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Forest Area to Support Landbird Population Goals for the Mississippi Alluvial Valley

Open-File Report 2020–1097
Version 1.1, August 2021

U.S. Department of the Interior
U.S. Geological Survey

Cover: Prothonotary Warbler

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By Daniel J. Twedt and Anne Mini

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	2.54	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	10.764	square feet (ft^2)
hectare (ha)	2.471	acre
hectare (ha)	0.003861	square mile (mi^2)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Abbreviations

BBS	North American Breeding Bird Survey
BCR	Bird Conservation Region
CI	credible interval
GIS	geographic information system
GPS	global positioning system
MAV	Mississippi Alluvial Valley
max	maximum
PIF	Partners in Flight
SD	standard deviation
USGS	U.S. Geological Survey
$>$	greater than
$\geq$	greater than or equal to
$<$	less than
$\leq$	less than or equal to

Forest Area to Support Landbird Population Goals for the Mississippi Alluvial Valley

By Daniel J. Twedt[1] and Anne Mini[2]

Abstract

Historically, the Mississippi Alluvial Valley (MAV) (Partners in Flight Bird Conservation Region #26) was predominantly bottomland hardwood forest, but natural vegetation has been cleared from about 80 percent of this ecoregion and converted primarily to agriculture. Because most bird species that are of conservation concern in this region are dependent on forested wetlands, bottomland hardwood forest is the habitat of greatest conservation concern in the MAV. Past conservation planning for forest-dwelling birds in this region has focused on habitat objectives with presumptions regarding bird population goals being met through habitat provision. To better define population objectives, we estimated current populations of silvicolous birds on the basis of detections during 10 years of North American Breeding Bird Surveys (BBS). For each species, we used their estimated population and historical (1966–2015) change in their relative abundance, as assessed from BBS data, to establish regional population goals. We used the variance associated with historical BBS trends to estimate the minimum forest area required to sustain greater than or equal to (≥) 25 breeding pairs, which we combined with predicted probability of occupancy to identify sustainable forested habitat. For 54 species, we used published empirical density estimates, as affected by forest management, to estimate the proportion of the population objective that could be provisioned within sustainable forest patches. The area of presumed population-sustaining habitat, under existing forest management, was sufficient to support the species' population objective for 23 species. We estimated that the target populations of seven additional species (Black-and-white Warbler, Brown Thrasher, Cerulean Warbler, Eastern Towhee, Indigo Bunting, Wood Thrush, and Yellow-breasted Chat) could be supported by current forest area through widespread changes in forest management. Target populations of seven other species (American Robin, Barred Owl, Boat-tailed Grackle, Chipping Sparrow, Eastern Phoebe, Mississippi Kite, and Red-headed Woodpecker) were accommodated within the MAV when populations in both forest and nonforest habitats are considered. For the remaining 20 species, we estimated the population increase needed to achieve their population goals. For these species, we estimated the additional area of forest restoration required to achieve their population goal within sustainable forest patches or, alternatively, the additional area of occupied habitat required to support their population goal within both forest and nonforest habitat. An additional 700,000 hectares of sustainable forest habitat may be enough to attain the forest-dependent population goals for most bird species within the MAV.

Introduction

Historical Background

The Partners in Flight (PIF) Bird Conservation Plan for the Mississippi Alluvial Valley, version 1 (Twedt and others, 1999), established avian population goals for this bird conservation region that were based on bottomland hardwood forest habitat objectives (Mueller and others, 2000). That plan surmised that source populations of high priority species such as Swainson's Warbler (scientific names in appendix 1), Prothonotary Warbler, Cerulean Warbler, and Swallow-tailed Kite would require contiguous patches of interior (that is, core) forest habitat encompassing greater than (>) 1.5 million hectares (ha) of bottomland forest that were distributed among 87 discrete bird conservation areas that were composed of 13 patches > 40,000 ha (100,000 acres), 36 patches > 8,000 ha (20,000 acres), and 52 patches > 4,000 ha (10,000 acres). Each patch of forest was presumed capable of harboring ≥ 500 pairs of each bird species dependent on a specified forest patch area. An arbitrary population goal of 500 breeding pairs (1,000 breeding individuals) per forest patch was adopted for MAV conservation planning as a population that was likely enough to buffer negative effects on reproductive success. Although minimum viable populations vary widely among species, generalized minimum viable population estimates have ranged from 250 (Reed and others, 1988) to several thousand (Flather and others, 2011). As such, ≥ 500 breeding pairs were deemed

[1] U.S. Geological Survey

[2] Lower Mississippi Valley Joint Venture

unlikely to be extirpated from bird conservation areas that harbored sufficient forest area.

The avian population goals stated within the 1999 Bird Conservation Plan for the Mississippi Alluvial Valley (Twedt and others 1999) were thus based on the amount of buffered forest interior (that is, forest core) habitat capable of supporting ≥ 500 breeding pairs of bird species of high conservation priority. Species of lower conservation priority were assumed to occur at higher densities than species of high conservation priority and therefore would be present within forest patches that composed Bird Conservation Areas at populations ≥ 500 breeding pairs. Notably, forest habitat objectives, and subsequently derived avian population goals, were based largely on the geographic distribution and condition of extant forest as well as perceived forest restoration opportunities. The resultant 1999 avian population goals were distributed among three forest-area classes on the basis of habitat availability (that is, the number of forest patches of sufficient size presumed capable of supporting ≥ 500 breeding pairs). These avian population goals were not species specific, nor were they tied to a species' conservation status (for example, population size, trend in abundance, or threats to population). In addition, since publication of the 1999 Bird Conservation Plan for the Mississippi Alluvial Valley, extensive reforestation within this region has increased the availability of forest habitat (King and others, 2006; Mitchell and others, 2016).

Current Approach

We sought to establish species-specific avian population goals for the Mississippi Alluvial Valley Bird Conservation Region that were based on (1) each species' current estimated population, (2) an empirically derived minimum sustainable population for the species, and (3) the species' historical population trend. Data collected under the auspices of the North American Breeding Bird Survey (BBS; Pardieck and others, 2019) were used to estimate species' populations, their probable minimum sustainable population, and their historical trends (Sauer and others, 2017). We subsequently evaluated the present state of forest habitat in the MAV to assess its capacity to provision avian population goals. This perceived capacity afforded knowledge regarding achievement of habitat objectives required to support desired avian populations, or alternatively, identified the area of additional habitat needed to support a species' population goal.

Our objectives were to (1) establish population goals for forest-dwelling (silvicolous) bird species in the MAV based on quantitative, regional avian surveys; (2) estimate the minimum sustainable population of each species that has a low likelihood (less than or equal to [≤] 1 percent) of extirpation over a 100-year interval; (3) estimate probability of occupancy of these species relative to measurable landscape covariates such as forest cover, flood frequency, and geographic location; (4) determine the minimum area of forest habitat required to support a sustainable population for each species based on published density estimates in forest habitat; and (5) estimate the population of each breeding species within those forest patches deemed capable of supporting sustainable populations of the species.

If the estimated regional population of a species, summed for all "sustainable populations," was less than the MAV population goal for that species, we hypothesize that additional management actions are likely required to attain the stated population goal. Possible management actions include (1) alteration of the type of silvicultural management (Twedt, 2012); (2) increasing the area of forest habitat through forest restoration (Twedt and others, 2006); or (3) for species not entirely dependent on forest habitat, identifying landscape changes likely to increase the area of occupied habitat.

Study Area

The Mississippi Alluvial Valley Bird Conservation Region (BCR; http://nabci-us.org/resources/bird-conservation-regions-map/#bcr26) is 11 million ha (24 million acres) that span seven states, Illinois, Missouri, Arkansas, Kentucky, Tennessee, Mississippi, and Louisiana (fig. 1).

Differences in topography and hydrology are expressed in 14 designated physiographic provinces (Chapman and others, 2004) composed of relatively flat, weakly dissected alluvial plains, natural levees, basins, and flats, point-bar formations, terraces, tributary floodplains, and depressional wetlands that extend from Cape Girardeau, Missouri, southward to the Gulf of Mexico (fig. 2). Elevation ranges from 0 to 200 meters (m) (0–660 feet). Local change in elevation is typically less than (<) 30 m but reaches 100 m along ridges and bluffs bordering the mainstem Mississippi River. For our analyses, we used the BCR boundary, as refined by the Lower Mississippi Valley Joint Venture, which well delineates the transition from alluvial floodplain and deltaic lands to upland habitats (http://www.arcgis.com/home/item.html?id=c72185797b564b5995f44e9bc367163e). We included all upland areas that were wholly contained within the boundary of this BCR (fig. 2).

Historical natural vegetation for most of the BCR is southern floodplain forest, dominated by oak-gum-cypress and elm-ash-cottonwood cover types. Codominant species within these forest types include overcup oak (*Quercus lyrata*), willow oak (*Q. phellos*), Nuttall oak (*Q. texana*), water oak (*Q. nigra*), sweetgum (*Liquidambar styraciflua*), water tupelo (*Nysssa aquatica*), American sycamore (*Platanus occidentalis*), sugarberry (*Celtis laevigata*), elms (*Ulmus* spp.), water hickory (*Carya aquatica*), baldcypress (*Taxodium distichum*), green ash (*Fraxinus pennsylvanica*), and other species (Oswalt, 2013).

Oak-hickory cover type forests occupy upland inclusions and the bordering loess bluffs. Codominant species in these upland forests include post (*Q. stellate*), southern red (*Q. falcata*), black (*Q. velutina*), Chinkapin (*Q. muehlenbergii*), and white (*Q. alba*) oaks along with shellbark *(C. laciniosa*),

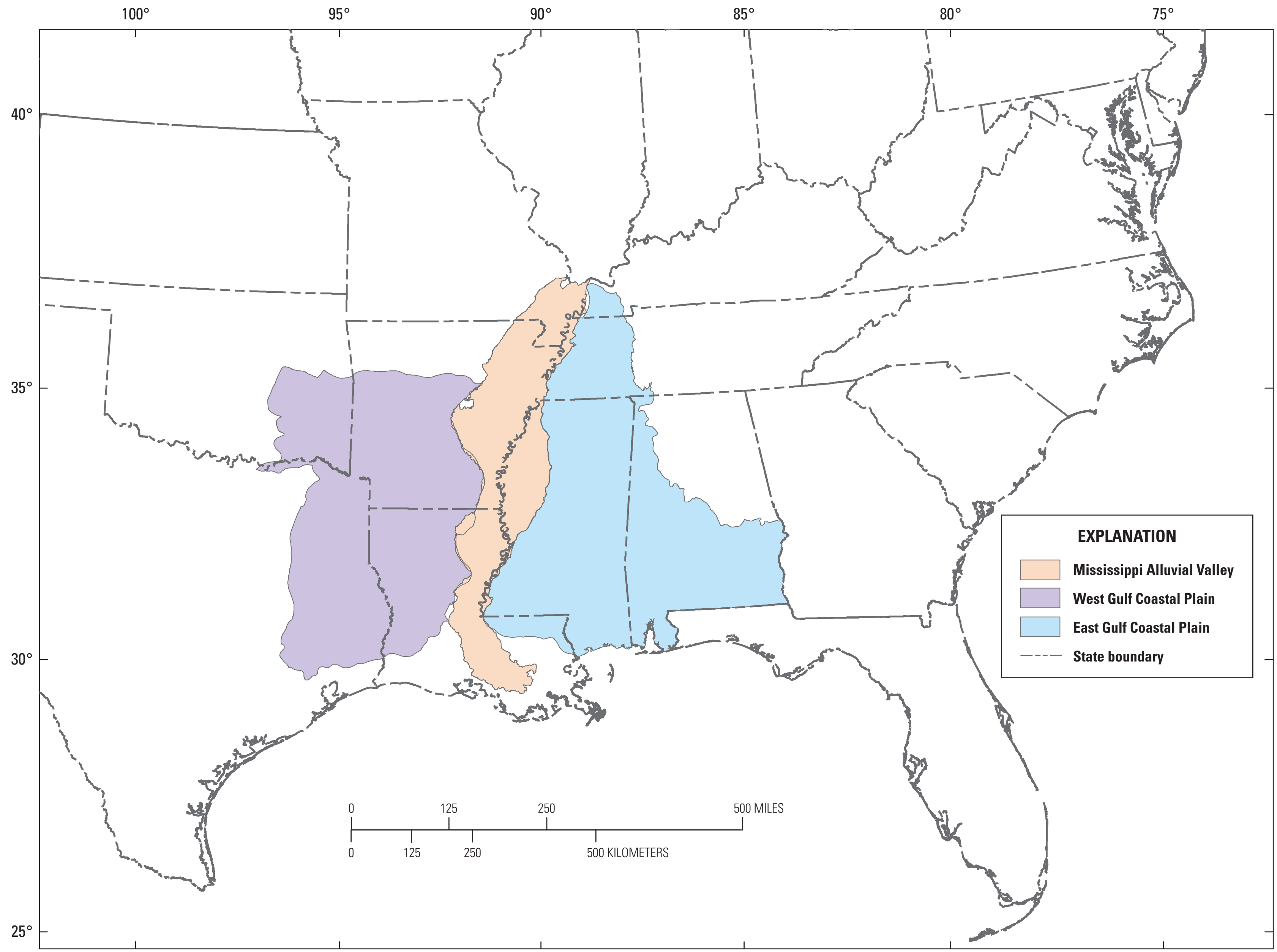

Figure 1. Bird Conservation Regions in the south-central United States.

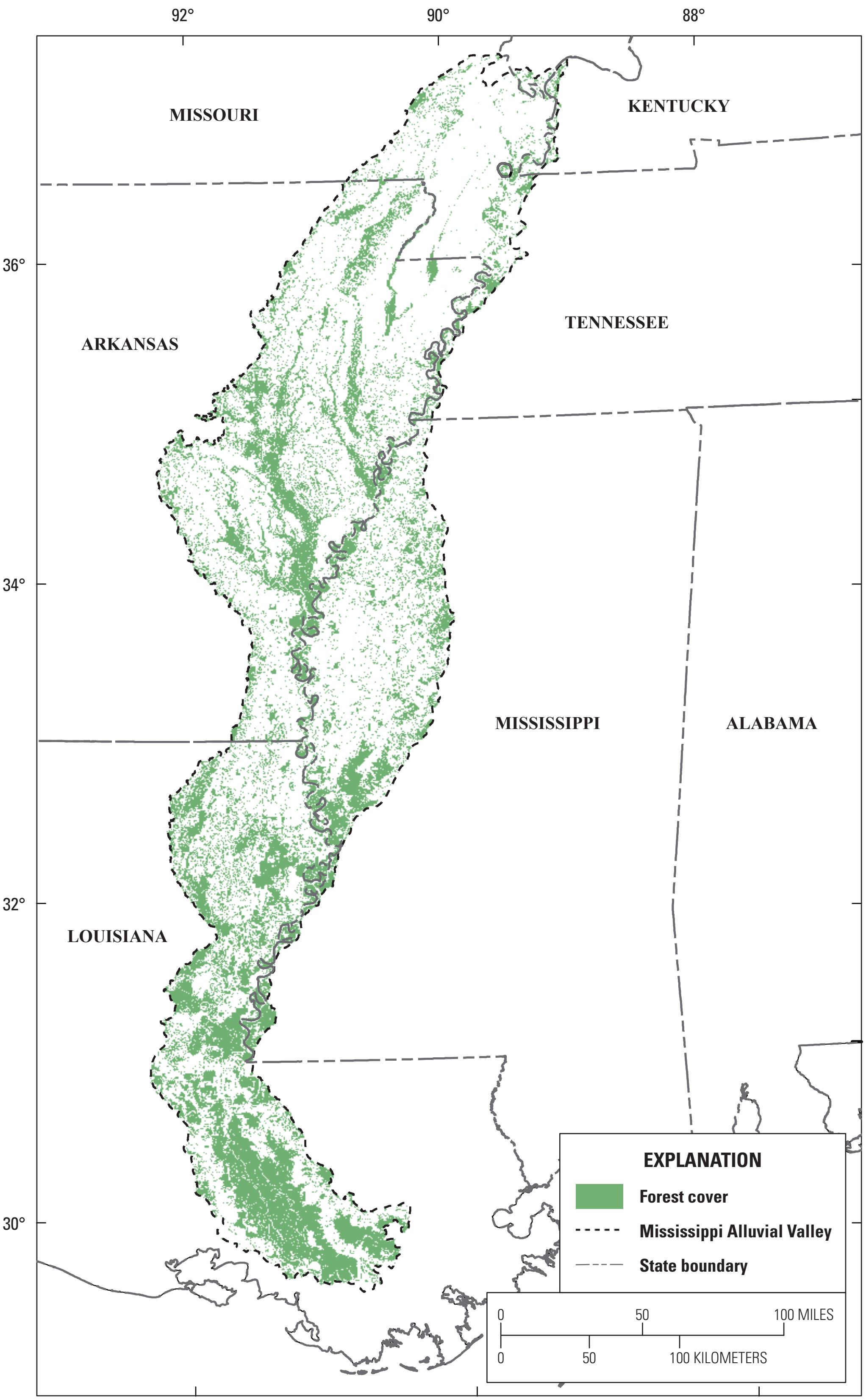

Figure 2. Boundary of and forest cover (Mitchell and others, 2016) in the Mississippi Alluvial Valley Bird Conservation Region (https://doi.org/10.5066/P90V76SY).

shagbark (*C. ovata*), and mockernut (*C. tomentosa*) hickories. Isolated native prairies within the MAV historically had bluestem (Andropogon spp.) and switchgrass (Panicum virgatum) as dominant grasses.

Average annual precipitation is 114 to 165 centimeters (cm) (45–65 inches). Historically extensive flooding dictated vegetative conditions within this BCR, but levees, dikes, and dams have altered the hydrology of the MAV (King and Keim, 2019). These hydrologic changes have affected the composition and structure of the remaining forest (Keim and others, 2006; Gee, 2012). Natural vegetation has been cleared from about 80 percent of this BCR (Rudis and Birdsey, 1986; Twedt and Loesch, 1999) and primarily converted to agriculture. Crops are principally cotton, soybean, and rice, but pasture, corn, sorghum, or sugar cane may be locally prevalent.

Methods

Population Estimation

To estimate current populations of silvicolous bird species within the MAV, we used time and distance at first detection data that were collected during North American Breeding Bird Surveys within the MAV from 2009 to 2015 (appendix 2, https://doi.org/10.5066/P9AFKXXK) following the methods identified by Twedt (2015). We supplemented these distance-time data with surveys of BBS routes wherein data were recorded using standard 3-minute observation periods (that is, no time or distance information collected) within the MAV from 2006 to 2015 (Pardieck and others, 2019).

Each BBS route encompassed 50 point-count locations (that is, stop locations; appendix 3, https://doi.org/10.5066/P9AFKXXK) that were separated by about 800 meters (m) (0.5 miles). At each count-location, a 3-minute duration, stationary point count was used to survey birds (Hamel and others, 1996). All surveys were conducted using BBS protocols wherein all individuals of each species heard or seen within 400 m (half the distance between count-locations) of the observer were recorded (https://www.pwrc.usgs.gov/BBS/participate/training/). On some routes that were surveyed from 2009 to 2015, observers also recorded (1) the time of first detection in 1-minute time intervals (0:00–0:59 minute, 1:00–1:59 minutes, or 2:00–2:59 minutes), and (2) the distance in two categories (≤50 m and >50 m) at which an individual was first detected (Sauer and others, 2019). Individual birds were recorded only once (at their first detection), not during each time interval during which they were detected. Thus, the sum of detections for each bird species in all distance-time categories was the species total reported when using standard BBS protocols.

There were 68 BBS routes (17 in Arkansas, 1 in Illinois, 1 in Kentucky, 27 in Louisiana, 15 in Mississippi, 4 in Missouri, and 3 in Tennessee) with count-locations within or adjacent to the MAV (fig. 1). Bird detections could only be associated with habitat in the MAV if they were recorded at a count-location within 400 m of the BCR boundary. Therefore, we limited data used for analyses to only those count-locations that were within a 400-m buffer surrounding the MAV. After count-locations beyond this boundary were truncated, we retained data from 2,912 count-locations (743 in Arkansas, 19 in Illinois, 20 in Kentucky, 1,129 in Louisiana, 713 in Mississippi, 166 in Missouri, and 121 in Tennessee). However, not all BBS routes were surveyed during all years of study and it was rare that a BBS route was surveyed more than once during a given year. We used all available data, which provided observations from 23,462 unique visits to count-locations.

Of these unique visits, 4,012 included information on time and distance to first detections of a species. For our analyses, we assumed that species detected during standard BBS counts had the same distance-time distribution as that of species' detections during distance-time counts. Accordingly, we assigned detection distance-time class on the basis of the observed distribution of the species. For species with ≥100 detections during distance-time-based BBS within the MAV, we used only MAV data to ascertain the distance-time distribution, but for species with <100 detections in the MAV, we expanded the dataset of distance-time BBS routes used to ascertain the distance-time distribution to include routes surveyed within the East and West Coastal Plain Bird Conservation Regions (fig. 1; Twedt, 2015; appendix 2, https://doi.org/10.5066/P9AFKXXK).

Within each distance category (i) during each time interval (j), we estimated the expected number of birds counted (X_{ij}) as defined by Farnsworth and others (2005) and applied by Twedt (2015) on the basis of the probability a bird is detected (ρ), which is a function of the probability a bird vocalizes or appears (P_a), with detection declining with increased distance from the observer proportional to effective detection distance (σ). We then estimated species-specific bird densities by using equation 1:

$$\widehat{D} = \frac{X..}{n\,\pi\,\widehat{\sigma}^2\left(2\widehat{P}_a - \frac{\widehat{P}_a^2}{2}\right)},$$

where

$\hat{D}$ is the estimated bird density (birds per square meter),

X.. is the number of birds counted,

n is the number of count-locations surveyed,

π is pi (about 3.1415),

$\hat{\sigma}$ is the effective detection distance in meters, and

$\hat{P}_a$ is the probability a bird vocalizes or appears for detection.

Estimated species densities were subsequently extrapolated to the area of the MAV occupied by each species (Partners in Flight Science Committee, 2013).

Even though bird populations were not constant among years of our study, we assumed that "bird territories" were constant among years, though individual birds may have changed among years. Additional assumptions of our analysis were that (1) birds did not move during the count period, (2) the probability a bird vocalized (or was otherwise available for detection) was the same for all birds of a species and constant throughout the count period, (3) birds were correctly assigned to distance categories, (4) birds are correctly identified and only counted once, and (5) bird detections are independent (Farnsworth and others, 2005).

Independence of detections was likely violated when species were detected in flocks. To address this concern, we calculated the mean number of detections per BBS count-location. We evaluated species with >2 detections per count-location, considered the likelihood of bias in detections associated with the species' behavior during the breeding season, and assessed the presumed inflationary effect on our population estimates. For 12 species (Barn Swallow, Black Vulture, Brown-headed Cowbird, Chimney Swift, Cliff Swallow, Common Grackle, European Starling, House Sparrow, Indigo Bunting, Northern Rough-winged Swallow, Purple Martin, and Red-winged Blackbird), we deemed nonindependence of detections likely to have inflated our population estimate. For these species, we used the more conservative population estimates provided within the Partners in Flight Population Estimates Database (Partners in Flight Science Committee, 2013), as these estimates were not dependent on time and distance of detections.

We estimated species densities that resulted from projecting our estimated species populations to the area of forest in the MAV (3,307,910 ha; Mitchell and others, 2016) or, for those species whose range does not encompass the entirety of the BCR (Partners in Flight Science Committee, 2013), the area of forest proportional to the range of the species within the MAV. For this BCR-wide density estimate, we assumed that the entire BCR population of the species had territories within forest habitat. For those species for which occupancy within the MAV was estimated, we also estimated their densities based on projection of species populations to the area of the MAV deemed occupied. Finally, we assessed the conformity of these projected BCR-wide avian densities with species densities that were independently reported from autecological studies in bottomland hardwood forests within this region (Norris and others, 2009; Twedt and Wilson, 2017).

Comparison with Previously Estimated Bird Populations

We compared our population estimates with those published for the MAV in the PIF Population Estimates Database (Partners in Flight Science Committee, 2013; Blancher and others, 2013). In addition, we updated the PIF database estimates, which was based on 1998–2007 BBS data (http://rmbo.org/pifpopestimates/), to reflect the average number of birds detected on random (that is, BBS route number <900) Breeding Bird Survey routes in the MAV during 2007–16. Additionally, for those species for which it was possible, we replaced the PIF categorical detection distance with an estimated effective detection distance that was empirically derived from Breeding Bird Surveys in the MAV. By definition, these effective detection distances represent the distance at which as many individuals of a species are detected within as beyond this distance (Thomas and others, 2002). Therefore, we surmised that half of all BBS detections of a species were within the effective detection distance.

Establishment of Population Goals

On the basis of published 1966–2015 avian population trend estimates for the MAV (Sauer and others, 2017), we categorized species as having (1) a positive (upward) population trend, including all values within the credible interval (CI) for the trend estimate; (2) a positive (upward) population trend, but one that included a negative (downward) trend value as the lower limit of the CI for the trend estimate; or (3) a negative (downward) trend estimate. For those species with a positive population trend (inclusive of CI), we assumed our current population estimate sufficed as the population goal for the MAV. For species with an apparent positive trend (although one with a CI that indicated a possible downward trend), we established a population goal that was the current population estimate retrojected by the lower CI value for 50 years. For species with a negative population trend from 1966 to 2015, we established a population goal that was the current population estimate retrojected by the negative trend estimate for 50 years. We exempted five nonnative species, Cattle Egret, Eurasian Collared-Dove, European Starling, House Sparrow, and Rock Pigeon, adopting a population goal for these species of no more than their current estimated population.

Estimation of Species Occupancy

We estimated rates of occupancy (Mackenzie and Nichols, 2004; Mackenzie and others, 2003, 2017) by silvicolous bird species in the MAV by using the distance-time BBS data we used for population estimation. However, BBS data for 2016 became available online prior to these analyses and we updated our dataset to included surveys spanning 10 years (2007–16). Typically, BBS routes were surveyed only once per year, but during 2010 and 2011 a few routes were surveyed up to four times during a year. Similarly, during 2012, 2014, and 2015 some routes were surveyed twice during a single year. In total, 20,668 different visits to count-locations during 2007–16 were used for occupancy analyses. The number of unique visits to count locations differs from that used for population estimation because of the different time periods considered (2006–15 and 2007–16).

We used presence (1) or absence (0) of a species detected within each 1-minute detection interval at any distance in our analyses. Because only the first detection of an individual bird was recorded during Breeding Bird Surveys (that is, a removal model; Farnsworth and others, 2002), once a species was detected, all subsequent 1-minute intervals during the same survey at a count-location (that is, during a 3-minute count period) were truncated from the analysis for that species.

We combined the presence-absence data from Breeding Bird Surveys with landscape data for geolocation, flood frequency, and habitat context as spatial covariates. Geolocation variables of latitude and longitude were standardized for values within our study area (X = -1.857 – 2.430; Y = -4.467 – 3.275). Forest habitat data at each geolocation included proportion (range = 0–1) of forest area, proportion of forest core, and proportion of forest edge derived from classification of 2011 Landsat imagery (Mitchell and others, 2016; http://gisweb.ducks.org/mavplanning/). Forest core included all forest habitat >250 m from nonforest habitats (Lower Mississippi Valley Joint Venture, 2015). In contrast, forest edge was all forest habitat within 60 m of nonforest habitat. We also included the proportion of urban/developed habitat based on the 2011 National Land Cover Dataset (https://www.mrlc.gov/nlcd2011.php; NLCD 2011 Land Cover). For our analyses, we included the proportions of area that were in these forest metrics (forest area, forest core, and edge habitat) as well as urban/developed habitat within three different radial distances: ≤200 m, ≤500 m, and ≤2,000 m.

A measure of the openness of forest canopy was obtained from the 2011 National Land Cover Dataset (https://www.mrlc.gov/nlcd2011.php; NLCD 2011 USFS Tree Canopy analytical). Likelihood of surface water at a location was derived from a Gulf Coastal Plain and Ozarks inundation frequency mosaic (Allen, 2015). These flood-frequency data were based on the frequency of observed flooding on a chronosequence of Landsat imagery (Allen, 2016). For our analyses, we determined the mean proportion of tree-canopy cover and the mean likelihood of flood inundation (range = 0–1) for all pixels within the three previously used radial distances: ≤200 m, ≤500 m, and ≤2,000 m.

Count-locations along BBS routes are ostensibly geographically fixed and observers stop at the same locations each year. In application, however, their geographic positions may be inaccurately known and, therefore, count-locations may vary slightly among years or among observers. We accounted for possible inaccuracies in geolocation of BBS count-locations by sorting their perceived accuracy into three categories (appendix 3, https://doi.org/10.5066/P9AFKXXK):

(1) The most accurate category was presumed to be BBS count-locations with geospatial coordinates that were reported by means of a global positioning system (GPS). In comparison to other locations, we assumed that landscape data were accurately associated with these locations. Even so, we accounted for minor variations in count-locations by averaging spatial covariate data associated with these locations for all pixels within 100 m of the location coordinates.

(2) Many count-locations have not been located using GPS technology but have descriptive identifications of their locations that allow likely geographic coordinates to be assigned using remote-sensing technology. Accordingly, for count-locations with sufficient descriptive information, such as "at the junction of Highway 78 & Route 53," or "at entrance to Freewill Baptist Church," we located these descriptive locations on satellite imagery using Google Earth (version 7.1.5.1557; https://www.google.com/earth/) and assigned those respective geographic coordinates to the count-location. Other count-locations along these routes that lacked precise descriptive identifications were assumed to be at the specified 0.5-mile (800-m) distance between count-locations along the designated route of travel. Because we were less certain of the accuracy of all count-locations along BBS routes in this category, we averaged spatial covariate data associated with these locations for all pixels within 200 m of the assigned location coordinates.

(3) Finally, a few BBS routes lacked geospatial information for count-locations, except for the geographic coordinates of the starting location and a mapped route of travel. For these BBS routes, we assigned geographic coordinates to count-locations at 0.5-mile (800-m) intervals along the designated route of travel. As these assigned geographic coordinates of count-locations are likely inaccurate, when taken over the entirety of the 25-mile (40-km) BBS route, we averaged the spatial covariate data associated with each of these count-locations for all pixels within 300 m of the assigned location coordinates.

We estimated occupancy by silvicolous birds in R (version 3.4.4; https://www.r-project.org/) by using the "colext" function of the Unmarked package (version 0.12-0; Fiske and Chandler, 2011) to fit colonization-extinction models (MacKenzie and others, 2003). Site occupancy, as well as colonization, and extinction rates were modeled with covariates (as described above) that varied among sites by using a logit link. The conditional detection rate was modeled with and without the day of year (DOY) the survey was conducted as a covariate that varied among sampling periods (that is, repeated surveys). Thus, we estimated four parameters: ρ, the probability of detecting the species; ψ, the probability that a surveyed location is occupied by the species; ε, the probability of extirpation from a survey location; and γ, the probability of colonization of a survey location (MacKenzie and others, 2003, 2006). We used Akaike information criteria (AIC; Burnham and Anderson, 2002) to evaluate performance of a null model (without covariates) and 153 additional models that assessed the effects of geographic coordinates and habitat context covariates on ψ, ε, and γ, as well as the effect of day of year on ρ (appendix 4). Although canopy cover and proportion of forest were correlated (table 1), we retained both variables in models to assess the effect of forest openness on species occupancy. When more than one model had substantial support, we used the respective model weights to spatially predict occupancy relative to covariate effects (appendix 5).

Marked geographic skewing of occupancy probability was noted for a few species, despite their having no known range limitation within the MAV. These geographic differences likely resulted from sparse detections of the species on few BBS routes. For these species, we removed the longitude (X) or both geographic covariates (X and Y) and repeated the above model-selection process. Geolocation covariates that were removed are reported with an "na" covariate designation

Table 1. Summary statistics and correlations among covariates used to model probability of occupancy of forest-dwelling birds in the Mississippi Alluvial Valley.

[F = proportion of forest, U = proportion of urban/developed, E = proportion of forest edge within 60 meters (m) of nonforest habitat, C = proportion of forest core greater than 250 m from nonforest habitat, W = mean probability of flooding, A = mean canopy cover. Summary statistics are maximum (max), mean, and standard deviation (SD).]

	Correlations						Summary statistics		
Covariate	**F**	**U**	**E**	**C**	**W**	**A**	**Max**	**Mean**	**SD**
200-m radius									
F	1.0000	-0.0839	0.3452	0.6802	0.1320	0.9098	1.0000	0.3067	0.3919
U	-0.0839	1.0000	-0.0011	-0.0733	-0.0906	-0.0700	1.0000	0.0165	0.0795
E	0.3452	-0.0011	1.0000	-0.2207	0.0296	0.2562	0.7785	0.0536	0.0848
C	0.6802	-0.0733	-0.2207	1.0000	0.0780	0.6864	1.0000	0.1112	0.2851
W	0.1320	-0.0906	0.0296	0.0780	1.0000	0.1058	1.0000	0.1449	0.2098
A	0.9098	-0.0700	0.2562	0.6864	0.1058	1.0000	1.0000	0.2809	0.3398
500-m radius									
F	1.0000	-0.0892	0.3701	0.7652	0.1850	0.9313	1.0000	0.3068	0.3530
U	-0.0892	1.0000	-0.0016	-0.0863	-0.1007	-0.0727	1.0000	0.0165	0.0681
E	0.3701	-0.0016	1.0000	-0.1835	0.0314	0.2660	0.5760	0.0535	0.0613
C	0.7652	-0.0863	-0.1835	1.0000	0.1231	0.7768	1.0000	0.1113	0.2564
W	0.1850	-0.1007	0.0314	0.1231	1.0000	0.1552	1.0000	0.1449	0.1798
A	0.9313	-0.0727	0.2660	0.7768	0.1552	1.0000	1.0000	0.2809	0.3082
2,000-m radius									
F	1.0000	-0.0894	0.3786	0.8588	0.3023	0.9582	1.0000	0.3080	0.2865
U	-0.0894	1.0000	-0.0047	-0.0931	-0.1196	-0.0669	0.9101	0.0166	0.0508
E	0.3786	-0.0047	1.0000	-0.0870	0.0411	0.2704	0.3038	0.0535	0.0386
C	0.8588	-0.0931	-0.0870	1.0000	0.2457	0.8756	1.0000	0.1124	0.2051
W	0.3023	-0.1196	0.0411	0.2457	1.0000	0.2628	1.0000	0.1442	0.1285
A	0.9582	-0.0669	0.2704	0.8756	0.2628	1.0000	0.9996	0.2821	0.2533

(appendix 6).

Estimation of Minimum Sustainable Populations of Silvicolous Bird Species

Using each species' relative population trend and associated credible intervals from historical (1966–2015) BBS data (Sauer and others, 2017), we estimated a minimum sustainable population for each silvicolous bird species in the MAV. The minimum sustainable population for each species was assumed to be the number of birds needed to ensure ≤1-percent probability that the population would be extirpated (that is, drop below a quasi-extinction threshold) during a 100-year period wherein annual population change was randomly selected from the CI associated with each species' population trend. We used the mean of 500 simulation replicates conducted in R (version 3.4.4; https://www.r-project.org/) as the presumed minimum sustainable population for each species. We arbitrarily set the quasi-extinction threshold at 25 breeding pairs. Because species with CIs associated with their trend estimates that were inclusively positive never declined in population, by default these species had a minimum sustainable population of 25 pairs.

Estimation of Area and Population in Sustainable Habitats

We uniquely identified and calculated the area in hectares for each contiguous forest patch in the MAV (fig. 2) using ERDAS Imagine 11.0.1 (https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine). We used the Raster Clump function to group contiguous forest patches. Patches were separated by at least one pixel (900 square meters [m^2]) around the entirety of the patch, such that corner connections (that is, diagonally connected pixels) retained continuity of the patch. We subsequently evaluated the capacity of each of these contiguous forest patches to harbor sustainable populations of a species.

We obtained published empirical estimates of avian densities within bottomland forests in the MAV. For most species, we used densities estimated for both silviculturally untreated (that is, control) stands and for stands subjected to silvicultural management (Norris and others, 2009; Twedt and Wilson, 2017). Densities for managed stands were associated with wildlife-forestry prescriptions (Twedt and Wilson, 2017) or with individual tree removal, group selection harvest, or more extensive harvest (for example, shelterwood) prescriptions (Norris and others, 2009). For some species, these primary sources for avian densities were augmented with empirical density estimates from other published sources. We used the average density among forest-stand treatments to estimate the minimum area capable of supporting a sustainable population as the minimum sustainable population/mean density. However, maximum occupancy by the species is assumed in this calculation of this minimum area. To account for variation in rates of occupancy, we assumed only forest patches wherein the product of their patch area (in hectares) and the probability of occupancy (0–1) exceeded this minimum area threshold were likely able to support a sustainable population.

After limiting habitat to only those forest patches deemed likely able to support a sustainable population of the species, we assumed that the probability of occupancy by the species was a proxy for the proportion of habitat occupied. Thus, the probability of count-site occupancy (ψ) approximated the proportion of area (that is, count sites) occupied by the species (Bailey and others, 2004; MacKenzie and Nichols, 2004; Zeller and others, 2011). Consequently, within each suitable patch, we assumed that the area of occupied habitat was that proportion of each 900-m^2 pixel that was deemed occupied (that is, ψ * 900). When these proportional areas were summed over the entirety of the BCR, this area effectively represented the total area of occupied habitat for sustainable populations of the species within the MAV.

We estimated each species' population within habitats harboring sustainable populations based on the species' likely densities within the MAV. However, these densities likely reflect past forest-management practices (Norris and others, 2009; Twedt and Wilson, 2017). To account for forest management, we used the U.S. Forest Service's Forest Inventory and Analysis (FIA) database (https://apps.fs.usda.gov/fia/datamart/datamart.html) to estimate the proportion of forest stands likely to have been subjected to management (that is, timber harvest). We found that of 2,574 FIA forest plots surveyed during 2006–13 within the counties that compose the MAV, 367 (14 percent) had evidence of silvicultural treatment within the past 5 years: 270 plots had cut trees whereas the remaining plots had other signs of silvicultural treatment (for example, regeneration). Of the cut FIA plots, 69 (26 percent) had been clear cut, with the remaining plots having been predominantly subjected to partial harvest (131 plots) or thinning (53 plots). We used density estimates for each species that were associated with silvicultural treatments proportional to the application of these treatments within the MAV. We then estimated each species' population as the number of territories that could be located within the entirety of occupied habitat within the MAV at these management-proportional species densities. In addition, we estimated a theoretical population for each species under the provision that different forest-management regimes (for example, no harvest, wildlife forestry, group selection, and so on) were assumed to be applied to all forest habitat. For each species, their estimated population provided our best estimate of the current capacity of MAV forests to provide habitat, and the largest theoretical estimate was the population that could be supported under optimal forest-management practices.

Establishment of Habitat Objectives

If a species' population goal was accommodated by the species' population within habitats harboring sustainable populations under existing management conditions, the extant habitat was presumed to be sufficient for the species. Where a species' population goal exceeded the capacity of extant habitat conditions to sustain that population, we examined the effect of changing management regime on populations. We ascertained whether the increase in population that would result from optimizing application of silvicultural treatments would be sufficient to meet the species' desired population goal. If change in forest management was deemed insufficient to achieve a species' population goal, we estimated the area (in hectares) of additional forest that would likely be required to attain each species' population goal given existing forest management and, alternatively, under optimal forest management.

For some species (for example, Orchard Oriole), predicted occupancy outside forest habitat was substantial. Therefore, a sizeable proportion of the population of these species likely occurs in nonforest habitat. For those species whose population goal was not deemed attainable within sustainable forest habitat and that had marked occupancy in nonforest habitat, we estimated their population within all habitats (except permanent water) in the MAV. If the area of all occupied habitat (forest and nonforest) was sufficient to achieve a species' population goal, we assumed that species' population goal was achieved, although we made no assertion regarding the sustainability of these species' populations. Where all occupied habitats were insufficient to achieve a species' population goal, we estimated the additional area of occupied habitat that would be required to attain its population goal. Because landscape covariate effects on occupancy varied among species, for each species lacking sufficient habitat to support its population goals we identified habitat conditions that would likely increase occupancy of the species within the MAV

Results

Population Estimates

We were able to estimate populations for 126 species of birds within the Mississippi Alluvial Valley BCR by using distance-time data from Breeding Bird Surveys (table 2). These populations ranged from <100 (Osprey and Scarlet Tanager) to several species with >1 million breeding birds within this ecoregion.

We modified PIF landbird population estimates (table 3; Partners in Flight Science Committee, 2013) to include an updated (2007–16) average number of detections of a species per BBS route and the effective detection distance derived from distance-time-based BBS data for 101 species. These modifications resulted in an increased estimated population for 85 species (table 3). Only 22 of the original PIF population estimates were within the confidence intervals of distance-time-based population estimates (table 2), whereas 39 of the population estimates that incorporated the revised detection-distance estimate were within these confidence intervals.

As our target population was forest-dwelling birds, we further examined a subset of presumed silvicolous avian species (table 4). When we assumed that the estimated avian populations of these species were equally distributed among all areas of forest habitat in the MAV that were within the species' range, the resulting densities ranged widely. However, for 41 species whose avian densities were reported from empirical studies within bottomland hardwood forests of the Mississippi Alluvial Valley BCR, our projected densities of most of these species (61 percent) were less than the range of avian densities from empirical studies (table 4). Consequently, only 13 of 41 species (32 percent) had projected density estimates within the range of avian densities reported from empirical studies. For these projections, all forest in the MAV was assumed to be equally occupied, but occupancy at a site within an occupied forest patch can be markedly less than 100 percent (Twedt and Wilson, 2017). Heterogeneous occupancy within forests indicates that projected densities may be less than observed densities.

Bird Population Goals

For each silvicolous species for which we were able to estimate a current population within the MAV, we established a regional population goal (table 5). Of the 126 species for which we established a population goal, 49 species had population goals that were their existing population estimates. For the other 77 species, population goals that exceeded their estimated populations were established by using retrojection of their 1966–2015 population trend (table 5).

Species Occupancy

We were able to estimate naïve occupancy (that is, occupancy without covariate effect) for 54 avian species (table 4). However, Akaike information criteria indicated that models with geographic coordinates and habitat context as covariates, as well as the effect of day of year, were better predictors of occupancy (appendix 5). When more than one model had substantial support (appendix 5), we used spatial models of the predicted species occupancy that were weighted to reflect model confidence (appendix 6). We used the best model (individual or weighted-average model) for each species to depict species occupancy as affected by covariates retained in the most supported models (appendix 7, https://doi.org/10.5066/P9YMSM8I).

Minimum Sustainable Populations of Silvicolous Bird Species

By using CIs associated with long-term population trends within the MAV (120 species) or the entirety of the eastern Breeding Bird Survey Region (7 species), we simulated long-term (100-year) change in their populations within the MAV (table 5). Random change within the CI that was associated with each species' long-term population trends was used as the basis for estimated minimum sustainable populations that ranged from 25 to 1,527 breeding pairs (table 5).

Area and Population in Sustainable Habitats

We assumed that the probability of count-site occupancy (ψ) approximated the proportion of area that was occupied by the species (Bailey and others, 2004; MacKenzie and Nichols, 2004; Zeller and others, 2011). Moreover, we assumed that all count-locations were representative of the entire study area. Consequently, the area occupied by a species was proportional to the probability of site occupancy by that species—that is, if the probability of site occupancy was x percent, then we assumed that x percent of the entire MAV (or range of species if less than the entire area of the MAV) was occupied.

The area of a forest patch that was required to support a minimum sustainable population of each species was determined by accounting for the average observed density of the species (table 6) as well as the predicted spatial probability of occupancy of the species (appendix 7, https://doi.org/10.5066/P9YMSM8I) within the forest patch. We assumed that within each forest patch of sufficient area to support a sustainable population, the area occupied was that proportion of each 900-m^2 pixel equivalent to its spatial occupancy for the species (appendix 8, https://doi.org/10.5066/P9YMSM8I). We summed the product of the probability of occupancy at a site (that is, a pixel value) and the patch area (that is, patch size in hectares) at the site over the entire MAV to estimate the area occupied by a species within patches deemed to be sustainable (table 7).

Table 2. Estimated populations of birds during the breeding season within the Mississippi Alluvial Valley Bird Conservation Region.

[Species populations estimated from distribution of detections at 23,462 point-count stops during North American Breeding Bird Surveys (BBS) conducted 2006–15, as assigned on the basis of distance (≤50 meters and >50 meters) and time (three 1-minute intervals) data from Breeding Bird Surveys conducted from 2009 to 2015. Detection data were used to calculate the proportion of observed distance (∑) that constituted the effective detection distance (EDD) and the probability of detection (ρ) which were used to estimate densities (number of birds per hectare) and their associated confidence limits (CL). Densities were extended to population estimates on the basis of the area within the range of the species in the Mississippi Alluvial Valley (MAV). SE, standard error; km^2, square kilometers; ---, not estimated]

Species	∑	∑ (SE)	EDD	EDD (SE)	ρ	ρ (SE)	Density	Density CL	Area range (km^2)[1]	MAV population	MAV population CL
Acadian Flycatcher	0.113	0.002	45	1	0.818	0.050	0.058	0.049–0.069	103,221	597,418	509,508–713,480
American Crow	0.504	0.014	201	6	0.680	0.020	0.025	0.021–0.029	113,005	280,146	241,097–328,582
American Goldfinch	0.141	0.007	56	3	1.000	0.141	0.007	0.006–0.034	83,431	57,594	47,623–280,491
American Kestrel	0.117	0.009	47	4	1.000	0.186	0.003	0.002–0.006	53,866	16,033	11,937–31,840
American Redstart	0.114	0.006	46	2	0.682	0.127	0.011	0.007–0.019	95,962	103,495	67,912–186,497
American Robin	0.164	0.003	66	1	0.699	0.030	0.073	0.064–0.084	99,365	721,946	633,141–831,388
Anhinga	0.403	0.025	161	10	1.000	0.085	0.003	0.002–0.014	113,005	30,018	23,771–154,317
Baltimore Oriole	0.139	0.004	56	2	0.184	0.076	0.088	0.045–0.486	90,235	796,483	410,549–4,387,023
Bank Swallow	0.147	0.014	59	5	1.000	0.240	0.002	0.001–0.012	9,339	1,884	1,349–11,112
Barn Swallow[2]	0.125	0.001	50	0	0.803	0.019	0.302	0.282–0.324	113,005	3,410,929	3,188,162–3,659,785
Barred Owl	0.379	0.037	152	15	0.307	0.111	0.004	0.002–0.018	113,005	40,114	17,6t03–200,406
Bell's Vireo	0.147	0.046	59	18	0.704	0.599	0.0002	0.0001–0.005	51,915	1,231	364–25,574
Belted Kingfisher	0.168	0.019	67	8	0.565	0.206	0.002	0.001–0.01	99,740	20,064	8,849–104,166
Black Vulture[2]	0.354	0.017	141	7	0.378	0.057	0.012	0.008–0.02	113,005	134,470	89,106–226,700
Black-and-white Warbler	0.112	0.011	45	4	0.954	0.232	0.002	0.002–0.006	89,507	20,940	14,430–52,547
Black-bellied Whistling Duck	0.172	0.010	69	4	1.000	0.144	0.004	0.003–0.022	113,005	47,970	38,349–243,649
Black-crowned Nightheron	0.235	0.021	94	8	1.000	0.181	0.002	0.001–0.009	113,005	17,841	12,873–104,036
Black-necked Stilt	0.267	0.022	107	9	0.690	0.090	0.003	0.002–0.006	113,005	35,338	22,092–63,894
Blue Grosbeak	0.176	0.006	70	2	0.504	0.057	0.028	0.021–0.039	89,216	246,266	184,153–349,709
Blue Jay	0.219	0.004	88	1	0.469	0.025	0.102	0.088–0.121	113,005	1,156,573	995,088–1,362,703
Blue-gray Gnatcatcher	0.086	0.001	34	1	0.601	0.048	0.184	0.154–0.226	113,005	2,082,236	1,745,042–2,553,454
Boat-tailed Grackle	0.106	0.004	42	1	1.000	0.111	0.020	0.018–0.093	2,990	6,118	5,370–27,768
Broad-winged hawk	0.107	0.013	43	5	0.578	0.339	0.002	0.001–0.01	113,005	24,768	10,570–112,354
Brown Thrasher	0.137	0.004	55	2	0.757	0.058	0.028	0.022–0.035	113,005	312,242	252,071–398,741
Brown-headed Cowbird[2]	0.144	0.001	57	0	0.461	0.018	0.509	0.463–0.562	113,005	5,748,266	5,231,957–6,355,134
Canada Goose	0.286	0.017	115	7	0.820	0.055	0.005	0.004–0.007	113,005	58,629	42,901–83,957
Carolina Chickadee	0.109	0.001	44	1	0.465	0.033	0.290	0.248–0.346	113,005	3,280,917	2,806,868–3,914,137
Carolina Wren	0.173	0.002	69	1	0.741	0.015	0.240	0.225–0.257	113,005	2,711,610	2,537,359–2,904,560
Cattle Egret	0.222	0.003	89	1	0.823	0.014	0.121	0.113–0.131	113,005	1,371,512	1,273,972–1,480,205

Table 2. Estimated populations of birds during the breeding season within the Mississippi Alluvial Valley Bird Conservation Region.—Continued

[Species populations estimated from distribution of detections at 23,462 point-count stops during North American Breeding Bird Surveys (BBS) conducted 2006–15, as assigned on the basis of distance (≤50 meters and >50 meters) and time (three 1-minute intervals) data from Breeding Bird Surveys conducted from 2009 to 2015. Detection data were used to calculate the proportion of observed distance (∑) that constituted the effective detection distance (EDD) and the probability of detection (ρ) which were used to estimate densities (number of birds per hectare) and their associated confidence limits (CL). Densities were extended to population estimates on the basis of the area within the range of the species in the Mississippi Alluvial Valley (MAV). SE, standard error; km², square kilometers; ---, not estimated]

Species	∑	∑ (SE)	EDD	EDD (SE)	ρ	ρ (SE)	Density	Density CL	Area range (km²)[1]	MAV population	MAV population CL
Cedar Waxwing	0.175	0.041	70	16	1.000	0.568	0.000	0.0003–0.004	113,005	3,133	1,471–42,309
Cerulean Warbler	0.171	0.037	69	15	1.000	0.285	0.000	0.0004–0.002	113,005	4,346	2,153–24,675
Chimney Swift[2]	0.176	0.004	71	2	0.225	0.048	0.108	0.072–0.2	113,005	1,226,027	812,221–2,255,029
Chipping Sparrow	0.322	0.038	129	15	1.000	0.189	0.001	0.001–0.005	113,005	9,249	6,107–61,681
Chuck-will's-widow	0.156	0.028	62	11	1.000	0.280	0.001	0.0005–0.002	86,920	4,668	2,529–21,252
Cliff Swallow[2]	0.154	0.002	61	1	1.000	0.017	0.156	0.15–0.167	15,304	239,469	229,706–255,544
Common Gallinule	0.131	0.012	52	5	1.000	0.174	0.002	0.002–0.005	113,005	27,224	19,790–54,165
Common Grackle[2]	0.184	0.001	74	1	0.515	0.013	0.447	0.416–0.483	113,005	5,056,004	4,702,178–5,453,463
Common Ground Dove	0.150	0.090	60	36	1.000	0.969	0.000	0.0001–0.006	113,005	567	120–70,979
Common Moorhen	0.139	0.014	56	5	0.979	0.177	0.002	0.001–0.004	113,005	22,377	15,558–47,421
Common Nighthawk	0.134	0.008	53	3	0.894	0.125	0.005	0.004–0.009	113,005	57,958	42,517–96,199
Common Yellowthroat	0.129	0.002	52	1	0.719	0.038	0.079	0.068–0.092	113,005	889,110	769,591–1,041,643
Coppers Hawk	0.123	0.024	49	10	1.000	0.590	0.001	0.0005–0.005	92,535	4,826	2,512–50,548
Dickcissel	0.144	0.001	58	0	1.000	0.013	0.321	0.312–0.337	89,551	2,875,510	2,792,336–3,014,044
Downy Woodpecker	0.156	0.004	62	2	0.184	0.059	0.117	0.068–0.332	113,005	1,320,084	762,988–3,747,816
Eastern Bluebird	0.180	0.005	72	2	0.247	0.057	0.066	0.042–0.131	113,005	742,531	472,781–1,482,081
Eastern Kingbird	0.150	0.005	60	2	0.458	0.068	0.031	0.022–0.048	113,005	347,718	246,994–540,628
Eastern Meadowlark	0.308	0.008	123	3	0.566	0.027	0.037	0.031–0.044	113,005	417,454	352,167–501,857
Eastern Phoebe	0.157	0.010	63	4	0.865	0.106	0.005	0.003–0.008	51,114	24,211	17,234–39,202
Eastern Screech-Owl	0.181	0.072	73	29	0.489	0.703	0.0002	0.0001–0.009	113,005	2,034	366–97,290
Eastern Towhee	0.177	0.004	71	2	0.755	0.039	0.033	0.028–0.039	94,338	309,678	261,461–372,565
Eastern Whip-poor-will	0.188	0.098	75	39	1.000	0.607	0.0001	0.0001–0.49	18,484	119	29–906,452
Eastern Wood-Pewee	0.181	0.005	72	2	0.708	0.044	0.027	0.022–0.033	91,495	243,987	200,201–303,951
Eurasian Collared-Dove	0.190	0.005	76	2	0.685	0.043	0.027	0.022–0.034	75,378	202,666	166,023–252,914
European Starling[2]	0.196	0.002	78	1	0.500	0.016	0.305	0.28–0.335	113,005	3,451,555	3,162,617–3,783,915
Field Sparrow	0.224	0.015	90	6	0.753	0.080	0.005	0.003–0.007	87,543	40,814	27,835–64,845
Fish Crow	0.190	0.006	76	2	0.606	0.048	0.026	0.021–0.034	88,087	228,536	181,264–297,520
Grasshopper Sparrow	0.209	0.023	84	9	0.460	0.235	0.002	0.001–0.007	66,521	14,231	9,675–49,215
Gray Catbird	0.101	0.010	41	4	0.557	0.281	0.004	0.002–0.015	91,497	34,581	15,547–134,012

Table 2. Estimated populations of birds during the breeding season within the Mississippi Alluvial Valley Bird Conservation Region.—Continued

[Species populations estimated from distribution of detections at 23,462 point-count stops during North American Breeding Bird Surveys (BBS) conducted 2006–15, as assigned on the basis of distance (≤50 meters and >50 meters) and time (three 1-minute intervals) data from Breeding Bird Surveys conducted from 2009 to 2015. Detection data were used to calculate the proportion of observed distance (∑) that constituted the effective detection distance (EDD) and the probability of detection (ρ) which were used to estimate densities (number of birds per hectare) and their associated confidence limits (CL). Densities were extended to population estimates on the basis of the area within the range of the species in the Mississippi Alluvial Valley (MAV). SE, standard error; km^2, square kilometers; ---, not estimated]

Species	∑	∑ (SE)	EDD	EDD (SE)	ρ	ρ (SE)	Density	Density CL	Area range (km^2)[1]	MAV population	MAV population CL
Great Blue Heron	0.312	0.012	125	5	1.000	0.062	0.008	0.007–0.035	113,005	86,484	74,632–400,275
Great Crested Flycatcher	0.151	0.003	60	1	0.628	0.042	0.053	0.044–0.065	113,005	594,633	495,183–729,778
Great Egret	0.479	0.013	191	5	0.677	0.020	0.027	0.023–0.032	113,005	306,856	265,182–358,247
Great Horned Owl	0.286	0.045	114	18	1.000	0.276	0.0005	0.0004–0.004	113,005	5,390	5,048–44,535
Great-tailed Grackle	0.103	0.011	41	5	0.767	0.304	0.002	0.001–0.014	113,005	24,948	13,934–152,954
Green Heron	0.252	0.013	101	5	1.000	0.098	0.005	0.016–0.023	113,005	53,483	180,938–261,026
Hairy Woodpecker	0.117	0.009	47	3	0.617	0.184	0.005	0.003–0.016	113,005	59,939	32,244–179,080
Hooded Warbler	0.166	0.009	66	4	0.093	0.135	0.041	0.009–0.025	111,785	460,265	103,718–766,856
Horned Lark	0.171	0.003	68	1	0.660	0.033	0.061	0.052–0.071	97,105	590,377	508,722–693,984
House Finch	0.171	0.012	68	5	0.681	0.118	0.004	0.003–0.009	99,316	44,652	27,580–85,381
House Sparrow[2]	0.131	0.001	52	0	0.742	0.017	0.350	0.327–0.375	113,005	3,952,252	3,697,945–4,235,723
Inca Dove	0.179	0.022	72	9	0.698	0.195	0.001	0.001–0.005	113,005	16,025	7,934–55,742
Indigo Bunting[2]	0.137	0.001	55	0	0.846	0.014	0.392	0.372–0.414	113,005	4,429,388	4,205,156–4,672,976
Kentucky Warbler	0.170	0.010	68	4	0.541	0.101	0.009	0.005–0.016	99,417	85,684	53,985–161,477
Killdeer	0.187	0.002	75	1	0.819	0.017	0.125	0.116–0.136	113,005	1,414,892	1,308,040–1,535,124
Lark Sparrow	0.140	0.015	56	6	0.477	0.245	0.003	0.001–0.01	83,478	22,368	8,716–80,561
Least Tern	0.175	0.014	70	6	1.000	0.197	0.002	0.004–0.013	113,005	26,105	41,821–145,743
Little Blue Heron	0.322	0.007	129	3	1.000	0.034	0.026	0.024–0.111	113,005	292,362	269,777–1,254,885
Loggerhead Shrike	0.138	0.003	55	1	0.715	0.051	0.038	0.031–0.047	113,005	427,881	351,906–533,607
Louisiana Waterthrush	0.112	0.020	45	8	0.391	0.494	0.001	0.0004–0.006	95,282	13,728	3,541–60,303
Mississippi Kite	0.190	0.005	76	2	0.272	0.056	0.055	0.036–0.101	78,336	434,043	285,595–793,661
Mottled Duck	0.284	0.084	114	33	0.702	0.307	0.0002	0.0001–0.008	113,005	2,661	826–88,505
Mourning Dove	0.247	0.002	99	1	0.804	0.009	0.248	0.236–0.261	113,005	2,800,763	2,661,475–2,950,724
Northern Bobwhite	0.322	0.015	129	6	0.875	0.036	0.009	0.007–0.011	113,005	96,374	76,821–123,739
Northern Cardinal	0.202	0.001	81	1	0.838	0.009	0.359	0.344–0.376	113,005	4,060,569	3,885,711–4,247,081
Northern Flicker	0.203	0.015	81	6	0.313	0.160	0.007	0.005–0.014	113,005	77,920	59,746–160,554
Northern Mockingbird	0.166	0.001	66	1	0.828	0.014	0.264	0.249–0.28	113,005	2,981,297	2,815,269–3,162,487
Northern Parula	0.125	0.002	50	1	0.497	0.044	0.104	0.085–0.132	113,005	1,174,943	957,578–1,491,024

Table 2. Estimated populations of birds during the breeding season within the Mississippi Alluvial Valley Bird Conservation Region.—Continued

[Species populations estimated from distribution of detections at 23,462 point-count stops during North American Breeding Bird Surveys (BBS) conducted 2006–15, as assigned on the basis of distance (≤50 meters and >50 meters) and time (three 1-minute intervals) data from Breeding Bird Surveys conducted from 2009 to 2015. Detection data were used to calculate the proportion of observed distance (∑) that constituted the effective detection distance (EDD) and the probability of detection (ρ) which were used to estimate densities (number of birds per hectare) and their associated confidence limits (CL). Densities were extended to population estimates on the basis of the area within the range of the species in the Mississippi Alluvial Valley (MAV). SE, standard error; km², square kilometers; ---, not estimated]

Species	∑	∑ (SE)	EDD	EDD (SE)	ρ	ρ (SE)	Density	Density CL	Area range (km²)[1]	MAV population	MAV population CL
Northern Rough-winged Swallow[2]	0.124	0.002	50	1	1.000	0.035	0.071	0.067–0.08	113,005	803,328	754,138–899,532
Orchard Oriole	0.132	0.002	53	1	0.352	0.045	0.134	0.102–0.187	113,005	1,512,770	1,157,664–2,113,424
Osprey	0.136	0.016	54	7	1.000	0.224	0.001	0.001–0.003	163	21	14–56
Ovenbird	0.151	0.057	60	23	0.698	0.706	0.0002	0.0001–0.008	113,005	1,826	460–85,689
Painted Bunting	0.141	0.003	56	1	0.306	0.045	0.135	0.1–0.2	96,861	1,310,373	968,839–1,939,783
Pileated Woodpecker	0.337	0.017	135	7	0.287	0.066	0.013	0.008–0.029	113,005	149,834	87,990–328,393
Pine Warbler	0.119	0.013	48	5	0.838	0.247	0.002	0.001–0.007	4,008	797	482–2,609
Prairie Warbler	0.148	0.041	59	16	0.549	0.566	0.0004	0.0001–0.004	6,779	249	66–2,992
Prothonotary Warbler	0.117	0.001	47	1	0.663	0.027	0.222	0.2–0.249	105,911	2,352,351	2,117,795–2,633,422
Purple Martin[2]	0.180	0.002	72	1	0.723	0.017	0.164	0.152–0.179	113,005	1,856,178	1,713,000–2,018,131
Red-bellied Woodpecker	0.259	0.004	104	2	0.545	0.022	0.081	0.071–0.093	113,005	914,653	802,982–1,051,007
Red-eyed Vireo	0.145	0.004	58	1	0.734	0.049	0.034	0.028–0.043	113,005	387,218	319,529–480,347
Red-headed Woodpecker	0.190	0.008	76	3	0.356	0.076	0.022	0.014–0.042	113,005	244,390	154,236–474,829
Red-shouldered Hawk	0.237	0.012	95	5	0.540	0.069	0.010	0.007–0.015	113,005	110,691	76,327–174,937
Red-tailed Hawk	0.212	0.011	85	4	0.708	0.067	0.008	0.006–0.012	113,005	93,691	68,110–136,366
Red-winged Blackbird[2]	0.197	0.001	79	0	0.886	0.005	1.332	1.303–1.361	113,005	15,049,274	14,723,593–15,385,539
Rock Pigeon	0.216	0.009	86	3	1.000	0.084	0.008	0.007–0.039	113,005	95,747	82,370–444,738
Ruby-throated Hummingbird	0.092	0.003	37	1	0.265	0.113	0.069	0.035–0.457	113,005	779,245	394,637–5,160,097
Scarlet Tanager	0.169	0.065	67	26	0.740	0.617	0.0001	0.0001–0.008	3,104	46	12–2,339
Scissor-tailed Flycatcher	0.149	0.011	60	4	0.761	0.131	0.004	0.003–0.008	2,022	869	549–1,642
Snowy Egret	0.292	0.011	117	5	0.513	0.047	0.016	0.012–0.023	113,005	184,585	139,011–256,235
Summer Tanager	0.146	0.003	58	1	0.463	0.048	0.067	0.053–0.09	113,005	761,747	598,291–1,015,391
Swainson's Warbler	0.134	0.011	54	5	0.713	0.177	0.003	0.002–0.009	98,331	33,279	19,136–84,221
Swallow-tailed Kite	0.219	0.027	88	11	1.000	0.116	0.001	0.001–0.002	15,988	1,785	1,154–3,754
Tree Swallow	0.170	0.020	68	8	1.000	0.156	0.001	0.001–0.003	35,372	4,621	3,063–10,144
Tufted Titmouse	0.196	0.003	78	1	0.703	0.023	0.086	0.077–0.097	113,005	973,914	873,580–1,092,392
Warbling Vireo	0.225	0.014	90	6	1.000	0.132	0.003	0.008–0.017	104,896	33,505	81,759–173,094
White-breasted Nuthatch[3]	---	---	54	2	1.000	5.293	0.004	0.003–0.016	89,915	31,515	27,318–145,102

Table 2. Estimated populations of birds during the breeding season within the Mississippi Alluvial Valley Bird Conservation Region.—Continued

[Species populations estimated from distribution of detections at 23,462 point-count stops during North American Breeding Bird Surveys (BBS) conducted 2006–15, as assigned on the basis of distance (≤50 meters and >50 meters) and time (three 1-minute intervals) data from Breeding Bird Surveys conducted from 2009 to 2015. Detection data were used to calculate the proportion of observed distance (∑) that constituted the effective detection distance (EDD) and the probability of detection (ρ) which were used to estimate densities (number of birds per hectare) and their associated confidence limits (CL). Densities were extended to population estimates on the basis of the area within the range of the species in the Mississippi Alluvial Valley (MAV). SE, standard error; km^2, square kilometers; ---, not estimated]

Species	∑	∑ (SE)	EDD	EDD (SE)	ρ	ρ (SE)	Density	Density CL	Area range (km^2)[1]	MAV population	MAV population CL
White-eyed Vireo	0.119	0.001	47	1	1.000	0.027	0.136	0.13–0.148	113,005	1,539,719	1,470,061–1,675,053
White-faced Ibis	0.196	0.002	78	1	1.000	0.012	0.002	0.002–0.002	113,005	23,262	22,264–24,732
White-winged Dove	0.177	0.039	71	16	0.553	0.382	0.001	0.0002–0.004	113,005	6,105	1,890–47,636
Wild Turkey	0.557	0.157	223	63	1.000	0.084	0.0002	0.0001–0.001	76,968	1,624	675–9,152
Wood Duck	0.301	0.016	121	6	0.206	0.078	0.017	0.008–0.08	113,005	195,309	95,823–907,767
Wood Thrush	0.304	0.022	122	9	0.760	0.069	0.004	0.002–0.006	95,000	33,978	22,988–54,188
Worm-eating Warbler	0.103	0.006	41	2	0.343	0.168	0.001	0.0003–0.018	95,605	6,058	2,753–170,815
Yellow Warbler	0.181	0.042	73	17	0.489	0.406	0.001	0.0001–0.004	32,761	1,769	480–13,297
Yellow-billed Cuckoo	0.267	0.005	107	2	0.377	0.028	0.080	0.066–0.1	113,005	905,594	744,227–1,129,399
Yellow-breasted Chat	0.186	0.003	74	1	0.958	0.020	0.069	0.063–0.075	103,297	709,054	648,219–778,600
Yellow-throated Vireo	0.137	0.007	55	3	0.587	0.112	0.010	0.007–0.019	93,874	97,496	62,556–180,890
Yellow-throated Warbler	0.170	0.012	68	5	1.000	0.179	0.003	0.005–0.016	113,005	33,333	59,945–178,782

[1] Area range (km^2) from Population Estimates Database (Partners in Flight Science Committee, 2013)

[2] Population estimate likely inflated as a result of nonindependence of detections.

[3] Effective detection distance (EDD) from Twedt (2015)

Table 3. Partners-in-Flight population estimates and revisions for the Mississippi Alluvial Valley.

[Partners in Flight (PIF) Science Committee (2013) population estimates for the Mississippi Alluvial Valley (MAV) and revised population estimates that incorporate more recent (2007–16) average number of birds of a species detected per Breeding Bird Survey (BBS) route (rte) and species-specific detection distance (DD) as derived from distance-time-based Breeding Bird Survey data. Comparison distance-time-based population estimate for the MAV are provided in table 2. Densities were determined as the revised PIF population estimate for MAV distributed within the area (table 2) of the species range (Density in MAV) or the forested proportion of this area (Density in MAV forest); birds/rte, birds per route; m, meters; ha, hectares; ---, not estimated]

Species	1998–2007 BBS average (birds/rte)	2007–2016 BBS average (birds/rte)	Original DD (m)	Revised DD (m)	Pair adjust	Time adjust	Original PIF population estimate for MAV	Revised PIF population estimate for MAV	Density in MAV (birds/ha)	Density in MAV forest (birds/ha)
Acadian Flycatcher	1.007	1.251	125	45	2	1.19	109,965	527,085	0.051	0.174
American Crow	25.245	20.138	400	201	1.75	1.55	307,815	486,210	0.043	0.147
American Goldfinch	0.992	0.545	125	56	1.25	1.32	75,044	102,843	0.012	0.042
American Kestrel	0.233	0.207	200	47	1.25	1.21	6,302	50,684	0.009	0.032
American Redstart	0.103	0.118	100	46	2	1.06	15,721	42,860	0.004	0.015
American Robin	11.039	7.157	200	66	2	2.34	927,823	2,761,975	0.278	0.950
Baltimore Oriole	1.643	1.736	125	56	1.75	1.13	149,191	392,668	0.044	0.149
Barn Swallow[1]	19.138	18.708	200	59	1.5	1.17	602,168	3,382,036	0.299	0.027
Barred Owl	0.566	0.755	200	152	2	8.97	182,533	210,857	0.019	0.064
Bell's Vireo	0.009	0.011	125	59	2	1.27	1,096	2,883	0.001	0.002
Belted Kingfisher	0.259	0.110	200	67	2	1.29	11,996	22,700	0.002	0.008
Black Vulture[1]	1.139	1.760	400	141	1.5	1.94	14,901	92,683	0.008	0.028
Black-and-white Warbler	0.024	0.006	100	45	2	1.16	3,950	2,267	0.000	0.001
Blue Grosbeak	2.456	2.353	125	70	2	1.47	331,759	506,748	0.057	0.194
Blue Jay	15.010	10.636	200	88	1.25	1.16	393,059	719,321	0.064	0.217
Blue-gray Gnatcatcher	3.184	3.259	50	34	1.75	1.52	2,434,025	2,693,740	0.238	0.814
Boat-tailed Grackle	0.882	0.821	200	42	1.25	1.57	31,219	329,562	1.102	3.766
Broad-winged Hawk	0.052	0.025	125	43	2	2.52	12,064	24,303	0.002	0.007
Brown Thrasher	2.734	1.780	200	55	1.5	1.13	83,253	358,295	0.032	0.108
Brown-headed Cowbird[1]	16.697	21.840	125	57	1.75	1.17	1,573,051	4,947,814	0.438	1.496
Carolina Chickadee	5.958	6.956	125	44	1.25	1.23	422,533	1,990,819	0.176	0.602
Carolina Wren	17.800	23.160	200	69	1.5	1.33	639,351	3,494,425	0.309	1.056
Chimney Swift[1]	6.426	3.758	200	71	1.75	1.12	226,406	525,234	0.046	0.159
Chipping Sparrow	0.754	0.342	125	129	2	1.85	128,226	27,268	0.002	0.008
Chuck-will's-widow	0.617	0.030	300	62	2	19.50	192,205	110,588	0.013	0.043
Cliff Swallow[1]	3.054	14.691	200	61	1	1.24	68,095	1,760,427	1.150	3.930
Common Grackle[1]	60.254	38.584	200	74	1.25	1.50	2,033,190	4,755,196	0.421	1.438
Common Nighthawk	0.462	0.353	300	53	2	6.46	47,778	583,720	0.052	0.176

Table 3. Partners-in-Flight population estimates and revisions for the Mississippi Alluvial Valley.—Continued

[Partners in Flight (PIF) Science Committee (2013) population estimates for the Mississippi Alluvial Valley (MAV) and revised population estimates that incorporate more recent (2007–16) average number of birds of a species detected per Breeding Bird Survey (BBS) route (rte) and species-specific detection distance (DD) as derived from distance-time-based Breeding Bird Survey data. Comparison distance-time-based population estimate for the MAV are provided in table 2. Densities were determined as the revised PIF population estimate for MAV distributed within the area (table 2) of the species range (Density in MAV) or the forested proportion of this area (Density in MAV forest); birds/rte, birds per route; m, meters; ha, hectares; ---, not estimated]

Species	1998–2007 BBS average (birds/rte)	2007–2016 BBS average (birds/rte)	Original DD (m)	Revised DD (m)	Pair adjust	Time adjust	Original PIF population estimate for MAV	Revised PIF population estimate for MAV	Density in MAV (birds/ha)	Density in MAV forest (birds/ha)
Common Yellowthroat	6.310	4.788	125	52	2	1.16	675,038	1,479,765	0.131	0.447
Cooper's Hawk	0.033	0.039	125	49	2	1.27	3,822	14,619	0.002	0.005
Dickcissel	33.185	28.369	200	58	1.75	1.13	1,184,179	6,018,632	0.672	2.296
Downy Woodpecker	2.927	2.504	125	62	2	1.32	356,456	619,892	0.055	0.187
Eastern Bluebird	3.797	2.815	125	72	1.5	1.10	288,907	322,832	0.029	0.098
Eastern Kingbird	2.833	1.339	125	60	1.75	1.14	259,675	266,317	0.024	0.081
Eastern Meadowlark	19.530	9.388	200	123	1.75	1.19	728,616	463,023	0.041	0.140
Eastern Phoebe	1.042	0.311	125	63	2	2.21	212,381	124,852	0.024	0.083
Eastern Screech-Owl	0.006	0.011	125	73	2	11.04	5,861	16,418	0.001	0.005
Eastern Towhee	3.747	2.755	125	71	2	1.30	448,895	511,481	0.054	0.185
Eastern Whip-poor-will	0.023	0.003	300	75	2	25.88	9,706	9,117	0.005	0.017
Eastern Wood-Pewee	3.587	2.603	200	72	2	1.14	147,596	413,279	0.045	0.154
Eurasian Collared-Dove	1.900	3.612	200	76	1.75	1.53	91,692	603,440	0.080	0.273
European Starling[1]	40.135	30.011	200	78	1	1.19	857,720	2,108,365	0.187	0.637
Field Sparrow	1.379	0.758	200	90	2	1.07	52,958	71,858	0.008	0.028
Fish Crow	3.170	2.664	400	76	1.25	1.62	28,831	335,586	0.038	0.130
Grasshopper Sparrow	0.554	0.220	125	84	2	1.45	74,012	32,585	0.005	0.017
Gray Catbird	0.195	0.088	125	41	2	1.58	28,267	59,538	0.007	0.022
Great Crested Flycatcher	3.243	3.160	200	60	1.75	1.25	127,181	688,401	0.061	0.208
Great Horned Owl	0.233	0.135	300	114	2	11.62	43,229	86,810	0.008	0.026
Hairy Woodpecker	0.213	0.168	125	47	2	1.29	25,321	70,540	0.006	0.021
Hooded Warbler	0.388	0.187	125	66	2	1.20	42,700	36,995	0.003	0.011
Horned Lark	6.013	5.446	200	68	2	1.29	279,948	1,096,807	0.113	0.386
House Finch	1.113	0.482	125	68	1.75	1.07	95,854	70,125	0.007	0.024
House Sparrow[1]	35.321	21.857	125	52	1	1.06	1,728,488	3,090,296	0.273	0.934
Inca Dove	0.020	0.171	125	72	1.25	1.43	1,625	21,170	---	---
Indigo Bunting[1]	23.005	23.229	125	55	2	1.38	2,918,527	7,610,885	0.674	2.301
Kentucky Warbler	0.339	0.240	125	68	2	1.15	35,787	42,716	0.004	0.015

Table 3. Partners-in-Flight population estimates and revisions for the Mississippi Alluvial Valley.—Continued

[Partners in Flight (PIF) Science Committee (2013) population estimates for the Mississippi Alluvial Valley (MAV) and revised population estimates that incorporate more recent (2007–16) average number of birds of a species detected per Breeding Bird Survey (BBS) route (rte) and species-specific detection distance (DD) as derived from distance-time-based Breeding Bird Survey data. Comparison distance-time-based population estimate for the MAV are provided in table 2. Densities were determined as the revised PIF population estimate for MAV distributed within the area (table 2) of the species range (Density in MAV) or the forested proportion of this area (Density in MAV forest); birds/rte, birds per route; m, meters; ha, hectares; ---, not estimated]

Species	1998–2007 BBS average (birds/rte)	2007–2016 BBS average (birds/rte)	Original DD (m)	Revised DD (m)	Pair adjust	Time adjust	Original PIF population estimate for MAV	Revised PIF population estimate for MAV	Density in MAV (birds/ha)	Density in MAV forest (birds/ha)
Lark Sparrow	0.208	0.187	200	56	1.5	1.15	6,425	36,969	0.004	0.015
Loggerhead Shrike	3.659	2.306	125	55	1.25	1.19	250,255	407,291	0.036	0.123
Louisiana Waterthrush	0.029	0.028	200	45	2	1.55	1,630	15,135	0.002	0.005
Mississippi Kite	0.829	2.058	300	76	1.75	2.34	27,076	523,871	0.067	0.228
Mourning Dove	55.149	55.245	200	99	1.75	1.31	2,266,254	4,632,638	0.410	1.400
Northern Bobwhite	7.869	3.044	200	129	1.75	1.46	361,206	167,938	0.015	0.051
Northern Cardinal	56.760	49.537	200	81	2	2.32	4,728,155	12,578,917	1.113	3.803
Northern Flicker	0.792	0.377	200	81	1.25	1.18	20,937	30,407	0.003	0.009
Northern Mockingbird	30.633	26.763	200	66	1.5	1.06	879,448	3,527,802	0.312	1.066
Northern Parula	2.417	4.179	100	50	2	1.11	385,888	1,334,182	0.118	0.403
Northern Rough-winged Swallow[1]	2.367	5.317	125	50	1.75	1.10	210,147	1,474,907	0.131	0.446
Orchard Oriole	4.349	4.019	125	53	1.75	1.06	372,597	957,806	0.085	0.290
Osprey	0.012	0.121	300	54	1.25	1.25	144	23,320	1.428	4.877
Painted Bunting	2.375	4.262	125	56	1.75	1.14	218,164	975,237	0.101	0.344
Pileated Woodpecker	1.348	1.931	300	135	2	1.62	34,954	123,647	0.011	0.037
Pine Warbler	0.642	0.080	125	48	2	1.07	63,106	26,615	0.066	0.227
Prairie Warbler	0.052	0.017	125	59	2	1.16	5,620	3,975	0.006	0.020
Prothonotary Warbler	4.837	8.342	125	47	2	1.04	461,840	2,816,611	0.266	0.909
Purple Martin[1]	22.447	16.774	200	72	1.25	1.11	560,686	1,616,453	0.143	0.489
Red-bellied Woodpecker	13.094	11.956	200	104	1.75	1.37	562,784	950,186	0.084	0.287
Red-eyed Vireo	0.972	1.702	125	58	2	1.29	115,532	469,951	0.042	0.142
Red-headed Woodpecker	2.641	1.369	200	76	1.25	1.19	70,850	127,201	0.011	0.038
Red-shouldered Hawk	0.787	1.380	200	95	2	1.20	34,000	132,054	0.012	0.040
Red-tailed Hawk	1.213	1.124	300	85	1.25	1.42	17,165	99,068	0.009	0.030
Red-winged Blackbird[1]	239.312	220.664	200	79	1.25	1.14	6,159,441	18,200,490	1.611	5.502
Rock Pigeon	3.862	1.441	200	86	1	1.57	109,303	110,281	0.010	0.033
Ruby-throated Hummingbird	0.680	0.515	50	37	2	1.27	498,590	344,906	0.031	0.104

Table 3. Partners-in-Flight population estimates and revisions for the Mississippi Alluvial Valley.—Continued

[Partners in Flight (PIF) Science Committee (2013) population estimates for the Mississippi Alluvial Valley (MAV) and revised population estimates that incorporate more recent (2007–16) average number of birds of a species detected per Breeding Bird Survey (BBS) route (rte) and species-specific detection distance (DD) as derived from distance-time-based Breeding Bird Survey data. Comparison distance-time-based population estimate for the MAV are provided in table 2. Densities were determined as the revised PIF population estimate for MAV distributed within the area (table 2) of the species range (Density in MAV) or the forested proportion of this area (Density in MAV forest); birds/rte, birds per route; m, meters; ha, hectares; ---, not estimated]

Species	1998–2007 BBS average (birds/rte)	2007–2016 BBS average (birds/rte)	Original DD (m)	Revised DD (m)	Pair adjust	Time adjust	Original PIF population estimate for MAV	Revised PIF population estimate for MAV	Density in MAV (birds/ha)	Density in MAV forest (birds/ha)
Scissor-tailed Flycatcher	0.432	0.430	200	60	2	1.60	24,845	137,448	0.680	2.322
Summer Tanager	2.646	2.055	125	58	2	1.35	328,569	592,746	0.052	0.179
Swainson's Warbler	0.054	0.025	200	54	2	1.34	2,613	8,194	0.001	0.003
Swallow-tailed Kite	0.029	0.129	300	88	1.25	1.75	500	13,169	0.008	0.028
Tree Swallow	0.255	0.138	200	68	1.75	1.15	9,264	21,637	0.006	0.021
Tufted Titmouse	8.289	8.972	200	78	1.25	1.15	214,474	763,208	0.068	0.231
Warbling Vireo	0.915	0.780	125	90	2	1.26	105,849	86,944	0.008	0.028
White-eyed Vireo	4.819	5.435	125	47	2	1.30	575,605	2,296,269	0.203	0.694
White-winged Dove	0.004	0.066	200	71	1.5	1.39	139	9,842	---	---
Wild Turkey	0.109	0.088	300	223	1.75	1.50	2,299	1,677	0.000	0.001
Wood Thrush	1.463	0.818	200	122	2	2.23	117,496	88,279	0.009	0.032
Worm-eating Warbler	0.002	0.008	125	41	2	1.44	290	5,076	0.001	0.002
Yellow Warbler	0.001	0.050	125	73	2	1.10	99	7,359	0.002	0.008
Yellow-billed Cuckoo	9.810	8.763	200	107	2	1.33	470,949	734,856	0.065	0.222
Yellow-breasted Chat	7.363	5.848	200	74	2	1.53	405,744	1,177,083	0.114	0.389
Yellow-throated Vireo	0.475	0.463	125	55	2	1.18	51,716	130,014	0.014	0.047
Yellow-throated Warbler	0.198	0.336	125	68	2	1.09	19,864	56,980	0.005	0.017

[1] Revised population estimate and associated density estimates are likely inflated as a result of nonindependence of detections.

Table 4. Avian densities within the Mississippi Alluvial Valley Bird Conservation Region.

[Densities (birds per hectare) were estimated on the basis of populations being equally distributed among the area of presumed occupied habitat (area of species range: table 2 × naïve ψ, occupancy estimated without covariates) or distributed among all forest area (3,307,910 hectares; Mitchell and others, 2016) proportional to the species range within this region. The range of densities from empirical studies (Norris and others, 2009; Twedt and Wilson, 2017) in bottomland hardwood forests of the Mississippi Alluvial Valley (MAV) are provided for comparison; ---, not estimated; NA, not estimated]

Species	MAV population estimate	Density projected to occupied area	Density projected to forest area	Minimum empirical density	Maximum empirical density	Naïve Ψ
Acadian Flycatcher	597,418	0.442	0.198	0.95	3.80	0.13
American Crow	280,146	0.067	0.085	0.11	0.36	0.37
American Goldfinch	57,594	0.120	0.024	---	---	0.06
American Redstart	103,495	0.272	0.037	0.02	0.58	0.04
American Robin	721,946	0.661	0.248	---	---	0.11
Baltimore Oriole	796,483	0.398	0.302	---	---	0.22
Barred Owl	40,114	0.210	0.012	0.02	0.55	0.02
Black-and-white Warbler	20,940	0.279	0.008	---	---	0.01
Blue Jay	1,156,573	0.233	0.350	0.07	0.26	0.44
Blue-gray Gnatcatcher	2,082,236	0.703	0.629	2.07	4.70	0.26
Boat-tailed Grackle[1]	6,118	1.811	0.070	---	---	0.01
Brown-headed Cowbird[2]	1,573,051	0.229	0.476	0.63	1.60	0.61
Brown Thrasher	312,242	0.064	0.094	---	---	0.44
Carolina Chickadee	3,280,917	0.958	0.992	0.89	1.99	0.30
Carolina Wren	2,711,610	0.494	0.820	1.37	3.10	0.49
Cerulean Warbler	4,346	0.039	0.001	0.03	0.07	0.01
Chipping Sparrow[1]	9,249	0.029	0.068	---	---	0.03
Chimney Swift[2]	226,406	0.063	0.068	0.03	0.03	0.32
Common Grackle[2]	2,033,190	0.396	0.615	---	---	0.45
Common Yellowthroat	889,110	0.269	0.269	0.04	0.57	0.29
Downy Woodpecker	1,320,084	0.252	0.399	0.45	1.82	0.46
Eastern Phoebe	24,211	0.067	0.016	---	---	0.07
Eastern Towhee	309,678	0.101	0.112	0.13	0.81	0.32
Eastern Wood-Pewee	243,987	0.091	0.091	0.08	0.42	0.29
Fish Crow	228,536	0.122	0.089	0.03	0.11	0.21
Field Sparrow[1]	40,814	0.104	0.016	---	---	0.04
Great Crested Flycatcher	594,633	0.183	0.180	0.24	0.60	0.29
Gray Catbird	34,581	---	0.013	---	---	NA
Hairy Woodpecker	59,939	0.024	0.018	0.03	1.59	0.22
Hooded Warbler	460,265	0.481	0.141	0.16	0.62	0.09
Indigo Bunting[2]	2,918,527	0.719	0.882	0.71	1.50	0.55

Table 4. Avian densities within the Mississippi Alluvial Valley Bird Conservation Region.—Continued

Species	MAV population estimate	Density projected to occupied area	Density projected to forest area	Minimum empirical density	Maximum empirical density	Naïve Ψ
Kentucky Warbler	85,684	0.112	0.029	0.17	0.55	0.08
Louisiana Waterthrush	13,728	---	0.005	---	---	NA
Mississippi Kite	434,043	0.348	0.189	---	---	0.16
Northern Cardinal	4,060,569	0.525	1.228	1.24	3.30	0.68
Northern Flicker	77,920	---	0.024	---	---	NA
Northern Parula	1,174,943	0.547	0.355	0.40	1.80	0.19
Orchard Oriole	1,512,770	0.337	0.457	0.03	20.60	0.40
Painted Bunting	1,310,373	0.629	0.462	0.03	0.71	0.22
Pileated Woodpecker	149,834	0.045	0.045	0.13	0.29	0.29
Pine Warbler	797	0.116	0.007	---	---	0.02
Prothonotary Warbler	2,352,351	0.755	0.759	0.50	1.77	0.29
Red-bellied Woodpecker	914,653	0.165	0.277	0.50	1.25	0.49
Red-eyed Vireo	387,218	0.312	0.117	0.45	1.30	0.11
Red-headed Woodpecker	244,390	0.206	0.074	0.02	0.18	0.11
Red-shouldered Hawk	110,691	0.058	0.033	0.03	0.08	0.17
Ruby-throated Hummingbird	779,245	0.220	0.236	1.00	12.77	0.31
Summer Tanager	761,747	0.177	0.230	0.38	0.97	0.38
Swainson's Warbler	33,279	0.090	0.012	0.06	0.20	0.04
Swallow-tailed Kite	1,785	---	0.004	---	---	NA
Tufted Titmouse	973,914	---	0.294	1.28	1.75	NA
Warbling Vireo	33,505	---	0.011	---	---	NA
White-breasted Nuthatch	28,164	0.076	0.011	0.08	0.43	0.04
White-eyed Vireo	1,539,719	0.577	0.465	1.06	3.50	0.24
Wild Turkey	1,624	0.001	0.001	---	---	0.17
Wood Thrush	33,978	0.041	0.012	0.02	0.10	0.09
Yellow-billed Cuckoo	905,594	0.172	0.274	0.35	1.10	0.47
Yellow-breasted Chat	709,054	0.291	0.234	0.06	1.20	0.24
Yellow-throated Vireo	97,496	0.061	0.035	0.06	0.32	0.17
Yellow-throated Warbler	33,333	0.033	0.010	0.02	0.07	0.09

[1] Species not modeled as a silvicolous species.

[2] Population estimate from Partners in Flight Science Committee (2013).

Table 5. Fifty-year population trend for avian species in the Mississippi Alluvial Valley.

[Trends and their upper (UCL) and lower (LCL) credible interval limits are based on 1966–2015 North American Breeding Bird Survey route data (Sauer and others, 2017) in the Mississippi Alluvial Valley Bird Conservation Region (MAV) that were used to predict the minimum sustainable population (MSP) and establish species population goals based on current estimated populations (table 2); n, number; SD, standard deviation; NA, not applicable]

Species	Routes (n)	Relative abundance	50-year trend	Trend LCL	Trend UCL	MSP	MSP (SD)	Area range	Estimated MAV population	MAV population goal
Acadian Flycatcher	38	0.48	3.18	1.22	4.99	25	0	103,221	597,420	597,420
American Crow	56	15.63	1.73	1	2.47	25	0	113,005	280,150	280,150
American Goldfinch	13	0.05	1.79	-2.41	5.77	26	1	83,431	57,590	126,990
American Kestrel	19	0.22	3.15	0.84	5.6	25	0	53,866	16,030	16,030
American Redstart	10	0.03	5.44	-0.2	11.67	25	0	95,962	103,500	113,840
American Robin	43	5.62	1.78	0.86	2.65	43	0	99,365	721,950	721,950
Anhinga	27	0.24	8.16	5.16	11.48	25	0	113,005	30,020	30,020
Baltimore Oriole	42	1.87	-2.87	-4.06	-1.71	224	3	90,235	796,480	1,939,440
Barn Swallow[1]	59	15.79	2.64	1.83	3.47	25	0	113,005	602,170	602,170
Barred Owl	43	0.35	2.31	0.57	4.05	25	0	113,005	40,110	40,110
Bell's Vireo	9	0.09	-6.48	-11.9	-1.88	1527	49	51,915	1,230	5,220
Belted Kingfisher	36	0.14	0.31	-1.63	2.49	48	1	99,740	20,060	36,420
Black Vulture[1]	23	1.01	1.88	-2.19	5.22	111	0	113,005	14,900	31,220
Black-and-white Warbler	5	0.02	-1.17	-7.77	5.99	25	7	89,507	20,940	33,190
Black-bellied Whistling-Duck	9	0.01	53.29	36.58	74.87	25	0	113,005	47,970	47,970
Black-crowned Night-Heron	19	0.44	3.65	-0.93	9.51	25	0	113,005	17,840	26,140
Black-necked Stilt	21	0.16	12.22	4.53	22.55	25	0	113,005	35,340	35,340
Blue Grosbeak	47	1.46	4.3	3.02	5.56	32	0	89,216	246,270	246,270
Blue Jay	59	15.30	-0.26	-0.78	0.28	59	1	113,005	1,156,570	1,306,930
Blue-gray Gnatcatcher	45	1.74	1.09	-0.37	2.59	32	1	113,005	2,082,240	2,467,450
Blue-winged Teal	8	0.02	2.33	-9.44	15.85	27	2	113,005	4,460	25,540
Boat-tailed Grackle	13	2.40	2.03	-2.87	6.83	25	1	2,990	6,120	14,900
Broad-winged Hawk	19	0.05	0.87	-2.53	3.92	38	1	113,005	24,770	56,100
Brown Thrasher	57	2.62	-1.39	-2.17	-0.54	105	1	113,005	312,240	529,250
Brown-headed Cowbird[1]	59	22.12	0.1	-0.79	0.98	50	1	113,005	1,573,050	2,194,410
Canada Goose	19	0.12	17.36	4.45	27.88	25	0	113,005	58,630	58,630
Carolina Chickadee	53	6.85	-0.26	-1.09	0.59	60	1	113,005	3,280,920	3,707,440
Carolina Wren	58	17.16	1.38	0.63	2.13	27	0	113,005	2,711,610	2,711,610
Cattle Egret[2]	48	151.50	-0.01	-2.37	2.37	56	2	113,005	1,371,510	1,371,510
Cerulean Warbler[3]	NA	NA	-2.65	-3.45	-1.72	40	NA	113,005	4,350	10,100
Chimney Swift[1]	56	8.80	-2.18	-3.08	-1.27	157	2	113,005	226,410	473,190

Table 5. Fifty-year population trend for avian species in the Mississippi Alluvial Valley.—Continued

Species	Routes (n)	Relative abundance	50-year trend	Trend LCL	Trend UCL	MSP	MSP (SD)	Area range	Estimated MAV population	MAV population goal
Chipping Sparrow	10	0.29	6.4	2.86	10.7	25	0	113,005	9,250	9,250
Chuck-will's-widow	16	0.52	-2.46	-4.92	-0.14	188	4	86,920	4,670	10,410
Cliff Swallow[1]	27	0.04	30.32	20.89	41.68	25	0	15,304	68,100	68,100
Common Gallinule	8	0.06	10.75	3.81	18.04	25	0	113,005	27,220	27,220
Common Grackle[1]	59	111.84	-3.6	-4.39	-2.83	323	3	113,005	2,033,190	5,692,930
Common Nighthawk	38	0.48	-1.72	-3.73	0.4	129	3	113,005	57,960	107,800
Common Yellowthroat	52	9.20	-4.28	-5.11	-3.43	459	4	113,005	889,110	2,791,810
Cooper's Hawk	18	0.02	3.88	0.17	7.1	25	0	92,535	4,830	4,830
Dickcissel	47	72.97	1.55	0.43	2.67	25	0	89,551	2,875,510	2,875,510
Double-crested Cormorant	10	0.08	12.41	1.86	25.58	25	0	113,005	1,240	1,240
Downy Woodpecker	56	2.17	0.67	-0.23	1.55	38	1	113,005	1,320,080	1,471,890
Eastern Bluebird	48	1.27	3.11	1.85	4.37	25	0	113,005	742,530	742,530
Eastern Kingbird	52	2.39	-1.87	-2.75	-1.03	134	2	113,005	347,720	672,830
Eastern Meadowlark	58	38.32	-3.44	-4.14	-2.75	296	2	113,005	417,450	1,135,470
Eastern Phoebe	12	0.38	0.89	-0.9	2.77	36	1	51,114	24,210	35,110
Eastern Screech Owl[3]	NA	NA	-1.29	-2.46	-0.36	40	NA	113,005	2,030	3,350
Eastern Towhee	53	2.56	0.57	-0.28	1.43	40	1	94,338	309,680	353,030
Eastern Whip-poor-will[3]	NA	NA	-3.25	-4.01	-2.52	40	NA	18,484	120	310
Eastern Wood-Pewee	45	1.38	1.24	0.16	2.32	29	1	91,495	243,990	243,990
Eurasian Collared-Dove[2]	50	0.01	25.86	18.14	32.86	25	0	75,378	202,670	202,670
European Starling[1,2]	59	58.19	-1.77	-2.64	-0.87	128	2	113,005	857,720	857,720
Field Sparrow	24	0.74	-3.85	-8.25	-1.98	377	7	87,543	40,810	119,380
Fish Crow	34	5.55	-0.31	-2.15	1.78	64	2	88,087	228,540	263,960
Grasshopper Sparrow	10	0.20	-0.97	-4.24	2.49	92	4	66,521	14,230	21,130
Gray Catbird	25	0.09	-0.38	-2.42	1.67	67	2	91,497	34,580	41,150
Great Blue Heron	51	1.39	2.98	1.11	5.17	25	0	113,005	86,480	86,480
Great Crested Flycatcher	58	2.22	1.2	0.22	2.15	29	1	113,005	594,630	594,630
Great Egret	48	13.05	4.87	2.74	7.12	25	0	113,005	306,860	306,860
Great Horned Owl	33	0.07	5.36	1.67	9.88	25	0	113,005	5,390	5,390
Great-tailed Grackle[3]	NA	NA	1.59	0.19	2.94	40	NA	113,005	24,950	27,320
Green Heron	52	1.81	-0.83	-1.95	0.26	80	1	113,005	53,480	75,680
Hairy Woodpecker	44	0.27	-2.11	-3.81	-0.39	155	3	113,005	59,940	123,170
Hooded Warbler	25	0.63	-0.07	-2.5	2.37	58	2	111,785	460,270	476,370

Table 5. Fifty-year population trend for avian species in the Mississippi Alluvial Valley.—Continued

[Trends and their upper (UCL) and lower (LCL) credible interval limits are based on 1966–2015 North American Breeding Bird Survey route data (Sauer and others, 2017) in the Mississippi Alluvial Valley Bird Conservation Region (MAV) that were used to predict the minimum sustainable population (MSP) and establish species population goals based on current estimated populations (table 2); n, number; SD, standard deviation; NA, not applicable]

Species	Routes (n)	Relative abundance	50-year trend	Trend LCL	Trend UCL	MSP	MSP (SD)	Area range	Estimated MAV population	MAV population goal
Horned Lark	41	12.17	0.84	-0.47	2.16	36	1	97,105	590,380	729,120
House Finch	29	0.04	13.67	6.95	20.15	25	0	99,316	44,650	44,650
House Sparrow[1,2]	59	135.10	-4.08	-4.8	-3.34	413	3	113,005	1,728,490	1,728,490
Inca Dove	11	0.00	23.09	13.58	34.91	25	0	113,005	16,030	16,030
Indigo Bunting[1]	58	19.97	0.54	-0.14	1.24	40	1	113,005	2,918,530	3,122,820
Kentucky Warbler	35	0.37	-0.04	-1.94	1.87	56	2	99,417	85,680	87,400
Killdeer	59	15.55	1.93	1.21	2.65	25	0	113,005	1,414,890	1,414,890
Lark Sparrow	8	0.20	5.36	0.64	9.98	25	0	83,478	22,370	22,370
Least Tern	5	0.20	13.2	1.75	26.52	25	0	113,005	26,110	26,110
Little Blue Heron	50	13.83	-1.62	-3.29	0.14	122	2	113,005	292,360	529,180
Loggerhead Shrike	54	4.47	-1.43	-2.39	-0.42	108	1	113,005	427,880	733,820
Louisiana Waterthrush	4	0.00	7.76	-2.78	23.94	25	0	95,282	13,730	32,810
Mallard	27	0.47	4.24	0.39	8.17	25	0	113,005	83,030	83,030
Mississippi Kite	41	0.88	4.63	2.7	6.48	25	0	78,336	434,040	434,040
Mottled Duck	11	0.22	-3.65	-8.14	0.85	358	13	113,005	2,660	7,520
Mourning Dove	59	57.87	0.76	0.08	1.45	36	1	113,005	2,800,760	2,800,760
Northern Bobwhite	55	20.52	-4.98	-5.86	-4.21	660	5	113,005	96,370	336,340
Northern Cardinal	59	59.37	0.25	-0.18	0.67	46	1	113,005	4,060,570	4,426,020
Northern Flicker	42	0.67	-2.67	-4.09	-1.31	204	3	113,005	77,920	181,940
Northern Mockingbird[1]	59	50.60	-0.42	-0.87	0.05	64	1	113,005	2,981,300	3,607,370
Northern Parula	44	3.38	-3.38	-4.78	-1.86	294	4	113,005	1,174,940	3,160,600
Northern Rough-winged Swallow	46	2.91	1.58	-1.71	4.66	27	1	113,005	210,150	389,820
Orchard Oriole	52	8.87	-3.26	-4.09	-2.43	271	3	113,005	1,512,770	3,978,590
Osprey[3]	NA	NA	3.57	2.25	4.45	25	0	163	20	20
Ovenbird[3]	NA	NA	-0.05	-0.34	0.08	40	NA	113,005	1,830	1,870
Painted Bunting	45	5.57	-1.7	-2.86	-0.59	124	2	96,861	1,310,370	2,424,190
Pileated Woodpecker	48	1.17	1.01	-0.16	2.15	33	1	113,005	149,830	161,820
Pine Warbler	14	0.74	-0.09	-4.08	4.39	62	3	4,008	800	830
Prairie Warbler	6	0.17	1.19	-3.58	6.18	34	2	6,779	250	700
Prothonotary Warbler	51	7.68	-1.4	-2.47	-0.3	107	2	105,911	2,352,350	3,999,000
Purple Martin[1]	57	50.05	-1.45	-2.78	-0.15	110	2	113,005	560,690	967,180

Table 5. Fifty-year population trend for avian species in the Mississippi Alluvial Valley.—Continued

Species	Routes (n)	Relative abundance	50-year trend	Trend LCL	Trend UCL	MSP	MSP (SD)	Area range	Estimated MAV population	MAV population goal
Red-bellied Woodpecker	58	9.27	1.6	0.93	2.29	25	0	113,005	914,650	914,650
Red-eyed Vireo	43	1.07	-0.56	-2.12	1	71	1	113,005	387,220	495,640
Red-headed Woodpecker	42	2.28	-0.84	-2.13	0.51	81	2	113,005	244,390	347,030
Red-shouldered Hawk	40	0.82	0.82	-0.63	2.36	36	1	113,005	110,690	145,560
Red-tailed Hawk	50	0.42	5.74	4.28	7.26	25	0	113,005	93,690	93,690
Red-winged Blackbird[1]	59	488.45	-0.02	-0.81	0.77	53	1	113,005	6,159,440	6,221,030
Rock Pigeon[2]	43	12.50	-4.72	-6.84	-2.66	592	11	113,005	95,750	95,750
Ruby-throated Hummingbird	9	0.01	-1.36	-3.06	0.33	107	0	113,005	779,250	1,309,130
Scarlet Tanager[3]	NA	NA	-0.24	-0.44	-0.05	40	NA	3,104	50	50
Scissor-tailed Flycatcher	13	0.16	7.78	5.12	10.59	25	0	2,022	870	870
Snowy Egret	36	2.41	6.14	3.1	9.76	25	0	113,005	184,580	184,580
Summer Tanager	51	1.98	1.47	0.1	2.76	26	1	113,005	761,750	761,750
Swainson's Warbler	12	0.17	0.58	-3.16	4.78	45	2	98,331	33,280	85,860
Swallow-tailed Kite	8	0.02	12.31	4.46	21.81	25	0	15,988	1,790	1,790
Tree Swallow	8	0.02	6.54	-1.2	15.52	25	0	35,372	4,620	7,390
Tufted Titmouse	58	5.37	2.55	1.78	3.34	25	0	113,005	973,910	973,910
Warbling Vireo	8	0.28	1.93	-1.5	5.92	25	1	104,896	33,510	58,630
White Ibis	30	26.71	6.91	1	12.94	25	0	113,005	1,935,350	1,935,350
White-breasted Nuthatch	7	0.03	4.2	-1.56	10.44	25	0	89,915	31,520	56,110
White-eyed Vireo	51	7.91	-1.36	-2.35	-0.38	104	1	113,005	1,539,720	2,586,730
White-faced Ibis	11	4.64	8.7	-3.66	21.61	25	0	113,005	23,260	65,830
White-winged Dove	9	0.00	23.74	9.4	36.25	25	0	113,005	6,100	6,100
Wild Turkey	16	0.04	4.77	-1.12	12.86	25	0	76,968	1,620	2,530
Wood Duck	48	2.74	0.44	-1.37	2.39	44	1	113,005	195,310	329,100
Wood Thrush	36	1.61	-2.12	-3.29	-0.95	153	2	95,000	33,980	69,990
Worm-eating Warbler[3]	NA	NA	0.46	-0.24	1.24	40	NA	95,605	6,060	6,780
Yellow Warbler	6	0.02	2.37	-3.82	10.38	25	1	32,761	1,770	5,150
Yellow-billed Cuckoo	59	12.13	-0.97	-1.72	-0.19	85	1	113,005	905,590	1,344,810
Yellow-breasted Chat	52	11.62	-1.6	-2.55	-0.64	117	2	103,297	709,050	1,276,300
Yellow-throated Vireo	30	0.32	1.5	-0.72	3.74	27	1	93,874	97,500	132,590
Yellow-throated Warbler	26	0.07	4.51	0.15	9.81	25	0	113,005	33,330	33,330

[1] Population estimate from Population Estimates Database (Partners in Flight Science Committee, 2013); values from table 3.

[2] Non-native species with population goal of no increase in population.

[3] Trend from Eastern Breeding Bird Survey Region.

Table 6. Empirical estimates of bird densities in forest habitat subjected to different silvicultural management.

[Density (birds per hectares) estimates are from Twedt and Wilson (2017), Norris and others, (2009), or other published sources as indicated. Mean density was used to calculate the area) of forest required to support the estimated minimum sustainable population (MSP) of each species (table 5); ---, not available]

	Twedt and Wilson		Norris and others				Other sources			
Species	Control[1]	Treated[2]	Control[1]	Single tree[3]	Group select[4]	Extensive harvest[5]	Source #1	Source #2	Mean density	MSP area hectares
Acadian Flycatcher	3.279	1.474	3.400	3.050	1.800	1.400	[6]0.640	[7]1.100	2.018	12
American Crow	0.114	0.155	0.300	0.175	0.250	0.210	---	---	0.201	125
American Goldfinch	---	---	---	---	---	---	[8]0.780	---	0.780	33
American Redstart	0.027	0.027	0.260	0.390	0.580	---	---	---	0.257	97
American Robin	---	---	[9]0.120	---	[9]0.480	[9]0.840	---	---	0.480	90
Barred Owl	0.230	0.040	0.060	0.060	0.060	0.060	---	---	0.085	294
Baltimore Oriole	---	---	---	---	---	---	---	---	[10]0.302	701
Black-and-white Warbler	---	---	---	---	---	---	[11]0.015	[6]0.346	0.180	139
Blue-gray Gnatcatcher	3.695	2.251	3.800	3.500	4.700	4.700	---	---	3.774	9
Brown-headed Cowbird	0.922	0.766	1.200	1.500	1.300	1.600	---	---	1.215	41
Blue Jay	0.181	0.087	0.100	0.100	0.100	0.100	---	---	0.111	530
Brown Thrasher	---	---	[12]0.160	[12]0.340	[12]0.780	[12]1.670	---	---	0.738	142
Carolina Chickadee	1.722	1.024	1.450	1.520	1.100	1.600	---	---	1.403	43
Carolina Wren	1.596	1.472	2.050	3.100	2.600	2.600	---	---	2.236	12
Cerulean Warbler	---	---	[13]0.025	---	[13]0.070	[13]0.030	---	[14]0.108	0.058	25,957
Chimney Swift	---	---	0.030	0.030	0.030	0.030	---	---	0.030	5,236
Common Grackle	0.023	0.023	0.060	0.060	0.060	0.060	---	---	0.048	6,776
Common Yellowthroat	0.063	0.084	0.140	---	0.570	---	---	---	0.214	2,144
Downy Woodpecker	0.952	0.588	0.730	0.730	0.730	0.730	---	---	0.743	51
Eastern Phoebe	---	---	---	---	---	---	---	---	0.017	2,090
Eastern Towhee	0.238	0.169	0.180	0.470	0.810	---	---	---	0.373	107
Eastern Wood-Pewee	0.328	0.280	0.080	0.170	0.140	---	---	---	0.200	146
Fish Crow	---	---	0.061	---	---	---	---	---	0.061	1,055
Great Crested Flycatcher	0.485	0.320	0.240	0.240	0.240	0.240	[15]0.270		0.291	91
Gray Catbird	0.020	0.020	---	---	---	---	---	---	0.020	3,326
Hairy Woodpecker	0.126	0.112	0.070	0.070	0.070	0.070	---	---	0.086	1,798
Hooded Warbler	0.257	0.208	0.620	0.620	0.620	0.620	[16]0.250	[17]0.420	0.452	128

Table 6. Empirical estimates of bird densities in forest habitat subjected to different silvicultural management.—Continued

[Density (birds per hectares) estimates are from Twedt and Wilson (2017), Norris and others, (2009), or other published sources as indicated. Mean density was used to calculate the area) of forest required to support the estimated minimum sustainable population (MSP) of each species (table 5); ---, not available]

	Twedt and Wilson		Norris and others				Other sources			
Species	Control[1]	Treated[2]	Control[1]	Single tree[3]	Group select[4]	Extensive harvest[5]	Source #1	Source #2	Mean density	MSP area hectares
Indigo Bunting	0.869	0.779	1.000	1.500	1.200	1.100	---	---	1.075	37
Kentucky Warbler	0.251	0.306	0.240	0.320	0.550	---	---	[18]0.220	0.315	178
Louisiana Waterthrush	---	---	---	---	---	---	---	---	[19]0.005	5,000
Mississippi Kite	---	---	0.020	0.020	0.020	0.020	---	---	0.020	1,250
Northern Cardinal	1.781	1.334	2.950	1.950	1.600	2.750	---	---	2.061	22
Northern Flicker	0.009	0.017	---	---	---	---	---	---	0.013	15,692
Northern Parula	1.092	0.521	0.800	0.450	0.400	1.800	[20]0.350	[21]2.050	0.933	315
Orchard Oriole	0.060	0.128	---	0.120	---	---	---	---	0.103	2,643
Painted Bunting	0.082	0.075	0.220	---	---	---	---	---	0.126	987
Pine Warbler	---	---	---	---	---	---	---	---	[20]0.007	8,749
Pileated Woodpecker	0.220	0.153	0.160	0.160	0.160	0.160	---	---	0.169	193
Prothonotary Warbler	1.611	0.651	1.500	1.450	1.000	0.700	---	[22]1.200	1.159	92
Red-bellied Woodpecker	0.954	0.734	0.950	1.250	1.100	0.500	---	---	0.915	27
Red-eyed Vireo	0.903	0.521	1.150	0.600	0.720	0.850	---	---	0.791	90
Red-headed Woodpecker	0.087	0.047	---	0.080	0.090	---	---	---	0.076	1,071
Red-shouldered Hawk	0.033	0.032	0.080	0.080	0.080	0.080	[23]0.027	---	0.059	617
Ruby-throated Hummingbird	3.790	4.735	1.450	2.200	1.000	---	---	---	2.635	41
Swallow-tailed Kite	---	---	---	---	---	---	[24]0.002	[25]0.001	0.002	10,689
Summer Tanager	0.712	0.449	0.620	0.620	0.620	0.620	---	---	0.607	43
Swainson's Warbler	0.109	0.078	0.110	0.110	0.110	0.110	---	---	0.105	428
Tufted Titmouse	1.597	1.377	---	---	---	---	---	---	1.487	17
Warbling Vireo	---	---	[26]0.07	---	---	[26]0.03	---	[27]0.025	0.042	127
White-breasted Nuthatch	0.290	0.091	---	---	---	---	---	---	0.191	131
White-eyed Vireo	1.415	1.175	2.600	2.400	2.700	3.500	---	---	2.298	45
Wild Turkey	---	---	---	---	---	---	[28]0.001	[29]0.002	0.002	10,000
Wood Thrush	0.074	0.070	0.022	0.051	---	---	---	[30]0.230	0.089	1,717

Table 6. Empirical estimates of bird densities in forest habitat subjected to different silvicultural management.—Continued

[Density (birds per hectares) estimates are from Twedt and Wilson (2017), Norris and others, (2009), or other published sources as indicated. Mean density was used to calculate the area) of forest required to support the estimated minimum sustainable population (MSP) of each species (table 5); ---, not available]

	Twedt and Wilson		Norris and others				Other sources			
Species	**Control[1]**	**Treated[2]**	**Control[1]**	**Single tree[3]**	**Group select[4]**	**Extensive harvest[5]**	**Source #1**	**Source #2**	**Mean density**	**MSP area hectares**
Yellow-breasted Chat	0.081	0.363	0.700	0.740	0.450	0.750	[31]0.526	---	0.650	266
Yellow-billed Cuckoo	0.802	0.582	0.270	0.140	0.150	---	[19]0.310		0.180	131
Yellow-throated Vireo	0.190	0.080	---	---	---	---	---	---	0.035	150
Yellow-throated Warbler	0.034	0.036	---	---	---	---	---	---	0.035	714

[1]Control = Unharvested forest

[2]Treated = Forest subjected to prescribed timber harvest of mixed severity

[3]Single tree = Forest harvested by removal of single trees or small clusters of trees leaving small canopy gaps

[4]Group select = Forest harvested by removal of patches or clumped groups of trees resulting in small to large canopy openings

[5]Extensive harvest = Forest subjected to extensive removal by clear-felling or shelterwood harvests that removed most of the canopy

[6]James and Neal, 1986

[7]Bakermans and Rodewald, 2006

[8]McGraw and Middleton, 2017

[9]Pitts, 1984

[10]projected density in forest from table 4

[11]www.lmvjv.org/hsi_model/Bird_Models.aspx

[12]Graber and others, 1970

[13]Curley and others, 2012

[14]Sheehan and others, 2014

[15]Canterbury and Blockstein, 1997

[16]MacClintock and others, 1977

[17]Chiver and others, 2011

[18]Gibbs and Faaborg, 1990

[19]Hamel, 1992

[21]Moldenhauer and Regelski, 2012

[20]Graber and others, 1983

[22]Petit, 1988

[23]Townsend, 2006

[24]Cely and Sorrow, 1990

[25]Sykes and others, 1999

[26]Hobson and Schieck, 1999

[27]Shea and others, 2017

[28]Grisham, 2007

[29]Miller and Conner, 2005

[30]Holmes and Sherry, 1988

[31]Nolan, 1963

Table 7. Estimated populations of avian species within forest patches of sufficient area to be deemed capable of supporting sustainable populations.

[For species with estimated extant populations in the Mississippi Alluvial Valley Bird Conservation Region that were less than the regional population goal for the species, we estimated the area (in hectares [ha]) of additional habitat that would be required to support the desired population goal (table 5) under “existing” forest management (about 14 percent treated by means of harvest, of which 4 percent was clearcut) as well as under a theoretical “optimal” management regime wherein all forest was managed to support maximum densities of the species; --- not determined]

Species	Existing area (ha) of sustaining habitat	Population supported with existing management	Theoretical population supported with “optimal” management	Additional habitat (ha) needed with existing management	Additional habitat (ha) needed with “optimal” management
Acadian Flycatcher	1,463,971	4,751,318	4,977,501	0	0
American Crow	1,250,454	363,444	375,136	0	0
American Goldfinch[1]	23,884	---	18,630	---	138,928
American Redstart	1,022,985	291,295	593,331	0	0
American Robin	84,146	14,641	70,683	5,170,358	775,314
Baltimore Oriole[1]	170,825	---	54,664	---	5,889,915
Barred Owl	139,202	29,107	32,016	54,112	35,205
Black-and-white Warbler[1]	381,703	---	131,917	---	0
Blue Jay	907,752	154,917	164,303	6,863,743	6,312,843
Blue-gray Gnatcatcher	2,483,604	9,594,162	11,672,939	0	0
Brown Thrasher	518,428	129,918	865,775	1,533,531	0
Brown-headed Cowbird	2,262,120	2,780,145	3,619,392	0	0
Carolina Chickadee	1,643,539	2,703,983	2,830,174	617,784	509,444
Carolina Wren	2,322,879	4,937,279	7,200,925	0	0
Cerulean Warbler	231,143	6,553	24,963	134,497	0
Chimney Swift	128,774	3,863	3,863	15,644,177	15,644,147
Common Grackle	596,792	35,808	35,808	94,285,408	94,285,408
Common Yellowthroat	1,459,759	95,337	832,063	13,945,088	3,438,147
Downy Woodpecker	2,052,731	1,872,009	1,954,200	0	0
Eastern Phoebe[1]	234,220	---	3,990	---	1,826,387
Eastern Towhee	1,033,651	238,360	837,257	469,200	0
Eastern Wood-Pewee	832,368	268,622	273,017	0	0
Fish Crow[1]	784,155	---	47,833	---	3,543,051
Great Crested Flycatcher	2,125,937	992,494	1,169,265	0	0
Hairy Woodpecker	709,656	88,324	89,417	280,959	267,915
Hooded Warbler	1,173,550	727,601	727,601	0	0
Indigo Bunting	2,188,109	2,247,188	3,282,164	842,768	0
Kentucky Warbler	743,008	194,259	408,654	0	0
Mississippi Kite	1,383,174	27,663	27,663	20,318,992	20,318,992
Northern Cardinal	2,448,619	6,998,153	7,223,426	0	0
Northern Parula	974,920	1,003,378	1,998,586	2,131,513	566,835
Orchard Oriole	813,003	54,861	104,064	56,440,222	30,269,698
Painted Bunting	625,594	50,817	137,631	29,293,680	10,393,456
Pileated Woodpecker	1,019,439	216,763	224,277	0	0

Table 7. Estimated populations of avian species within forest patches of sufficient area to be deemed capable of supporting sustainable populations.—Continued

[For species with estimated extant populations in the Mississippi Alluvial Valley Bird Conservation Region that were less than the regional population goal for the species, we estimated the area (in hectares [ha]) of additional habitat that would be required to support the desired population goal (table 5) under "existing" forest management (about 14 percent treated by means of harvest, of which 4 percent was clearcut) as well as under a theoretical "optimal" management regime wherein all forest was managed to support maximum densities of the species; --- not determined]

Species	Existing area (ha) of sustaining habitat	Population supported with existing management	Theoretical population supported with "optimal" management	Additional habitat (ha) needed with existing management	Additional habitat (ha) needed with "optimal" management
Pine Warbler[1]	15,760	---	110	---	103,242
Prothonotary Warbler	1,524,008	2,294,242	2,455,177	1,154,514	958,299
Red-bellied Woodpecker	2,116,886	2,004,691	2,646,108	0	0
Red-eyed Vireo	850,090	938,754	977,604	0	0
Red-headed Woodpecker	535,061	44,196	48,155	3,720,365	3,320,870
Red-shouldered Hawk	1,131,811	90,545	90,545	687,676	687,676
Ruby-throated Hummingbird	1,796,383	6,995,026	8,505,874	0	0
Summer Tanager	1,713,170	1,170,215	1,219,777	0	0
Swainson's Warbler	1,074,276	118,170	118,170	0	0
Swallow-tailed Kite[1]	202,865	---	406	---	689,840
Tufted Titmouse	976,196	1,535,361	1,558,985	0	0
Warbling Vireo	134,852	8,684	9,440	775,621	702,783
White-breasted Nuthatch	865,859	232,145	251,099	0	0
White-eyed Vireo	1,749,353	4,607,796	6,122,736	0	0
Wild Turkey[1]	768,433	---	1,537	---	498,311
Wood Thrush	936,040	68,855	215,289	15,519	0
Yellow-billed Cuckoo	1,801,919	1,401,533	1,445,139	0	0
Yellow-breasted Chat	1,193,874	436,301	1,432,649	2,191,485	0
Yellow-throated Vireo	1,023,483	182,078	317,280	0	0
Yellow-throated Warbler	224,275	7,675	8,074	748,500	701,649

[1]Densities associated with different type of silvicultural management were not estimated.

The estimated, presumably sustainable, total populations supported by these occupied areas likely are dependent on the effect of forest management on species density. Therefore, we estimated the sustainable population of each species by assuming avian densities associated with different forest management (Norris and others, 2009; Twedt and Wilson, 2017) and for the combination of management that reflected existing regional forest conditions within the past 5 years (that is, 86 percent of area untreated and 14 percent treated [typically through timber harvest]). The 14 percent treated stands were composed of 4 percent clearcut and 10 percent other treatment type.

Under this existing forest-management regime, forest habitat in patches deemed capable of sustaining populations was sufficient to support our designated population goals for 23 species but was insufficient to support population goals for 23 species (table 7). Because we lacked treatment-specific densities for some bird species, we were unable to estimate populations under existing management regime for eight species (American Goldfinch, Baltimore Oriole, Black-and-white Warbler, Eastern Phoebe, Fish Crow, Pine Warbler, Swallow-tailed Kite, and Wild Turkey; table 7). Theoretically, if all forest was managed under a treatment regime that supported the

Existing area of forest habitat appears adequate to support avian population goals for 30 species under current or improved forest management.

highest density of the species, populations of seven of these species (Black-and-white Warbler, Brown Thrasher, Cerulean Warbler, Eastern Towhee, Indigo Bunting, Wood Thrush, and Yellow-breasted Chat) could achieve their regional population goals within extant forest habitat. Thus, it appears that the area of existing forest habitat is sufficient, given current or improved forest management, to achieve target population goals for 30 of 54 silvicolous species.

Using the same estimated species densities that we used to estimated populations within current sustainable forest habitat, we projected the amount of additional sustainable forest habitat needed to provide habitat supportive of population goals (table 7). For many (32) of these presumed silvicolous species, forest area was positively related to their probability of occupancy (appendix 6). For these species, increasing the area of forest within the MAV will likely increase their populations.

We found little association, or a negative association, with forest area for other species for which we modeled occupancy (appendix 6). Therefore, increasing the area of forest available for these species may not markedly increase their populations. Moreover, occupancy models for several of these species (for example, Common Grackle, Orchard Oriole) indicated a substantial proportion of their population was present in nonforest habitats (appendix 7, https://doi.org/10.5066/P9YMSM8I). For these species, we estimated occupied habitat for the entirety of the MAV on the basis of their spatial occupancy models (appendix 6; appendix 8, https://doi.org/10.5066/P9YMSM8I) without regard to habitat type (except for exclusion of permanent water).

As with forest habitat, we estimated the area (that is, proportion of each 900-m^2 pixel; appendix 9, https://doi.org/10.5066/P9YMSM8I) being occupied by each species. We summed the area of occupied habitat for the MAV and

Table 8. Estimated populations within all forest and nonforest habitat area (except permanent water) for avian species that did not achieve their target population goals within existing forest habitat.

[For species with estimated extant populations in the Mississippi Alluvial Valley Bird Conservation Region that were less than the regional population goal for the species (table 5), we estimated the number of additional birds needed to attain their desired population (table 5); ha, hectares; density, birds per ha]

Species	Density in occupied habitat[1]	Population goal	Area (ha) of occupied habitat	Total habitat-based population	Additional birds needed to meet population goal	Additional occupied area (ha) needed to support population goal
American Goldfinch	0.12	126,990	392,545	46,963	80,027	668,909
American Robin	0.661	721,950	1,221,976	807,124	0	0
Baltimore Oriole	0.398	1,939,440	1,672,973	665,174	1,274,266	3,204,892
Barred Owl	0.21	40,110	1,122,847	235,846	0	0
Blue Jay	0.233	1,306,930	4,079,686	951,127	355,803	1,526,152
Boat-tailed Grackle[2]	1.811	14,900	10,201	18,472	0	0
Chimney Swift	0.063	473,198	1,418,875	89,960	383,238	6,044,562
Chipping Sparrow[2]	0.029	9,250	421,804	12,029	0	0
Common Grackle	0.396	5,692,930	4,680,249	1,854,788	3,838,142	9,684,914
Common Yellowthroat	0.269	2,791,810	3,896,315	1,046,274	1,745,536	6,500,363
Eastern Phoebe	0.067	35,110	680,748	45,480	0	0
Field Sparrow[2]	0.104	119,380	506,735	52,616	66,764	642,993
Fish Crow	0.122	263,960	1,455,870	178,168	85,792	701,032
Mississippi Kite	0.348	434,040	1,890,872	658,926	0	0
Orchard Oriole	0.337	3,978,590	5,256,054	1,772,334	2,206,256	6,542,901
Painted Bunting	0.629	2,424,190	1,361,833	856,903	1,567,287	2,490,812
Red-headed Woodpecker	0.206	347,030	2,234,194	460,170	0	0
Red-shouldered Hawk	0.058	145,560	1,297,662	74,770	70,790	1,228,577
Swallow-tailed Kite[3]	0.002	1,790	558,733	1,117	673	336,500
Wild Turkey	0.001	2,530	1,737,261	2,195	335	265,148

[1] Density (birds per hectare) in occupied habitat (from table 4).

[2] Species was not previously modeled within forest habitat.

[3] Density estimate from published literature.

estimated the population of each species supported, presuming densities were equivalent to our previous population estimate (from distance-time models) distributed among the occupied (naïve estimate) proportion of the MAV (table 4). Of 20 species whose population we estimated within all habitat types in the MAV, including 3 species (Boat-tailed Grackle, Chipping Sparrow, and Field Sparrow) that were not previously modeled within forest habitat, 7 species had enough occupied habitat within the MAV to support their target population goals (table 8). For the other 13 species, we estimated the area of additional occupied habitat that would be required to support their target population goals (table 8).

Discussion

Species with Sufficient Extant Habitat

We found 23 species had sufficient sustainable forest-patch habitat to support their population goals under existing forest-management conditions in the MAV. Therefore, according to the estimates used in this study, no additional forest restoration would be needed to support the population goals of these species. Even so, some species had estimated populations that were below the population that could presumably occupy available suitable habitat. For these species, factors other than breeding habitat may be limiting their breeding populations within the MAV.

For 31 species whose population goals exceed the capacity of extant, sustainable forest habitat to accommodate their population goal, population deficits need to be accommodated. Therefore, we assessed the theoretical effect of one or more specific types of forest management (for example, no harvest or group-selection harvest) on their estimated MAV populations. Presuming universal application of the forest management that results in "optimal" density for the species, seven additional species would have sufficient existing sustainable habitat to support their population goals (table 7). For these species, their target population goals could be achieved solely through changes in forest management. Optimal forest management, however, may differ among species. Thus, consideration could be needed regarding conflicting effects of management among species.

For species whose occupancy models indicate a substantial proportion of their population may be present in nonforest habitat, inclusion of populations supported by nonforest habitat may be appropriate. When we accounted for populations of these species within all habitat types in the MAV, five species (American Robin, Barred Owl, Eastern Phoebe, Mississippi Kite, and Red-headed Woodpecker) appeared to have sufficient habitat to support their population goals—albeit not solely within presumed self-sustaining forest patches or under the current forest-management paradigm. Of three additional species we did not consider when assessing only forest habitat, two species (Boat-tailed Grackle and Chipping Sparrow) appeared to have sufficient populations within all habitat types to attain their respective population goals (table 8). Again, however, we did not attempt to assess the sustainability of bird populations within nonforest habitats.

Species for which Additional Habitat is Required

For species whose population goals could not be accommodated within existing sustainable forest patches nor within both forest and nonforest habitats, their population deficits may be accommodated through additional habitat. Existing habitat in the MAV appears unable to support population goals of 20 species. For these species, we estimated the additional area of reforestation (table 7) or the area of additional occupied habitat (table 8) that would likely be required to enable attainment of population goals.

The addition of about 700,000 ha of appropriately managed forest within sustainable forest patches may be sufficient for attainment of the population goals for 12 species (American Goldfinch, American Robin, Barred Owl, Carolina Chickadee, Hairy Woodpecker, Northern Parula, Pine Warbler, Red-shouldered Hawk, Swallow-tailed Kite, Warbling Vireo, Wild Turkey, and Yellow-throated Warbler; table 7). This additional forest area might be achieved through afforestation of 700,000 ha currently in agriculture. However, rather than haphazard afforestation throughout this BCR, it may be more efficient to undertake judicious forest restoration that transforms existing nonsustainable forest patches to forest patches deemed capable of sustaining the species. Indeed, placement of afforestation so as to increase the area of nonsustainable forest patches and thereby convert these patches to sustainable habitat could markedly reduce the afforested area required to achieve avian population goals (Twedt and others, 2006).

One additional species, Prothonotary Warbler, may benefit substantially from additional area of sustainable-forest patches. However, forest restoration alone may be insufficient for this species. Occupancy of Prothonotary Warbler was not

Reforestation of an additional 700,000 hectares within the Mississippi Alluvial Valley may be sufficient to attain the forest-bird population goals for Lower Mississippi Valley Joint Venture

strongly associated with forest area even though a positive association with canopy cover was noted (appendix 6). The autecology of Prothonotary Warblers indicates the likelihood of a strong association with swamp-forest within the MAV that was corroborated by our spatial models. Thus, increasing the area of forest habitat within flood-prone locations may increase abundance of this species. Even so, with a marked negative 50-year population trend of -2.5 (Sauer and others 2017), attainment of this species' population goal may be difficult. Despite this difficulty, existing sustainable habitat supports a relatively abundant Prothonotary Warbler population of about 2.3 million in the MAV (table 7). Restoration of 700,000 ha of sustainable forest habitat may increase the population of Prothonotary Warblers by more than 600,000 to a population of nearly 3 million.

For two additional species (Field Sparrow and Fish Crow), an approximately 700,000-ha increase in total area of occupied habitat may be enough to attain their population goals within all habitats in the MAV (table 8). However, as our occupancy model for Field Sparrow indicated a negative association with forest area (appendix 6), it is uncertain whether reforestation alone would be sufficent to increase the area of occupied habitat for this species. We noted a similar negative association between forest area and occupancy for Baltimore Oriole, Blue Jay, and Painted Bunting in the MAV (appendix 6). Consequently, additional reforestation may only marginally increase populations of these species. Indeed, the most supported occupancy models for these species indicates the likelihood of a strong positive association with forest edge. Thus, athough these species are forest dwelling in the MAV, they are most often associated with forest openings and edges. The lack of association between their occupancy and forest area buttresses this habitat association and indicates that factors other than simply increasing forest area may be needed to increase abundance of these species.

As with Prothonotary Warbler, the 50-year trends in abundance for five other species (Blue Jay, Chimney Swift, Common Grackle, Common Yellowthroat, and Orchard Oriole) indicate a population decline (table 5). Thus, achievement of population goals for these species may be challenging. For each of these species, a substantial portion of their population was found in nonforest habitat (appendix 7, https://doi.org/10.5066/P9YMSM8I). Consequently, our models indicate substantial increases in sustainable forest area are needed to attain their population goals in the MAV, which may exceed the area available for forest restoration. The lack of a population response to increased forest cover may be because occupancy of Orchard Oriole was negatively related to forest area. Similarly, occupancies of Chimney Swift and, to a lesser extent, Blue Jay were strongly linked to urban areas (appendix 6). Therefore, afforestation will likely have little effect on populations of these species.

Occupancies of Common Grackle and Common Yellowthroat, on the other hand, were positively related to forest area (appendix 6). Even so, with most Common Grackles found within nonforest habitat, reforestation of 700,000 ha may not markedly increase the population of this species (table 8). Nevertheless, with an estimated population of >2 million, Common Grackle is among the most populous bird species in the MAV.

With a 50-year trend decline of 4.28, Common Yellowthroat has had one of the most drastic declines in population within this ecoregion. Because of this precipitous decline, we suggest that increasing the presumed current population of <900,000 to nearly 3 million birds may be an insuperable population goal. Notably, if the population goal for Common Yellowthroat is reduced to a more achievable 10-percent increase, the area of forest restoration required to provide this habitat would be about 850,000 ha. Thus, our forest restoration target of 700,000 ha may achieve most of the needed increase in habitat for this species.

A target of 700,000 ha of additional sustainable forest habitat represents about 10 percent of restorable lands in the MAV (Mitchell and others, 2016). If achieved by mean of afforestation, this area of additional forest cover would increase the current 32 percent forest cover in the MAV (Mitchell and others, 2016) to about 39 percent forest cover. If this restoration were restricted to the highest priority restoration lands in this ecoregion (Twedt and others, 2006; https://doi.org/10.5066/P90V76SY), these afforested areas may be able to contribute to forest patches of sufficient area to be deemed sustainable habitat and thereby provision habitat to support avian population goals. Consequently, judicious afforestation that catalyzes conversion of existing forest to forest patches capable of sustaining breeding bird populations may result in less total forest restoration required to achieve avian population goals.

Summary

Of 45 avian species whose populations we estimated, existing forest area and management conditions in the Mississippi Alluvial Valley likely support sustainable populations of 23 species that are sufficent to achieve their population goals. For these species, no change in forest management nor additional forest restoration may be needed to support their population goals. However, for those species whose population goals exceed the capacity of extant, sustainable forest habitat to accommodate their population goals, population deficits may need to be accommodated. Change in forest management to optimize species densities might accommodate population goals of seven additional species within existing sustainable forest habitat. For other species, a substantial proportion of their populations may be in nonforest habitat. When estimated populations within forest and nonforest habitats were considered, six more species appeared to have sufficient habitat to support their population goals. However, these populations were not solely within self-sustaining forest patches and we did not assess the sustainability of bird populations within nonforest habitats.

For 18 species whose population goals could not be accommodated either within existing sustainable forest patches or within both forest and nonforest habitats, we estimated 700,000 hectares of additional sustainable forest habitat may be required to accommodate their population goals. However, judicial afforestation that converts existing nonsustaining forest habitat to sustainable forest habitat may result in sufficient habitat to support population goals of these species with less than 700,000 hectares of afforestation.

References Cited

Allen, Y., 2015, Inundation frequency of the Gulf Coastal Plain and Ouachitas: accessed August 16, 2019, at https://gisweb.ducks.org/arcgis/rest/services/SRO/GCPO_Flood_Frequency/MapServer. [Also available at https://www.sciencebase.gov/catalog/item/5617e3c3e4b0cdb063e3fc35.]

Allen, Y., 2016, Landscape scale assessment of floodplain inundation frequency using Landsat imagery: River Research and Applications, v. 32, no. 7, p. 1609–1620, accessed Auguest 16, 2019, at https://doi.org/10.1002/rra.2987.

Bailey, L.L., Simons, T.R., and Pollock, K.H., 2004, Estimating site occupancy and species detection probability parameters for terrestrial salamanders: Ecological Applications, v. 14, no. 3, p. 692–702, accessed August 16, 2019, at https://doi.org/10.1890/03-5012.

Bakermans, M.H., and Rodewald, A.D., 2006, Scale-dependent habitat use of Acadian Flycatcher (Empidonax virescens) in central Ohio: Auk, v. 123, no. 2, p. 368–382, accessed August 16, 2019, at https://doi.org/10.1642/0004-8038(2006)123[368:SHUOAF]2.0.CO;2.

Blancher, P.J., Rosenberg, K.V., Panjabi, A.O., Altman, Couturier, A.R., Thogmartin, W.E., and the Partners in Flight Science Committee, 2013, Handbook to the Partners in Flight Population Estimates Database (ver. 2.0): PIF Technical Series No 6, accessed August 16, 2019, at http://pif.birdconservancy.org/PopEstimates/downloads/Handbook%20to%20the%20PIF%20Population%20Estimates%20Database%20Version%202.0.pdf.

Burnham, K.P., and Anderson, D.R., 2002, Model selection and multimodel inference—A practical information-theoretic approach (2d ed.): New York, Springer-Verlag, 454 p.

Canterbury, G.E., and Blockstein, D.E., 1997, Local changes in a breeding bird community following forest disturbance: Journal of Field Ornithology, v. 68, no. 4, p. 537–546, accessed August 16, 2019, at https://sora.unm.edu/sites/default/files/journals/jfo/v068n04/p0537-p0546.pdf.

Cely, J.E., and Sorrow, J.A., 1990, The American Swallow-tailed Kite in South Carolina: Columbia, S.C., South Carolina Wildfire and Marine Resources Department, Nongame and Heritage Trust Fund Publication no. 1, 160 p.

Chapman, S.S., Kleiss, B.A., Omernik, J.M., Foti, T.L., and Murray, E.O., 2004, Ecoregions of the Mississippi Alluvial Plain (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,150,000), accessed August 16, 2019, at http://ecologicalregions.info/htm/map_eco.htm.

Chiver, I., Ogden, L.J., and Stutchbury, B.J., 2011, Hooded Warbler (Setophaga citrina) (ver. 2.0), in Poole, A.F., ed., The birds of North America: Ithaca, New York, Cornell Lab of Ornithology, accessed August 16, 2019, at https://doi.org/10.2173/bna.110.

Curley, S., Master, T., and George, G., 2012, Population distribution, density and habitat preference of the Cerulean Warbler (Setophaga cerulea) in the Delaware Water Gap National Recreation Area: Ornitologia Neotropical, v. 23, p. 351–357. [Also available at https://www.fs.usda.gov/treesearch/pubs/45177.]

Farnsworth, G.L., Pollock, K.H., Nichols, J.D., Simons, T.R., Hines, J.E., and Sauer, J.R., 2002, A removal model for estimating detection probabilities from point-count surveys: Auk, v. 119, no. 2, p. 414–425, accessed August 16, 2019, at https://www.jstor.org/stable/4089888.

Farnsworth, G.L., Nichols, D.J., Sauer, J.R., Fancy, S.G., Pollock, K.H., Shriner, S.A., and Simons, T.R., 2005, Statistical approaches to the analysis of point count data—A little extra information can go a long way, in Ralph, C.J., and Rich, T.D., eds., Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference, General Technical Report PSW-GTR-191, Albany, California; U.S. Department of Agriculture, Forest Service, p. 736–743. [Also available at https://www.fs.usda.gov/treesearch/pubs/32061.]

Fiske, I., and Chandler, R., 2011, unmarked—An R package for fitting hierarchical Models of wildlife occurrence and abundance: Journal of Statistical Software, v. 43, no. 10, p. 1–23, accessed August 16, 2019, at http://www.jstatsoft.org/v43/i10/.

Flather, C.H., Hayward, G.D., Beissinger, S.R., and Stephens, P.A., 2011, Minimum viable populations—Is there a 'magic number' for conservation practitioners?: Trends in Ecology and Evolution, v. 26, no. 6, p. 307–316. [Also available at https://www.fs.usda.gov/treesearch/pubs/38156.]

Gee, H., 2012, The effects of hydrologic modifications on floodplain forest tree recruitment and growth in the Mississippi River Alluvial Valley, USA: Baton Rouge, Louisiana State University, Ph.D. dissertation 1585, 140 p. [Also available at https://digitalcommons.lsu.edu/gradschool_dissertations/1585.]

Gibbs, J.P., and Faaborg, J., 1990, Estimating the viability of Ovenbird and Kentucky Warbler populations in forest fragments: Conservation Biology, v. 4, no. 2, p. 193–196, accessed August 16, 2019, at https://doi.org/10.1111/j.1523-1739.1990.tb00108.x.

Graber, J.W., Graber, R.R., and Kirk, E.L., 1983, Illinois birds—Wood warblers: Illinois Natural History Survey Biological Notes no. 118, 144 p. [Also available at http://hdl.handle.net/2142/26734.]

Graber, R.R., Graber, J.W., and Kirk, E.L., 1970, Illinois birds—Mimidae: Illinois Natural History Survey Biological Notes no. 68, 38 p. [Also available at http://hdl.handle.net/2142/17287.]

Grisham, B.A., 2007, Spatial ecology, habitat selection, and survival of wild turkey gobblers in a managed bottomland hardwood forest: Baton Rouge, Louisiana, Louisiana State University Master's thesis 55, 41 p. [Also available at https://digitalcommons.lsu.edu/gradschool_theses/55.]

Hamel, P.B., 1992, Land manager's guide to the birds of the South: Asheville, North Carolina, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, General Technical Report SE-22, 437 p. [Also available at https://www.fs.usda.gov/treesearch/pubs/2702.]

Hobson, K.A., and Schieck, J., 1999, Changes in bird communities in boreal mixedwood forest—Harvest and wildfire effects over 30 years: Ecological Applications v. 9, no. 3, p. 849–863, accessed December 5, 2019, at https://doi.org/10.1890/1051-0761(1999)009[0849:CIBCIB]2.0.CO;2.

Holmes, R.T., and Sherry, T.W., 1988, Assessing population trends of New Hampshire forest birds—Local versus regional patterns: Auk, v. 105, no. 4, p. 756–768. [Also available at https://sora.unm.edu/sites/default/files/journals/auk/v105n04/p0756-p0768.pdf.]

James, D.A., and Neal, J.C., 1986, Arkansas birds—Their distribution and abundance: Fayetteville, Arkansas, University of Arkansas Press, 402 p.

Keim, R.F., Chambers, J.L., Hughes, M.S., Nyman, J.A., Miller, C.A., Amos, B.J., Conner, W.H., Day, J.W., Jr., Faulkner, S.P., Gardiner, E.S., King, S.L., McLeod, K.W., and Shaffer, G.P., 2006, Ecological consequences of changing hydrological conditions in wetland forests of coastal Louisiana, in Xu, Y.J., and Singh, V.P., eds., Coastal environment and water quality: Highlands Ranch, Colorado, Water Resources Publications, LLC, p. 383–396. [Also available at https://www.fs.usda.gov/treesearch/pubs/25325.]

King, S.L., and Keim., R.F., 2019, Hydrologic modifications challenge bottomland hardwood forest management: Journal of Forestry, v. 117, no. 5, p. 504–514, accessed December 5, 2019, at https://doi.org/10.1093/jofore/fvz025.

King, S.L., Twedt, D.J., and Wilson, R.R., 2006, The role of the Wetlands Reserve Program in conservation efforts in the Mississippi Alluvial Valley: Wildlife Society Bulletin, v. 34, no. 4, p. 914–920, accessed August 19, 2019, at https://doi.org/10.2193/0091-7648(2006)34[914:TROTWR]2.0.CO;2.

Lower Mississippi Valley Joint Venture, 2015, MAV Forest Breeding Bird Decision Support Model—Update 2015: accessed August 19, 2019, at https://static1.squarespace.com/static/5bb3865d2727be6f94acf2fc/t/5bec7942b8a045d24a276e8c/1542224195084/LMVJV_FBBDSM_2015_Summary.pdf.

MacClintock, L., Whitcomb, R.F., and Whitcomb, R.L., 1977, Evidence for the value of corridors and minimization of isolation in preservation of biotic diversity: American Birds, v. 31, p. 6–16, accessed August 19, 2019, at https://sora.unm.edu/sites/default/files/journals/nab/v031n01/p00006-p00016.pdf.

Mackenzie, D.I., and Nichols, J.D., 2004, Occupancy as a surrogate for abundance estimation: Animal Biodiversity and Conservation, v. 27, no. 1, p. 461–467, accessed August 19, 2019, at http://abc.museucienciesjournals.cat/files/ABC-27-1-pp-461-467.pdf.

Mackenzie, D.I., Nichols, J.D., Hines, J.E., Knutson, M.G., and Franklin, A.B., 2003, Estimating site occupancy, colonization and local extinction probabilities when a species is not detected with certainty: Ecology, v. 84, no. 8, p. 2200–2207, accessed August 19, 2019, at https://doi.org/10.1890/02-3090.

Mackenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L., and Hines, J.E., 2017. Occupancy estimation and modeling—Inferring patterns and dynamics of species occurrence (2d ed.): London, Academic Press, 648 p. [Also available at https://www.elsevier.com/books/occupancy-estimation-and-modeling/mackenzie/978-0-12-407197-1.]

McGraw, K.J., and Middleton, A.L., 2017, American Goldfinch (Spinus tristis) (ver. 2.1), in Rodewald, P.G., ed., The birds of North America: Ithaca, N.Y., Cornell Lab of Ornithology. [Also available at https://doi.org/10.2173/bna.amegfi.02.1.]

Miller, D.A., and Conner, L.M., 2005, Seasonal and annual home ranges offemale Eastern Wild Turkeys in a managed pine landscape in Mississippi: Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies, v. 59, p. 89–99.

Mitchell, M., Wilson, R.R., Twedt, D.J., Mini, A.E., and James, J.D., 2016, Object-based forest classification to facilitate landscape-scale conservation in the Mississippi Alluvial Valley— Remote sensing applications: Society and Environment, v. 4, p. 55–60, accessed August 19, 2019, at https://doi.org/10.1016/j.rsase.2016.01.003.

Moldenhauer, R.R., and Regelski, D.J., 2012, Northern Parula (Setophaga americana) (ver. 2.0), in Poole, A.F., ed., The birds of North America: Ithaca, N.Y., Cornell Lab of Ornithology. [Also available at https://doi.org/10.2173/bna.215.]

Mueller, A.J., Twedt, D.J., and Loesch, C.R., 2000, Development of management objectives for breeding birds in the Mississippi Alluvial Valley, in Bonney, R., Pashley, D.N., Cooper, R., and Niles, L., eds., Strategies for bird conservation—The Partners in Flight planning process: Proceedings of the 3rd Partners in Flight workshop, Cape May, N.J., October 1–5, 1995, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Proceedings RMRS-P-16, p. 12–17. [Also available at http://static.birds.cornell.edu/pifcapemay/mueller.htm.]

Nolan V., Jr., 1963, Reproductive success of birds in a deciduous scrub habitat: Ecology, v. 44, no. 2, p. 305–313, accessed August 19, 2019, at https://doi.org/10.2307/1932177.

Norris, J.L., Chamberlain, M.L., and Twedt, D.J., 2009, Effects of wildlife forestry on abundance of breeding birds in bottomland hardwood forests of Louisiana: Journal of Wildlife Management, v. 73, no. 8, p. 1368–1379, accessed August 19, 2019, at https://doi.org/10.2193/2008-497.

Oswalt, S.N., 2013, Forest resources of the lower Mississippi Alluvial Valley: Asheville, N.C., U.S. Department of Agriculture, Forest Service, Southern Research Station, General Technical Report SRS–177, 29 p. [Also available at https://www.fs.usda.gov/treesearch/pubs/43960.]

Pardieck, K.L., Ziolkowski, D,J., Jr., Lutmerding, M., V. Aponte, V., and Hudson, M.-A.R., 2019. North American Breeding Bird Survey dataset 1966–2018 (ver. 2018.0): Laurel, Md., U.S. Geological Survey Patuxent Wildlife Research Center, accessed February 6, 2020, at https://doi.org/10.5066/P9HE8XYJ.

Partners in Flight Science Committee, 2013, Population Estimates Database (ver. 2013): accessed October 30, 2018, at http://pif.birdconservancy.org/#.

Petit, L.J., 1986, Factors affecting the reproductive success of Prothonotary Warblers (Protonotaria citrea) nesting in riverine habitat: Unpublished Master's thesis, Bowling Green, Ohio, Bowling Green State University, 80 p.

Pitts, T.D., 1984, Description of American Robin territories in northwest Tennessee: The Migrant, v. 55, no. 1, p. 1–6, accessed August 19, 2019, at http://www.tnbirds.org/MigrantOnline/V055/v055n1.htm.

Reed, J.M., Doerr, P.D., and Walters, J.R., 1988, Minimum viable population size of the Red-cockaded Woodpecker: Journal of Wildlife Management, v. 52, no. 3, p. 385–391, accessed August 19, 2019, at https://www.jstor.org/stable/3801578.

Rudis, V.A., and Birdsey, R.A., 1986, Forest resource trends and current conditions in the lower Mississippi Valley: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Resource Bulletin SO–116, New Orleans, La., 7 p. [Also available at https://www.fs.usda.gov/treesearch/pubs/2785.]

Sauer, J.R., Niven, D.K., Hines, J.E., Ziolkowski, D.J., Jr., Pardieck, K.L., Fallon, J.E., and Link, W.A., 2017, The North American Breeding Bird Survey—Results and analysis 1966–2015 (ver. 2.07.2017): Laurel, Md., U.S. Geological Survey Patuxent Wildlife Research Center, accessed October 30, 2018, at https://www.mbr-pwrc.usgs.gov/bbs/bbs.html.

Sauer, J.R., Link, W.A., Ziolkowski, D.J., Jr., Pardieck, K.L., and Twedt, D.J., 2019, Consistency counts—Modeling the effects of a change in protocol on Breeding Bird Survey counts: Condor, v. 121, no. 2, p. 1–12, accessed August 17, 2019, at https://doi.org/10.1093/condor/duz009.

Shea, E.L., Schulte, L.A., and Palik, B.J., 2017, Decade-long bird community response to the spatial pattern of variable retention harvesting in red pine (Pinus resinosa) forests: Forest Ecology and Management v. 402, p. 272–284, accessed August 19, 2019, at https://doi.org/10.1016/j.foreco.2017.07.053.

Sheehan, J., Wood, P.B., Buehler, D.A., Keyser, P.D., Larkin, J.L., Rodewald, A.D., Wigley, T.B., Boves, T.J., George, G.A., Bakermans, M.H., Beachy, T.A., Evans, A., McDermott, M.E., Newell, F.L., Perkins K.A., and White. M., 2014, Avian response to timber harvesting applied experimentally to manage Cerulean Warbler breeding populations: Forest Ecology and Management, v. 321, p. 5–18, accessed August 19, 2019, at https://doi.org/10.1016/j.foreco.2013.07.037.

Sykes, P.W., Kepler, C.B., Litzenberger, K.L., Sansing, H.R., Lewis E.T.R., and Hatfield, J.S., 1999, Density and habitat of breeding Swallow-tailed Kites in the lower Swannee ecosystem, Florida: Journal of Field Ornithology, v. 70, p. 321–336, accessed August 19, 2019, at https://sora.unm.edu/sites/default/files/journals/jfo/v070n03/p0321-p0336.pdf.

Thomas, L., Buckland, S.T., Burnham, K.P., Anderson, D.R., Laake, J.L., Borchers, D.L., and Strindberg. S., 2002, Distance sampling, in El-Shaarawi, A.H., and Piegorsch, W.W., eds., Encyclopedia of environmetrics., v. 1.: Chichester, U.K., J. Wiley & Sons, Ltd., p. 544–552. [Also available at http://distancesampling.org/downloads/dist_encyc_env.pdf.]

Townsend, K.A.L., 2006, Nesting ecology and sibling behavior of Red-shouldered Hawks at the St. Francis Sunken Lands Wildlife Management Area in northeastern Arkansas; Unpublished Master's thesis, Jonesboro, Arkansas, Arkansas State University, 125 p.

Twedt, D.J., 2012, Wildlife forestry, in Okia, C.A., ed., Global perspectives on sustainable forest management: Rijeka, Croatia, IntechOpenINTECH, chapter 10, p. 161–190, accessed August 18, 2019, at http://www.intechopen.com/books/global-perspectives-on-sustainable-forest-management/wildlife-forestry.

Twedt, D.J., 2015, Estimating regional landbird populations from enhanced North American Breeding Bird Surveys: Journal of Field Ornithology, v. 86, no. 4, p. 352–368, accessed August 19, 2019, at https://doi.org/10.1111/jofo.12118.

Twedt, D.J., and Loesch, C.R., 1999, Forest area and distribution in the Mississippi Alluvial Valley—Implications for breeding bird conservation: Journal of Biogeography, v. 26, no. 6, p. 1215–1224, accessed August 19, 2019, at https://doi.org/10.1046/j.1365-2699.1999.00348.x.

Twedt, D., Pashley, D., Hunter, C., Mueller, A., Brown, C., and Ford, R., 1999, Partners in Flight Bird Conservation Plan for the Mississippi Alluvial Valley: Vicksburg, Mississippi, Partners in Flight, 74 p. [Also available at https://static1.squarespace.com/static/5bb3865d2727be6f94acf2fc/t/5bedd052aa4a991d649bf506/1542312026011/MAV_PIF_PLAN.pdf.]

Twedt, D.J., and Wilson, R.R., 2017, Breeding birds in managed forests on public conservation lands in the Mississippi Alluvial Valley: Forest Ecology and Management, v. 384, p. 180–190, accessed August 19, 2019, at https://doi.org/10.1016/j.foreco.2016.10.031.

Twedt, D.J., Uihlein, W.B. III, and Elliott, A.B., 2006, A spatially explicit decision support model for restoration of forest bird habitat: Conservation Biology, v. 20, no. 1, p. 100–110, accessed August 19, 2019, at https://doi.org/10.1111/j.1523-1739.2005.00303.x.

Zeller, K.A., Jijhawan, S., Salom-Perez, R., Potosme, S.H., and Hines, J.E., 2011, Integrating occupancy modeling and interview data for corridor identification—A case study for jaguars in Nicaragua: Biological Conservation, v. 144, no. 2, p. 892–901, accessed August 19, 2019, at https://doi.org/10.1016/j.biocon.2010.12.003.

Appendix 1. Bird species

Table 1.1. Scientific names and alpha codes of birds.

[Avian species present within the Mississippi Alluvial Valley Bird Conservation Region (in alphabetical order), their scientific names, and the corresponding four-letter alpha codes]

Species	Scientific name	Alpha code
Acadian Flycatcher	Empidonax virescens	ACFL
American Crow	Corvus brachyrhynchos	AMCR
American Goldfinch	Spinus tristis	AMGO
American Kestral	Falco sparverius	AMKE
American Redstart	Setophaga ruticilla	AMRE
American Robin	Turdus migratorius	AMRO
Anhinga	Anhinga anhinga	ANHI
Baltimore Oriole	Icterus galbula	BAOR
Bank Swallow	Riparia riparia	BANS
Barn Swallow	Hirundo rustica	BARS
Barred Owl	Strix varia	BADO
Bell's Vireo	Vireo bellii	BEVI
Belted Kingfisher	Megaceryle alcyon	BEKI
Black Vulture	Coragyps atratus	BLVU
Black-and-white Warbler	Mniotilta varia	BAWW
Black-bellied Whistling Duck	Dendrocygna autumnalis	BBWD
Black-crowned Nightheron	Nycticorax nycticorax	BCNH
Black-necked Stilt	Himantopus mexicanus	BNST
Blue Grosbeak	Passerina caerulea	BLGR
Blue Jay	Cyanocitta cristata	BLJA
Blue-gray Gnatcatcher	Polioptila caerulea	BGGN
Boat-tailed Grackle	Quiscalus major	BTGR
Broad-winged hawk	Buteo platypterus	BWHA
Brown Thrasher	Toxostoma rufum	BRTH
Brown-headed Cowbird	Molothrus ater	BHCO
Canada Goose	Branta canadensis	CANG
Carolina Chickadee	Poecile carolinensis	CACH
Carolina Wren	Thryothorus ludovicianus	CARW
Cattle Egret	Bubulcus ibis	CAEG
Cedar Waxwing	Bombycilla cedrorum	CEDW
Cerulean Warbler	Setophaga cerulea	CERW
Chimney Swift	Chaetura pelagica	CHSW
Chipping Sparrow	Spizella passerina	CHSP
Chuck-will's-widow	Caprimulgus carolinensis	CWWI
Cliff Swallow	Petrochelidon pyrrhonota	CLSW
Common Gallinulle	Gallinula galeata	COGA
Common Grackle	Quiscalus quiscula	COGR
Common Ground Dove	Columbina passerina	COGD

Table 1.1. Scientific names and alpha codes of birds.—Continued

[Avian species present within the Mississippi Alluvial Valley Bird Conservation Region (in alphabetical order), their scientific names, and the corresponding four-letter alpha codes]

Species	Scientific name	Alpha code
Common Morrhen	Gallinula chloropus	COMO
Common Nighthawk	Chordeiles minor	CONI
Common Yellowthroat	Geothlypis trichas	COYE
Coppers Hawk	Accipiter cooperii	COHA
Dickcissel	Spiza americana	DICK
Downy Woodpecker	Picoides pubescens	DOWO
Eastern Bluebird	Sialia sialis	EABL
Eastern Kingbird	Tyrannus tyrannus	EAKI
Eastern Meadowlark	Sturnella magna	EAME
Eastern Phoebe	Sayornis phoebe	EAPH
Eastern Screech-Owl	Megascops asio	EASO
Eastern Towhee	Pipilo erythrophthalmus	EATO
Eastern Whip-poor-will	Caprimulgus vociferus	EWPW
Eastern Wood-Pewee	Contopus virens	EAWP
Eurasian Collared-Dove	Streptopelia decaocto	EUCD
European Starling	Sturnus vulgaris	EUST
Field Sparrow	Spizella pusilla	FISP
Fish Crow	Corvus ossifragus	FICR
Grasshopper Sparrow	Ammodramus savannarum	GRSP
Gray Catbird	Dumetella carolinensis	GRCA
Great Blue Heron	Ardea herodias	GBHE
Great Crested Flycatcher	Myiarchus crinitus	GCFL
Great Egret	Bubo virginianus	GREG
Great Horned Owl	Bubo virginianus	GHOW
Great-tailed Grackle	Quiscalus mexicanus	GTGR
Green Heron	Butorides virescens	GRHE
Hairy Woodpecker	Picoides villosus	HAWO
Hooded Warbler	Setophaga citrina	HOWA
Horned Lark	Eremophila alpestris	HOLA
House Finch	Carpodacus mexicanus	HOFI
House Sparrow	Passer domesticus	HOSP
Inca Dove	Columbina inca	INDO
Indigo Bunting	Passerina cyanea	INBU
Kentucky Warbler	Geothlypis formosa	KEWA
Killdeer	Charadrius vociferus	KILL
Lark Sparrow	Chondestes grammacus	LASP
Least Tern	Sternula antillarum	LETE
Little Blue Heron	Egretta caerulea	LBHE
Loggerhead Shrike	Lanius ludovicianus	LOSH
Louisiana Waterthrush	Parkesia motacilla	LOWA

Table 1.1. Scientific names and alpha codes of birds.—Continued

[Avian species present within the Mississippi Alluvial Valley Bird Conservation Region (in alphabetical order), their scientific names, and the corresponding four-letter alpha codes]

Species	Scientific name	Alpha code
Mississippi Kite	Ictinia mississippiensis	MIKI
Mottled Duck	Anas fulvigula	MODU
Mourning Dove	Zenaida macroura	MODO
Northern Bobwhite	Colinus virginianus	NOBO
Northern Cardinal	Cardinalis cardinalis	NOCA
Northern Flicker	Colaptes auratus	NOFL
Northern Mockingbird	Mimus polyglottos	NOMO
Northern Parula	Setophaga americana	NOPA
Northern Rough-winged Swallow	Stelgidopteryx serripennis	NRWS
Orchard Oriole	Icterus spurius	OROR
Osprey	Pandion haliaetus	OSPR
Ovenbird	Seiurus aurocapilla	OVEN
Painted Bunting	Passerina ciris	PABU
Pileated Woodpecker	Dryocopus pileatus	PIWO
Pine Warbler	Setophaga pinus	PIWA
Prairie Warbler	Setophaga discolor	PRAW
Prothonotary Warbler	Protonotaria citrea	PROW
Purple Martin	Progne subis	PUMA
Red-bellied Woodpecker	Melanerpes carolinus	RBWO
Red-eyed Vireo	Vireo olivaceus	REVI
Red-headed Woodpecker	Melanerpes erythrocephalus	RHWO
Red-shouldered Hawk	Buteo lineatus	RSHA
Red-tailed Hawk	Buteo jamaicensis	RTHA
Red-winged Blackbird	Agelaius phoeniceus	RWBL
Rock Pigeon	Columba livia	ROPI
Ruby-throated Hummingbird	Archilochus colubris	RTHU
Scarlet Tanager	Piranga olivacea	SCTA
Scissor-tailed Flycatcher	Tyrannus forficatus	STFL
Snowy Egret	Egretta thula	SNEG
Summer Tanager	Piranga rubra	SUTA
Swainson's Warbler	Limnothlypis swainsonii	SWWA
Swallow-tailed Kite	Elanoides forficatus	STKI
Tree Swallow	Tachycineta bicolor	TRES
Tufted Titmouse	Baeolophus bicolor	TUTI
Warbling Vireo	Vireo gilvus	WAVI
White-breasted Nuthatch	Sitta carolinensis	WBNU
White-eyed Vireo	Vireo griseus	WEVI
White-faced Ibis	Plegadis chihi	WFIB
White-winged Dove	Zenaida asiatica	WWDO
Wild Turkey	Meleagris gallopavo	WITU

Table 1.1. Scientific names and alpha codes of birds.—Continued

[Avian species present within the Mississippi Alluvial Valley Bird Conservation Region (in alphabetical order), their scientific names, and the corresponding four-letter alpha codes]

Species	Scientific name	Alpha code
Wood Duck	Aix sponsa	WODU
Wood Thrush	Hylocichla mustelina	WOTH
Worm-eating Warbler	Helmitheros vermivorum	WEWA
Yellow Warbler	Setophaga petechia	YEWA
Yellow-billed Cuckoo	Coccyzus americanus	YBCU
Yellow-breasted Chat	Icteria virens	YBCH
Yellow-crowned Nightheron	Nyctanassa violacea	YCNH
Yellow-throated Vireo	Vireo flavifrons	YTVI
Yellow-throated Warbler	Setophaga dominica	YTWA

Appendix 2. Bird detections during North American Breeding Bird Surveys

Distribution of initial detections of birds during North American Breeding Bird Surveys (2009–15) among three 1-minute time intervals (0:00–0:59 minute, 1:00–1:59 minutes, or 2:00–2:59 minutes), and two distance categories (≤50 meters [m] and >50 m). Available at https://doi.org/10.5066/P9AFKXXK.

Appendix 3. Locations of stops on North American Breeding Bird Survey routes

Geospatial locations of stops (that is, count-locations) along North American Breeding Bird Survey Routes or route equivalents used for 3-minute point counts of birds within or near (<30 miles [mi] [48 kilometers]) the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative boundary. As designated by QUALITY variable, presumed geospatial coordinates were (1) determined by using handheld or vehicular global positioning system (GPS) devices, (2) visually determined from Google Earth imagery on the basis of description provided by volunteer bird surveyors, or (3) assigned sequentially at 0.5-mi (~800-m) intervals from predetermined starting point (https://www.pwrc.usgs.gov/BBS/RawData/) along designated survey route. Available at https://doi.org/10.5066/P9AFKXXK.

Appendix 4. Model covariates

Table 4.1. Models used to assess species occupancy.

[Models were evaluated by using "colext" function of the Unmarked package (version 0.12–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

ψ	col	ext	p
•	•	•	•
F200XY	•	•	•
W200XY	•	•	•
A200XY	•	•	•
U200XY	•	•	•
C200XY	•	•	•
E200XY	•	•	•
F500XY	•	•	•
W500XY	•	•	•
A500XY	•	•	•
U500XY	•	•	•
C500XY	•	•	•
E500XY	•	•	•
F2000XY	•	•	•
W2000XY	•	•	•
A2000XY	•	•	•
U2000XY	•	•	•
C2000XY	•	•	•
E2000XY	•	•	•
FW200	•	•	•
FA200	•	•	•
FC200	•	•	•
FE200	•	•	•
AW200	•	•	•
AC200	•	•	•
AE200	•	•	•
UA200	•	•	•
UC200	•	•	•
UE200	•	•	•
CW200	•	•	•
EW200	•	•	•
FW500	•	•	•
FA500	•	•	•
FC500	•	•	•
FE500	•	•	•
AW500	•	•	•

Table 4.1. Models used to assess species occupancy.—Continued

[Models were evaluated by using "colext" function of the Unmarked package (version 0.12–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

ψ	col	ext	p
AC500	•	•	•
AE500	•	•	•
UA500	•	•	•
UC500	•	•	•
UE500	•	•	•
CW500	•	•	•
EW500	•	•	•
FWA200	•	•	•
FWE200	•	•	•
FWC200	•	•	•
AWE200	•	•	•
CWA200	•	•	•
UEA200	•	•	•
FWAC200	•	•	•
FWAE200	•	•	•
FWA500	•	•	•
FWE500	•	•	•
FWC500	•	•	•
AWE500	•	•	•
CWA500	•	•	•
UEA500	•	•	•
FWAC500	•	•	•
FWAE500	•	•	•
FW200XY	•	•	•
FA200XY	•	•	•
FC200XY	•	•	•
FE200XY	•	•	•
AW200XY	•	•	•
AC200XY	•	•	•
AE200XY	•	•	•
UA200XY	•	•	•
UC200XY	•	•	•
UE200XY	•	•	•
CW200XY	•	•	•
EW200XY	•	•	•
FW500XY	•	•	•
FA500XY	•	•	•
FC500XY	•	•	•

Table 4.1. Models used to assess species occupancy.—Continued

[Models were evaluated by using “colext” function of the Unmarked package (version 0.12–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

ψ	col	ext	p
FE500XY	•	•	•
AW500XY	•	•	•
AC500XY	•	•	•
AE500XY	•	•	•
UA500XY	•	•	•
UC500XY	•	•	•
UE500XY	•	•	•
CW500XY	•	•	•
EW500XY	•	•	•
FWA200XY	•	•	•
FWE200XY	•	•	•
FWC200XY	•	•	•
AWE200XY	•	•	•
CWA200XY	•	•	•
UEA200XY	•	•	•
FWAC200XY	•	•	•
FWAE200XY	•	•	•
FWA500XY	•	•	•
FWE500XY	•	•	•
FWC500XY	•	•	•
AWE500XY	•	•	•
CWA500XY	•	•	•
UEA500XY	•	•	•
FWAC500XY	•	•	•
FWAE500XY	•	•	•
FW200XY	FW200XY	FW200XY	•
FA200XY	FA200XY	FA200XY	•
FC200XY	FC200XY	FC200XY	•
FE200XY	FE200XY	FE200XY	•
AW200XY	AW200XY	AW200XY	•
AC200XY	AC200XY	AC200XY	•
AE200XY	AE200XY	AE200XY	•
UA200XY	UA200XY	UA200XY	•
UC200XY	UC200XY	UC200XY	•
UE200XY	UE200XY	UE200XY	•
CW200XY	CW200XY	CW200XY	•
EW200XY	EW200XY	EW200XY	•
FW500XY	FW500XY	FW500XY	•

Table 4.1. Models used to assess species occupancy.—Continued

[Models were evaluated by using “colext” function of the Unmarked package (version 0.12–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

ψ	col	ext	p
FA500XY	FA500XY	FA500XY	•
FC500XY	FC500XY	FC500XY	•
FE500XY	FE500XY	FE500XY	•
AW500XY	AW500XY	AW500XY	•
AC500XY	AC500XY	AC500XY	•
AE500XY	AE500XY	AE500XY	•
UA500XY	UA500XY	UA500XY	•
UC500XY	UC500XY	UC500XY	•
UE500XY	UE500XY	UE500XY	•
CW500XY	CW500XY	CW500XY	•
EW500XY	EW500XY	EW500XY	•
FWA200XY	FWA200XY	FWA200XY	•
FWE200XY	FWE200XY	FWE200XY	•
FWC200XY	FWC200XY	FWC200XY	•
AWE200XY	AWE200XY	AWE200XY	•
CWA200XY	CWA200XY	CWA200XY	•
UEA200XY	UEA200XY	UEA200XY	•
FWAC200XY	FWAC200XY	FWAC200XY	•
FWAE200XY	FWAE200XY	FWAE200XY	•
FWAEU200XY	FWAEU200XY	FWAEU200XY	•
FWA500XY	FWA500XY	FWA500XY	•
FWE500XY	FWE500XY	FWE500XY	•
FWC500XY	FWC500XY	FWC500XY	•
AWE500XY	AWE500XY	AWE500XY	•
CWA500XY	CWA500XY	CWA500XY	•
UEA500XY	UEA500XY	UEA500XY	•
FWAC500XY	FWAC500XY	FWAC500XY	•
FWAE500XY	FWAE500XY	FWAE500XY	•
FWAEU500XY	FWAEU500XY	FWAEU500XY	•
FW200XY	FW200XY	FW200XY	t
FA200XY	FA200XY	FA200XY	t
FW500XY	FW500XY	FW500XY	t
FA500XY	FA500XY	FA500XY	t
FWA200XY	FWA200XY	FWA200XY	t
FWE200XY	FWE200XY	FWE200XY	t
FWAC200XY	FWAC200XY	FWAC200XY	t
FWAE200XY	FWAE200XY	FWAE200XY	t
FWAEU200XY	FWAEU200XY	FWAEU200XY	t

Table 4.1. Models used to assess species occupancy.—Continued

[Models were evaluated by using “colext” function of the Unmarked package (version 0.12–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

ψ	col	ext	p
FWA500XY	FWA500XY	FWA500XY	t
FWE500XY	FWE500XY	FWE500XY	t
FWAE500XY	FWAE500XY	FWAE500XY	t
FWAEU500XY	FWAEU500XY	FWAEU500XY	t

References Cited

Fiske, I., and Chandler, R., 2011, unmarked—An R package for fitting hierarchical models of wildlife occurrence and abundance: Journal of Statistical Software, v. 43, no. 10, p. 1–23, accessed August 16, 2019, at http://www.jstatsoft.org/v43/i10/.

Mackenzie, D.I., Nichols, J.D., Hines, J.E., Knutson, M.G., and Franklin, A.B., 2003, Estimating site occupancy, colonization and local extinction probabilities when a species is not detected with certainty: Ecology, v. 84, no. 8, p. 2200–2207, accessed August 19, 2019, at https://doi.org/10.1890/02-3090.

Appendix 5. Most supported occupancy models

Table 5.1. Covariates of models with most support for estimating species occupancy.

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using “colext” function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
Acadian Flycatcher					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	7239.6	0	0.84	0.84
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	7243.0	3.4	0.15	0.99
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	7249.5	9.94	0.006	1.00
American Crow					
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	26333.7	0	0.4	0.4
ψ(CWA500XY); col(CWA500XY); ext(CWA500XY); p(.)	19	26334.2	0.5	0.31	0.72
ψ(UEA500XY); col(UEA500XY); ext(UEA500XY); p(.)	19	26335.5	1.78	0.17	0.88
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	26336.9	3.22	0.081	0.96
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	26339.7	6.04	0.02	0.98
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	26340.1	6.4	0.016	1.00
American Goldfinch					
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(t)	17	1348.8	0	0.39	0.39
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	1349.4	0.57	0.29	0.69
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	1350.6	1.79	0.16	0.85
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	1352.5	3.66	0.063	0.91
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(t)	17	1352.9	4.05	0.052	0.96
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	1353.9	5.12	0.03	0.99
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(.)	16	1359.3	10.45	0.002	1.00
American Redstart					
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	1471.3	0	0.5	0.5
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	1471.4	0.11	0.48	0.98
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	1478.6	7.29	0.013	0.99
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	1480.1	8.81	0.006	1.00
American Robin					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	9033.6	0	1	1.00
Barred Owl					
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	465.4	0	0.99	0.99
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(.)	25	476.8	11.34	0.003	1
Baltimore Oriole					
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	6214.3	0	0.97	0.97

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	6221.3	7.06	0.028	1.00
Black-and-white Warbler					
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(t)	17	240.8	0	0.4	0.4
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(t)	17	242.3	1.52	0.19	0.58
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(.)	16	242.8	2.02	0.14	0.73
ψ(FE500XY); col(FE500XY); ext(FE500XY); p(.)	16	243.3	2.49	0.11	0.84
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(t)	20	244.9	4.07	0.052	0.89
ψ(FC500XY); col(FC500XY); ext(FC500XY); p(.)	16	246.3	5.51	0.025	0.92
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	246.5	5.69	0.023	0.94
ψ(AE500XY); col(AE500XY); ext(AE500XY); p(.)	16	248.4	7.56	0.009	0.95
ψ(UA500XY); col(UA500XY); ext(UA500XY); p(.)	16	248.4	7.61	0.009	0.96
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	248.7	7.9	0.008	0.97
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(.)	16	249.0	8.22	0.007	0.97
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	249.3	8.51	0.006	0.98
ψ(AW200XY); col(AW200XY); ext(AW200XY); p(.)	16	249.6	8.79	0.005	0.98
ψ(UA200XY); col(UA200XY); ext(UA200XY); p(.)	16	249.8	9.01	0.004	0.99
ψ(FWC500XY); col(FWC500XY); ext(FWC500XY); p(.)	19	250.2	9.42	0.004	0.99
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	251.0	10.19	0.002	0.99
ψ(AE200XY); col(AE200XY); ext(AE200XY); p(.)	16	251.7	10.89	0.002	0.99
ψ(AC200XY); col(AC200XY); ext(AC200XY); p(.)	16	252.4	11.65	0.001	1.00
Blue-gray Gnatcatcher					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	10778.8	0	0.62	0.62
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	10779.8	1	0.38	1.00
Brown-headed Cowbird					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	32362.4	0	0.55	0.55
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	32362.9	0.44	0.45	1.00
Blue Jay					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	25750.7	0	1	1.00
Brown Thrasher					
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(t)	20	7210.9	0	0.97	0.97
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(t)	17	7218.1	7.21	0.026	1.00
Boat-tailed Grackle					
ψ(UC200XY); col(UC200XY); ext(UC200XY); p(.)	16	2680.8	0	0.93	0.93

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using “colext” function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	2688.9	8.16	0.016	0.94
ψ(FWC500XY); col(FWC500XY); ext(FWC500XY); p(.)	19	2689.6	8.82	0.011	0.95
ψ(CW500XY); col(CW500XY); ext(CW500XY); p(.)	16	2689.8	8.99	0.01	0.96
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(.)	16	2690.8	10.04	0.006	0.97
ψ(FWC200XY); col(FWC200XY); ext(FWC200XY); p(.)	19	2691.3	10.54	0.005	0.98
ψ(UEA500XY); col(UEA500XY); ext(UEA500XY); p(.)	19	2691.3	10.58	0.005	0.98
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(.)	19	2691.4	10.61	0.005	0.98
ψ(AC200XY); col(AC200XY); ext(AC200XY); p(.)	16	2691.4	10.66	0.005	0.99
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	2691.8	11.09	0.004	0.99
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	2692.2	11.4	0.003	1.00
Carolina Chickadee					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(.)	25	16342.1	0	0.65	0.65
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	16344.1	2	0.24	0.89
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(.)	22	16346.6	4.51	0.068	0.96
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	16348.6	6.51	0.025	0.99
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(.)	22	16350.8	8.68	0.009	1.00
Carolina Wren					
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	37351.0	0	0.92	0.92
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	37355.8	4.83	0.082	1.00
Cerulean Warbler					
ψ(A2000XY); col(.); ext(.); p(.)	7	242.9	0	0.8	0.8
ψ(F2000XY); col(.); ext(.); p(.)	7	247.5	4.55	0.082	0.88
ψ(A2000XY); col(A2000XY); ext(A2000XY); p(.)	13	247.6	4.65	0.078	0.96
ψ(F2000XY); col(F2000XY); ext(F2000XY); p(.)	13	250.4	7.43	0.019	0.98
ψ(A500XY); col(.); ext(.); p(.)	7	254.1	11.18	0.003	0.98
ψ(UA500XY); col(.); ext(.); p(.)	8	255.3	12.36	0.002	0.99
ψ(FA500XY); col(.); ext(.); p(.)	8	255.5	12.53	0.002	0.99
ψ(AW500XY); col(.); ext(.); p(.)	8	256.0	13.02	0.001	0.99
ψ(AE500XY); col(.); ext(.); p(.)	8	256.1	13.14	0.001	0.99
ψ(AC500XY); col(.); ext(.); p(.)	8	256.1	13.17	0.001	0.99
ψ(A200XY); col(.); ext(.); p(.)	7	257.0	14.01	0.001	0.99
ψ(UA200XY); col(.); ext(.); p(.)	8	257.2	14.22	0.001	0.99
ψ(CWA500XY); col(.); ext(.); p(.)	9	257.3	14.31	0.001	0.99
ψ(AC200XY); col(.); ext(.); p(.)	8	257.4	14.44	0.001	0.99

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWA500XY); col(.); ext(.); p(.)	9	257.4	14.46	0.001	0.99
ψ(FA200XY); col(.); ext(.); p(.)	8	257.9	15	0	0.99
ψ(AWE500XY); col(.); ext(.); p(.)	9	257.9	15	0	1.00
Chipping Sparrow					
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	1067.9	0	0.41	0.41
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	1068.4	0.53	0.32	0.73
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	1069.2	1.35	0.21	0.94
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	1071.8	3.94	0.057	1.00
Chimney Swift					
ψ(CWA500XY); col(CWA500XY); ext(CWA500XY); p(.)	19	8265.8	0	0.51	0.51
ψ(UA500XY); col(UA500XY); ext(UA500XY); p(.)	16	8266.5	0.64	0.37	0.88
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	8269.5	3.69	0.08	0.96
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	8270.8	5.01	0.041	1.00
Common Grackle					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	28646.1	0	1	1.00
Common Yellowthroat					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	14452.3	0	0.8	0.8
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	14455.1	2.76	0.2	1.00
Downy Woodpecker					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	10560.6	0	0.99	0.99
ψ(CWA200XY); col(CWA200XY); ext(CWA200XY); p(.)	19	10571.1	10.51	0.005	1.00
Eastern Phoebe					
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(t)	20	1998.5	0	1	1.00
Eastern Towhee					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	10830.5	0	0.84	0.84
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	10833.9	3.36	0.16	1.00
Eastern Wood-Pewee					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	9435.6	0	0.75	0.75
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	9437.9	2.25	0.24	0.99

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	9444.5	8.92	0.009	1.00
Fish Crow					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	6105.4	0	0.59	0.59
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	6106.6	1.21	0.32	0.91
ψ(FWC500XY); col(FWC500XY); ext(FWC500XY); p(.)	19	6109.	3.99	0.08	0.99
ψ(FWC200XY); col(FWC200XY); ext(FWC200XY); p(.)	19	6114.7	9.34	0.006	1.00
Field Sparrow					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	1808.9	0	1	1.00
Great Crested Flycatcher					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	12448.3	0	1	1.00
Great Horned Owl (models not used for predicting occupancy)					
ψ(AE200); col(.); ext(.); p(.)	6	913.6	0	0.046	0.05
ψ(AC200); col(.); ext(.); p(.)	6	913.6	0.01	0.046	0.09
ψ(AE500); col(.); ext(.); p(.)	6	913.6	0.07	0.045	0.14
ψ(FE500); col(.); ext(.); p(.)	6	914.0	0.39	0.038	0.18
ψ(UA200); col(.); ext(.); p(.)	6	914.3	0.69	0.033	0.21
ψ(UE500); col(.); ext(.); p(.)	6	914.6	1.01	0.028	0.24
ψ(A200XY); col(.); ext(.); p(.)	7	914.6	1.01	0.028	0.26
ψ(AC200XY); col(.); ext(.); p(.)	8	914.7	1.19	0.026	0.29
ψ(FA200); col(.); ext(.); p(.)	6	914.8	1.20	0.025	0.31
ψ(UA500); col(.); ext(.); p(.)	6	914.8	1.21	0.025	0.34
ψ(C2000XY); col(.); ext(.); p(.)	7	914.8	1.23	0.025	0.36
ψ(AW200); col(.); ext(.); p(.)	6	914.8	1.24	0.025	0.39
ψ(CWA500); col(.); ext(.); p(.)	7	914.8	1.26	0.025	0.41
ψ(CWA200); col(.); ext(.); p(.)	7	914.9	1.34	0.024	0.44
ψ(AE500XY); col(.); ext(.); p(.)	8	915.1	1.53	0.021	0.46
ψ(A2000XY); col(.); ext(.); p(.)	7	915.2	1.64	0.02	0.48
ψ(A500XY); col(.); ext(.); p(.)	7	915.2	1.68	0.02	0.5
ψ(EW500); col(.); ext(.); p(.)	6	915.3	1.75	0.019	0.52
ψ(AWE200); col(.); ext(.); p(.)	7	915.4	1.83	0.018	0.54
ψ(AE200XY); col(.); ext(.); p(.)	8	915.4	1.84	0.018	0.56
ψ(UEA200); col(.); ext(.); p(.)	7	915.4	1.89	0.018	0.57
ψ(FA500); col(.); ext(.); p(.)	6	915.5	1.92	0.018	0.59
ψ(AWE500); col(.); ext(.); p(.)	7	915.5	1.99	0.017	0.61

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FC500); col(.); ext(.); p(.)	6	915.6	2.06	0.017	0.63
ψ(FW500); col(.); ext(.); p(.)	6	915.6	2.06	0.016	0.64
ψ(F500XY); col(.); ext(.); p(.)	7	915.7	2.12	0.016	0.66
ψ(AC500); col(.); ext(.); p(.)	6	915.7	2.17	0.016	0.67
ψ(AW500); col(.); ext(.); p(.)	6	915.7	2.17	0.016	0.69
ψ(FWE500); col(.); ext(.); p(.)	7	915.9	2.30	0.015	0.7
ψ(FE500XY); col(.); ext(.); p(.)	8	915.9	2.37	0.014	0.72
ψ(FWAE200); col(.); ext(.); p(.)	8	916.2	2.64	0.012	0.73
ψ(E500XY); col(.); ext(.); p(.)	7	916.3	2.71	0.012	0.74
ψ(UA200XY); col(.); ext(.); p(.)	8	916.5	2.95	0.011	0.75
ψ(AW200XY); col(.); ext(.); p(.)	8	916.6	2.99	0.01	0.76
ψ(UE200); col(.); ext(.); p(.)	6	916.6	3.00	0.01	0.77
ψ(UEA200XY); col(.); ext(.); p(.)	9	916.7	3.13	0.01	0.78
ψ(FWA200); col(.); ext(.); p(.)	7	916.7	3.14	0.01	0.79
ψ(F2000XY); col(.); ext(.); p(.)	7	916.8	3.25	0.009	0.8
ψ(CWA500XY); col(.); ext(.); p(.)	9	916.9	3.38	0.009	0.81
ψ(UA500XY); col(.); ext(.); p(.)	8	917.0	3.46	0.008	0.82
ψ(AWE500XY); col(.); ext(.); p(.)	9	917.1	3.50	0.008	0.83
ψ(.); col(.); ext(.); p(.)	4	917.1	3.51	0.008	0.83
ψ(FA500XY); col(.); ext(.); p(.)	8	917.1	3.55	0.008	0.84
ψ(EW200); col(.); ext(.); p(.)	6	917.2	3.62	0.008	0.85
ψ(AC500XY); col(.); ext(.); p(.)	8	917.2	3.64	0.008	0.86
ψ(AW500XY); col(.); ext(.); p(.)	8	917.2	3.67	0.007	0.86
ψ(FE200); col(.); ext(.); p(.)	6	917.3	3.71	0.007	0.87
ψ(AWE200XY); col(.); ext(.); p(.)	9	917.3	3.75	0.007	0.88
ψ(CWA200XY); col(.); ext(.); p(.)	9	917.3	3.77	0.007	0.89
ψ(FWAC200); col(.); ext(.); p(.)	8	917.3	3.78	0.007	0.89
ψ(FWA500); col(.); ext(.); p(.)	7	917.5	3.92	0.007	0.9
ψ(FWAE500); col(.); ext(.); p(.)	8	917.5	3.98	0.006	0.91
ψ(FWC500); col(.); ext(.); p(.)	7	917.6	4.05	0.006	0.91
ψ(FC500XY); col(.); ext(.); p(.)	8	917.7	4.10	0.006	0.92
ψ(FW500XY); col(.); ext(.); p(.)	8	917.7	4.12	0.006	0.92
ψ(UEA500); col(.); ext(.); p(.)	7	917.7	4.17	0.006	0.93
ψ(UC500); col(.); ext(.); p(.)	6	917.7	4.18	0.006	0.93
ψ(UE500XY); col(.); ext(.); p(.)	8	917.8	4.25	0.006	0.94
ψ(FWE500XY); col(.); ext(.); p(.)	9	917.9	4.33	0.005	0.95
ψ(EW500XY); col(.); ext(.); p(.)	8	918.2	4.65	0.005	0.95

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using “colext” function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(CW500); col(.); ext(.); p(.)	6	918.5	4.90	0.004	0.95
ψ(FC200); col(.); ext(.); p(.)	6	918.5	4.96	0.004	0.96
ψ(E200XY); col(.); ext(.); p(.)	7	918.7	5.13	0.004	0.96
ψ(FWAE500XY); col(.); ext(.); p(.)	10	919.0	5.43	0.003	0.96
ψ(U2000XY); col(.); ext(.); p(.)	7	919.1	5.49	0.003	0.97
ψ(FWA500XY); col(.); ext(.); p(.)	9	919.1	5.55	0.003	0.97
ψ(FWE200); col(.); ext(.); p(.)	7	919.2	5.61	0.003	0.97
ψ(UEA500XY); col(.); ext(.); p(.)	9	919.2	5.63	0.003	0.98
ψ(FWAC500); col(.); ext(.); p(.)	8	919.5	5.90	0.002	0.98
ψ(FW200); col(.); ext(.); p(.)	6	919.6	6.08	0.002	0.98
ψ(FWC500XY); col(.); ext(.); p(.)	9	919.7	6.10	0.002	0.98
ψ(C500XY); col(.); ext(.); p(.)	7	919.8	6.27	0.002	0.98
ψ(UE200XY); col(.); ext(.); p(.)	8	920.2	6.64	0.002	0.99
ψ(UC200); col(.); ext(.); p(.)	6	920.4	6.85	0.002	0.99
ψ(FWC200); col(.); ext(.); p(.)	7	920.5	6.91	0.002	0.99
ψ(EW200XY); col(.); ext(.); p(.)	8	920.6	7.03	0.001	0.99
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(t)	17	920.7	7.16	0.001	0.99
ψ(FWAC500XY); col(.); ext(.); p(.)	10	921.0	7.48	0.001	0.99
ψ(CW200); col(.); ext(.); p(.)	6	921.0	7.49	0.001	0.99
ψ(UC500XY); col(.); ext(.); p(.)	8	921.3	7.71	0.001	1.00
Gray Catbird (no valid estimate of ψ)					
Great-tailed Grackle (models not used for predicting occupancy)					
ψ(AW200XY); col(AW200XY); ext(AW200XY); p(.)	16	87.6	0	0.14	0.14
ψ(FW200XY); col(FW200XY); ext(FW200XY); p(.)	16	87.7	0.11	0.13	0.26
ψ(UA200XY); col(UA200XY); ext(UA200XY); p(.)	16	88.1	0.53	0.1	0.37
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(t)	17	89.2	1.62	0.06	0.43
ψ(FW200XY); col(FW200XY); ext(FW200XY); p(t)	17	89.2	1.63	0.06	0.49
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	89.2	1.66	0.059	0.55
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	89.8	2.18	0.045	0.59
ψ(EW500XY); col(EW500XY); ext(EW500XY); p(.)	16	90.4	2.79	0.034	0.62
ψ(UA500XY); col(UA500XY); ext(UA500XY); p(.)	16	90.9	3.27	0.026	0.65
ψ(UC200XY); col(UC200XY); ext(UC200XY); p(.)	16	90.9	3.29	0.026	0.68
ψ(EW200XY); col(EW200XY); ext(EW200XY); p(.)	16	91.0	3.4	0.025	0.7
ψ(UE200XY); col(UE200XY); ext(UE200XY); p(.)	16	91.5	3.89	0.019	0.72
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(.)	16	92.0	4.38	0.015	0.74
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(t)	17	92.0	4.44	0.015	0.75
ψ(FC500XY); col(FC500XY); ext(FC500XY); p(.)	16	92.7	5.07	0.011	0.76

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(.); col(.); ext(.); p(.)	4	92.9	5.28	0.01	0.77
ψ(CWA200XY); col(CWA200XY); ext(CWA200XY); p(.)	19	92.9	5.33	0.009	0.78
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(.)	19	93.2	5.59	0.008	0.79
ψ(FWE200XY); col(FWE200XY); ext(FWE200XY); p(.)	19	93.4	5.81	0.007	0.8
ψ(FWC200XY); col(FWC200XY); ext(FWC200XY); p(.)	19	93.4	5.82	0.007	0.8
ψ(AWE200XY); col(AWE200XY); ext(AWE200XY); p(.)	19	93.5	5.95	0.007	0.81
ψ(UEA200XY); col(UEA200XY); ext(UEA200XY); p(.)	19	94.0	6.4	0.006	0.82
ψ(UE500); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.82
ψ(CW200); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.82
ψ(FE200); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.83
ψ(AW200); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.83
ψ(EW200); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.84
ψ(AC500); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.84
ψ(FA500); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.85
ψ(FC500); col(.); ext(.); p(.)	6	94.4	6.86	0.004	0.85
ψ(UE200); col(.); ext(.); p(.)	6	94.4	6.87	0.004	0.86
ψ(AE500); col(.); ext(.); p(.)	6	94.4	6.87	0.004	0.86
ψ(UC200); col(.); ext(.); p(.)	6	94.5	6.87	0.004	0.86
ψ(UA500); col(.); ext(.); p(.)	6	94.5	6.88	0.004	0.87
ψ(EW500); col(.); ext(.); p(.)	6	94.5	6.88	0.004	0.87
ψ(CW500); col(.); ext(.); p(.)	6	94.5	6.88	0.004	0.88
ψ(AC200); col(.); ext(.); p(.)	6	94.5	6.88	0.004	0.88
ψ(UC500); col(.); ext(.); p(.)	6	94.5	6.88	0.004	0.89
ψ(FW500XY); col(FW500XY); ext(FW500XY); p(.)	16	95.2	7.62	0.003	0.89
ψ(CW500XY); col(CW500XY); ext(CW500XY); p(.)	16	95.2	7.64	0.003	0.89
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(.)	16	95.3	7.72	0.003	0.89
ψ(FE200XY); col(FE200XY); ext(FE200XY); p(.)	16	95.4	7.82	0.003	0.9
ψ(AE200); col(.); ext(.); p(.)	6	95.4	7.83	0.003	0.9
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	95.4	7.83	0.003	0.9
ψ(FC200XY); col(FC200XY); ext(FC200XY); p(.)	16	95.4	7.85	0.003	0.91
ψ(AE200XY); col(AE200XY); ext(AE200XY); p(.)	16	95.4	7.87	0.003	0.91
ψ(AC200XY); col(AC200XY); ext(AC200XY); p(.)	16	95.5	7.89	0.003	0.91
ψ(FA200); col(.); ext(.); p(.)	6	95.7	8.13	0.002	0.91
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(.)	19	95.7	8.17	0.002	0.92
ψ(CW200XY); col(CW200XY); ext(CW200XY); p(.)	16	95.9	8.31	0.002	0.92
ψ(FWE200XY); col(FWE200XY); ext(FWE200XY); p(t)	20	96.0	8.38	0.002	0.92
ψ(FE500XY); col(FE500XY); ext(FE500XY); p(.)	16	96.1	8.5	0.002	0.92

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(AWE200); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.92
ψ(FWC200); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.92
ψ(FWE500); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(UEA500); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(CWA200); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(W500XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(A200XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(FWE200); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.93
ψ(A500XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(C500XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(E200XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(W200XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(C2000XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(UEA200); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.94
ψ(E500XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(C200XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(U2000XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(F2000XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(U200XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(E2000XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(U500XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.95
ψ(W2000XY); col(.); ext(.); p(.)	7	96.4	8.86	0.002	0.96
ψ(A2000XY); col(.); ext(.); p(.)	7	96.5	8.87	0.002	0.96
ψ(F200XY); col(.); ext(.); p(.)	7	96.5	8.89	0.002	0.96
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	96.5	8.94	0.002	0.96
ψ(AE500XY); col(AE500XY); ext(AE500XY); p(.)	16	96.5	8.95	0.002	0.96
ψ(UEA500XY); col(UEA500XY); ext(UEA500XY); p(.)	19	96.6	9	0.002	0.96
ψ(FC200); col(.); ext(.); p(.)	6	96.6	9	0.002	0.97
ψ(FW500); col(.); ext(.); p(.)	6	96.6	9.01	0.002	0.97
ψ(UA200); col(.); ext(.); p(.)	6	96.6	9.01	0.002	0.97
ψ(UC500XY); col(UC500XY); ext(UC500XY); p(.)	16	96.6	9.04	0.002	0.97
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(t)	20	97.6	10.01	0.001	0.97
ψ(F500XY); col(.); ext(.); p(.)	7	97.7	10.16	0.001	0.97
ψ(FW200); col(.); ext(.); p(.)	6	97.9	10.3	0.001	0.97
ψ(AW500); col(.); ext(.); p(.)	6	97.9	10.32	0.001	0.97
ψ(FE500); col(.); ext(.); p(.)	6	97.9	10.35	0.001	0.97
ψ(FWAC500); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAE500); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(AE200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FA500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FW500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(UA200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(EW200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(EW500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FC200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(AC200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(AE500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FWAE200); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FC500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(UA500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(UC200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FA200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(AW500XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.98
ψ(FWAC200); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.99
ψ(CW200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.99
ψ(FE200XY); col(.); ext(.); p(.)	8	98.4	10.86	0.001	0.99
ψ(FW200XY); col(.); ext(.); p(.)	8	98.4	10.87	0.001	0.99
ψ(UE200XY); col(.); ext(.); p(.)	8	98.5	10.87	0.001	0.99
ψ(FE500XY); col(.); ext(.); p(.)	8	98.5	10.88	0.001	0.99
ψ(UC500XY); col(.); ext(.); p(.)	8	98.5	10.88	0.001	0.99
ψ(AC500XY); col(.); ext(.); p(.)	8	98.5	10.88	0.001	0.99
ψ(AW200XY); col(.); ext(.); p(.)	8	98.5	10.89	0.001	0.99
ψ(UE500XY); col(.); ext(.); p(.)	8	98.5	10.89	0.001	0.99
ψ(CW500XY); col(.); ext(.); p(.)	8	98.5	10.89	0.001	0.99
ψ(FWA200); col(.); ext(.); p(.)	7	98.6	11	0.001	0.99
ψ(AWE500); col(.); ext(.); p(.)	7	98.6	11.01	0.001	0.99
ψ(CWA500); col(.); ext(.); p(.)	7	98.6	11.01	0.001	0.99
ψ(FWC500); col(.); ext(.); p(.)	7	98.6	11.01	0.001	0.99
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	98.7	11.08	0.001	0.99
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(.)	22	98.8	11.19	0.001	0.99
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	98.8	11.22	0.001	0.99
ψ(FWA500); col(.); ext(.); p(.)	7	99.0	11.43	0	1.00
Hairy Woodpecker					
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	1229.8	0	0.63	0.63

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	1231.6	1.88	0.25	0.88
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	1233.9	4.18	0.078	0.96
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	1236.6	6.79	0.021	0.98
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	1237.2	7.38	0.016	1.00
Hooded Warbler					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	2204.2	0	0.92	0.92
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	2209.7	5.57	0.057	0.98
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	2212.0	7.83	0.018	1.00
Indigo Bunting					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	38407.3	0	0.61	0.61
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	38408.2	0.93	0.39	1.00
Kentucky Warbler					
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(.)	19	2654.6	0	0.51	0.51
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(.)	16	2655.7	1.13	0.29	0.79
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	2657.9	3.32	0.096	0.89
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	2659.4	4.78	0.046	0.94
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	2660.2	5.61	0.031	0.97
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(.)	19	2660.4	5.77	0.028	1.00
Louisiana Waterthrush (no valid estimate of ψ)					
Mississippi Kite					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	7590.8	0	1	1.00
Northern Cardinal					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	50581.8	0	0.59	0.59
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	50582.9	1.09	0.34	0.94
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	50587.9	6.09	0.028	0.97
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	50589.0	7.17	0.016	0.98
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(.)	22	50590.5	8.68	0.008	0.99
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	50590.6	8.83	0.007	1.00
Northern Flicker (no valid estimate of ψ)					
Northern Parula					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(.)	25	8831.3	0	0.8	0.8
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(.)	22	8836.4	5.1	0.063	0.87

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	8837.4	6.05	0.039	0.91
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	23	8837.4	6.05	0.039	0.95
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(.)	19	8839.4	8.04	0.014	0.96
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(.)	22	8839.7	8.39	0.012	0.97
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	8840.2	8.88	0.01	0.98
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	8840.8	9.43	0.007	0.99
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	8841.7	10.34	0.005	0.99
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	8842.6	11.24	0.003	1.00
Orchard Oriole					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	13427.3	0	0.63	0.63
ψ(FWE200XY); col(FWE200XY); ext(FWE200XY); p(t)	20	13428.7	1.39	0.31	0.94
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	13432.0	4.67	0.061	1.00
Painted Bunting					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	11797.9	0	1	1.00
Pine Warbler					
ψ(CWA500XY); col(.); ext(.); p(.)	9	408.4	0	0.55	0.55
ψ(UEA500XY); col(.); ext(.); p(.)	9	410.1	1.63	0.25	0.80
ψ(FWAC500XY); col(.); ext(.); p(.)	10	411.7	3.23	0.11	0.91
ψ(AC500XY); col(.); ext(.); p(.)	8	414.4	5.99	0.028	0.94
ψ(AWE500XY); col(.); ext(.); p(.)	9	414.5	6.03	0.027	0.96
ψ(FWAE500XY); col(.); ext(.); p(.)	10	416.0	7.54	0.013	0.98
ψ(FWC500XY); col(.); ext(.); p(.)	9	418.3	9.85	0.004	0.98
ψ(UEA200XY); col(.); ext(.); p(.)	9	418.4	9.96	0.004	0.99
ψ(AE500XY); col(.); ext(.); p(.)	8	418.7	10.22	0.003	0.99
ψ(FWAC200XY); col(.); ext(.); p(.)	10	419.4	10.9	0.002	0.99
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	419.4	10.9	0.002	0.99
ψ(UEA500); col(.); ext(.); p(.)	7	420.6	12.12	0.001	0.99
ψ(FWE500XY); col(.); ext(.); p(.)	9	420.6	12.19	0.001	1.00
Pileated Woodpecker					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	7853.5	0	0.7	0.7
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	7855.3	1.73	0.3	1.00

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
Prothonotary Warbler					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	18398.1	0	0.93	0.93
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	18403.4	5.3	0.066	1.00
Red-bellied Woodpecker					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	31064.1	0	0.94	0.94
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	31069.5	5.39	0.063	1.00
Red-eyed Vireo					
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(t)	20	7488.4	0	0.45	0.45
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	7489.6	1.23	0.24	0.69
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	7489.8	1.47	0.21	0.91
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	7493.0	4.63	0.044	0.95
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(.)	19	7493.9	5.5	0.029	0.98
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	7494.9	6.5	0.017	1.00
Red-headed Woodpecker					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	5530.7	0	0.99	0.99
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	5541.7	11.04	0.004	1.00
Red-shouldered Hawlk					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	5069.1	0	1	1.00
Ruby-throated Hummingbird					
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(.)	19	3535.3	0	0.49	0.49
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(.)	16	3536.	1.34	0.25	0.74
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	3538.7	3.38	0.09	0.83
ψ(AWE500XY); col(.); ext(.); p(.)	9	3540.7	5.36	0.033	0.86
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	3541.0	5.65	0.029	0.89
ψ(FWAE500XY); col(.); ext(.); p(.)	10	3542.3	7.03	0.014	0.9
ψ(AE500XY); col(AE500XY); ext(AE500XY); p(.)	16	3542.4	7.04	0.014	0.92
ψ(AW500XY); col(.); ext(.); p(.)	8	3542.4	7.1	0.014	0.93
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	3542.6	7.32	0.013	0.94
ψ(FWAC500XY); col(.); ext(.); p(.)	10	3542.9	7.55	0.011	0.95
ψ(FWA500XY); col(.); ext(.); p(.)	9	3542.9	7.63	0.011	0.96
ψ(UEA500XY); col(.); ext(.); p(.)	9	3543.4	8.11	0.008	0.97
ψ(AE500XY); col(.); ext(.); p(.)	8	3544.2	8.91	0.006	0.98

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
ψ(AWE500XY); col(AWE500XY); ext(AWE500XY); p(.)	19	3544.3	8.94	0.006	0.98
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	3545.2	9.86	0.004	0.99
ψ(CWA500XY); col(.); ext(.); p(.)	9	3546.2	10.88	0.002	0.99
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	3546.6	11.28	0.002	0.99
ψ(A500XY); col(.); ext(.); p(.)	7	3547.4	12.04	0.001	0.99
ψ(AC200XY); col(AC200XY); ext(AC200XY); p(.)	16	3547.7	12.4	0.001	0.99
ψ(AC500XY); col(.); ext(.); p(.)	8	3547.8	12.46	0.001	0.99
ψ(FA500XY); col(.); ext(.); p(.)	8	3547.8	12.48	0.001	1.00
Swallow-tailed Kite					
ψ(CWA500XY); col(.); ext(.); p(.)	9	659.4	0	0.58	0.58
ψ(AC500XY); col(.); ext(.); p(.)	8	662.1	2.73	0.15	0.73
ψ(FWA500XY); col(.); ext(.); p(.)	9	662.2	2.83	0.14	0.87
ψ(AW500XY); col(.); ext(.); p(.)	8	665.6	6.18	0.027	0.9
ψ(FWAC200XY); col(.); ext(.); p(.)	10	666.2	6.76	0.02	0.92
ψ(CWA200XY); col(.); ext(.); p(.)	9	666.2	6.78	0.02	0.94
ψ(AWE500XY); col(.); ext(.); p(.)	9	666.6	7.22	0.016	0.95
ψ(FA500XY); col(.); ext(.); p(.)	8	667.6	8.23	0.01	0.96
ψ(FWAE200XY); col(.); ext(.); p(.)	10	669.4	9.96	0.004	0.97
ψ(AE500XY); col(.); ext(.); p(.)	8	669.4	10.01	0.004	0.97
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	669.5	10.08	0.004	0.98
ψ(A2000XY); col(.); ext(.); p(.)	7	669.5	10.13	0.004	0.98
ψ(UEA500XY); col(.); ext(.); p(.)	9	669.7	10.24	0.004	0.98
ψ(UA500XY); col(.); ext(.); p(.)	8	669.8	10.34	0.003	0.99
ψ(A500XY); col(.); ext(.); p(.)	7	670.0	10.57	0.003	0.99
ψ(AC200XY); col(.); ext(.); p(.)	8	670.0	10.58	0.003	0.99
ψ(FWA200XY); col(.); ext(.); p(.)	9	670.3	10.85	0.003	0.99
ψ(FWC200XY); col(.); ext(.); p(.)	9	672.8	13.38	0.001	1.00
Summer Tanager					
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	11045.9	0	0.33	0.33
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	11047.1	1.14	0.19	0.52
ψ(AE500XY); col(AE500XY); ext(AE500XY); p(.)	16	11047.1	1.16	0.19	0.7
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	11047.9	1.95	0.12	0.83
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	11048.9	3.01	0.074	0.9
ψ(AWE500XY); col(AWE500XY); ext(AWE500XY); p(.)	19	11049.3	3.37	0.061	0.96
ψ(CWA500XY); col(CWA500XY); ext(CWA500XY); p(.)	19	11050.3	4.37	0.037	1.00

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
Swainson's Warbler					
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	904.8	0	0.56	0.56
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	905.5	0.62	0.41	0.97
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	910.4	5.56	0.035	1.00
Tufted Titmouse					
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(t)	26	4100.9	0	1	1.00
Warbling Vireo					
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(t)	20	2209.7	0	0.57	0.57
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	2211.4	1.72	0.24	0.81
ψ(FWE200XY); col(FWE200XY); ext(FWE200XY); p(t)	20	2211.9	2.2	0.19	1.00
White-breasted Nuthatch					
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	979.4	0	0.66	0.66
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	980.9	1.5	0.31	0.97
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	986.6	7.15	0.018	0.98
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(t)	17	987.1	7.63	0.014	1.00
White-eyed Vireo					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	16309.4	0	0.98	0.98
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(t)	23	16317.6	8.22	0.016	1.00
Wild Turkey					
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	763.4	0	0.74	0.74
ψ(FWA500XY); col(FWA500XY); ext(FWA500XY); p(.)	19	768.0	4.52	0.077	0.81
ψ(UA500XY); col(UA500XY); ext(UA500XY); p(.)	16	769.5	6.1	0.035	0.85
ψ(AE500XY); col(AE500XY); ext(AE500XY); p(.)	16	769.8	6.37	0.031	0.88
ψ(CWA500XY); col(CWA500XY); ext(CWA500XY); p(.)	19	770.5	7.05	0.022	0.9
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	770.7	7.27	0.019	0.92
ψ(UA200XY); col(UA200XY); ext(UA200XY); p(.)	16	770.8	7.31	0.019	0.94
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	771.1	7.69	0.016	0.96
ψ(FWAC500XY); col(FWAC500XY); ext(FWAC500XY); p(.)	22	772.1	8.67	0.01	0.97
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	773.3	9.82	0.005	0.97
ψ(UEA500XY); col(UEA500XY); ext(UEA500XY); p(.)	19	773.4	9.97	0.005	0.98
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(.)	16	773.7	10.26	0.004	0.98
ψ(FWE500XY); col(FWE500XY); ext(FWE500XY); p(.)	19	774.1	10.61	0.004	0.98
ψ(F2000XY); col(.); ext(.); p(.)	7	774.1	10.63	0.004	0.99
ψ(A2000XY); col(.); ext(.); p(.)	7	774.3	10.88	0.003	0.99
ψ(AWE500XY); col(AWE500XY); ext(AWE500XY); p(.)	19	774.7	11.25	0.003	0.99
ψ(AW200XY); col(AW200XY); ext(AW200XY); p(.)	16	775.6	12.13	0.002	1.00

Table 5.1. Covariates of models with most support for estimating species occupancy.—Continued

[Species, the number of of model parameters (k), Akaike information criterion (AIC), increase in Akaike information criterion from best model with AIC = 0 (ΔAIC), model weight (w), and cumulative model weight (∑w). Models were evaluated by using "colext" function of the Unmarked package (ver. 0.12-–0; Fiske and Chandler, 2011) fitting colonization-extinction models (MacKenzie and others, 2003). Site occupancy (psi; ψ), as well as colonization (col), and extinction (ext) rates were modeled with covariates: • = no covariate, F = proportion of forest, W = mean probability of flooding, A = mean canopy cover, U = proportion of urban/developed, C = proportion of forest core greater than 250 meters (m) from nonforest habitat, E = proportion of forest edge within 60 m of nonforest habitat, X = longitude, Y = latitude, within 200-, 500-, or 2,000-m radial distance. Conditional detection rate (p) was modeled with and without the day of year (t) the survey was conducted.]

Models with most support for each species	*k*	AIC	ΔAIC	w	∑w
Wood Thrush					
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(.)	19	4489.9	0	0.49	0.49
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(t)	20	4491.7	1.78	0.2	0.68
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(.)	16	4493.0	3.11	0.1	0.79
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(.)	22	4493.9	3.99	0.066	0.85
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(t)	17	4494.6	4.68	0.047	0.9
ψ(AW200XY); col(AW200XY); ext(AW200XY); p(.)	16	4495.3	5.33	0.034	0.93
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(t)	23	4496.2	6.25	0.021	0.96
ψ(CWA200XY); col(CWA200XY); ext(CWA200XY); p(.)	19	4496.3	6.37	0.02	0.98
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	4498.8	8.92	0.006	0.98
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	4499.3	9.4	0.004	0.99
ψ(UA200XY); col(UA200XY); ext(UA200XY); p(.)	16	4500.0	10.05	0.003	0.99
ψ(FA500XY); col(FA500XY); ext(FA500XY); p(.)	16	4500.4	10.48	0.003	0.99
ψ(AWE200XY); col(AWE200XY); ext(AWE200XY); p(.)	19	4501.0	11.05	0.002	0.99
ψ(AE200XY); col(AE200XY); ext(AE200XY); p(.)	16	4501.1	11.16	0.002	1.00
Yellow-breasted Chat					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	18802.6	0	1	1.00
Yellow-billed Cuckoo					
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(t)	26	27893.1	0	0.93	0.93
ψ(FWAEU500XY); col(FWAEU500XY); ext(FWAEU500XY); p(.)	25	27898.4	5.28	0.066	1.00
Yellow-throated Vireo					
ψ(FWAE500XY); col(FWAE500XY); ext(FWAE500XY); p(.)	22	2605.7	0	0.92	0.92
ψ(FWAEU200XY); col(FWAEU200XY); ext(FWAEU200XY); p(.)	25	2611.9	6.21	0.041	0.96
ψ(AW200XY); col(AW200XY); ext(AW200XY); p(.)	16	2614.6	8.86	0.011	0.97
ψ(FA200XY); col(FA200XY); ext(FA200XY); p(.)	16	2615.2	9.53	0.008	0.98
ψ(FWA200XY); col(FWA200XY); ext(FWA200XY); p(.)	19	2615.9	10.25	0.006	0.98
ψ(AW500XY); col(AW500XY); ext(AW500XY); p(.)	16	2616.2	10.53	0.005	0.99
ψ(AC500XY); col(AC500XY); ext(AC500XY); p(.)	16	2617.3	11.61	0.003	0.99
ψ(FWAE200XY); col(FWAE200XY); ext(FWAE200XY); p(.)	22	2617.5	11.8	0.003	0.99
ψ(UA500XY); col(UA500XY); ext(UA500XY); p(.)	16	2618.4	12.71	0.002	1.00
Yellow-throated Warbler					
ψ(FWAC200XY); col(FWAC200XY); ext(FWAC200XY); p(t)	23	1814.0	0	1	1.00

References Cited

Fiske, I., and Chandler, R., 2011, unmarked—An R package for fitting hierarchical models of wildlife occurrence and abundance: Journal of Statistical Software, v. 43, no. 10, p. 1–23, accessed August 16, 2019, at http://www.jstatsoft.org/v43/i10/.

Mackenzie, D.I., Nichols, J.D., Hines, J.E., Knutson, M.G., and Franklin, A.B., 2003, Estimating site occupancy, colonization and local extinction probabilities when a species is not detected with certainty: Ecology, v. 84, no. 8, p. 2200–2207, accessed August 19, 2019, at https://doi.org/10.1890/02-3090.

Appendix 6. Model parameter weights

Table 6.1. Model parameters used to estimate species occupancy.

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = "na" were not considered during final model selection; model covariates with beta coefficients = "ni" were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
ACFL	500	0.84	-5.429	2.250	0.085	4.911	4.223	-3.915	ni	-0.424	0.502
ACFL	500	0.15	-5.151	2.227	-0.172	5.101	4.194	ni	ni	-0.510	0.733
AMCR	500	0.40	-1.526	ni	ni	2.521	0	0	-1.098	0.156	-0.642
AMCR	500	0.32	-1.516	ni	ni	1.461	3.873	-2.628	ni	0.229	-0.770
AMCR	500	0.16	-1.531	ni	0.077	2.514	ni	ni	-1.093	0.159	-0.654
AMCR	500	0.08	-1.536	1.170	-0.104	1.401	ni	ni	-1.275	0.160	-0.657
AMCR	500	0.02	-1.520	0.430	0.194	1.030	3.510	-2.575	ni	0.220	-0.773
AMCR	500	0.02	-1.520	0.447	0.212	1.001	3.553	-2.534	ni	0.220	-0.768
AMGO	500	0.39	-5.142	5.592	ni	-7.106	ni	ni	ni	0.632	1.443
AMGO	200	0.29	-4.110	-1.006	-6.213	0.217	0	ni	-2.173	0.614	1.702
AMGO	500	0.16	-4.305	-11.613	-4.881	7.973	17.268	ni	ni	0.747	1.703
AMGO	200	0.06	-5.116	-1.068	ni	0.661	ni	ni	ni	0.720	1.575
AMGO	500	0.05	-3.829	1.432	-5.168	ni	ni	ni	ni	0.552	1.672
AMGO	200	0.03	-4.806	-0.959	-3.299	1.359	-2.262	ni	ni	0.800	1.542
AMRE	200	0.50	-5.643	0.746	ni	5.082	ni	ni	ni	-1.398	0.635
AMRE	200	0.48	-6.359	0.964	1.643	5.583	ni	ni	ni	-1.301	0.634
AMRE	200	0.01	-5.200	0.337	-0.150	3.790	ni	ni	0.310	0.351	-0.825
AMRE	500	0.01	-5.677	-0.325	1.008	5.039	4.954	ni	ni	-1.641	1.006
AMRO	500	1.00	-1.333	0.574	0.195	-5.344	-3.041	1.030	ni	na	na
BADO	200	0.96	-3.220	-37.440	-45.870	25.180	64.600	-50.680	ni	na	-2.130
BADO	200	0.04	-3.290	-29.920	-35.440	20.700	52.740	0	ni	na	-2.290
BAOR	500	0.97	-2.350	-4.583	3.807	0.725	18.047	0	ni	0.588	-0.004
BAOR	500	0.03	-2.440	-4.132	3.023	2.819	8.916	8.954	ni	0.233	0.413
BAWW	500	0.40	-9.594	9.611	-5.238	ni	ni	ni	ni	-0.278	1.477
BAWW	500	0.19	-9.760	7.980	ni	1.530	ni	ni	ni	-0.630	1.500
BAWW	500	0.14	-9.297	9.377	-5.912	ni	ni	ni	ni	-0.402	1.870
BAWW	500	0.11	-8.550	8.610	ni	ni	-6.080	ni	ni	-0.740	1.940

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = “na” were not considered during final model selection; model covariates with beta coefficients = “ni” were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
BAWW	500	0.05	-8.422	9.052	-5.124	ni	-7.861	ni	ni	-0.269	1.481
BAWW	200	0.03	-6.167	4.376	ni	ni	ni	ni	1.272	-0.854	0.506
BAWW	500	0.02	-9.439	8.200	-5.356	1.395	ni	ni	ni	-0.221	1.371
BGGN	200	0.62	-3.618	1.092	1.411	6.827	2.825	-6.487	ni	-0.413	1.244
BGGN	200	0.38	-3.619	1.155	1.389	6.822	2.651	-6.518	ni	-0.429	1.242
BHCO	500	0.55	-1.056	-2.398	2.571	5.159	7.949	-6.002	ni	0.231	-0.406
BHCO	500	0.45	-1.070	-2.416	2.637	5.091	8.091	-5.867	ni	0.234	-0.396
BLJA	500	1.00	-0.398	-3.014	-5.331	3.513	9.640	5.430	ni	na	0.516
BRTH	500	1.00	-0.598	0.763	-5.100	-1.635	5.107	4.979	ni	na	0.142
BTGR	200	0.93	-43.362	ni	ni	ni	ni	5.770	-8.148	0.175	-22.750
BTGR	500	0.02	-85.362	9.890	0.040	-13.850	-10.950	6.460	ni	-1.960	-46.170
CACH	200	0.65	-2.862	1.254	1.176	2.643	0.254	0.300	ni	0.385	-0.616
CACH	200	0.24	-2.861	1.254	1.176	2.643	0.250	0.300	ni	0.385	-0.617
CACH	200	0.07	-2.847	1.241	1.154	2.646	0.280	ni	ni	0.390	-0.633
CACH	200	0.03	-2.847	1.241	1.154	2.644	0.281	ni	ni	0.390	-0.634
CACH	200	0.01	-2.800	1.101	1.231	2.660	ni	ni	0.626	0.382	-0.620
CARW	200	0.92	-1.582	0.254	1.581	2.816	4.962	ni	ni	0.137	-0.200
CARW	200	0.08	-1.590	0.249	1.592	2.824	4.940	0.267	ni	0.134	-0.192
CERW	2000	0.80	-13.720	ni	ni	13.890	ni	ni	ni	-1.320	4.520
CERW	2000	0.08	-14.700	14.570	ni	ni	ni	ni	ni	-1.650	4.720
CERW	2000	0.08	-10.710	ni	ni	11.360	ni	ni	ni	-2.380	4.490
CERW	2000	0.02	-11.480	11.890	ni	ni	ni	ni	ni	-2.660	4.640
CHSP	200	0.41	-8.176	0.095	7.593	-0.611	ni	ni	-59.157	-0.451	4.378
CHSP	200	0.32	-11.930	-6.760	6.760	1.920	20.030	9.380	ni	-1.280	7.080
CHSP	500	0.21	-6.503	-0.763	5.884	0.474	1.617	12.350	ni	-0.334	2.669
CHSP	500	0.06	-6.700	-0.911	7.672	0.619	ni	ni	ni	-0.239	2.614
CHSW	500	0.81	-2.381	ni	ni	ni	ni	38.553	0.111	na	-0.099
CHSW	500	0.13	-2.544	ni	ni	ni	ni	39.423	0.554	na	0.532
CHSW	500	0.05	-2.837	2.401	1.650	-1.700	-0.456	39.864	ni	na	-0.016

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = "na" were not considered during final model selection; model covariates with beta coefficients = "ni" were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
CHSW	500	0.01	-2.600	ni	ni	ni	2.600	35.040	ni	na	-0.024
COGR	500	1.00	-0.037	0.599	3.850	-1.885	-4.336	1.991	ni	na	0.151
COYE	500	0.96	-1.096	0.768	0.082	2.010	-1.720	-0.866	ni	na	na
COYE	500	0.04	-1.114	0.653	0.052	1.783	-0.873	-0.718	ni	na	na
DOWO	200	0.99	-2.306	-4.419	1.299	8.257	14.609	8.176	ni	0.297	0.082
EAPH	500	1.00	-8.980	4.790	-14.050	ni	16.780	ni	ni	-1.520	5.810
EATO	200	0.84	-1.895	0.334	-2.410	1.450	5.622	-4.970	ni	-0.072	-0.072
EATO	200	0.16	-1.966	1.804	-2.495	-0.501	6.592	-1.772	ni	0.916	-1.720
EAWP	200	0.75	-3.3662	-0.4367	1.9736	3.0215	4.8478	-4.5107	ni	0.0225	1.0759
EAWP	200	0.24	-3.6908	-1.2622	2.3952	4.4805	6.6565	-4.1774	ni	0.0691	1.1455
EAWP	200	0.01	-3.6903	-1.4755	2.4305	4.4262	6.9891	-4.099	ni	0.0698	1.1539
FICR	500	0.59	-3.4054	1.1359	4.9974	0.0931	0.962	0.535	ni	-0.3901	-1.5238
FICR	500	0.32	-3.905	2.112	4.548	-0.024	ni	ni	-1.777	-0.56	-1.815
FICR	500	0.08	-4.319	2.319	4.369	ni	ni	ni	-2.573	-0.331	-2.023
FISP	500	1.00	-3.923	-5.622	-3.493	5.415	4.932	-22.543	ni	1.628	0.411
GCFL	200	1.00	-3.424	0.445	4.039	5.507	3.149	-1.205	ni	0.362	0.581
GRCA	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni
GHOW	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni
GTGR	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni
HAWO	200	0.99	-2.85	1.44	3.93	2.39	ni	ni	-5.03	na	na
HAWO	200	0.01	-2.498	-0.139	3.714	2.828	ni	ni	ni	na	na
HOWA	500	0.6	-7.9	1.16	6.17	7.63	ni	ni	ni	na	na
HOWA	500	0.11	-7.98	1.07	6.17	7.82	ni	ni	ni	na	na
HOWA	500	0.08	-7.8838	1.4304	6.4537	7.2817	-0.0778	ni	ni	na	na
HOWA	500	0.07	-8.37	164	6.37	8.08	ni	ni	-1.01	na	na
HOWA	500	0.07	-5.883	-0.886	4.55	6.518	ni	ni	ni	na	na
HOWA	200	0.03	-7.862	1.504	6.351	7.296	-0.758	ni	ni	na	na
HOWA	500	0.03	-7.95		4.87	7.84	6.78	ni	ni	na	na
INBU	500	0.61	-1.0716	0.0573	-1.8767	2.9487	12.9187	-4.253	ni	-0.0621	0.769

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = “na” were not considered during final model selection; model covariates with beta coefficients = “ni” were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
INBU	500	0.39	-1.0783	0.0295	-1.8688	2.9703	12.9603	-4.2328	ni	-0.0603	0.7702
KEWA	200	0.61	-3.469	-1.964	-2.261	5.262	ni	ni	0.878	na	na
KEWA	200	0.24	-3.956	ni	ni	4.119	ni	ni	-0.282	na	na
KEWA	500	0.05	-3.28	ni	ni	3.84	-3.08	-6.93	ni	na	na
KEWA	200	0.03	-3.695	ni	-2.491	4.06	ni	ni	-0.265	na	na
KEWA	200	0.03	-3.891	-0.561	-1.506	3.45	ni	ni	ni	na	na
LOWA	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni
MIKI	500	1.00	-3.805	0.269	2.513	5.725	-7.272	0.843	ni	0.134	-0.894
NOCA	500	0.59	-0.4921	-3.0778	1.536	6.4201	4.7775	-0.7912	ni	0.0203	-0.0199
NOCA	500	0.34	-0.4947	-3.0695	1.5456	6.3967	4.7942	-0.7836	ni	0.0215	-0.0189
NOCA	500	0.03	-0.4829	-3.1685	1.2458	6.4246	4.9701	ni	ni	0.0516	-0.0554
NOCA	500	0.02	-0.4855	-3.16	1.2551	6.4035	4.9848	ni	ni	0.0528	-0.0545
NOFL	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni	ni
NOPA	200	0.8	-6.47	2.91	5.47	2.64	-1.1	-2.19	ni	1.2	-2.14
NOPA	200	0.07	-6.52	2.86	5.33	2.86	-1.15	ni	ni	1.11	-1.95
NOPA	200	0.04	-6.54	2.88	5.33	2.82	-1.08	ni	ni	1.12	-1.96
NOPA	200	0.04	-6.49	2.93	5.46	2.6	-1.05	-2.15	ni	1.21	-2.15
OROR	200	0.94	-0.198	-1.976	1.437	1.789	1.114	ni	ni	na	0.306
OROR	200	0.04	-0.046	-1.959	1.518	1.596	1.148	-0.902	ni	na	0.241
OROR	200	0.02	-0.148	-1.901	2.238	2.082	ni	ni	-0.045	na	0.439
PABU	500	1.00	-4.068	-4.226	4.727	4.796	10.256	-5.029	ni	-0.721	-1.798
PIWA	500	0.6	-4.009	2.921	-15.799	ni	ni	ni	ni	na	0.406
PIWA	500	0.13	-4.025	-0.0351	-8.607	1.0486	8.2344	ni	ni	na	0.1233
PIWA	500	0.12	-4.821	2.933	-9.852	ni	4.645	ni	ni	na	0.431
PIWA	200	0.06	-3.461	-0.7355	-10.1349	1.861	ni	ni	ni	na	0.0638
PIWA	200	0.03	-3.825	0.323	-11.796	2.234	ni	ni	-3.466	na	0.124
PIWA	500	0.02	-5.645	-1.352	-9.561	4.48	10.381	5.308	ni	na	0.606
PIWA	500	0.02	-3.403	-0.66	-9.162	1.971	ni	ni	ni	na	0.194
PIWO	500	0.70	-3.490	2.687	2.207	0.461	1.492	-3.890	ni	0.580	-0.671

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = “na” were not considered during final model selection; model covariates with beta coefficients = “ni” were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
PIWO	500	0.30	-3.505	2.736	2.291	0.488	1.371	-3.874	ni	0.581	-0.675
PROW	500	0.93	-3.760	-0.230	7.007	4.563	-3.247	-3.247	ni	0.195	-0.974
PROW	500	0.07	-3.741	-0.168	6.525	4.650	-1.320	ni	ni	0.138	-0.777
RBWO	500	0.94	-1.147	-0.640	1.356	3.472	2.570	-1.293	ni	-0.002	-0.135
RBWO	500	0.06	-1.186	-0.543	1.470	3.453	2.317	ni	ni	-0.031	-0.082
REVI	500	0.45	-4.1287	-0.6994	3.6687	4.2247	ni	ni	ni	0.0477	-0.3688
REVI	500	0.24	-4.2346	-0.304	3.448	4.2736	ni	ni	-0.62	0.0558	-0.4062
REVI	500	0.21	-4.1386	-0.9941	4.208	4.5443	-0.7502	-2.6677		0.0502	-0.4677
REVI	500	0.04	-4.0391	-0.59	3.7048	4.1202	-1.2484	ni	ni	0.0496	-0.3659
REVI	500	0.03	-4.108	-0.631	3.5578	4.1892	ni	ni	ni	0.0641	-0.3895
REVI	500	0.02	-4.088	-0.854	4.221	4.459	-1.261	-2.769	ni	0.068	-0.492
RHWO	200	0.99	-2.348	-1.456	1.081	1.831	12.325	1.875	ni	0.356	0.209
RHWO	200	0.01	-2.199	-1.943	0.341	1.927	12.878	ni	ni	0.394	0.128
RSHA	500	1.00	-5.655	0.899	0.251	6.721	-4.208	-3.067	ni	0.926	-1.407
RTHU	500	0.49	-2.1122	1.9579	2.7023	1.6248	ni	ni	ni	0.588	0.4527
RTHU	500	0.25	-1.738	1.862	ni	1.629	ni	ni	ni	0.19	0.329
RTHU	500	0.09	-2.445	1.678	2.512	1.796	4.493	ni	ni	0.09	0.465
RTHU	500	0.03	-3.015	ni	2.044	4.795	4.312	ni	ni	0.295	0.492
RTHU	500	0.03	-2.1986	2.1879	2.5994	1.723	ni	ni	-0.631	0.0793	0.4492
RTHU	500	0.02	-2.994	0.525	2.062	4.247	3.788	ni	ni	0.285	0.492
STKI	500	0.15	-13.82	ni	3.68	8.68	ni	ni	-5.73	-2.05	-4.32
STKI	500	0.14	-14.98	ni	ni	9.44	ni	ni	-7.15	-2.34	-5.37
STKI	500	0.03	-14.38	-6.89	5.28	13.49	ni	ni	ni	-2.1	-4.68
STKI	500	0.02	-14.4	ni	4.69	5.9	ni	ni	ni	-2.67	-4.84
STKI	200	0.02	-15.46	-2.92	4.62	10.26	ni	ni	-4.85	-2.14	-5.72
STKI	200	0.02	-13.88	ni	4.39	7.07	ni	ni	-5.66	-2.07	-4.95
SUTA	500	0.33	-4.004	-3.373	0.698	9.647	8.367	ni	ni	-0.589	1.229
SUTA	500	0.19	-4.178	-4.266	1.577	11.169	7.854	1.652	ni	-0.698	1.409
SUTA	500	0.19	-3.72	ni	ni	5.48	7.12	ni	ni	-0.56	1.08

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = "na" were not considered during final model selection; model covariates with beta coefficients = "ni" were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
SUTA	500	0.12	-4.001	-3.369	0.694	9.647	8.343	ni	ni	-0.591	1.23
SUTA	500	0.07	-4.18	-4.26	1.57	11.16	7.86	1.64	ni	-0.7	1.41
SUTA	500	0.06	-3.798	ni	0.729	5.55	6.777	ni	ni	-0.581	1.119
SUTA	500	0.04	-3.413	ni	1.174	6.249	ni	ni	-1.216	-0.549	1.115
SWWA	200	0.56	-6.96	0.922	1.682	6.057	ni	ni	1.696	-1.455	1.722
SWWA	200	0.41	-7.223	1.666	0.998	6.53	ni	ni	ni	-1.461	1.865
SWWA	200	0.03	-6.817	1.606	0.961	6.37	-2.732	ni	ni	-1.446	1.845
TUTI	500	1.00	-4.416	4.914	-4.290	2.319	-10.802	-355.641	ni	0.915	0.091
WAVI	500	0.57	-9.2	5.51	5.32	ni	-4.71	ni	ni	1.64	3.28
WAVI	200	0.24	-4.396	1.556	ni	-1.955	ni	ni	ni	0.751	1.554
WAVI	200	0.19	-5.4911	0.0304	2.8157	ni	3.6481	ni	ni	0.5075	2.1496
WBNU	200	0.84	-8.411	-0.51	4.027	9.47	ni	ni	ni	-0.284	4.391
WBNU	200	0.06	-8.111	-0.734	4.197	9.196	ni	ni	0.711	-0.28	4.208
WBNU	200	0.04	-7.8803	-0.038	ni	8.6113	ni	ni	ni	-0.0609	3.9004
WBNU	500	0.04	-8.205	-0.658	ni	8.6	ni	ni	ni	-0.617	5.152
WEVI	500	0.98	-4.259	-1.689	4.131	8.119	-0.804	-1.201	ni	-0.401	-0.184
WEVI	500	0.02	-4.266	-1.728	3.960	8.156	-1.050		ni	0.350	-0.183
WITU	500	0.34	-3.834	0.919	ni	3.862	ni	ni	ni	na	na
WITU	200	0.32	-3.74	1.01	ni	4.25	ni	ni	ni	na	na
WITU	500	0.11	-3.19	3.71	-1.64	ni	ni	ni	ni	na	na
WITU	500	0.05	-3.17	ni	ni	3.86	ni	-12.54	ni	na	na
WITU	200	0.05	-3.496	-0.151	6.651	3.427	ni	ni	ni	na	na
WITU	200	0.03	-3.67	ni	ni	3.84	4.06	ni	ni	na	na
WOTH	500	0.49	-2.701	0.568	-3.223	4.053	ni	ni	ni	-0.196	1.149
WOTH	500	0.2	-2.9396	3.6671	-1.1799	ni	ni	ni	ni	-0.0569	1.1067
WOTH	500	0.1	-2.9068	0.2053	ni	3.8226	ni	ni	ni	-0.0183	1.0991
WOTH	500	0.06	-2.627	0.647	-3.116	4.029	-1.022	ni	ni	-0.02	1.174
WOTH	500	0.05	-2.9051	0.1966	ni	3.8479	ni	ni	ni	-0.0195	1.1067
WOTH	500	0.04	-2.62	ni	-3.254	4.444	ni	ni	ni	-0.227	1.161

Table 6.1. Model parameters used to estimate species occupancy. —Continued

[Species identified by alpha code (see app. 1), radius distance of habitat considered (200, 500, or 2,000 meters [m]), model weight, model intercept, and model covariate beta coefficients associated with: Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 m of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude. We used model averages to predict spatial occupancy, based on model weights, when more than one model had support. Model covariates with beta coefficients = "na" were not considered during final model selection; model covariates with beta coefficients = "ni" were not included in selected model.]

Species	Scale (m)	Model weight	Intercept	Forest	Water	Canopy	Edge	Urban	Core	X	Y
YBCH	500	1.00	-2.638	-1.617	0.129	4.759	6.675	-4.854	ni	-0.183	0.266
YBCU	500	0.93	-1.081	-3.073	1.700	5.006	8.278	-6.179	ni	-0.168	0.300
YBCU	500	0.07	-1.105	-3.040	1.377	5.083	8.291	-5.536	ni	-0.110	0.316
YTVI	500	0.92	-4.703	-2.639	0.468	8.253	2.882	ni	ni	0.447	-0.662
YTVI	200	0.04	-4.311	-0.857	1.825	4.934	1.714	5.099	ni	0.964	-1.046
YTVI	200	0.02	-4.355	ni	1.356	5.301	ni	ni	ni	0.612	-0.794
YTWA	500	0.56	-7.700	9.760	ni	-4.050	ni	ni	ni	na	-5.060
YTWA	200	0.44	-9.430	5.550	-3.740	-4.430	-9.930	0.330	ni	na	-5.520

Appendix 7. Predicted avian species occupancy

Predicted probability of spatial occupancy by 54 silvicolous bird species in the Mississippi Alluvial Valley Bird Conservation Region as predicted by most supported models of occupancy on the basis of eight covariates (Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 meters (m) of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude) that were evaluated at three spatial scales (200-, 500-, and 2,000-m radial distances). Data available at https://doi.org/10.5066/P9YMSM8I.

Appendix 8. Area of sustainable forest habitat

Area [square meters (m^2) per 900-m^2 pixel] presumed to be occupied by 54 silvicolous bird species in the Mississippi Alluvial Valley Bird Conservation Region within forest habitat that likely harbors sustainable populations. Models based on predicted minimum sustainable population size and by the most supported models of occupancy on the basis of eight covariates (Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 meters (m) of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 m from nonforest habitat, X = longitude, and Y = latitude) that were evaluated at three spatial scales (200-, 500-, and 2,000-m radial distances). Data available at https://doi.org/10.5066/P9YMSM8I.

Appendix 9. Area of forest and nonforest occupied habitat

Area [square meters (m^2) per 900-m^2 pixel] presumed occupied by 20 bird species in the Mississippi Alluvial Valley Bird Conservation Region within all forest and nonforest habitat (except permanent water) as predicted by most supported models of occupancy on the basis of eight covariates (Forest = proportion of forest, Water = mean probability of flooding, Canopy = mean canopy cover, Edge = proportion of forest edge within 60 meters (m) of nonforest habitat, Urban = proportion of urban/developed, Core = proportion of forest core >250 meters (m) from nonforest habitat, X = longitude, and Y = latitude) that were evaluated at three spatial scales (200-, 500-, and 2,000-m radial distances). Data available at https://doi.org/10.5066/P9YMSM8I.

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