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Conservation–Protection of Forests for Wildlife in the Mississippi Alluvial Valley

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Abstract: The nearly ubiquitous bottomland hardwood forests that historically dominated the Mississippi Alluvial Valley have been greatly reduced in area. In addition, changes in hydrology and forest management have altered the structure and composition of the remaining forests. To ameliorate the detrimental impact of these changes on silvicolous wildlife, conservation plans have emphasized restoration and reforestation to increase the area of interior (core) forest habitat, while presuming negligible loss of extant forest in this ecoregion. We assessed the conservation–protection status of land within the Mississippi Alluvial Valley because without protection, existing forests are subject to conversion to other uses. We found that only 10% of total land area was currently protected, although 28% of extant forest was in the current conservation estate. For forest patches, we prioritized their need for additional conservation–protection based on benefits to forest bird conservation afforded by forest patch area, geographic location, and hydrologic condition. Based on these criteria, we found that 4712 forest patches warranted conservation–protection, but only 109 of these forest patches met our desired conservation threshold of >2000 ha of core forest that was >250 m from an edge. Overall, 35% of the area of forest patches warranting conservation–protection was protected within the conservation estate. Even so, for those forest patches identified as most in need of conservation–protection, less than 10% of their area was currently protected. The conservation–protection priorities described fill an unmet need for land trusts and other conservation partners pursuing strategic forest protection in support of established bird conservation objectives.

Keywords: protected areas; conservation estate; conservation planning; bottomland hardwood forest

1. Introduction

Deforestation and conversion of land to agricultural production, abetted by levees and other flood mitigation projects, have markedly decreased the extent of bottomland hardwood forests in the Mississippi Alluvial Valley [1–3]. Because of this decreased forest area, many populations of forest-dependent wildlife have declined [4]. To increase the area of forest habitat for the conservation of migratory birds and other wildlife, conservation delivery professionals have relied on reforestation (also known as afforestation) to restore converted forest land. The Lower Mississippi Valley Joint Venture partnership (www.lmvjv.org) has promoted reforestation in this ecoregion for over two decades, as evidenced by avian conservation plans [5] and conservation decision support tools that prioritize restoration locations to enhance the conservation of breeding birds [6]. These avian conservation plans and restoration models were largely premised on the area and location of extant forest. Additional loss of extant forest not only has a direct negative impact on species using these habitats, but may adversely affect the efficiency of ongoing forest restoration if areas of forest loss are adjacent to ongoing forest restoration.

Protected areas that are owned or managed by conservation-oriented entities and lands subjected to perpetual conservation-oriented easements or servitudes are effective methods of ensuring permanence of extant habitat, while concurrently conserving wildlife biodiversity and providing a range of other socio-economic benefits [7]. Indeed, the United Nations Aichi Biodiversity Target is that by 2020 "at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures" [8]. Despite this mandate, the conservation–protection status of bottomland forests in the Mississippi Alluvial Valley has neither been quantified nor prioritized. Similarly, the degree to which existing protected areas are ecologically representative of historical bottomland forests is unknown. The Mississippi Alluvial Valley is of particular importance to North American biodiversity and ecosystem services as the largest floodplain in North America. It seasonally supports 40% of North America's waterfowl, 107 species of land birds breed in the ecoregion, and threatened and endangered species, such as pallid sturgeon, depend on floodplain dynamics of the Mississippi River. Thus, conservation–protection of forests in the Mississippi Alluvial Valley would greatly contribute to the United Nations Aichi Biodiversity Target.

To better understand current threats to bottomland forests and reduce the likelihood of future forest loss in the Mississippi Alluvial Valley, we sought to identify and characterize the conservation–protection status of existing forests and to prioritize additional need for forest protection within this ecoregion. We deemed forest areas to have protected conservation status when a reduced likelihood of being converted to non-forest habitat was conveyed via public (federal, state, or local government) or non-governmental conservation organization (NGO) ownership or from perpetual conservation-oriented easements or servitudes that were recorded in local land records.

Guided by the biological underpinning of a minimum area of core forest (i.e., interior forest buffered from deleterious forest edge effects), we sought to ascertain the current and future contribution of each forest patch for bird conservation based on existing levels of conservation–protection, landscape context, and hydrologic condition. Specifically, we evaluated the current level of conservation–protection for forest patches with sufficient area of core forest to be deemed important for forest-breeding birds. In addition, we presumed a greater need for conservation–protection for forest patches that were proximate to high priority reforestation zones, with the intention of increasing the efficacy of ongoing forest restoration efforts [6]. Finally, because forest patches less prone to frequent flooding have been disproportionately converted to agricultural use [1,2], we also presumed an increased need for conservation–protection of these forest patches.

2. Materials and Methods

2.1. Study Area

The Mississippi Alluvial Valley Bird Conservation Region (http://nabci-us.org/resources/bird-conservation-regions-map/#bcr26) is a relatively flat, weakly dissected alluvial plain of >10 million ha within 7 states: Illinois, Missouri, Arkansas, Kentucky, Tennessee, Mississippi, and Louisiana (Figure 1). Topographic and hydrologic differences subdivide this region into 14 physiographic provinces [9]. In this ecoregion, forest-dwelling birds are of great conservation concern because over two-thirds of the area that was formerly forested has been converted to other land uses.

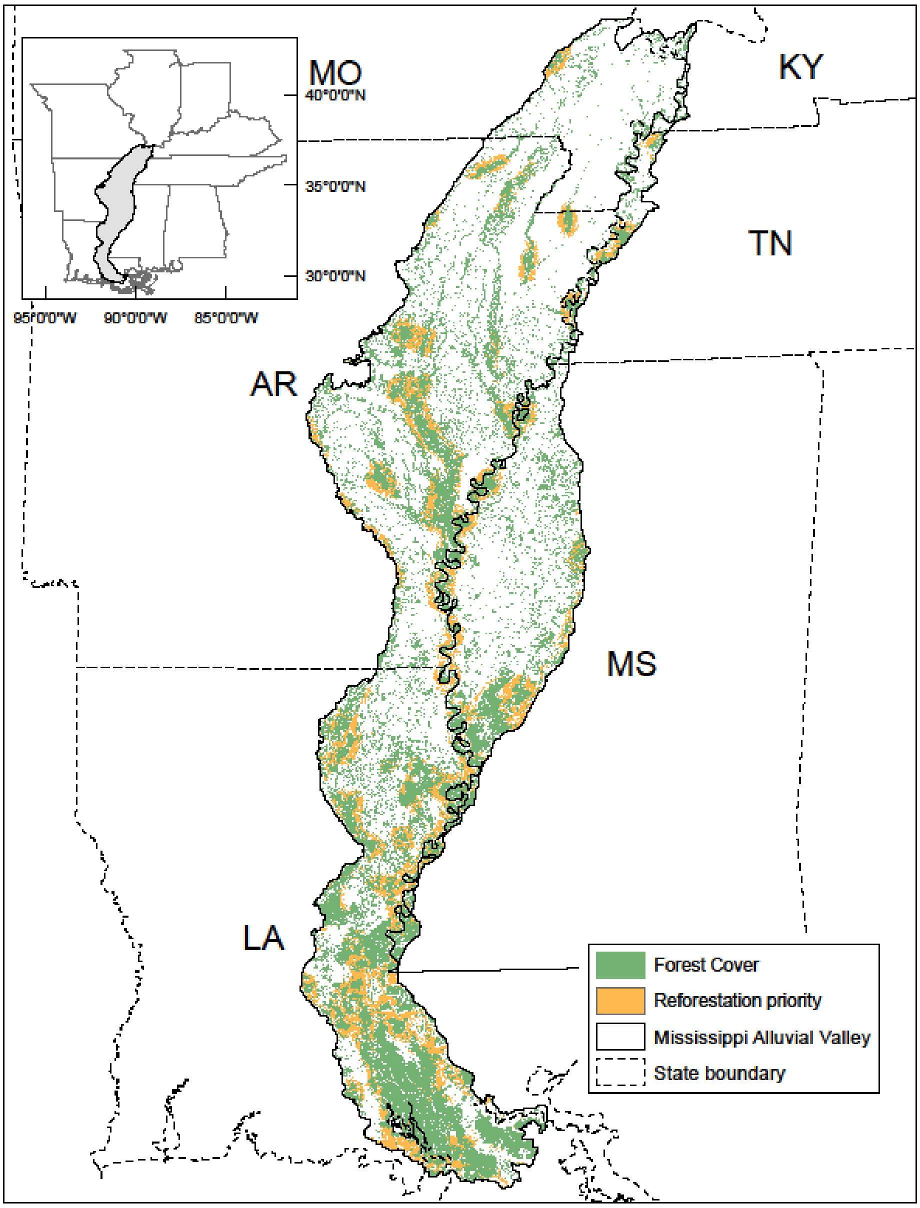

Figure 1. Forest habitat (green [3]) and high priority zones for forest restoration (brown [6]) within the Mississippi Alluvial Valley.

Average annual precipitation is 114–165 cm. Natural vegetation has been cleared from most of this ecoregion [1,2,10], being primarily converted to agriculture. Historically, extensive flooding dictated vegetative conditions, but levees, dikes, and dams have markedly altered the hydrology of the Mississippi Alluvial Valley [11]. These hydrological changes have influenced the composition and structure of the remaining forested wetlands [12–14].

Forest cover currently comprises approximately 30% of area within the Mississippi Alluvial Valley [3]. Remaining floodplain forests are dominated by oak-gum-cypress and elm-ash-cottonwood cover types. Co-dominant species within these forest types include oaks [overcup (*Quercus lyrata*), willow (*Quercus phellos*), Nuttall (*Quercus nuttallii*), water (*Quercus nigra*), and cherrybark (*Quercus pagodaefolia*)] as well as sweetgum (*Liquidambar styraciflua*), water hickory (*Carya aquatica*), sugarberry (*Celtis laevigata*), American elm (*Ulmus americana*), bald cypress (*Taxodium distichum*), green ash (*Fraxinus pennsylvanica*), and others [1]. Oak-hickory forests occur on isolated upland inclusions (e.g., Crowley's Ridge) within this floodplain. Co-dominant upland tree species include post (*Quercus stellate*), southern red (*Quercus falcata*), black (*Quercus velutina*), chinkapin

(*Quercus muehlenbergii*), and white (*Quercus alba*) oaks along with mockernut hickory (*Carya tomentosa*) and others [10].

2.2. Data Sources

Boundary: For our analyses, we used the Lower Mississippi Valley Joint Venture's conservation planning boundary for the Mississippi Alluvial Valley Bird Conservation Region because it well delineates the transition from alluvial floodplain and deltaic lands to upland habitat. We included all upland inclusions that were wholly contained within this boundary (Figure 1; http://www.arcgis.com/home/item.html?id=c72185797b564b5995f44e9bc367163e).

Forest: We used a binary forest classification derived from 2011 Landsat satellite imagery [3] to identify extant forest habitat within, and 1 km beyond, the Mississippi Alluvial Valley boundary (Figure 1; SROWEB.DBO.T2011_forest_w_reforestation; https://gisweb.ducks.org/arcgis/rest/services/SRO/Forest_2011/MapServer/0).

Reforestation priority: Reforestation (i.e., afforestation) priorities for bird conservation have been established for restorable lands within the Mississippi Alluvial Valley. These priorities are intended to effectively increase the number of forest patches that harbor >2000 ha of core forest, while concurrently targeting more than 60% forest cover within local (320 km^2) landscapes and restoration of higher elevation bottomland hardwood forests [6]. We extracted and used the highest (upper 10%) priority restoration zone from this reforestation decision support model (Figure 1; LMVJV/FBBDSM_2011; https://gisweb.ducks.org/arcgis/rest/services/LMVJV/FBBDSM_2011/MapServer).

Flood frequency: We used the inundation frequency of lands in the Gulf Coastal Plain and Ouachita Mountains (GCPO), including the Mississippi Alluvial Valley, that was developed from 50 Landsat scenes and 1334 total images depicting inundation extent under varying hydrologic conditions [15]. Inundation frequency ranged from 0% to 100% (in Supplementary Materials: GCPO Inundation Frequency Mosaic; https://www.sciencebase.gov/catalog/item/5617e3c3e4b0cdb063e3fc35).

Conservation estate: We identified lands owned or managed by conservation-oriented entities, either public or private, and lands subjected to perpetual conservation-oriented easements or servitudes from 7 geographic information system (GIS) source files:

1. Protected Areas Database of the United States 2.0, 2018: From the U.S. Geological Survey Gap Analysis Project, this database included public and non-profit lands and waters. Most were public lands owned in fee title, but the database also contained long-term easements, leases, agreements, and congressional (e.g., Wilderness Area), executive (e.g., National Monument), and administrative (e.g., Area of Critical Environmental Concern) designations as documented in agency management plans (https://doi.org/10.5066/P955KPLE).
2. National Conservation Easement Data, 2018: A public–private partnership database of locations for more than 150,000 conservation easements and land trusts throughout the United States (https://www.conservationeasement.us/).
3. Ducks Unlimited Conservation Easements, 2017: Locations for lands under conservation easement with Ducks Unlimited, Inc., a non-governmental conservation organization (https://gisweb.ducks.org/arcgis/rest/services/LMVJV_Parcel/Parcel_Private/MapServer/1).
4. Wetlands Reserve Program, 2016: Location information for lands under federal conservation easements with the U.S. Department of Agriculture. These conservation easements included the Wetland Reserve Program, Wetland Reserve Enhancement Program, and Wetland Reserve Enhancement Partnership. These data are not publicly accessible.
5. State Wildlife Management Areas, 2015: A Lower Mississippi Valley Joint Venture compiled database of locations for state-owned or managed wildlife conservation areas as provided by the conservation agencies of their state partners (https://gisweb.ducks.org/arcgis/rest/services/SRO/WildlifeManagementArea/MapServer/0)

6. National Wildlife Refuge System, 2015: Locations of existing U.S. Fish and Wildlife Service and National Wildlife Refuges as well as designated "areas of interest" for potential future acquisition by the National Wildlife Refuge system (https://gis.fws.gov/arcgis/rest/services/FWSCadastral_Internet/MapServer/2).
7. The Nature Conservancy, Louisiana Lands, 2018: Locations of lands owned or managed by the non-governmental conservation organization, The Nature Conservancy in Louisiana. These data are not publicly accessible.

All GIS raster data were obtained or converted to 30 m (900 m^2) pixel resolution for analyses. Unless otherwise stated, GIS manipulations were accomplished within ArcMap (Version 10.5.1; Environmental Systems Research Institute, Redlands, CA, USA). The above files were merged to create a unified depiction of the current conservation estate within the Mississippi Alluvial Valley (Figure 2; in Supplementary Materials: https://doi.org/10.5066/P90V76SY).

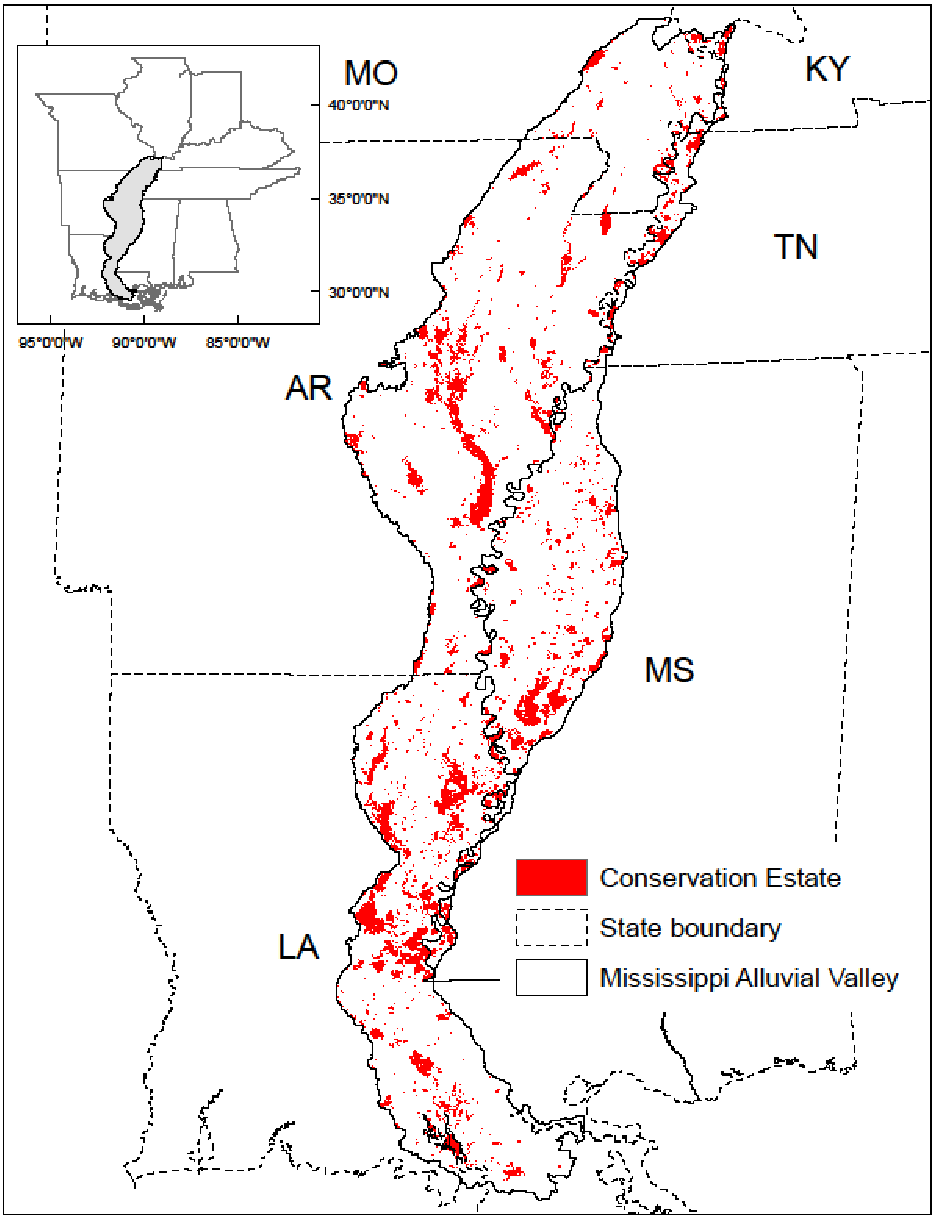

Figure 2. The existing conservation estate within the Mississippi Alluvial Valley wherein conservation–protection is legally mandated or culturally implied. Data sources are provided in text.

2.3. Forest Patches

Previous planning efforts for the conservation of forest-breeding birds in the Mississippi Alluvial Valley have made the biological assumption that birds occur at higher density, have increased probability of survival, and have greater reproductive success within forest interiors (i.e., core forest) [6,16,17]. To mitigate the presumed detrimental influences associated with forest edges [18], initial conservation planning in this region used a conservative 1000 m buffer from 'hostile' edges [19]. More recent conservation plans have assumed that a buffer distance of 250 m is enough to mitigate the detrimental effects of hostile edges [16].

We identified all extant forest patches (core forest plus the buffer), including reforested areas, within the Mississippi Alluvial Valley [3]. After identifying and including non-hostile habitats, we extracted core-forest areas that were >250 m from a hostile forest edge [16]. We considered cropland, pasture, grassland, aquaculture, urban, and suburban habitats to be hostile edges because these ecotones with forest tend to promote predator incursions [20] and greater abundance of the nest parasite, brown-headed cowbird (*Molothrus ater*) [21]. Conversely, we considered shrublands, emergent wetlands, and natural water bodies to be non-hostile habitats, such that forest core habitats extended to the boundary of these non-hostile edges.

Once core forest was identified, we used the ERDAS Imagine (Hexagon Geospatial, Madison, Alabama) raster processing software to clump (i.e., group) and uniquely identify all contiguous areas of core forest, hereafter referred to as 'core clumps'. Core clumps were separated from other clumps by at least one pixel (900 m^2) around the entirety of the clump, such that corner connections (i.e., diagonally connected pixels) retained continuity of the clump. The area (ha) of each forest core clump was then calculated.

In addition to reliance on forest interior habitat, previous conservation planners also assumed that a large area of core forest is needed to ensure occupancy by enough breeding individuals to diminish the likelihood of extirpation of a species from the forest patch and to provide habitat diversity consistent with the needs of priority bird species [5]. The minimum area of core forest previously recommended was 2000 ha [6]. Ongoing evaluation of habitat needs for breeding birds in this ecoregion suggests that a 2000 ha area of core forest would support populations with less than 1% likelihood of extirpation over 100 years for 46 out of 56 (82%) breeding species. Therefore, our goal was to emphasize core forest of >2000 ha. We recognized that additional forest restoration adjacent to core clumps <2000 ha could result in core clumps that exceed this threshold area. Therefore, we retained all core clumps ≥1600 ha (80% of 2000 ha). In addition, because reforestation efforts continue to focus restoration within higher priority forest restoration zones, we retained all core clumps (regardless of ha area) that were adjacent to the highest (upper 10%) reforestation priority zones (Figure 1).

We reestablished the entirety of forest patches for this set of core clumps that were ≥1600 ha or adjacent to high restoration priority zones (Figure 3), by returning the 250 m non-core forest buffer. Concurrently, we retained only forested habitat by removing water and herbaceous wetland habitat from these forest patches.

2.4. Conservation–Protection

For each forest patch meriting consideration for conservation–protection, as described above, we determined the percentage of the patch that was outside the conservation estate. Thus, forest patches with a value of 100 had no existing conservation–protection and were in greatest need of forest protection. Conversely, those patches with a value of 0 were fully protected and no additional forest protection was warranted. We adjusted the perceived need for conservation–protection of each forest patch, which was initially based solely on percent area not protected, to account for location and hydrology.

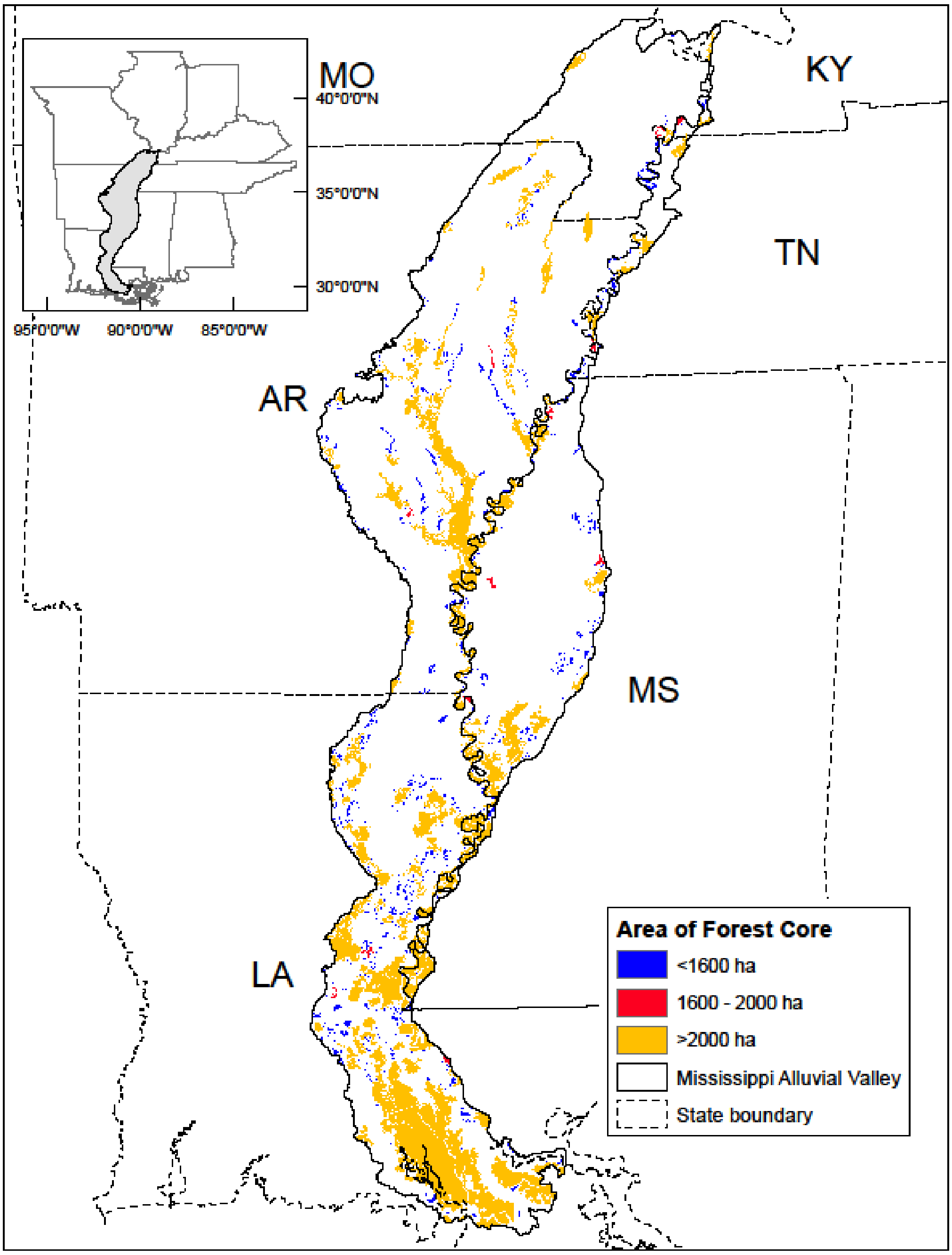

Figure 3. Extant forest patches within the Mississippi Alluvial Valley with merit for protection to support bird conservation by virtue of having interior core habitat (>250 from hostile edge) area >1600 ha or being located adjacent to high priority (upper 10%) restoration zones. Data source: this study.

2.5. Location

Because core forest patches with <2000 ha of core area were perceived to have less than optimal conservation value for forest-breeding birds, we reduced the perceived need for conservation–protection of core forest patches with 1600–2000 ha by 50% and core forest patches with <1600 ha by 100%. Conversely, we granted patches an increased need for protection when core forest patches were adjacent to the highest priority reforestation areas and therefore have greater potential for expansion of their core area. Within these high priority forest restoration areas, we increased the attributed need for protection by 40% of their initial perceived need for conservation–protection for patches with ≥2000 ha of core forest and by 20% of their initial perceived need for conservation–protection for patches with <2000 ha of core forest (Table 1).

Table 1. Adjustments to attributed need for additional conservation–protection (% of patch unprotected) of forest patches within the Mississippi Alluvial Valley; reduced for small core area (% of original conservation–protection value), increased (20% or 40% of original conservation–protection value) when location was within a high priority reforestation zone, and further increased up to 20% relative to dryness of forest patch.

Area (ha)	Percent of Original Core Area Conservation–Protection Value	Reforestation Zone Addition	Hydrology Addition
≥2000	100%	40%	20% of dryness coefficient
1600–2000	50%	20%	20% of dryness coefficient
<1600	0%	20%	20% of dryness coefficient

2.6. Hydrology

To benefit priority forest-breeding birds, conservation plans previously placed increased emphasis on retention and restoration of bottomland forest sites that are less prone to prolonged flooding [6,16]. This emphasis on drier bottomland sites was because these forests had been disproportionately converted to agriculture [2] and continue to be more suitable for conversion to non-forest use than flood-prone forests. Moreover, bottomland forests with limited flooding tend to support more understory vegetation and are therefore important for ground-nesting silvicolous bird species [6]. The excessive loss of bottomland forests that are less prone to prolonged flooding may be exacerbated within the conservation estate by the bias of protected areas to be located on less-threatened land that is not easily converted to other uses [22].

For each of the forest patches deemed to have merit for bird conservation by virtue of having a core forest habitat area >1600 ha or being located adjacent to high priority restoration zones, we calculated their mean flood probability from inundation frequency data [15]. The resultant mean percent flood frequency was inverted and scaled (0–100) as a coefficient of dryness, such that 100 represented the least flood-prone forest patches and 0 represented the most flood-prone patches. Because we perceived drier forest patches to be of greater conservation value, we granted an increase in need for conservation–protection proportional to forest patch dryness (dryness coefficient x 0.2). As such, the least flood-prone forest patches received up to 20% increase in need for protection, whereas the most flood-prone patches received a negligible increase.

3. Results

Although we found only 10% of the area within the Mississippi Alluvial Valley was protected within the current conservation estate, most (84%) of this protected area was forested. Of the 3.1 million ha of extant forest [3], 882,000 ha (28%) was protected within the conservation estate. Forested land in the Mississippi Alluvial Valley had a greater frequency of flooding (17.5% ± 24.7%; mean ± SD) compared with lands not currently forested (13.3% ± 25.1%). We found an even greater propensity for flooding (23.7% ± 30.0%) for those lands protected within the current conservation estate.

For effective conservation of silvicolous birds, we determined 4712 core forest patches, harboring >2 million ha of forest, met our criteria for needing additional conservation–protection (Figure 3). Most of this area, approximately 1.5 million ha, was within 109 forest patches that exceeded our desired threshold area of ≥2000 ha of core forest. Over 1.3 million ha within these forest patches lack current conservation protection (Table 2).

Table 2. Proposed need for additional conservation–protection (2 = least in need; 100 = most in need) of 4710 forest patches within the Mississippi Alluvial Valley, their total area, and proportion of area protected within the current conservation estate.

Conservation–Protection Need	Total Area (ha)	Area (ha) in Conservation Estate	Proportion of Area in Conservation Estate	Cumulative Area (ha) to Provide Complete Conservation–Protection (From Most in Need)
2	371	311	0.84	1,323,272
3	160	136	0.85	1,323,212
4	15,465	14,072	0.91	1,323,188
6	10,106	9404	0.93	1,321,795
7	5838	5596	0.96	1,321,093
8	1011	953	0.94	1,320,851
9	14,693	12,529	0.85	1,320,793
10	7962	6769	0.85	1,318,629
11	3094	2057	0.66	1,317,436
12	8628	5585	0.65	1,316,399
13	535	454	0.85	1,313,356
14	12,758	8750	0.69	1,313,275
15	12,480	6789	0.54	1,309,267
16	8820	6071	0.69	1,303,576
18	22,296	14,965	0.67	1,300,827
19	87,473	8542	0.10	1,293,496
20	13,482	9525	0.71	1,214,565
21	3693	2316	0.63	1,210,608
22	11,732	8201	0.70	1,209,231
24	47,806	39,724	0.83	1,205,700
25	5302	4448	0.84	1,197,618
26	17,206	10,723	0.62	1,196,764
27	13,019	9855	0.76	1,190,281
30	4013	3083	0.77	1,187,117
31	18,136	12,754	0.70	1,186,187
32	8274	5511	0.67	1,180,805
33	10,425	6993	0.67	1,178,042
34	1682	833	0.50	1,174,610
35	31,466	19,432	0.62	1,173,761
36	58,741	41,255	0.70	1,161,727
37	96,216	66,954	0.70	1,144,241
39	8771	5819	0.66	1,114,979
41	5200	2379	0.46	1,112,027
43	82,826	49,515	0.60	1,109,206
44	22,468	12,558	0.56	1,075,895
45	5391	2455	0.46	1,065,985
46	14,053	8578	0.61	1,063,049
48	1447	117	0.08	1,057,574
49	5471	1	0.00	1,056,244
50	34,401	17,404	0.51	1,050,774
51	191,264	97,227	0.51	1,033,777
52	4484	1333	0.30	939,740
53	6467	2815	0.44	936,589
54	1824	5	0.00	932,937
56	41,907	17,458	0.42	931,118
58	6333	2330	0.37	906,669
60	9265	2859	0.31	902,666
61	12,571	4879	0.39	896,260
62	9355	428	0.05	888,568
63	34,378	13,383	0.39	879,641
64	19,885	6786	0.34	858,646
65	5251	1995	0.38	845,547
66	3038	887	0.29	842,291
68	54,873	16,071	0.29	840,140
69	1859	574	0.31	801,338
70	2308	665	0.29	800,053
71	2341	692	0.30	798,410
74	50,496	11,598	0.23	796,761
75	15,667	3548	0.23	757,863
77	15,841	3106	0.20	745,744
80	456,125	69,700	0.15	733,009
82	5031	868	0.17	346,584
84	8256	793	0.10	342,421
85	15,084	1822	0.12	334,958
86	90,798	693	0.01	321,696
87	1559	73	0.05	231,591
88	25,155	1852	0.07	230,105
89	18,785	384	0.02	206,802
90	41,379	5281	0.13	188,401

Table 2. *Cont.*

Conservation–Protection Need	Total Area (ha)	Area (ha) in Conservation Estate	Proportion of Area in Conservation Estate	Cumulative Area (ha) to Provide Complete Conservation–Protection (From Most in Need)
91	22,839	804	0.04	152,303
92	9867	134	0.01	130,268
93	34,567	906	0.03	120,535
94	61,553	0	0.00	86,874
95	4170	164	0.04	25,321
97	13,472	445	0.03	21,315
100	8297	9	0.00	8288
Total	2,039,255	715,983		

When we accounted for the forest area of a patch, its location within high priority reforestation zones, propensity for flooding, and the proportion of the patch within the existing conservation estate, the attributed need for conservation–protection ranged from 2 (least in need) to 100 (most in need). We masked areas within these forest patches that were in the current conservation estate, as these areas are already protected, and displayed the attributed need for conservation–protection of the remaining forest patches (Figure 4; https://doi.org/10.5066/P90V76SY).

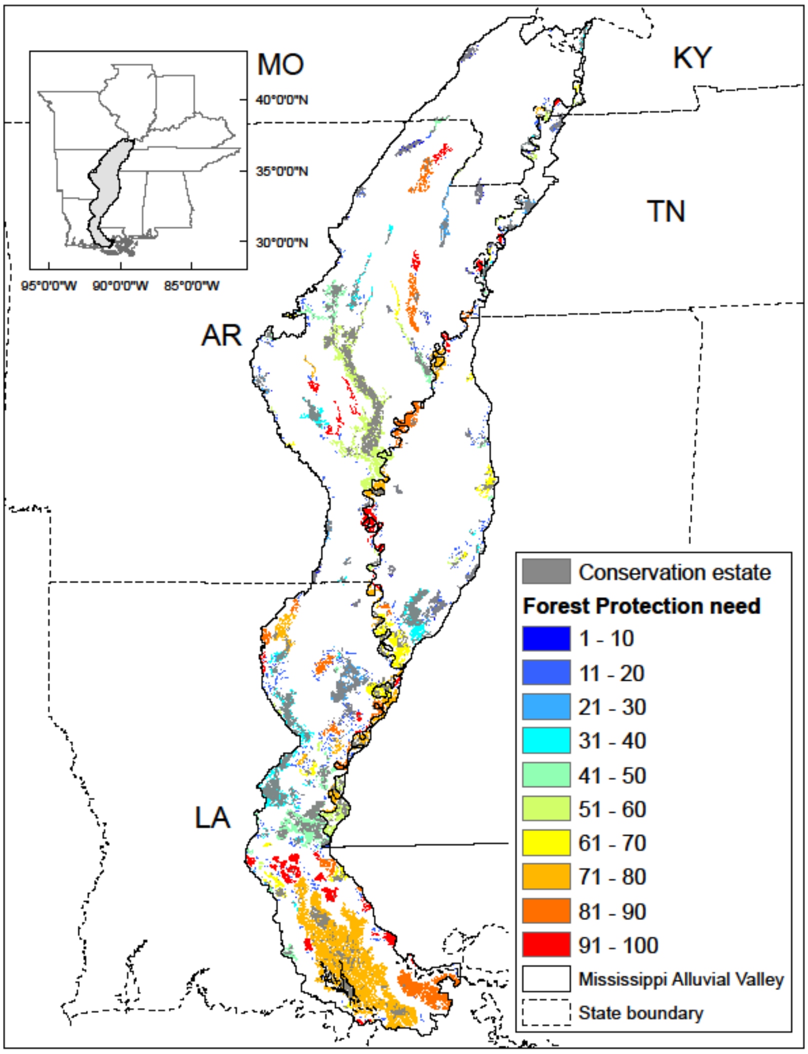

Figure 4. Modeled priority (1 = low, 100 = high) of forest patches for additional conservation–protection to conserve silvicolous birds within the Mississippi Alluvial Valley. Areas with existing conservation–protection within targeted forest patches are depicted as conservation estate.

Of the 109 patches with core forest area that exceeded our target of ≥2000 ha, 36% of their area was in the current conservation estate. For all forest patches deemed in greatest need of additional protection (i.e., conservation–protection need >90), ≤4% of their area was protected within the conservation estate (Table 2).

4. Discussion

Our primary motivation for this assessment was to assess the current vulnerability of extant forest in the Mississippi Alluvial Valley to potential future conversion to a non-forest habitat. Although the Convention on Biological Diversity's Aichi Biodiversity Target (i.e., that at least 17% of terrestrial and inland water habitat be in the conservation estate) was intended as a national benchmark, the 10% protection within the Mississippi Alluvial Valley ecoregion falls well shy of this objective. Attainment of the 17% target within this ecoregion would entail increasing the area of the current conservation estate by >700,000 ha—nearly doubling the area of forest currently under conservation–protection.

Our finding that the Mississippi Alluvial Valley extant forest, and even more so the existing conservation estate, has a greater flood frequency than non-forest land supports prior conclusions that protected areas are biased towards locations that are unlikely to face land conversion pressures even in the absence of protection [22]. Worldwide, this bias in conservation–protection leads to more protected areas being at higher elevations with steeper slopes. Conversely, within the topographically limited Mississippi River floodplain this bias is toward lower, more flood-prone locations. Even though our conservation–protection model granted increased emphasis to less flood-prone bottomland forest, the existing bias of increased flood frequency associated with extant forest may overwhelm our intention of increasing the ecological representativeness of protected forests.

The vagile and often migratory habits of birds, which were our conservation emphasis during this study, suggest that connectivity of protected areas is not of paramount importance. Therefore, despite the Aichi Biodiversity Target of establishing well-connected protected areas [23], our conservation–protection model does not accentuate connectedness of lands within the conservation estate. Nevertheless, conservation planners may choose to place greater emphasis on areas that provide linkage between existing protected areas or that provide linkages between isolated populations of less vagile, resident species of conservation concern (e.g., Louisiana black bear, *Ursus americanus luteolus*; [24]). Alternatively, landscapes currently depauperate in habitat within the conservation estate may benefit through the provision of foundational conservation–protection of extant forest areas.

Our final model of perceived need for conservation–protection of bottomland forests included numerous, small, core forest patches, many of which were markedly below our core forest target of 2000 ha. We included these small, core forest patches because of their location within reforestation priority zones, and our hope that future forest restoration will increase their forest core area. Even though we included these small patches as in need of additional protection, their need for protection was markedly reduced relative to larger core forest patches.

We have assigned priority for conservation–protection to core forest patches in this ecoregion but these priorities should not be viewed as a directive or desire for increased public ownership of these forests. Indeed, private conservation easements, such as those executed with Ducks Unlimited or The Nature Conservancy, may be equally effective at long-term conservation of these bottomland forests [25,26].

5. Conclusions

We established the relative priority of more than 4000 forest patches in the Mississippi Alluvial Valley for increased conservation–protection for wildlife, based on their area, location, and hydrology. Only 109 of these forest patches exceeded our targeted threshold area of >2000 ha of core forest. Attainment of the international standard of 17% of area within the conservation estate will require nearly doubling the >700,000 ha of forest that is currently protected within the Mississippi Alluvial

Valley. Adding this additional forest within areas targeted for forest restoration will improve the likelihood of increasing the area of existing forest patches to >2000 ha.

Extant forest within the Mississippi Alluvial Valley was skewed toward lands that are frequently flooded. Those forests that are currently afforded conservation–protection by virtue of being within the existing conservation estate also had a greater likelihood of frequent flooding. This bias in flood condition suggests that granting increased priority for conservation protection to less flood-prone forests was justified.

As conservation partners in the Mississippi Alluvial Valley invest their limited resources for conservation of forest landscapes capable of sustaining breeding bird populations, guidance with respect to more focused forest protection facilitates greater efficiency in conservation actions. As such, the conservation–protection priorities we identified fill an unmet need for land trusts and other conservation partners pursuing strategic protection in support of Joint Venture objectives. This positive impact is two-fold: (1) protecting forest tracts in 'high need' of protection will directly benefit species using these habitats and (2) retaining the efficacy of past and ongoing reforestation efforts predicated on the presence of adjacent core forest. Conservation delivery networks of the Joint Venture (https://www.lmvjv.org/conservation-delivery-networks), in particular, are uniquely poised to utilize this information for efficiently and effectively protecting forest lands in this region.

Supplementary Materials: Data layers depicting the Bird Conservation Region boundary, forest cover, and reforestation priority are available as digital map layers at http://gisweb.ducks.org/conservationplanning/). Digital data for flood frequency within the Gulf Coastal Plain and Ozark region are available at https://www.sciencebase.gov/catalog/item/5617e3c3e4b0cdb063e3fc35 [27]. Digital representation of existing conservation estate and conservation–protection priority of forest patches in the Mississippi Alluvial Valley are available at https://doi.org/10.5066/P90V76SY [28].

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