Management and Conservation Article

Effects of Wildlife Forestry on Abundance of Breeding Birds in Bottomland Hardwood Forests of Louisiana

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ABSTRACT Effects of silvicultural activities on birds are of increasing interest because of documented national declines in breeding bird populations for some species and the potential that these declines are in part due to changes in forest habitat. Silviculturally induced disturbances have been advocated as a means to achieve suitable forest conditions for priority wildlife species in bottomland hardwood forests. We evaluated how silvicultural activities on conservation lands in bottomland hardwood forests of Louisiana, USA, influenced species-specific densities of breeding birds. Our data were from independent studies, which used standardized point-count surveys for breeding birds in 124 bottomland hardwood forest stands on 12 management areas. We used Program DISTANCE 5.0, Release 2.0 (Thomas et al. 2006) to estimate density for 43 species with >50 detections. For 36 of those species we compared density estimates among harvest regimes (individual selection, group selection, extensive harvest, and no harvest). We observed 10 species with similar densities in those harvest regimes compared with densities in stands not harvested. However, we observed 10 species that were negatively impacted by harvest with greater densities in stands not harvested, 9 species with greater densities in individual selection stands, 4 species with greater densities in group selection stands, and 4 species with greater densities in stands receiving an extensive harvest (e.g., >40% canopy removal). Differences in intensity of harvest influenced densities of breeding birds. Moreover, community-wide avian conservation values of stands subjected to individual and group selection, and stands not harvested, were similar to each other and greater than that of stands subjected to extensive harvest that removed >40% canopy cover. These results have implications for managers estimating breeding bird populations, in addition to predicting changes in bird communities as a result of prescribed and future forest management practices. (JOURNAL OF WILDLIFE MANAGEMENT 73(8):1368–1379; 2009)

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Bottomland hardwood forests within the Mississippi Alluvial Valley (MAV), USA, have been severely altered, deforested, and are highly fragmented (Twedt and Loesch 1999), yet they continue to provide important breeding habitat for many bird species (Pashley and Barrow 1993, Heitmeyer et al. 2005). The primary cause of bottomland hardwood losses has been the conversion of these forests to agricultural production. Additional destruction to bottomland hardwood forests has been caused by construction of flood-control structures and reservoirs, the invasion of non-indigenous species, and historic silvicultural practices. Historically, forest management has emphasized clear-cut or diameter-limit harvests and regeneration of merchantable trees (Meadows and Stanturf 1997), often at the expense of the residual forest structure. Today, many extant forests in the MAV physiographic region are even-aged, having closed canopies and little understory vegetation as a consequence of past forest management. As these forests mature and senesce, increased heterogeneity of their vegetation structure results locally from tree-fall gaps or regionally from extreme wind events (e.g., tornados or hurricanes) or other natural disturbances (e.g., flood or fire). Alternatively, increased heterogeneity of forest structure can be achieved via prescribed silvicultural treatments. Indeed, conservation partners in the MAV have recently defined desired forest conditions and provided quantitatively based forest management recommendations wherein prescribed silvicultural treatments are used to enhance wildlife habitat (Wilson et al. 2007).

Silvicultural alternatives to historical harvest methods (e.g., partial harvest, variable-retention harvest, or clustered thinning) can be used to promote stand-level structural heterogeneity and protect biological legacies by retaining large live trees, snags, and coarse woody debris (Mitchell and Beese 2002). Because these stand-level conditions benefit many silvicolous wildlife species, they are collectively referred to as wildlife forestry. Harvest prescriptions intended to enhance wildlife habitat must be site-specific, but generally wildlife forestry prescriptions result in reduced canopy cover and basal area through selective timber harvests such as individual selection, group selection, species selection, or shelterwood harvest (Table 1; Fig. 1).

Wildlife forestry is designed to produce a forest matrix with dense shrub and herbaceous understory intermixed with retained trees, including some with large diameters. Furthermore, wildlife forestry is intended to be economically viable, yet provide forest habitat capable of supporting sustainable populations of priority silvicolous wildlife, such as Louisiana black bear (*Ursus americanus luteolus*), Rafinesque's big-eared bat (*Plecotus rafinesquii*), and breeding songbirds, as well as game species such as white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*).

Although there is much debate over the extent and cause of declines in populations of some silvicolous birds, modifications to forest structure may be a contributing

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Table 1. Description of harvest strategies associated with bottomland hardwood stands on managed forests in Louisiana, USA, where 10-minute point counts (Counts) were conducted to survey breeding birds from 2000 to 2005.

Code	Harvest	Description	Stands	Counts
NOT	No harvest	No harvests within the past 30 yr.	63	1,475
IND	Individual selection	Harvest of scattered, undesirable individual trees, with <30% canopy removed.	32	808
GRP	Group selection	Harvest of small groups of trees (<1 ha), with 30–40% of canopy removed.	12	389
EXT	Extensive	Includes species selection and shelterwood harvest. Species selection harvested trees of select species, with 40–60% canopy removed. Shelterwood removed most trees and reduced canopy cover by 70–80%. Thus, extensive harvest removes >40% canopy.	17	342

factor (Hagen and Johnston 1992, Rappole and McDonald 1994, Holmes and Sherry 2001). Consequently, examining effects of silvicultural activities on breeding bird populations may provide insight into the changes occurring with bird populations. Many studies have investigated avian responses to silvicultural practices, including partial harvests (Vanderwell et al. 2007), but often these studies examined avian response to commercial, timber-oriented harvests, or they were constrained by lack of replication and an inability to evaluate data from multiple sites that used consistent methodologies (Morrison 1992, Harrison and Kilgo 2004, Heltzel and Leberg 2006, Simons et al. 2006). Moreover, assessing densities of breeding birds with respect to silvicultural activities will provide managers with information allowing more effective management decisions.

Our objectives were to estimate species-specific densities of breeding birds in bottomland hardwood forests and to assess differences in species-specific density estimates among silvicultural harvest regimes commonly used in wildlife forestry. We hypothesized that species-specific bird densities would be different among the continuum of harvest strategies and related to silvicultural activities. For example, harvest strategies that provide gaps in overstory canopy cover, an increase in ground cover, and an uneven-age distribution of trees would be beneficial to gap-dependent birds. In contrast, stands managed with no harvest strategies, which have a closed and higher canopy structure and less edge habitat than in actively harvested forest, would be compatible with forest-interior birds.

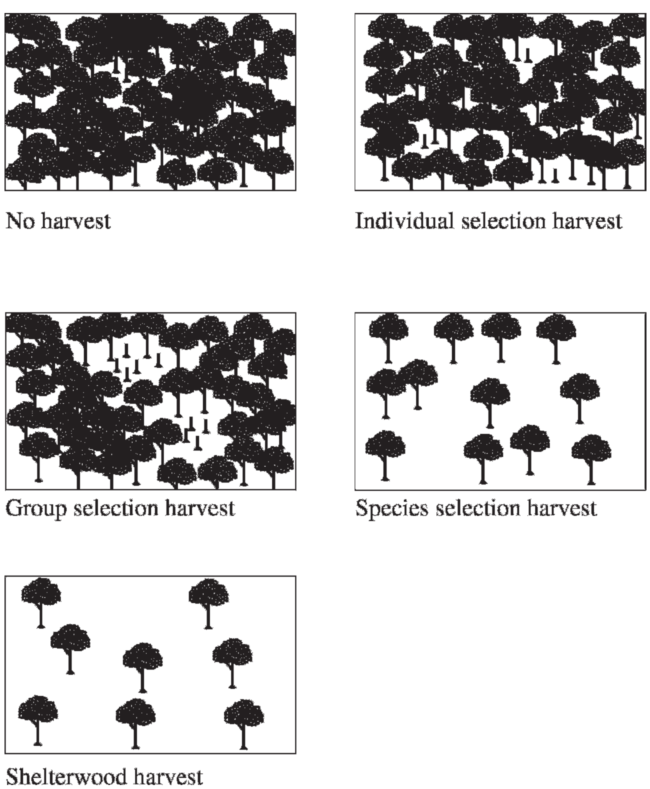

Figure 1. Illustrations of 5 harvest strategies (species selection, individual selection, group selection, shelterwood, and no harvest) implemented between 1977 and 2005, in bottomland hardwood forests stands in Louisiana, USA, where point-count surveys were conducted.

STUDY AREA

We obtained data from point-count surveys within 128 bottomland hardwood forest stands on 10 Wildlife Management Areas managed by the Louisiana Department of Wildlife and Fisheries (LDWF) and 2 National Wildlife Refuges managed by the United States Fish and Wildlife Service (USFWS) in Louisiana (Table 2). Sites extended from north to south Louisiana.

Forest stands ranged from 50 ha to 500 ha and were characterized as relatively flat, poorly drained, and subject to seasonal flooding. Predominate overstory species across our study areas included American elm (*Ulmus americana*), water hickory (*Carya aquatica*), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanica*), bald cypress (*Taxodium distichum*), water oak (*Quercus nigra*), Nuttall oak (*Q. texana*), sweet pecan (*Carya illinoinesis*), and overcup oak (*Q. lyrata*). Stands had a continuum of gap to open canopies coinciding with prescribed harvest regimes, which included stands with no harvest and stands subjected to individual selection harvest, group selection harvest, and extensive harvest such as species selection harvest or shelterwood harvests (Table 1; Fig. 1). Stands without harvest had no silvicultural activity applied during the previous 30 years, whereas stands with harvest were manipulated within 0–26 years before point-count surveys (Table 2). However, all stands (including stands with no harvest) were harvested at least once historically, so all of the stands we sampled were minimally second-growth forests. Although harvests predated the publication of desired forest conditions (Wilson et al. 2007), most were prescribed to enhance wildlife habitat by increasing forest heterogeneity while retaining forest canopy.

METHODS

We developed our data set from 5 independent studies of 3,014 breeding season (Apr–Jul) point-count surveys

Table 2. Wildlife Management Areas (WMA) and National Wildlife Refuges (NWR) in Louisiana, USA, where point counts were conducted between 2000 and 2005, to survey breeding birds within bottomland hardwood forest stands subjected to different harvest regimes: not harvested (NOT), individual selection (IND), group selection (GRP), species selection (SCT), or shelterwood (SWD).

Location	Area (ha)	Harvest	Stands	Yr harvested	Age[a]
Big Lake WMA	7,782	IND	3	1991, 2000, 2001	12, 3, 2
		SCT	1	1985	18
		NOT	4		
Dewey Wills WMA	24,000	IND	2	1990, 1999	13, 4
		SWD	2	1989, 2002	14, 1
		NOT	4		
Ouachita WMA	4,204	SWD	3	2000	3
		GRP	1	1996	7
		IND	1	1994	9
		NOT	7		
Pearl River WMA	14,177	IND	3	1987–1995	9–17
		SCT	4	1986–1989	15–18
		SWD	1	1995	9
		NOT	6		
Pomme de Terre WMA	6,343	NOT	6		
Red River WMA	16,867	GRP	1	2001	2
		IND	1	2002	1
		NOT	2		
Russell Sage WMA	6,810	GRP	2	1989	14
		IND	4	1986–2002	1–17
		SCT	4	1977–1986	17–26
		NOT	3		
Sherburne WMA[b]	17,652	GRP	4	2000–2005	0–3
		IND	8	1991–2005	0–12
		NOT	5		
Spring Bayou WMA	5,061	NOT	7		
Tensas NWR	28,200	GRP	4	1999–2001	2–6
		IND	10	1995–2002	1–10
		NOT	17		
Three Rivers WMA	11,080	SCT	2	1985	18
		NOT	2		

[a] Age is the yr from point-count survey to last harvest.
[b] Included adjacent federal conservation lands on Atchafalaya NWR and Bayou des Ourses (owned by United States Army Corps of Engineers).

conducted for a period of 2–3 years between 2000 and 2005 (Heltzel 2004, Carroll 2005, LeGrand 2005). Point-count locations within stands were 125–250 m apart and >100 m from roads or other habitat edges. Observers recorded distance from the point to each bird when first detected within distance intervals of 0–25 m, 25–50 m, 50–100 m, and >100 m, with a truncation distance of 150 m. Point counts, each of 10-minute duration, were conducted from 30 minutes before sunrise up to 4 hours after sunrise.

We modeled species-specific detection functions and densities of land birds, pooled across years and management areas, from categorical distance data using Program DISTANCE. For those species with >50 detections in one or more harvest regime, we fit detection models with harvest strategy (individual selection, group selection, extensive harvest, and no harvest) as a covariate using a half-normal base function with either cosine or hermite polynomial adjustments and a uniform base function with cosine or simple polynomial adjustments (Laake et al. 1993; Buckland et al. 2001, 2004). We used chi-square goodness of fit tests to assess model fit, and Akaike's Information Criterion (Burnham and Anderson 2002) and visual inspection of the detection probability density graphs (Buckland et al. 2001, 2004) to select the most parsimonious of these competing models. For species rarely detected at distances beyond 100 m, categorical distance data were truncated to provide the best fit model. For species with <50 detections in a harvest regime, we reported number of observations (Appendix I) and did not include that harvest regime within that species' model. In addition, 4 species had few (<50) detections in every harvest regime, but >50 total detections (combining all harvest regimes); therefore, we estimated forest-wide estimates for these species. Forest-wide estimates pooled all harvest regimes and no harvest stands to obtain density estimates.

We compared species-specific density estimates among harvest regimes using Program CONTRAST (Hines and Sauer 1989), which uses a chi-square analysis with multiple comparisons (Sauer and Williams 1989). To assess effects of 3 harvest regimes on avian density estimates relative to density estimates in stands not harvested, we used a priori contrast statements that compared species-specific density estimates in stands not harvested to their density estimates in stands subjected to 1) individual selection harvest, 2) group selection harvest, and 3) extensive harvest. If we did not detect a significant difference ($\alpha = 0.05$) between density estimates in stands with no harvest and all 3 harvest regimes, we pooled harvest regimes (including harvests with <50 detections, which were not compared) and no harvest stands to obtain forest-wide density estimates using Program DISTANCE. If we detected significant differences among harvest regimes and stands not harvested, and the

Table 3. Forest-wide detection probability (DP), density estimates ($\hat{D}$; birds/ha), coefficient of variation, and effective detection radius (EDR) for species detected >50 times (n) during breeding bird point-count surveys conducted between 2000 and 2005 in bottomland hardwood forests in Louisiana, USA, whose densities on stands not harvested did not differ from densities subjected to ≥1 harvest regime, and 4 species that were infrequently detected within stands harvested and not harvested but had sufficient (>50) detections for forest-wide estimates (Appendix). Comparisons between density estimates in stands not harvested and harvest regimes were compared with those harvest strategies that the species had >50 detections; however, forest-wide density estimates were derived from detections in all harvest regimes and stands not harvested.

Species	n	DP	$\hat{D}$	%CV	EDR
Barred owl (*Strix varia*)[a]	414	0.31	0.06	16.06	83.92
Blue jay (*Cyanocitta cristata*)[b]	332	0.36	0.10	22.11	60.02
Chimney swift (*Chaetura pelagica*)[c]	52	0.06	0.03	24.18	37.59
Common grackle (*Quiscalus quiscula*)[c]	64	0.04	0.06	37.14	31.56
Downy woodpecker (*Picoides pubescens*)	1,554	0.10	0.73	8.29	47.45
Great crested flycatcher (*Myiarchus crinitus*)[b]	715	0.14	0.24	14.06	56.58
Hairy woodpecker (*Picoides villosus*)[c]	107	0.06	0.07	16.11	36.72
Hooded warbler (*Wilsonia citrine*)	1,018	0.17	0.62	12.35	41.76
Mississippi kite (*Ictinia mississippiensis*)[c]	62	0.10	0.02	23.89	48.56
Mourning dove (*Zenaida macroura*)[b]	705	0.38	0.09	8.81	92.27
Pileated woodpecker (*Dryocopus pileatus*)	1,003	0.29	0.16	15.36	80.26
Red-shouldered hawk (*Buteo lineatus*)[d]	399	0.24	0.08	8.44	73.02
Summer tanager (*Piranga rubra*)	791	0.06	0.62	5.70	36.83
Swainson's warbler (*Limnothlypis swainsonii*)[d]	309	0.13	0.11	19.95	53.34

[a] No density estimate within group selection harvest regime.
[b] No density estimate within extensive harvest regime.
[c] No treatment had >50 detections.
[d] No density estimates within group selection harvest and extensive harvest regimes.

greatest density estimate for that species was in stands not harvested, we inferred that harvest regimes negatively affected that species. For species in which we detected a significant difference among harvest regimes and stands not harvested, and the greatest density estimate for that species was in stands managed with one of the harvest regimes, we assessed differences in densities among harvest regimes using Program CONTRAST and a second set of contrast statements to compare individual selection, group selection, and extensive harvest. We assessed each harvest strategy differences with an a priori $\alpha = 0.05$.

Of the 140 species recorded, 43 species of land birds had >50 observations from which we estimated detection probabilities and density estimates. We compared densities among 3 harvest regimes (individual selection, group selection, and extensive harvest) and no harvest for 19 species; among individual selection, group selection, and no harvest for 10 species; among individual selection, extensive harvest, and no harvest for one species (barred owl [*Strix varia*]); between individual selection and no harvest for 4 species; and between group selection and no harvest for one species (common yellowthroat [*Geothlypis trichas*]). In addition, we compared estimates of density between individual and group selection harvest for red-headed woodpecker (*Melanerpes erthrocephalus*).

As a measure of community-wide avian conservation value associated with each harvest regime and stands not harvested, we calculated avian conservation significance (ACS) value for each regime (Nuttle et al. 2003, Twedt 2005). We based the ACS value of each harvest regime (individual selection, group selection, extensive harvests, and no harvest) on Partners in Flight (PIF) concern scores (Carter et al. 2000) and our estimates of species densities. For species with no estimate of density in a harvest regime (because detections were <50), we provided a replacement density estimate by assuming their density was half the lowest estimate of density for that species within any other harvest regime.

RESULTS

Density estimates for 10 species did not differ between stands not harvested and any harvest regimes; thus, we estimated forest-wide density estimates for these species (Table 3). In addition, Mississippi kite (*Ictinia mississippiensis*), chimney swift (*Chaetura pelagica*), hairy woodpecker (*Picoides villosus*), and common grackle (*Quiscalus quiscula*) were infrequently detected regardless of harvest regime, but they had sufficient (>50) detections for forest-wide estimates of detection probability and density and were relatively uncommon (<1 bird/ha; Table 3).

Densities for 8 species were 23–60% greater in stands not harvested than in any one of the harvest regimes (Fig. 2). Density estimates for American crow (*Corvus brachyrhynchos*), northern cardinal (*Cardinalis cardinalis*), red-eyed vireo (*Vireo olivaceus*), and yellow-throated vireo (*Vireo flavifrons*) were greatest in stands not harvested but decreased 35% to 47% in stands managed with individual selection harvest. Conversely, density estimates for Acadian flycatcher (*Empidonax virescens*), Carolina chickadee (*Poecile carolinensis*), prothonotary warbler (*Protonotaria citrea*), and yellow-billed cuckoo (*Coccyzus americanus*) were greatest in stands not harvested and similar in individual selection harvested stands but were 23–60% less in the 2 more intensive harvest regimes (group selection and extensive harvest). In addition, fish crow (*Corvus ossifragus*) and painted bunting (*Passerina ciris*) only had >50 detections in stands that were not harvested.

Density estimates for 17 species were greater in at least one harvest regime than in stands not harvested (Fig. 3). Density estimates of brown-headed cowbird (*Molothrus* *ater*), eastern wood pewee (*Contopus virens*), ruby-throated hummingbird (*Archilochus colubris*), red-winged blackbird (*Agelaius phoeniceus*), wood thrush (*Hylocichla mustelina*), and red-bellied woodpecker (*Melanerpes carolinus*) were 26%, 53%, 39%, 80%, 60%, and 23% greater, respectively, in stands harvested with individual selection than in stands not harvested. Densities of eastern towhee (*Pipilo cholorurus*), yellow-breasted chat (*Icteria virens*), and indigo bunting (*Passerina cyanea*) were 26–83% greater in individual and group selection stands than in stands not harvested, but densities in extensive harvest were up to 23% less or there were too few detections to estimate density. Similarly, densities of American redstart (*Setophaga ruticilla*), Kentucky warbler (*Oporornis formosus*), and common yellowthroat were 54%, 58%, and 79% greater, respectively, in stands subjected to group selection than in stands with no harvest, but they were infrequently detected in extensive harvest stands. Conversely, densities of blue-gray gnatcatcher (*Polioptila caerulea*), tufted titmouse (*Baeolophus bicolor*), and white-eyed vireo (*Vireo griseus*) were 21% to 32% greater in stands with an extensive harvest than in stands with no harvest. Only Carolina wren (*Thryothorus ludovicianus*) had consistently greater (up to 48%) densities in stands subjected to any one of the harvests than in stands with no harvest regime. Surprisingly, density estimates for northern parula (*Parula americana*) were >2 times greater within stands subjected to extensive harvest but decreased up to 47% in stands with individual and group selection harvest compared with stands not harvested. In addition, orchard orioles (*Icterus spurius*) had >50 detections only within individual selection stands, and red-headed woodpecker only had >50 detections in individual and group selection stands.

The avian conservation significance value associated with each harvest regime, based on Partners in Flight concern score and density estimates of 39 species, was greatest for stands harvested with individual selection (ACS = 1,014) and stands not harvested (ACS = 973). Avian conservation significance value for group selection harvest (ACS = 922) was reduced only by 9%, but stands subjected to extensive harvest had an 18% reduction (ACS = 830).

DISCUSSION

Our study provides quantitative estimates of density for 43 species of breeding birds within bottomland forests of the MAV. We found that harvest regimes within these forests influenced densities of most silvicolous birds, because 25 of the 36 species included in our analyses had densities that differed between stands harvested and stands not harvested. Prescribed harvest regimes within managed bottomland forests create a continuum of habitat conditions from dense shrubby understory to a more open, patchy forest structure, depending on the extent of tree removal and the subsequent successional pathway. For example, shelterwood selection that removes most trees and retains only a few larger diameter trees creates large openings in the forest, thereby enabling shade-intolerant vegetation to regenerate. On the other end of the continuum, small canopy gaps that result from individual selection harvests provide only small patches of shade-tolerant vegetation in the understory. Thus, not unexpectedly, we found birds that occupy these different ecological niches were influenced by the continuum of harvests regimes. For example, forest-interior species (e.g., prothonotary warbler and Acadian flycatcher) were more abundant in stands that were not harvested, whereas species dependent on shrub-scrub habitat (e.g., indigo bunting and yellow-breasted chat) were more abundant in stands subjected to a harvest regime.

Of the continuum of harvest regimes we examined, stands managed with extensive harvest (i.e., shelterwood and species selection harvest) had the greatest deviation from stands not harvested and the lowest ACS value. Shelterwood silviculture tends to produce 2-aged stands with few remaining canopy trees and a dense understory (Lanham et al. 2002). Similarly, species selection harvest removes up to 60% of the canopy by removing early successional species to promote growth of later successional species that produce hard mast (e.g., oaks). Species with greatest densities in extensive harvest included blue-gray gnatcatcher, tufted titmouse, and white-eyed vireo, which were all common in shrub to forest habitat and abundant (>1.5 birds/ha) regardless of harvest regime. Unexpectedly, we observed greatest densities of northern parula, an upper-canopy forest-interior species, in stands managed with extensive harvest. Although northern parula density estimates decreased by 54% in stands not harvested as opposed to extensive harvested stands, density estimates in individual and group harvest stands were 47% less than in stands not harvested. The underlying reason for this apparent discrepancy was unclear. Previous studies in West Virginia, USA, and the Missouri Ozarks, USA (Nichols 1996, Annad and Thompson 1997), reported increased bird diversity in stands where shelterwood harvests were used as a partial harvest strategy, presumably because sufficient canopy cover and structural diversity were retained. However, these studies reported a reduction in forest-interior birds with a corresponding increase in early successional species, consistent with our findings and that of others (Webb et al. 1977, Baker and Lacki 1997, Klaus et al. 2005). Small-scale canopy gaps are important for many species of forest birds (Bowen et al. 2007, Hunter et al. 2001), but we suggest that extensive harvest (shelterwood or species selection harvest) in the MAV may temporarily reduce canopy cover beyond that required to support most forest-interior species, although we certainly recognize that this will diminish as succession proceeds within the stand.

Other studies have demonstrated the importance of group selection harvest for shrub nesting and ground foraging birds (Annand and Thompson 1997, Rodewald and Smith 1998, Somershoe et al. 2003, Heltzel and Leberg 2006, Holmes and Pitt 2007). Moreover, forest-interior birds may not be negatively impacted by group selection if sufficient mature trees are retained (Moorman and Guynn 2001). We observed greatest densities of species that nest and forage in shrubs and dense undergrowth (e.g., common yellowthroat) and forest-edge species such as yellow-breasted chat and eastern towhee in stands managed with group selection

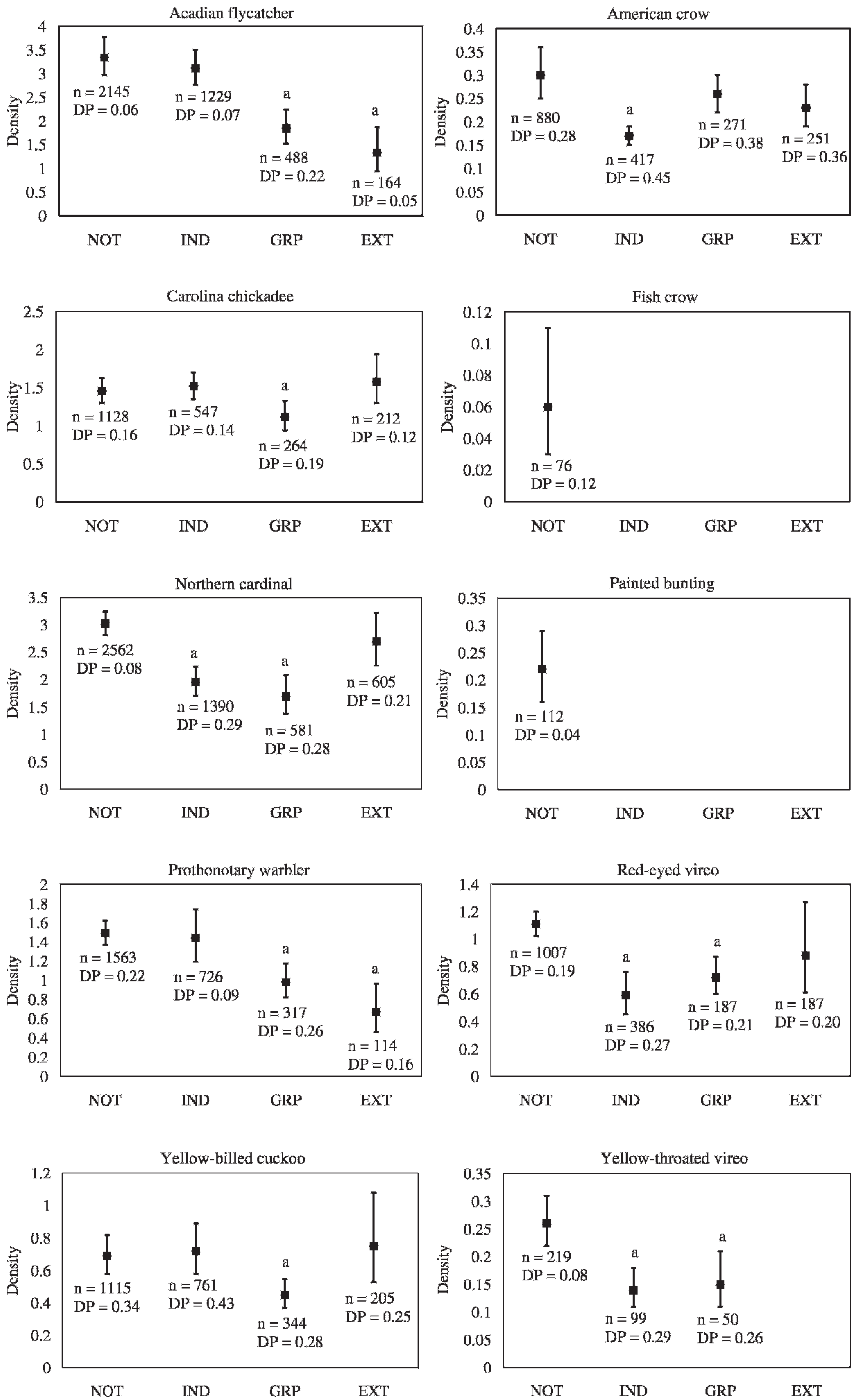

Figure 2. Estimated densities ($\hat{D}$ = birds/ha) and corresponding 90% confidence intervals for breeding birds detected during point-count surveys conducted between 2000 and 2005 in bottomland hardwood forests stands in Louisiana, USA, with densities greater based on Program CONTRAST analysis (α = 0.05) in stands not harvested (NOT) than in one or more of the prescribed to a harvest regimes (e.g., individual selection [IND], group selection [GRP], or extensive harvest [EXT]). a = Density estimates differed significantly from density estimates in stands not harvested. Density estimates were based on the number of birds detected (n) and their detection probabilities (DP) with regard to harvest strategy.

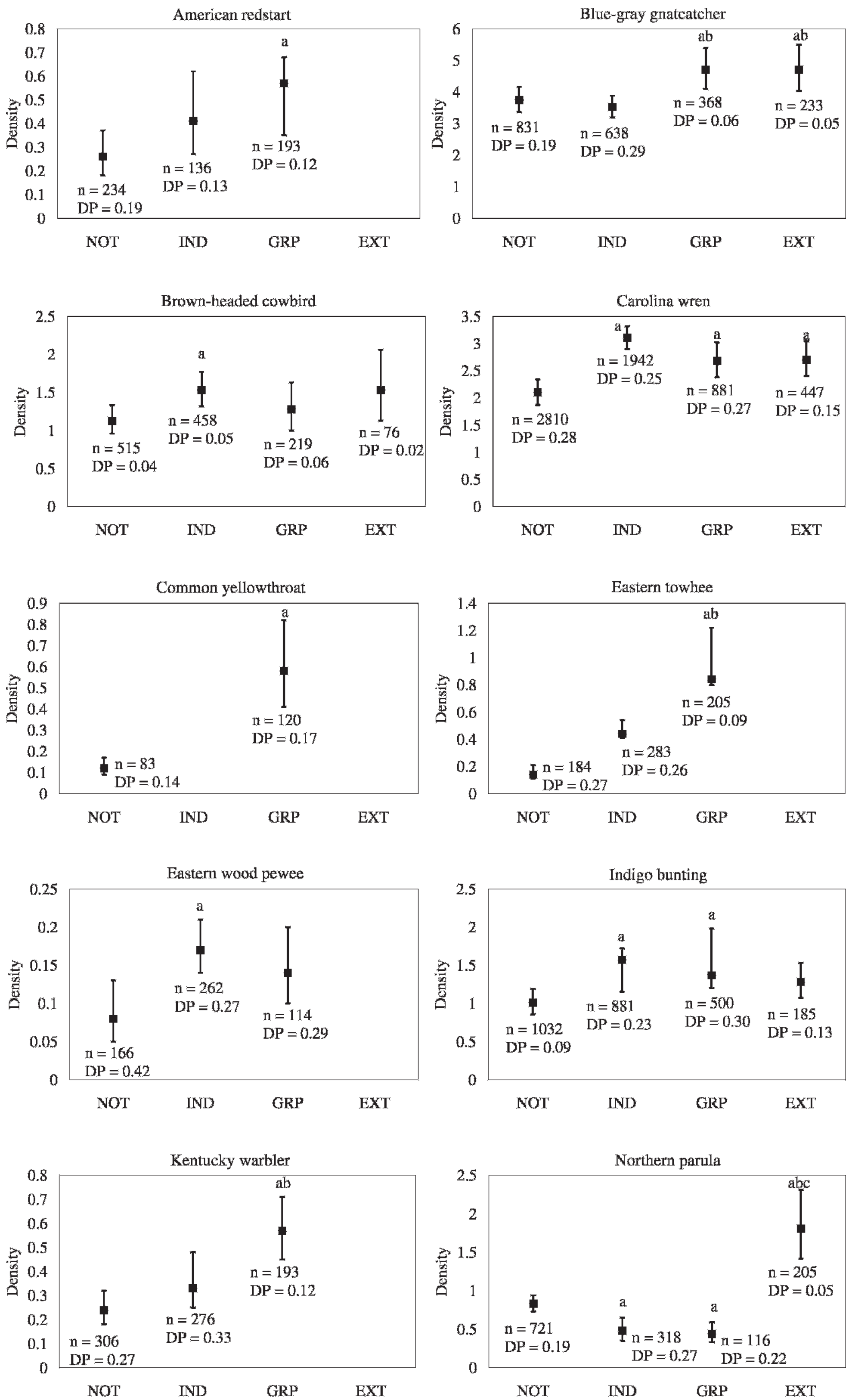

Figure 3. Comparison of density estimates ($\hat{D}$ = birds/ha) of breeding land birds detected during point-count surveys conducted between 2000 and 2005 in bottomland hardwood forests stands in Louisiana, among 3 harvest strategies (individual selection [IND], group selection [GRP], extensive harvest [EXT]) and stands not harvested (NOT) using Program CONTRAST analyses (α = 0.05; a = density estimates differed from density estimates in stands not harvested; b = density estimates differed from density estimates stands subjected to individual selection harvest; c = density estimates differed from density estimates stands subjected to group selection harvest). Density estimates and 90% confidence intervals were generated by Program DISTANCE and based on the number of birds detected (n) and their detection probabilities (DP) with regard to harvest strategy.

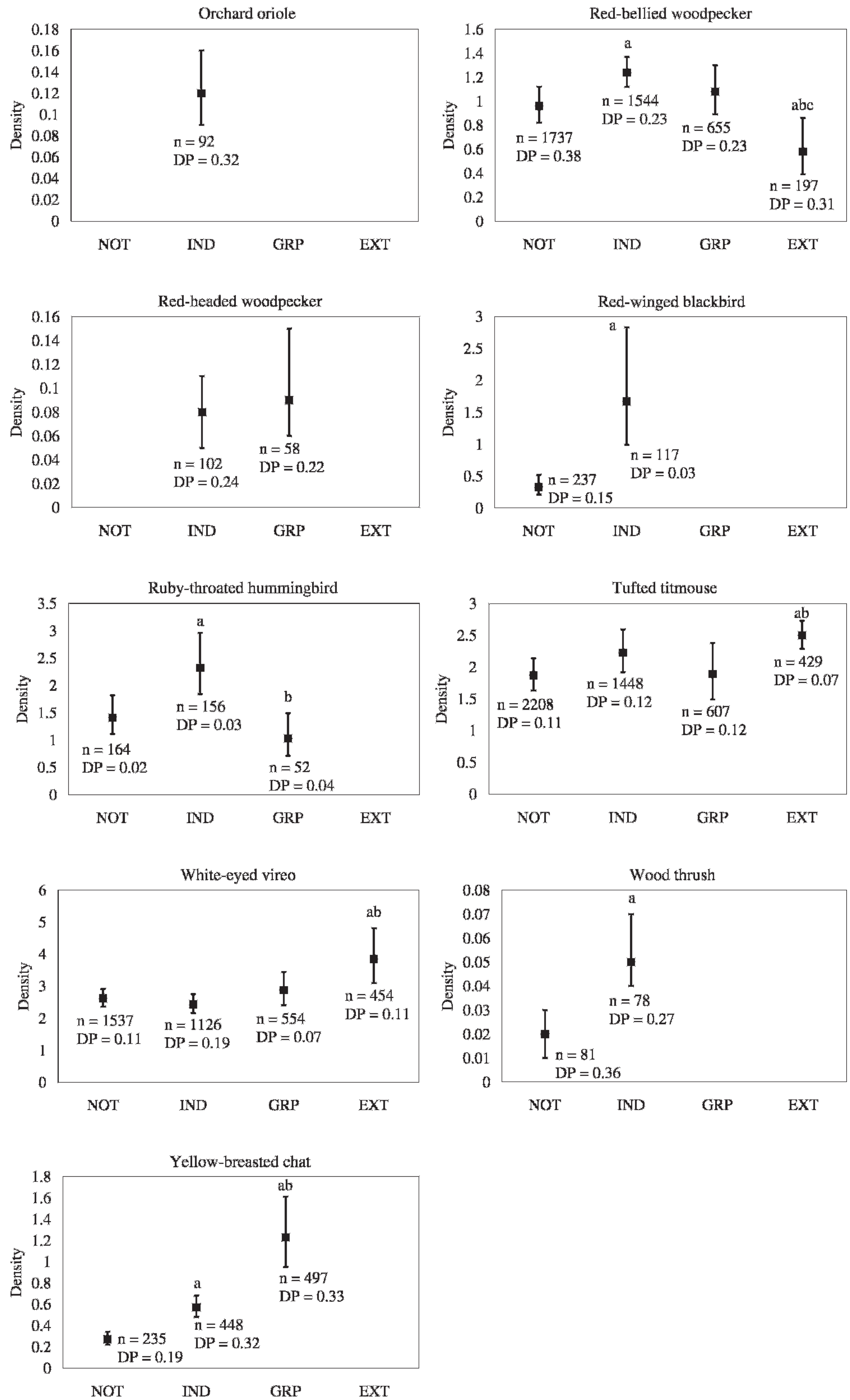

Figure 3. Continued.

harvest. Notably, we observed 50% greater densities of Kentucky warblers, a forest-interior species, in stands managed with group selection harvest than in stands with no harvest. Kentucky warblers characteristically nest in mid and understory vegetation and forage on the forest floor or understory.

Individual selection harvest resulted in the least disturbance to existing forest condition compared with the continuum of harvest regimes we studied, but it still creates gaps in overstory canopy cover, increases ground cover, and creates an uneven-age distribution of trees. Bowen et al. (2007) suggested that these small-scale canopy gaps are essential for many forest birds. Similarly, our ACS value for stands with individual selection harvests were the highest and most similar to stands not harvested. Furthermore, compared with stands not harvested, densities of 6 species were similar to stands harvested with individual selection, but densities of these species were less in stands harvested with group selection or extensive harvest. For example, densities of Acadian flycatcher were similar in stands not harvested compared with individual selection harvest but were reduced by 41% in group selection harvest and 57% in extensive harvest. Likewise, densities of prothonotary warbler were similar in individual selection and stands not harvested, but they were reduced by 32% in group selection and 53% in extensive harvest stands. Conversely, the 8 species with greater densities in stands harvested with individual selection rather than in stands not harvested occupy a diverse array of habitat niches, suggesting that individual selection harvest not only retains a large proportion of the bird community associated with mature forest but also provides habitat for early successional species.

Previous studies have suggested that not harvesting forests may benefit forest-interior birds that require closed canopies and are sensitive to edge effects (Thompson 1993, Annand and Thompson 1997, Rodewald and Smith 1998, Twedt et al. 1999, Jobes et al. 2004). Densities of American crow, northern cardinal, red-eyed vireo, and yellow-throated vireo were less than in stands with any harvest compared with densities in stands not harvested, whereas Acadian flycatcher, Carolina chickadee, prothonotary warbler, and yellow-billed cuckoo densities decreased in stands that were subjected to harvest that exceeded the intensity of individual selection harvest. American crow and northern cardinal are widespread species of little conservation concern. Because American crows can negatively impact other species, greater densities of this species may be of management concern. In addition, brood parasites, brown-headed cowbirds, were 26% less in stands not harvested relative to stands with individual selection harvest.

Carolina chickadees, although a species of conservation concern, were abundant (>1 bird/ha) regardless of harvest regime. Yellow-throated vireo and yellow-billed cuckoo are typically associated with open woodlands and forest edges (Rodewald and James 1996, Hughs 1999); hence, the decreased densities in stands subjected to harvest were unexpected. Prothonotary warbler is an obligate cavity nesting species (Petit 1999, Whitehead and Taylor 2002) and had the greatest PIF concern score (20) of any species detected during our surveys; so, decreased densities of these species in response to tree harvest is noteworthy. The conservation value for stands not harvested was also greater than in stands managed with group selection and extensive harvest, although it did not differ markedly from the conservation value of stands managed with individual selection harvest. Although our measure of conservation value was based on those species for which we were able to calculate a density estimate and did not include all species detected, we suggest that the ACS value provided a relative means of comparison among the harvest regimes.

We recognize that changes in avian density that result from silvicultural treatments are transitory, with their temporal influence varying among species (Holmes and Pitt 2007). Stands within each of the harvest regimes we evaluated were varied with respect to time since disturbance (Table 2). This temporal disparity may have influenced our results relative to interpreting differences among harvest regimes. For example, it is reasonable to assume that avian densities in a stand manipulated with an extensive harvest regime would be different immediately after harvest compared with 5 or 10 years after harvest. However, we lacked sufficient data from stands of different ages to account for temporal differences within harvest regimes. Nonetheless, our data set included multiple stands within each harvest regime, which were surveyed at different stages of succession and vegetative response following harvest.

MANAGEMENT IMPLICATIONS

We suggest that conservation needs of breeding birds be considered at the species level when developing habitat management plans, although we recognize that addressing conservation needs of all breeding birds is problematic. We found that extensive harvest was less beneficial to many forest-interior species but was useful to several edge species. Therefore, we recommend managers limit the use of extensive harvest regimes that remove >40% of the overstory canopy cover for management of forest-interior species. Conversely, we recognize that harvesting >40% of the canopy might be necessary in meeting landscape-level and silvicultural objectives and was beneficial to some forest-edge birds. Alternatively, individual selection harvest tended to produce conditions conducive to a broad spectrum of species, and these stands contained greater species diversity. Similarly, group selection harvest maintained densities of many forest-interior species while providing habitat for early successional species. Thus, we suggest continued implementation of these harvest regimes, in addition to ensuring presence of not harvested stands within bottomland hardwood forest stands managed for wildlife conservation.

Finally, we suggest that our species-specific density estimates provide managers a means to anticipate change in bird communities resulting from application of different harvest regimes relative to forest management lacking prescribed silvicultural harvest. These estimates of bird density can be used for conservation planning at multiple spatial scales. Locally, managers can estimate avian populations within an area (i.e., refuge, management area) based on area of existing habitat that reflects previous (or lack of) prescribed silvicultural harvest. Furthermore, managers can predict changes in populations of forest birds as a result of future forest management activities. Regionally, conservation planners can use reported density estimates to make habitat-based population projections for comparison with survey-based population estimates (Rich et al. 2004). Moreover, we can predict changes in population potentially resulting from future forest management actions and thereby assess the capacity of the MAV Bird Conservation Region to attain stated population goals (Rich et al. 2004) or, if warranted, direct the formulation of alternative regional population goals for birds breeding in bottomland hardwood forests.

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Appendix. Number of detections for 43 species of breeding birds detected >50 times during point-count surveys conducted between 2000 and 2005, within bottomland hardwood stands not harvested (NOT) and stands subjected to individual selection (IND), group selection (GRP), or extensive (EXT; species selection or shelterwood) harvest on public conservation lands managed for wildlife in Louisiana, USA.

Species	NOT	IND	GRP	EXT
No. of point-count surveys	1,475	808	389	342
Acadian flycatcher (*Empidonax virescens*)	2,145	1,229	489	164
American crow (*Corvus brachyrhynchos*)	880	417	271	251
American redstart (*Setophaga ruticilla*)	234	136	88	29
Barred owl (*Strix varia*)	199	104	47	64
Blue-gray gnatcatcher (*Polioptila caerulea*)	832	640	369	233
Blue jay (*Cyanocitta cristata*)	124	139	53	38
Brown-headed cowbird (*Molothrus ater*)	515	458	219	76
Carolina chickadee (*Poecile carolinensis*)	1,131	547	265	212
Carolina wren (*Thryothorus ludovicianus*)	2,883	1,999	907	447
Chimney swift (*Chaetura pelagica*)	13	14	21	4
Common grackle (*Quiscalus quiscula*)	39	25	3	0
Common yellowthroat (*Geothlypis trichas*)	83	19	120	3
Downy woodpecker (*Picoides pubescens*)	698	523	242	91
Eastern towhee (*Pipilo cholorurus*)	184	283	205	18
Eastern wood pewee (*Contopus virens*)	166	262	114	13
Fish crow (*Corvus ossifragus*)	76	40	18	19
Great crested flycatcher (*Myiarchus crinitus*)	311	206	140	39
Hairy woodpecker (*Picoides villosus*)	52	31	18	6
Hooded warbler (*Wilsonia citrine*)	495	270	149	111
Indigo bunting (*Passerina cyanea*)	1,032	922	518	185
Kentucky warbler (*Oporornis formosus*)	306	276	193	48
Mississippi kite (*Ictinia mississippiensis*)	29	16	16	1
Mourning dove (*Zenaida macroura*)	236	304	147	18
Northern cardinal (*Cardinalis cardinalis*)	2,562	1,446	598	605
Northern parula (*Parula americana*)	731	322	119	205
Orchard oriole (*Icterus spurius*)	49	92	11	2
Painted bunting (*Passerina ciris*)	112	16	24	41
Pileated woodpecker (*Dryocopus pileatus*)	444	300	162	97
Prothonotary warbler (*Protonotaria citrea*)	1,601	726	322	114
Red-bellied woodpecker (*Melanerpes carolinus*)	1,911	1,544	655	197
Red-eyed vireo (*Vireo olivaceus*)	1,013	390	187	187
Red-headed woodpecker (*Melanerpes erthrocephalus*)	40	102	58	25
Red-shouldered hawk (*Buteo lineatus*)	231	85	42	41
Red-winged blackbird (*Agelaius phoeniceus*)	237	117	38	17
Ruby-throated hummingbird (*Archilochus colubris*)	164	156	52	13
Summer tanager (*Piranga rubra*)	365	241	125	60
Swainson's warbler (*Limnothlypis swainsonii*)	102	150	26	31
Tufted titmouse (*Baeolophus bicolor*)	2,208	1,448	607	429
White-eyed vireo (*Vireo griseus*)	1,537	1,135	554	454
Wood thrush (*Hylocichla mustelina*)	81	78	21	16
Yellow-billed cuckoo (*Coccyzus americanus*)	1,234	932	344	205
Yellow-breasted chat (*Icteria virens*)	235	448	497	49
Yellow-throated vireo (*Vireo flavifrons*)	219	99	50	37