful in the MAV landscape where forest cover is not the dominant matrix in many areas. However, this assessment carries the implicit assumption that the NLCD and LMVJV forest classification mosaic is accurate at delineating forest cover (Wickham et al. 2013, Mitchell et al. in review). We also assume that forest patch delineation measures taken here accurately represent the condition of "contiguous" forest cover outlined in the Integrated Science Agenda, which likely varies depending on perceived barriers of different priority wildlife species. Patches delineated along MAV subgeography boundaries should be used cautiously as they may be a component of a larger neighboring forest patch in other LCC subgeographies.

Forest patch criteria outlined in the LCC Science Agenda were derived from estimated minimum, mid-level, and high-level size criteria for forest breeding birds in the MAV (Mueller et al. 2000) that were integrated into the Partners in Flight Bird Conservation Plan for the MAV (Twedt et al. 1999) and adopted by the Lower Mississippi Valley Joint Venture Forest Resource Conservation Working Group (2007). It is thought that these bird-based objectives overlap

broadly with other taxa (e.g., bats of special concern, black bears), and conservation design efforts in the MAV target similar forest areas for multiple taxa (LMVJV Forest Resource Conservation Working Group (2007) and comprehensively (AR-MAV CDN 2012, LA-MS CDN 2013). However, future assessment of forest patch size needs of other taxa are necessary before these standards can be broadly applied. Further understanding is necessary to determine the exact relationship between forested wetland wildlife species and both patch size of forested wetland habitats and all forest. It is presumed here that forested wetland species outlined in the ISA will be more successful if their preferred habitat were situated within a hospitable larger forested patch, as opposed to an isolated forested wetland patch situated within an inhospitable matrix. Further assessment of priority species relationships to landscape configuration is warranted to address this question at the MAV scale.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Forest Patches in Mississippi Alluvial Valley subgeography (vector – polygon)

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Chapter 3: Condition, overstory canopy cover

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Overstory canopy cover: 60-70% (forested wetland)

The remaining landscape endpoints targeting the forested wetland desired ecological state outlined in the ISA relate to forest stand condition (structure and composition) within forested wetland systems. This includes targeting 60-70% overstory canopy cover (in addition to other structure and composition endpoints) in mature forested wetlands. These targets were suggested to promote biological and structural diversity within bottomland forest, providing for a heterogeneous distribution of canopy cover and resulting in a layered vertical structure where gaps are present (LMVJV Forest Resource Conservation Working Group 2007). Canopy gaps and the vertical understory structure that results have been a suggested habitat preference for several ISA-identified priority species including cerulean warbler (*Setophaga cerulea*) (e.g., Hamel 2000, Wood et al. 2006), Swainson's warbler (e.g., Graves 2002, Somershoe et al. 2003,) during parts of their annual cycle. However canopy gaps should be limited, with canopy reduction to no less than 50% canopy cover to provide vertical and herbaceous understory structure but maintain the integrity of the bottomland system (LMVJV Forest Resource Conservation Working Group 2007).

Data Sources and Processing Methods

We used the 2011 National Land Cover Database (NLCD) U.S. Forest Service Tree Canopy (analytical) product (USDA Forest Service Remote Sensing Applications Center 2014) combined with the forested wetland mask derived above for assessment of overstory canopy cover within forested wetlands in the Mississippi Alluvial Valley (MAV) and other GCPO subgeographies. The USFS forest canopy layer contains values representing the unmasked proportion of each 30x30m pixel covered by tree canopy (0 to 100%) produced using random forest regression algorithms (Breiman 2001, Cutler et al. 2007). To align with resolution of the forested wetland mask we sought to generate an average proportion of tree canopy cover across 30 m pixels within each 250 m forested wetland cell in the GCPO geography. To calculate average canopy cover we first aggregated 30 m canopy cover cells to 240 m using a mean function and a cell factor of 8 (the aggregate function in ArcGIS only allows for cell factor aggregation, not aggregation to a desired pixel size, whereas the resample function in ArcGIS does not allow for calculation of averages over the resampled cell size). We then resampled the 240 m cell aggregate to 250 m resolution using a nearest neighbor algorithm. This produced an approximation of the average tree canopy cover within each 250 m forested wetland pixel. We next reclassified the average tree canopy layer (0-60% = 0; 60-70% = 1; 70-100% = 0) to identify 250 m cells with 60-70% forest canopy cover. We also reclassified to extract cells with >70% canopy cover for comparison. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we used zonal statistics in ArcGIS to calculate the proportional area (acres forested wetland (60-70 ft^2/ac basal area)/acres HUC 12) within each HUC 12 watershed. We also used the same aggregation and resampling technique to assess average standard error (ranging from 0-46%) of the NLCD tree canopy cover product in GCPO forested wetlands. Standard error on the NLCD tree canopy analytical product represents model uncertainty associated with each tree canopy cover pixel, and is calculated using the estimated variance on canopy cover from the random forest regression analysis. Pixel-level standard error measures are available as the second band of the NLCD tree canopy analytical product.

Summary of Findings

Forested wetlands with 60-70% tree canopy cover were sparse in the MAV and throughout the GCPO geography, with 265,298 forested wetland acres in the MAV subgeography within the target tree canopy range (**Table FW.6**). This represents less than 6% of the total MAV forested wetland acreage (as determined by the forested wetland mask described above), whereas 74% of forested wetlands in the MAV geography exhibited canopy cover >70%. Pixels within the forested wetland canopy target were distributed throughout forested wetlands in the MAV, but were found in greatest proportion in areas of the lower MAV, particularly within the lower portions of the Atchafalaya Basin, but also in areas near the Mississippi River in eastern Louisiana and western Mississippi in and around the Red River, Three Rivers and Grassy Lakes Wildlife Management Areas in Louisiana (**Figure FW.4**). However many of these areas also demonstrate a large proportion of forested wetlands containing >70% canopy cover as well (**Figure FW.5**). Forested wetland pixels within the target 60-70% canopy cover range in the MAV exhibited a mean standard error of 18.5% (range 6.3-39.5), whereas forested wetlands exhibiting >70% canopy cover exhibited less uncertainty, with a mean standard error of 8.8% (range 0.28-34.2) in the MAV. Of the 265,298 acres of forested wetlands in the MAV meeting the target landscape endpoint of 60-70% canopy cover, 13% (34,935 acres) are currently under permanent state, federal or other protection (GAP status 1-3), whereas 28% (974,722 acres) of the 3.4 million acres of forested wetlands with >70% canopy cover, are protected. These acres represent possible opportunities for forest management within existing protected lands to meet desired targets.

Table FW.6. Forested wetland acres with 60-70% and >70% tree canopy cover and mean and range of standard error estimates within each GCPO subgeography, calculated from the 2011 National Land Cover Database (NLCD) USFS Tree Canopy analytical product extracted through the forested wetland mask.

Geographic extent	60-70% canopy cover (acres)	Mean SE (range)	>70% canopy cover (acres)	Mean SE (range)
Mississippi Alluvial Valley	265,298	18.5 (6.3 – 39.5)	3,437,542	8.8 (0.3 – 34.2)
East Gulf Coastal Plain	229,870	18.5 (6.6 – 35.1)	3,093,618	9.4 (0.5 – 33)
West Gulf Coastal Plain	149,313	18.4 (6.6 – 37.7)	2,577,461	7.9 (0.4 – 34.9)
Ozark Highlands	12,633	17.9 (10.3 – 29.8)	41,992	15.1 (3.4 – 25.5)
Gulf Coast	112,541	25.1 (8.7 – 39.7)	1,107,464	15.7 (0.7 – 35.8)
Gulf Coastal Plains and Ozarks (full extent)	769,655	19.5 (6.3 – 39.7)	10,258,077	9.5 (0.3 – 35.8)

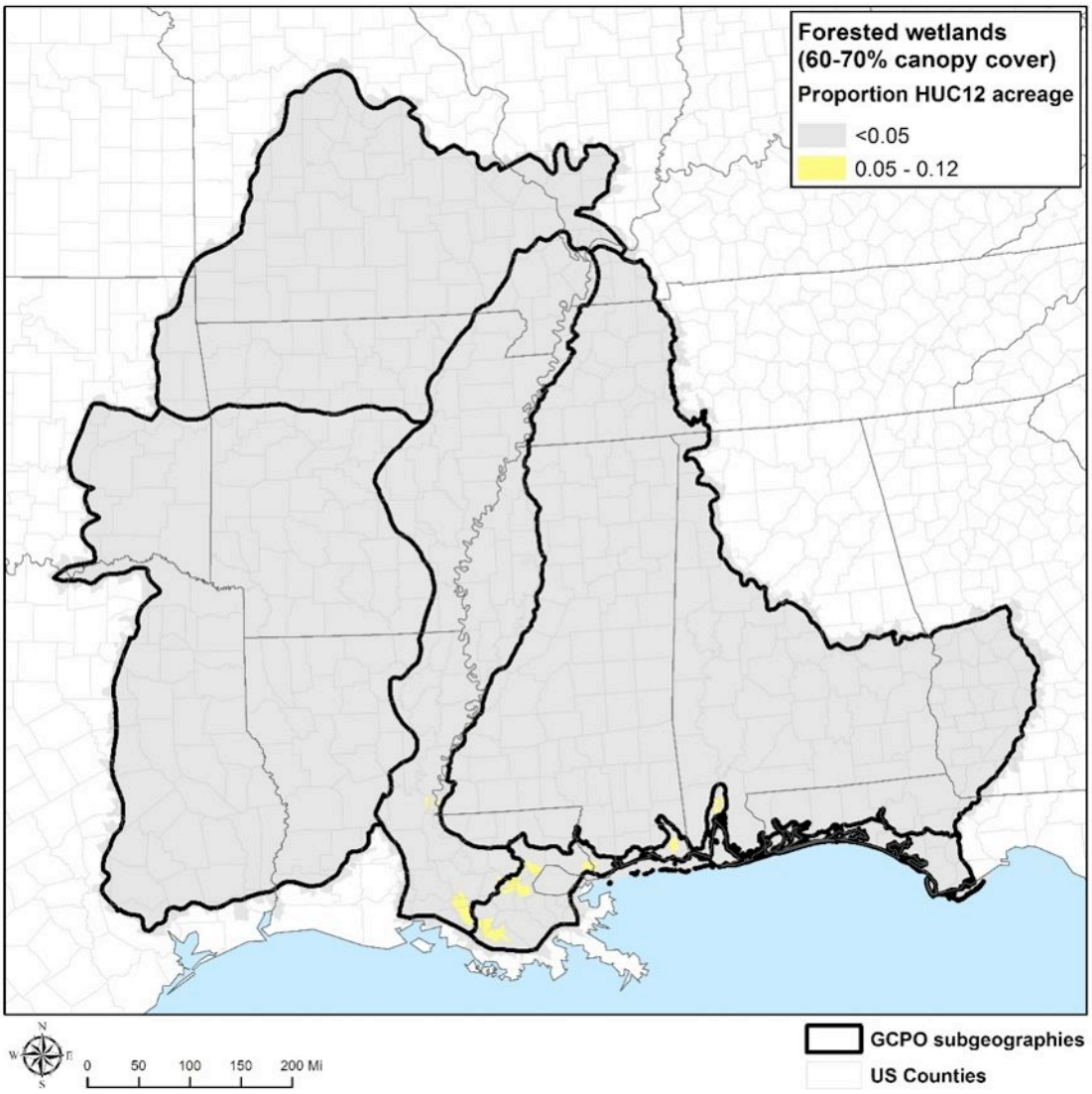

Figure FW.4. Proportional coverage of forested wetland acres with 60-70% forest canopy cover normalized by acres within each HUC 12 watershed in the Mississippi Alluvial Valley subgeography and across the entire GCPO LCC geography.

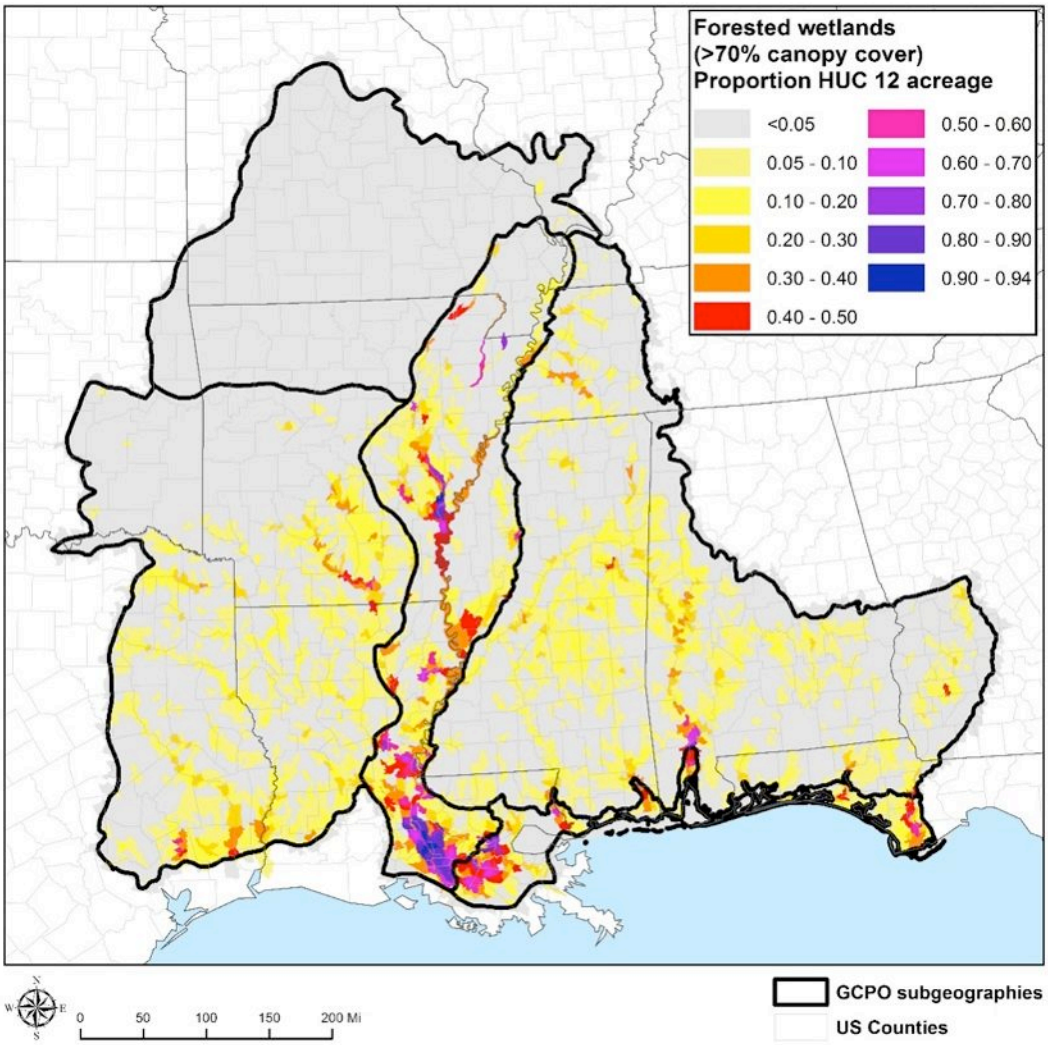

Figure FW.5. Proportional coverage of forested wetland acres with >70% forest canopy cover (i.e., opportunities for management) normalized by acres within each HUC 12 watershed in the Mississippi Alluvial Valley subgeography and across the entire GCPO LCC geography.

Future Directions and Limitations

The target landscape endpoint of 60-70% forest canopy cover is derived from recommended stand conditions for bottomland hardwood forests in the MAV (LMVJV Forest Resource Conservation Working Group 2007). These targets were suggested to promote biological and structural diversity within bottomland forest stands. Targeted stand conditions to promote complex forest structure for forest interior wildlife include a heterogeneous forest canopy with ample gaps and layered vertical structure. The results of this assessment support the premise that these heterogeneous canopy conditions are limited throughout the GCPO.

In addition to assuming the forested wetland mask accurately classifies GCPO forested wetlands (e.g., NLCD accuracy assessment in Hollister et al. 2004), this assessment relies on the assumption that tree canopy cover estimates using regression algorithms for the 60-70% canopy range are calculated with little bias. It is evident that standard error estimates for

forested wetland pixels within the target 60-70% canopy cover have a higher degree of uncertainty compared to pixels with >70% cover, though sample size for estimation of means is not consistent. Nonetheless, an 18% standard error suggests uncertainty in canopy cover estimates is tolerable for the purposes of this assessment. A future direction could incorporate weights of uncertainty into canopy estimation within the 60-70% range. A potential alternative to use of NLCD 2011 tree canopy cover data is to assess LANDFIRE percent tree canopy (LANDFIRE 2013), which provides 10 percentile range estimates of forest canopy cover for pixels instead of unique pixel percentage estimates provided by the NLCD canopy layer. LANDFIRE forest canopy cover is part of the LANDFIRE fuels data group and is defined as the stand-level percent of tree canopy; it is also limited to LANDFIRE existing vegetation types of forest and woodland. However, it is unclear whether forested wetlands are included in this forested/woodland classification.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Forested Wetlands w/60-70% Canopy Cover (raster) (vector – polygon: proportion of HUC 12)

Technical References

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Chapter 4: Condition, midstory cover

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Midstory cover 25-40%

Recommendations for desired forest stand conditions for bottomland systems in the MAV include limited cover and layering of multi-dimensional canopies to promote forest structure and floristic diversity (LMVJV Forest Resources Working Group 2007). Limited presence of forest midstory provides added vertical structure and may increase biological diversity in MAV forested wetland systems. However wildlife associations with midstory forest structure depend on life history strategies and habitat needs of the species (e.g., Norris et al. 2009). Midstory in a forested wetland system may increase the prevalence of several midstory specialist bird species such as Carolina wren (*Thryothorus ludoci*), several Mimidae species, some Turdidae species, red-eyed (*Vireo olivaceus*), white-eyed (*V. griseus*), and yellow-throated (*V. flavifrons)* vireos, Kentucky (*Geothlypis formosa*) and hooded (*Setophaga citrina*) warblers, with all exhibiting midstory specialist tendencies (Dickson and Noble 1978) suggesting midstory may be an important element of biological diversity in the MAV. However management for midstory cover may come at the expense of species preferring closed canopy systems, such as the prothonotary warbler (*Protonotaria citrea*), which respond poorly to forest management that promotes vertical structure (Twedt et al. 2001, Heltzel and Leberg 2006). The ISA-defined endpoint targets 25 – 40% midstory cover to meet the needs of the suite of priority wildlife species in MAV forested wetland systems, and was derived from the set of desired conditions outlined by the LMVJV Forest Resource Conservation Working Group (2007) to create "floristic diversity within the forest midstory and understory".

Data Sources and Processing Methods

The standardized Forest Inventory and Analysis (FIA) national program, which collects data using standardized field protocols across counties in every state annually, may be the only landscape-scale data source feasible to investigate potential forest midstory in the absence of other large-scale data sources. However, FIA data plots may have limited application due to the largely non-forested matrix in the MAV. Though midstory is not defined specifically in any of the Phase 2 or 3 FIA database fields, FIA data provides some fields from which forest midstory characteristics could be extrapolated if plot representation were at appropriate scales in the MAV (Woudenberg et al. 2010). We used FIA-imputed data on midstory density (trees/ac) (USDA Forest Service Remote Sensing Applications Center [USFS], personal communication) extracted through the forested wetland mask as a proxy for assessment of forested wetland midstory cover within the MAV and other GCPO geographies. We assume that midstory density reflects midstory cover, though the direct relationship is not precisely defined. The USFS imputed midstory density data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the FIA program. Midstory density was calculated using FIA phase II fields where Crown Class Code = 5, which indicates trees that were "overtopped" and includes trees with crowns entirely below the primary canopy and receiving no direct light from above or from the sides (Woudenberg et al. 2010). This value was intersected with tree diameter values of 4.3-9.8" to better assess midstory-sized trees (and eliminate inclusion of shrub cover). The intersection of these two FIA data fields was then imputed to 250 m resolution using MODIS satellite imagery and other ancillary datasets. We used an extract by mask function in ArcGIS to delineate midstory density in forested wetlands, using the USFS imputed midstory density layer as input data and the forested wetland layer described above as a mask overlay. Once extracted, we binned the data into quantiles and used the second quantile of midstory density values to represent 20-40% of midstory density values as a

surrogate for 25-40% cover as defined in the endpoint. We reclassified the second quantile to a binary (0,1) data layer for assessment. We also reclassified the top 3 quantiles for comparison to assess midstory densities greater than the presumed target.

Summary of Findings

FIA-imputed midstory density measures as a proxy for midstory cover suggest greater acreage of forested wetlands may exhibit desired midstory cover than desired overstory canopy cover, with nearly 1.3 million acres (28%) of forested wetlands exhibiting 92-169 midstory trees/acre in the MAV subgeography (**Table FW.7**). Over 1.8 million acres (39%) of forested wetland exhibited midstory density greater than 169 trees/acre. Pixels within the 2nd quantile of midstory density values were distributed widely throughout forested wetlands in the MAV, but were found in greatest proportion in riparian areas near the White River in Arkansas and in the lower Atchafalaya Basin in Louisiana (**Figure FW.6**). However, similar to overstory canopy cover, many of these areas also demonstrate a large proportion of forested wetlands containing >169 midstory trees/acre as well, suggesting large bottomland systems offer mix of midstory cover availablity (**Figure FW.7**). Of the nearly 1.3 million acres of forested wetlands in the MAV with midstory density 92-169 trees/acre, 26% (328,727 acres) are currently under permanent state, federal or other protection (GAP status 1-3), whereas 29% (521,346 acres) of the 1.8 million acres of forested wetlands with >169 midstory trees/acre are protected and may present opportunities for midstory management.

Table FW.7. Forested wetland acres with 92-169 midstory trees/ac (TPA), representing the second quantile of midstory density estimates, or 20-40% of midstory density values (as a proxy for 25-40% midstory cover) imputed to GCPO subgeographies from plot-level Forest Inventory and Analysis data. This is compared to areas with midstory density presumably above the desired target (>40% of midstory density values).

Geographic extent	Acres midstory 92-169 TPA (2nd quantile)	Acres midstory 169-1,388 TPA (3rd- 5th quantile)
Mississippi Alluvial Valley	**1,286,337**	**1,802,123**
East Gulf Coastal Plain	663,215	2,748,937
West Gulf Coastal Plain	441,284	2,298,850
Ozark Highlands	25,421	48,278
Gulf Coast	294,874	751,370
Gulf Coastal Plains and Ozarks (full extent)	2,711,130	7,649,557

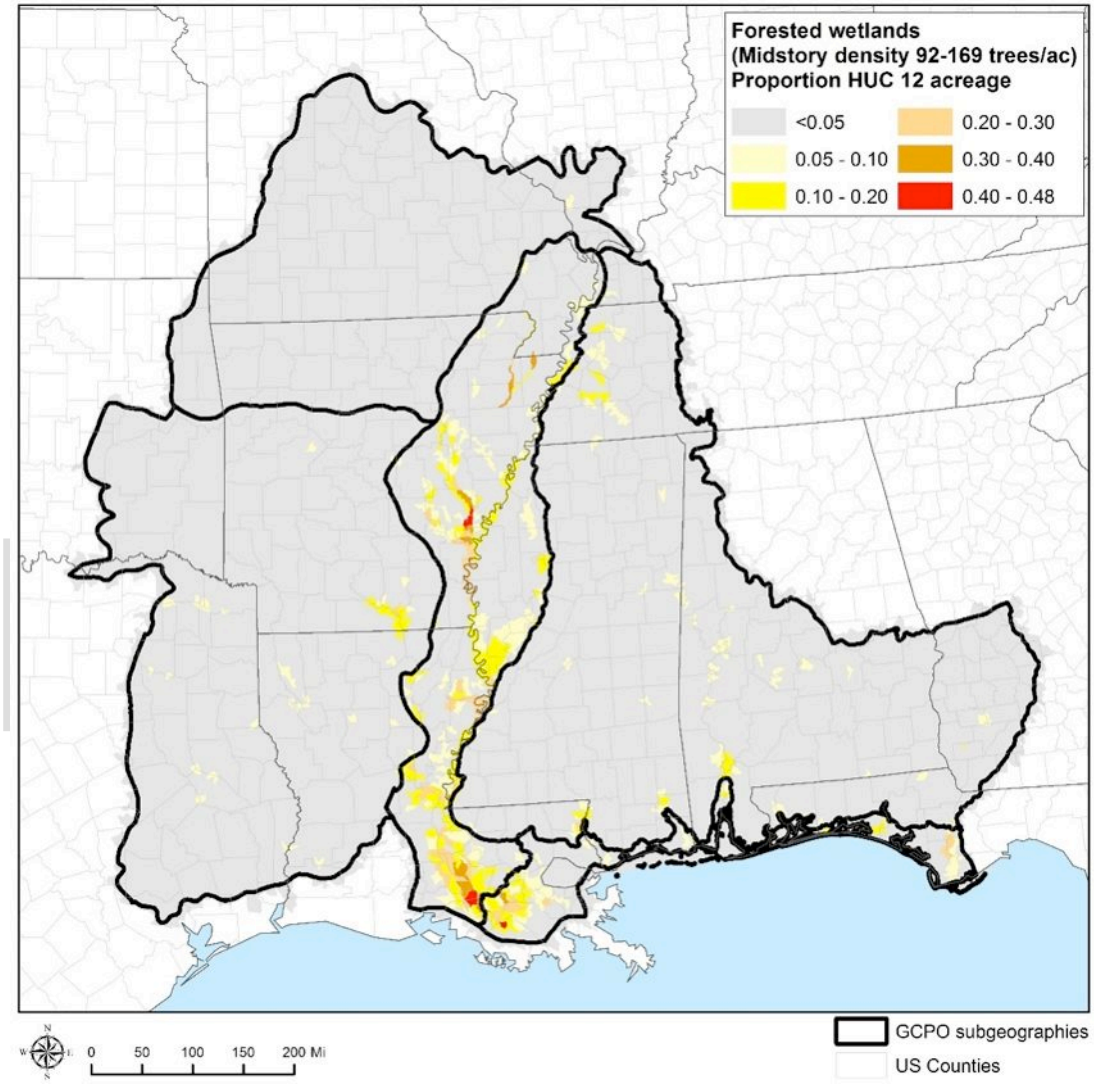

Figure FW.6. Proportional coverage of forested wetland acres with 92-169 midstory trees/acre (i.e., second quantile of midstory density values as proxy for 25-40% midstory cover) normalized by acres within each HUC 12 watershed in the Mississippi Alluvial Valley subgeography and across the entire GCPO LCC geography.

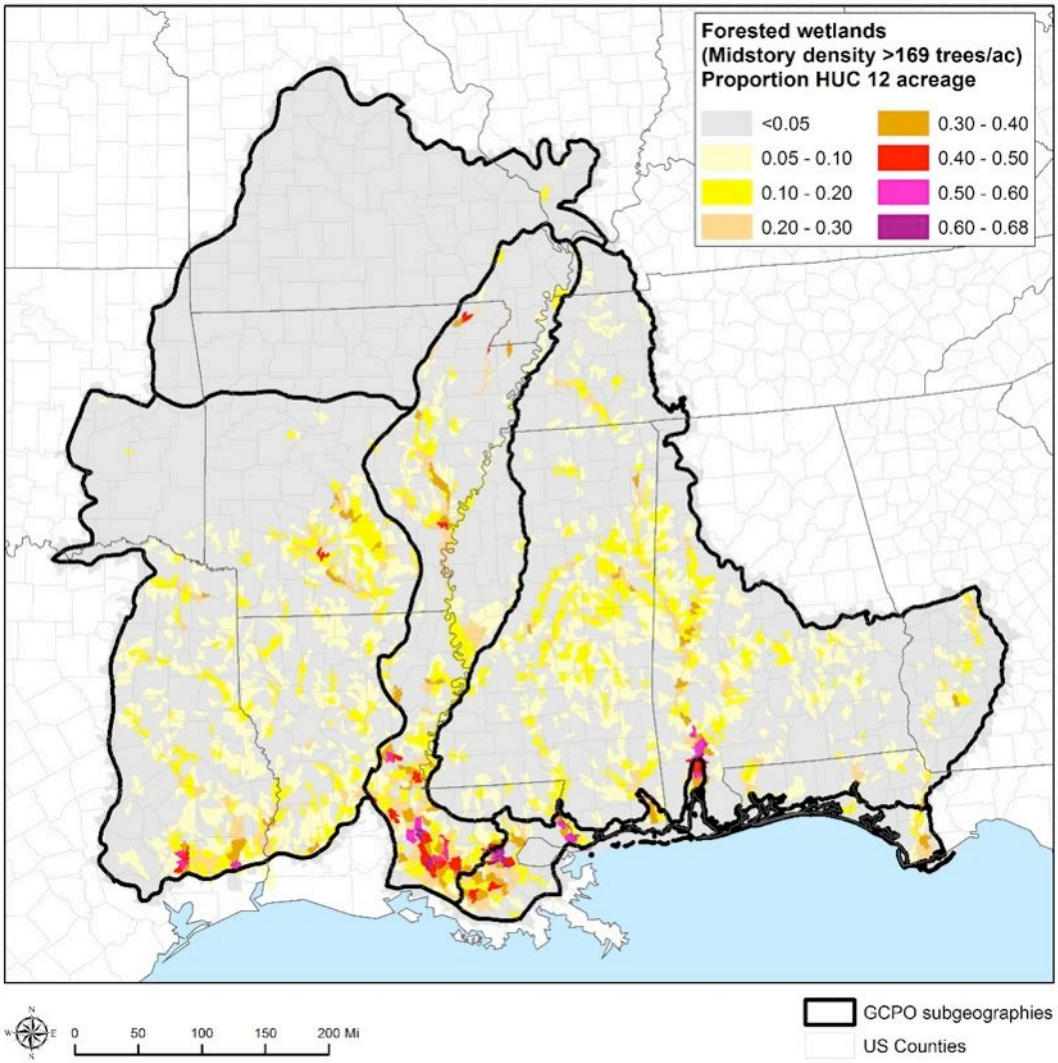

Figure FW.7. Proportional coverage of forested wetland acres with >169 midstory trees/ acre (i.e., opportunities for midstory management) normalized by acres within each HUC 12 watershed in the Mississippi Alluvial Valley subgeography and across the entire GCPO LCC geography.

Future Directions and Limitations

Though it is widely accepted that many wildlife species depend on a forest midstory to meet various life requisites, forest characteristics that define midstory are often poorly described and vary by system and geography. Improved clarity in defining forest midstory and species relationships with midstory structure in MAV forested wetland systems is needed in the GCPO LCC Integrated Science Agenda. Field measurements like crown class, height and diameter collected as part of forest inventories or research studies may provide the ability to quantify forest mid-story. However, difficulties assessing midstory structure across large spatial extents make assessments of wildlife associations with midstory habitat difficult beyond the site scale. Metrics of midstory cover and midstory density represent separate but related measures to characterize forest structure (e.g., Hedman et al. 2000). These measures are correlated, but reflect different aspects of midstory character. In this assessment we used available imputed data on midstory density as a proxy for assessing targeted measures of midstory cover. We

acknowledge that these metrics are likely highly correlated, but the direct relationship between quantiles of midstory density and proportion of midstory cover is not defined. Thus we encourage some caution when interpreting the results presented here relative to the defined ISA endpoint.

Advanced remote sensing capabilities like LiDAR have been shown to effectively delineate midstory canopy in forested systems and aid in assessment of wildlife species relationships with midstory cover where data is available (e.g., Hill and Broughton 2009, Lesak et al. 2011). Prediction of midstory cover using LiDAR could prove to be another promising and accurate option for wildlife studies (Martinuzzi et al. 2009), provided ubiquitous LiDAR coverage can be obtained across the GCPO geography in a timely manner. However, as stated in the following assessment of forest understory, LiDAR coverage at this scale may not be available for several more years in the GCPO.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Forested Wetlands w/92-169 trees/acre midstory density (raster) (vector – polygon: proportion of HUC 12)

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Chapter 5: Condition, understory cover

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Understory cover 25-40%

The GCPO ISA targets a range of understory cover between 25-40% as one of the suite of conditions required to meet the desired ecological state of MAV forested wetland systems. The understory endpoint was derived from recommendations to promote floristic and structural diversity within forested wetland stands through complex vertical forest structure (LMVJV Forest Resource Conservation Working Group 2007). Forest understory is an instrumental component of any forest ecosystem and its structure will determine presence or absence of many wildlife species (Suchar and Crookston 2010). Understory, and its influence on light, water and nutrient availability at the forest floor also plays an integral role in driving overstory regeneration and forest plant associations (Suchar and Crookston 2010). However, accessing spatially-explicit data on vertical structure below the primary forest canopy with remote sensing technologies is challenging. Evaluation of forest understory composition must therefore be conducted using either highly advanced remote sensing capabilities, such as LiDAR (e.g., Hill and Broughton 2009, Martinuzzi et al. 2009, Wing et al. 2012), by collecting field measurements at the plot level and imputing to a larger landscape, or by using a metric surrogate to represent understory cover. While many studies on wildlife-habitat associations quantify vegetative understory as one of a series of potential factors influencing habitat selection, they are often conducted at the site or multi-site scale using a variety of field protocols. This, combined with the difficulties associated with collecting understory vegetation data via remote sensing technologies, make assessments of wildlife associations with understory habitat challenging across a large landscape scale.

Data Sources and Processing Methods

The Forest Inventory and Analysis (FIA) program provides potential for assessment of forest understory with data collected using standardized field protocols across counties in every state annually, however it may have limited capacity in MAV forested systems due to the largely non-forested matrix throughout the geography. If FIA were to provide a representative sample of MAV forested systems, then there may be potential to parse out forest understory data by querying metrics related to tree diameter, crown height, and tree species from various tables in the FIA Phase 2 database (Woudenberg et al. 2010). However, this would require a time-intensive effort that would be susceptible to subjectivity in decision points regarding species, heights and diameters. Phase 3 FIA forest health plots also provide some information on understory trees by characterizing crown position (field CPOSCD value = 3 [Understory] in table TREE) on Phase 3 plots (Woudenberg et al. 2010). However, Phase 3 FIA forest health assessments that include understory vegetation structure and crown position metrics are only characterized on every 16th FIA plot (one plot per 96,000 acres) and data at these increments are too sparse to provide the landscape-level assessment that is necessary across the entire MAV and GCPO geographies. There is also uncertainty whether metrics on crown position of individual trees in the forest canopy combined with other metrics like crown width could be accurately applied to models of percent understory canopy cover at the plot level. This and other metrics have been tested using linear regression outside the GCPO geography with limited results (Suchar and Crookston 2010). Reliance on FIA-derived products may also exclude herbaceous understory cover such as forest grass and cane cover and cover of important soft mast producing vine and shrub species.

One potential surrogate for a forest understory metric is the USFS forest carbon stocks of the contiguous United States layer (Figure FW.5; Wilson et al. 2013a). To assess forest carbon Wilson et al. (2013b) used plot-level FIA data from 2000-2009 and a Phenological Gradient Nearest Neighbor method, which combines use of canonical correspondence analysis with k-nearest neighbor imputation, multi-season vegetation indices from 250 m resolution MODIS satellite imagery to derive phenology information, the mean monthly climate data from the Daymet climatological model, topographic data derived from Digital Elevation Models, and Omernik's Level III ecoregion data layers. Carbon source data were gathered from the FIA

database table COND fields CARBON_UNDERSTORY_AG and CARBON_UNDERSTORY_BG, which calculate tons/acre of carbon in seedlings, shrubs and bushes above and below ground at FIA subplots (Woudenberg et al. 2010). These estimates incorporate metrics of geographic area, FIA forest type and carbon density of live trees into carbon stock models to calculate per area carbon tonnage (Smith and Heath 2008). They then characterized forest carbon stocks (in Megagrams [Mg] per hectare [ha]) across a series of categories, including above- and below-ground live understory. In **Figure FW.8** we examine the potential for surrogacy of forest understory carbon stock assessment within GCPO forested wetlands by extracting the understory carbon stock layer through the forested wetland mask described above to produce a layer of understory carbon stock on GCPO forested wetland pixels. However we have no measure at this point for determining the relationship between understory carbon stock and percent understory cover so we did not include the carbon stock assessment in further compilation of landscape endpoints. We also evaluated LANDFIRE (2010) as a potential source of understory canopy cover, which has detailed breakdowns by percentage of tree, shrub, and herbaceous cover, but is limited in its ability to assess understory cover.

Summary of Findings, Future Directions and Limitations

Forest understory carbon stocks are similar across the MAV (typically <1-2 Mg/ha) and distinctly depauperate compared to the east and west gulf coastal plains regions within the GCPO geography. As would be expected, portions of the MAV subgeography where inundation frequency is typically greater show less understory carbon stock than bottomland draws in other parts of the GCPO geography. This is particularly evident in the major riverine floodplain areas such as the White River in Arkansas, Atchafalaya Basin in Louisiana, and forested wetlands areas around the Mississippi River (**Figure FW.8**). However, the relationship between forest understory carbon stocks and forest understory cover has yet to be developed in the MAV. Linking forest understory carbon stocks to estimates of forest understory cover may be possible through models incorporating measures of understory biomass and warrants further exploration (Muukkonen et al. 2006). Prediction of understory cover using LiDAR proves to be another promising and accurate option for wildlife studies (Martinuzzi et al. 2009, Wing et al. 2012), provided ubiquitous LiDAR coverage can be obtained across the GCPO geography. However, this will not likely occur in the near future as LiDAR is costly to obtain and available publicly in only a handful of areas in the GCPO LCC geography.

Desired forest stand conditions for bottomland systems in the MAV should encourage development of structural and species diversity in the forested wetland system, including promotion of limited habitat components for woody and herbaceous understory species (LMVJV Forest Resources Working Group 2007). Wildlife associations with understory forest structure depends on life history strategies and habitat needs of the species (exemplified in Norris et al. 2009). Species with preference for overstory-dominated forests with limited canopy gaps, such as prothonotary warbler (*Protonotaria citrea*) and acadian flycatcher (*Empidonax virescens*), respond poorly to bottomland forest management that increases prevalence of forest understory (Heltzel and Leberg 2006, Norris et al. 2009). However, other species respond favorably to added stratification of forest vertical structure and presence of a native understory in the MAV (Norris et al. 2009), particularly understory specialists like Swainson's (*Limnothlypis swainsonii*), hooded (*Wilsonia citrina*), and Kentucky warbler (*Oporornis formosus*) (Heltzel and Leburg 2006, Anich et al. 2010). Data evaluating species relationships with understory habitats is conspicuously lacking for other non-avian taxa. Presence of a limited and balanced understory in a bottomland system suggests presence of adequate forest canopy gaps promoting growth at the forest floor and should promote habitat use by wildlife species that are understory specialists. However, further research is needed to evaluate the importance of each of these community types to priority wildlife species in forested wetland systems in the MAV. Further, the term understory needs to be better defined in the ISA, particularly to determine if it characterizes

herbaceous and woody components simultaneously and at which vegetation height understory transitions to mid-story.

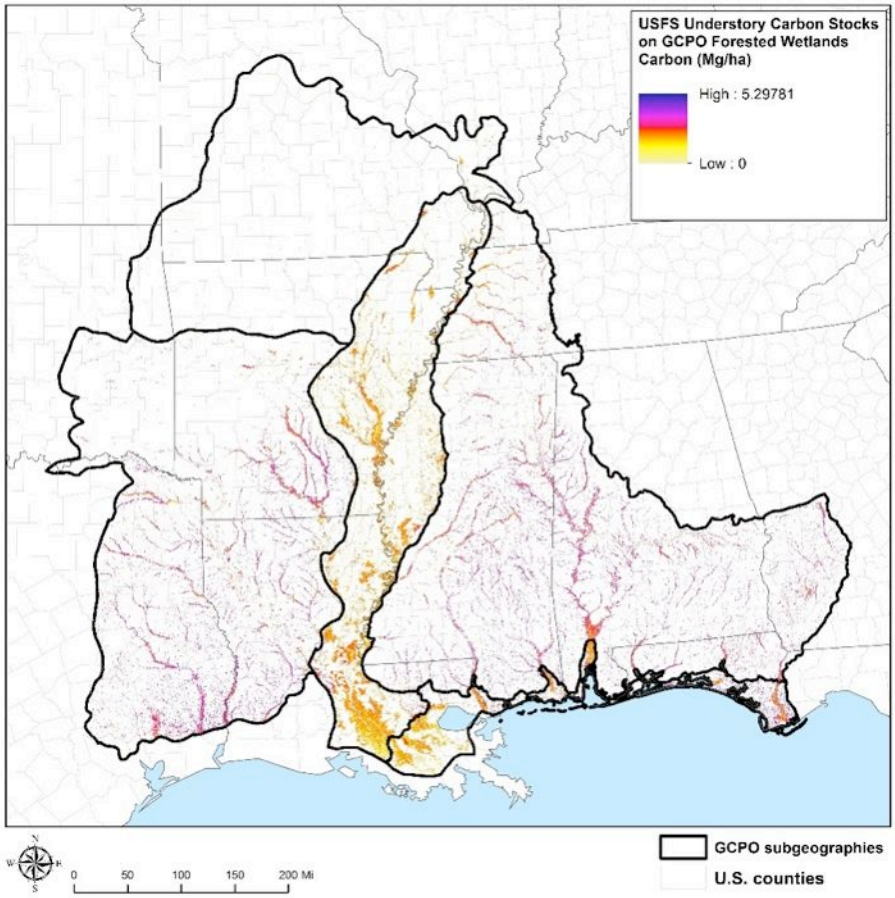

Figure FW.8. FIA-derived forest understory carbon stocks (Mg/ha; Wilson et al. 2013a) as an example of a potential proxy for assessment of understory cover on forested wetlands in the GCPO geography.

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Chapter 6: Condition, basal area

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Basal Area 60-70 ft^2/ac (forested wetland)

Basal area is a measure of the cross-sectional area of trees calculated by multiplying the foresters' constant (0.005454) by the squared diameter of each tree to determine a measure of tree area (ft^2 or m^2) per unit area (acre or ha). Basal area can be thought of as the "footprint occupied by trees" in a given area, and is one of the primary forest inventory metrics used in southeastern forest management (LMVJV Forest Resource Conservation Working Group 2007). Similar to an assessment of forest canopy cover, basal area provides a measure of horizontal structure, and is closely associated with measures of vertical structure (e.g., canopy cover, Cade 1997). Basal area has been shown to be a predictor of habitat use in some LCC priority species in MAV forested wetland systems, including black bear denning site preferences (Oli et al. 1997), and prothonotary warbler breeding habitat associations (Heltzel and Leburg 2006).

The GCPO ISA targets basal area measures between 60-70 ft^2/ac as one of the suite of conditions required to meet the desired ecological state of MAV forested wetland systems. This range was derived from recommendations to manage a proportion of forest stands to 60-70 ft^2/ac basal area with ≥25% of trees from older age classes suggesting a limited presence of larger and well-spaced trees will promote complex forest structure and optimum wildlife habitat in the system (LMVJV Forest Resource Conservation Working Group 2007).

Data Sources and Processing Methods

We used USFS total live tree basal area data (USDA Forest Service Remote Sensing Applications Center, personal communication) extracted through the forested wetland mask for assessment of forested wetland basal area within the Mississippi Alluvial Valley (MAV) and other GCPO geographies. The USFS per-species (Wilson et al. 2013) and total live tree basal area data product provides raster maps for the conterminous U.S. generated using a weighted k-nearest neighbor and canonical correspondence analysis from a combination of vegetation phenology data produced from 250 m resolution MODIS satellite imagery, ancillary environmental data, NLCD tree canopy cover data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA) (Wilson et al. 2012). Note live tree basal area estimates were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame.

The USFS total live tree basal area layer was created in the target resolution for this assessment (250 m). We used an extract by mask function in ArcGIS to delineate basal area in forested wetlands, using the USFS total live tree basal area layer as input data and the forested wetland mask representing the intersection of two or more classified forested wetland pixels from the gap NLCD/GAP/IF overlay described above. We then reclassified the product to pull out pixels with basal area in the target 60-70 ft^2/ac range. We repeated this process to assess forested wetlands with basal area greater than the target (>70 ft^2/ac) for comparison. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres forested wetland (60-70 ft^2/ac basal area)/acres HUC 12) within each HUC 12 watershed.

Summary of Findings

Imputed basal area values ranged from 0 – 285 ft^2/ac on GCPO forested wetlands, with average basal area 78 ft^2/ac. We estimate 387,507 acres (8%) of forested wetlands in MAV meet the landscape endpoint target of 60-70 ft^2/ac (**Table FW.8**), and 62,487 of those acres are currently under protected status (GAP status 1-3). For comparison, nearly 2.5 million acres (54%) of forested wetlands in the MAV are estimated to exhibit >70 ft^2/ac basal area, with 710,288 of those acres currently protected. In the MAV forested wetlands with basal areas in the target range were found in the greatest concentrations in east-central Louisiana in and around Red River, Dewey W. Wills, and Spring Bayou Wildlife Management Areas and Lake Ophelia National Wildlife Refuge (**Figure FW.9**). We also observed a concentration of forested wetlands exhibiting basal area within the target range in the West Gulf Coastal Plain subgeography in southern Arkansas in and around Felsenthal National Wildlife Refuge when assessed by HUC12 watershed. MAV forested wetlands with basal area >70 ft^2/ac were dominant along the Atchafalaya basin in Louisiana and portions of the White River watershed in Arkansas (**Figure FW.10**).

Table FW.8. Acreage of forested wetland habitat with 60-70 ft^2/ac and >70 ft^2/ac basal area within the Mississippi Alluvial Valley and GCPO LCC geography calculated from the U.S. Forest Service Total Live Tree Basal Area layer.

Geographic extent	Forested wetland acres (60-70 ft^2/ac BA)	Forested wetland acres (>70 ft^2/ac BA)
Mississippi Alluvial Valley	**387,507**	**2,491,948**
East Gulf Coastal Plain	530,751	2,334,433
West Gulf Coastal Plain	421,283	1,708,130
Ozark Highlands	10,425	43,799
Gulf Coast	81,869	913,131
Gulf Coastal Plains and Ozarks (full extent)	1,431,835	7,491,441

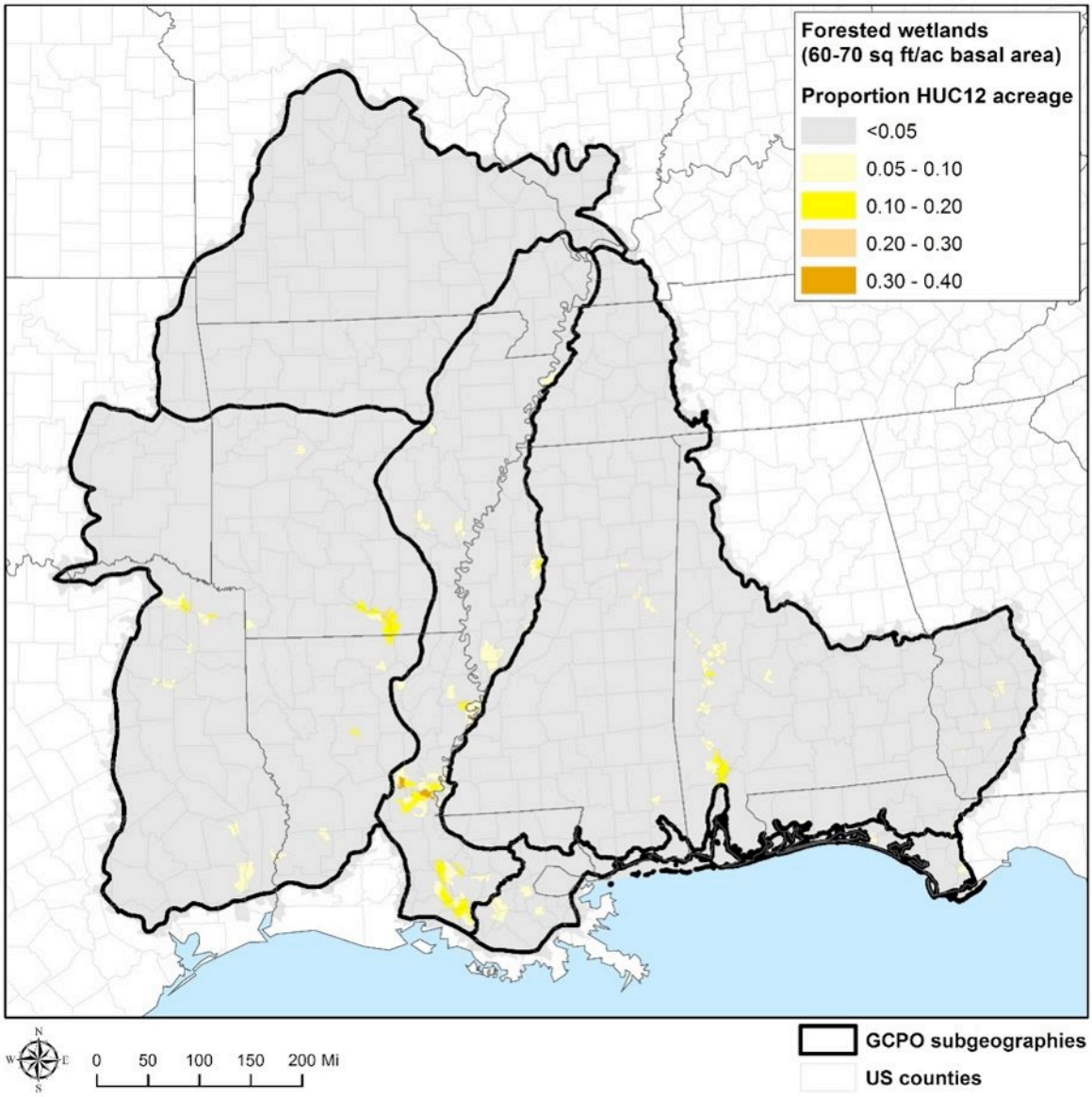

Figure FW.9. Proportional coverage of forested wetland acres with 60-70 ft^2/ac basal area normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the Mississippi Alluvial Valley and GCPO LCC geography.

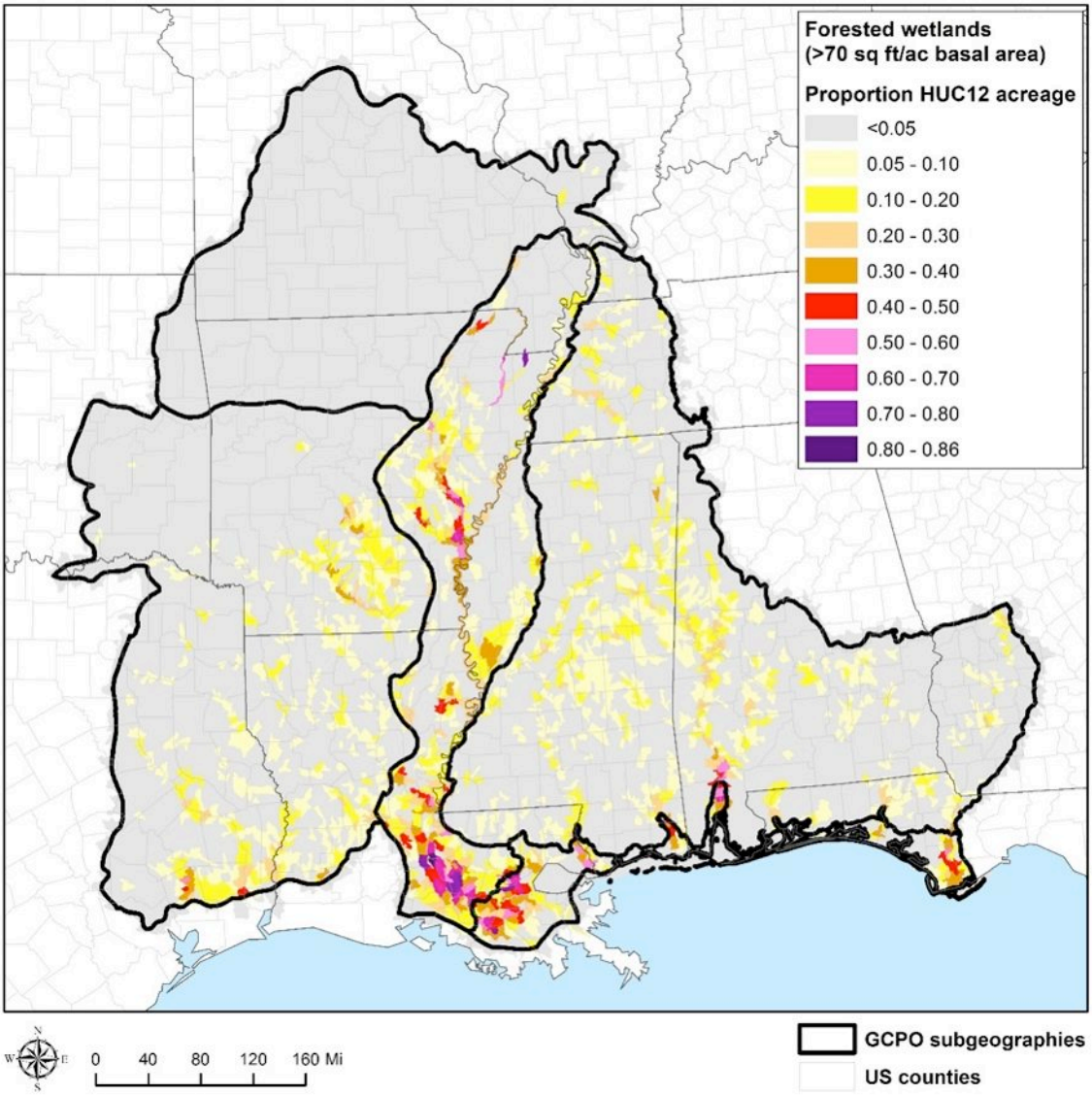

Figure FW.10. Proportional coverage of forested wetland acres with >70 ft²/ac basal area normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the Mississippi Alluvial Valley and GCPO LCC geography.

Future Directions and Limitations

The results of this assessment support the premise that these desired forest structure conditions are limited throughout the MAV and GCPO, but evident from imputed data in areas where active management to meet basal area targets may be occurring. There is also ample potential for management on protected and non-protected lands to better achieve target basal areas. Live tree basal area estimates relied on a combination of remote sensing, ancillary environmental data and plot-level FIA data to impute a continuous data layer. FIA data plots are collected at one plot per 6,000 acres across the landscape, are typically restricted to forest strata (Bechtold and Patterson 2005), and depend on the representativeness of plot-level data to the surrounding landscape (Riemann et al. 2010). However, the FIA program is one of the

only landscape-scale forest characterizations collected in a systematic and standardized manner presently available. Because of these assumptions we recommend acreage estimates of target basal area across the MAV and GCPO landscape be used cautiously and acknowledge all potential limitations in interpretation. Future directions include use of plot-level data from the comprehensive forest characterization database currently being developed by the GCPO LCC and LMVJV Forest Resource Conservation Working Group that aims to coalesce FIA and other local bottomland forest inventory datasets into a single web-enabled database system.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Forested Wetlands w/60-70 ft^2/ac Basal Area (raster) (vector – polygon: proportion of HUC 12)

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Chapter 7: Condition, tree stocking

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Tree stocking: 60-70%

Tree stocking is a weighted relative measure of stand density which takes into account tree diameter, plot condition, plot stockability, crown competition and other characteristics of forest inventory plots with live trees (Arner et al. 2001). Metrics like tree stocking and basal area are commonly used measures to determine density of trees in a forest. For years tree stocking was defined and measured in different ways, but in the last decade has been standardized in Forest Inventory and Analysis data collection and analysis (Arner et al. 2001). Previous algorithms for southern bottomland forests suggest 60-70% stocking would represent a bottomland stand with approximately 65-75 ft^2/ac basal area and about 150-175 trees per acre for trees with a quadratic mean diameter of 9-30" (Goelz 1995, Goelz and Meadows 1997). These predicted relationships between tree stocking rates and basal area are consistent with both the landscape endpoints outlined in the GCPO Integrated Science Agenda and the suggestions for desired forest conditions outlined by the LMVJV Forest Resource Conservation Working Group (2007).

Data Sources and Processing Methods

We used USFS imputed percent tree stocking data (USDA Forest Service Remote Sensing Applications Center, personal communication) extracted through the forested wetland mask for assessment of forested wetland tree stocking within the Mississippi Alluvial Valley (MAV) and other GCPO geographies. The USFS imputed tree stocking data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA). Note percent tree stocking estimates were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. The USFS imputed percent tree stocking layer was created in the target resolution for this assessment (250 m). We used an extract by mask function in ArcGIS to delineate percent tree stocking in forested wetlands, using the USFS imputed percent tree stocking layer as input data and the forested wetland mask representing the intersection of two or more classified forested wetland pixels from the gap NLCD/GAP/IF overlay described above. We then reclassified the product to pull out pixels with tree stocking in the target 60-70% range. We repeated this process to assess forested wetlands with tree stocking less than (<60%) and greater than (>70%) the target for comparison. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres forested wetland (60-70 ft^2/ac basal area)/acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Summary of Findings

Analysis using imputed FIA tree stocking data suggests substantially greater forested wetland acreage in the MAV exhibits the target 60-70% tree stocking rate (727,030 acres, or 16%; **Table FW.9**) as compared to the target 60-70 ft^2/ac basal area (387,507 acres or 8%; **Table FW.8**). However, given there is a presumed relationship between tree stocking rate and basal area, it is unclear whether this difference results from is a data anomaly, or observation of a disjunct relationship between the two measures. Assuming tree stocking rates were correctly imputed we estimated 208,418 acres within the target 60-70% stocking range are currently under protected status (GAP status 1-3). We also estimate 475,677 acres of MAV forested wetlands

exhibited tree stocking measures >70%, whereas 3,436,133 acres exhibited stocking rates <60%, suggesting stocking across most MAV forested wetlands is below the target range, which is contrary to that observed in the assessment of basal area above (**Table FW.9**). In the MAV forested wetlands with tree stocking rates in the target range were found in the greatest concentrations near Big Lake Wildlife Management Area and Big Lake National Wildlife Refuge, White River National Wildlife Refuge, and St. Francis Sunken Lands Wildlife Management Area in Arkansas; Hillside National Wildlife Refuge in Mississippi; and in several areas within the Atchafalaya basin, and large forested wetland patches in Cat Island National Wildlife Refuge and eastern Evangeline Parish in Louisiana (**Figure FW.11**). We also observed a concentration of forested wetlands exhibiting tree stocking rates within the target range in southern portions of the Atchafalaya basin outside the GCPO MAV subgeography, as well as areas in the Bogue Chitto National Wildlife Refuge, Pearl River Wildlife Management Area and and a large patch of forested wetlands adjacent to the Tennessee-Tombigbee Waterway in Itawamba County Mississippi. Unfortunately there was limited overlap in areas of concentration in target stocking rates when compared to target basal area measures.

Table FW.9. Acreage of forested wetland habitat within the target 60-70% and below (<60%) and above (>70%) target tree stocking rates within the Mississippi Alluvial Valley and GCPO LCC geography calculated from imputed Forest Inventory and Analysis tree stocking data provided by the U.S. Forest Service Remote Sensing Applications Center.

Geographic extent	Forested wetland acres (60-70% stocking)	Forested wetland acres (<60% stocking)	Forested wetland acres (>70% stocking)
Mississippi Alluvial Valley	**727,030**	**3,435,133**	**475,677**
East Gulf Coastal Plain	740,559	2,705,508	311,044
West Gulf Coastal Plain	590,288	2,247,854	168,109
Ozark Highlands	4,556	104,865	1,097
Gulf Coast	253,098	791,215	346,735
Gulf Coastal Plains and Ozarks (full extent)	2,315,530	9,284,575	1,302,661

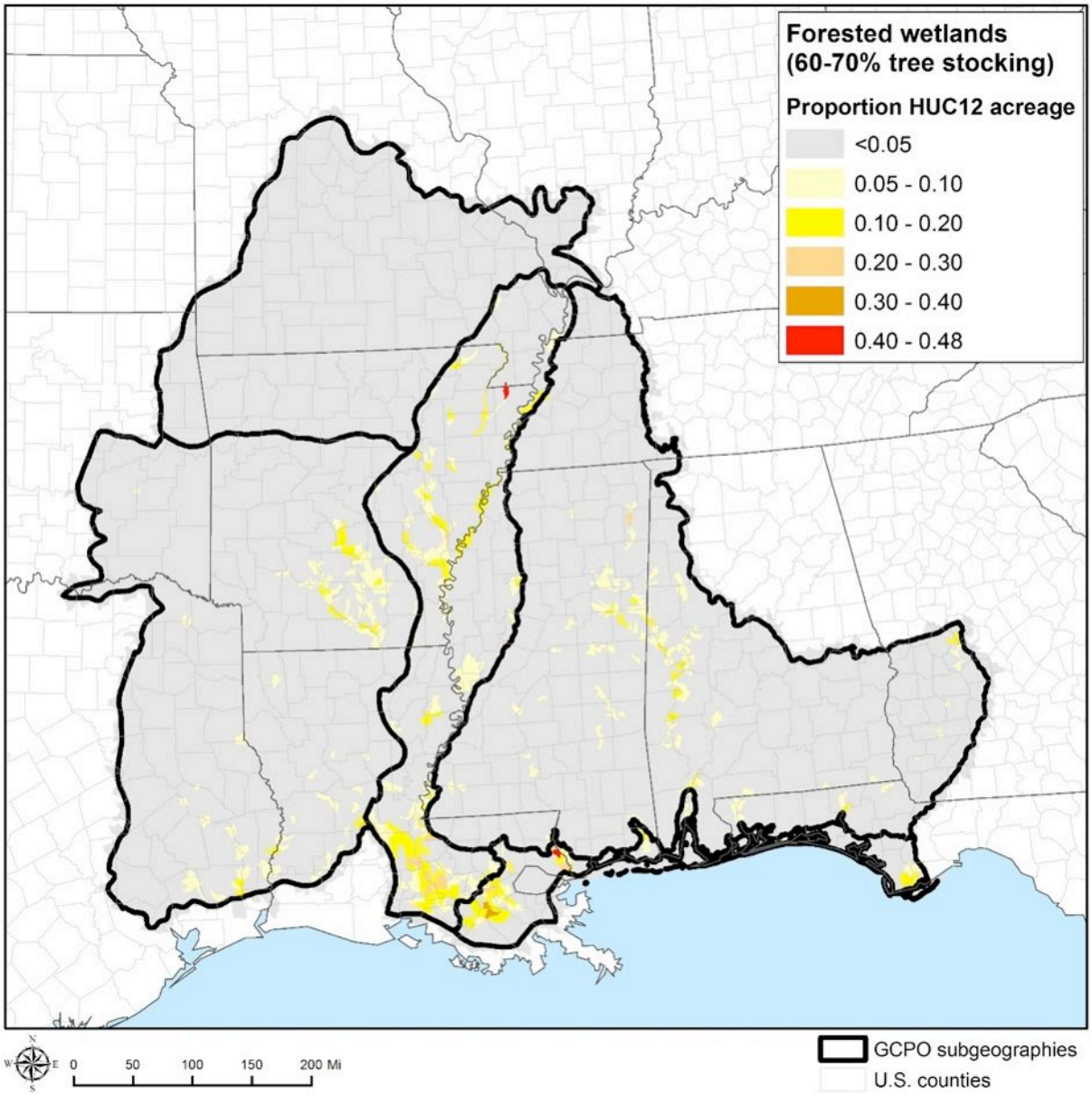

Figure FW.11. Proportional coverage of forested wetland acres with 60-70% tree stocking normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the Mississippi Alluvial Valley and GCPO LCC geography.

Future Directions and Limitations

An implicit assumption with use of FIA data to extrapolate to scales beyond the plot level is that forest conditions observed on the FIA plot are representative of the surrounding landscape. We are in currently in the process of assessing FIA-imputed tree stocking rate measures and their utility in this section of the assessment given the presumed disconcordance with measures of basal area. Unfortunately, FIA data are one of the only landscape-scale forest characterizations collected in a systematic and standardized manner presently available so we may have to wait

to resolve this issue until data from the aforementioned Forest Characterization Database is available.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Forested Wetlands w/60-70% Tree Stocking (raster) (vector – polygon: proportion of HUC 12)

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Chapter 8: Condition, large snags

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Large (>26” dbh) snags: 0.2/ac (forested wetlands)

Standing dead trees, or snags, are an important habitat element in any forested system and provide diurnal or seasonal shelter for many species (Davis et al. 1983). Desired forest stand conditions in the MAV recommend density of dens or large tree cavities with one visible hole per 10 acres or >2 stems of ≥26” dbh per 10 acres (i.e., 0.2 large stems per acre) (LMVJV Forest Resource Conservation Working Group 2007). This measure was adopted and adapted in the GCPO LCC Integrated Science Agenda to >0.2 snags/acre of snags >26”In diameter as one of the condition endpoints contributing to the desired ecological state for forested wetland systems. Availability of den sites for Louisiana black bears (*Ursus americanus luteolus*) in MAV forested wetland systems is especially important since female black bears have been shown to use tree dens exclusively in non-commercial forests (White et al. 2001). Other waterfowl species such as wood ducks (*Aix sponsa*) and hooded mergansers (*Mergus cucullatus*), as well as several woodpecker and bat species also make use of cavities in large snags for roosting, denning and nesting (LMVJV Forest Resource Conservation Working Group 2007).

Data Sources and Processing Methods

We used USFS imputed density of enormous snags data (USDA Forest Service Remote Sensing Applications Center, personal communication) extracted through the forested wetland mask for assessment of forested wetland snag density within the Mississippi Alluvial Valley (MAV) and other GCPO geographies. The USFS imputed snag density data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA). Density of enormous snags was imputed from plot-level FIA data coalescing standing dead trees >5” with dbh >26”. Note estimates of snag density were calculated on a per-acre-of-land basis, though forested lands were the primary sampling frame. The USFS-imputed percent enormous snag density layer was created in the target resolution for this assessment (250 m). We used an extract by mask function in ArcGIS to delineate enormous snag density in forested wetlands, using the USFS imputed enormous snag density layer as input data and the forested wetland mask representing the intersection of two or more classified forested wetland pixels from the gap NLCD/GAP/IF overlay described above. We then reclassified the product to pull out pixels with enormous snag density meeting the target 0.2 enormous snags/acre and above. Note the ISA endpoint targets exactly 0.2 snags >26”/ac, but due to data limitations we have assessed this endpoint to include all enormous snags with 0.2/ac density or greater. We also evaluated snag densities of all sizes for comparison. We assessed acreage by summing the count of pixels within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres forested wetland (>0.2/ac snags >26”)/ acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Summary of Findings

Using imputed FIA-data we estimate density across all snag sizes ranged from 0-36 snags/acre, with a mean of 3.66 snags/acre (3.53 SD) on MAV forested wetlands. In comparison density of snags >26” in diameter ranged from 0-3.78 snags/acre on MAV forested wetlands, with a mean of 0.08 snags/ac (0.32 SD). We estimate 433,423 acres (9%) of MAV forested wetland contain

densities of large snags >0.2/ac (**Table FW.10**), with 121,159 acres currently in protected status (GAP status 1-3). As much as 91% of forested wetland acres in the MAV have large snag densities below the target range (<0.2 large snags/acre). In the MAV, forested wetlands with large snag densities >0.2/acre were found in the greatest concentrations in some portions of the Atchafalaya Basin and in and around Red River and Pom De Terre Wildlife Management Areas and Lake Ophelia National Wildlife Refuge in Louisiana, and St. Francis Sunken Lands and Black River Wildlife Management Areas in Arkansas (**Figure FW.12**). Using non-imputed plot-level FIA data we found the largest measured snag in a forested wetland system in the GCPO geography was inventoried in 2011 in West Feliciana Parish, Louisiana and measured 95.2" in diameter. Concentration of large snag densities >0.2/acre were also found in forested wetlands in other GCPO subgeographies including areas in and around Upper Ouachita National Wildlife Refuge and Lower Ouachita Wildlife Management Area in Louisiana and Arkansas, and in large patches of forested wetland within and near the Apalachicola River Water Management Area, Apalachicola River Wildlife and Environmental Area, and Apalachicola National Forest (**Figure FW.12**).

Table FW.10. Acreage of forested wetland habitat demonstrating the target >0.2 large snags (>26")/acre within the Mississippi Alluvial Valley and GCPO LCC geography calculated from imputed Forest Inventory and Analysis snag diameter and density data provided by the U.S. Forest Service Remote Sensing Applications Center.

Geographic extent	Acres large snag (>26") density >0.2/acre
Mississippi Alluvial Valley	**433,423**
East Gulf Coastal Plain	317,329
West Gulf Coastal Plain	178,425
Ozark Highlands	13,112
Gulf Coast	209,437
Gulf Coastal Plains and Ozarks (full extent)	1,151,726

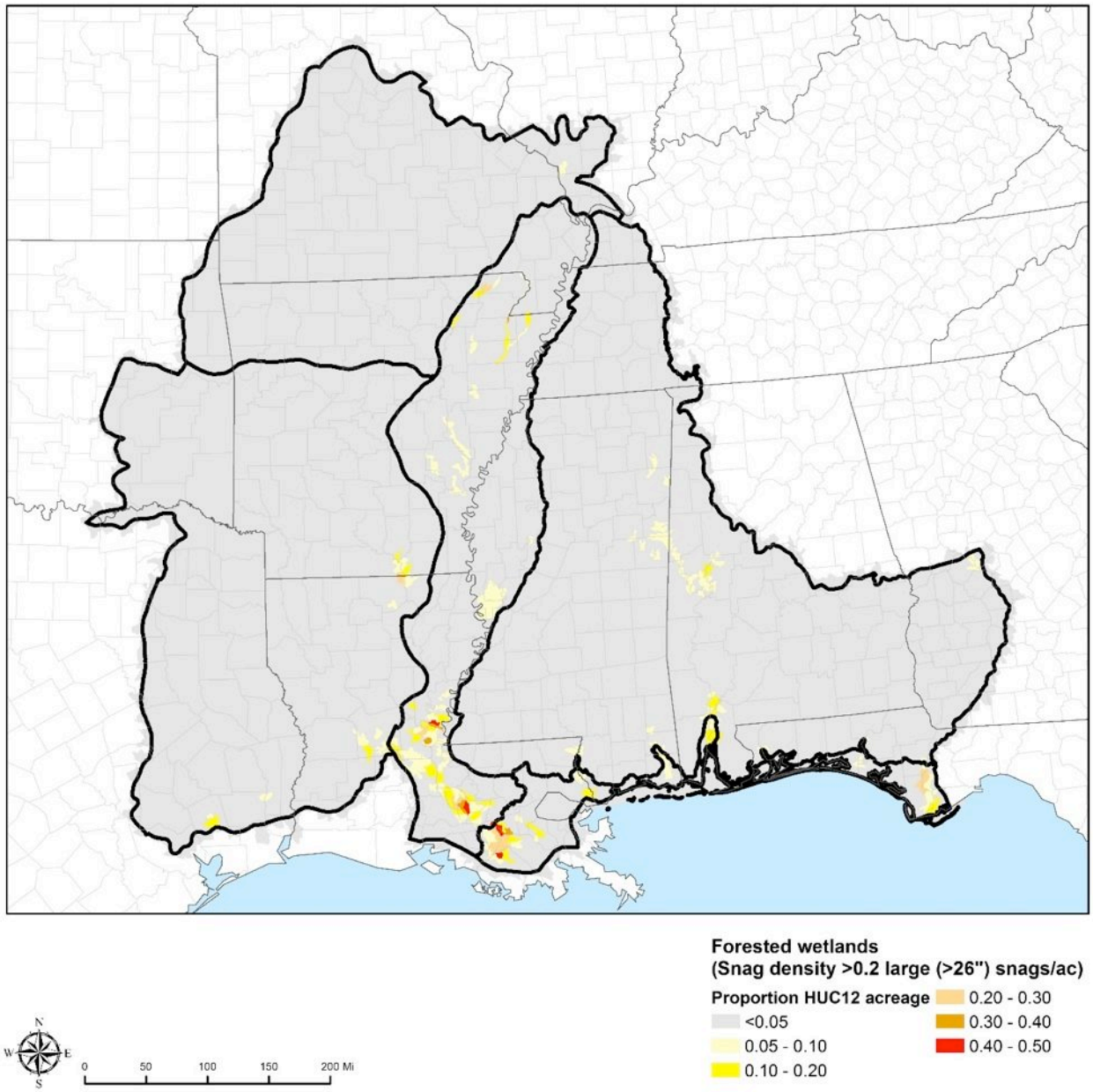

Figure FW.12. Proportional coverage of forested wetland acres with >0.2 large snags (>26")/acre normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the Mississippi Alluvial Valley and GCPO LCC geography.

Future Directions and Limitations

In an assessment west of the MAV subgeography in the Mark Twain National Forest of Missouri, Titus (1983) found an optimum density of 2 dens >19" diameter per acre in alluvial floodplain forests, with a minimum recommendation of 1 den per acre, to support wildlife populations in that landscape. He also found these habitats supported some of the greatest diversity of cavity and den species compared to other forest habitat types in Missouri. Louisiana black bears are

known to require even larger (>33-36” dbh) cavity trees for denning than specified in this assessment (Oli et al. 1997, Black Bear Conservation Committee 2005) and may use up to 4 dens during a single denning season (Weaver and Pelton 1994, Oli et al. 1997). They exhibit a distinct preference for bald cypress (*Taxodium distichum*) and overcup oak (*Quercus lyrata*) for denning in Louisiana (Weaver and Pelton 1994), and Arkansas (Oli et al. 1997). Consideration should be given to whether targeting snags >26” will provide sufficient assessment of potential denning habitat availability for black bears in the MAV. The GCPO LCC is currently working with black bear researchers from the University of Maryland to better determine radio-collared black bear habitat preferences to support future refinements of ISA endpoints.

FIA data are one of the only landscape-scale systematic forest characterizations presently available. However, estimates of large snag density presented here implicitly assume that FIA data plots collected once per 6,000 acres across the landscape are representative of snag densities within the remainder of the MAV forested wetland system (Bechtold and Patterson 2005). Users should exercise caution when drawing inference from imputed FIA-data, and recognize its potential limitations. Future directions include use of the comprehensive forest characterization database currently being developed by the GCPO LCC in concert with the LMVJV Forest Resource Conservation Working Group to coalesce both FIA and other forest inventory datasets for analysis. Future directions may also include use of advanced remote sensing technologies such as LiDAR to supplement plot-level forest inventory data and produce large-scale mapping of snag densities (e.g., Martinuzzi et al. 2009). However, assessment across the entire GCPO geography will not be possible until LiDAR becomes available for much of the remainder of the region.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- USFS FIA-imputed large (>26”) snag density >0.2/ac (raster) (vector – polygon by HUC 12)

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Chapter 9: Condition, diverse tree species

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Diverse tree species composition

Increasing complexity of forest structure may optimize wildlife food and cover opportunities in MAV forested wetland systems (Allen 1997, LMVJV Forest Resources Working Group 2007). Black bear and waterfowl are known to benefit from forage resources offered by mast producing tree species and may benefit from a diversity of florescence and senescence times and a variety of forage options if multiple tree species are present in a system (LMVJV Forest Resources Working Group 2007). Different foliage-roosting bat species may also exhibit preferences for different tree species for diurnal roosts (e.g., Gooding and Langford 2004), and insectivorous bird species have been shown to exhibit an overall strong preference for a diverse tree species composition in MAV bottomland forests (Gabbe et al. 2002). Historical accounts of old-growth and/or undisturbed bottomland forest systems in the MAV suggest a range of 15-22 tree species on select sites in Arkansas and Louisiana (Allen 1997 and citations within). However, restoration efforts promoting seasonally flood-tolerant bottomland forest may have resulted in forest systems that are poor in tree species diversity (Allen 1997, Twedt 2004). The GCPO LCC recognized species associations with tree species diversity in the ISA by suggesting forested wetlands with a diverse tree species composition be one of the target endpoints making up the desired ecological state for MAV forested wetland systems.

Data Sources and Processing Methods

We used 2000-2009 live tree species basal area outputs imputed from plot-level Forest Inventory and Analysis (FIA) data (Wilson et al. 2013) to assess per-pixel species richness as a proxy for tree species composition within MAV and GCPO forested wetlands. We first extracted each individual tree species basal area through the forested wetland mask, retaining all tree species with >5 sq ft/ac basal area within a 250 m (15.44 ac) pixel. This approach provided a suite of 52 tree species within the GCPO forested wetland mask from which to assess richness (**Table FW.11**). We reclassified species-level outputs to a binary state, assigning species present in each pixel a value of 1 and all else 0. We then used map algebra to sum imputed species presence data to calculate a measure of raw species richness per pixel within forested wetlands. In the absence of empirical targets we assessed acreage of forested wetlands within tree species richness bins (<5, 5-15, 15-30, >30 species/250 m pixel) in each geographic construct by summing the count of pixels within each bin in each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. For display we calculated the proportional area (acres forested wetland for richness values <15 tree species/pixel and 15-48 tree species/pixel per acres HUC 12) within each HUC 12 watershed using zonal statistics in ArcGIS.

Table FW.11. Individual tree species estimated to be present on GCPO forested wetlands calculated from imputed Forest Inventory and Analysis live tree species basal area data

FIA SPCD	Common name	Scientific name		FIA SPCD	Common name	Scientific name
0043	Atlantic white-cedar	*Chamaecyparis thyoides*		0692	Ogeechee tupelo	*Nyssa ogeche*
0067	s. red-cedar	*Juniperus virginiana*		0693	black gum	*Nyssa sylvatica*
0068	e. red cedar	*Juniperus virginiana*		0694	swamp tupelo	*Nyssa biflora*
0107	sand pine	*Pinus clausa*		0691	water tupelo	*Nyssa aquatica*
0110	shortleaf pine	*Pinus echinata*		0701	eastern hophornbeam	*Ostrya virginiana*
0111	slash pine	*Pinus elliottii*		0711	sourwood	*Oxydendrum arboreum*
0115	spruce pine	*Pinus glabra*		0712	paulownia	*Paulownia tomentosa*
0121	longleaf pine	*Pinus palustris*		0720	bay spp.	*Persea spp.*
0128	pond pine	*Pinus serotina*		0722	water elm	*Planera aquatica*
0129	e. white pine	*Pinus strobus*		0731	American sycamore	*Platanus occidentalis*

produced by the U.S. Forest Service Remote Sensing Applications Center (Wilson et al. 2013).

Summary of Findings

Tree species richness (i.e., number of tree species generated from imputed data) on MAV forested wetlands ranged from 0 - 43 species per 250 m (15.44 ac) pixel, with mean species richness at 18.21 species per pixel (**Table FW.12**). MAV forested wetlands exhibited lower mean tree species richness than forested wetlands in all other GCPO subgeographies except the Gulf Coast. Overall mean tree species richness across the GCPO geography was 20.82 species/pixel (SD 7.87, range 0 – 48). We estimate 67% of MAV forested wetlands exhibited richness values between 15-30 tree species per pixel, with 21% exhibiting 5-15 tree species (**Table FW.12**). Richness values >15 tree species were also found in greatest proportion in the other GCPO subgeographies, except in the Gulf Coast where forested wetlands exhibited <15 tree species/pixel in greatest proportion (**Figures FW.12-14**). Richness values tended to increase with upstream distance from regularly flooded mainstem big rivers in the GCPO geography (**Figure FW.12**). Areas with the greatest proportion of acres of richness values >15 tree species were found along HUC 12 watersheds along the White River in Arkansas and in several areas of the Atchafalaya Basin in Louisiana (**Figure FW.13**). Areas exhibiting the greatest proportion of low tree species richness included southern portions of the Atchafalya Basin primarily in the Gulf Coast subgeography of the LCC (**Figure FW.14**).

Table FW.12. Acreage of forested wetland habitat demonstrating the target >0.2 large snags (>26")/acre within the Mississippi Alluvial Valley and GCPO LCC geography calculated from imputed Forest Inventory and Analysis snag diameter and density data provided by the U.S. Forest Service Remote Sensing Applications Center.

Geographic extent	Mean no. tree species	Range	Acres FW <5 tree species (% of FW)	Acres FW 5 - 15 tree species (% of FW)	Acres FW 15-30 tree species (% of FW)	Acres FW >30 tree species (% of FW)
Mississippi Alluvial Valley	**18.21 (SD 7.44)**	**0 - 43**	**338,241 (7.3%)**	**1,000,405 (21%)**	**3,107,085 (67%)**	**179,985 (3.9%)**

East Gulf Coastal Plain	25.27 (SD 6.89)	0 - 48	32,896 (0.9%)	297,268 (7.9%)	2,529,724 (67.3%)	889,378 (23.7%)
West Gulf Coastal Plain	22.59 (SD 6.08)	0 - 44	40,494 (1.3%)	302,905 (10%)	2,415,994 (80%)	243,090 (8.1%)
Ozark Highlands	21.05 (SD 8.34)	0 - 42	9,606 (8.6%)	9,961 (9%)	81,823 (74%)	9,575 (8.6%)
Gulf Coast	14.68 (SD 7.13)	0 - 36	99,151 (7.1%)	749,485 (54%)	511,693 (37%)	24,556 (1.8%)
Gulf Coastal Plains and Ozarks (full extent)	20.82 (SD 7.87)	0 - 48	520,388 (4%)	2,360,024 (18%)	8,646,318 (67%)	1,346,584 (10%)

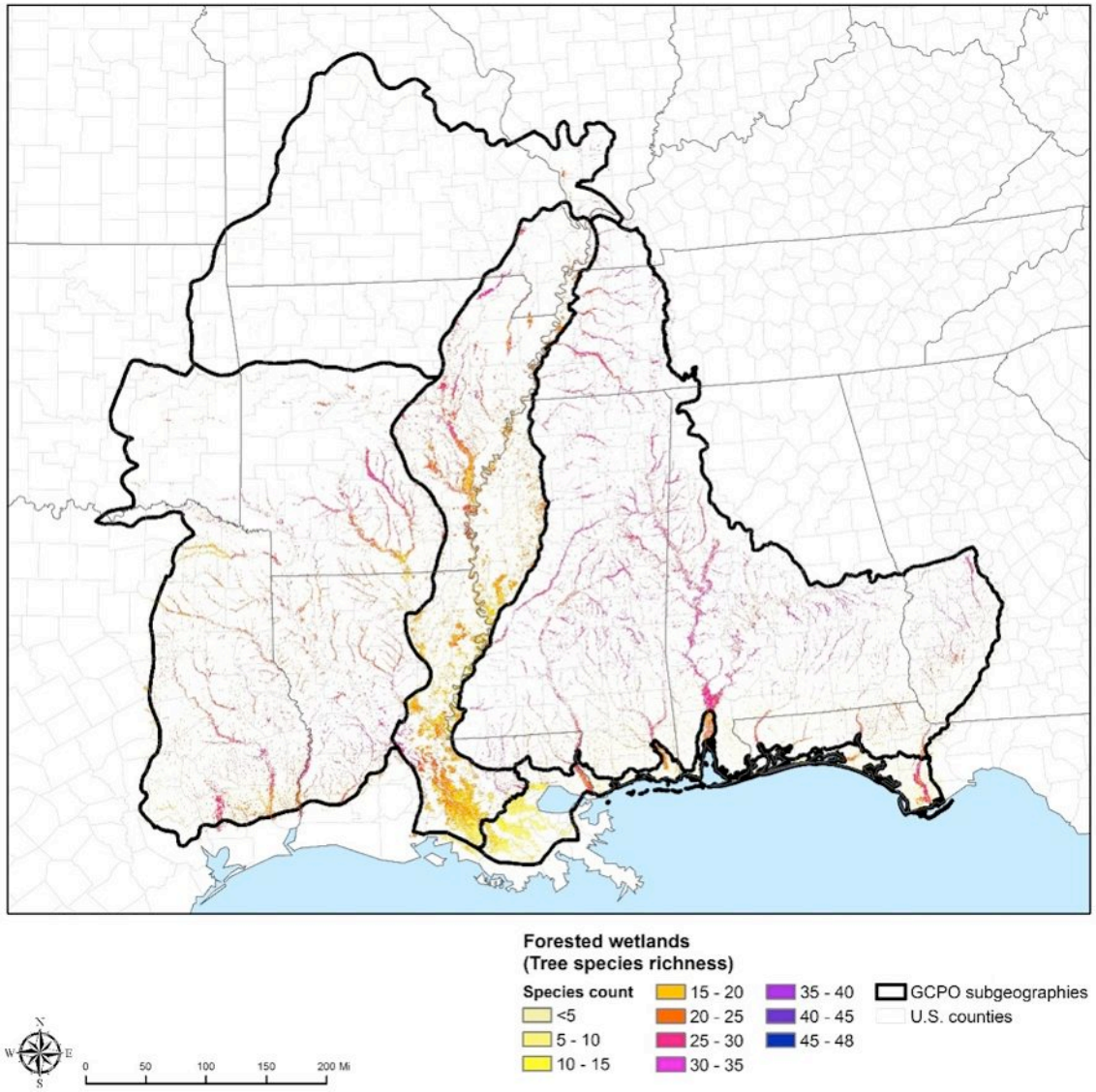

Figure FW.13. Estimated tree species richness (number of tree species/250 m pixel) for forested wetland in the MAV and across the GCPO geography estimated from imputed species-level live tree basal area data (Wilson et al. 2013) generated from the Forest Inventory and Analysis Program.

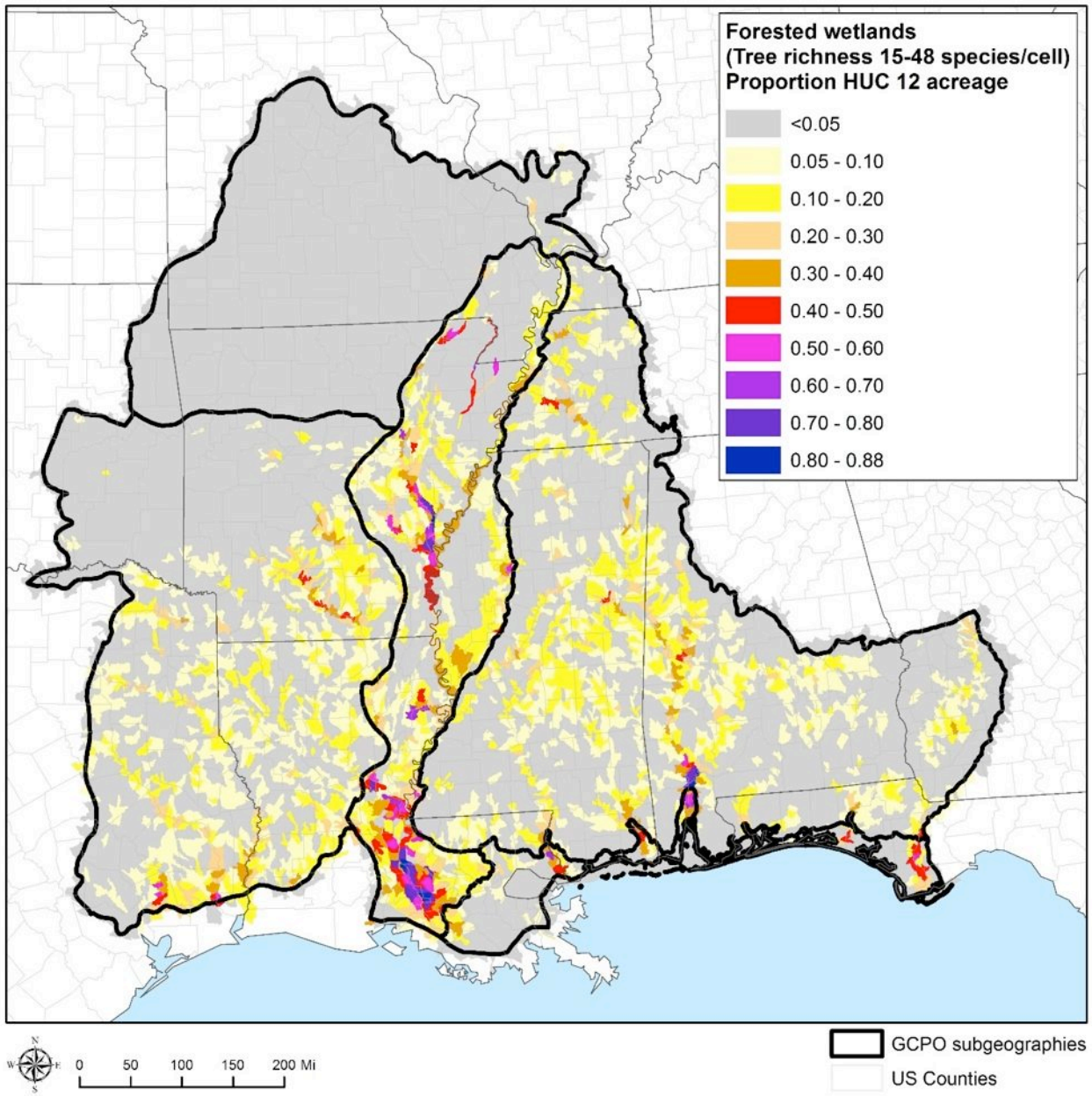

Figure FW.14. Proportional coverage of forested wetland acres with number of tree species between 15-48 species/pixel normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the MAV and GCPO LCC geography.

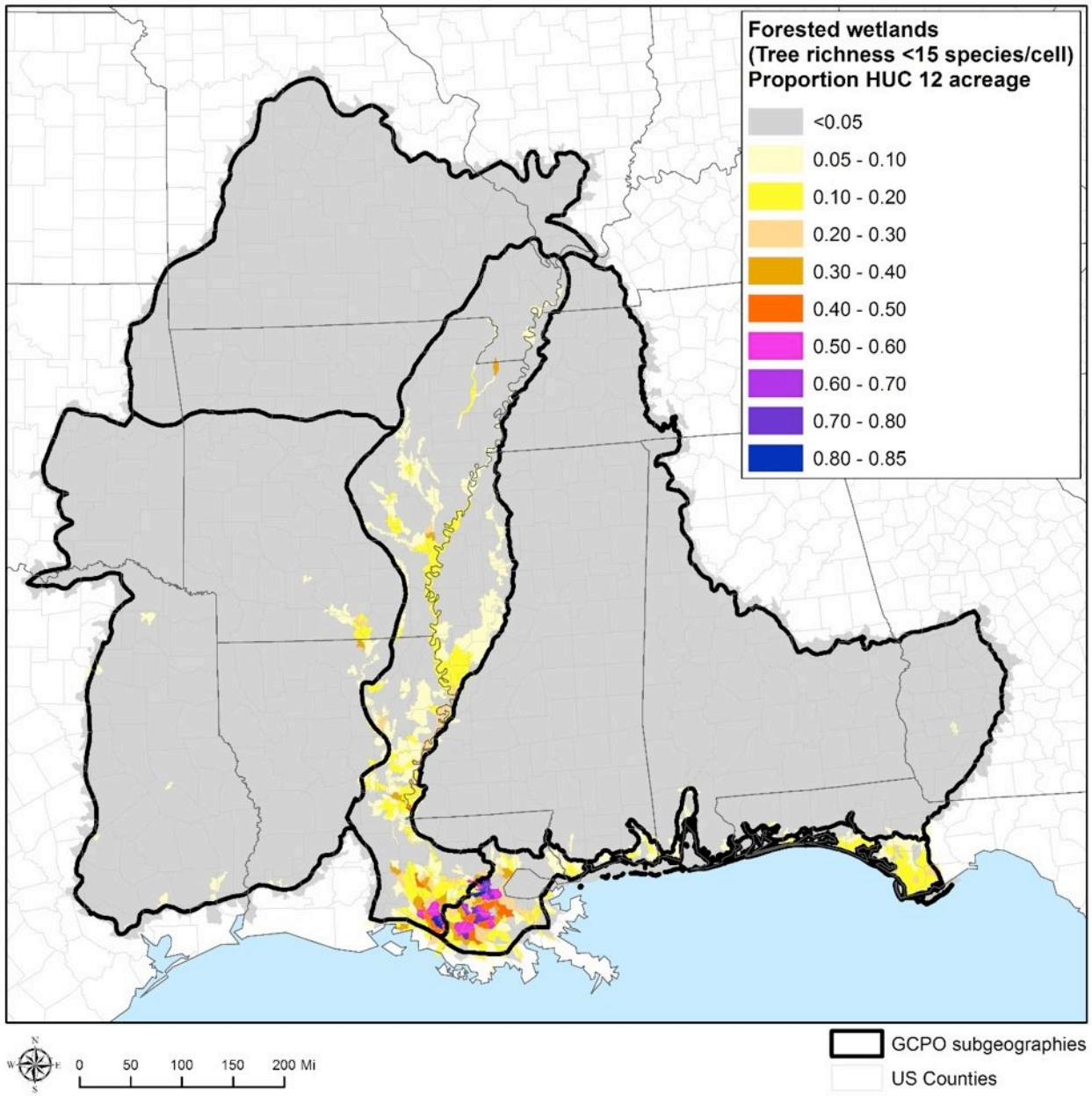

Figure FW.15. Proportional coverage of forested wetland acres with number of tree species <15 species/pixel normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the MAV and GCPO LCC geography.

Future Directions and Limitations

The results of this initial assessment suggest that the desired forest condition of a diverse tree species composition on forested wetlands is more prevalent than not throughout the MAV subgeography, provided you consider a system with >15 tree species representative of diverse species composition. However, without clear diversity targets and with limited bottomland forest FIA plot data in the MAV we suggest inference to LCC Science Agenda endpoints should be

approached cautiously. Reliance on imputed FIA data brings with it a suite of caveats regarding the relationship between imputed and empirical data. However, if the outcomes are used acknowledging that the intent of this analysis is to demonstrate relative spatial relationships with species diversity over the large landscape scale, then the results are very interesting. The connection between tree species composition/diversity and wildlife species distribution/ abundance also needs to be better defined and determined to be a useful metric in evaluating species-habitat associations. This largely explains why diversity targets in the ISA were left intentionally vague and thus explains why we targeted simple species richness measures in this assessment in lieu of abundance-based diversity metrics such as the Shannon diversity index. Future directions include use of the comprehensive forest characterization database currently being developed by the GCPO LCC in concert with the LMVJV Forest Resource Conservation Working Group to coalesce both FIA and other forest inventory datasets in bottomland systems for analysis.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- FIA-imputed Tree Species Richness on GCPO Forested Wetlands (raster)

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Chapter 10: Condition, cane and overstory vines

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Occurrence of cane and overstory vines

Data Sources and Processing Methods

While some information on vegetation species and growth habits in vegetation subplots of the Forest Inventory and Assessment could be used to assess the condition of both occurrence of cane and overstory vines, these data are currently too sparse to provide the landscape-level assessment that is necessary across the entire MAV and beyond.

Giant cane (*Arundinaria gigantea*) and switch cane (*Arundinaria tecta*, or *Arundinaria gigantea tecta*), both bamboo relatives, are distributed throughout the MAV and GCPO geographies and typically occur in low-lying transition zones between swamp and mesic forests with mesic to wet soils (Taylor 2006). Cane is often associated with river and stream banks (and often termed river cane for this reason), floodplains, levees, swamplands and other wet sites (Taylor 2006). Cane can be found in either smaller patches established in the forest understory or large canebrakes consisting of an open canopy and a cane-dominated vegetative community over a large area. Canebrakes (i.e., cane-dominated vegetative communities) were once abundant (estimated at hundreds of thousands of acres) and integral to early Americans across the southern landscape (Platt et al. 2009); but land use changes in the 18th and 19th centuries resulting from disease impacts following European exploration and later European settlement reduced canebrake systems to the status of critically endangered (Noss et al. 1995, Platt and Brantley 1997, Brantley and Platt 2001, Stewart 2007). Canebrakes have been documented in all states in the GCPO geography, and as early as the 1600's in Arkansas, Louisiana, Mississippi and Missouri (see Platt and Brantley 1997 and citations therein). Canebrakes are fire-dependent systems and need infrequent fire (7-10 year intervals) to maintain the system in secondary succession (Brantley and Platt 2001, Taylor 2006). Canebrakes will sprout quickly following fire if return intervals are infrequent enough to sustain the rhizome (Brantley and Platt 2001, Taylor 2006). Canebrakes have also historically been one of the most palatable and high-yielding cattle forage options in the South (Taylor 2006, Stewart 2007). Cane-dominated patches of habitat have been associated with several important species in the MAV and GCPO (Platt et al. 2001) including black bear (*Ursus americanus*), and Bachman's (*Vermivora bachmanii*) and Swainson's warblers (*Limnothlypis swainsonii*), among many others (Thomas et al. 1996, Platt et al. 2001, Anich et al. 2010).

Native vine species occurrences are less well-documented, but have been shown to be an important (see discussion below) and species rich community in MAV forested wetlands (Devall 1990). Preference for habitats with occurrence of vines by many forested wetland species indicate this may be an overlooked but important part of some species' habitat selection strategies. However, data is typically limited to site-specific wildlife population research that links a species' habitat preferences to certain vegetation characteristics. To our knowledge, efforts have not been put in place outside of limited vegetation data in Phase 3 Forest Inventory and Analysis (FIA) datasets to adequately quantify presence and habitat use of vine habitats.

FIA Phase 3 forest health plots provide some information on vegetation species and growth habits in vegetation subplots (Bechtold and Patterson 2005). In Phase 3 forest health assessments understory vegetation structure is characterized on every 16th FIA plot (one plot per 96,000 acres). If desired, cane species within the *Arundinaria* genus could be queried out of the VEG_PLOT_SPECIES and REF_PLANT_DICTIONARY tables in the FIA. Woody vines could be also be categorized by querying the GROWTH_HABIT field for the "vine" growth habit type of the VEG_PLOT_SPECIES and REF_PLANT_DICTIONARY tables (U.S. Forest Service 2014). However, data at these increments are too sparse to provide the landscape-level assessment that is necessary across the entire MAV and beyond. Some state Natural Heritage Program data and state herbarium records on cane and vine occurrence are also available, but

these data are typically collected opportunistically, may have outdated records, and likely do not provide a representative sample of either cane or vine habitat type nor mappable data distribution.

Summary of Findings, Future Directions and Limitations

Occurrence of vine and cane have been shown as direct habitat associations by several priority wildlife species (see summary in Platt et al. 2001). Though not limited to cane habitats, populations of Swainson's warblers have repeatedly been shown to prefer cane and vine for nesting and foraging substrate (Graves 2002, Somershoe et al. 2003, Peters et al. 2005, Brown et al. 2009, Anich et al. 2010). Over 81% of sites occupied by Swainson's warblers at White River National Wildlife Refuge in Arkansas exhibited occurrence of cane in one study (Brown et al. 2009), though vines were not associated with species occurrence in this particular study. One study examining habitat associations of Swainson's warblers in canebrake systems suggested species occurrence was positively influenced by cane density and lower tree canopy height (Peters et al. 2005). Cane has also been shown to provide important nesting substrate for hooded warblers (Kilgo et al. 1996) and Kentucky warblers (Sallabanks et al. 2000) in the MAV and beyond. A literature synthesis of canebrake fauna by Platte et al. (2001) suggests several rodent species, including beaver (*Castor canadensis*) flourish in cane systems. Other mammals like swamp rabbits (*Sylvilagus aquaticus*), white-tailed deer (*Odocoileus virginianus*), bobcat (*Lynx rufus*) and black bear all make use of cane patches for cover and forage when they are available. Swamp rabbits may even be restricted to cane habitats in some parts of the species' range (Platt et al. 2001). Bachman's warbler, now thought to be extinct, is believed to have been a cane specialist (Platt et al. 2001). Many other bird, reptile, and invertebrate species also use cane habitats (Platt et al. 2001). Canebrake rattlesnake (*Crotalus horridus atricaudatus*), a subspecies of timber rattlesnakes (*Crotalus horridus*) is thought by its namesake to be a canebrake specialist as well (Platt et al. 2001). Coarse estimates of species richness recorded in literature on canebrakes over time include occurrences of 23 mammalian, 16 avian, 4 reptilian, and 7 invertebrate species. Cane is also found to positively benefit water quality in riparian habitats, as it acts to stabilize banks and reduce nitrates and sediments (Schoonover and Williard 2003, Schoonover et al. 2006). Though evidence is limited, native vine diversity in forested wetland systems in the MAV is also thought to provide quality habitat in forest canopy gaps for wildlife species requiring vines for nesting substrate or preferring vines for roosting, foraging, or escape cover. Devall (1990) found 11 species of vine in one forested wetland system in one Louisiana swamp. However, threats posed by encroachment of invasive viney species are widespread and may threaten the integrity of native vine habitat components within the forested wetland system.

Desired forest stand conditions for bottomland systems in the MAV encourage development of structural and species diversity in the forest system, including promotion of habitat components of native vines and cane, in addition to other woody species (LMVJV Forest Resources Working Group 2007). Vine and cane presence in a bottomland system likely suggests the existence of adequate forest canopy gaps promoting both vertical and horizontal structural diversity. However, further research is needed to evaluate the importance of each of these community types, particularly vine habitat components, to many priority wildlife species. Platt et al. (2001) suggested "a formal assessment has yet to be undertaken and information on which to base management decisions is altogether lacking" when discussing the lack of comprehensive knowledge of present-day canebrake systems. Data that does exist on species-habitat associations is primarily site-specific (e.g., Anich et al. 2010) and difficult to interpolate to the landscape scale. Tracking canebrake restoration efforts that use translocation of propagated rhizomes (see descriptions in Platt and Brantley 1993, Zaczek et al. 2004) would also be important to evaluate the impacts of restoration efforts across projects.

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Chapter 11: Condition, natural flow patterns

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Condition*

Desired Landscape Endpoint: Flow patterns mimicking natural hydrology

Forested wetlands are natural reservoirs that mitigate the downstream flooding effects of water inputs into the system (Kellison and Young 1997). Forested wetlands in the MAV capture backwater flooding and facilitate lateral exchange of water, sediments, and nutrients which drive the unique bottomland physical and biological structure of these systems (Junk et al. 1989, Kellison and Young 1997). However, their degree of saturation depends on factors such as the water table, evapotranspiration, amount of water input, and surface and groundwater flow (Jackson et al. 2004). Changes to flow velocity and inundation frequency in bottomland forest systems induce changes in forest productivity and nutrient transport (Lockaby et al. 1997). Maintaining a natural flow regime -- natural patterns of hydrologic magnitude, frequency, duration, and timing -- not only enhances the biotic integrity of the forest bottomland system, but also influences downstream water quality (Kellison and Young 1997, Poff et al. 1997). Though

hydrologic flow largely regulates the productivity and diversity of forested wetland systems, natural flow regimes are difficult to define (Poff et al. 1997).

Data Sources and Processing Methods

To assess potential flow patterns and hydrology in MAV forested wetlands systems, we examined data from the National Hydrographic Dataset (NHDPlus v2) using thresholds derived from the assessment of flow in medium-low gradient streams. We also used floodplain inundation frequency data developed by Allen (in press) in comparison in the MAV and GCPO geographies. NDH data provides mean annual flow estimates for all stream/river segments in the MAV and other subgeographies. Streams and rivers in this coarse assessment were restricted to segments with flow (Q0001A) > 10 cfs, or cumulative drainage area (TotDASqKM) > 10 km^2, (see Section ### for a more detailed assessment of flow in priority aquatic systems). We examined NHD flowline segments that were within 500 m of forested wetland pixels by converting pixels to point features (based on pixel centroid), then using select by location to select stream segments within 500 m. We then selected out segments with flow >10 cfs and cumulative drainage area > 10 km^2. We also used the GCPO Floodplain Inundation Frequency Mosaic, described in Section ## and developed by Allen (in press) as a basis for estimating floodplain availability, lateral connectedness, and permanent inundation in the MAV. This layer used leaf-off 1983-2011 Landsat 5 and 7 imagery Climate Data Records to assess inundation extent from areas where band 5 spectral signatures <500, or 501-1200 with NDVI <0.42 and slope <10% (see further description in Section #). For this assessment, floodplains were determined to be intermittently inundated, i.e., laterally connected, if frequency of inundation ranged between 10 and 90%, and were considered permanently inundated at >90% (see Section ### for more details). Inundation frequency was calculated based on a per-pixel index of proportion of Landsat scenes in which each pixel was classified to a wet condition. Each 30 m pixel in the GCPO geography was classified based on the proportion of inundation (0-1) over time, with 1 indicating 100% of scenes classified the pixel as wet. We resampled the IF dataset to a 250 m resolution using a nearest neighbor algorithm for this analysis. We then extracted the IF dataset through the forested wetland masks to evaluate forested wetlands that exhibited <10% inundation, 10-50% inundation, and >50% inundation.

Summary of Findings

As expected, mean annual flow in areas adjacent to MAV forested wetlands was double or greater than that of the other GCPO geographies, with the influence from the Mississippi River and its major tributaries dominating flow estimates in this region (**Table FW.13; Figure FW.16**). More information differentiating annual flow estimates in GCPO headwaters, creeks, small rivers, and medium tributaries and mainstems can be found in Section # assessing flow in medium-low gradient streams and rivers. However, it is not possible to surmise which mean annual flow rates in the MAV would be representative of “natural hydrology” and quantify how far estimated flow rates are from seasonal natural targets. Further the relationship between linear flow rates as provided by NHD and lateral exchange of water to floodplain forests needs to be further defined. Lateral flow in most mainstem big river systems is considered to be permanently altered by the extensive network of federal protection levees (see Section #) begging consideration regarding how natural hydrology could even be quantified in MAV forested wetland systems. If so identifying forested wetland systems where natural hydrology is still somewhat intact in both the MAV and remaining GCPO is paramount. Estimates of relative inundation frequency, suggest MAV forested wetlands contain the greatest total amount of intermittently (>10% inundation) flooded area compared to the other GCPO subgeographies

(**Table FW.14; Figure FW.17**). However, it must be noted that the forested wetland mask used in this portion of the assessment was developed using the inundation frequency as one of the three layer overlays from which pixels with two or more layers in agreement were classified as forested wetlands. Therefore an assessment of inundation frequency rates from within this mask introduces redundancy in analysis; however also demonstrates that inundation in forested systems via a remote sensing approach is challenging at a large scale. We therefore recommend results be approached cautiously.

Table FW.13. Estimated mean annual flow (cfs) (standard deviation, and range) in medium-low gradient streams and big rivers within 500 m of forested wetland pixels in the MAV and GCPO subgeographies based on NHDPlusv2 (adapted from Secton #).

Geographic extent	Mean annual flow (ft^3/sec)	SD	Range
Mississippi Alluvial Valley	**7,412**	**57,102**	**0 – 653,632**
East Gulf Coastal Plain	717	4,967	0 – 515,475
West Gulf Coastal Plain	627	3,276	0 – 51,178
Ozark Highlands	3,479	20,020	0 – 282,793
Gulf Coast	3,351	32,780	0 – 517,017
Gulf Coastal Plains and Ozarks (full extent)	2,145	25,939	0 – 653,632

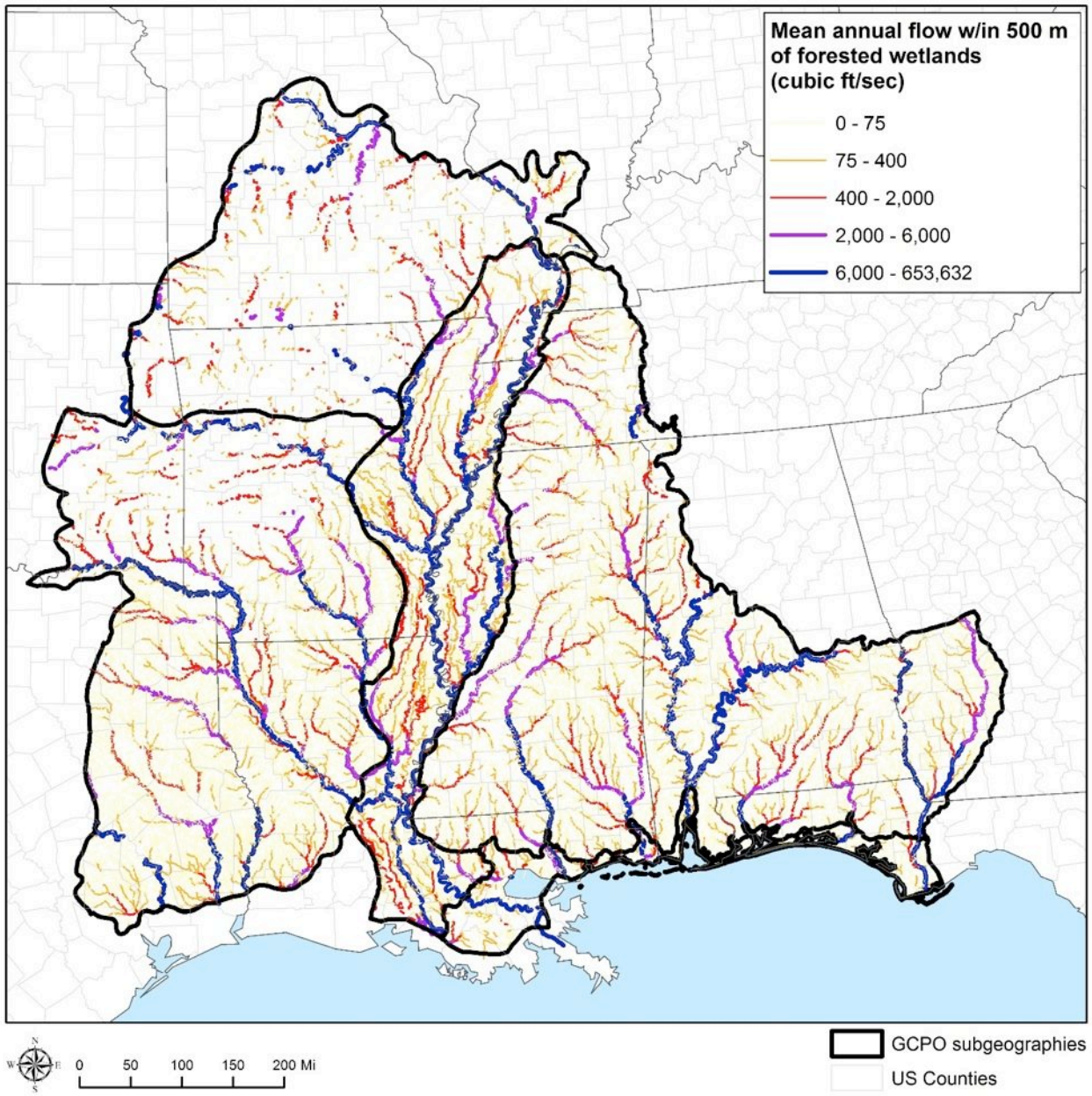

Figure FW.16. Mean annual flow based on NHDPlusv2 river and stream segments within 500 m of forested wetland pixels in the MAV and other GCPO subgeographies (see Section # for comprehensive flow assessment).

Table FW.14. Estimated mean floodplain inundation frequency (and standard deviation) on GCPO forested wetlands, and acres of forested wetlands subject to <10%, 10-50%,

and >50% inundation in the MAV and GCPO subgeographies based on the GCPO LCC Inundation Frequency layer (adapted from Secton #).

Geographic extent	Mean IF	Acres FW <10% inundation rate	Acres FW 10-50% inundation rate	Acres FW >50% inundation rate
Mississippi Alluvial Valley	**25.80% (SD 28.84)**	**1,930,494**	**1,814,926**	**915,942**
East Gulf Coastal Plain	13.17% (SD 23.41)	2,546,326	868,914	352,820
West Gulf Coastal Plain	13.67% (SD 23.04)	1,973,984	763,169	281,437
Ozark Highlands	29.81% (SD 32.39)	40,216	43,954	27,552
Gulf Coast	15.41% (SD 21.92)	757,748	524,218	116,402
Gulf Coastal Plains and Ozarks (full extent)	18.21% (SD 26.04)	7,248,768	4,015,181	1,694,153

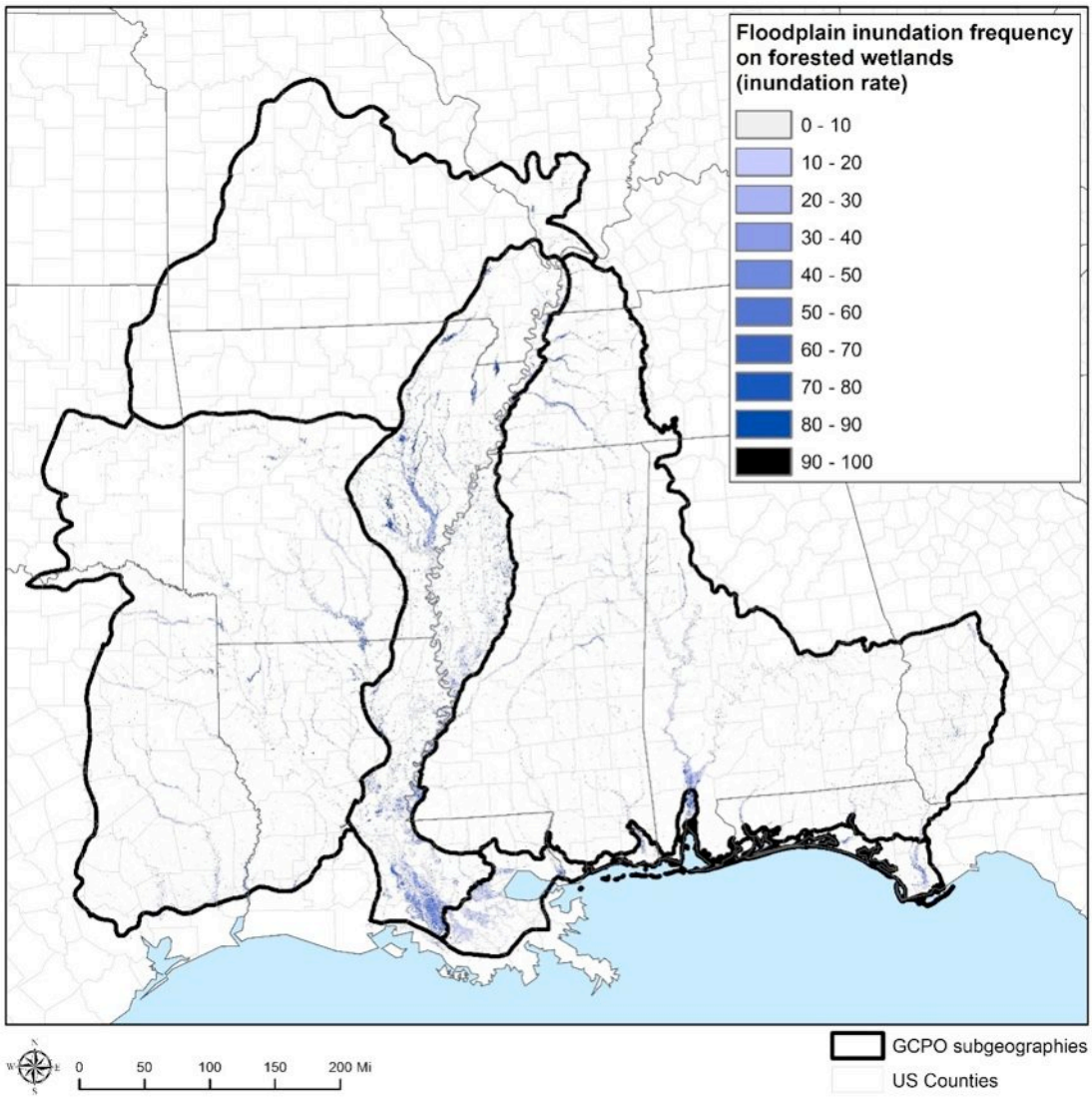

Figure FW.17. Floodplain inundation frequency extracted through the MAV and GCPO LCC forested wetland mask.

Future Directions and Limitations

It is widely recognized that there is limited capability to measure and map flow velocity using empirical data across large landscapes (Poff et al. 1997, Kilmas et al. 2009). However, advances in modeling techniques could make development of historic, present, and future models of landscape-scale flow possible. For example, flow could partially be addressed by recent work by LaFontaine et al. (2013), which takes a multi-model approach to assessing flow within the GCPO LCC. This approach develops a monthly Water Balance Model and Precipitation Runoff Modeling System to estimate natural flow volume and historic, present, and predicted streamflow in the GCPO. However, it is uncertain whether these models could be applied to seasonally inundated bottomlands or forested wetlands in riparian areas receiving overbank flooding. Restoring forested wetland systems to a natural hydrology requires an improved definition of a historic, or natural, hydrological condition in these highly-altered

systems. Models of historic flow regimes in forested wetlands, similar to the LaFontaine et al. (2013) work, may provide the necessary foundation from which concrete flow endpoints can be developed as needed. Estimates of historic and present flow, combined with frequency of flood inundation will reveal many conservation opportunities to restore natural hydrology in MAV forested wetland systems. Assessment of connectedness for intermittently inundated floodplains from the inundation frequency data might also be useful for determining hydrologic impacts on forested wetland systems (see Section #).

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- USGS TNM National Hydrography Dataset (vector – line)
- GCPO LCC Floodplain Inundation Frequency (raster)

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Chapter 12: Temporal considerations, successional stages

Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Temporal Considerations*

Desired Landscape Endpoint: An appropriate distribution of successional stages, with <10% of local landscape in early successional stage at any given time

Maintaining a limited proportion of successional habitat may benefit priority species in the MAV forested wetland system by providing soft mast as well as thickets of escape cover. Species like black bear (*Ursus americanus*), American woodcock (*Scolopax minor*), cerulean (*Dendroica cerulea*) and Swainson's warblers (*Limnothlypis swainsonii*) benefit from food resources and cover produced by canopy gaps (e.g., Dessecker and McAuley 2001, Bednarz et al. 2005). Forested wetland management should therefore be approached temporally, with forest regeneration in mind, by promoting an appropriate distribution of successional stages, with <10% of local landscape in early successional stage at any given time, with the exception of reforestation tracts (LMVJV Forest Resource Conservation Working Group 2007).

Data Sources and Processing Methods

We used USFS imputed forest stand age data (USDA Forest Service Remote Sensing Applications Center, personal communication) extracted through the forested wetland mask as a proxy for assessing distribution of successional stages on forested wetlands in the Mississippi Alluvial Valley (MAV) and other GCPO geographies. The USFS imputed stand age data product provides raster maps for the conterminous U.S. generated using 250 m resolution MODIS satellite imagery, ancillary environmental data, and 2000-2009 plot-level field data from the Forest Inventory and Analysis National Program (FIA). We used an extract by mask function in ArcGIS to delineate imputed stand age in forested wetlands, using the USFS imputed percent stand age layer as input data and the forested wetland mask representing the intersection of two or more classified forested wetland pixels from the gap NLCD/GAP/IF overlay described above. In the absence of discrete thresholds regarding the relationship between stand age and successional stage, we evaluated forested wetland stand age (acres and percent) in quantiles (0-22, 22-32, 32-42, 42-52, and 52-105 years). We assessed acreage by GCPO subgeography by summing the count of pixels of each quantile bin within each geographic construct and multiplying by pixel resolution (250 x 250 m = 62,500 m^2) and converting to acres. We also developed a comparative evaluation of forested wetland stands <22 years vs. >52 years (least and greatest quantile) by calculating the proportion of HUC 12 watershed area represented by each bin to highlight watersheds where a prevalence of early-successional forested wetlands and late-successional forested wetlands may be located.

Summary of Findings

Imputed stand ages ranged from 0 – 105 years on GCPO forested wetlands. Using the quantile approach to bin imputed stand age data we estimated that 70% of MAV forested wetland stands are <52 years old, with 19% estimated to be in an "early successional" stage (<22 years old) (**Table FW.15**), suggesting the distribution of stand age in MAV forested wetlands is skewed toward younger age-class forests. We estimate 29% of MAV forested wetlands are in mid-to-late successional stages (52-105 years). This estimate is similar to that observed in the Gulf Coast subgeography, but more than twice that of the East and West Gulf Coastal Plain and Ozark Highlands subgeographies, which exhibit between 10-12% of forested wetlands with stand age >52 years (**Table FW.15**). The Ozarks Highlands appears to have the youngest forested wetland stands in the GCPO, though data is limited primarily to the Missouri bootheel in this subgeography (**Figure FW.18**). When assessing by proportion of HUC 12 watershed we found limited coverage of early successional (<22 years) forested wetlands primary along the Mississippi River in the northern half of Louisiana and southern half of Arkansas, and also

extending into the Mississippi delta (**Figure FW.19**). However, these HUC12 watersheds are areas where substantial investments in conservation easements and public lands management have taken place, including areas in Warren, Issaquena, Sharkey, and other counties in Mississippi and areas east of the Red River Wildlife Management Area in Louisiana and Mississippi. Hot spots for older age class forested wetland systems can be found within the White River National Wildlife Refuge in Arkansas, Red River Wildlife Management Area and Atchafalaya Basin in Louisiana, Pascagoula River Wildlife Management Area in Mississippi, and Upper Delta Wildlife Management Area in the Mobile Bay of Alabama (**Figure FW. 20**). This points to the critical importance of protected public lands in providing later seral stage bottomland habitats for wildlife.

Table FW.15. Acres and percent of forested wetlands binned by quantiles of imputed forest stand age values (<22, 22-32, 32-42, 42-52, and 52-105 years) in the MAV and other GCPO LCC subgeographies generated using imputed stand age data provided by the U.S. Forest Service Remote Sensing Applications Center.

Geographic extent	Acres <22 Y (% FW)	Acres 22-32 Y (%FW)	Acres 32-42 Y (% FW)	Acres 42-52 Y (% FW)	Acres 52-105 Y (% FW)
Mississippi Alluvial Valley	902,166 (19%)	549,068 (12%)	733,810 (16%)	1,087,294 (23%)	1,362,430 (29%)
East Gulf Coastal Plain	795,679 (21%)	1,004,761 (27%)	863,308 (23%)	648,945 (17%)	444,156 (12%)
West Gulf Coastal Plain	566,489 (19%)	791,092 (26%)	779,246 (26%)	560,218 (19%)	313,499 (10%)
Ozark Highlands	33,112 (30%)	27,058 (24%)	25,035 (23%)	15,104 (14%)	10,873 (10%)
Gulf Coast	215,244 (15%)	200,742 (14%)	195,229 (14%)	298,225 (21%)	482,874 (35%)
Gulf Coastal Plains and Ozarks (full extent)	2,512,689 (19%)	2,572,720 (20%)	2,596,628 (20%)	2,609,786 (20%)	2,613,832 (20%)

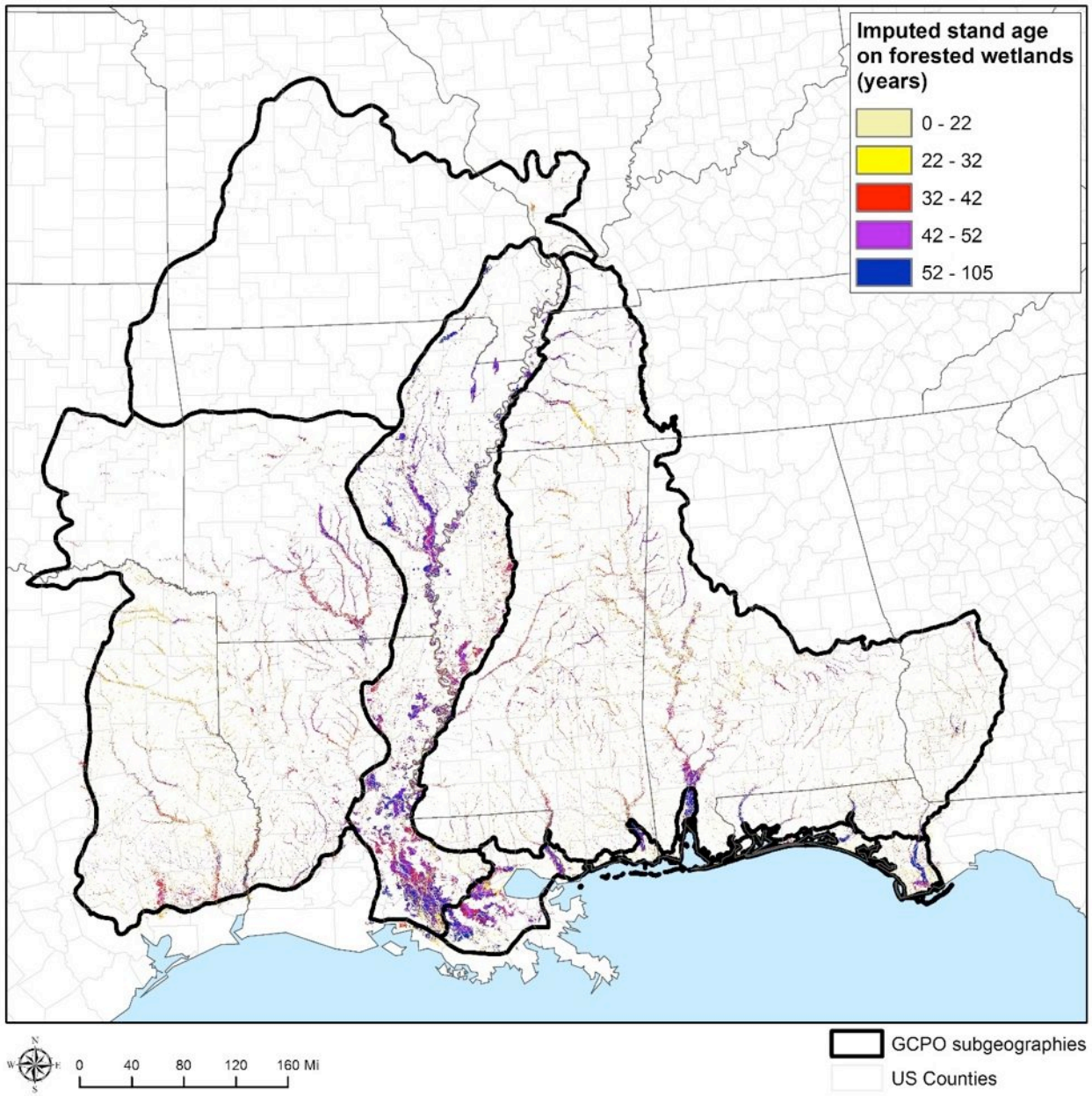

Figure FW.18. Imputed forest stand age values binned by quantiles (<22, 22-32, 32-42, 42-52, and 52-105 years) in the MAV and other GCPO LCC subgeographies generated using imputed stand age data provided by the U.S. Forest Service Remote Sensing Applications Center.

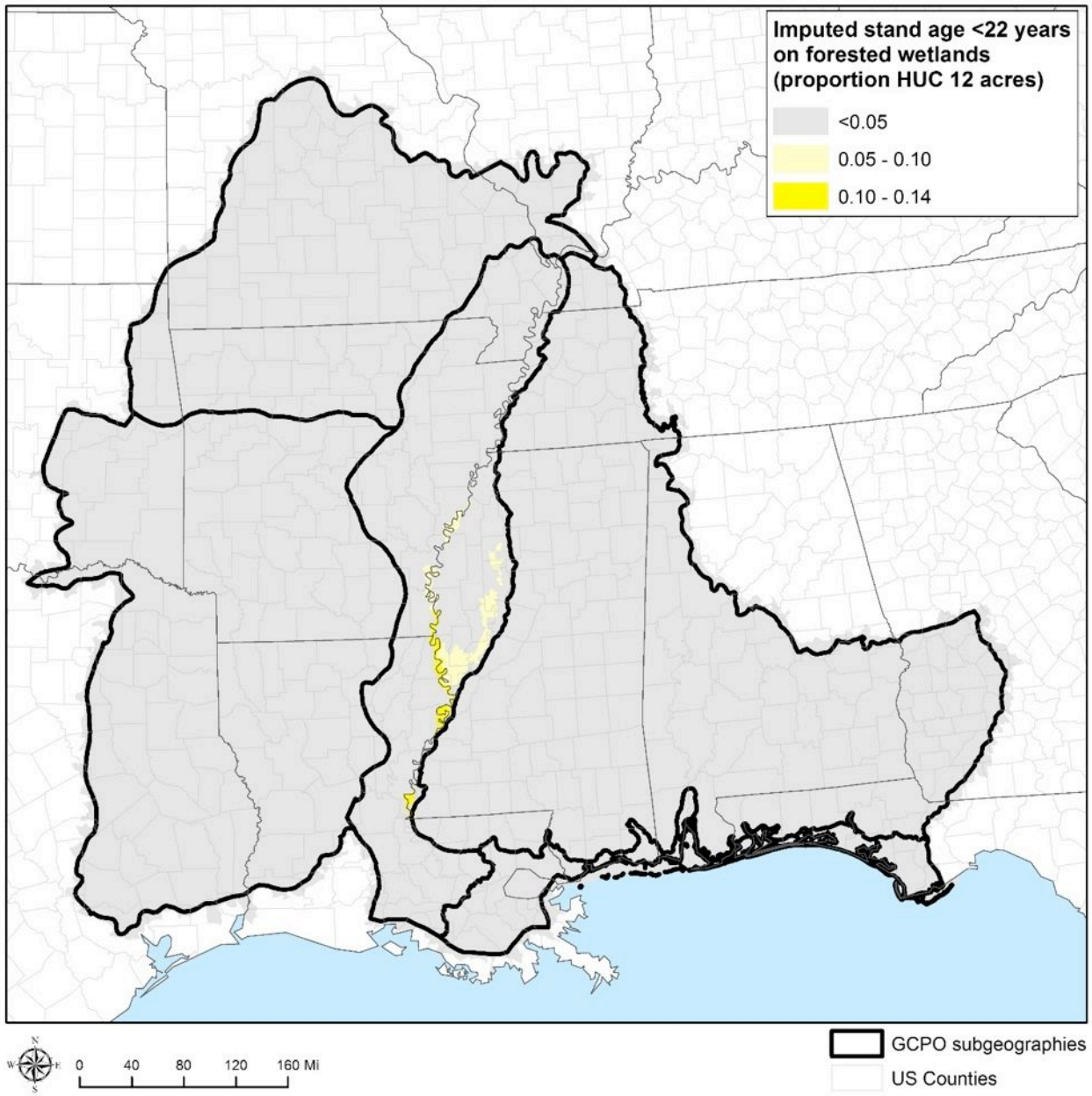

Figure FW.19. ***Proportional coverage of forested wetland acres with stand age <22 years old normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the MAV and GCPO LCC geography.***

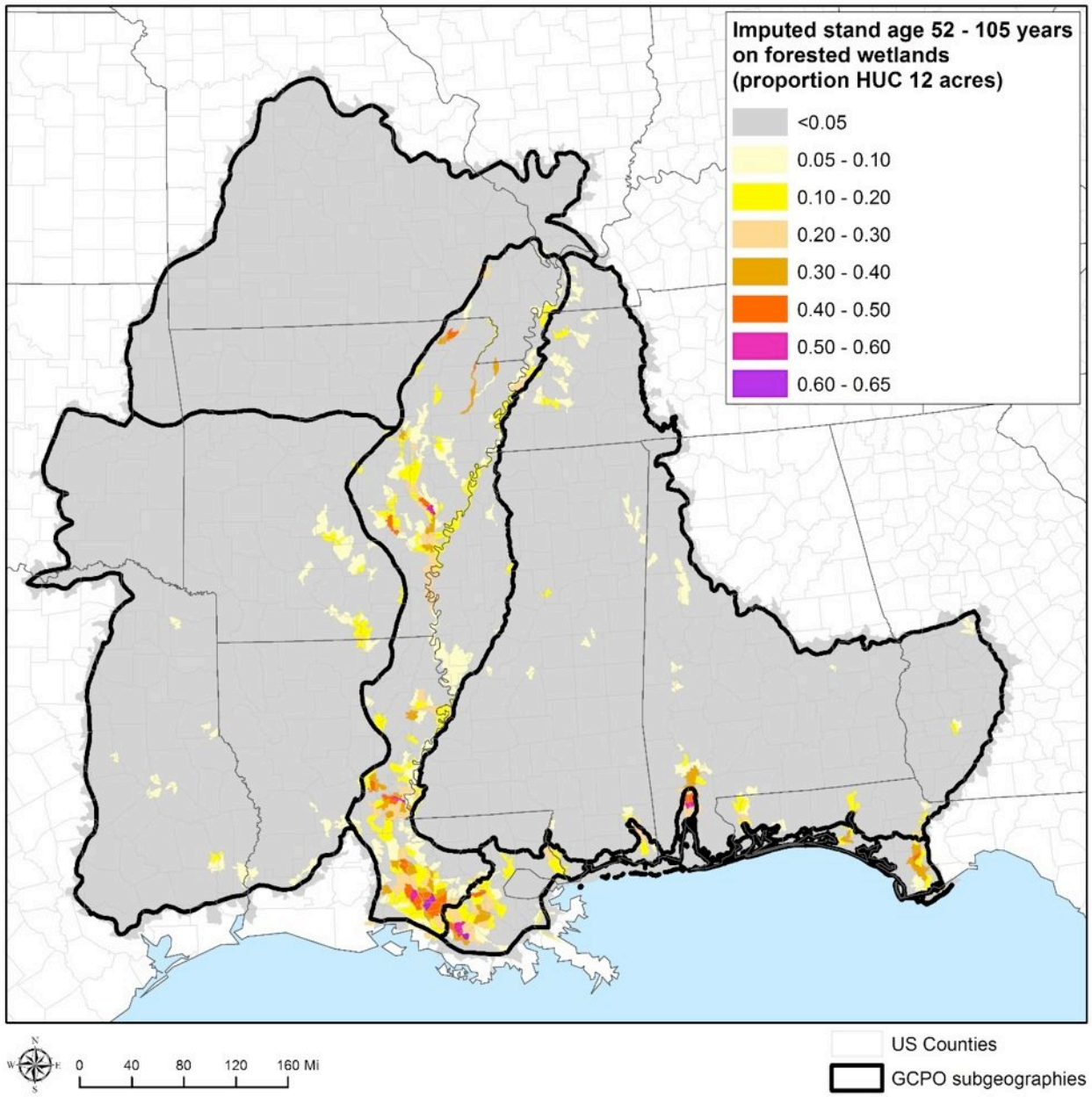

Figure FW.20. ***Proportional coverage of forested wetland acres with stand age >52 years old normalized by acres within each HUC 12 watershed and imputed from plot-level Forest Inventory and Analysis data by the U.S. Forest Service Remote Sensing Applications Center in the MAV and GCPO LCC geography.***

Future Directions and Limitations

Quantifying an appropriate distribution of successional stages is challenging and this endpoint was likely developed as intentionally vague until linkages between forested wetland succession and LCC priority species are better defined in the MAV. Without understanding how LCC priority species respond to amount and distribution of successional habitat patches in forested wetland

systems in the MAV, it is difficult to define and assess what an “appropriate” distribution of successional stages might be. As these relationships are explored further, we expect this endpoint will be clarified and refined to reflect ecological hypotheses regarding desired distribution of seral stages within MAV forested wetland systems. Results from this assessment of imputed stand age data provide coarsely estimated areas where early and late successional forested wetland systems are likely to be present throughout the LCC subgeographies, but the ephemeral nature of forested habitats may render this metric difficult to compare over time as assessments may not adequately capture successional changes in the landscape. Addition of empirical MAV forest restoration plot data from the forthcoming Forest Characterization Database data may provide supporting information if empirical data on plots over time could indicate variation in stand age.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Imputed forest stand age in GCPO forested wetlands (raster)

Technical References

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Subgeography: **MISSISSIPPI ALLUVIAL VALLEY**

Ecological System: **Forested Wetlands**

Landscape Attribute: *Amount*

Desired Landscape Endpoint: 3.7 million acres forested wetlands

The goals of the ecological assessment of forested wetlands were to determine where in the MAV and other GCPO geographies forested wetland systems exist in or nearly-in the desired ecological state outlined in the GCPO LCC Integrated Science Agenda, and how much acreage exists in the desired state relative to defined acreage targets. This information then provides an input layer into GCPO LCC Landscape Conservation Design efforts in combination with information on existing conservation investments, partner priorities, potential threats, and species-habitat associations to create a blueprint for large-scale conservation efforts into the future. The endpoint targeting 3.7 million acres of forested wetlands with a suggested 35-50% in the desired ecological state at a given point in time was initially derived from recommendations for forest breeding songbirds in the Partners in Flight Bird Conservation Plan for the Mississippi Alluvial Valley (Twedt et al. 1999), which was then incorporated into broad-scale recommendations for enhancing wildlife habitat in MAV bottomland forests by the Lower Mississippi Valley Joint Venture (LMVJV Forest Resource Conservation Working Group 2007). To address this 3.7 million acre target we used individual landscape endpoint data described in sections above to calculate a series of condition index values as a baseline for assessing amount of forested wetlands within or near the desired ecological state for this system.

Data Sources and Processing Methods

To assess the acreage target, we first used a series of raster calculations to compile a per-pixel draft condition index value for GCPO forested wetlands based on the number of configuration and condition endpoints met within each forested wetland pixel and a derived point scoring system (**Figure FW.21**). To complete this calculation all data meeting target landscape endpoints were first reclassified to a binary value of 1 or 0, reflecting whether the endpoint target was met or not.

Pixels not identified as a forested wetland but that were identified as having the potential to be forested wetland were given a score of 1, provided the pixels were not classified as developed or an open-water reservoir. Potential forested wetlands were derived from a combination of potential forested wetland classes the Mississippi Alluvial Hydrogeomorphic Model (HGM), the Central Hardwoods Potential Natural Vegetation layer, and the Landfire Biophysical Settings layer, whereas developed areas were extracted from the 2011 National Land Cover Database, and open water reservoir areas were extracted from the National Hydrography Dataset. This layer identified where forested wetlands could potentially be on the landscape based on edaphic, geographic and local site conditions. This layer was also reclassified to a binary 1 or 0 for calculation of the condition index value.

Pixels identified as forested wetlands were given a score of 2, whereas pixels found in extensively forested surrounding landscapes were given a score of 6, and pixels found in large (>10,000 ac) forest patches were given a score of 12. Pixels meeting condition endpoints of canopy cover, basal area, tree stocking, snag density, and midstory density were given one additional point for each endpoint, totaling up to five points. This scoring system allowed for calculation of a condition index value based on the decision tree outlined in **Figure FW.21**. Under this scoring system forested wetland pixels not meeting configuration endpoints of forest patch size or extensively forested landscapes scored a condition index value from 2-7, depending on how many condition endpoints were met. Forested wetland pixels not found in large (>10,000 ac) forest patches but that were found in extensively forested surrounding landscapes scored a condition index value from 8-13, depending on condition endpoints,

whereas forested wetland pixels that were found in large (>10,000 ac) forest patches but not in extensively forested surrounding landscapes scored a condition index value from 14-19. Forested wetland pixels that were found in large (>10,000 ac) forest patches and in extensively forested surrounding landscapes scored a condition index value from 20-25. An index value of 25 represents forested wetland pixels that are estimated to be in the desired ecological state, as determined by the suite of measurable condition endpoints. Condition index values were developed in a series of ArcGIS raster calculator computations to classify each pixel in the GCPO landscape to a value from 0 to 25, with 0 representing pixels that were not nor had the potential to be forested wetlands, 1 representing pixels that were not presently forested wetlands but had the potential to be, and values from 2 to 25 representing the gradient of index values associated with pixels that were classified as forested wetland.

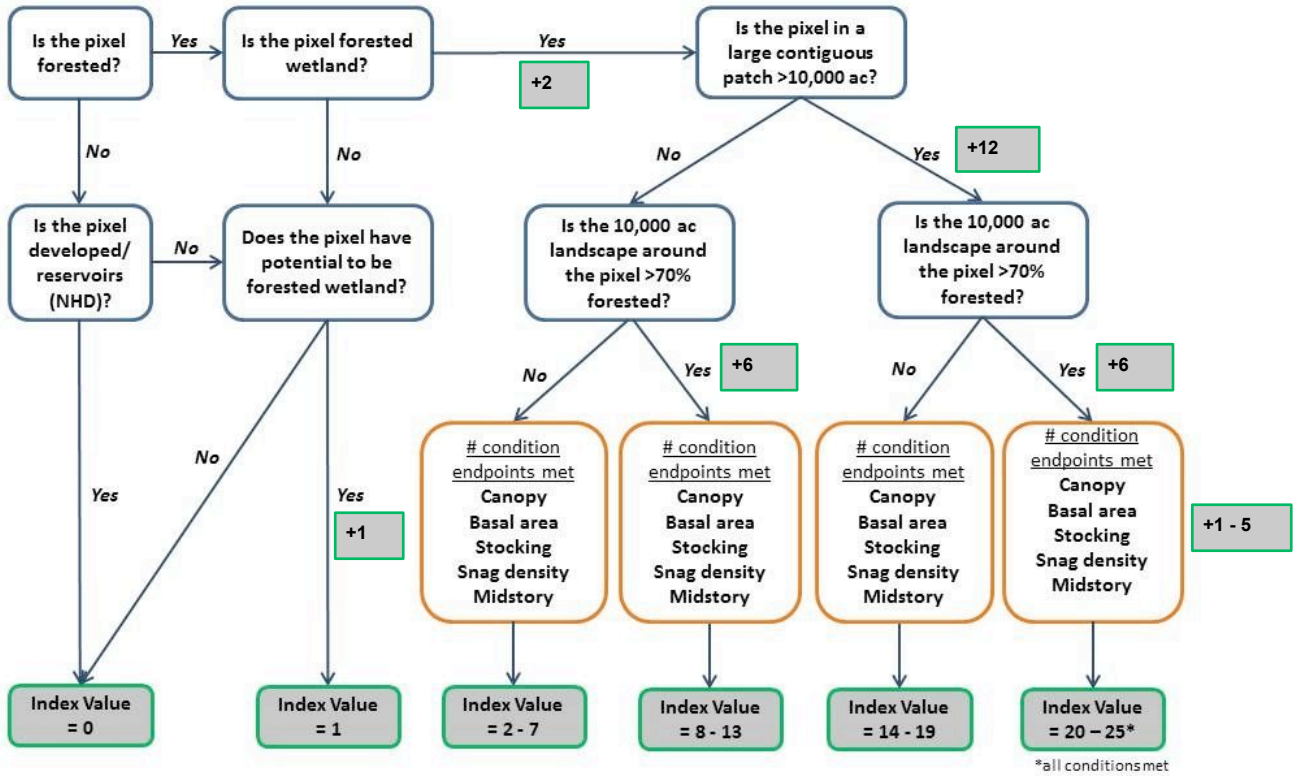

Figure FW.21. Draft decision tree for assigning condition index values based on meeting forested wetland landscape endpoints for incorporation into the GCPO LCC conservation blueprint for forested wetland systems. An index value of 25 suggests a particular forested wetland pixel is found in a large forest patch, in an extensively forested landscape, and within targets of overstory canopy cover, basal area, tree stocking, large snag density, and midstory density.

Summary of Findings

When examining acres of forested wetlands using the composite GAP/NLCD/IF layer we found 4.6 million acres of forested wetland in any condition in the MAV subgeography of the GCPO LCC. This suggests forested wetlands make up over 50% of the estimated 9.2 million acres of forest in the MAV. However, very few of those acres are in or near the ISA-defined desired ecological state for MAV forested wetlands. We found no pixels in the MAV subgeography and only 2 pixels (31 ac) in the GCPO West Gulf Coastal Plain subgeography demonstrated a

condition index value of 25 (i.e., met all quantifiable ISA landscape endpoints) (**Table FW.16**). This suggests only minute portions of the landscape exhibit all the quantifiable features of the desired ecological state for forested wetlands, as determined on a per-250 m^2 pixel (15.44 ac) scale. However, though virtually no pixels met targets for all quantifiable endpoints, many more pixels met some portion of the condition endpoints. For example, in the MAV over 32,000 acres met three condition endpoint criteria in addition to being found in large patches in heavily forested landscapes. Over 294,000 acres met two or more condition endpoints, and over 904,000 acres met at least one condition endpoint in addition to meeting criteria for large patch size and extensively forested landscapes (**Table FW.16**). Summing across acres with condition index values ≥21, we estimate about 27% of forested wetlands meet both configuration endpoints and at least one condition endpoint, and 7% meet at least two condition endpoints in the MAV. These results are promising, though falls short of the target 35-50% of forested wetlands in the desired ecological state. However there appears to be ample potential for restoring existing forested wetland systems to better meet the proposed desired ecological state for this system in the MAV.

Table FW.16. Amount of forested wetland (acres) in each Condition Index Value (CIV) category (see Fig. FW.21) calculated by summing CIV pixels in the Mississippi Alluvial Valley and other GCPO subgeographies. A CIV of 25 means all quantifiable endpoints were met, reflecting the desired ecological state for the forested wetland system. A CIV of 24 means forested wetlands met all endpoint targets except one condition metric, 23 means forested wetlands met all but 2 condition endpoints, and so on.

	Acres in CIV								
Geographic extent	**2-7**	**8-13**	**14-19**	**20**	**21**	**22**	**23**	**24**	**25**
Mississippi Alluvial Valley	**915,169**	**4,880**	**1,492,701**	**992,884**	**904,544**	**294,688**	**32,510**	**463**	**0**
East Gulf Coastal Plain	472,295	3,135	2,071,205	587,771	480,697	123,707	17,884	417	0
West Gulf Coastal Plain	287,228	2,193	1,347,851	702,381	540,882	11,3267	11,351	1,066	31
Ozark Highlands	58,502	448	30,255	10,780	8,015	2,409	108	0	0
Gulf Coast	161,576	1,158	377,237	395,384	306,302	132,958	16,046	386	0
Gulf Coastal Plains and Ozarks (full extent)	1,894,772	11,815	5,319,247	2,689,199	2,240,441	667,029	77,900	2,332	31

In the MAV forested wetlands in fair to good condition (condition index ≥21) were located throughout the MAV with heavy prevalence in the Atchafalaya Basin in Louisiana, along the White River in Arkansas, and areas near the Mississippi River in north central Louisiana and parts of the Mississippi Delta (**Figure FW.22**). Other areas around the GCPO geography included forested wetlands associated with the Mobile Bay in Alabama, Apalachicola Bay in Florida and several other drainages in the East and West Gulf Coastal Plain and Gulf Coast subgeographies of the LCC. As expected, forested wetlands were limited in extent in the Ozark Highlands subgeography. We estimate 445,206 acres of forested wetlands with condition index values ≥21 are located on federal, state, or non-profit protected lands with a GAP status between 1-3 in the MAV subgeography. This suggests 36% of MAV forested wetlands with a condition index value ≥21 are currently permanently protected, and ample opportunity for conservation on quality forested wetland habitat in private landholdings or incremental easements in the MAV. **Figure FW.23** shows an example of several protected and non-protected forested wetland pixels in and around Red River, Three Rivers, Grassy Lakes, Pomme De Terre, Spring Bayou, and Dewey W. Wills Wildlife Management Areas and Lake

Ophelia National Wildlife Refuge all demonstrating forested wetlands estimated to be in or near good ecological condition (condition index values ≥21).

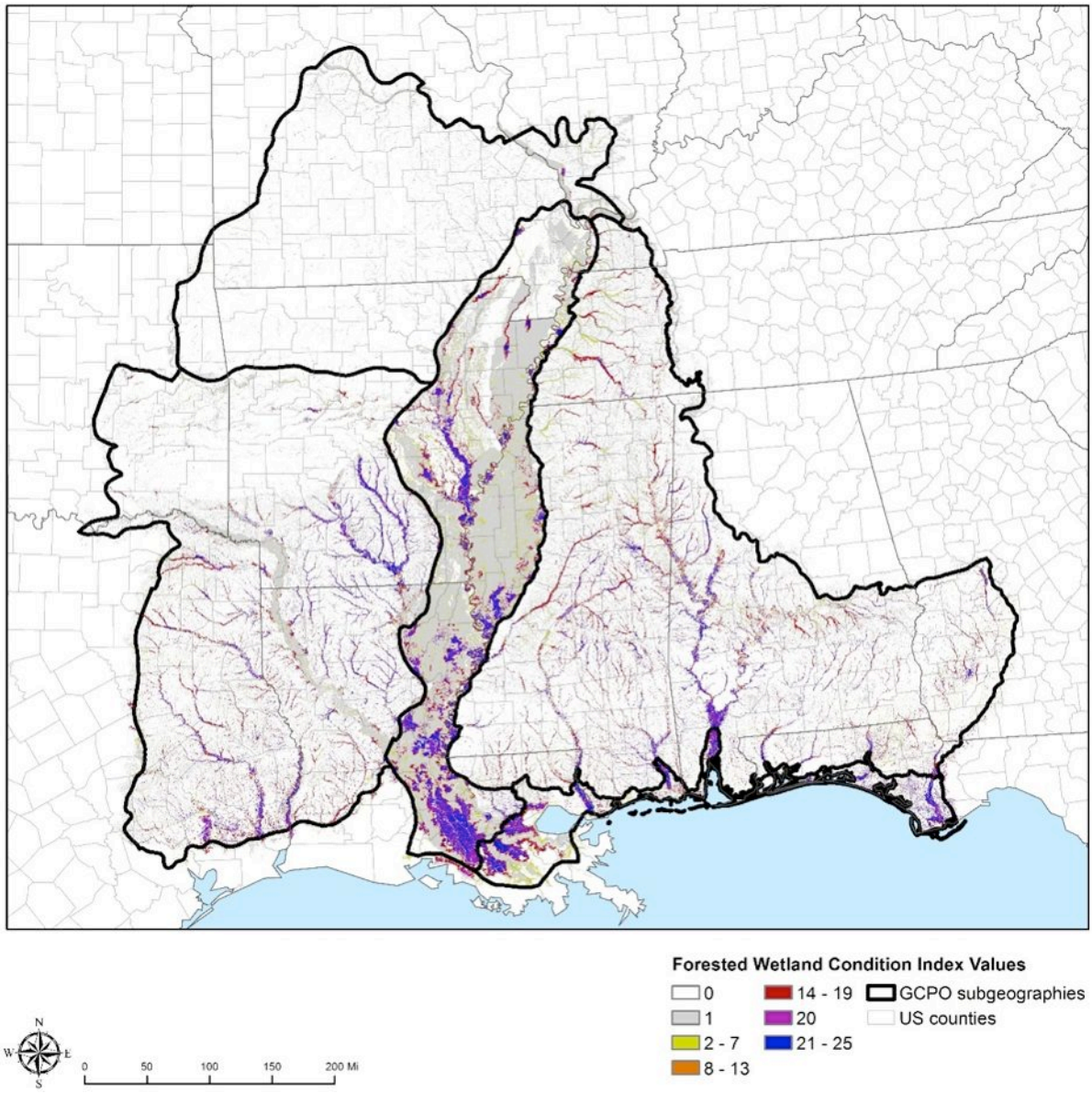

Figure FW.22. Draft condition index value scores in categories (2-7, 8-13, 14-19, 20, 21-25) based on the decision tree outlined in Figure FW.21 for use in the GCPO LCC conservation blueprint for forested wetland systems.

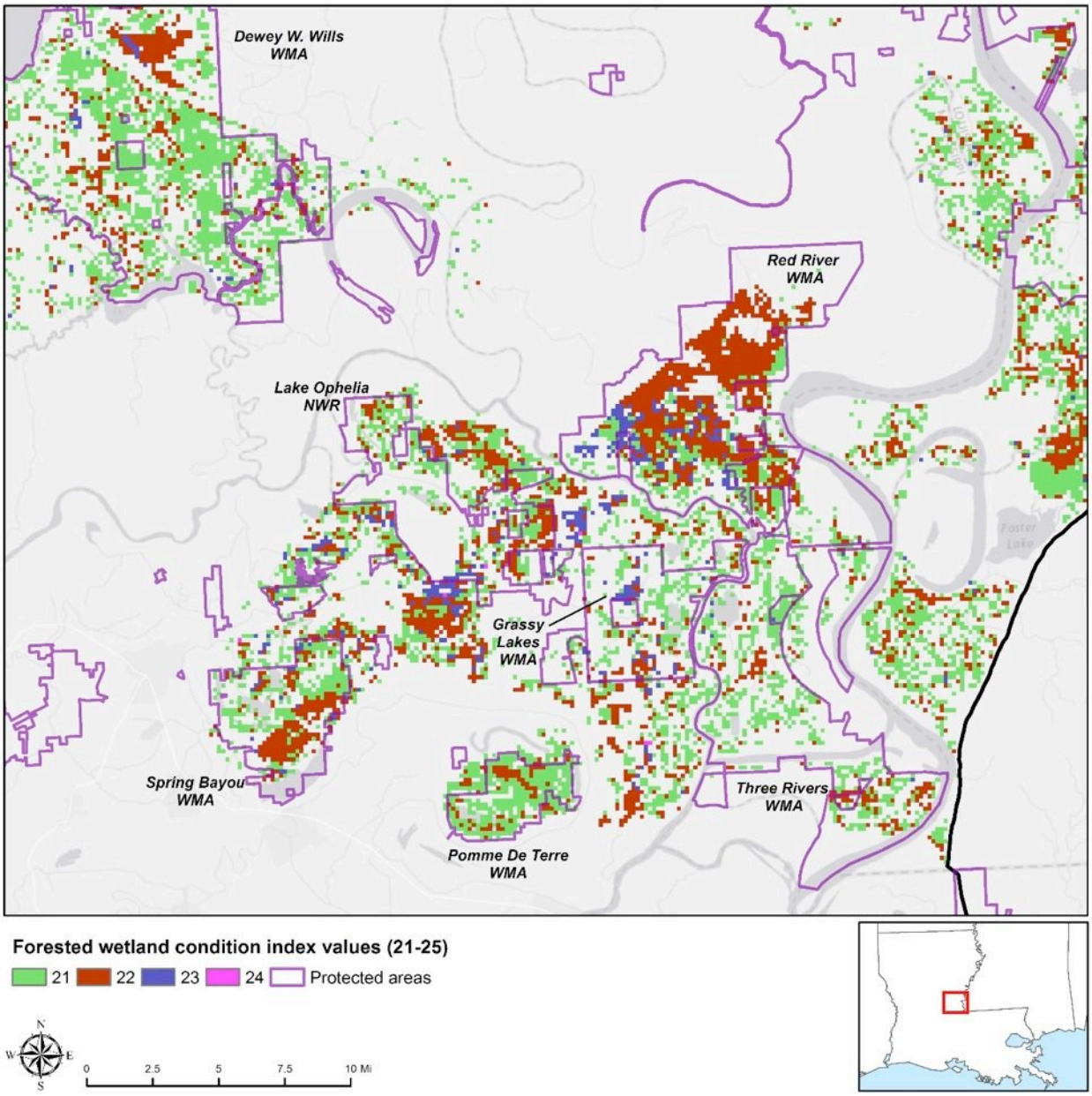

Figure FW.23. Example of forested wetland pixels found in large and extensively forested landscapes on public protected and private non-protected lands in east central Louisiana meeting as many as four out of the five condition endpoints and suggesting these areas are approaching the desired ecological state for forested wetland systems in the MAV subgeography as defined by the GCPO LCC Integrated Science Agenda. A condition index value of 24 means all but one target for condition endpoints is met on a given pixel, 23 means all but two, and so on.

Future Directions and Limitations

This target was defined based on a presumed requirement of 3.7 million acres of forested wetland to sustain a source population of breeding songbirds (Twedt et al. 1999). If assessed simply by presence of forested wetland habitats, regardless of condition, on the landscape, measures of forested wetlands estimated in this assessment far surpass the target. However, if assessed by amount of forested wetland that reflects the ISA-defined desired ecological state for the system, our estimates suggest a much smaller fraction of the MAV area meet the defined targets of configuration and condition. However, it is important to recognize that the 3.7 million acre target defined by the ISA is based from estimated habitat needs of forest breeding songbirds. The reality is that acreage targets will vary based on needs of priority wildlife species, such that overall habitat amount needs of a Louisiana black bear or even waterfowl may not be accurately reflected in this target. Our objective is to continually refine ISA targets based on improved understanding of priority species/habitat relationships over time such that future ISA landscape endpoint targets more accurately reflect the habitat needs over the range of priority species within a system. Continued engagement by species and habitat experts within the LCC partnership through this dynamic and iterative process will be paramount.

Estimates presented here implicitly assume that forested wetland classification as defined by land cover classification efforts like NLCD, GAP, and inundation frequency layers are accurate in determining the extent of forested wetland systems. We hope that data discrepancies across classifications have been at least partially resolved through use of the composite overlay where ≥2 layers must classify a pixel as forested wetland for that pixel to be used in the forested wetland mask for subsequent assessment of condition endpoints. However, we recognize that a composite approach such as this also had the potential to compound uncertainties across datasets, which are not assessed in this rapid assessment but may be a source of concern.

We also recognize that by using the pixel based approach toward calculating condition index values we are not considering scores of neighboring pixels into the calculation of areas or patches of forested wetland in or near the ISA defined desired ecological state for forested wetland systems. We will continue to adapt and evolve this approach over time and a moving window analysis that considers neighboring pixel scores into condition index values and may be implemented to add the neighboring pixel component to delineate patches of high quality forested wetland habitat in the future.

Conservation Planning Atlas Links to Available Geospatial Data Outputs

- Condition Index Value scores for GCPO forested wetlands (raster)

Technical References

LMVJV Forest Resource Conservation Working Group. 2007. Restoration, management, and monitoring of forest resources in the Mississippi Alluvial Valley: recommendations for enhancing wildlife habitat. R. Wilson, K. Ribbeck, S. King, and D. Twedt, editors. Lower Mississippi Valley Joint Venture.

Twedt, D., D. Pashley, C. Hunter, A. Mueller, C. Brown, and B. Ford. 1999. Partners in Flight Bird Conservation Plan for the Mississippi Alluvial Valley (Physiographic Area #05). Version 1.0. Partners In Flight. <http://www.partnersinflight.org/bcps/plan/MAV_plan.html>

Conclusion: Final Insights, Opportunities and Future Directions for MAV Forested Wetlands

The desired ecological state defined by the GCPO LCC Integrated Science Agenda targets 35 – 50% of a total 3.7 million acres of forested wetlands in the MAV that reflect "*local landscapes that are extensively forested with large contiguous patches of forest with a naturally diverse canopy containing a floristic diversity within the midstory and understory"*. The results of this assessment support the premise that though forested wetland area in the MAV is greater than the target 3.7 million acres, the proportion of forested wetlands actually reflecting the desired ecological state for the system is much more limited throughout. However, the results also suggest there is ample opportunity to manage existing forested wetlands in addition to restoring potential forested wetlands on the MAV landscape to better reach desired targets.

Landscape endpoint limitations

Targets for MAV forested wetland systems were developed in an avian context and it is critical that the LCC refine and revise targets to better reflect other priority taxa in this system, including representing habitat condition and configuration needs of black bear and Rafinesque's big-eared bat. The LCC has recognized this need and has a funded project underway with University of Maryland examining bear-habitat associations with defined ISA landscape endpoints. Other monitoring projects such as the Mobile Acoustical Bat Monitoring Program sponsored by the U.S. Fish and Wildlife Service National Wildlife Refuge System Southeast Inventory and Monitoring Network may help the LCC in understanding habitat associations of Rafinesque's big-eared bat.

Landscape endpoints represent hypothesized target thresholds, or the range of conditions for a particular landscape/habitat feature that we expect the suite of priority species to prefer. However, in many cases relationships among species and habitat are only generally understood, such that knowledge of a preferred range of habitat conditions is speculative. This issue is precipitated when attempting to hypothesize target thresholds across a suite of species. However, the ISA was intentionally built for continued refinement and revision and provides a "strawman" from which improved data and understanding of species-habitat relationships can be facilitated. In some cases discrete targets are provided, such as landscape endpoints for forested wetland patch size and amount, where targets were derived primarily from needs of forest breeding birds. This will be adjusted to include other target species' patch size and amount requirements as more information on those relationships comes to light. In some cases species-habitat information is so limited or unavailable, or relationships are so site-specific that vague non-prescriptive landscape endpoints are the only reasonable option. Endpoints like "diverse tree species composition" and "occurrence of cane and overstory vines" are examples of such cases. It is widely acknowledged that some priority species require these habitat features, but to what degree they require them is less well understood. Relationships among priority species and endpoints such as these must be better defined to be determined as a useful measure of desired system state. In other cases it will be difficult to define a range of threshold values due to a system that is extremely altered. As an example, the forested wetland endpoint targeting "flow pattern mimicking natural hydrology" will be challenging to measure as determinations of natural hydrology are hampered by the extensive network of protection levees in the MAV geography. This is particularly challenging as hydrologic flow is likely the primary regulator of forested wetland integrity.

Finally in some cases the ASMT will re-evaluate the priority species endpoints to determine if those species are appropriate indicators of a healthy forested wetland system. The LCC is actively engaged with the Adaptation Science Management Team to refine ISA targets based on improved understanding of priority species and species-habitat relationships over time such that future ISA endpoint targets more accurately reflect the habitat needs over the range of priority

species within a system. Improved data applicable to the GCPO scale and refinement of landscape endpoints such that they are quantifiable will greatly assist in making the ISA and subsequent system assessments more ecologically meaningful and measurable. Continued engagement by the Adaptation Science Management Team as well as species and habitat experts within the LCC partnership through this dynamic and iterative process will be paramount.

Data limitations

In addition to limitations regarding definition of ISA landscape endpoints, there are also situations where the geospatial data available to address an endpoint is limited in scope, resolution, or temporal scale. Issues experienced even in the initial delineation of a forested wetland mask were complicated by the availability of multiple and often non-congruent land cover datasets from which to base the assessment. We resolved this problem using dataset overlays, but that approach has the potential to complicate the analysis as each dataset was generated using a different vintage of imagery, and different classification approach. In our efforts to be conservative we risked compounding uncertainties through the stack overlay process. This risk permeates through the assessment since as many as eight derived datasets, each with unknown measures of uncertainty are stacked to create the final condition index values. Other data issues also arose during the assessment, such as inconsistent spatial resolution of input datasets, and the need to scale data to a common resolution. We typically scaled up to a 250 m resolution in this assessment, which caused the loss or dilution of information originally available in 30 m resolution datasets. This issue is a common one and not isolated to the GCPO's ecological assessment. This has been resolved in other situations such as the National Wetlands Inventory and the Florida Cooperative Land Cover, where projects of different lineages and different classification methods are readily combined into composite cover maps, provided they meet a certain defined standard.

Many of the endpoint analyses featured in the assessment of forested wetlands were built from imputed plot-level data of the standardized Forest Inventory and Analysis (FIA) national program. Advantages of this approach are that outputs are based on empirical data collected using standardized field protocols across counties in every state annually. However, continuous layers imputed from FIA data may have limited application in MAV forested wetland systems due to the largely non-forested matrix in the MAV. Also, in some cases, like the assessment of midstory cover, imputed FIA data was used as a proxy for the target metric. In this case rather than calculate proportion of midstory cover, data on midstory density was available, and without an empirical model of the relationship between percent cover and density, we were left to use quantiles or bins of data values as a proxy for proportion of cover. These issues could be resolved if future ISA revisions defined the midstory endpoint in terms of density, or if the relationship between midstory density and cover were better defined. Until resolved, we encourage some caution when interpreting the results derived from proxy measures of the defined ISA endpoint. In other cases the data simply was not available at the scale required for this assessment, such as for analyses related to percent understory cover and occurrence of cane and vine. These may reflect endpoints that are truly only measureable at the plot-level or local scale, and we recommend users of condition index values adjust for these measures if they are available at the appropriate application scale.

Future directions

Refinements in understanding of species-habitat relationships will result in improvements in delineation of ISA endpoints over time. In MAV forested wetland systems it will be critical to continue aligning with existing partners like the Lower Mississippi Valley Joint Venture, Ducks

Unlimited, and other organization throughout future ISA endpoint iterations. Endpoints will also likely be adjusted to incorporate variation in priority systems, such as is already underway in aquatic systems with the LCC-funded project refining freshwater aquatic landscape condition and species endpoints led by the Southeast Aquatic Resources Partnership, and in the pine system with the LCC-funded southern open pine desired forest conditions project led by NatureServe. Improvements in spatially-explicit data will also aid in refinement of individual endpoint assessment and the composite condition index scores. Progress toward improved geospatial datasets like comprehensive LiDAR coverage at Quality Level 2 or better across the GCPO LCC will greatly enhance our ability to assess vertical forest structure in many LCC priority systems.

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