Mississippi Valley Division,
Regional Planning and Environment Division South

Yazoo Backwater Area Water Management

APPENDIX F-4 Terrestrial Wildlife

November 2024

SECTION 1

Yazoo Backwater Area Wildlife Assessments

1.1 INTRODUCTION

The following appendixes provide assessments for a variety of wildlife taxa, and one plant species, for the proposed Yazoo Backwater Water Management Plan. We include assessments for Migratory Landbirds (Appendix A); Shorebirds (Appendix B); Great Blue Heron (Appendix C); Secretive Marsh Birds (Appendix E)

There are four alternatives for the Yazoo Backwater Water Management Plan. Of these four, the No Action Alternative (Alternative 1), and two alternatives (Alternative 2 and Alternative 3) that involve construction and use of a 25,000 cubic feet per second (cfs) pump were considered in wildlife assessments. Alternative 4, with no pumps involved, was not assessed separately but would result in the same hydrologic and habitat conditions as Alternative 1. Both Alternative 2 and Alternative 3 involve a 25,000 cfs pump, which will keep backwater managed at 90 ft during crop season and up to 93 ft during non-crop season. Both alternative 2 and alternative 3 also involve modifying the operation of Steele Bayou WCS to optimize fisheries exchange. Both Alternatives 2 and 3 also incorporate acquisition and flood proofing of residential and commercial properties up to 93 ft. The only difference between Alternative 2 and 3 is defining the crop season and non-crop season date ranges. Alternative 2 has a crop season of 15 March to 15 October, and a non-crop season of 16 October to 14 March. Alternative 3 has a crop season of 25 March to 15 October and a non-crop season of 16 October to 24 March.

1.2 ACTION AREA AND PROJECT BACKGROUND

The Yazoo Backwater Study Area (YSA; Figure 1), includes the entire project footprint and all areas that may be directly (pump construction) or indirectly (changes in hydrology) affected by the various federal actions described above and not merely the immediate area involved in the action (50 CFR 402.02).

The Yazoo Backwater Study Area

The YSA is located in west central Mississippi immediately north of Vicksburg, Mississippi, and includes all or portions of Humphreys, Issaquena, Sharkey, Warren, Washington, and Yazoo counties, Mississippi, and part of Madison Parish, Louisiana.

The triangular-shaped area, also referred to as the Yazoo Backwater Area, extends northward about 65 miles to the latitude of Hollandale and Belzoni, Mississippi, and comprises about 1,446 square miles. The Big Sunflower and Little Sunflower rivers, Deer Creek, and Steele Bayou flow through the Action Area. These four streams drain 4,093 square miles of the Mississippi Alluvial Valley (MAV) and include a major portion of the Mississippi Delta. The Action Area is bordered to the west by the descending bank of the mainline Mississippi River levee, the west bank levees of the Whittington Auxiliary Channel and to the east by the Sunflower River and Steele Bayou connecting channel, and to the south by the Yazoo River. The drainage area extends from the confluence of Steele Bayou with the Yazoo River north to the vicinity of Clarksdale, Mississippi, and has an average width of approximately 30 miles. The Mississippi Delta alluvial plain is generally flat with slopes averaging 0.3 to 0.9 feet per mile. Interior drainage of the area is accomplished by structures at the mouth of the Little Sunflower River (upper ponding area) and the mouth of Steele Bayou (lower ponding area).

The YSA contains approximately 926,000 acres of which approximately 500,000 acres are lands within the 100-year flood frequency (Figure 1). The area historically has been subject to periodic backwater flooding from the Mississippi and Yazoo Rivers, and headwater flooding (when the Steele Bayou gates are closed due to high water levels from the Mississippi River) from the Big Sunflower River and Steele Bayou.

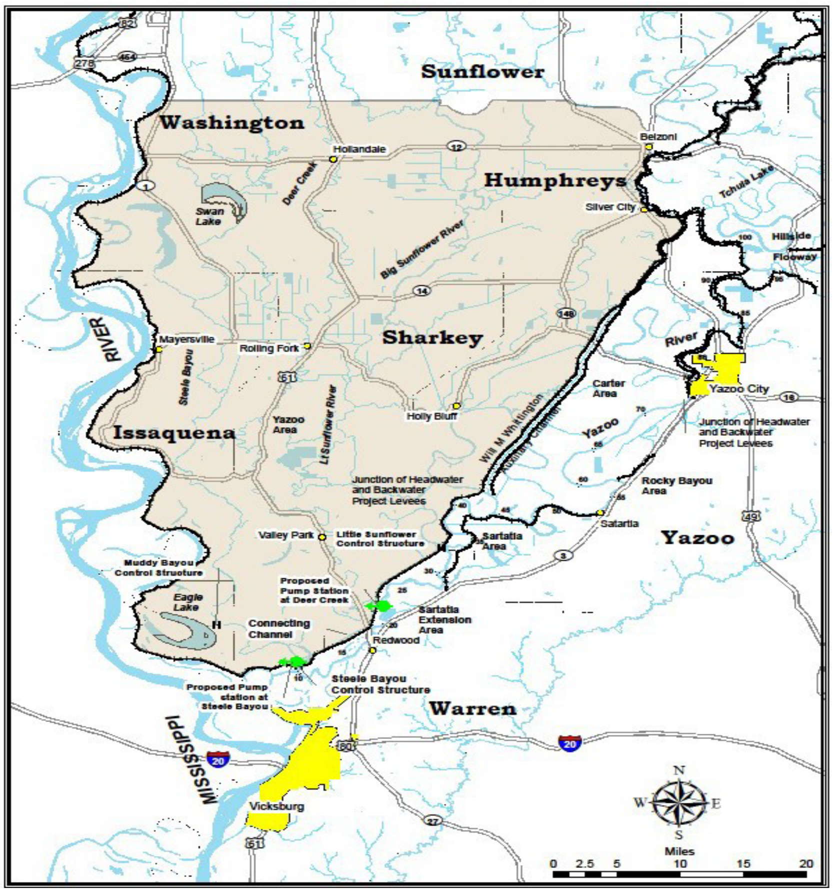


Figure 1. The Yazoo Study Area (tan shading) includes Issaquena, Humphreys, and Sharkey Counties, and parts of Washington, Sunflower, and Warren Counties, in west-central Mississippi.

1.3 PROJECT BACKGROUND

The proposed Water Management Plan would implement a 25,000 cfs pump station that will be in operation when Steele Bayou water control structure is closed, and landside water levels reach 93 feet National Geodetic Vertical Datum (NGVD 29) during the non-crop season. Pump operation will result in a reduction of flooded acres above 90 feet (NGVD 29) during the crop season for some years, primarily within the southern portion of the Yazoo Backwater Area (YBA). The most likely impacts of the Proposed Plan within the YBA would be changes in hydrology within forested habitats which may result in potential alteration of forest structure and composition over time.

The proposed Yazoo Pumps are designed to pump water out of the Yazoo Backwater Area into the Yazoo River during high flooding events. At the Steele Bayou Water Control Structure (WCS), when the interior landside water level reaches 93.0 ft, the proposed pump would be initiated to reduce the water level to 90.0 ft during each flood event in the non-crop (16 Oct-14 Mar, Alternative 2 or 16 Oct-24 Mar, Alternative 3) season and maintain the level at or below a threshold of 90.0 ft during the crop (15 Mar-15 Oct, Alternative 2; or 25 Mar-15 Oct, Alternative 3) season. Across the 1978-2020 Period of Record, under each pumping alternative, the pumps would have operated at least one day in just 3/43 (7%) of years during the non-crop season and would have operated at least one day in 17/43 (40%) of years during the crop season (Fig. 2-110 in Appendix A-Engineering Report).

1.4 SPECIES SELECTION FOR ANALYSES

The original Yazoo Backwater Area (YSA) Wildlife and Endangered Plants Team consisted of subject matter experts from the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC) and the U.S. Army Engineer District, Vicksburg (CEMVK); U.S. Fish and Wildlife Service (USFWS), Mississippi Ecological Services Office (MSFO); and U.S. Environmental Protection Agency (EPA), Region 4 and Headquarters. The purpose of the team was to work collaboratively to identify focal species and appropriate assessment methodologies for investigation in the YSA.

Through interagency collaboration in 2023, this Team selected a suite of species and/or taxa for assessments in the YSA, with full concurrence of the species list by the USACE, USFWS, and EPA. The ERDC-EL then developed a detailed draft assessment methodology for each species or taxa (Table 1) and these methods were presented, discussed, and ultimately agreed upon by all parties.

In recent years, some species of conservation concern that are likely present in potentially affected wetland areas have been federally listed under the Endangered Species Act, including the northern long-eared bat (*Myotis septentrionalis*), while others, such as the tricolored bat (*Perimyotis subflavus*) and the alligator snapping turtle (*Macrochelys temminckii*), have been proposed for listing. Assessments are necessary to estimate the impacts that proposed alteration of water levels and flooding events may have on these and other species of concern. These proposed assessments are presented below.

Table 1. List of species or taxa selected for assessments in the YBA (with proposed methods)

Species or Taxa	Proposed Methodologies
Prothonotary Warbler	Tirpak et al. 2009a
Kentucky Warbler	Tirpak et al. 2009a
Wood Thrush	Tirpak et al. 2009a
Acadian Flycatcher	Tirpak et al. 2009a
King Rail	Remotely sensed landscape data to quantify any change in emergent wetland abundance
Great Blue Heron	Visual surveys for rookeries and other roosting/foraging birds; MaxEnt modeling and Habitat Evaluation Procedures (HEP)
Shorebirds	USACE-certified shorebird migration model
Waterfowl	Duck-use Days Model
Northern Long-eared Bat	Large-scale modeling efforts
Tricolored Bat	Large-scale modeling efforts
Alligator Snapping Turtle	Large-scale modeling efforts
Pondberry	Continued long-term monitoring with inclusion of new hydrological data from groundwater monitoring wells

1.5 HYDROLOGIC MODELING INPUTS AND METHODS

The ERDC-EL Wildlife Team requested the analysis of Period-of-Record (POR) hydrology for several different wildlife taxa. These included Great Blue Herons (GBHE), shorebirds (spring and fall), and waterfowl. The seasons were based on the primary annual periods that these associations are present in the Yazoo Backwater Project Area. The season for GBHE is 15Mar through 31Jul (Terrestrial Season 1 – TS1). Shorebirds had two seasons - spring (15Apr through 15Jun, or Terrestrial Season 2 – TS2) and autumn (1Jul through 15Oct, or Terrestrial Season 3 – TS3). The final terrestrial association is for dabbling ducks, and they are generally present from 1Nov through the end of February (Terrestrial Season 4 – TS4). For migratory landbirds, and for secretive marsh birds, we used TS1 data.

This is the first study the CEMVK has been involved with for GBHE and shorebirds, and no models have been established to perform these analyses. However, CEMVK believes that the EnviroFish model provides the necessary outputs for these analyses. The EnviroFish model calculates four daily statistics, which are water depth (water surface elevation), total rearing area, restricted rearing area, and spawning area. The restricted rearing bin of the EnviroFish model allows the user to establish minimum and maximum water depths. GBHE require a water depth range of 0 to 1.5 feet, and shorebirds require a depth range of 0 to 0.67 feet (8 inches). Thus, when examining the Excel tables of EnviroFish results, the restricted rearing (r-rearing) column is the appropriate column to use.
The preferred foraging habitat for GBHE is water with a depth up to 18 inches. The EnviroFish model calculates the daily acres of shallow (up to 18-inch) inundation available during the spring GBHE season. The hydrologic analysis then provides statistics summarizing the range of potential habitat available. The first value is the "average daily flooded acres" (ADFA). In addition to the mean ADFA, the minimum, maximum and 75th percentile values for daily stage and daily flooded acres are provided.

The preferred foraging habitat for shorebirds includes water up to 8 inches (0.67 feet) in depth. The EnviroFish model calculated the daily acres of inundation up to 8 inches available during the spring and fall shorebird seasons (TS2 and TS3 respectively). The spreadsheet provides statistics for the POR for the two seasons. The statistics are the mean daily flooded acres up to 8 inches (regardless of cover type and other factors affecting habitat suitability scores which were then assessed in final modeling), and the minimum, maximum, the 25th and 75th percentiles of both the daily stages and the daily flooded acres at this depth.

Waterfowl analyzed in this report will feed in water up to 18 inches in depth and utilize deeper water for resting/loafing. EnviroFish was used to determine the available feeding and resting/loafing habitats. The feeding depth (1.5 feet) was used for the maximum restricted rearing depth and 0 feet was used as the minimum. The total rearing area minus the restricted rearing area would be the resting area.

ArcMap coverages of the mean and 75th percentile elevations were created with the FESM mapping tool for the Base (Alternative 1), Alternative 2, and Alternative 3. The ERDC-EL received 75th percentile spatial layers for Alternative 1 (Base) and Alternative 2, but not Alternative 3. Under Alternative 3 (crop season March 25-Oct 15), the pumps would have operated 26 fewer days in total across the entire 43-year POR (average of 0.6 days/year; Table 2- 31 in Appendix A). Alternative 2 was modeled in ArcGIS for comparison to base conditions for all analyses of wildlife taxa due to this alternative having 26 more pumping days over the POR. As such, under Alternative 3, there would be equal to or slightly less impact on a yearly basis and average spatial extents of projected flooding are nearly identical.

SECTION 2

Appendix A MIGRATORY LANDBIRDS

U.S. Army Engineer Research and Development Center Environmental Laboratory Ecological Resources Branch Vicksburg, Mississippi

2.1 INTRODUCTION

The Migratory Bird Treaty Act (MBTA) of 1918 (16 U.S.C. 703-712; Ch. 128), prohibits the direct and intentional take (including killing, capturing, selling, trading, and transport) of protected migratory bird species without prior authorization by the Department of Interior U.S. Fish and Wildlife Service (USFWS). Historically, this prohibition had been interpreted by the U.S. Department of the Interior (DOI) to apply to both deliberate acts intended to take or kill migratory birds as well as the incidental taking or killing of such birds. In 2017, the DOI office issued a ruling, Solicitor's Opinion M-37050 that interpreted the statute as not prohibiting incidental take but instead only applying to "direct and affirmative purposeful actions that reduce migratory birds, their eggs, or their nests, by killing or capturing, to human control." However, in 2021, Solicitor's M-37050 was permanently revoked when the DOI Office of the Solicitor issued Solicitor's Opinion M-37065 returned the interpreted prohibition to its original state. Currently, the USACE Director of Civil Works directs the USACE to minimize the incidental take of migratory birds to the extent practicable, and to coordinate as appropriate with the USFWS, as stated in the MBTA.

A migratory bird species is included on the list of MBTA-protected species if it meets one or more of the following criteria (50 CFR §10.13):

1. It occurs in the United States or U.S. territories as the result of natural biological or ecological processes and is currently, or was previously listed as, a species or part of a family protected by one of the four international treaties or their amendments.
2. Revised taxonomy results in it being newly split from a species that was previously on the list, and the new species occurs in the United States or U.S. territories as the result of natural biological or ecological processes.
3. New evidence exists for its natural occurrence in the United States or U.S. territories resulting from natural distributional changes and the species occurs in a protected family.

The list of migratory bird species protected by the MBTA is primarily based on bird families and species included in the four international treaties with Canada, Russia, Japan, and Mexico. The list of bird species is contained in 50 C.F.R. §10.13. (referred to frequently as the 10.13 list) which was last updated in 2023 (Federal Register Vol. 88, No. 145), includes 1,106 species, and incorporates the most current scientific information on taxonomy and natural distribution.

USFWS regulations include most native birds found in the U.S. as species protected by the MBTA, including species that do not migrate internationally, and even species that do not migrate at all. See 50 C.F.R. for the complete list of bird species protected under the MBTA.

In addition to the 10.13 list, the USFWS maintains a list of "Birds of Conservation Concern" or BoCC. The 1988 amendment to the Fish and Wildlife Conservation Act mandates that the USFWS identify species, subspecies, and populations of all migratory nongame birds that without additional conservation action are likely to become candidates for listing under the Endangered Species Act (ESA) of 1973, as amended. The USFWS *Birds of Conservation Concern 2021* (BoCC*;* USFWS 2021) is the most recent effort to carry out this mandate[1].

The overall goal of the BoCC list is to identify those bird taxa (beyond those already designated as federally threatened or endangered) that represent the highest conservation priorities of the USFWS. The 2021 BoCC list includes 269 individual bird taxa that are priorities for conservation actions. Of the four species analyzed in this migratory landbirds appendix as part of assessing potential impacts of the Yazoo Backwater Pumps Project on migratory landbirds, Kentucky Warbler (KEWA: *Oporornis formosus*), Prothonotary Warbler (PROW: *Protonotaria citrea*), and Wood Thrush (WOTH: *Hylocichla mustelina*) are considered BoCC by the USFWS. The fourth species, the Acadian Flycatcher (ACFL: *Empidonax virescens*) is not a species identified as a BoCC; however, this species is strongly associated with bottomland hardwoods and other forested wetlands, and therefore is a good migratory species to assess the impacts of the Yazoo pump operations on forested wetlands habitat.

Considerable data on the distribution, abundance, and population trends of migratory birds are more widely available in recent years because of online citizen science data repositories (e.g., the Cornell University Laboratory of Ornithology eBird® platform; Cornell 2024) that allow users to report bird sightings anywhere in the world. eBird, which currently includes more than 1.5 billion bird records, contributes a wealth of information on the distribution and abundance of birds, making it the most robust avian database in existence.

Habitat loss, feral and free-ranging domestic dogs and cats, pesticides, climate change, light pollution, and a variety of other stressors are all known to contribute to declines for migratory birds (Terborgh 1989, Rosenberg et al. 2019). Habitat loss or alteration is believed to be the leading cause of many of these declines and, in particular, the loss of floodplain forests in the Mississippi Alluvial Valley (MAV) has contributed to population declines and even extinction of floodplain forest-dependent birds, including the Ivory-billed Woodpecker (*Campephilus principalis*) and Bachman's Warbler (*Vermivora bachmanii*) (Twedt et al. 1999). Water resources development in many parts of the world has resulted in serious reductions in the frequency, extent, and duration in which floodplain forests are inundated, leading to significant habitat change and loss of productivity (McGinness et al. 2018).

Specifically for the MAV, restoration has focused largely on forested wetlands to benefit breeding landbirds, recreational hunting and fishing, hydrologic restoration of wetland habitats to support migrating shorebirds and wintering waterfowl, and modification of the flood control infrastructure along the mainstem Mississippi River to benefit at-risk and threatened and endangered species. Since migratory birds that utilize forest and forested wetland habitat have experienced significant declines (Rosenberg et al. 2019), these birds are often the target beneficiaries of reforestation and bottomland hardwood (BLH) restoration in the MAV (Twedt et al. 2007). In addition to forest restoration, issues of forest size, landscape context, presence of forest corridors, and overall landscape configuration are important in long-term considerations for forest bird conservation. A draft update to the BoCC list has been completed by the USFWS, but as of the date of this report has not been officially released. The Water Management Plan will implement a 25,000 cfs pump station that will be in operation when Steele Bayou water control structure is closed and manage landside water levels up to 93 feet National Geodetic Vertical Datum (NGVD 29) during the non-crop season. Pump operation will result in a reduction of backwater flooded acres above 90 feet (NGVD 29) during the crop season. The most likely impacts of the Water Management Plan within the YBA would be changes in hydrology within forested habitats in years in which operation of the pumps occurred. Loss of floodplain forests acres could potentially have the most negative impacts on migratory birds that require varying levels of annual inundation upon the landscape to maintain habitat to meet life-history needs. Other habitats in the region important to non-forest migratory birds, including herbaceous, pasture, old field, scrub/shrub, and agricultural lands, might also be impacted due to decreases in intermittent flooding events which are covered in other Appendices (See Appendix B (Shorebirds), and Appendix E (Secretive Marsh Birds).

In this report, we assessed the indirect impacts of the construction and operation of the proposed Water Management Plan on migratory birds that are known to utilize BLH within the YBA by incorporating a quantitative spatial model derived from Tirpak et al. (2009). The models within, "Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plains/Ouachitas Bird Conservation Regions" provide a framework for determining differences in habitat suitability with changing landscape alterations. We focus on four of these migratory birds within this model known to utilize BLH in the YBA and that have certified Habitat Suitability Index (HSI) models available for application in the study area. These models have been certified through the USACE ECO-PCX. The species included in these certified models include the ACFL, KEWA, PROW, and WOTH. Internal and external reviews determined that all four species HSI models were suitable for use within the Yazoo Basin based on habitat features within the region and life-history traits of each species.

2.1.1 Wood Thrush

Wood Thrush typically breed in large, mature forested systems, including forested wetland habitats (Evans et al. 2020). However, this species likely does not nest often in flooded cypress swamps or other forested wetland types that are flooded for long periods during the nesting season. During a two-week July field effort in 2020 while conducting Habitat Evaluation Procedures at areas within the one- and two-year floodplain of the YBA, no detections were made of WOTH. Because this species nests near or on the ground, and a large percentage of potential nesting habitat was flooded throughout most of the 2020 breeding season (one of the most extensive flooding events in four decades), the lack of detections was not surprising. If operation of the Water Management Plan, as expected, reduces flooding extent and duration in many of the forested habitats within the YBA, then

the subsequent growth of the understory may improve habitat for this and other forest birds that nest on or near the ground. The reduction in extent and duration of flooding in the YBA, particularly during March through June, will clearly be of benefit to WOTH, and other near to ground-nesting species that rely on significant understory vegetation growth for cover. eBird Observations: Scattered observations of WOTH occurred in the YBA, mostly between 2014 and 2020; most observations have been between one and three individuals.
Some areas where detections occurred included DNF, Tara Wildlife facility, Mahannah WMA, Panther Swamp NWR, Sunflower WMA, and Morgan Brake NWR. Most observations occurred during early spring to mid-summer.

2.1.2 Prothonotary Warbler

The PROW is a cavity-nesting species dependent on forested wetland habitats (Petit 2020). This species is common to abundant in forested areas along the Mississippi River and in the YBA along forested rivers, creeks, oxbows, sloughs, and other depressional wetlands, especially those that hold water during the breeding season. Because of their dependence on these floodplain features, they are a good indicator species for many of the wetland-dependent birds in the YBA. The relative impacts of the Water Management Plan on PROW (and other wetland-dependent birds) will depend on a) flooding frequency, extent, and duration above elevation 90 feet (NGVD 29), b) local flooding and floodplain inundation from precipitation-driven flood events above 90 feet (NGVD 29) within the YBA, and c) the extent to which isolated wetlands and water bodies fill and hold water subsequent to these local events. eBird Observations: Many observations of Prothonotary Warblers are documented in the YBA, particularly in the DNF, Yazoo NWR, Panther Swamp NWR, Mahannah WMA, and Sky Lake WMA. Most observations dated between 2000 and 2020, and most detections ranged from one to eight individuals. Detection dates are mainly in the early spring, but some observations are in the late summer to early fall.

2.1.3 Kentucky Warbler

The KEWA is a Neotropical migrant found in upland and forested wetlands in the southeastern and mid-Atlantic regions of the United States (McDonald 2020). Its northern extent can reach into the Great Lake states. Population density decreases southerly, and this species is uncommon to rare along the extreme southern portions of MAV. This species requires dense ground and understory cover for nesting (McDonald 2020), a feature that may not be present in bottomland hardwood systems that are flooded for much of the year. Therefore, this species, in addition to the Wood Thrush (see above) and others, may benefit when flood extent and duration in forested habitats within the YBA are reduced. Reducing flood events will promote growth of the understory, likely increasing the breeding habitat for this species. eBird Observations: Scattered observations of KEWA in the YBA, with most at the DNF, Mahannah WMA, and Yazoo NWR. Most observations occurred between 2010 and 2020, and most detections were of one to three individuals during the early spring. During the July 2020 field investigations only a single singing male KEWA was detected across much of the DNF, further suggesting very low abundance in the YBA.

2.1.4 Acadian Flycatcher

The ACFL is a relatively common forest breeding species that utilizes a variety of mature forest types, include BLH, upland hardwoods, and mixed forests that may be dominated by pine (Allen et al. 2020). This species ranges north up to Wisconsin and the Great Lakes, east to New York and Connecticut, south to Florida, and west to Texas and Oklahoma (Allen et al. 2020). It reaches its highest density in the southeast in Georgia, Alabama, and Mississippi. Breeding sites are generally near water, and it is relatively common in forested areas throughout the YBA. This species requires perches that permit an open view for aerial capture of prey, generally flying insects. This bird often makes a nest between 1 to 3 m in height at the end of a branch. eBird Observations: Several hundred detections between 2000 and 2024 in forested habitats throughout the YBA, with most detections occurring in the Delta National Forest. Other areas where this bird is relatively common include the Yazoo National Wildlife Refuge and Panther Swamp National Wildlife Refuge.

2.2 OBJECTIVES

The objectives of this appendix are to:

1. Present information on species composition and habitat availability for four focal migratory bird species within the boundaries of the YBA and discuss potential changes that could occur due to the construction and operations of the Yazoo pump under the Alternatives.
2. Develop HSI spatial models for the four focal migratory bird species based on methods described by Tirpak et al. (2009).
3. Assess projected changes within HSI models for the four target species due to changes in hydrology and subsequent indirect impacts of the Yazoo pump operations under the Alternatives.
4. Provide recommendations and mitigation approaches to account for habitat loss and degradation by operations of the Yazoo pump on the four migratory focal species,

2.3 PROJECT AREA

Currently, the YBA consists largely of agricultural lands with scattered remnants of BLH and cypress/tupelo swamps (Wakeley 2007). In prior YBA studies, the cypress/tupelos swamps were determined to be too small and low in frequency to justify a separate forest class; therefore, are combined with BLH forests to provide a broad overview of available forest types (Wakeley 2007). Smith and Klimas (2002) note various forest subtypes within the YBA, including, 1) sweetgum/water oak, 2) white oaks, red oaks, and other hardwoods, 3) hackberry, elm, and ash, 4) Covercup oak and water hickory, 5) cottonwood, 6) willow, 7) riverfront hardwoods, and 8) cypress tupelo. Respective acreages of these forest subtypes in the YBA are not provided, however, it is noted that within the YBA, only approximately 10 percent of the original forested habitat remains, with the remaining lands converted to agriculture (Smith and Klimas 2002). A detailed description of the overall YBA and associated plans with operation of a pumping station can be referenced in the Background section of the FEIS.

2.4 METHODS

HSI Model Development

Spatially explicit Habitat Suitability Index (HSI) models for four migratory bird species were developed for the YBA based on Tirpak et al (2009) for the following species: Acadian Flycatcher (ACFL), Prothonotary Warbler (PROW), Kentucky Warbler (KEWA) and Wood Thrush (WOTH). Eight essential habitat variables across all species were identified based on the species needs (i.e. predictor variables). The models for each species included a subset of predictors from the eight variables that were converted to individual variable suitability indices based on their species/habitat relationship and represented as a numerical scale from 0 (unsuitable habitat) to 1 (ideal conditions). Finally, the resultant suitability indices for each bird species model were combined to produce an overall HSI score for that species. All data were stored in a raster tif format with 98.43 ft pixel resolution in the NAD83 Albers projection to match the hydrology layers provided by CEMVK.

2.5 PREDICTOR VARIABLE METHODOLOGY

The predictor variables are data-driven from sources such as existing geospatial layers and field surveys. The predictor variables for each migratory bird species were selected from a list of the eight predictor variables and include habitat age (i.e. landform, landcover, succession age class), occurrence of water, distance to water, percent canopy cover, forest patch size, landscape composition, snag density and small stem density. The following sections detail methods used to derive each of the eight variables (Table A-1) and any assumptions that were incorporated with constructing the predictor layers within the spatial model.

Conditions considered in our modeling:

1. Alternative 1 (No action alternative): No implementation of a pump station to alter hydrology, only use of the Steele Bayou water control structure with gate opening and closure as has been performed historically over the POR.
2. Alternative 2: 25,000 cfs pump; backwater managed at 90.0 ft during crop season (15Mar-15Oct) and up to 93.0 ft during noncrop season (16Oct-14Mar).

Hydrological data provided by the U.S. Army Corps of Engineers, Vicksburg District provided estimated flood extent and depth throughout the YBA under with and without pump conditions. Two of the conditions (Alternatives 2 and 3) yielded no significant difference in their anticipated hydrological impacts in the YBA; therefore, we only consider the impacts of Alternative 2 and the no-action alternative in our comparisons. We use this comparison to reveal gains or losses in HSI breeding habitat values throughout the YBA to assess the potential impact of the proposed Yazoo pump operations.

Habitat Age

Habitat age was derived from a composite of three factors including landforms, land cover, and succession age class. The first factor, landforms, were derived by calculating geomorphon landforms from 2022 USGS National Elevation Dataset 3DEP digital elevation model representing the 3D surface elevation of the Yazoo Basin Backwater (YBW) project area.

Geomorphons are common landform features that are obtained through terrain classification using a neighborhood pixel method that identifies patterns in elevation difference, slope, aspect, and line of sight. The resultant landforms were then consolidated into three landform types that match the Tirpak et al. 2009 suitability index matrix: floodplain-valley (flat, hollow, valley, and pit), terrace-mesic (footslope, slope, shoulder) and xeric-ridge (peak, ridge, and spur). The second factor, land cover type, was derived from the 2022 USDA Cropscape data layer. The habitat classes within this layer were consolidated into Tirpak et al. 2009 classes as follows: low density residential (developed/low intensity), transitional shrubland (shrubland), deciduous forest, evergreen forest, mixed forest, orchard-vineyard (fruit trees), woody wetlands and nonforest (crops, developed, developed medium intensity, developed high intensity). The third factor, successional age class, as represented in the suitability index matrix includes grass-forb, shrub-seedling, sapling, pole, and saw. Since spatial layers were not available for successional age class, we defined successional age with the best information available. Age thresholds were applied to the 2021 USGS Forest Stand Age Projection spatial layer (Stohl et al. 2018) based on 2012 field survey measurements of forest stand age and basal area for the Delta National Forest (Wesley 2012). Where forests less than 2 years were considered shrub-seedling, between 2-62 years are pole, and saw timber was greater than 62 years. In addition, shrubland from the 2022 Cropscape dataset were included in the shrub-seedling category. This method allowed us to make broad assumption, given limited data, to estimate and extrapolate those age categories across the YBW project area.

Occurrence of Water

Occurrence of water was derived using focal statistical analysis where each pixel was analyzed for the water presence based on a 9x9 neighborhood pixel window (885.8 ft X 885.8 ft) method. A binary value (1/0) or (yes/no) was assigned to the center pixel based on water occurrence in the window. Water areas used in the analysis were a composite of four sources for two scenarios, baseline and alternative 1. Baseline condition combined the following sources: 1) National Hydrologic Dataset waterbody polygons, 2) flowline named streams and rivers buffered 50ft on each side, 3) flowline intermittent streams, perennial streams, and artificial paths, and 4) MVK baseline hydrology layer (Alternative 1) for terrestrial season March 15-July 31 75% percentile, while Alternative 2 condition utilized sources 1-3 and MVK alternative 2 hydrology layers for terrestrial season March 15-July 31.

Distance to Water

Distance to water was calculated using Euclidean distance from a known water source to a maximum distance of 2000 ft. Water areas used in the analysis were a composite of four sources for two scenarios, Alternative 1 (i.e. baseline) and Alternative 2. Baseline condition applied the following sources: 1) National Hydrologic Dataset waterbody polygons, 2) flowline named streams and rivers buffered 50ft on each side, 3) flowline intermittent streams, perennial streams, and artificial paths, and 4) BASELINE Conditions: CEMVK hydrology layer for terrestrial season March 15-July 31 75% percentile, while Alternative 2 condition utilized sources 1-3 and CEMVK Alternative 2 hydrology layer for terrestrial season March 15-July 31.

Percent Canopy Cover

Percent canopy cover was derived from the USDA Forest Service 2021 Tree Canopy Cover dataset (Housman et al. 2023). The data was then clipped to forest areas as represented in the 2022 USDA Cropscape (https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php) data layer classes: shrubland, deciduous forest, evergreen forest, mixed forest, woody wetlands, and developed/low intensity (per Tirpak et al. 2009 model to capture residential trees).

Forest Patch Size

Forest patch size was derived from the 2022 USDA Cropscape data layer classes: shrubland, deciduous forest, evergreen forest, mixed forest, woody wetlands, and developed/low intensity (per Tirpak et al. 2009 model to capture residential trees) and consolidated into one forest class layer. The layer was then converted to a polygon where hectare values were calculated for each forest polygon or patch. Finally, the forest patch layer was converted to a raster using the hectare values to represent the forest patch size.

Landscape Composition

Landscape Composition was defined as the percentage of forest that falls within either a 1-km or 10-km radius of a given landscape (Tirpak et al. 2009). It was obtained by overlaying the forest cover layer onto a 1-km or 10-km radius hexagon grid and calculating the percentage of forest within each hexagon. The forest layer was sourced from the 2022 USDA Cropscape data layer classes: shrubland, deciduous forest, evergreen forest, mixed forest, woody wetlands, and developed/low intensity (per Tirpak et al. 2009 model to capture residential trees).

Snag Density

Snag density was measured as the number of snags per hectare and were derived from forest survey plots collected in the Delta National Forest (DNF) and surrounding public land areas, mostly in the southern portion of the YBW. From the available plots, Thiessen polygons were generated to represent a zonal boundary for each input plot/point. Since data was not available for the remaining non-public forests in the YBW, a mean snag density of 12 was calculated based on the available information from the DNF forest plots. Next, the forest polygon layer was used to assign the mean snag density based on the total hectares in each forest patch. Forest patches less than a hectare were assigned a 0 value. The snag density field of values were used to generate a raster image. This method allowed for broad assumptions, given limited data, to estimate and extrapolate snag density across the YBW project area.

Small Stem Density

Small stem density is defined as the average stem count less than 4 inches diameter breast high (DBH) per hectare and represented in two forms, density per one hundred stems and density per one thousand stems (Tirpak et al. 2009). Stem densities were derived from a limited number of 12 ft-radius survey subplots collected in the DNF and surrounding public land areas, mostly in the southern portion of the YBW (Berkowitz et al. 2021, Price and Berkowitz 2020) From the available plots, Thiessen polygons were generated to represent a zonal boundary for each input plot/point. Next, stem densities were converted from stem/12 ft radius plot to a stem/ha. Since data was not available for the remaining non-public forests in the YBW, a mean value was calculated from the available DNF plots, mean one hundred stem count stem density was 11 and mean one thousand stem count was 1. Next, the forest polygon layer was used to assign the mean stem count for each forest area. Non-public forest areas less than a hectare were assigned a 0 value. The small stem density values were used to generate a raster image. This method allowed for broad assumptions, given limited data, to estimate and extrapolate small stem density across the YBW project area.

2.6 AVIAN-SPECIFIC HABITAT SUITABILITY INDICES

Acadian Flycatcher (ACFL)

The ACFL model includes five predictor variables that define the species/habitat relationship including habitat age, distance to water, canopy cover, forest patch size, and landscape composition (percent forest in a 1-km radius window). Next, the tables and graphs below (obtained directly from Tirpak et al. 2009) were used to transform each predictor variable into a raster suitability index where values range from 0 as unsuitable habitat to 1 as ideal condition (Tirpak et al 2009).

The final overall HSI raster was calculated using the equation below, where SI1 = habitat age, SI2 = distance to water, SI3 = canopy cover, SI4 = forest patch size, SI5 = landscape composition (percent forest in a 1-km radius window): Overall HSI = $((SI1 * SI3)^{0.500} * (Max(SI4 \text{ or } SI5) * SI2)^{0.500})^{0.500}$

Table 6.—Relationship of landform, landcover type, and successional age class to suitability index scores for Acadian flycatcher habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.050	0.917	1.000
	Deciduous	0.000	0.000	0.050	0.917	1.000
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.042	0.667	0.834
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.033	0.500	0.667
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000

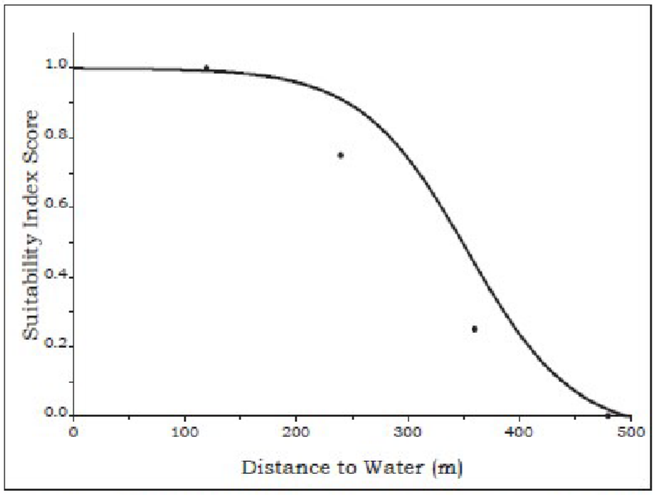


Figure 2.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1 - (1.049 / (1 + (1664.953 * e $^{-0.021 * \text{distance to water}}$))).

Table 7.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat

Distance to water (m)[a]	SI score
0[b]	1.00
120[c]	1.00
240[b]	0.75
360[b]	0.25
480[b]	0.00

[a]Water defined as streams from the National Hydrography Dataset (medium resolution) or classified as water, woody wetlands, or emergent herbaceous wetlands in the National Land Cover Dataset.

[b]Assumed value.

[c]Woolfenden and others (2005).

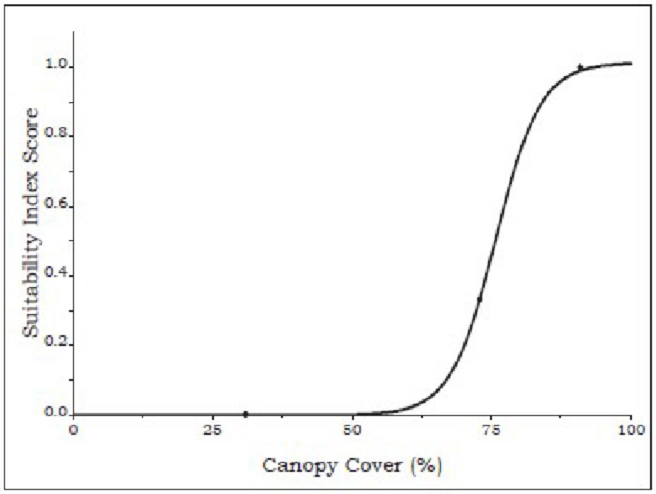


Figure 3.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1.013 / (1.000 + (144082770 * e $^{-0.246 * \text{canopy cover}}$)).

Table 8.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat

Canopy cover (percent)	SI score
0[a]	0.00
31[b]	0.00
73[b]	0.33
91[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Prather and Smith (2003).

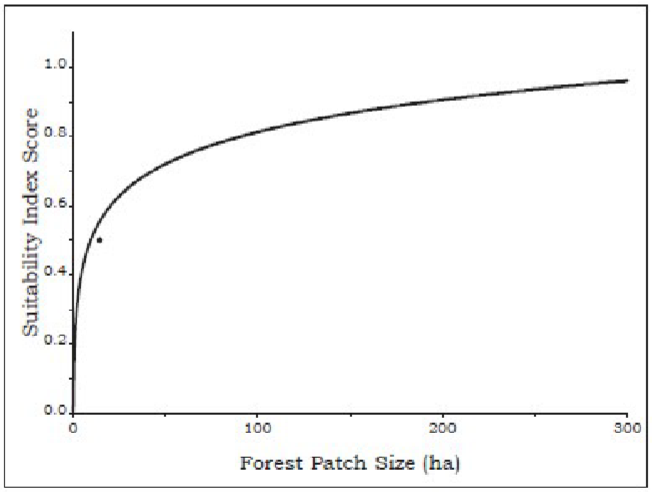


Figure 4.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 0.174 * ln(forest patch size) + 0.010.

Table 9.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat

Forest patch size (ha)	SI score
0.2[a]	0.0
15[a]	0.5
312[b]	1.0

[a]Robbins and others (1989).
[b]Wallendorf and others (2007).

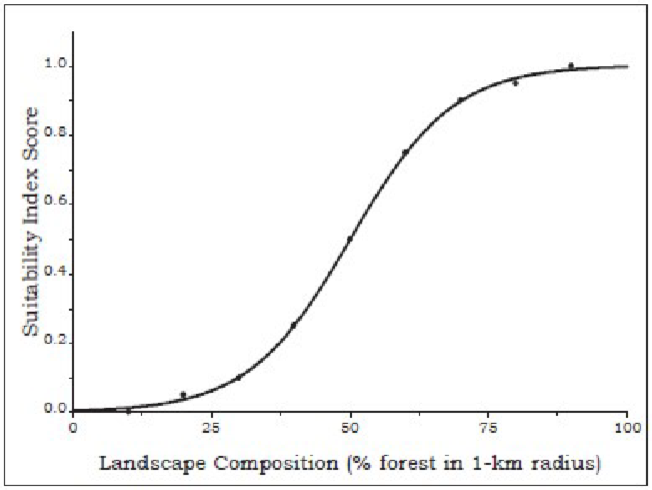


Figure 5.—Relationship between landscape composition and suitability index (SI) scores for Acadian flycatcher habitat. Equation: $\text{SI score} = 1.005 / (1.000 + (221.816 * e^{-0.108 * (\text{landscape composition})}))$.

Table 10.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for Acadian flycatcher habitat

Local landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed that value.
[b]Dononvan and others (1997).

Prothonotary Warbler (PROW)
The Prothonotary Warbler model includes five predictor variables that define the species/habitat relationship including habitat age, occurrence of water, forest patch size, landscape composition (percent forest in a 1-km radius window), and snag density. Next, the tables and graphs below (obtained directly from Tirpak et al. 2009) were used to transform each predictor variable into a raster suitability index where values range from 0 as unsuitable habitat to 1 as ideal condition (Tirpak et al 2009).

The final overall HSI raster was calculated using the equation below, where SI1 = habitat age, SI2 = occurrence of water, SI3 = forest patch size, SI4 = landscape composition (percent forest in a 1-km radius window), SI5 =snag density:
Overall HSI = $((SI1 * SI5)^{0.500} * (Max(SI3 \text{ or } SI4) * SI2))^{0.500}$

Table 112.—Relationship of landform, landcover type, and successional age class to suitability index scores for prothonotary warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.100	0.300	0.400
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.100	0.300	0.400
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.300	0.800	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800

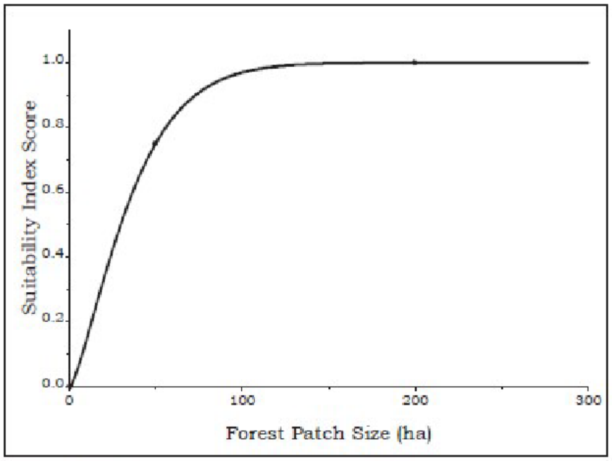


Figure 66.—Relationship between forest patch size and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = $1.002 - 1.001 * e^{-0.031 * (\text{forest patch size} ^ 0.968)}$.

Table 113.—Influence of occurrence of water on suitability index (SI) scores for prothonotary warbler habitat

9 × 9 pixel window contains water	SI score
Yes	1.0
No	0.0

Table 114.—Influence of forest patch size on suitability index (SI) scores for prothonotary warbler habitat

Forest patch area (ha)[a]	SI score
0	0.00
50	0.75
200	1.00
500	1.00

[a]Assumed value.

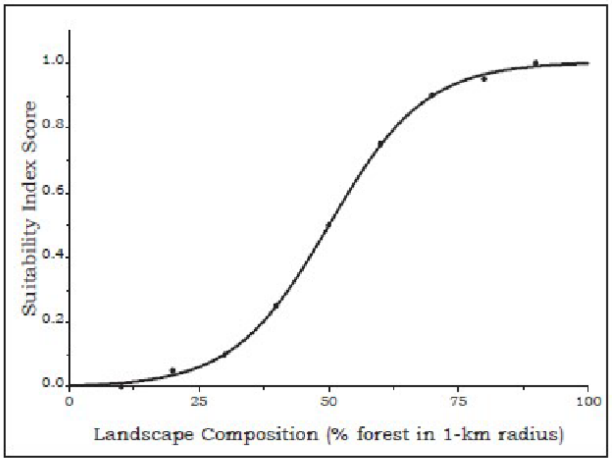


Figure 67.—Relationship between landscape composition and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = $1.005 / (1.000 + (221.816 * e^{-0.108 * (\text{landscape composition})}))$.

Table 115.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for prothonotary warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

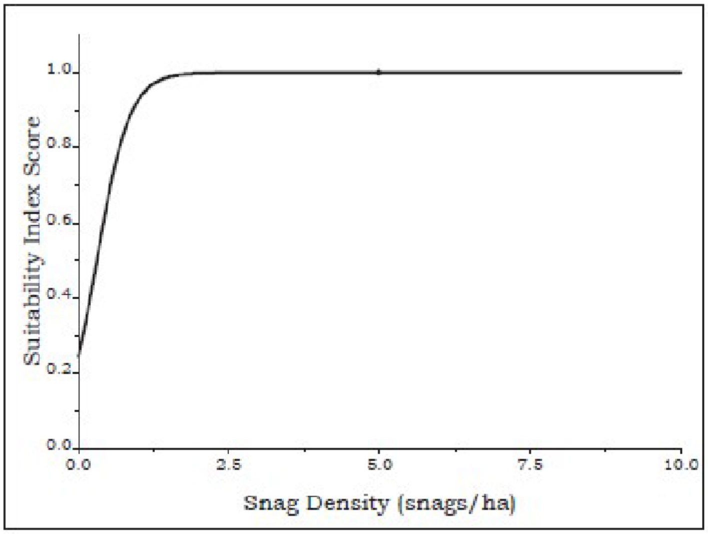


Figure 68.—Relationship between snag density and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = 1.000 / (1 + (3.113 * $e^{-3.689 \text{ * snag density}}$)).

Table 116.—Influence of snag density on suitability index (SI) scores for prothonotary warbler habitat

Snag density (snags/ha)	SI score
0[a]	0.25
5[b]	1.00
20[a]	1.00

[a]Assumed value.
[b]McComb and others (1986).

Kentucky Warbler (KEWA)

The KEWA model includes four predictor variables that define the species/habitat relationship including habitat age, forest patch size, landscape composition (percent forest in a 10-km radius window), and small stem density (per 1000 stems). Next, the tables and graphs below (obtained directly from Tirpak et al. 2009) were used to transform each predictor variable into a raster suitability index where values range from 0 as unsuitable habitat to 1 as ideal condition (Tirpak et al 2009).

The final overall HSI raster was calculated using the equation below, where SI1 = habitat age, SI2 = small stem density (per 1000 stems), SI3 = forest patch size, SI4 = landscape composition (percent forest in a 10-km radius window):
Overall HSI = $((SI1 * SI2)^{0.500} * (SI3 * SI4)^{0.500})^{0.500}$

Table 73.—Relationship of landform, landcover type, and successional age class to suitability index scores for Kentucky warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.417	0.667	0.667
	Deciduous	0.000	0.667	0.417	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.667	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.500	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000

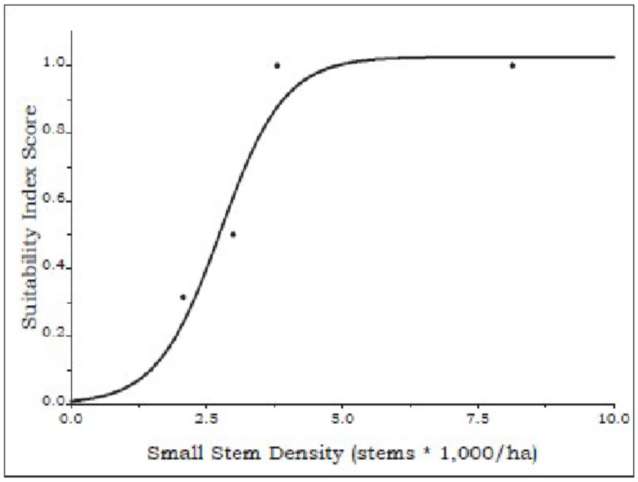


Figure 41.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Kentucky warbler habitat. Equation: SI score = 1.026 / (1.000 + (111.558 * e -1.707 * $^{(\text{small stem density / 1000})}$)).

Table 74.—Influence of small stem (< 2.5 cm d.b.h.) density (stems/ha) on suitability index (SI) scores for Kentucky warbler habitat

Small stem density	SI score
0.000[a]	0.000
2.077[b]	0.316
3.000[c]	0.500
3.812[b]	1.000
8.148[b]	1.000
47.600[d]	1.000

[a]Assumed value.
[b]Annand and Thompson (1997).
[c]Wenny and others (1993).
[d]Kilgo and others (1996).

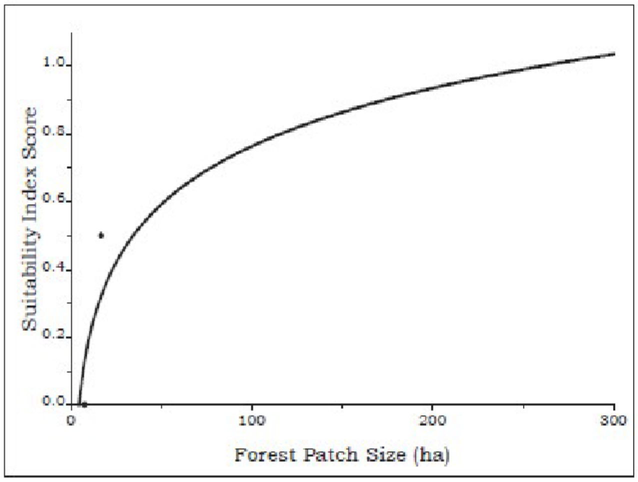


Figure 42.—Relationship between forest patch size and suitability (SI) scores for Kentucky warbler habitat. Equation: SI score = 0.248 * ln(forest patch size) – 0.377.

Table 75.—Influence of forest patch size on suitability index (SI) scores for Kentucky warbler habitat

Forest patch size (ha)	SI score
8[a]	0.0
17[b]	0.5
300[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

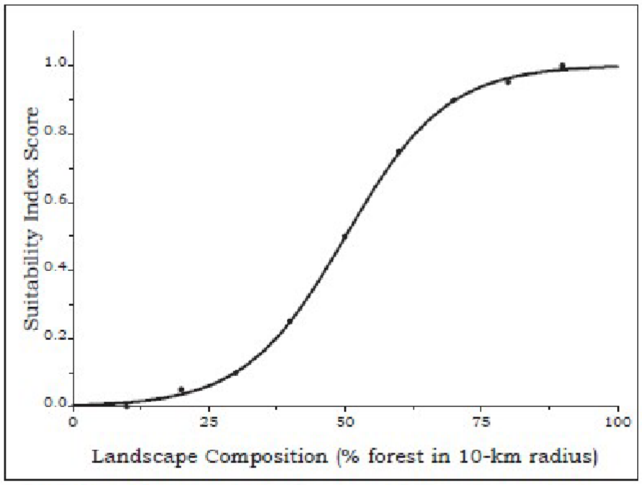


Figure 43.—Relationship between landscape composition and suitability index (SI) scores for Kentucky warbler habitat. Equation: $SI\ score = 1.005 / (1.000 + (221.816 * e^{-0.108 * (landscape\ composition)}))$.

Table 76.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for Kentucky warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donorvan and others (1997).

<u>Wood Thrush (WOTH)</u>

The WOTH model includes five predictor variables that define the species/habitat relationship including habitat age, canopy cover, forest patch size, landscape composition (percent forest in a 1-km radius window), and small stem density (per 100 stems). Next, the tables and graphs below (obtained directly from Tirpak et al. 2009) were used to transform each predictor variable into a raster suitability index where values range from 0 as unsuitable habitat to 1 as ideal condition (Tirpak et al 2009).

The final overall HSI raster was calculated using the equation below, where SI1 = habitat age, SI2 = forest patch size, SI3 = landscape composition (percent forest in a 1-km radius window), SI4 = small stem density (per 1000 stems), SI5 = canopy cover:
Overall HSI = $((SI1 * SI4 * SI5)^{0.333} * Max(SI2\ or\ SI3))^{0.500}$

Table 142.—Relationship of landform, landcover type, and successional age class to suitability index scores for wood thrush habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.250	0.750	0.750	1.000
	Transitional-shrubland	0.000	0.250	0.750	0.750	1.000
	Deciduous	0.000	0.250	0.750	0.750	1.000
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.250	0.500	0.500	1.000
Terrace-mesic	Low-density residential	0.000	0.250	0.500	0.500	0.834
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.250	0.500	0.500	0.834
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.334	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.334	0.667	0.500	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.334	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000

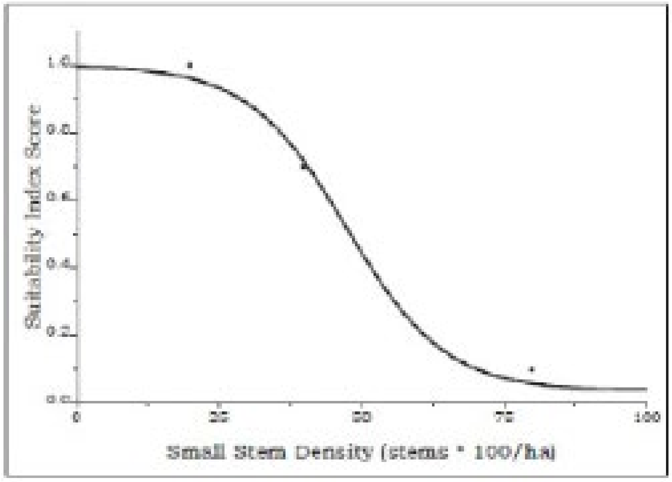


Figure 67.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1 - (0.963 / (1 + (243.780 * $e^{-0.116 \, * \, (\text{small stem density} \, / \, 100)}$)).

Table 145.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) on suitability index (SI) scores for wood thrush habitat

Small stem density[a]	SI score
0	1.0
20	1.0
40	0.7
80	0.1
100	0.0

[a]Assumed value.

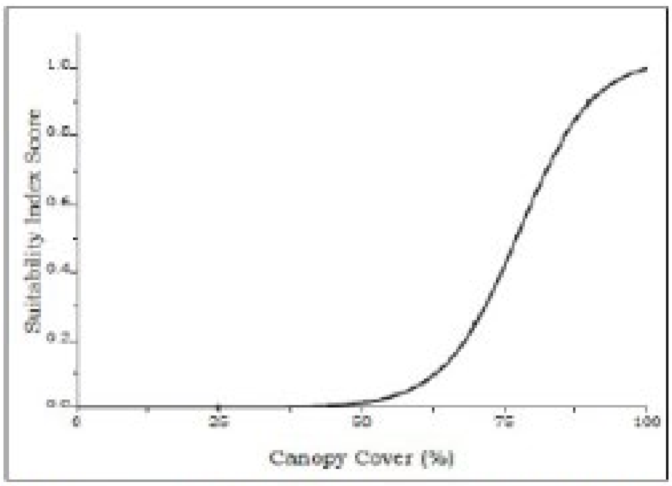


Figure 68.—Relationship between canopy cover and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.032 / (1 + (141241.54 * $e^{-0.153 \, * \, \text{canopy cover}}$)).

Table 146.—Influence of canopy cover (percent) on suitability index (SI) scores for wood thrush habitat

Canopy cover (percent)	SI score
25[a]	0.00
70[b]	0.25
90[b]	0.90
100[b]	1.00

[a]Hoover and Brittingham (1998).
[b]Annand and Thompson (1997).

2.7 HABITAT UNITS

We generated a HSI score for each raster pixel within the model according to the previously mentioned predictor layers that were subsequently incorporated into the final HSI equation for each species. We quantified how many acres within the modeled areas was associated with each HSI score to the 0.01 suitability level which resulted in 100 categories (i.e. 0.0-.01, 0.1-0.2,....0.99-1.00). We multiplied the acres within each HSI category by the final HSI score to generate the total habitat units across the modeled area for each of the two scenarios (Alternative 1 and 2). The difference between the calculated habitat units between Alternative 1 and Alternative 2 was determined for subsequent calculations to generate mitigation habitat units to offset any losses associated with the operation of the pumps. We constructed a spatial HSI model for KEWA and WOTH using their associated predictor variables; however, it is important to note that neither of these species have predictor variables associated with water. Therefore, only one model scenario was constructed for each species and no losses were calculated for either KEWA or WOTH.

We used the same predictor variables and HSI equation to generate different scenarios for which mitigation could be achieved depending on the quantity of each suitability index. We calculated these mitigation habitat units over the length of the project life, which is assumed to be 50 years. We calculated these units under the assumption that from the first year of reforestation to Year 10, the area would be categorized as “grass/shrub” as defined in Tirpak et al. 2009. From Year 11-30, we assumed succession to the “sapling” phase; Year 31-50 as the “pole” phase. We further defined the remaining variables for each species (i.e. ACFL and PROW) with specific inputs to each variable to generate a hypothetical mitigation HSI score of the habitat over the project life. Actual mitigation scores used to offset losses will depend on final conditions at the mitigation site, for example the size of forest block established or the presence of water within 200 m. We provide general guidelines for calculating mitigation habitat units for the ACFL (Tables A-2 and A-3) and PROW (Table A-4 and A-5) for consideration on how best to offset any habitat losses to landbirds in BLH forest in the YBA.

2.8 RESULTS

YBA Project Area

The broader temporal window of March 15 through July 31 was used for analyses to incorporate the period between early spring arrival by neotropical migrants and post-fledging dispersal. This period resulted in 138 days annually and 5,984 days throughout the 43-year POR. Under the scenario that the pumps would have been operational across the POR with Alternative 2 (crop season March 15-Oct 15), pumps would have been operational only 851 days (< 6% of time).

Under Action Alternative 3 (crop season March 25-Oct 15), the pumps would have operated 26 fewer days across the entire 43-year POR. This very small difference would result in nearly an identical spatial layer as Alternative 2 with only slightly fewer pumping days (0.6 days/year) in the Alternative 3 scenario; therefore, only Alternative 2 was modeled in ArcGIS for comparison to Alternative 1 conditions. We modeled a total of 387,462 acres within the 2 to 100-year floodplain for determining differences between with and without pump conditions. The one-year floodplain is not expected to be altered as it is situated below elevation 90 at which the pumping station operates.

HSI Model Results for Focal Species

The ACFL model (Figure A-1) resulted in a total of 88,839 and 88,690 habitat units under Alternative 1 and Alternative 2. The PROW model (Figure A-2) resulted in a total of 66,064 and 65,370 habitat units, respectively, under Alternative 1 and Alternative 2. On average, there was a reduction of 149 and 694 habitat units annually with Alternative 2 across the POR for the ACFL and PROW, respectively. In order to mitigate, we generated a scenario where reforestation of croplands that would be situated at or below the 2-year floodplain to maintain proper hydrology for the species along with other habitat parameters would offset losses in habitat units. Under the scenario for ACFL (Table A-2 and A-3), 444 acres of BLH reforestation would be required to offset losses and 1,056 acres to offset losses to PROW (Table A-4 and A-5). Mitigation acres required to offset these losses will change depending on how mitigation habitat units are created under the prescribed HSI formulas; with ERDC-EL recommending certain metrics be achieved to meet the current formula for determining the hypothetical HSI score under the given conditions. Under the hypothetical example for PROW, 694 HU lost annually would result in a total of 34,700 HU lost over the project life. Therefore, to calculate acreage of BLH needed to offset the HU loss would equate to the 34,700 HU divided by 32.9 HU/acre across the project life.

ERDC-EL conducted habitat modeling for KEWA and WOTH in addition to the other two species that are dependent on presence of water on the landscape. Results of this analysis do not consider hydrology or backwater events on the landscape as these species habitat parameters within the model do not incorporate features related to water. Both species are ground or near-ground nesters; therefore, significant flooding events, as happened in 2019 and 2020, almost certainly eliminates breeding for that year where flood duration extends into the breeding season. Overall HSI scores were high for WOTH (Figure A-3) within the modeled area of the YBA, while HSI scores for KEWA were low to moderate (Figure A-3). According to the HSI models, 29,985 acres within the 5-year floodplain had an HSI score greater than or equal to
0.75 HSI and 35,483 acres greater than or equal to a 0.5 HSI for WOTH. KEWA resulted in much fewer acres of suitable habitat within the 5-year floodplain, with only 51 acres greater than or equal to 0.75 HSI and 2,272 acres greater than or equal to 0.50 HSI.

2.9 POTENTIAL AREAS AS MITIGATION FOR MIGRATORY LANDBIRDS

GIS and aerial imagery were used to identify 18 discrete habitat blocks, consisting of approximately 6,500 acres that would be highly beneficial as easement or mitigation lands for connecting larger blocks of forest that will provide important landscape linkages and movement corridors (Figure A-4). These locations were further grouped into seven corridors for connecting larger tracts of forest (Figures A-4 and A-55). Two sites that are lower in elevation (Sites 4 and 7) would be high priority as these sites could serve as wetland mitigation sites where hydrologic functions could be restored (Figure A-5). Both sites were still partially inundated during field visits in mid-July 2020 with numerous wading birds (e.g., Great and Snowy Egrets) and migratory shorebirds (e.g., Greater Yellowlegs) present. Sites 1-3 would serve as critical wildlife corridors to connect large, forested tracts between the Mississippi River and DNF. Sites 4-7 would serve as corridors to connect larger tracts of forest as well as connecting DNF to Panther Swamp NWR (Figures A-4 and A-5). Site 4 also contained what appeared to be a potential Snowy Egret rookery on the edge of forest and immediately adjacent to a small depressional area still fully inundated during a July 2020 field visit.

2.10 DISCUSSION

We found that there will be minor impacts to two of our focal species with the operation of the proposed pumping schedule. Specifically, we found a reduction of 149 and 694 habitat units annually with Alternative 2 across the POR for the ACFL and PROW, respectively. Furthermore, only, in approximately 42% of years (18 of 43), would the pumps have been operational more than 5 days in the breeding season (Mar 15-July 31) and in 53% of years the pumps would not have operated at all (at any time of the year) based on the currently proposed 90.0 and 93.0 foot managed elevations. In approximately 50% of years within the POR the average elevation during the breeding season exceeded elevation 80 NGVD, which is generally the stage at which interior flooding begins (Table A-6). This indicates that in the majority of years, breeding territories are established based on proximity to existing water sources which are abundant throughout the YBA. Certainly, the additional water from backwater events may provide for additional habitat for PROW (Table A-7), as reflected in our modeling efforts. However, birds migrating from the tropics would have no prior knowledge of current-year conditions until they arrive. Oftentimes, birds' site fidelity depends on the prior year's success (Hoover 2003). Therefore, it is possible that improved habitat conditions related to increased inundation within the floodplain could positively affect reproductive success in some years, but these flooded conditions may not be available the following year due to annual variation in flooding patterns, whereas flooding extents and associated habitat availability would be more temporally stable if high-intensity flooding (e.g., in ~35% of years in which pumps operate) is lessened. Furthermore, in years in which flooding was significant such as during 1979, 2011, 2019, and 2020, it is almost certain that conditions within BLH forest across the YBA were unsuitable for breeding by ground- nesting individuals such as KEWA or WOTH, and significant flooding of PROW nest cavities may have occurred. Not only could severe flooding events significantly reduce PROW productivity over a breeding season if numerous nests are flooded (Flaspohler 1996) but return rates the following year after severe flooding in affected areas could also be substantially reduced, as documented with female PROW in a Florida study (Diggs and Wood 2010).

The duration of impact on ground- and understory-nesting birds that require specific vegetation structure is the focus of a current ERDC-EL investigation. In May of 2022 and 2023, we deployed 29 Acoustic Recording Units (ARUs) in the DNF across a representative elevation gradient (84.5 - 97.6 ft). We used autonomous classification (BirdNET) to classify the thousands of hours of recordings we collected and filtered our results to include only the most confident detections. We recorded 26,351 detections of ACFL, 38,365 detections of PROW, 195 detections of KEWA, and 218 detections of WOTH (Table A-8). We found that, within the Delta National Forest, species that rely on the forest floor for some portions of their reproductive cycle are relatively sparse and are found almost exclusively at the highest elevation portions of the nearly 61,000-acre forest (Figures A-7). During the 2019 backwater flood, in which the entire Delta National Forest was inundated through July, species such as WOTH, KEWA, and Swainson's Warbler almost certainly failed to reproduce at a level necessary to prevent negatively influencing population dynamics and may not have produced any surviving juveniles within the extensively inundated region. ERDC-EL will be deploying ARUs for a third season of data collection in 2024.

Construction and removal of habitat for the pump station will have moderate indirect impacts to some forest-dwelling BoCC associated with small-scale forest habitat fragmentation, along with the direct impacts of habitat loss within the construction footprint Forest fragmentation may reduce reproductive success and alter the composition of bottomland forest communities by increasing predation rates along forest edges and by decreasing presence of birds that require forest interior habitat (Robinson et al. 1995). Species that are generalists in their habitat selection and are known to utilize edge habitat may displace forest interior-dependent species and can act to recruit more edge species to the area. In this way, forest fragmentation of intact forests may have long-term adverse impacts on forest bird communities (Betts et al. 2017, Valente and Betts 2018). To minimize impacts to migratory birds, especially those that require large intact forests, efforts should be made to minimize to the extent practicable the footprint of forest habitat removal. In addition, construction should take place, to the extent practicable, between approximately 1 August and 28 February to minimize impacts to nesting birds.

Pump operations are not expected to begin until the water level rises at the Steele Bayou WCS above 90 feet (NGVD 29). When pump station operation is initiated in years when inundation levels reach or exceed 90 feet (NGVD 29), the water levels likely will not be significantly lowered below this threshold; at this threshold all or most depressional and other wetland habitats at and below 90 feet (NGVD 29) remain inundated. It is important to note that before March 15, water levels may reach up to 93 feet (NGVD 29) which would inundate significantly more depressions that would remain inundated for some period into the breeding season depending on local precipitation events. Our models which relied heavily on hydrologic inputs were not able to capture many of these areas which have microtopography not necessarily captured by the FESM model as areas recede; therefore, it is likely that many areas that were considered of lower habitat suitability due to the modeled absence of water were underestimated.

Bottomland hardwoods above elevation 90 feet (NGVD 29) would receive reduced future flooding due to operation under the Proposed Plan in some years, which could potentially affect reproductive success. Changes resulting from altered hydrologic regimes will likely benefit species inhabiting more terrestrial habitats, while those species relying on periodic inundation could be negatively impacted to varying degrees. For example, a reduction of flood frequency and duration in BLH forests may positively influence migratory ground or near ground-nesting species such as WOTH, Hooded Warbler (*Setophaga citrina*) and

KEWA by allowing an increase in understory vegetation density and structure, thereby increasing suitability of these habitats as breeding sites. Reduced flooding may also enhance habitat for forest birds that primarily forage on the ground, such as WOTH and Swainson's Warbler (Reiley et al. 2017) and is an additional benefit of reduced flooding for some forest birds in the YBA. Species that may be negatively impacted by hydrologic changes within the overall YBA are those that are abundant within the YBA and utilize BLH and floodplain forests extensively during the breeding season. Wetland- dependent species such as PROW and ACFL that rely on forested wetlands during the breeding season, and which are frequently detected in the YBA adjacent to streams and depressional wetlands, would likely be negatively impacted to a degree by a decrease in inundated forest at elevations above 90 feet (NGVD 29) during the breeding season.

It is important to note that when constructed, the Yazoo Pump will not be operational every year (based on the POR; see Introduction section of current appendix and Engineering Appendix), and when it does operate, it will likely only operate for a few days or weeks (excluding extreme flooding events). Therefore, the actual impacts of pump operations may be less than anticipated. It is essential to more thoroughly understand the flooding extent and duration above elevation 90 feet (NGVD 29) resulting from local precipitation events, and flood and floodplain inundation events either locally or as a result of rain within the larger watershed. Although the Water Management Plan is expected to reduce the acres of flooded habitat above 90 feet (NGVD 29), floodplain inundation from precipitation-driven flood events will fill many isolated wetlands and water bodies (e.g., meander scars, sloughs, gravel bars, borrow pits, old depressions, and/or oxbows [Wharton et al. 1982]) independently of the Steele Bayou water control structure operation, and pump station operation. An undetermined number of these landscape features are hydrologically influenced by overbank and/or distributary flooding when local drainages (e.g., Little Sunflower River, Steele Bayou) receive local precipitation and inundate the floodplain (either by overbank flooding or via tributaries of these rivers). Furthermore, there are a multitude of these depressional floodplain features in the YBA that are inundated and will hold water for long durations when the water control structure is closed. Some of these features are hydrologically connected to channels that allow them to drain when the water control structure is subsequently opened; yet an undetermined number of these features are isolated water bodies that, when inundated, retain water well into summer (if not longer) and do not drain. Though we currently do not have acreage estimates for these landscape features, these areas are likely significant for a diverse suite of bird species and should be included in future analyses.

The acquisition of easement and mitigation lands are often influenced by land availability, price, willingness to sell, and current land-use. It is prudent to acquire lands strategically that maximize potential benefits for wildlife and that assist in the mitigation offset from habitat loss or alteration. Strategic planning should provide significant value to new easement and mitigation lands that are restored within the MAV. A field assessment was conducted of potential conservation easement or fee-owned mitigation sites that would provide opportunities for (a) landscape connectivity from the Mississippi River, through the DNF, to Panther Swamp NWR. (b) creation of moist-soil management (MSM) units or BLH restoration within agricultural fields having suitable topography for maintaining hydrology; and (c) reduction of forest habitat fragmentation through strategic acquisition of agricultural lands that could be replanted to BLH forest. GIS and aerial imagery were used to identify habitat blocks within the Yazoo Study Area that could provide for these potential benefits. Considered criteria included least amount of distance required to connect larger forest blocks, interspersion of forest and agricultural areas, presence of streams for which riparian rehabilitation would provide connections, and presence of depressional areas that likely are inundated during portions of the year. The areas were digitized in GIS and prioritized based on perceived ease of connecting habitat fragments with the smallest acreage to create movement corridors, existing wildlife use, and current hydrology (e.g., some lower elevation sites likely may not need water control structures to function).

Following our initial and independent assessment of targeted mitigation areas, we consulted Elliott et al. (2020) to determine if there was correspondence between their priority restoration sites and ours. Elliott et al. (2020) assessed the conservation–protection status of land within the MAV and prioritized the need for additional conservation–protection based on benefits to forest bird conservation, forest patch area, geographic location, and hydrologic condition (Figure A-6). They focused on habitat blocks of core forest greater than 2,000 hectares and more than 250 meters from an edge. Similarly, the Lower Mississippi Valley Joint Venture (LMVJV) partnership has long promoted strategic reforestation in the MAV for the conservation of breeding birds (Twedt et al. 1999). We found direct and high correspondence between the two independent assessments, suggesting these focal areas are of high conservation value for meeting the future needs of the regional avifauna.

Though replanted mitigation sites will not replace lost habitat structure and functions for approximately 20-30 years (for mature forest obligates) and not fully until 50 years or more for mature forest, there are incremental benefits realized each year of the project life resulting from successive suites of migratory bird species that exploit each successive vegetation community as sites progress from sapling/shrub communities (a habitat type that is currently lacking across the YBA) to mature forest. This is particularly true for those species that utilize sapling/shrub habitat during approximately the first five years after replanting. Multiple early-successional species, including several migratory BoCC (USFWS 2021), could benefit from these early- successional mitigation areas include breeding Prairie Warblers (*Setophaga citrea*), Yellow- breasted Chats (*Icteria virens*), and Dickcissels (*Spiza americana*), migrants including Golden- winged Warblers (*Vermivora chrysoptera*), and overwintering Henslow's Sparrows (*Centronyx henslowii*), Field Sparrows (*Spizella pusilla*), and LeConte's Sparrows (*Ammospiza leconteii*).

Mitigation efforts to restore forested habitat conditions in the YBA (a region that has largely been cleared for agriculture in recent centuries) would not only benefit the four breeding species assessed in this analysis, but also would benefit a multitude of declining migratory landbird species throughout their annual cycles, including Cerulean Warblers (S*etophaga cerulea*; Buehler et al. 2020), Golden-winged Warblers (Confer et al. 2020), and other species of conservation concern that migrate through the MAV, as well as forest-dwelling species that breed in the North and overwinter in the YBA that also include species of conservation concern (e.g., Rusty Blackbirds; *Euphagus carolinus*; Avery 2020), We recommend future songbird monitoring (through collaboration with conservation groups) within mitigation areas to assess avian responses, and to assess habitat conditions of restoration sites through an adaptive management process that can inform potential further habitat management efforts (e.g., forest management) at mitigation sites to enhance effectiveness at these sites and other future USACE mitigation sites.

TABLES

Table A-1. Landscape variables used in HSI values for each of the four focal species.

Variable	Species' HSI Model formulation
Habitat Age	ACFL, KEWA, PROW, WOTH
Occurrence of Water	PROW
Distance to Water	ACFL
Percent Canopy Cover	ACFL, WOTH
Forest Patch Size	ACFL, KEWA, PROW, WOTH
Landscape Composition	ACFL, KEWA, PROW, WOTH (all at the 1-km scale)
Snag Density	PROW
Small Stem Density	KEWA, WOTH

Table A-2. Hypothetical example derived from ACFL metrics within the Tirpak et al. (2009) model to determine mitigation SI scores for generating final HSI output.

	Years	Input	SI Score
Variable 1	0-10 years	Grass/Shrub	0
	11-30 years	Sapling	0.05
	31-50 years	Pole	1.0
Variable 2	Distance to water (m)	<300 m	0.75
Variable 3	Canopy cover (%)	>80%	0.75
Variable 4	Forest patch size (ha)	>75 ha	0.75
Variable 5	Local landscape composition (% forest)	>70%	0.9

Table A-3. Hypothetical example derived from ACFL metrics within the Tirpak et al. (2009) model to determine mitigation HSI to determine AAHU/acre needed to offset losses.

Project	HSI	Total AAHU within Project Life
Final HSI 0-10 years	0.00	0.0 AAHU/Acre
Final HSI 11-30 years	0.40	8.0 AAHU/Acre
Final HSI 31-50 Years	0.84	16.8 AAHU/Acre
Total Across Project Life		24.8 AAHU/Acre

Table A-4. Hypothetical example derived from PROW metrics within the Tirpak et al. (2009) model to determine mitigation SI scores for generating final HSI output.

	Years	Input	SI Score
Variable 1	0-10 years	Grass/Shrub	0
	11-30 years	Sapling	0.3
	31-50 years	Pole	0.8
Variable 2	Water present (yes/no)	Yes	1
Variable 3	Forest patch size (ha)	50 ha	0.75
Variable 4	% forest in 1 km	0.8	0.95
Variable 5	Snags/ha	5	1

Table A-5. Hypothetical example derived from PROW metrics within the Tirpak et al. (2009) model to determine mitigation HSI to determine AAHU/acre needed to offset losses

Total AAHU within Project Life Project Life	HSI Score	Period
Final HSI 0-10 years	0	0.0 AAHU/Acre
Final HSI 11-30 years	0.7213	14.5 AAHU/Acre
Final HSI 31-50 Years	0.9218	18.5 AAHU/Acre
Total Across Project Life		32.9 AAHU/Acre

Table A-6. Average elevation during breeding season over the POR.

Year	Average Elevation (March 15-July31)	Year	Average Elevation (March 15-July31)
1978	77.6	2000	72.1
1979	85.0	2001	74.7
1980	77.3	2002	80.8
1981	72.7	2003	77.0
1982	75.9	2004	77.7
1983	84.3	2005	72.7
1984	83.7	2006	71.4
1985	76.6	2007	74.5
1986	72.5	2008	87.3
1987	73.5	2009	83.1
1988	71.6	2010	80.4
1989	79.9	2011	86.4
1990	81.4	2012	72.5
1991	81.8	2013	83.9
1992	72.1	2014	77.9
1993	84.6	2015	85.7
1994	81.6	2016	79.6
1995	80.4	2017	81.1
1996	79.7	2018	83.0
1997	83.4	2019	97.5
1998	83.0	2020	89.2
1999	78.4	Average (POR)	79.7

Table A-7. Total area inundated with respect to elevation (NGVD 29).

Elevation (feet NGVD 29)	Total Acres
80	9,443
81	11,972
82	14,867
83	18,553
84	24,462
85	32,015
86	44,214
87	57,918
88	79,843
89	105,795
90	136,133
91	168,488
92	195,389
93	224,779
94	258,447
95	292,911
96	331,860
97	376,959
98	422,852
99	463,029
100	506,144
101	544,024
102	583,998
103	625,583

Table A-8. Number of detections of the four focal species modeled in this Appendix from ARU study in the Delta National Forest, 2022-2023.

	Detections (2022)	Unique ARUs 2022	Total ARUs	Detections (2023)	Unique ARUs 2023	Total ARUs 2023
KEWA	106	4	26	11	4	29
WOTH	5	4	26	84	5	29
ACFL	2,343	26	26	3,994	28	29
PROW	2,075	25	26	3,129	26	29

FIGURES

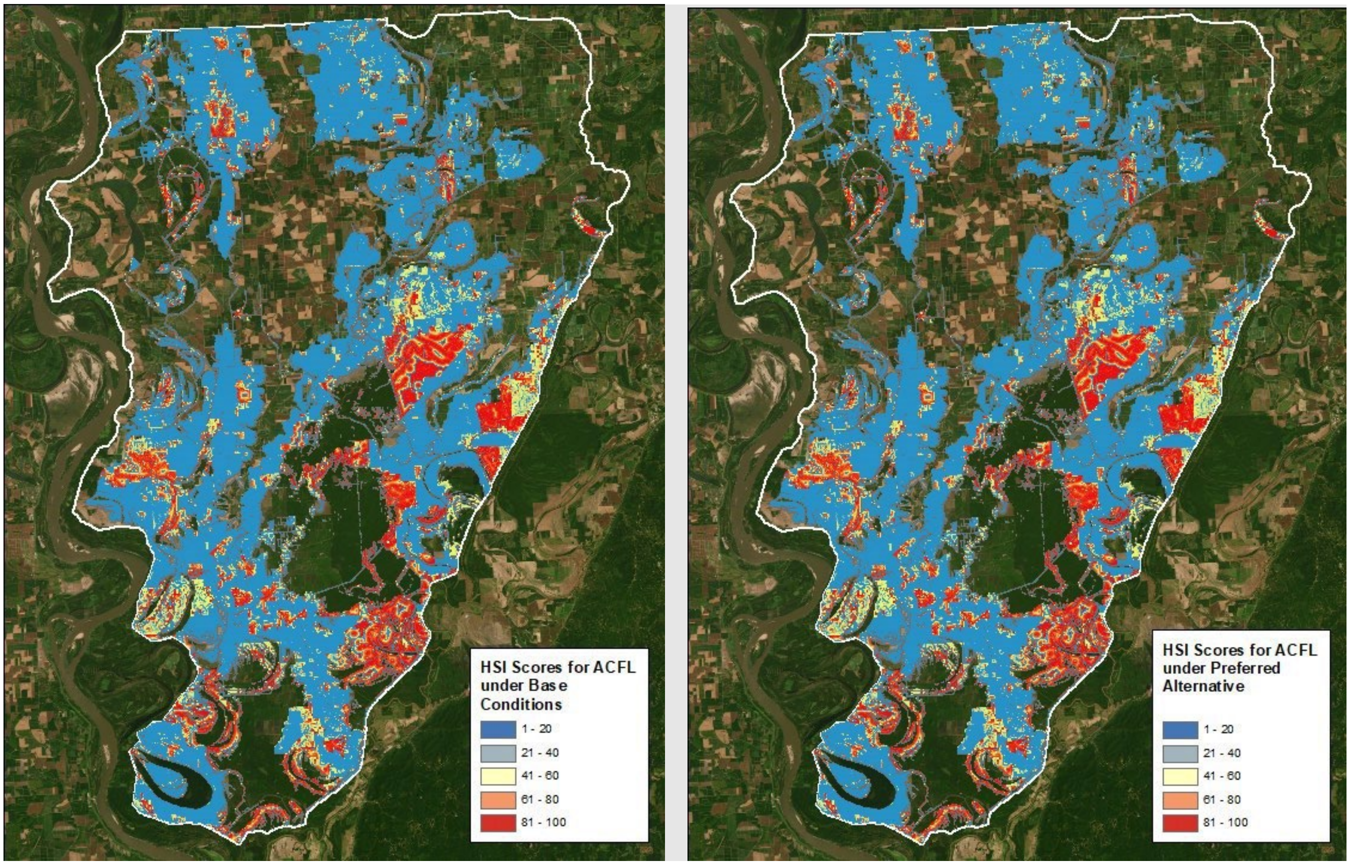


Figure A-1. Acadian Flycatcher HSI model within the YBA based on modified inputs to the Tirpak et al. 2009 methodology. Symbology in legend equates to the .01-1.0 HSI (e.g. 1-20 equal to .01-0.20 HSI). Alternative 1 (left) and Alternative 2 (right) modeled output in the YBA.

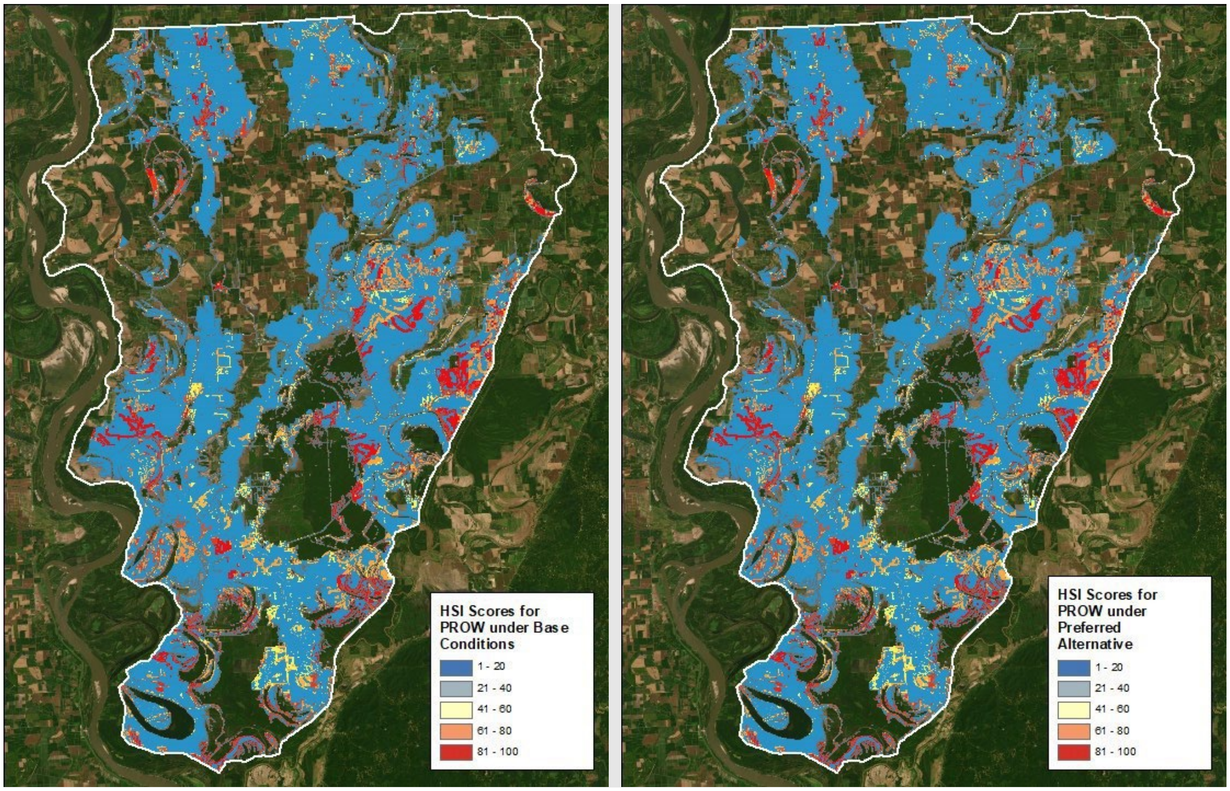


Figure A-2. Prothonotary Warbler HSI model within the YBA based on modified inputs to the Tirpak et al. 2009 methodology. Symbology in legend equates to the .01-1.0 HSI (e.g. 1-20 equal to .01-0.20 HSI). Alternative 1 (left) and Alternative 2 (right) modeled output in the YBA

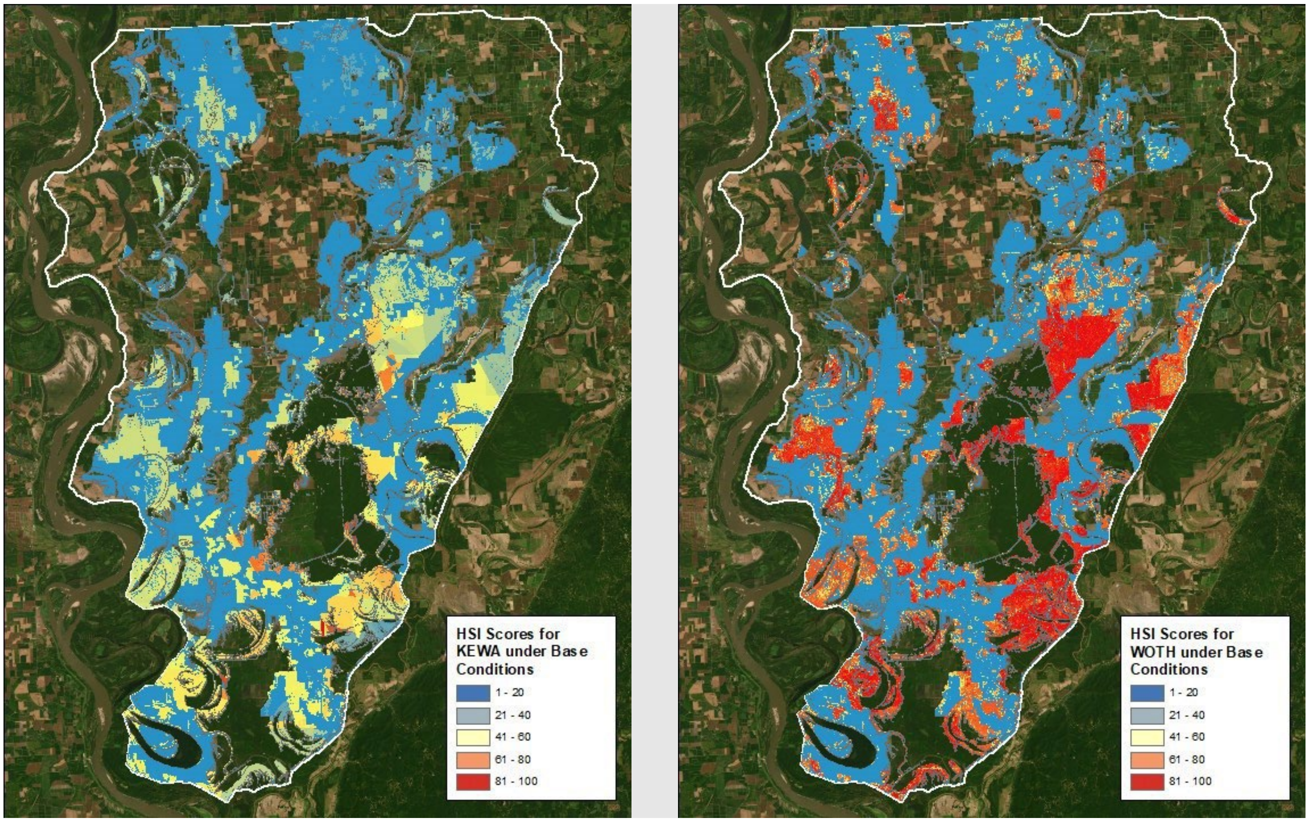


Figure A-3. Kentucky Warbler (left) and Wood Thrush (right) HSI model within the YBA based on modified inputs to the Tirpak et al. 2009 methodology. Symbology in legend equates to the .01-1.0 HSI (e.g. 1-20 equal to .01-0.20 HSI).

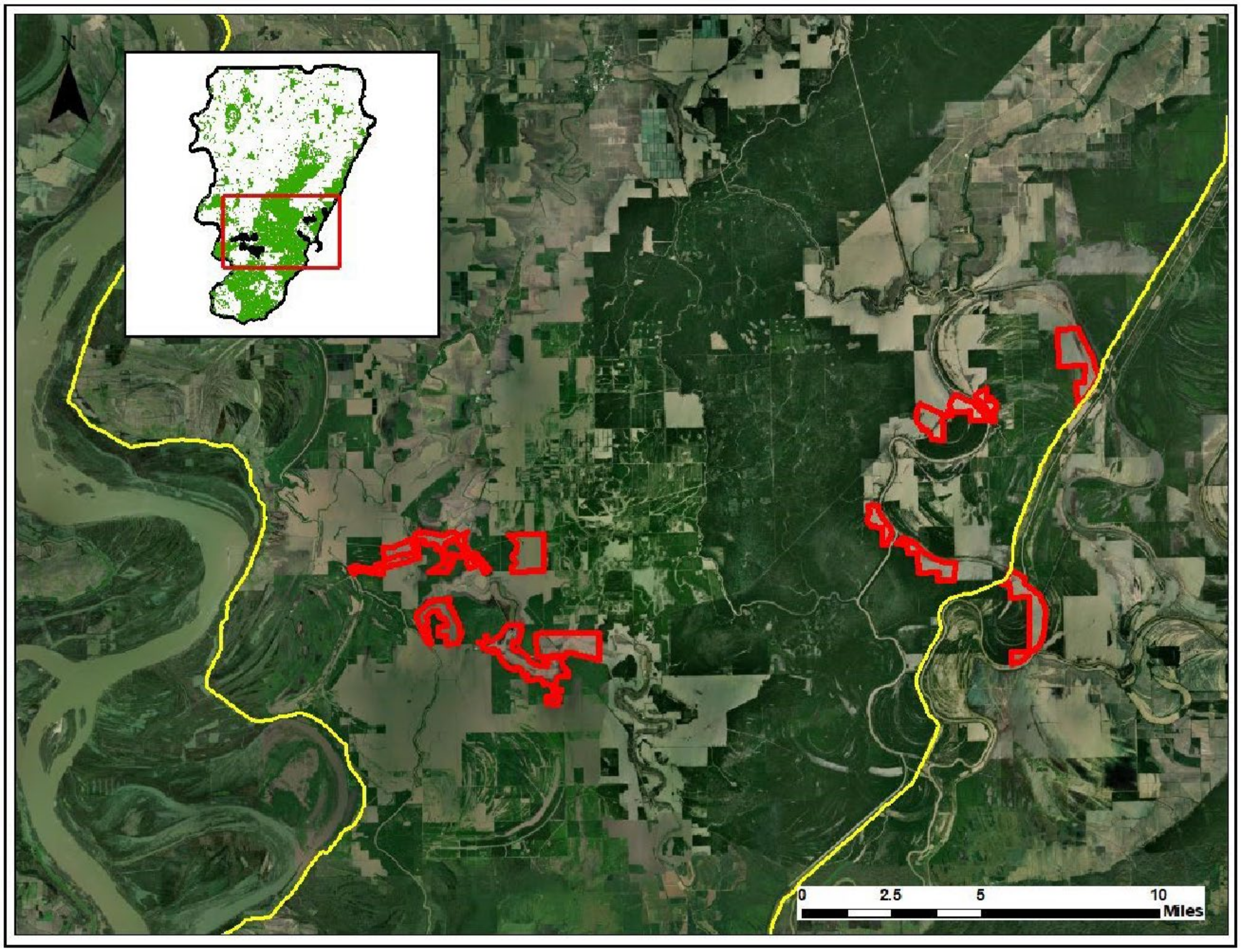
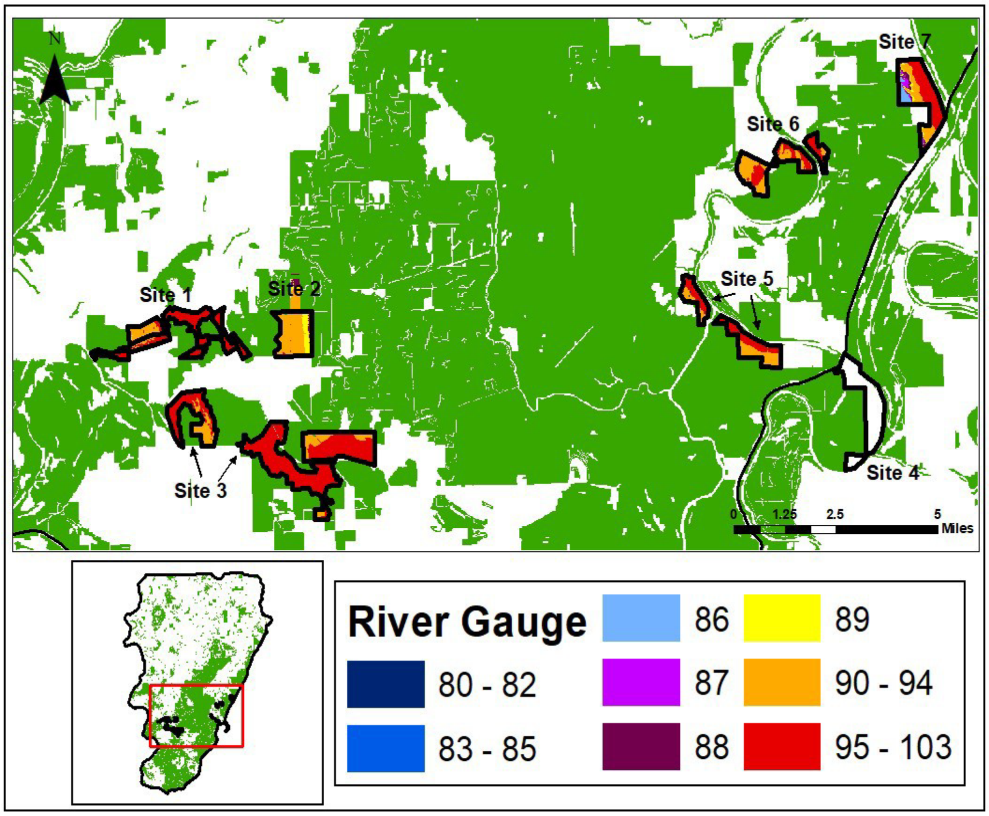
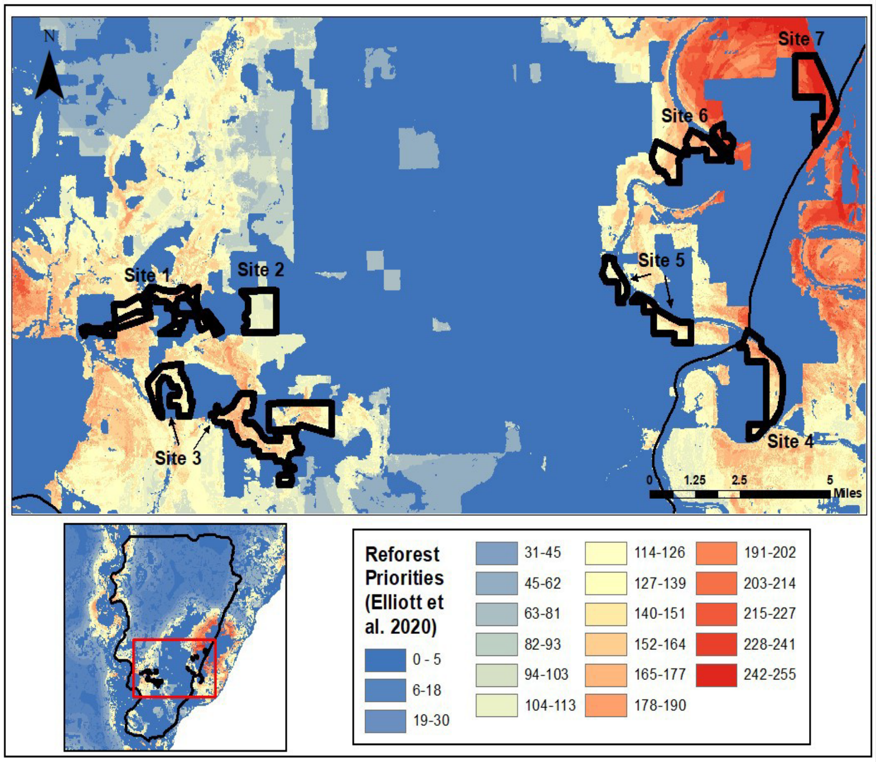


Figure A-4. Recommended mitigation and conservation easement lands in the Yazoo Study Area.


N
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
0 1.25 2.5 5 Miles
River Gauge
80 - 82
83 - 85
86
87
88
89
90 - 94
95 - 103


N
Site 1
Site 2
Site 3
Site 4
Site 5
Site 6
Site 7
0 1.25 2.5 5 Miles
Reforest Priorities (Elliott et al. 2020)
0 - 5
6-18
19-30
31-45
45-62
63-81
82-93
94-103
104-113
114-126
127-139
140-151
152-164
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215-227
228-241
242-255

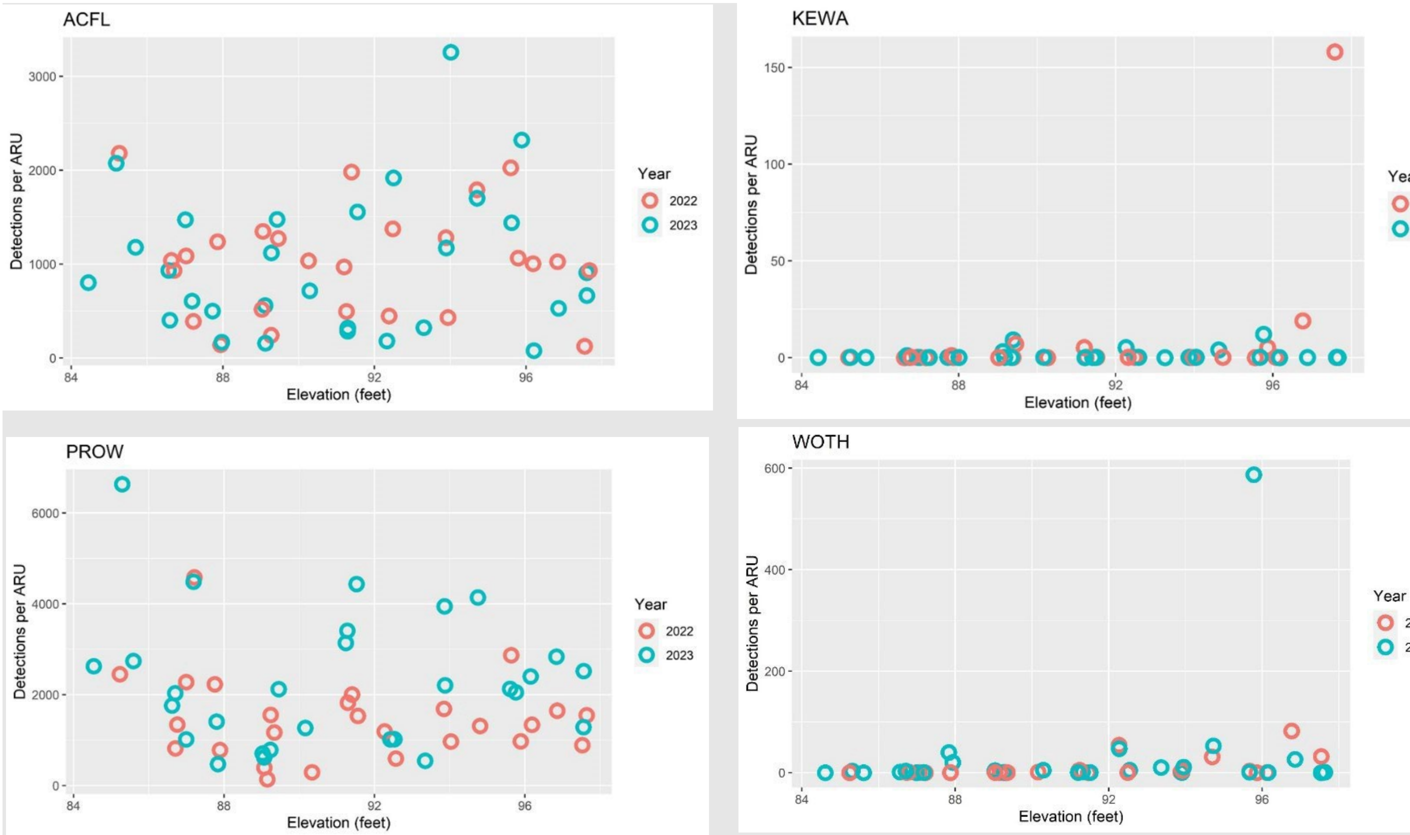

Figure A-7. Number of detections from ARUs in the DNF during spring 2022 and 2023 for the four focal species (ACFL-top left; KEWA-top right; PROW-bottom left; WOTH-bottom right).

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SECTION 3 APPENDIX B SHOREBIRDS

U.S. Army Engineer Research and Development Center Environmental Laboratory Ecological Resources Branch Vicksburg, Mississippi

INTRODUCTION

3.1 SHOREBIRD BACKGROUND

Shorebirds belong to a broad taxonomic Order (*Charadriiformes)* that encompasses multiple taxa, including plovers, yellowlegs, godwits, and sandpipers. Critical habitat for migrating shorebirds typically includes shallowly inundated or recently dewatered open areas, such as mud flats, intertidal zones, and barren agricultural fields. The Yazoo Backwater Area is located within the Mississippi Flyway and serves as a migratory stopover area for dozens of species of shorebirds during both spring and fall (Twedt et al., 1998). Most shorebirds that occur in the project area do so en route to their boreal breeding range in the spring, or on their way south to their non-breeding grounds in the autumn. High quality stopover habitat is critical to the annual survival of these species, some of which are only halfway through bi-annual migrations of over 9,000 miles when they stopover within the Mississippi Delta (Brlík et al., 2022; McDuffie et al., 2022). It is estimated that 68% of North American shorebird species have declined in population abundance since 1970, with an overall decline in shorebird abundance of nearly 40% in that same period (Rosenberg et al., 2019). Threats to shorebirds are diverse and occur at all stages of the annual cycle (Boyd and Piersma, 2001; Fernández and Lank, 2008; Melville et al., 2016). For many shorebirds, loss of migratory staging habitat is the predominant driver of population decline (Murray et al., 2018). Migratory shorebird habitat in the Mississippi Delta consists primarily of flooded/wet agricultural areas (pre-planting in the spring, or post-harvest in the fall), aquacultural areas including catfish farms, and the edges of water bodies, such as farm ponds and oxbow lakes. Shorebird habitat within the Yazoo Backwater Area tends to be more abundant in the spring when heavy precipitation and rising rivers can increase the amount of moist soil on the landscape. In the Mississippi Delta, migratory shorebird habitat can be sparse in the late summer/autumn, due to dry conditions. Common shorebird species that occur within the project area include (but are not limited to) Least Sandpiper (*Calidris minutilla*), Greater Yellowlegs (*Tringa melanoleuca*), Dunlin (*Calidris alpina*), Semipalmated Sandpiper (*Calidris pusilla*), Long-billed Dowitcher (*Limnodromus scolopaceus*), Stilt Sandpiper (*Calidris himantopus*), and Pectoral Sandpiper (*Calidris melanotos*).

3.2 SPECIES SELECTION FOR ANALYSES

The Yazoo Backwater Area (YBA) Wildlife and Endangered Plants Team consists of subject matter experts from the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center (ERDC) and Vicksburg District (CEMVK); U.S. Fish and Wildlife Service (USFWS), Mississippi Ecological Services Office (MSFO); and U.S. Environmental Protection Agency (EPA), Region 4 and Headquarters. The purpose of the team was to work collaboratively to identify focal species and appropriate assessment methodologies for investigation in the Yazoo Backwater Area.

3.3 METHODS

We used the Shorebird Migration Model (Clark and Jordan, 2017) to quantify change in shorebird habitat quality between base (no action) and alternate conditions. The shorebird model incorporates seven environmental variables to quantify the ecological value of an area to migratory shorebirds (Table B-1). We followed the shorebird model as closely as possible, although we had to make concessions in places where we lacked data sources for certain variables. Data sources for the seven variables were obtained from publicly available sites (e.g. Landfire Land Cover; Landfire 2022) or developed in-house (e.g. hydrology layers generated by USACE; Table B-2). Following the shorebird migration model, we assigned a numerical weight, ranging from 0 to 1, to each environmental factor.

Table B-1. Environmental variables incorporated within the shorebird model obtained from Clark and Jordan (2017)

Variable	Description
Water Depths	Water depth
Water Availability	Reliability of water availability within the season of question
Aquatic Invertebrates	Density of aquatic invertebrates
Vegetative Cover	Vegetation type
Disturbance	Human disturbance
Hydrologic Conditions	Inter-annual predictability of hydrology

Management Capabilities	Presence of impoundments and water control capabilities

We used Program R (R Core Team, 2022) to create a spatial layer for the entire Yazoo Backwater Area (raster) for each variable. We then combined the layers per the model (Figure B-1) to generate a habitat suitability surface for Alternatives 1, 2, and 3. (Figures B-2 and B-3).

We combined two sources of data to generate the total number of Habitat Units (HUs) per scenario. First, using extensive hydrological data for the period-of-record (POR; 1978-2020), MVK provided estimates of seasonal acres flooded 8 inches or less using the ENVIRO-FISH model (Table B-3, Figure B-4). This provided us with the number of acres flooded to suitable depths within each Hydrologic Unit Code (HUC). Secondly, we used the results of our shorebird spatial analysis to extract the ratio of habitat suitability scores within each HUC (Table B-4, Column 2). We then used those extracted ratios in conjunction with data about acres flooded to suitable depth (8 inches or less) within each HUC to generate the number of acres of each suitability score within each HUC (Table B-4, column 4). Each acreage was multiplied by the suitability score associated with it to generate habitat units for each suitability score (Table B-4, column 5).

To assess mitigation estimates for potential loss of shorebird habitat under each Alternative, we first decided about the quality of any moist-soil mitigation habitat that might be established through land acquisition and subsequent management. We did this by estimating realistic values for each model parameter and entering those values into the shorebird model (Table B-5 and Figure B-5). Assuming that any recommended mitigation for shorebirds would include appropriate land cover (e.g., mostly non-vegetated shallowly inundated soils) to meet life-history needs during spring and autumn migration, we used an optimal HSI score (1.0) for most parameters. We used less than optimal scores for certain parameters (Invertebrate density, Vegetative Cover, Management Capability) to reflect the fact that even specially created areas may have less than ideal invertebrate density or vegetative cover. Additionally, these areas are likely to have less than five impoundments with full water control capability. These parameter scores may need to be adjusted (in either direction) based on real world scenarios, and this will lead to a suggested mitigation area different than what we present here. For example, an inability to maintain proper water depth in mitigation areas will lead to a lower suitability score, and thus a need for a larger mitigation area.

Table B-2. Data sources for each model variable used for the 2024 shorebird analysis within the YBW EIS

Variable	Data source
Water Depths	USACE Vicksburg District. Areas that averaged 0.01 – 0.7 feet (8.4 inches) of water during the season of note (spring or fall) were assigned a score of 1.0, indicating optimal conditions. All other water depths, including upland, were assigned a zero.
Water Availability	With limited information regarding how water availability changes within the season (spring or fall), conservative measures were taken to give an optimal conditions score (1.0) to areas that achieved optimal water depth for the entire season (see prior variable)

Aquatic Invertebrates	We were unable to collect any information regarding aquatic invertebrate density within the project area within the allotted time frame. Because of this uncertainty, we took a conservative approach to maximize mitigation estimates and assigned all undeveloped areas an optimal score (1.0), and developed areas (urbanized/suburbanized areas, impervious surfaces) a zero.
Vegetative Cover	USGS LANDFIRE (LF2022_EVT_230_CONUS) vegetation classifications. We assigned agricultural and herbaceous land cover types (with vegetation less than or equal to 0.3 m in height as potentially shorebird-suitable). These land cover types were assigned an optimal score (1.0), and all other land cover types were assigned a zero.
Disturbance	We assigned developed areas a zero, with all other areas assigned as optimal with a 1.0.
Hydrologic Conditions	We used hydrologic information from the USACE Vicksburg District regarding the 1, 2, and 5-year floodplains to score this variable. We considered areas in the 1-year floodplain as optimal (1.0), 2-year (0.7) and 5-year (0.4) floodplains as moderate, and anything above the 5-year floodplain as suboptimal (0.1).
Management Capabilities	To our knowledge, there are no entities using water control structures/ impoundments to intentionally manage for shorebirds. Thus, we assigned the entire project area a 0.

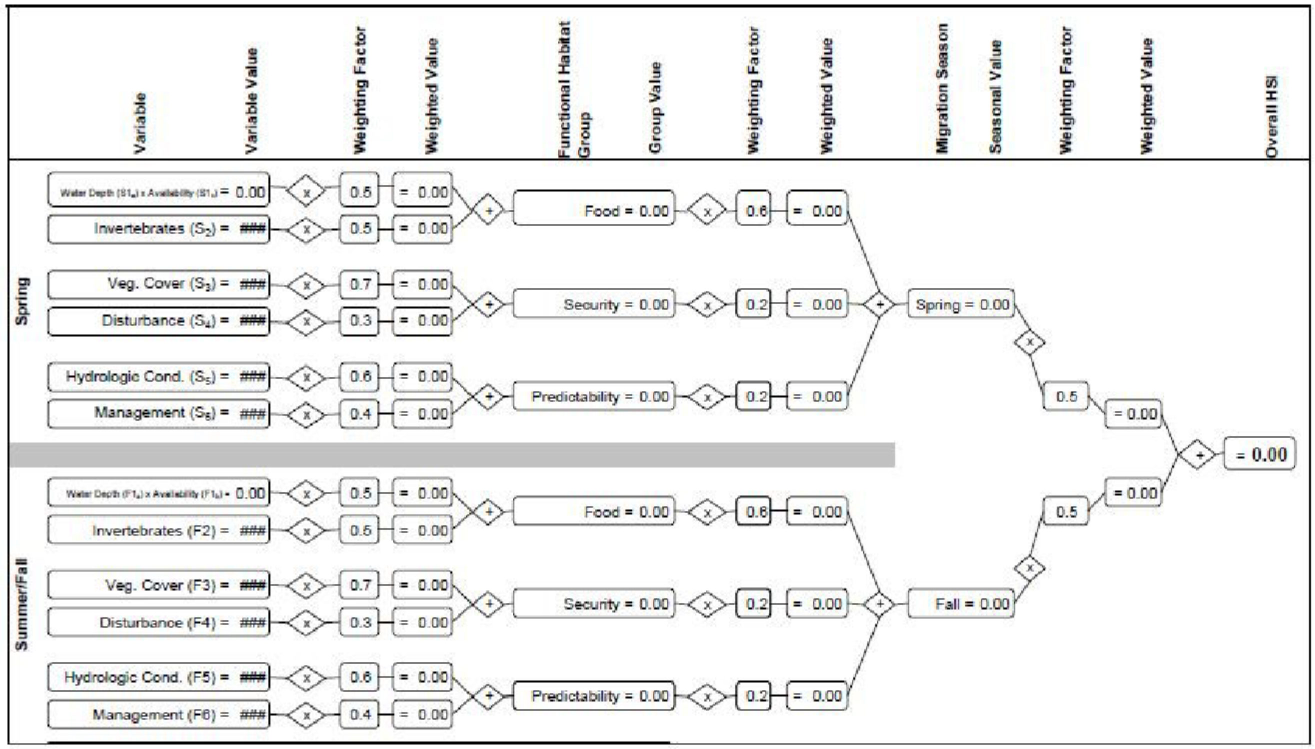

Figure B-1. The mathematical structure of the shorebird migration model (Clark and Jordan, 2017). Image taken directly from publication. We utilized only the spring portion of the model, given that effects of the proposed alternatives in the fall are negligible based on the period of record. This is a conservative option, given that including the fall portion would result in less effects and less mitigation.

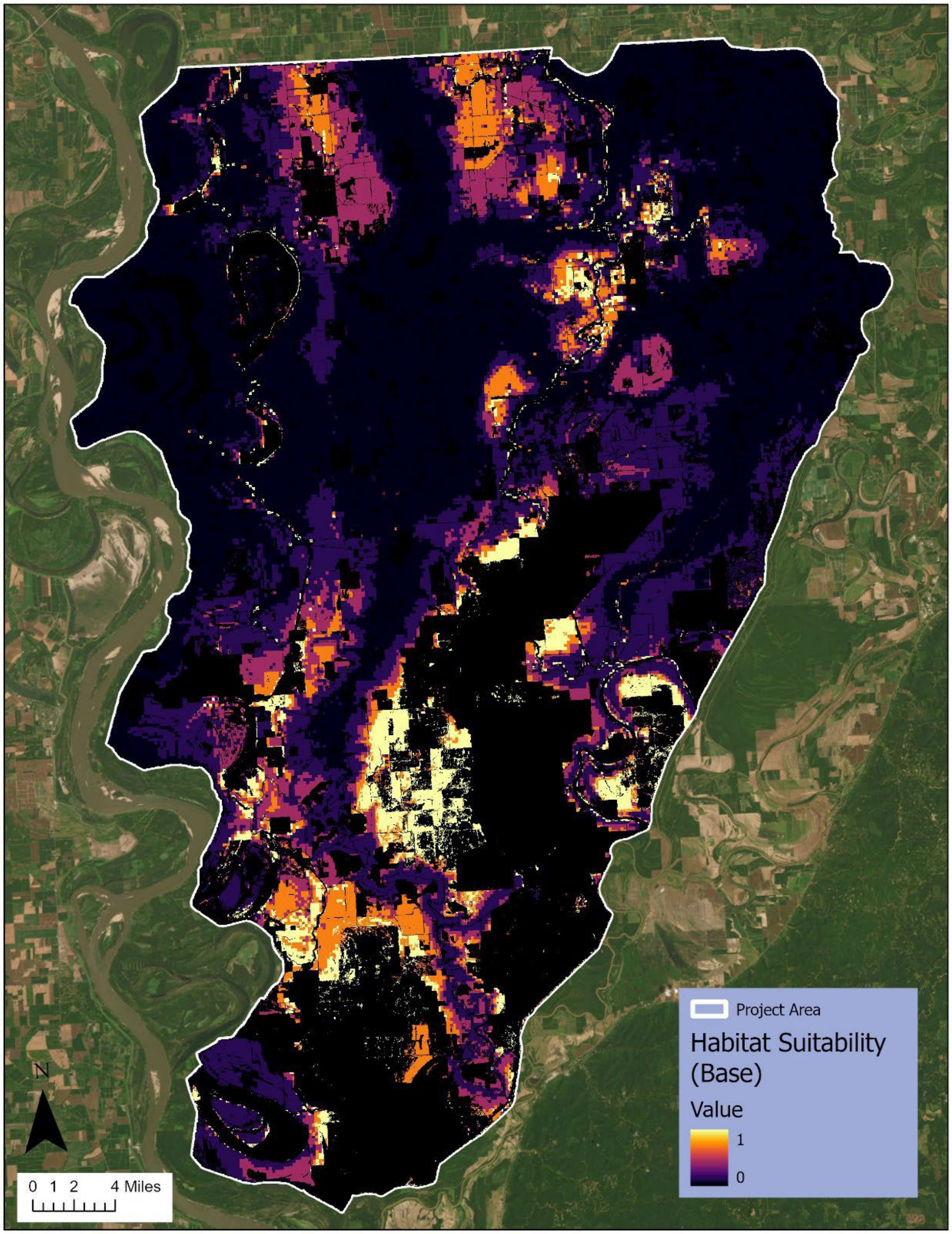

Figure B-2. Habitat suitability surface under the Alternative 1 (no action) scenario.

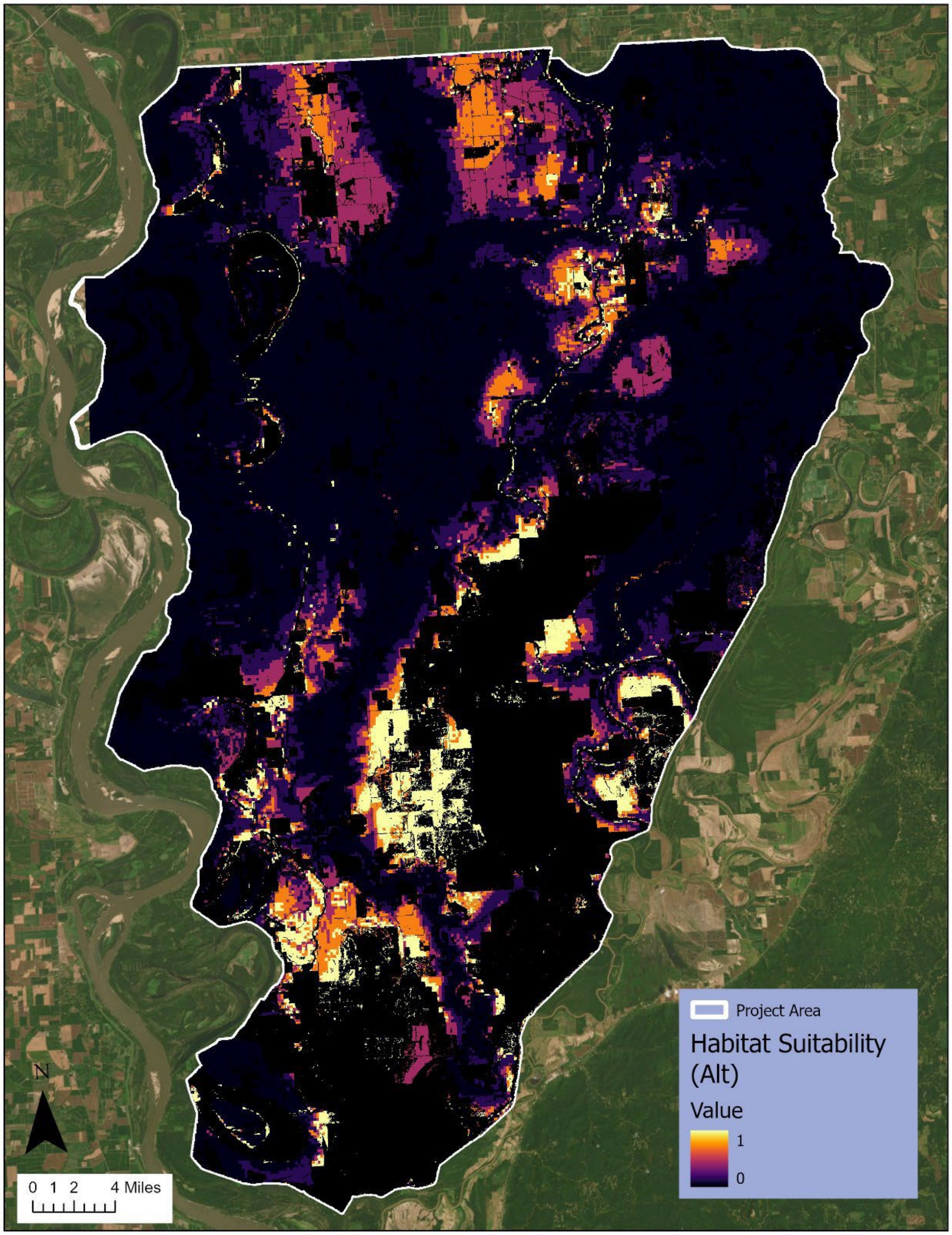

Figure B-3. Habitat suitability surface under the Alternative 2/3 scenarios.

3.4 RESULTS

We found that both of the action alternatives (Alternative 2, crop season March 15-October 15; Alternative 3, crop season March 25-October 15) resulted in a loss of approximately 352 HUs per year relative to Alternative 1 (Table B-6). Over the course of the 50-year project life, this translates to a loss of approximately 17,630 HUs relative to the no-action alternative. The suggested mitigation for the 50-year project life is approximately 403 HUs over the project life for both Alternative 2 and 3 (Table B-6). This is based on the annual loss of HUs divided by the mitigation HU/acre (0.874).

3.5 DISCUSSION

The pumping operation of either of the alternative actions will results in a loss of seasonal shorebird habitat relative to the no-action plan, albeit a relatively minor one. Migrating shorebirds rely on shallowly inundated/ recently dewatered open areas for foraging. Infrastructure that reduces the amount of water on the landscape in a flood year will naturally reduce shorebird habitat as well. Mitigation for most other environmental analyses for the Yazoo Backwater Area focuses on bottomland hardwood habitat. We recommend that mitigation for any loss of shorebird habitat under either action Alternative be acquisition of open land (e.g., agricultural land) with water management capabilities that maintain open wet substrate with sparse vegetation. Mitigation for shorebirds has some advantages over other taxa. Firstly, unlike bottomland hardwood forest, shorebird habitat can provide full benefits to the target taxa almost immediately (Helmers, 1992). There is no lag time to allow for habitat maturation, although there may be a delay in invertebrate colonization of inundated soils (Evans et al., 1999). Secondly, migratory shorebird habitat is easy to create relative to the more complex needs of some of the other species in this analysis (see Appendix A, C, D). Creating shorebird habitat requires the ability to manipulate water levels. Thirdly, shorebird habitat can be beneficial to a wide range of taxa. For example, shorebird habitat should be completely inundated during the winter in order to restrict vegetative growth and prepare the soil for the arrival of migrant shorebirds. While inundated, these shorebird impoundments can provide valuable foraging habitat for overwintering dabbling waterfowl (Appendix D) and Blue Grosbeak (Passerina caerulea). The main difficulty of creating shorebird habitat is that water management capability is required; both the physical infrastructure and also the time and knowledge to manage the water properly. Water levels must be manipulated throughout the year in order to create maximum benefits to shorebirds. There may be opportunities to leverage existing water control capabilities within the project area. For example, many agricultural fields already have water control structures, and are graded in such a way that provide the proper gradient of water depths. Leveraging existing structures and topography of the landscape as it relates to hydrology will assist with locating optimal sites in which to create shorebird habitat within the YBA.

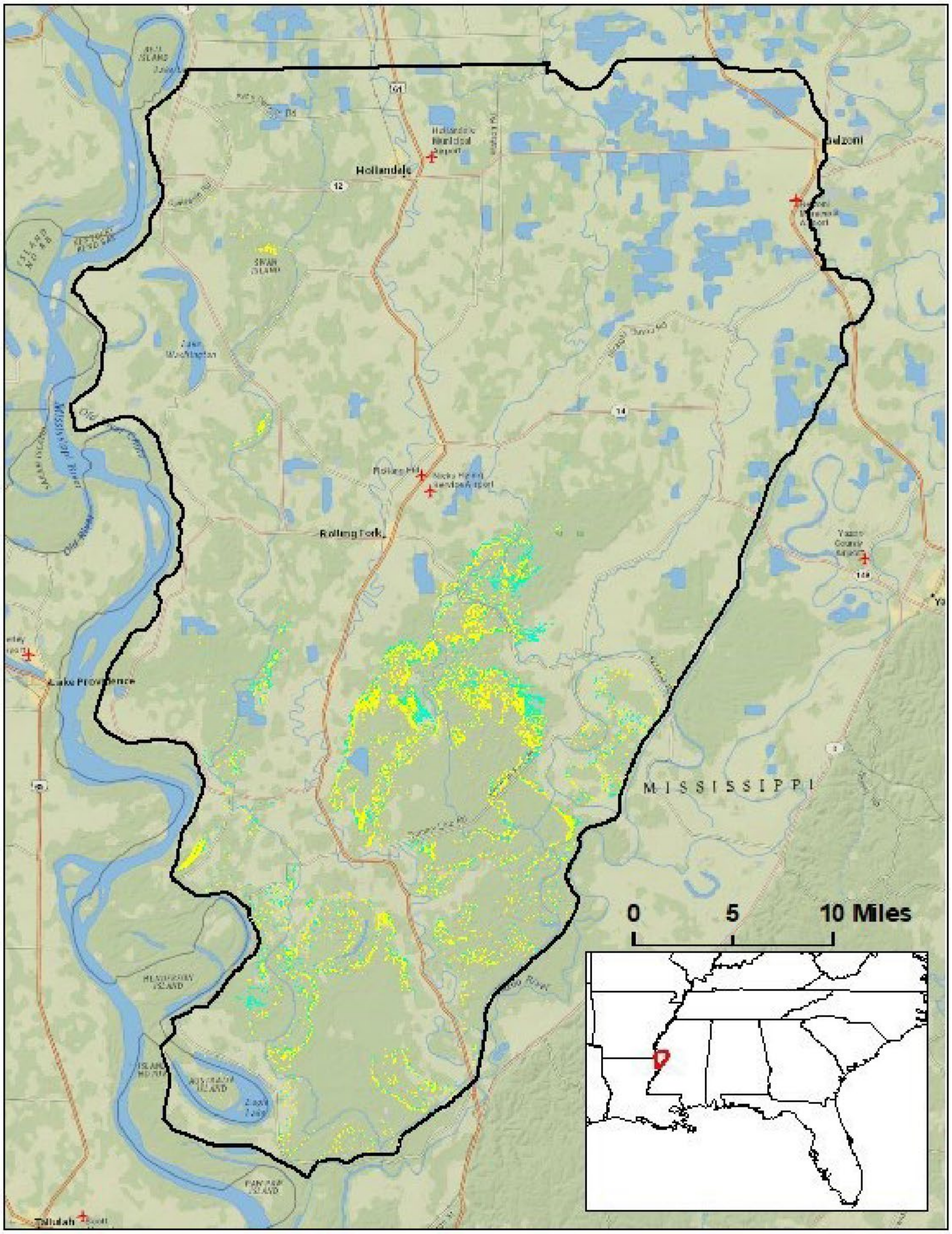

Figure B-4. Areas expected to be inundated less than or equal to 8 inches in depth according to the 75th percentile for the hydrological POR for the Action Alternative (yellow) and the No Action Alternative (teal).

Table B-3. Total acres in each HUC flooded (8 inches or less)			
HUC	Flooded Acres (Alt 1)	Flooded Acres (Alt 2)	Flooded Acres (Alt 3)
SF Little Calleo	54.1	50.6	50.6
SF Anguilla	604.9	434.7	434.3
SF Holly Bluff	1304.4	925.7	922.6
SF Little Sunflower	3893.6	4226.7	4227.0
SB Steele Grace	255.2	160.4	160.4
SB Steele Bayou	2953.2	2476.2	2476.3

Table B-4. Example scenario demonstrating how the number of habitat units was generated by multiplying flooded acres by suitability score.				
Suitability Score	Proportion	Total Acres Flooded within HUC (MVK)	Flooded Acres per Score	Habitat Units
0.00	0.25	100	25	0.00
0.5	0.50	100	50	25
1.0	0.25	100	25	25
Total				50

Table B-5. Habitat suitability parameters for future mitigation areas. These are hypothetical scores that reflect realistic habitat suitability metrics for created shorebird habitat. These scores are subject to change, depending on the habitat quality of constructed shorebird habitat.

Variable	Score
Water Depth	1
Availability	1
Invertebrate Density	0.8
Vegetative Cover	0.7
Disturbance	1
Predictability	1
Management Capability	0.7

Food Score = ((Water Depth X Water Availability) / 2 + (Invertebrate Density) / 2) X 0.6

\+

Security Score = (Vegetative Cover X 0.7 + Disturbance X 0.3) X 0.2

\+

Predictability Score = (Predictability X 0.6 + Management Capability X 0.4) X 0.2

=

HSI Score

Figure B-5. Calculation for scoring the quality of created shorebird habitat, as derived from the shorebird model. See Table B-5 for hypothetical variable values. See Table B-1 for variable descriptions.

Table B-6. Mitigation values. Mitigation acres is equal to annual HUs lost divided by the HU value of each acre of shorebird habitat created.

Scenario	HUs	Annual Loss of HUs	HU loss (Project Life)	Mitigation HU/acre/yr	Mitigation acres
Alt 1– No Action	2,211.22	-	-	-	-
Alternative 2	1,858.78	352.44	17,622	0.874	403.25
Alternative 3	1,858.38	352.84	17,642	0.874	403.71

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SECTION 4 APPENDIX C

GREAT BLUE HERON HABITAT ASSESSMENT

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4.1 INTRODUCTION

The Great Blue Heron (GBHE; *Ardea herodias*) is a long-legged wading bird found throughout Mississippi (and much of North America) in freshwater wetlands, lakes and reservoirs, flooded meadows, agricultural fields, and along ditches and riverbanks (Vennesland and Butler 2020). Great Blue Herons are a good indicator species for other wading birds because they typically forage and nest in the same or similar habitats (with varying degrees of overlap) as many of the following wetland-associated Pelecaniformes wading species (often in the same nesting colonies as GBHE) that inhabit the Yazoo Backwater Area (YBA): Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*), Snowy Egret (*Egretta thula*), Little Blue Heron (*Egretta caerulea*), Tricolored Heron (*Egretta tricolor*), Green Heron (*Butorides virescens*), Black-crowned Night-Heron (*Nycticorax nycticorax*), Yellow-crowned Night-Heron (*Nyctanassa violacea*), White Ibis (*Eudocimus albus*), White-faced Ibis (*Plegadis chihi*), and Roseate Spoonbill (*Platalea ajaja*).
Important components of GBHE breeding ecology, including foraging habitat, and nesting habitat suitability and availability, may potentially be influenced by the proposed Yazoo Pumps on breeding populations in the YBA. Regional and continental population trends, as well as ecological requirements for the GBHE considered in this assessment, are described below:

Population status

Based on annual Breeding Bird Survey (BBS) data (Sauer et al. 2021; Fig. C-1), GBHE increased in abundance in the Lower Mississippi Alluvial Valley region (LMAV) from 1966 through the turn of the century but have since leveled off and have possibly begun to decline since peaking in 2008. Survey-wide (across the United States and parts of Canada) the BBS data implies that the population has been declining in recent decades since peaking in the 1990's (see Fig. C-1). The LMAV represents a region with the highest density of GBHE in North America (Saur et al 2021, Fink et al. 2022, eBird 2023) and supports high densities of other wading birds as well. Loss and degradation of wetlands used for colonial nesting and foraging habitat is believed to be a primary driver of historic, and likely recent, population declines of GBHE (English 1978, Parnell et al. 1988). Although in some populations availability of forested nesting habitat is not believed to drive population trends of GBHE (Williams et al. 2007), increases in recent decades in some portions of their range have been in part attributed to increases in forest cover in regions where nesting habitat is lacking. Conversely, conversion of forested wetlands to agricultural fields likely has been a factor of the historic trend (prior to and throughout the BBS survey period) across the vast agricultural landscape that comprises much of the YBA. Foraging habitat, especially important near nesting locations where adults must feed young and fledglings must learn to forage on their own, has been impacted by dramatic anthropogenic changes to hydrologic patterns across the region (e.g., flood control measures and draining wetlands for agriculture).

Consistently, the population size of nesting colonies is correlated with amount and quality of nearby wetland habitat and the species demonstrates strong territorial behavior likely relating to limited resources and prey availability (Vennesland and Butler 2020).

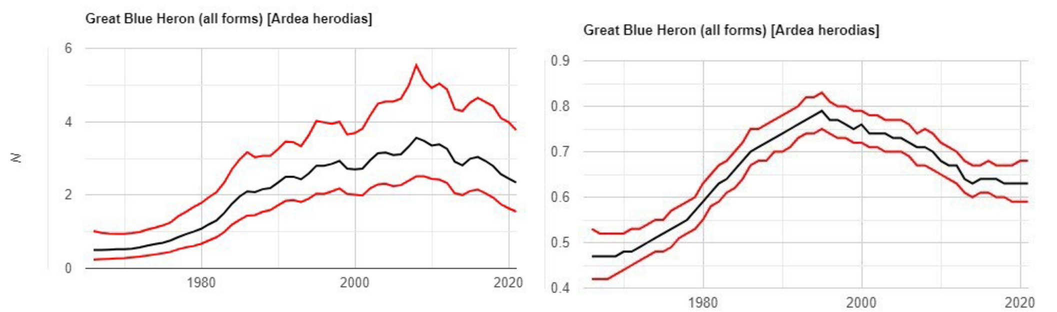

Figure C-1. Breeding Bird Survey relative abundance trends (mean and 95% CI) across the Mississippi Alluvial Valley Bird Conservation Region (left) and throughout the in the U.S. and Canada breeding range (right) (Sauer et al. 2021).

Nesting Habitat

The GBHE nesting period is typically February to May (Vennesland and Butler 2020). GBHE are a colonial-nesting species, and nesting colonies (heronries) can be found in mature forested habitats near suitable wetland foraging areas (Short and Cooper 1985, Vennesland and Butler 2020). Eggs typically hatch after 4 weeks and nestlings typically fledge 11-12 weeks after hatching (~4 months from egg-laying to fledging; Vennesland and Butler 2020). Cypress-tupelo swamps are often preferred in the northern Gulf Coast region (Portnoy 1997, Vennesland and Butler 2020) and this preference appears to be present in the YBA based on historical locations. GBHE often nest colonially with other wading bird species and these heronries can consist of several pairs to thousands of pairs (Vennesland and Butler 2020). Heronry locations are sometimes re-used for years or decades depending on changing habitat conditions at heronry sites or across the foraging landscapes, and likelihood of new heronry site establishment diminishes with distance from current or former heronry sites because herons typically develop new heronries at suitable sites close to old heronries (Short and Cooper 1985).

Foraging Habitat

In the Lower Mississippi Alluvial Valley (LMAV), GBHE forage in a variety of wetland habitat types including emergent wetlands, open water (e.g., ponds and edges of lakes and rivers), sloughs, flooded fields, catfish ponds, and forested wetlands (Thompson 1979, Vennesland and Butler 2020). Fish, usually 5-30 cm long (Willard 1977) typically make up the bulk of the GBHE's diet, although the species is an opportunistic feeder that will also eat amphibians, reptiles, rodents, birds, large insects, snails, and crustaceans (Vennesland and Butler 2020). During the breeding season, foraging is often done socially, usually within 2.3-6.5 km of nesting colonies, although distances to foraging areas have been documented up to 20.4 km from colonies along the Mississippi River Valley and up to 30 km elsewhere (Krebs 1978, Thompson 1979, Vennesland and Butler 2020). The 1985 HSI model (Short and Cooper 1985) quantified high quality potential foraging habitat within the breeding season using a continuous variable with highest value (1.0 SI) given to foraging habitat within 1.0 km of the heronry site and decreasing to the lowest value (0.1 SI) at $\geq$10 km.
Herons and other wading birds forage in shallow water (< 0.5 m preferred by GBHE; Short and Cooper 1985), with greater foraging success and thus higher likelihood of increased breeding productivity associated with high fish and other prey concentrations in shallow waters.

Susceptibility to Human Disturbance

Many heronries are in remote areas and some studies have demonstrated abandonment due to human disturbance (especially early in the breeding season) and thus some HSI models reduce or negate habitat suitability near human development (Short and Cooper 1985, Dragelis-Dale 2008). However, other studies have shown that GBHE can become habituated to noise including traffic and other human activity (Anderson 1978, Grubb 1979, Kelsall and Simpson 1980). Tolerance for some human activity, especially repeated mechanical noise such as vehicle traffic, may be more prevalent than thought when the 1985 HSI model (Short and Cooper 1985) was developed (Vos et al. 1985, Carlson and McLean 1996, Rodgers, and Smith 1995, Vennesland 2000, 2010). Indeed, there are many GBHE colonies within city limits throughout the United States, although in rural areas it is possible that disturbances during the early nesting season could still disrupt nesting and potentially cause abandonment. Other than within the immediate vicinity of pump construction, pump operation would be unlikely to substantially affect human disturbance impacts on GBHE breeding activities across the YBA in most years, perhaps with the exception of extreme flood events in which pumping could potentially shorten the duration of reduced periods of anthropogenic activity (e.g., vehicular, and agricultural activity) in the region.

HSI Model Development

Here, we use known observations of GBHE based on eBird (https://ebird.org/) and Global Biodiversity Information Facility (GBIF) records (https://gbif.org) as well as known historic or currently active waterbird breeding colonies (Mueller 1995, Stevens and Litton 2006) to assess the anticipated areas of potential impact of proposed YBA pump operation during the core nesting and post-breeding season (Mar15-Jul31). This period was chosen to quantify the nestling and post-fledging periods in which abundant food and foraging habitat availability are most critical to GBHE (and other wading bird) populations. This period also represents the portion of the year in which the greatest amount of backwater flooding occurs in a typical year. We used a Maxent Habitat Suitability Index (HSI) modeling approach (Phillips et al. 2006, Montana Natural Heritage Program 2022, Phillips et al. 2023) to assess nesting and foraging HSI for GBHE. Selected habitat variables in our models are based on the original HSI model developed by Short and Copper (1985) and a GBHE Maxent HSI model created by the Montana Natural Heritage Program (2022). Hydrological historic data (from the 1978-2020 Period of Record; POR) and modeled hydrological spatial layers that represent average backwater flooding conditions under base and alternative scenarios were provided by the U.S. Army Corps of Engineers, Mississippi Valley Division. We used these layers to assess areas and acreages of net gains or losses in ≤ 18-inch water depth (potential foraging habitat) due to proposed pumping activities.
Conditions assessed in our modeling:

1) Alternative 3: 25,000 cubic feet per second (cfs) pumps; backwater managed at 90.0 ft during crop season (25 Mar-15 Oct) and up to 93.0 ft during non-crop season (16 Oct-24 Mar). Modify operation of Steele Bayou WCS to optimize fisheries exchange (open until flood stage of 75.0 ft; historically was managed at lower threshold).
2) Alternative 2: 25,000 cfs pumps; backwater managed at 90.0 ft during crop season (15 Mar-15 Oct) and up to 93.0 ft during noncrop season (16 Oct-14 Mar). Modify operation of Steele Bayou WCS to optimize fisheries exchange (open until flood stage of 75.0 ft; historically was managed at lower threshold).
3) Alternative 1 (Base): No action alternative – no pump operations or changes to Steele Bayou WCS operation to impact hydrology of the YBA.

Potential impacts are expected to be similar between Alternative 3 and Alternative 2 scenarios but Alternative 2 would result in more pumping days. Based on the POR, differences in the amount of flooded acreage would be zero in most (91%) years over the period of record comparing Alternative 3 and Alternative 2 scenarios (Fig. 2-112 in Appendix A). Between 1978 and 2020, the pumps would have operated a total of 26 additional days between 15 Mar and 24 Mar under Alternative 2.

4.2 OBJECTIVES

Our modeling approach was designed to evaluate GBHE breeding habitat suitability across the YBA and to assess potential areas of impact resulting from altered hydrology based on proposed pumping alternatives during the GBHE breeding season. In this modeling effort, our objectives include:

1. Assess baseline predicted GBHE occurrence during the breeding season in the YBA using eBird and other GBIF records throughout the LMAV and a Maxent modeling approach (Philips et al. 2006, Montana Natural Heritage Program 2022).
2. Assess breeding habitat suitability across the YBA under baseline conditions. This modeling approach was designed to assign habitat suitability index values for GBHE nesting habitat requirements using current and historic heronry locations (Mueller 1995, Stevens, and Litton 2006) throughout the YBA as occurrence data in a YBA-specific Maxent model that is informed by the LMAV-occurrence model described above.
3. Calculate average annual habitat units (AAHU) from the nesting habitat HSI raster that overlap with average backwater flooding extent at ≤ 18-inch water depth throughout the YBA under base and alternative scenarios.
4. Calculate recommended mitigation acreages to offset potential losses or degradation of habitat based on the AAHU calculations under each scenario and make recommendations for management and monitoring of GBHE and other wading birds into the future.

4.3 PROJECT AREA

Currently, the YBA consists largely of agricultural lands with scattered remnants of bottomland hardwoods and cypress/tupelo swamps (Wakeley 2007). In prior YBA studies, the cypress/tupelos swamps were determined to be too small and low in frequency to justify a separate forest class, and therefore are combined with bottomland hardwood forests to provide a broad overview of available forest types (Wakeley 2007). Smith and Klimas (2002) note various forest subtypes within the YBA, including, 1) sweetgum/water oak, 2) white oaks, red oaks, and other hardwoods, 3) hackberry, elm, and ash, 4) overcup oak and water hickory, 5) cottonwood, willow, 7) river front hardwoods, and 8) cypress tupelo. Respective acreages of these forest subtypes in the YBA are not provided, however, it is noted that within the YBA, only a fraction of the original forested habitat remains, with the majority of remaining lands converted to agriculture (Smith and Klimas 2002).

4.4 METHODS

Model Development: Baseline GBHE Occurrence Model

Due to a limited amount of occurrence data (with 1 km or less spatial resolution) during the breeding season within the YBA, we chose to first model a baseline index of GBHE habitat suitability throughout the entire LMAV that is north of 31º latitude as to not model coastal habitat. This extent includes the whole of the YBA and from this model, we extracted the modeled habitat suitability raster from within the YBA. We downloaded GBHE occurrence data from the GBIF database, with a filter of 1 km coordinate uncertainty (GBIF 2023), between 2004–2023 breeding seasons. We downloaded additional occurrence data from eBird (eBird Basic Dataset 2023) across the same years and same period, and removed all traveling checklists with sampling effort >1 km. We clipped observations to the extent of the YBA in ArcGIS Pro.

We spatially rarefied the occurrence records using the Rarefy tool in the species distribution model (SDM) toolbox 2.0 (Brown et al. 2017), randomly removing occurrences within 5 km of other occurrences, resulting in a spatially unique data set of 194 occurrences. These occurrence locations largely represent GBHE in foraging habitat, and the resulting HSI raster was later incorporated into a YBA-specific nesting HSI model.

The Baseline GBHE Occurrence Model includes 6 continuous and 3 categorical environmental variables based on metrics from the Short and Cooper (1985) HSI model and another published GBHE Maxent HSI model (Montana Natural Heritage Program 2022). Environmental variables were resampled in ArcGIS Pro to a 1-km resolution to match the 1-km resolution of the occurrence data. Prior to modeling in the Maxent presence-background program (version 3.4.3; Phillips et al. 2023), we extracted all environmental layers to the extent of the LMAV. We included all environmental variables, regardless of possible collinearity, as our goal for this model was not to describe or rank the most important environmental variables, but to build a model that predicts areas most likely to be used by GBHE (Montana Natural Heritage Program 2022). We ran used 10-fold cross-validation to assess model error and specified 10,000 maximum iterations, 10,000 maximum background points, and a (default) 0.00001 convergence threshold. Variables used in the Baseline GBHE Occurrence Model are described below.

1) *National Land Cover Database (NLCD) Category*: These data are available from the U.S. Geological Survey (https://www.usgs.gov/centers/eros/science/national-land- coverdatabase) and provides landcover at 30-m spatial resolution over the conterminous United States with a 16-legend based on the Anderson Level II classification system. Categories include A) Open Water, B) Developed, Open Space, C) Developed, Low Intensity, D) Developed, Medium Intensity, E) Developed, High Intensity, F) Barren Land, G) Deciduous Forest, H) Evergreen Forest, I) Mixed Forest, J) Shrub/Scrub, K) Herbaceous, L) Hay/Pasture, M) Cultivated Crops, N) Woody Wetlands, and O) Emergent Herbaceous Wetlands
2) *National Wetlands Inventory (NWI) Category*: These data are available by the U.S. Fish and Wildlife Service (https://www.fws.gov/program/national-wetlands-inventory) and provide information on wetland types. Categories include A) Lake, B) Freshwater Pond, C) Freshwater Emergent Wetland, D) Freshwater Forested/Shrub Wetland, E) Riverine, and F) Other.
3) *Landfire Coverage Category*: These data are provided by the Department of

the Interior and the U.S. Geological Survey (https://www.landfire.gov/) and provides national geospatial layers, databases and ecological models for vegetation and other landscape features. Categories included were A) Open Water, B) Development, C) Barren, D) Cropland, E) Aquaculture, F) Forest with ≤ 60% Tree Cover, G) Forest with ≥61% Tree Cover, H) Shrub Cover, and I) Herbaceous Cover.

4) *Distance to Water Feature*: Distance from each 1-km pixel within the LMAV to the nearest water feature (includes lakes, ponds, swamp/marsh, reservoirs, streams, canals, and rivers) as defined by the U.S. Geological Survey's National Hydrography Dataset area feature (https://www.usgs.gov/national-hydrography/national-hydrography-dataset). Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
5) *Distance to Emergent Herbaceous Wetland*: Distance from each 1-km pixel within the LMAV to herbaceous wetland as defined by the NWI layer. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
6) *Distance to Lake or Pond*: Distance from each pixel within the LMAV to lakes or ponds as defined by the NWI layer. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
7) *Distance to Open Water*: Distance from each pixel within the LMAV to open water as defined by the NLCD layer. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
8) *Distance to Woody Wetlands*: Distance from each pixel within the LMAV to woody wetland habitat as defined by the NLCD layer. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
9) *Elevation*: National Elevation Dataset, available from the U.S. Geological Survey (https://www.usgs.gov/publications/national-elevation-dataset).

Model Development: Heronry Habitat Suitability

We classified the resulting HSI raster from the Baseline GBHE Occurrence Model output (described above) using Jenks' Natural Breaks and calculated a distance to areas with ≥ 0.49 HSI (Fig. C-2) to represent distance to moderate/high suitability of foraging habitat for inclusion as an environmental layer in a YBA-specific breeding habitat HSI Maxent model. This model uses 7 occurrences of historic GBHE nesting locations within the YBA to predict nesting habitat suitability throughout the YBA. Similarly low occurrence sample sizes have been used to assess habitat suitability for other wildlife species using Maxent (Pearson et al. 2007, Papes and Gaubert 2007). Model parameterization was the same for this final model as for the first model described above. Besides the distance to ≥ 0.49 HSI habitat layer derived from the first model, 6 additional environmental variables (Table C-3) were included based on recommendations in Short and Cooper (1985). Variables used in the GBHE Breeding HSI Model are described below.

1) *Distance to ≥ 0.49 HSI* from the Baseline GBHE Occurrence Model raster output as an index for distance to foraging habitat.

2) *Distance to Average ≤ 18-inch backwater flooding (15Mar-31Jul)*- average flooding layer across the 1978-2020 Period of Record, provided by MVK.
3) *Landfire Coverage Category*: These data are provided by the Department of the Interior and the U.S. Geological Survey (https://www.landfire.gov/) and provides national geospatial layers, databases and ecological models for vegetation and other landscape features. Categories included were A) Open Water, B) Development, C) Barren, D) Cropland, E) Aquaculture, F) Forest with ≤ 60% Tree Cover, G) Forest with ≥61% Tree Cover, H) Shrub Cover, and I) Herbaceous Cover.
4) *Distance to Permanent Water Feature*: Distance from each 1-km pixel within the YBA to the nearest water feature (includes lakes, ponds, swamp/marsh, reservoirs, streams, canals, and rivers) as defined by the U.S. Geological Survey's National Hydrography Dataset area feature (https://www.usgs.gov/national-hydrography/national- hydrographydataset). Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
5) *Distance to Wetland*: Distance from each pixel within the YBA to a wetland as defined by the NWI layer. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
6) *Distance to Developed Land*: Distance from each pixel within the LMAV to human development as defined by the NLCD database. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
7) *Distance to Woody Wetlands*: Distance from each pixel within the LMAV to woody wetland habitat as defined by the NLCD database. Geodesic distances were calculated in ArcGIS Pro using the Distance Accumulation Tool.
8) *Elevation*: National Elevation Dataset, available from the U.S. Geological Survey.

Methods of quantifying AAHU and suggested mitigation acreages

To spatially assess differences in average annual habitat units (AAHU) among the project scenarios, we applied the GBHE breeding HSI raster to hydrological data provided by the hydrologist contractor for the USACE Vicksburg District. From hydrologic data across the POR, daily flooded acreages flooded ≤18 inches under base and alternative pumping scenarios were calculated using the Enviro-Fish model (Kilgore et al. 2012). This output provided average daily flooded acres at GBHE suitable foraging depth within each Hydrologic Unit Code (HUC) within the project area. To join the GBHE HSI raster spatially to these average acreages flooded to a depth up to 18", we calculated total acreages for each 0.01 increment of the HSI range between 0 and 1 within spatial layers provided by MVK (under the Base and Alternative 2 scenarios) that represent average shallow flooding conditions across the POR when flooding does occur. We extracted these ratios of each habitat suitability score separately within each HUC. Although a corresponding spatial layer for Alternative 3 was not provided, differences between Alternative 2 and Alternative 3 are minimal (see Table C-2), and the Alternative 2 spatial layer was used to generate HUC-specific HSI ratios for Alternative 2 and Alternative 3 scenarios. These ratios were then applied to the average daily flooded acreages for the base (Alternative 1), Alternative 2, and

Alternative 3 scenarios (up to 18” depth) from the Enviro-Fish analysis output provided by MVK (summarized in Table C-1) to calculate average AAHU in each HUC for each scenario. This was done by multiplying each suitability score with the proportion of the acreage associated with it, multiplied by the average daily flooded acres (up to 18” depth” in each HUC to generate habitat units. To calculate suggested mitigation acreages, we first used the formula HSI = $(VI \times V2 \times V3 \times V4 \times V5 \times V6)^{1/2}$ to calculate habitat suitability indices (Short and Cooper 1985) for mitigation scenarios (variables and associated SI values are defined in Table C-2). These HSI values associated with mitigation scenarios were applied to the net differences in AAHU (summed across HUC regions) between base and alternative scenarios to calculate recommended mitigation acreages.

Across the POR, the pumps would have operated in 20 of 43 (47%) years (Figure 2-110 in Appendix A). Thus, availability of shallow water foraging habitat would have been unchanged among project scenarios in 53% of years. As such, between 15 Mar and 31 Jul, modeled median daily flooded acreages ≤ 18-inch depth across the POR across the entire YBA were only 59 acres less in the Alternative 2 scenario compared with Base conditions and 51 acres less for the Alternative 3 scenario compared with Base conditions (Table C-1). However, mean daily flooded acreages differed by 1,482 acres (Alternative 3) and 1,510 acres (Alternative 2) compared with base conditions for ≤ 18-inch-depth flooding. These mean differences in daily flooded acres would not have been consistent even throughout the entireties of the GBHE breeding seasons within the 47% of years in which pumps would have operated, as pump operation durations would have varied from 4-158 days over the 20 years in which pumping would have occurred; Figure 2-112 in Appendix A) but our modeling and mitigation calculations are calculated under these mean flooded acreage conditions and reflect areas most likely to be affected by proposed pumping activities on a most frequent basis.

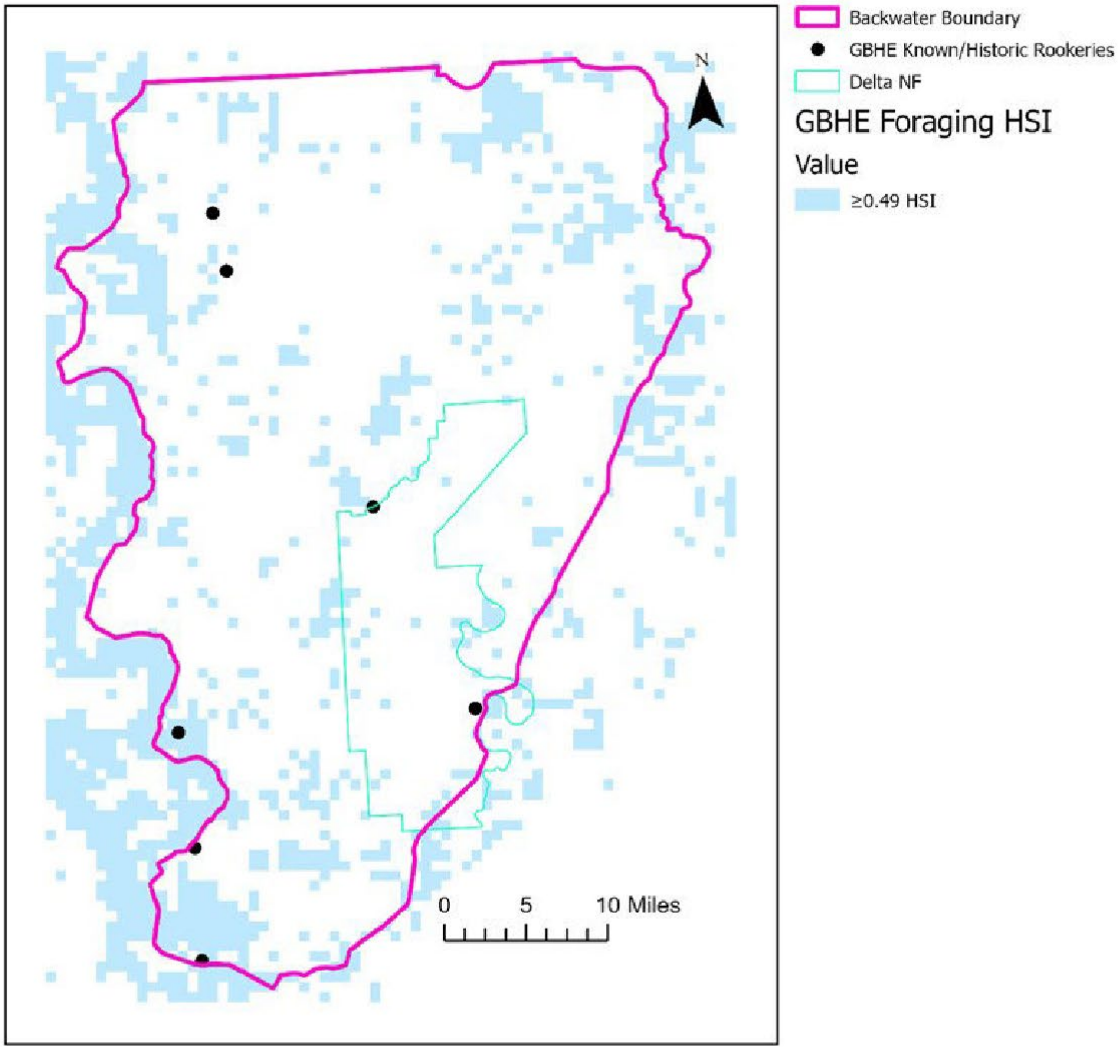

Figure C-2. Raster output from Baseline Great Blue Heron Occurrence Model from eBird/GBIF occurrence data throughout the Lower Mississippi Alluvial Valley. Distance to ≥0.49 HSI pixels calculated from this raster (an index for distance to foraging habitat) was incorporated as an input into the nesting habitat HSI model. Locations of known/historic heronries based on state-wide colonial bird survey data that was provided by Mississippi Wildlife, Fisheries and Parks.

Table C-1. Median and mean flooded acreages under project scenarios based on period of record data and models provided by MVK.

	Total inundation acres (median)	Total inundation acres (mean)
Alternative 2	11690	46380
Alternative 3	11753	46622
Base (Alternative 1)	11956	57723
Alternative 2 minus Base	-266	-11345
Alternative 3 minus Base	-204	-11101

	Acres flooded ≤18” depth (median)	Acres flooded ≤18” depth (mean)
Alternative 2	2187	13343
Alternative 3	2195	13370
Base (Alternative 1)	2247	14852
Alternative 2 minus Base	-59	-1510
Alternative 3 minus Base	-51	-1482

Table C-2. Habitat variables and suitability index scores (SI) used to calculate acreages of reforested bottomland hardwood forest needed to offset loss of average annual habitat units (AAHU) under Alternative 3 and Alternative 2 scenarios. Variables and SI values are defined by Short and Cooper (1985).

V1	Within 1 km of shallow water foraging habitat = 1.0 SI. Within 3 km = 0.8 SI. Within 5 km = 0.6 SI. >10 km, 0.1 SI.
V2	Foraging habitat must have prey (typically fish) and shallow water up to 0.5 meters deep. Yes = 1.0 SI, No = 0.0 SI.
V3	Must be disturbance-free within 100 m of foraging area. Yes = 1.0 SI, No = 0.0 SI
V4	Must have tree grove at least 0.4 ha in area within 250 meters of water, with trees at least 5 m high, branches at least 2.5 cm diameter, and open canopy or emergent trees. Yes = 1.0, No = 0.0.
V5	Must be disturbance-free within 250 m (land) or 150 m (water) of potential nest sites (Yes = 1.0, No = 0.0).
V6	Proximity of potential nest site to active nest (within 1 km = 1.0 SI, within 5 km = 0.8 SI, within 10 km = 0.6 SI, >20km = 0.1 SI).

4.5 RESULTS

The results of the Maxent Great Blue Heron breeding HSI model describes habitat suitability across the YBA associated with known/historic nesting habitat and nearby foraging habitat. With an Area Under the Curve (AUC) value of 0.84, the breeding HSI model was an improvement over the LMAV-wide model based on eBird/GBIF observations (AUC 0.69). The breeding HSI model, based on known/historic heronry locations and informed by the presence of water (both permanent and average backwater flooding) across the landscape, highlights the importance of woody wetlands and proximity to foraging habitat (Table C-3 and Fig. C-3) as suggested in Short and Cooper (1985).

Higher HSI pixels tended to be in the southern half of the YBA, where there is more bottomland hardwood forest and more backwater flooding (Figs. C-4 and C-5), whereas the northern half of the YBA is dominated by agricultural fields with exceptions of higher HSI in the Yazoo, Holt Collier, and Theodore Roosevelt National Wildlife Refuges and Leroy Percy State Park.

Table C-3. The following provides estimates of relative contributions of the environmental variables to the Maxent model. To determine the first estimate, in each iteration of the training algorithm, the increase in regularized gain is added to the contribution of the corresponding variable, or subtracted from it if the change to the absolute value of lambda is negative. For the second estimate, for each environmental variable in turn, the values of that variable on training presence and background data are randomly permuted. The model is reevaluated on the permuted data, and the resulting drop in training AUC is shown in the table, normalized to percentages. As with the variable jackknife, variable contributions should be interpreted with caution when the predictor variables are correlated. Values shown are averages over replicate runs.

Variable Percent	t contribution Permutation	n importance
Distance to Woody Wetlands	31.8	65.8
Distance to ≤ 18” flooding layer	25	12.2
Distance to permanent Water (NHD)	21.9	11.8
Landfire Cover Category	10.4	2
Distance to >0.49 HSI, LMAV model	8.6	5.8
Distance to Developed	2.3	2.3
Elevation	0	0.1

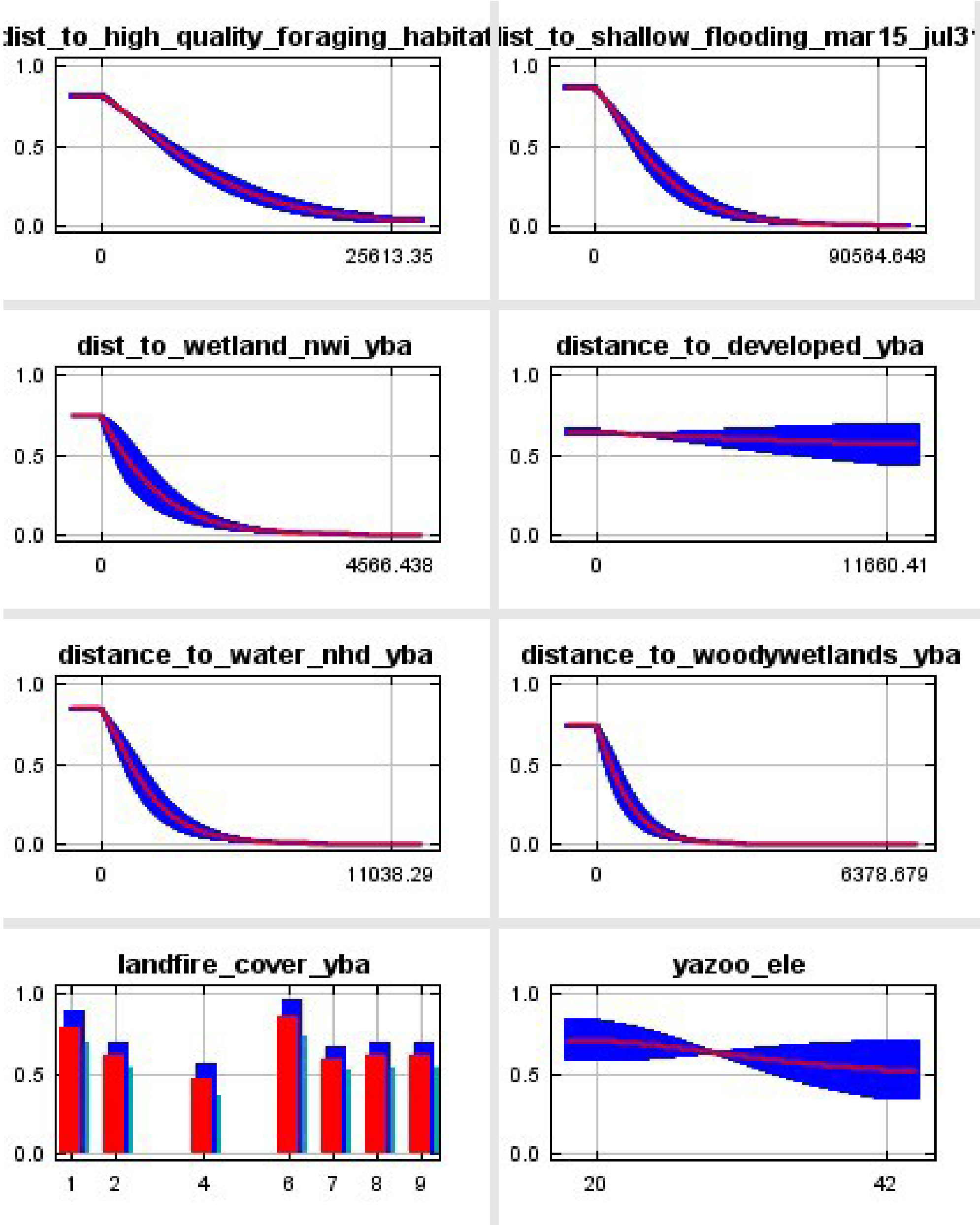

Figure C-3. Response curves from Maxent heronry HSI model

These curves show how each environmental variable affects the Maxent prediction. Each of the following curves represents a different model, namely, a Maxent model created using only the corresponding variable. These plots reflect the dependence of predicted suitability both on the selected variable (distances were measured in feet, elevation is in meters) and on dependencies induced by correlations between the selected variable and other variables. The curves show the mean response of the 7 replicate Maxent runs (red) and +/- one standard deviation (blue). Landfire cover categories that influenced the model are 1) Open Water, 2) Development, 4) Cropland, 6) Forest with ≤ 60% Tree Cover, 7) Forest with ≥61% Tree Cover, 8) Shrub Cover, and 9) Herbaceous Cover.

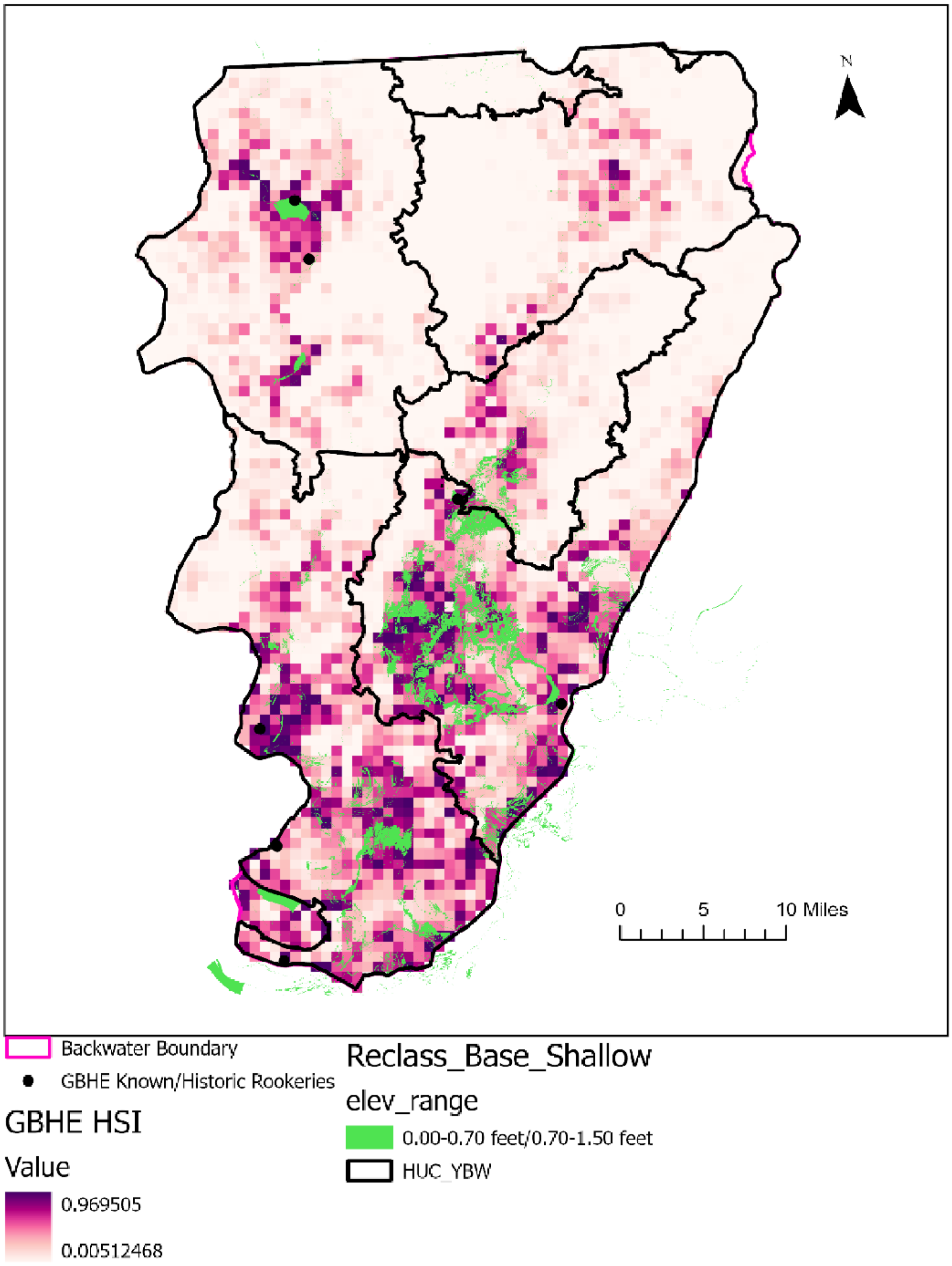

Figure C-4. Great Blue Heron Habitat Suitability Index (HSI) raster overlayed with ≤ 18-inch inundation layer (75th percentile of base conditions) across 15 Mar-31 Jul over the 1978-2020 period of record. GBHE Known/Historic Rookeries are more visible in Figure C-5.

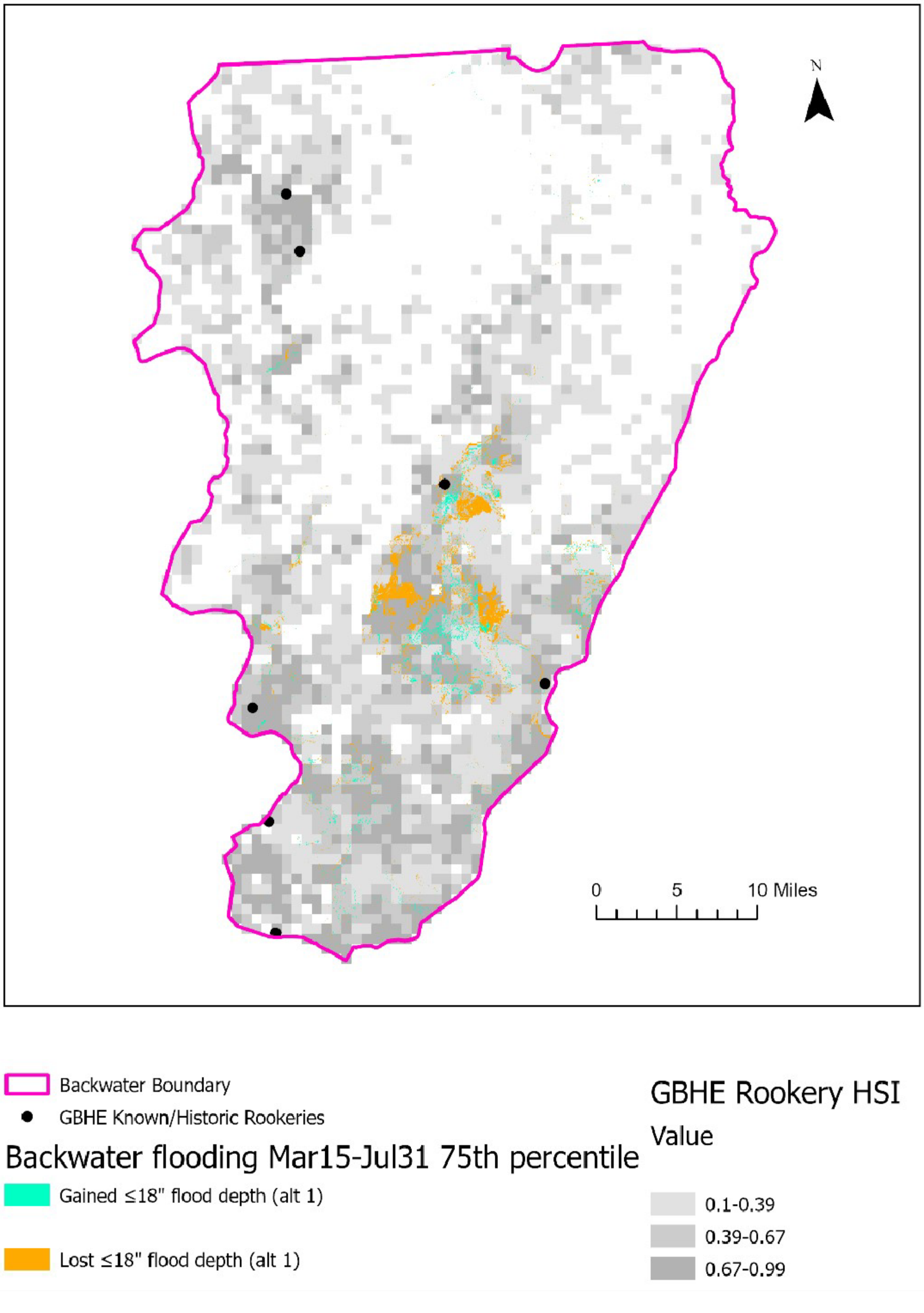

Figure C-5. Great Blue Heron Habitat Suitability Index (HSI) raster overlaid with net gains and losses of≤18-inch inundation (at the 75th percentile of base conditions) across 15Mar-31Jul over the 1978-2020 period of record. Pixels with <0.1 HSI are transparent for display purposes, all pixels with corresponding HSI were included in data analysis.

Net losses of AAHU under Alternative 3 (-698 AAHU) and Alternative 2 (-714 AAHU) were similar (Table C-4). Net losses of average daily flooded acreage values represent approximately ~10% of the total mean daily flooded acres at ≤ 18” depth. These are differences under mean flooding conditions and are not to be considered permanent losses of habitat, as there would be no difference in AAHU in ~53% of years over the POR (i.e., based on stage levels at Steele Bayou WCS that would have initiated pumping). Recommended acreages of bottomland hardwood forest reforestation to offset these mean losses of AAHU (Table C-5) vary with distance from active heronries and distance from foraging habitat (Short and Cooper 1985). Additional optimization of heronry suitability is to place mitigation areas near foraging habitat, defined as water at <0.5 m depth throughout the breeding season, with prey (i.e., fish, or perhaps high abundance of amphibians; Short and Cooper 1985). Furthermore, GBHE require nesting sites within ~250 m of water, ≤ 250 m from sources of human disturbance, have an open/broken canopy, and contain trees >5m high with branches >2.5 cm in diameter for nesting (Short and Cooper 1985). Thus, these conditions are necessary to maintain for mitigation acres to have the potential to benefit GBHE (as well as associated wading bird species).

Table C-4. Average area of backwater flooding inundation up to 18” depth, associated Average Annual Habitat Units calculated using the HSI raster, in alternatives 3&2 and base scenarios.

Model Alternative Conditions	Acres Flooded Up to 18”	AAHU
Alternative 3	13,370	7,465
Alternative 2	13,343	7,450
Base (Alternative 1)	14,852	8,163
Alternative 3 Minus Base	-1,482	-698
Alternative 2 Minus Base	-1,510	-714

Table C-5. Mitigation Scenarios for Bottomland Hardwood Forest Restoration to offset loss of habitat units associated with Alternative 3 and Alternative 2 scenarios. Acreage associated with higher habitat suitability index (HSI) scores (e.g., closer to foraging habitat or closer to existing heronry locations) is lower than acreage further from foraging habitat or further from existing heronries. Foraging habitat is defined as per Short and Cooper (1985): shallow water (≤ 0.5 m) with prey (i.e., fish).

Reforested bottomland hardwood forest with emergent trees*	Project Life (Years)	Year	HSI	AAHU Mitigation Over Project Life	Mitigation (Acres) to Offset Loss Alternative 3†	Mitigation (Acres) to Offset Loss Alternative 2‡
If no emergent trees >5 m high/branches 2.5 cm diameter	1-5	5	0.00	0.00	-	0
Within 1 km of heronry site, within 1 km of foraging habitat	6-50	45	1.00	45.00	776	793
Within 5 km of heronry site, within 1 km of foraging habitat	6-50	45	0.89	40.25	867	887
Within 10 km of heronry site, within 1 km of foraging habitat	6-50	45	0.77	34.86	1,001	1,024
>20 km of heronry site, within 1 km of foraging habitat	6-50	45	0.32	14.23	2,453	2,509
Within 1 km of heronry site, within 3 km of foraging habitat	6-50	45	0.89	40.25	867	887
Within 5 km of heronry site, within 3 km of foraging habitat	6-50	45	0.80	36.00	969/	992
Within 10 km of heronry site, within 3 km of foraging habitat	6-50	45	0.69	31.18	1,119	1,145
Within 10 km of heronry site, within 3 km of foraging habitat	6-50	45	0.28	12.73	2,742	2,805
Within 1 km of heronry site, within 5 km of foraging habitat	6-50	45	0.77	34.86	1,001	1,024

* Must be within 250 m of water and at least 250 m from human disturbance, must have open canopy or emergent trees that are at least 5 m high and branches at least 2.5 cm diameter.

†
698 AAHU loss for alternative 3; 698x50 year project life = 34,900 HUs

‡
714 AAHU loss for alternative 2; 714x50-year project life = 35,700 HUs

Table C-6. Locations of known historic GBHE nesting sites within the Yazoo Backwater Area. Locations of historic heronries based on state-wide colonial bird survey data that was provided by Mississippi Wildlife, Fisheries and Parks. Some locations were adjusted based on Google Earth imagery in which nests or herons/egrets were visible or nearest likely habitat (e.g., open canopy forest near water) within 1 km of provided historic locations, for which Datum was unknown and precision was variable. Location accuracy ~1 km based on aerial imagery and site visits.

Site	Latitude	Longitude	County	Notes
1	32.67	-91.04	Issaquena	
2	32.47	-91.03	Warren	
3	33.13	-90.98	Washington	Yazoo NWR. 2 GBHE in flight within 2 km on Feb 27, 2024, exact site not visited
4	32.86	-90.82	Sharkey	One GBHE within 1 km 29 Feb 2024, exact site not visited
5	32.68	-90.73	Sharkey	Multiple vacant nests in cypress swamp. 29 Feb 2024
6	32.57	-91.03	Warren	Confirmed active, GBHE at nests but not yet incubating. 29 Feb 2024
7	33.08	-90.96	Washington	Yazoo NWR. Less than 1 km from agricultural land
8	32.84	-90.49	Yazoo	Located outside of project area, not used in HSI modeling but within 8 km of YBA boundary Nests confirmed in recent eBird records, in Panther Swamp NWR ~2 km outside of YBA.
9	32.81	-90.59	Yazoo	Approximate location. Not used in HSI modeling
10	32.46	-90.82	Warren	Located outside of project area, not used in HSI modeling but within 4 km of YBA boundary

4.6 DISCUSSION

Great Blue Heron HSI values determined from our Maxent breeding habitat model were most positively associated with proximity to woody wetlands, proximity to foraging habitat, proximity to <18-inch backwater flooding and distance to wetlands (which each represent potential foraging habitat) and the cover types “Open Water” and “Tree Cover at <60% Canopy Cover”. These results support earlier HSI models for this species that have identified distance to water and foraging habitat, and availability of stands of trees with open canopy near water as important characteristics of quality GBHE breeding habitat (Short and Cooper 1985, Corley et al. 1997, Montana Natural Heritage Program 2022). The historic heronry locations used in our modeling, as well as those occurring outside but in close proximity to the YBA are found in forested wetlands (described in historic records as wooded swamps or bottomland hardwood forest) and were found within the Yazoo National Wildlife Refuge, Delta National Forest, Panther Swamp National Wildlife Refuge, and private lands.

Timing of flooding events appears to be important to GBHE population dynamics. Following drydowns (i.e., periods of receding water), fish concentrations can be multiplied substantially (Carter et al. 1973, Loftus and Eklund 1994, Howard et al. 1995) and wading birds recognize and utilize such areas where foraging efficiency is greatly increased (Kushlan 1981, Erwin 1983, Vennesland and Butler 2020). Hydrologic conditions that result in abundant availability of shallow water, especially when associated with drydowns corresponding with increased fish concentrations, are associated with high quality breeding habitat for herons and other wading birds (Smith and Collopy 1995, Gawlik et al. 2004). Such drydowns often occur seasonally (Carter et al. 1973, Loftus and Eklund 1994) and are most common in the YBA during latter portions of the nesting season and post-fledging season (typically the highest water levels over the 1978-2020 Steele Bayou water level period of record were in Mar-May). However, extreme flooding events may negatively affect GBHE and other wading birds if water depths increase to a level where preferred shallow water foraging habitat near nesting colonies is unavailable during the breeding season, or if prey concentration and visibility is significantly reduced in the breeding/post-breeding periods.

Based on the literature, impact of extreme flood events on GBHE can have negative effects on reproductive success. For example, along the upper Mississippi River, nest initiation was delayed, and average clutch size was reduced due to an extreme flooding event (Custer et al. 1996). Furthermore, prolonged high-water levels in the late breeding and early post-breeding season (Jun-Aug) along the Illinois River resulted in a decreased nesting population the following year while flooding events prior to and during the early nesting period had little effect on breeding (Bjorklund and Holm 1997). Thus, extreme, and prolonged flooding events (such as the 2019 flood of the YBA that inundated a vast area for 219 days with a peak flood stage of 98.2 feet in May) may result in poor breeding success at established colonies, although this has not been directly assessed in the YBA. Although flooding events would increase the extent of shallow water foraging habitat across the YBA, pumping water from the YBA during extreme flooding events could expedite drydown conditions that may be conducive to better foraging habitat for GBHE and other wading birds near their established breeding colonies. It is important to note that this report only considers alterations with hydrology between base and alternative scenarios that contribute to losses of habitat and does not attempt to quantify any benefits that may be gained from drawdowns or perhaps other potential beneficial factors of pumping, such as preventing hypoxia (that can lead to fish die-offs and thus decrease GBHE food availability) in long-standing floodwaters or reducing accumulation of environmental contaminants (e.g., methylmercury) as a result of the operation of the pumps.

It is possible that in some years foraging conditions and perhaps fecundity could potentially be negatively impacted by pumping. This possibility could be offset by mitigation as suggested in Table C-5. These mitigation recommendations would not have to stand alone and could be incorporated with overlap of mitigation efforts for wetland losses and those suggested for waterfowl, songbirds, waterfowl, and other wildlife taxa as described in this Appendix. Mitigation suggestions proposed in this appendix to offset potential negative effects should benefit GBHE and a plethora of other species that associate with bottomland hardwood forests that contain open canopy conditions (e.g., canopy-gap specialist species and those that favor a dense understory typical within canopy gaps, that breed or migrate through the YBA such as Wood Thrush, Cerulean Warblers, Swainson's Warblers, and Hooded Warblers). Heronries in the LMAV, including the YBA, are often associated with cypress swamps (Portnoy 1997, Vennesland and Butler 2020) and mitigation efforts involving conversion of agricultural lands near water that incorporate cypress plantings (where growing conditions are appropriate) may be most beneficial to GBHE and associated wading bird species. However, GBHE are known to nest in a variety of tree species, and inclusion of a diverse tree species composition in bottomland hardwood forest reforestation efforts that includes a component of cottonwood or other fast-growing species (that would speed up the process of providing potential GBHE nesting habitat and to ensure the necessary requirement of emergent trees within the canopy) along with slower-growing mast-producing species such as oaks that provide food for various wildlife species may be warranted. Ensuring that uneven canopy conditions persist, through well-spaced planting of trees or thinning as necessary to ensure broken canopy conditions that GBHE and a variety of other wildlife species select for, are recommended. Placing reforested mitigation acreage in close proximity to water will also provide higher value to numerous wildlife species (that breed or migrate through the YBA) that associate with woody wetlands and riparian conditions (e.g., Prothonotary Warblers, Wood Ducks, and Acadian Flycatchers).

To reduce mitigation acreages by providing more optimal potential GBHE nesting habitat, further surveys to determine locations of active heronries are recommended. A starting point would be to survey areas near historic heronries within or adjacent to the YBA (Table C-6). Protection of nesting colonies and nearby foraging areas are necessary to avoid population declines of GBHE and other colonial-nesting wading bird species, especially at and near colonies with the largest numbers of breeding birds (Butler 1997, Kelly et al. 2007). Furthermore, ensuring that habitat options are available across the landscape for nesting and foraging allows nesting colonies to change breeding locations as necessary as this species and other wading birds are known to do in response to changing prey availability (e.g., following a severe storm or drought; Kenyon et al. 2007, Jones 2010, Knight 2010). Annual monitoring of nesting colonies should be initiated to further understand the status and distribution of breeding colonies and the effects of environmental conditions, including drought and flood events, on the reproductive success and colony persistence in the YBA for GBHE and other colonial waterbird species. Such data can serve to monitor and further assess potential effects of the Yazoo pump operations if the pumps are constructed and operated as proposed in the Alternative 3 or Alternative 2 scenarios.

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SECTION 5 APPENDIX E SECRETIVE MARSH BIRDS

U.S. Army Engineer Research and Development Center Environmental Laboratory Ecological Resources Branch Vicksburg, Mississippi

5.1 INTRODUCTION

Secretive marsh birds, which include various species of bitterns, coots, gallinules, and rails, are seldom seen and infrequently heard. They often occupy freshwater and estuarine marshes and densely vegetated wetlands that are difficult to access. Typical avian sampling methods such as point count or transect surveys are unlikely to result in detection of these species. However, most secretive marsh birds, particularly rails, often respond to play-back recordings. Other marsh birds, including gallinules tend to be less secretive and more frequently seen. There are eight marsh bird species that may utilize portions of the Yazoo Backwater Area (YBA) during some portions of the year. The King Rail (*Rallus elegans*) is a possible breeder in the YBA and is sensitive to alterations in hydrology. The King Rail is a species of concern throughout its range (U.S. Fish and Wildlife Service [USFWS] 2021). The federally threatened Eastern Black Rail (*Laterallus jamaicensis*) could possibly move through the YBA during the migratory seasons.
Other potential migratory marsh birds that could move through the YBA during migration include the Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and Yellow Rail (*Coturnicops noveboracensis*). Finally, the Purple Gallinule (*Porphyrio martinicus*) and the Common Gallinule (*Gallinula galeata*), are two marsh birds that may breed in the YBA and are year-round residents along the Gulf Coast. These birds may be short-distance migrants that breed in the YBA and move to the Gulf Coast region during the nonbreeding season. Both gallinule species are relatively common, and neither are species of concern in the United States (U.S. Fish and Wildlife Service, 2021). All of the previously mentioned marsh birds are protected under the Migratory Bird Treaty Act of 1918 (16 U.S.C. 703-712; Ch. 128, (MBTA).

The USFWS maintains a list of “Birds of Conservation Concern.” The 1988 amendment to the Fish and Wildlife Conservation Act mandates that the USFWS identify species, subspecies, and populations of all migratory nongame birds that without additional conservation action are likely to become candidates for listing under the Endangered Species Act (ESA) of 1973, as amended. The USFWS *Birds of Conservation Concern 2021* (BoCC*;* USFWS 2021) is the most recent effort to carry out this mandate[1]. The overall goal of the BoCC list is to identify those bird taxa (beyond those already designated as federally threatened or endangered) that represent the highest conservation priorities of the USFWS. The 2021 BoCC list includes 269 individual bird taxa and are priorities for conservation actions, including King Rail and Yellow Rail.

Considerable data on the distribution, abundance, and population trends of migratory birds are more widely available in recent years because of online citizen science repositories (e.g., the Cornell University Laboratory of Ornithology eBird® platform; Cornell 2024) that allow users to report bird sightings anywhere in the world. eBird, which currently includes more than 1.5 billion bird records, contributes a wealth of information on the distribution and abundance of birds, making it the most robust avian database in existence.

Restoration in the Mississippi Alluvial Valley (MAV) has focused largely on forested wetlands to benefit breeding landbirds, recreational hunting and fishing, hydrologic restoration of wetland habitats to support migrating shorebirds and wintering waterfowl, and modification of the flood control infrastructure along the mainstem Mississippi River to benefit at-risk and threatened and endangered species. Since migratory birds that utilize forest and forested wetland habitat have experienced significant declines (Rosenberg et al. 2019), these birds are often the target beneficiaries of reforestation and bottomland hardwood restoration in the MAV (Twedt et al. 2007). In addition to forest restoration, issues of forest size, landscape context, presence of forest corridors, and overall landscape configuration are important in long-term considerations for forest bird conservation.
However, marsh birds may also be an important consideration is assessing the impacts of habitat degradation, especially for species of concern such as the King Rail.

The most likely impacts of the proposed Water Management Plan within the YBA would be changes in hydrology within forested habitats which may result in potential alteration of forest structure and composition over time. Loss of mature floodplain forests could potentially have the most negative impacts on migratory birds that require varying levels of annual inundation upon the landscape to maintain habitat to meet life-history needs. Other habitats in the region important to non-forest migratory birds, including herbaceous, pasture, old field, scrub/shrub, and agricultural lands, might also be impacted due to decreases in intermittent flooding events. These are the habitats that will likely be used by marsh birds. In this report, we assess the potential loss of marsh bird habitat under the alternative scenarios and compare to base conditions. There are no certified models for any marsh species applicable to the YBA; therefore, no recommendations will be provided potential mitigation or habitat restoration for these birds.

Assessment of Yazoo Pump Operations on Marsh Birds

We use known observations of eight marsh bird species from 2000-2024 to document the presence of these species within the YBA. Plus, we note the seasons when the birds were detected to assess the anticipated impacts of the Yazoo Pump operations during the breeding season (May through July), spring migratory season (March through May), late summer and fall migration (August through November), and the winter season (December through February). Hydrological data provided by the U.S. Army Corps of Engineers, Mississippi District provide estimated flood extent and depth throughout the YBA under 3 conditions. Two of the conditions (Alternatives 2 and 3) yield no significant difference in their anticipated hydrological impacts in the YBA; therefore, we only consider the impacts of Alternative 3 and the no pump condition (Alternative 1) in our comparisons. We use this comparison to reveal gains or losses in wetland habitats that may impact marsh bird populations throughout the YBA to assess the potential impact of the proposed Yazoo pump operations. Conditions considered in our modeling: Alternative 3: 25,000 cfs pump; backwater managed at 90.0 ft during crop season (25Mar-15Oct) and up to 93.0 ft during noncrop season (16Oct-24Mar). Alternative 1 (AKA Base scenario): No action alternative – pump operations to have no impact on hydrology of the YBA.

5.2 OBJECTIVES

The objectives of this appendix are to:

1) Present information on species composition and habitat availability for eight marsh birds that may utilize wetland habitats, with an emphasis on the King Rail.
2) Assess projected changes in habitat availability for marsh birds in the YBA due to changes in hydrology and subsequent direct impacts of the proposed water management plan.

5.3 METHODS

Assessment of Yazoo Pump Operations

We used the Cornell Laboratory of Ornithology's eBird® (Cornell 2020) to provide qualitative assessments about a species' possible presence in the YBA. While eBird data can assist in gathering insights into the distribution and relative abundance of birds, and those data undergo significant scientific vetting by regional qualified reviewers, dependence on observations associated with unequal efforts in coverage of remote areas, including the YBA, allows us to use these data only as an index of overall presence of species. This tool was not used to make definitive conclusions regarding the presence/absence of marsh bird species within the YBA.

We used remotely sensed landcover data in conjunction with hydrology data provided by MVK to evaluate marsh bird habitat within the project area under alternative 1(no action) and action alternative scenarios. We extracted the following land cover types from Landfire (2022) and Cropscape (USDA 2022): Eastern Warm Temperate Developed Herbaceous, Eastern Warm Temperate Urban Herbaceous, Mississippi River High Floodplain (Bottomland) Herbaceous, and Southeastern Ruderal Wet Meadow & Marsh. From the hydrology information provided by MVK (75% percentile flood inundation), we were able to identify areas flooded to 0-18 inches (useable water depth) and 0-8.4 inches (ideal water depth) under the no action and alternative scenarios. We combined this information regarding hydrological conditions with our marsh bird vegetation layer to identify areas where appropriate marsh bird habitat intersected areas of appropriate water depth. We were then able to analyze these layers to generate estimated gains and losses of marsh bird habitat (acreage) under the alternative 3. To calculate change in habitat units (HUs), we multiplied the acreage gained or lost by the Suitability Index (SI) associated with that pixel. Areas of ideal water depth (0.01-8.4 inches) received an SI score of 1.0, areas of useable water depth (8.4-18 inches) received a moderate SI score of 0.5.

5.4 RESULTS

IPaC and BoCC Results

The IPaC and BoCC analyses identified only King Rail and the Yellow Rail as the two species of marsh birds in the YBA that are considered USFWS BoCC. Another five species of marsh birds are possible in the YBA, and we use eBird to assess general presence/absence of these species in the YBA.

5.5 MARSH BIRD SPECIES FROM IPAC AND BOCC ANALYSES

5.5.1 King Rail

The King Rail is the only rail species listed as a BoCC that potentially breeds in the YBA. This species is rarely observed in the YBA, with only nine detections during the May-June breeding season between 2000 and 2024 (all observations occurred from 2021 to 2023). This species also utilizes open areas interspersed with shrubs (Pickens and Meanly 2020). Breeding sites are generally composed of standing vegetation < 1 m in height and water depths 10 cm or less (Pickens and Meanley 2020).

eBird Observations: Within the YBA, eBird includes nine known detections of the King Rail from 2021 to 2023. Eight detections were located in the Yazoo National Wildlife Refuge (NWR), and one detection was in the Muscadine Farms Wildlife Management Area (WMA). All detections occurred during the breeding season.

5.5.2 Eastern Black Rail

The Eastern Black Rail (*Laterallus jamaicensis jamaicensis*) utilizes salt marsh, freshwater marsh, and/or estuarine marsh habitats. The eastern population of Black Rail is currently listed as threatened under the ESA. Along the Eastern Coast, populations of the Black Rail have declined significantly (approximately 9% annually; Watts 2016), likely due to habitat loss from sea level rise and nest inundation in tidal freshwater marshes (Watts 2016, Smith et al. 2018, USFWS 2018). Importantly, inland populations of this species in North Carolina have virtually disappeared (Smith et al. 2018). Habitat loss on inland freshwater marshes from conversion to agriculture, plus increase of predation in fragmented habitats are thought to be drivers of population decline. The Yazoo Backwater Area likely has few, if any, Black Rails because of their rarity as well as the overall lack of emergent marsh habitat.

eBird Observations: Based on eBird data, the Eastern Black Rail has not been detected within the Yazoo Backwater Area. A frequency of occurrence between 0% - 2% for the Black Rail around McGehee, Arkansas, which is approximately 60 miles northwest of Rolling Fork, Mississippi, is documented in eBird.

5.5.3 Virginia Rail, Sora, and Yellow Rail

The Virginia Rail, Sora and Yellow Rail are species likely only to be present in the YBA during the migratory seasons, or during winter. The Sora generally winters along the coast and may be detected inland only rarely during the winter. All these species utilize freshwater and brackish marshes, including open grasslands, grassy marshes, and wetlands (Leston and Bookhout 2020, Conway 2020, Melvin, and Gibbs 2020). The Virginia Rail generally utilizes wetlands with water depths 15 cm or less (Conway 2020), while the Yellow Rail uses wetlands with water depths between 2 and 25 cm (Leston and Bookhout 2020). The Sora is the most versatile in using wetland habitats with water depths that range from 0 to over 50 cm in depth (Melvin and Gibbs 2020). Because all these species are considered uncommon transients in the Yazoo Backwater Area, we do not anticipate any significant adverse impacts associated with the proposed Alternative 2 or 3.

eBird Observations: Only two detections in eBird of the Virginia Rail occurred in the YBA between 2000 and 2024, and both were in the Yazoo NWR in December. Twenty Sora have been detected in the YBA during the spring from March through May, and 17 detections have occurred from October through December, suggesting these are fall migrants and perhaps overwintering individuals. Twenty-nine Sora detections have occurred in the Yazoo NWR, and eight detections have occurred in the Muscadine Farms WMA. Only four eBird detections of the Yellow Rail have been reported in the YBA (three in Yazoo NWR in November and another detection in Sunflower County occurred in April).

5.5.4 Purple and Common Gallinules

Purple and Common Gallinules are the most common marsh birds found in the YBA. Purple and Common Gallinules inhabit freshwater marshes that includes sedges, grasses, and rushes. They are often observed using dense mats of floating vegetation such and American lotus (Banner and Kiviat 2020, West and Hess 2020). They use similar habitats in the winter, though wetland may be more open. Wetlands used include lakes, ponds, reservoirs, marshes and flooded agricultural fields. Water depths tolerated by both species are usually between 15 and 120 cm (Banner and Kiviat 2020, West and Hess 2020).

eBird Observations: The Purple Gallinule has been detected in the Yazoo NWR and the Muscadine WMA. Based on eBird records, 49 detections have been reported from the Yazoo NWR from May to July, and 76 detections from October to November. Only one detection has been recorded at the Muscadine WMA in September. The Common Gallinule is more abundant, with detections scattered throughout the YBA. As with other marsh birds, the most frequent detections have occurred in the Yazoo NWR, with 108 detections. during spring and summer (April through July), and another 81 during the fall (September through November) and 24 during the winter (January through February), On the Muscadine WMA, 12 have been detected between October through December. Other scattered detections throughout the YBA include 29 birds during the spring (April – May) and another 3 birds between October and December.

5.6 HYDROLOGY ANALYSIS

In our analysis, we predict only minor losses of marsh bird habitat under the proposed pumping scenarios (Table E-1, Figure E-1). Our analysis found few instances where contiguous chunks of marsh bird habitat became less suitable under Alt 2/3. Instead, we found isolated pixels of lost and gained habitat scattered across the YBA. The largest concentration of habitat loss and gain occurs in an area that is just west of the Delta National Forest (Figure E-2). Although we identified areas of habitat loss within this sector, we also found correspondingly large areas of adjacent habitat gain. In the Yazoo NWR, where the majority of rail detections in the YBA have occurred. We predict minimal loss of marsh bird habitat under Alt 2/3 (Figure E-3).

Table E-1. Results of our analysis showing change in marsh bird habitat under the alternative 2/3 scenarios. The ideal (HSI = 1.0) water depth is 0-8.4 inches. Useable (HSI = 0.5) water depth is 0-18 inches.

Water Depth	Acres Gained	Acres Lost	No Change	Net Change (acres)	Net Change (HUs)
0-18 inches	379.6	390.2	832.5	-10.7	-24.0
0-8.4 inches	191.0	232.8	304.8	-41.8	-39.6

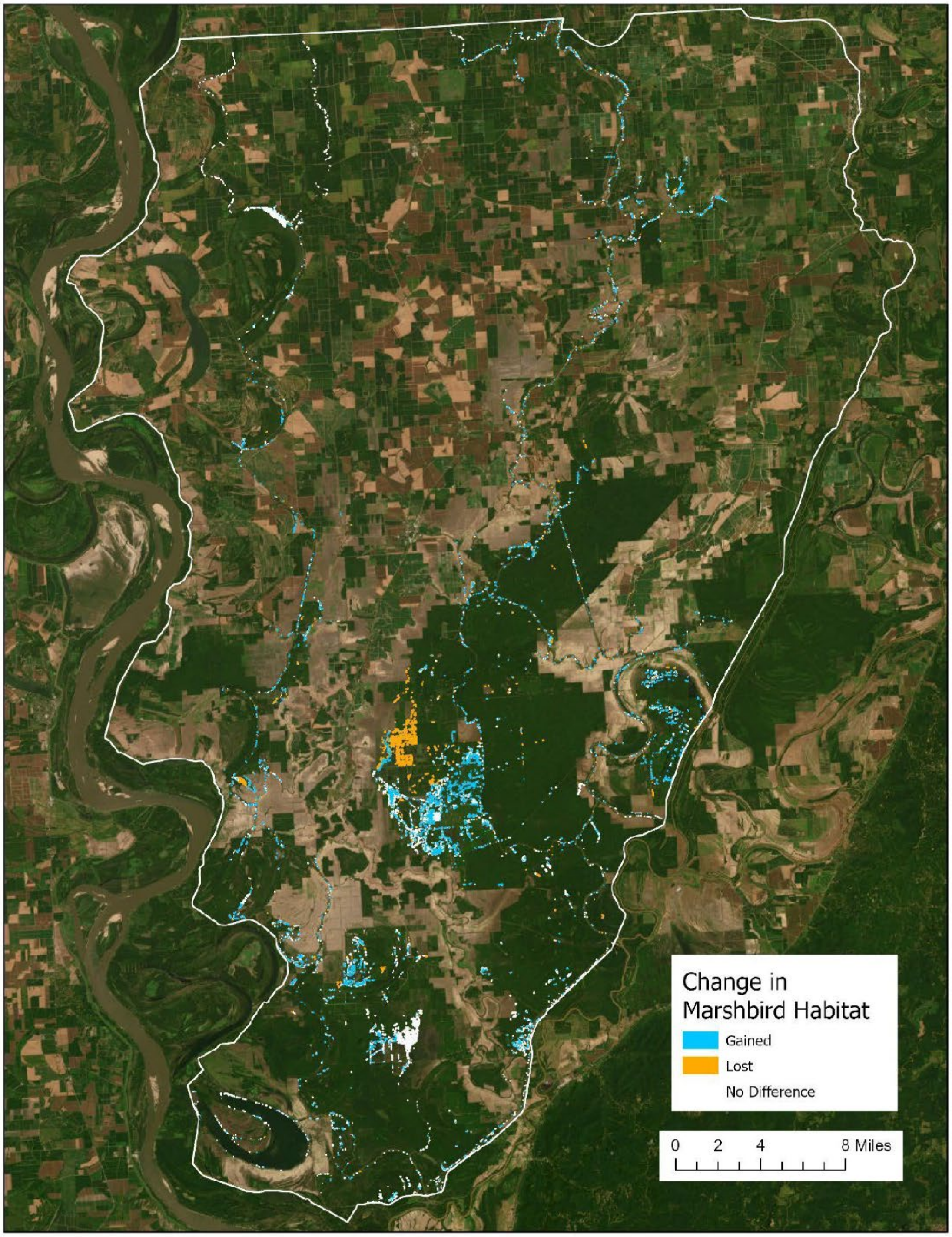

Figure E-1. Change in marsh bird habitat under Alt 2.

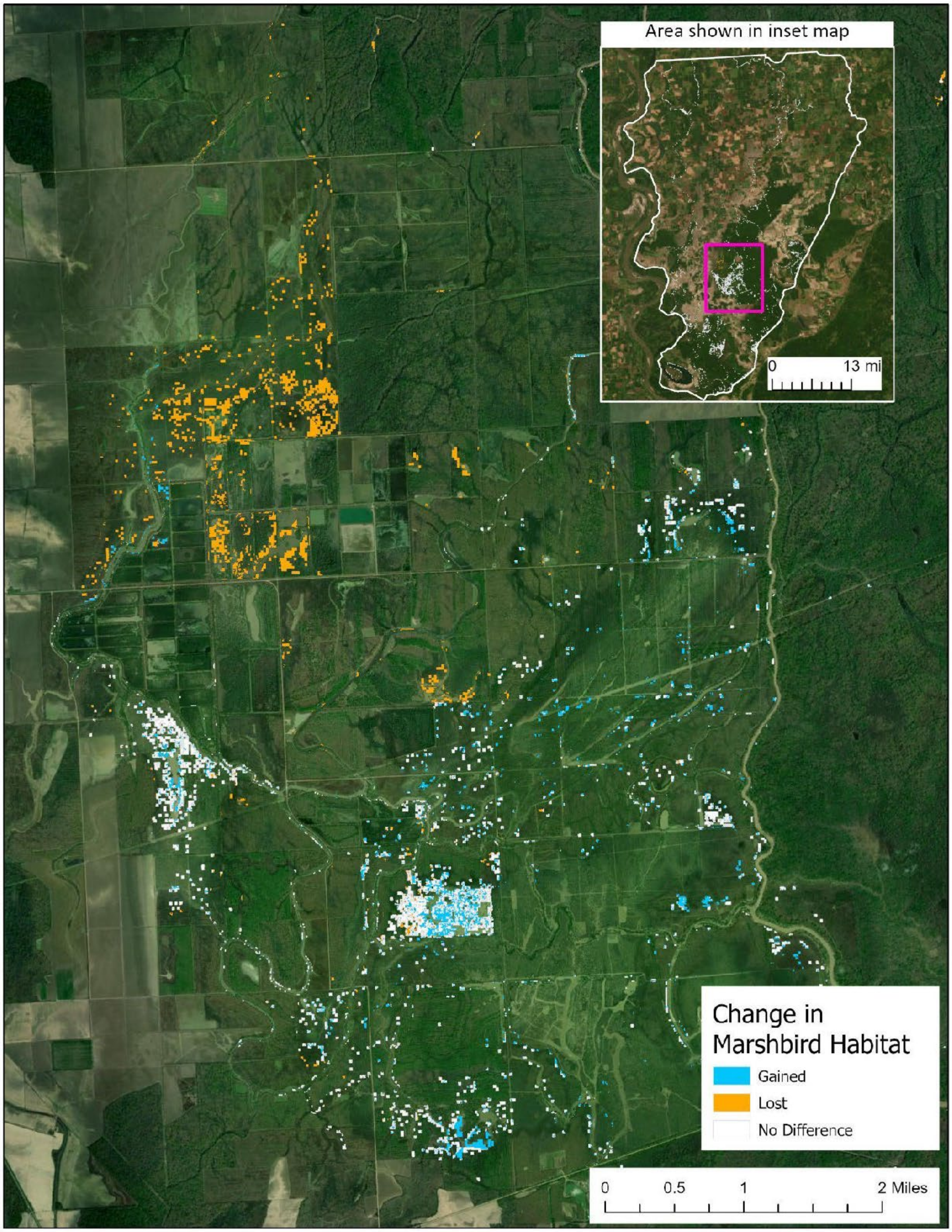

Figure E-2. Change in marsh bird habitat just west of the Delta National Forest.

Figure E-3. Change in marsh bird habitat under the alternative (Alt 2/3) scenarios at Yazoo National Wildlife Refuge

5.7 DISCUSSION

In general, most BoCC within the YBA identified by our IPaC analyses should experience few negative impacts with implementation of the proposed Water Management Plan. This includes several marsh bird species that have breeding or non-breeding ranges within only a relatively small proportion of the YBA, or that occur as transient migrants during spring and fall or overwintering seasons. Such species include King Rail (rare breeder in YBA), and Virginia Rail, Sora, and Yellow Rail which are uncommon migrants or overwintering species. The Eastern Black Rail has not been detected in the YBA and likely only occur on rare occasions. The most common marsh birds are the Purple and Common Gallinules. The King Rail is a species of concern that is a rare breeding in the YBW, primarily at Yazoo NWR. The Yellow Rail is also a species of concern that has a few sparse records within the YBA, all during the non-breeding season.

Our analysis predicts that there will be only minor losses in marsh bird habitat under the alternative pumping scenarios. Even with our liberal definitions of useable marsh bird habitat (0.01-18 inches of inundation intersecting herbaceous/emergent vegetation), we predict a net loss of only 10.7 average daily flooded acres (although the net average daily flooded acres lost at the ideal 0.01-8.4-inch depth was 41.8 acres). We found that losses in marsh bird habitat under the alternative pumping scenarios were almost completely balanced by gains in habitat. It may seem counterintuitive that infrastructure that reduces flooding could create habitat for taxa that rely on inundation. However, water that is too deep is as unsuitable to marsh birds as dry upland, and the reduction of flooding magnitude can bring the water in some areas that are or would be temporarily flooded at >18-in depths down to a level suitable for rails and other marsh birds. Furthermore, areas exhibiting net differences in average daily flooded acres (across years) between base (no action) and alternative scenarios would not have had differing hydrology in the majority of years over the 1978-2020 Period of Record (POR), as the pumps would have operated in just 47% of years over the POR under proposed pumping conditions (Fig. 2-110 in Appendix A-Engineering Report). Mitigation for marsh birds is not calculated because the project does not provide any biologically relevant impacts to marsh birds in the YBA. There are several factors that support this determination. First, projected loss of habitat is almost completely equaled by projected created habitat, minus approximately 10 acres of ideally flooded acres. Secondly, projected lost habitat typically consisted of scattered “pixels” across the landscape, typically of less than 0.5 acres in size. Lastly, the only section of contiguous projected lost habitat occurred in an area to the west of Delta National Forest. This area is primarily regenerating early successional vegetation. It has likely been classified as emergent vegetation by remote sensing methods because of its successional age; however, this area has been ground-truthed as an area where reforestation is to occur. Therefore, the area classified as emergent wetland is in a transitional stage to BLH forest that will not support marsh birds.

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SECTION 6 APPENDIX F ALLIGATOR SNAPPING TURTLE

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6.1 PROJECT BACKGROUND

The Yazoo Backwater Area (YBA) is a large, predominantly wetland area that is located within the Mississippi River Alluvial Plain in the southern Mississippi Delta. It is comprised of 925,398 total acres of land including 647,363 acres of agriculture and development and 278,035 acres of deepwater and wetland habitat (Dahl et al. 2009). The YBA is subject to frequent and significant flooding events that result in damage to the homes, crop fields, and wildlife present there. Historically, however, there have been concerns as to what effects lowering water levels and limiting flood events will have on surrounding wetland habitats as well as on species of concern that are or may be present within the YBA (EPA Recommended Determination 2008). Recent years have seen the federal listing of several additional species of concern, including as the alligator snapping turtle (*Macrochelys temminckii*; AST), likely to inhabit the affected wetlands, further complicating the challenge posed by the natural flooding patterns within the YBA.

6.2 ALLIGATOR SNAPPING TURTLE BACKGROUND

The AST, the largest freshwater turtle in North America, has a historical range that includes Texas, Louisiana, Mississippi, Alabama, Georgia, Florida, Oklahoma, Arkansas, Tennessee, Kentucky, Kansas, Missouri, Illinois, and Indiana. However, range contractions have occurred, and the species is functionally extirpated from Illinois, Indiana, and Kansas. Alligator Snapping Turtles have experienced decline and extirpations due to commercial harvest, watershed alteration, nesting habitat alteration and destruction, and incidental fishing mortality. The AST was federally listed as threatened by the USFWS in 2021.

Diagnostic characteristics include three prominent ridges along the carapace, the presence of supramarginal scutes between the pleural and marginal scutes, strongly hooked mandible, and lateral placement of eyes. Shell coloration is a grayish brown to brown as are the head, legs, and tail. A worm-like lure, that may be pinkish, light gray to white or dark purple, is in the lower jaw. The tail is quite long, approximately the length of the carapace. Adult males are larger size (up to 249 lbs., 113 kg) than females, with female maximum mass reaching about 80 lbs. (36.4 kg) (Trauth et al. 2004; Jensen et al. 2008; Ernst and Lovich 2009; Guyer et al. 2015; Krysko et al. 2019).

ASTs live in a variety of freshwater habitats from small streams to large rivers, oxbows, swamps, bayous, lakes, and canals with water clarity that ranges from clear to murky and turbid (Ernst and Lovich 2009). During high water events turtles will move out of deeper waters and channels into adjacent inundated flood plains (P. Delisle, pers. obs. in YBA). Brackish water habitats are also utilized. ASTs utilize shaded stream banks with intact riparian tree cover, an abundance of submerged logs, trees, and other in-stream structures. In bayou and swamp habitat, vegetated microhabitats, with plants such as cypress, tupelo, buttonbush, and floating aquatic vegetation, are occupied (Harrel et al. 1996; Riedle et al. 2006; Shipman and Riedle 2008; Howey and Dinkelacker 2009). Substrates of habitats include soft mud, clay, sand, gravel, and rocks. Juvenile turtles use submerged root masses, log jams, and entangled branches. Fish are the primary prey for the AST; however, they have a wide diet including crustaceans, mollusks, snakes, turtles, birds, mammals, and vegetation indicate that they are opportunistic feeders and scavengers (Elsey 2006; Ernst and Lovich 2009). The AST is unique in possessing a lingual appendage that resembles a worm and functions as a lure to attract prey. The stomach contents of an adult male AST found dead near Natchez, Mississippi, included corn cobs, red potatoes, and remnants of a buffalo and gar (L. Pearson, pers. obs.).

Age and SCL of maturity for females has been estimated at 13-21 years and 32.7-37.0 cm, and from 11-21 years and 37.8-41.9 cm for males (Dobie 1971; Tucker and Sloan 1997). Nesting in Mississippi, Georgia, and Florida occurs in April to May and may extend to June in other parts of the range (Ernst and Lovich 2009; L. Pearson and P. Delisle, pers. obs.). Females lay 9-61 eggs in a nest (mean: 35 eggs), generally within 20 m of the water and about 3 m above the waterline in sand or sandy soil mixed with silt and organic material (Ewert 1976; Ewert and Jackson 2023). There are few known nesting locations within the YBA due to the lack of nest surveys; however, observed nesting locations in low-lying and heavily forested floodplains included eastward facing, partially open-canopy banks (caused by tree falls) approximately 1-3 m above and 2-10 m from the waterline (Ewert 1976; L. Pearson and P. Delisle, pers. obs.). Counts of a depredated nest within the YBA produced a clutch of approximately 34 eggs (L. Pearson, pers. obs.). Females generally lay one clutch per year; however, there’s evidence that some females may lay one clutch every other year (Dobie 1971).

The AST is rarely observed moving overland, although a recent radio-telemetry study in the YBA documented occasional overland movement (P. Delisle, pers. comm.). Juveniles have been observed basking and nesting is the main terrestrial activity of the species (Ewert 1976; Carr et al. 2011). Individuals have been captured in baited nets in Alabama, Georgia, and Mississippi between March and October (Godwin and L. Pearson, pers. obs.). Bogosian (2010) suggests turtles in Louisiana may be inactive from October to February, although Boundy and Kennedy (2006) trapped substantial numbers in October and November. A radio-telemetry study within the YBA documented movements occurring every month of the year, with movement frequencies peaking in the active season (April to October; P. Delisle, pers. comm.). Additionally, egg incubation and hatchling emergence times of up to 143 days (May to September) should be considered when conducting any activities that may directly impact nesting locations, including nest inundation due to water fluctuations, heavy machinery compacting or destroying nests, limiting the placement of dredge spoils onto potential nesting banks during egg incubation (May to September), limiting the clearing of riparian forests, or controlling encroachment of invasive vegetation onto nesting locations.

The AST is known to occur in every county within the YBA, and there are current records from the Yazoo River, Sunflower River, Wolf/Broad Lake, Little Eagle Lake, Chotard Lake (reintroduced AST), and within Delta National Forest, Panther Swamp National Wildlife Refuge (NWR), and Yazoo NWR (Pearson et al. 2023). Habitats characteristics within the YBA that are important to the AST include abundant submerged and emergent woody debris including root masses, log jams and branches as well as substrates of mud, silt, clay, sand, or gravel, including deep holes, undercut banks, steep cutbacks, or sandbars. Cypress and Tupelo-lined swamps, bayous, and tributaries are important habitat types for AST. The nesting requirements of the AST include partially open canopy on high ground, at least 1m above and withing 30m of the waterline, preferably near deeper water and/or recent tree fall or upturned tree root mass with limited vegetative ground cover.

6.3 METHODS

To estimate the change in nesting habitat availability for ASTs, total inundated acres lost, and change in shoreline length we performed desktop modeling exercises in ArcGIS Pro (Esri 2020) utilizing data sources obtained from publicly available sites (e.g. National Land Cover Database) or developed in-house (e.g. hydrology layers generated by USACE). We began by mapping the average daily inundated extents provided by the Vicksburg District office (MVK) clipped the extent of the YBW project boundary for both pump and base conditions for the dates April 15 - June 15. This time period was selected to demonstrate the maximum expected variations between the two conditions as it had the maximum flood extent or highest degree of change in water level out of any seasonal period. Habitat was considered appropriate for AST nesting habitat when it occurred within 20 meters of the shoreline in woody wetlands forests at elevations above inundation levels. These parameters were selected because AST have been shown to nest primarily in forested wetland areas within 20 meters of the water's edge (Ewert 1976, Lovich and McCoy 1992). To accomplish this, land use cover data from USGS (NLCD, 2021) was used to identify woody wetlands within the project area. The inundated layers for both base (Alternative 1) and with pump (Alternative 2) were clipped to the woody wetlands layer using a pairwise clip to exclude non-forested areas and a 20-meter buffer was generated around the resulting Alternative 2 and Alternative 1 shorelines. Only portions of the buffer that occurred outside of inundated areas and at elevations above flood level for that season (April 15 - June 15) and POR (average daily inundation) were included. The remaining area of the resulting buffers were then used to estimate available turtle nesting habitat in square acres under both alternatives.

6.4 RESULTS

The woody wetland areas identified encompassed 34.25% or 317,000 acres of the total 925,398acre YBW area. As expected, inundated acres within the woody wetland forests identified decreased by approximately 7.20% from 154,850 acres to 143,642 acres between Alternative 1 and Alternative 2 conditions respectively. Predictably, the associated nesting habitat available within the YBW was also reduced, though less dramatically than expected.

Under Alternative 1 conditions, there were 26,587 acres of nesting habitat while 26,537 acres of nesting habitat was available under Alternative 2 conditions. The 50 acres lost therefore account for only a .09% loss in overall nesting habitat (Table F-1). While full-scope maps are provided (Figures F1-F2), the relatively narrow bands of nesting habitat are difficult to see. To remedy this, more focused maps for the two conditions that cover the southern and most inundated portion of the project area are also included (Figures F-3-F-4).

Table F-1 Data concerning total, loss/gain, and percent difference for woody wetland forest, available nesting habitat, and total shoreline length for Alternatives 1 and 2.

	Alternatives 1	Alternatives 2	Loss/Gain	Percent Difference
Woody Wetland Forest (Acres)	154,850	143,642	-11,208	-7.2
Available Nesting Habitat (Acres)	26,587	26,537	-50 26,725	-0.09
Shoreline Length (m)	11,111,433	11,138,158		0.24

There was also a small (.24%) increase in shoreline perimeter from 11,111,433 m (Alternative 1 conditions) to 11,138,158 m (Alternative 2 conditions). Although the change in shoreline length is not drastic, it is likely due to the more complex geometry that reduced water levels have in connection with micro-topographical changes in the landscape (Figure F-5).

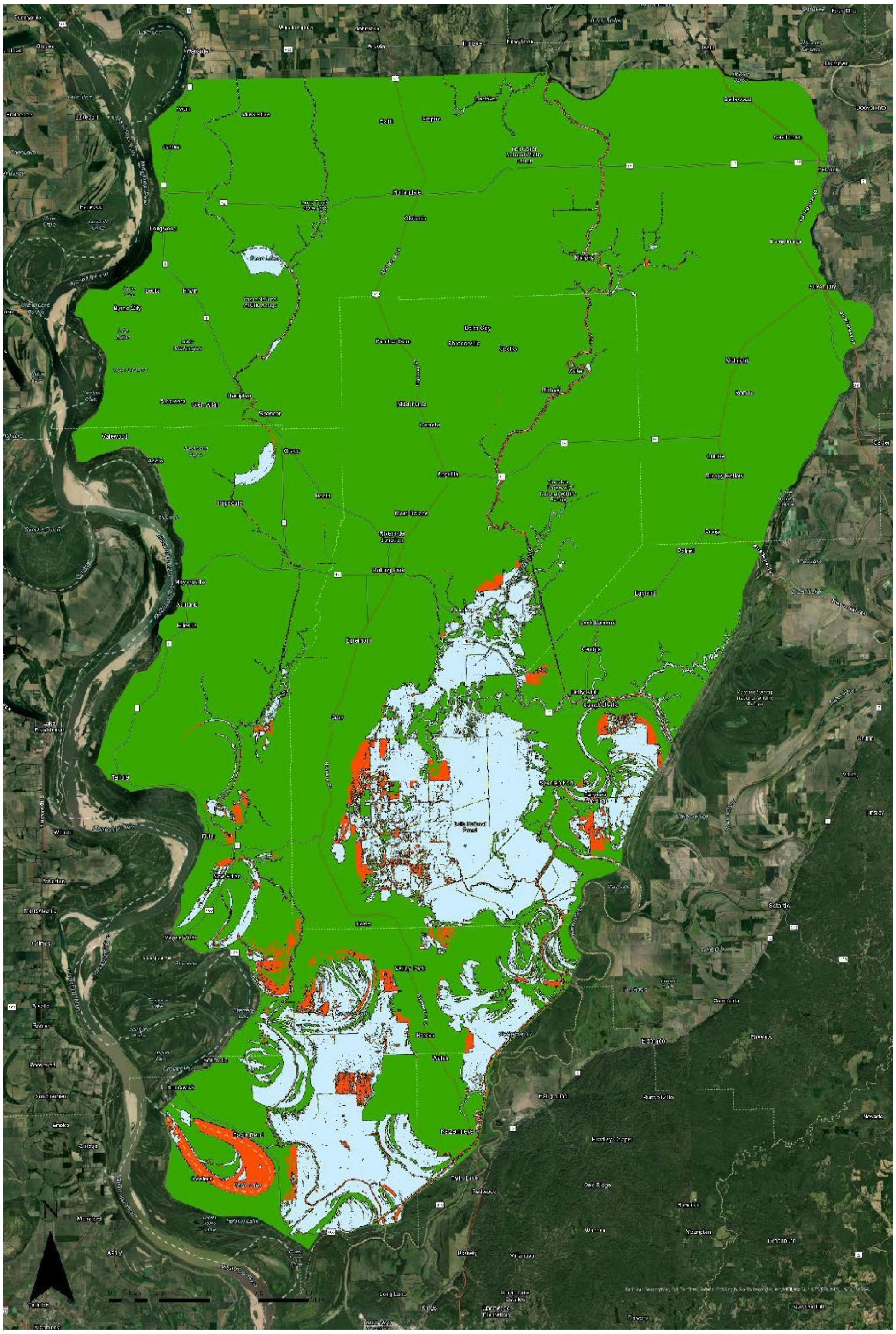

Figure F-1 *Model output investigating inundation and turtle nesting habitat (mapped in yellow but difficult to see at this scale) under Alternative 1 (no action) conditions. Areas in green are areas not inundated at base conditions without pump, red areas are areas inundated at base conditions, and light blue areas are areas inundated under base conditions that are clipped to woody wetlands (areas considered potentially suitable for nesting by AST).*

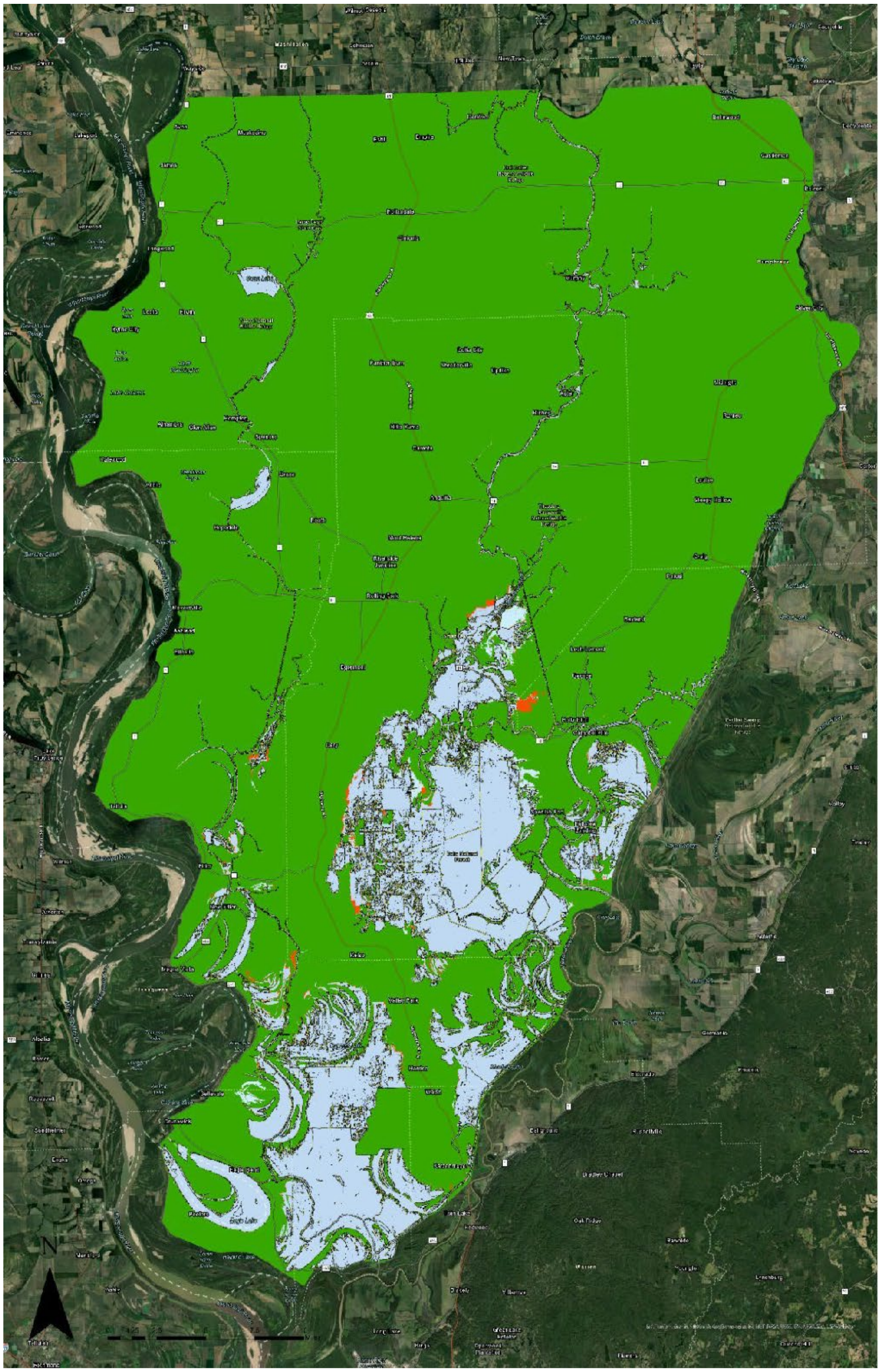

Figure F-2 *Model output investigating inundation and turtle nesting habitat (mapped in yellow but difficult to see at this scale) under Alternative 2 (pump) conditions. Areas in green are areas not inundated at Alternative 2 conditions without pump, red areas are areas inundated at Alternative 2 conditions, and light blue areas are areas inundated under Alternative 2 conditions that are clipped to woody wetlands (areas considered potentially suitable for nesting by AST).*

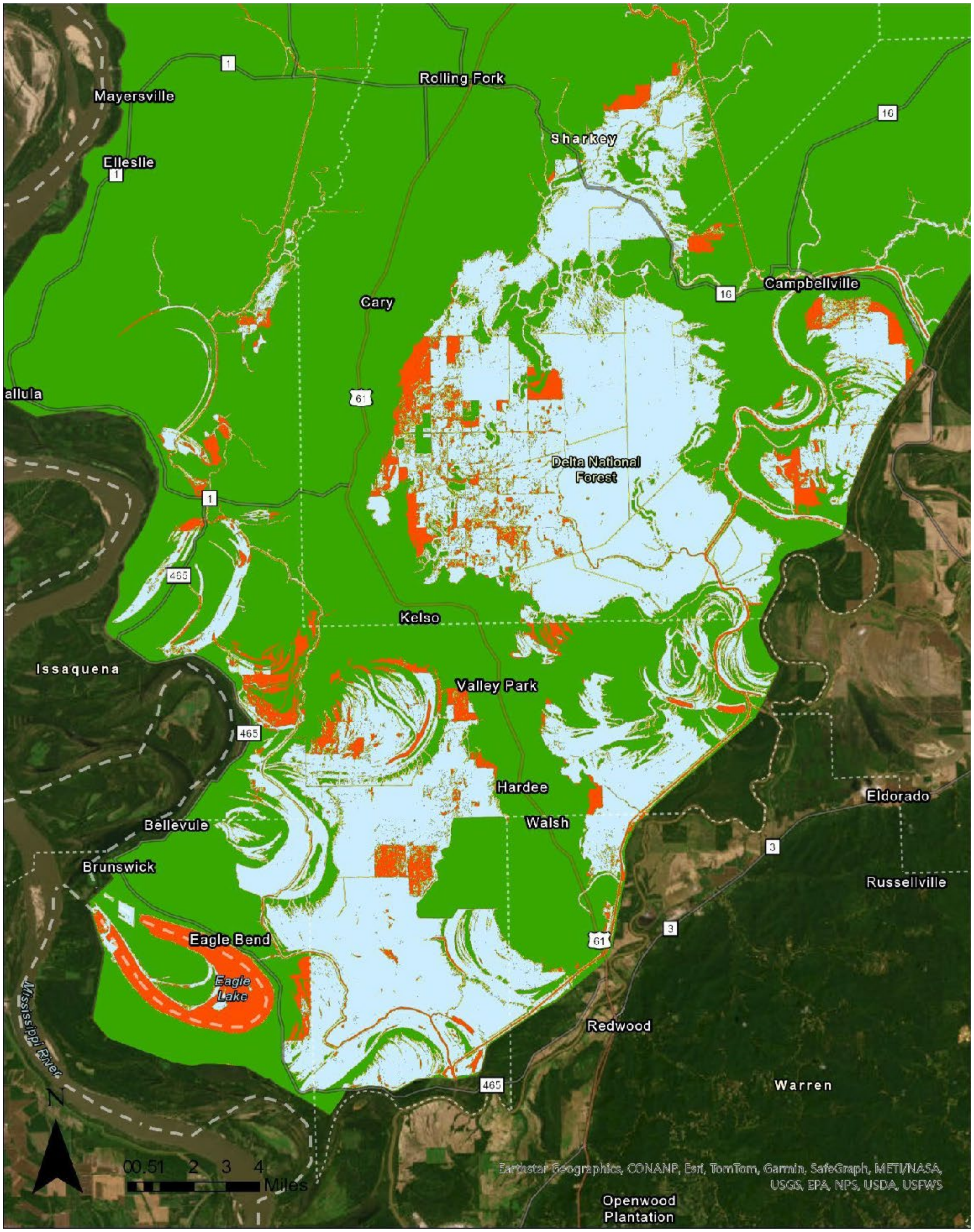

Figure F-3 *Model output investigating inundation and turtle nesting habitat for southern wetlands within the YSA project under Alternative 1 (no action) conditions. Areas in green are areas not inundated at base conditions without pump, red areas are areas inundated at base conditions, and light blue areas are areas inundated under base conditions that are clipped to woody wetlands (areas considered potentially suitable for nesting by AST).*

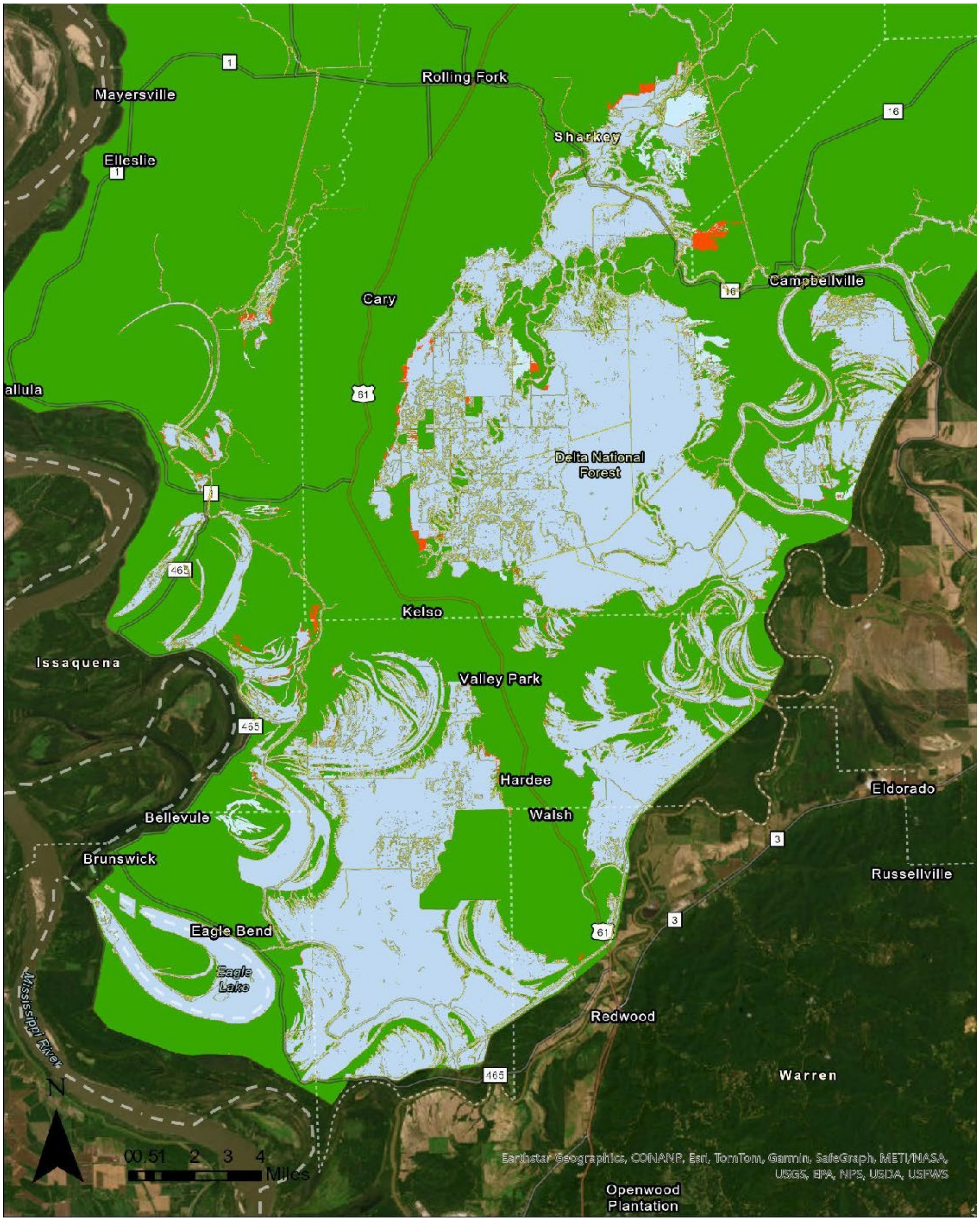

Figure F-4 *Model output investigating inundation and turtle nesting habitat for southern wetlands within the YBW project under Alternative 2 (pump) conditions. Areas in green are areas not inundated at Alternative 2 conditions without pump, red areas are areas inundated at Alternative 2 conditions, and light blue areas are areas inundated under Alternative 2 conditions that are clipped to woody wetlands (areas considered potentially suitable for nesting by AST).*

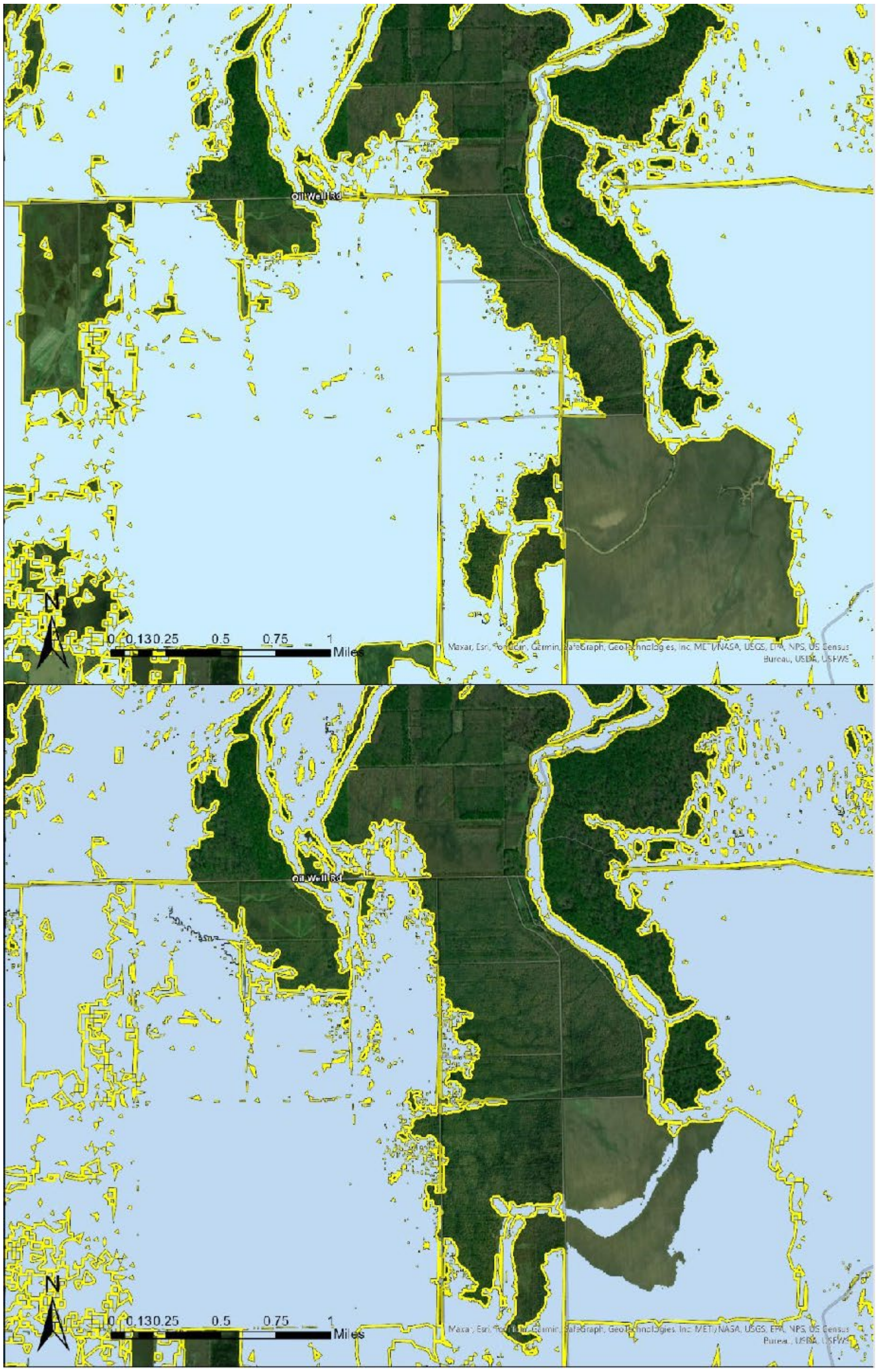

Figure F-5 Example area showing the difference in shoreline complexity and inundation between Alternative 1 (top) and Alternative 2 (bottom). Blue represents expected inundation and yellow indicates the presence of AST nesting habitat within 20 m of inundated woody wetland forests.

6.5 DISCUSSION

As expected, total acreage of nesting habitat present within the project area was reduced under Alternative 2 conditions. We did not, however, expect the change to be as subtle as our models indicated. Although there was a decrease in available nesting habitat within the project area, the 50 acres of habitat lost represented only 0.09% of the original nesting habitat available under Alternative 1 (base) conditions. This may be, in part, due to the increase in shoreline perimeter that resulted from changes in the complexity of shoreline geometry at lower water levels.

Increased shoreline complexity may benefit AST populations in several other ways as well. ASTs are, for example, typically found within 25 meters of a shoreline (Brent et al. 1996, Table F2). An increase in shoreline may, therefore, result in increased aquatic habitat availability.

Month	Mean water temp (C)	Number of fixes	(n = 12) Movement fixes (%)	Mean fix[1] distance (m)	Mean dist. from shoreline (m)	Mean water depth (cm)
Jan	9.1	113	7.1	12.0	13.9	135.9
Feb	10.3	108	4.6	11.1	14.8	130.4
Mar	13.8	128	21.9	136.1	16.2	128.1
Apr	19.1	87	75.9	224.4	16.6	117.4
May	24.7	88	76.1	306.1	16.3	120.9
Jun	27.2	73	76.7	312.3	21.1	125.0
Jul	29.1	114	82.5	257.6	18.3	120.3
Aug	27.1	116	78.4	180.6	18.0	110.9
Sep	25.9	121	75.2	274.1	14.8	112.2
Oct	19.9	132	61.4	182.5	15.7	122.1
Nov	13.3	131	29.8	88.7	13.1	116.5
Dec	9.3	116	6.0	31.2	13.6	124.4

[1] Movement fixes only

Table F2 *Summary relocation data for ASTs including mean distance from shoreline (Brent et al. 1996). Table taken directly from the original text.*

Loss of inundated acres occurred as expected across the project area, albeit relatively minor. Potential negative impacts of water levels could potentially reduce or alter AST's access to course woody debris, shade, and access to foraged resources such as berries and acorns. However, while it is well known that ASTs frequently consume acorns and other vegetation opportunistically when foraging, plant matter has not been shown to constitute a significant portion of their diet (Elsey 2006, Table F-3). Their preference for aquatic prey such as fish, mollusks, and carrion remain the primary focus of their feeding behavior. Although prey items may be temporarily condensed during pump events, they are primarily aquatic, and their movement patterns are likely to resemble AST movements.

Prey type	Percent frequency occurrence (of 109 samples)	Prey mass	
		Average (g) ± SEM	Range (g)
Invertebrates			
Crab	1.83	0.94 ± 0.59	0.35–1.53
Crawfish (*Procambarus clarkii*)	51.38	9.32 ± 1.82	0.01–59.32
Mollusc	47.71	3.53 ± 1.93	0.01–97.46
Insect	22.02	0.30 ± 0.10	0.01–1.78
Vertebrates			
Carp (*Cyprinus* sp.)	22.94	110.95 ± 26.39	3.31–477.84
Catfish (*Ictalurus* sp.)	2.75	21.96 ± 20.36	0.18–62.60
Gar (*Lepisosteus* sp.)	20.18	68.09 ± 19.90	0.07–334.23
Fish, unidentified	79.82	26.47 ± 6.73	0.01–387.12
Snake	6.42	16.74 ± 6.40	1.84–50.62
Turtle	30.28	16.66 ± 6.58	0.11–184.82
Bird	5.50	3.51 ± 2.00	0.02–12.59
Armadillo (*Dasypus novemcinctus*)	0.92	123.62 (n = 1)	123.62 (n = 1)
Muskrat (*Ondatra zibethicus*)	0.92	133.80 (n = 1)	133.80 (n = 1)
Nutria (*Myocastor coypus*)	21.10	273.76 ± 41.73	18.15–647.00
Opossum (*Didelphis virginiana*)	0.92	44.33 (n = 1)	44.33 (n = 1)
Hog (*Sus scrofa*)	1.83	18.81 ± 16.85	2.01–35.61
Raccoon (*Procyon lotor*)	0.92	26.68 (n = 1)	26.68 (n = 1)
Squirrel (*Sciurus* sp.)	0.92	252.26 (n = 1)	252.26 (n = 1)
Mammal, unidentified	7.34	5.53 ± 2.78	0.01–20.30
Bones, unidentified	14.68	10.08 ± 7.67	0.08–123.96
Eggs/membranes	6.42	3.21 ± 0.89	1.24–8.12
Other			
Vegetation	99.08	40.12 ± 8.27	0.01–662.07
Unidentified matter	96.33	9.49 ± 1.21	0.01–75.89
Non-food	25.69	2.71 ± 0.58	0.02–12.15

Table F3. *Summary dietary data for 109 ASTs (Elsey 2006). Taken directly from the original text.*

Water control structures, such as the proposed pumps, require trash gates to prevent debris from clogging the system and ensuring smooth water flow. These gates are essential for maintaining the integrity and functionality of the structures by blocking the entry of trash and other floating materials that could accumulate and cause blockages. In the absence of trash gates, debris can create significant obstructions, leading to altered water levels and flow patterns. This can have adverse effects on alligator snapping turtles. Blocked water control structures can disrupt their habitats, limit their access to food sources, and increase the risk of accidental entrapment or injury as turtles who wander too close to intake structures may struggle to escape and eventually drown. Furthermore, the accumulation of debris can lead to water quality degradation, impacting the health of the system overall. Therefore, a trash gate should be included in pump planning and should extend at least beyond the most intense areas of intake/flow. If necessary, some additional research and outreach between agencies and engineers could allow for improved design specifications concerning trash gate designs that would be most beneficial for alligator snapping turtles. In summary, although some nesting habitat and inundated land may be lost during the most extreme periods of variation, available shoreline is expected to increase, and improved flood control may prevent the destruction of existing nests during future high-water events. We therefore conclude that water level management practices utilizing pumps (as proposed in Alternative 2 are likely to affect but are unlikely to negatively affect AST populations within the YBW. Similarly, because pumping durations would be equal to or less than Alternative 2 under the Alternative 3 scenario (up to 10 fewer days of pumping), pumps would be unlikely to negatively affect AST populations.

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SECTION 7 APPENDIX G

NORTHERN LONG-EARED AND TRI-COLORED BATS

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7.1 INTRODUCTION

In this report, we assessed the indirect impacts of construction and operation of the proposed Yazoo Backwater Area (YBA) Water Management Plan on two bats species. Bats have been an increased focus of conservation efforts due to massive population declines from White Nose Syndrome (WNS). Since discovered in New York in 2006, WNS has resulted in the death of millions of hibernating bats. The once common northern long-eared bat (*Myotis septentrionalis*) and the tri-colored bat (*Perimyotis subflavus*) have experienced population declines of greater than 80% in recent years. This has resulted in the northern long-eared bat being federally listed as endangered and the tri-colored bat initial finding was that endangered listing is warranted (final decision is due out in the Summer of 2024).

Bats may utilize a large variety of roost sites. Bats are known to roost in snag trees (primarily in upland deciduous forests near water), leaf clusters, and human structures (culvert, buildings, bridges). During the summer season, bats can utilize a variety of roosts. This flexibility tends to minimize the importance of any single roost for these species as shown in Silvis et al. (2015). During the winter, bats are known to use culverts (Henderson and Broders 2008, Wetzel 2023). In a study conducted in the northern portion of the Mississippi Delta, bats were found in 48.8% of the 391 bridges and culverts sampled (Rosamond et al. 2018). Foraging areas of bats can be quite variable as bats tend to seek any insect swarms that might appear. In general, northern long-eared bats tend to forage in forest interiors (e.g., along trails, canopy gaps), while tricolored bats tend to forage along wetland and riparian areas (Broders et al. 2006; Hein et al. 2009).

7.2 OBJECTIVES

The objectives of this appendix are to: Assess the change in forest inundation as a result of the changes that could occur due to the construction and operations of the Yazoo pump under Alternative 2.

1) Assess the change in distance to open water from snags within the forested habitat as a result of the Yazoo pump operations under Alternative 2.
2) Assess the change in inundation of bridges and culverts as a result of the Yazoo pump operations under Alternative 2.
3) Discuss the potential impacts to the northern long-eared and tri-colored bats.

7.3 PROJECT AREA

Currently, the YBA consists largely of agricultural lands with scattered remnants of bottomland hardwood forest (BLH) and cypress/tupelo swamps (Wakeley 2007). In prior YBA studies, the cypress/tupelo swamps were determined to be too small and low in frequency to justify a separate forest class and, therefore, are combined with BLH forests to provide a broad overview of available forest types (Wakeley 2007). Smith and Klimas (2002) noted various forest subtypes within the YBA, including, 1) sweetgum/water oak, 2) white oaks, red oaks, and other hardwoods, 3) hackberry, elm, and ash, 4) overcup oak and water hickory, 5) cottonwood, 6) willow, 7) river front hardwoods, and 8) cypress tupelo. Respective acreages of these forest subtypes in the YBA are not provided, however, it is noted that within the YBA, only approximately 10 percent of the original forested habitat remains, with the remaining lands converted to agriculture (Smith and Klimas 2002). A detailed description of the overall YBA and associated plans with operation of a pumping station can be referenced in Section X of the FEIS.

7.4 METHODS

As little is known about the specific habitat use of bats within the Yazoo Backwater Area, a GIS analysis was undertaken to evaluate the impact of the two proposed scenarios: base condition (no pumps installed) and the Alternative 2 (pump installed and operated as described above). The average daily inundated area in the YBW from the period of 15 April – 15 June was provided by the U.S. Army Engineer District, Vicksburg (CEMVK) for the two scenarios. This time period has the highest inundation levels and represents the highest degree of change in water level in any seasonal period. Therefore, this period was used for all bat analyses to provide estimates for the acres impacted by implementation of Alternative 2 (Crop Season: March 15 through October 15). This project evaluated three metrics designed to assess the impacts of Alternative 2 on the northern long-eared and tri-colored bats.

1) Open water is important for bats for drinking source and/or foraging areas for emerging insects. We did not have locations of actual roosts within the YBW boundary, so we used snag trees located during surveys by the ERDC-EL Wetlands and Wildlife Teams as surrogates. For all snag trees, we calculated the distances from the tree location to the nearest water boundary for the two scenarios.
2) Roosting habitat is important to ensure suitable conditions for roost sites. One factor that is important around roost trees is the lack of clutter (i.e., obstacles). Pregnant and young bats need relatively uncluttered habitats to be able to maneuver effectively. Inundation during the early growing season is likely to reduce the development of understory, thereby improving roosting habitat. Thus, we compared the inundated forested habitat under the two scenarios to assess the potential impacts.
3) Finally, culverts and bridges can provide important roosting habitat in the project area, particularly during the winter hibernation season. As increased flooding can affect these culverts, we assessed the potential impact of Alternative 2 on roosting resources. Bat location data in culverts within the project area are extremely limited so we simply assessed the change in the number of culverts impacted by water levels under the two scenarios. MS TIGER data for streets, roads, and trails were acquired from MARIS along with perennial and intermittent stream data as line shapefiles (maris.mississippi.edu). Roads and streams were clipped to the YBW polygon boundary. Stream data were then merged to generate one layer representing all streams. Any overlapping street data were erased from the layer and all roads were merged to generate a single layer representing all roads and streets. A spatial intersection was performed using all streams and road layers to generate a point layer representing inferred bridge or culvert locations with the YBW boundary. An inverted spatial selection was performed within the inundation area for both the base and alternate water levels.

For each metric, comparisons were made between the base and Alternative 2 scenarios to enable assessment of the potential impact of Alternative 2 on the northern long-eared and tri-colored bats.

7.5 RESULTS

A sample of 114 potential roost trees were identified in the YBW boundary. Of these trees, 84 were located within the inundation area for both scenarios, thus we focused on assessing distance to water for the remaining 30 trees. The mean distance to water for Alternative 2's scenario minus the base scenario is 5.9 meters (range 0-5257 meters). This small difference indicates no biologically significant difference in distances of potential roost trees to open water access.

The National Land Cover Database (NLCD) crop cover layer was used to identify the 317K acres of woody wetlands forest cover. The inundation layers for the base and Alternate 1 scenarios were clipped using a pairwise to the woody wetlands layer to exclude non-forest. Total inundated acres of woody wetlands forest cover for the base scenario were 154,805. This acreage was reduced to 143,642 acres under the Alternative 2 scenario. This resulted, on average over the 43-year POR, in 11,163 fewer acres inundated under the Alternative 2 scenario. The pump station would have only operated 18 of the 43 years of the POR during the April 15-June 15 window referenced in this analysis (Figure 2-112 in Appendix A); in the majority of years, base and alternative backwater flooding acreages would have been equal. Initial GIS efforts resulted in 2,192-point locations for possible culvert/bridges. A spatial selection of all bridge/culvert point locations within the YBW was performed within the inundation area for both the base and preferred alternative water levels. This resulted in 233 bridge/culverts being inundated in the base condition and 224 bridge/culvert locations inundated under the Alternative 2 scenario. In addition, the difference in distance to inundation between the Alternative 2 and base scenario averaged 92m (range -125 to 1471m). This further suggests that fewer culverts and bridges would be flooded out during the Alternative 2 scenario.

7.6 DISCUSSION

While access to open water for drinking and/or foraging is important to bats, the analyses showed no biologically significant difference in the distance from snag trees to open water under the two scenarios. This likely was a result of the presence of large amounts of water on the landscape even under Alternative 2. The identified snags were not known to be bat roosts but instead were surrogates for the bat roosts in the area. However, the lack of differences was not likely due to the use of these surrogate trees. In addition, bats can fly miles over the course of a night during foraging efforts. Thus, even if there were small distances in the distance to water between the two scenarios, it is extremely unlikely to have even a negligible impact on the energetic balance of bats.

Forest management is a complex process. This analysis resulted in ~11,000 acres no longer being inundated under the Alternative 2 scenario as an average over the course of the 43year POR. This may mean that since these acres may no longer flood, then more vegetation in the shrub and subcanopy will develop. This increased complexity to the forest structure may make the habitat less suitable for bats. It is also important to mention that local hydrology from precipitation is a factor mostly unaccounted for in most historical Yazoo Backwater analyses, but the current Wetlands Appendix for this EIS provides significant information and details on the role of local precipitation in maintaining vast acreages of forested wetlands of the YBA. Two additional factors may limit the impact of this change on bats. First, not all of the impacted acreage occurs in habitat that is being used by bats. Secondly, this impact of ~11,000 acres is within the 317,000 acres of forested habitat within the YBW project area. This accounts for a potential impact of < 4% of the total forested area. As bat density of the two target species is likely low in the YBA, the true impact of the proposed change in hydrology is limited. Results of the analysis on changes in inundation at culverts/bridges showed that Alternative 2 had nine fewer culverts/bridges that would be inundated under this scenario. This may likely mean that these nine culverts have increased suitability for bats, thereby serving to increase bat roosting habitat. This is especially important as the sites are used during the winter hibernation period. Although backwater flooding events that would have initiated pumping activity over the POR have been rare during months of hibernation, pumping would have been initiated 1 Mar 2019 and 30 Jan 2020 at the start of extensive flooding events If extensive flooding were to occur in the winter season, bats in hibernation would not be able to arouse and move quickly enough, likely resulting in direct mortality events at flooded culverts or bridges. While tri- colored bats are known to heavily use culverts/bridges, northern long-eared bats also use these sites and thus both bat species might benefit from Alternative 2.

Overall, the small differences in distance to water and inundated forest along with a decrease in flooding at bridges and culverts, between the base and preferred alternative likely illustrates the lack of significant negative impact of Alternative 2 on bat populations. Similarly, because pumping durations would be equal to or less than Alternative 2 under the Alternative 3 scenario (up to 10 fewer days of pumping), there would be no significant negative impact to bat habitat under Alternative 3.

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