Research Article

Bird Response to Clear Cutting in Missouri Ozark Forests

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ABSTRACT We evaluated changes in breeding bird density and shifts in territory distribution with respect to clear cutting and timber stand improvement (TSI) of even-aged stands on >300 ha experimental management units as part of the Missouri Ozark Forest Ecosystem Project. After one harvest entry, clear cutting had positive effects on density of indigo bunting (*Passerina cyanea*), prairie warbler (*Dendroica discolor*), and yellow-breasted chat (*Icteria virens*) and negative effects on density of Acadian flycatcher (*Empidonax virescens*), ovenbird (*Seiurus aurocapilla*), and worm-eating warbler (*Helmitheros vermivorus*). In buffer regions within 100 m of clearcuts, indigo bunting, hooded warbler (*Wilsonia citrina*), wood thrush (*Hylocichila mustelina*), and Kentucky warbler (*Oporornis formosus*) densities increased and ovenbird density decreased. Breeding bird densities did not change in interior regions >100 m from clearcuts except for a small increase for wood thrush. Breeding Acadian flycatcher and ovenbird showed greater use of stands not treated with TSI. We recommend combining adjoining stands to keep clearcut sizes between 8 ha and 13 ha to reduce negative effects on ovenbirds by cutting. We suggest a 7-year offset between the timing of clear cutting and TSI to reduce their combined effects on ovenbird. (JOURNAL OF WILDLIFE MANAGEMENT 71(6):1899–1905; 2007)

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The effects of forest management on breeding bird density appear to vary with bird species, regional landscape characteristics, size of tree removal opening, and forest type (Thompson et al. 1995). Researchers have shown that recently harvested, regenerating forests are unsuitable habitat for mature forest-breeding birds, but these areas are productive habitat for some early successional species (Annand and Thompson 1997, Costello et al. 2000, King and DeGraaf 2000). However, lack of experimental manipulation has caused concern about the strength of the inferences drawn from these studies (Sallabanks et al. 2000).

In an effort to address forest management issues, the Missouri Department of Conservation (MDC) developed the Missouri Ozark Forest Ecosystem Project (MOFEP). This long-term, large-scale manipulative experiment was designed to test the effects of even-aged and uneven-aged forest management on a suite of biotic and abiotic response variables in Missouri, USA, oak-hickory forests (Brookshire and Shifely 1997; Shifley and Kabrick 2002). After the first of 7 rounds of cutting in a 100-year cutting cycle, Gram et al. (2003) evaluated breeding bird densities averaged over entire management compartments (sites >300 ha) and found that among mature forest-dwelling bird species, ovenbirds were most affected by forest management treatments. Gram et al. (2003) also found that territory densities of early successional species increased on sites receiving even-aged management. We used the same field data as Gram et al. (2003), but configured it to measure local-scale response of breeding birds to disturbances within even-aged management.

We compared changes in breeding bird density within forest habitat that was clearcut, within a 100-m buffer of clearcuts, and interior forest (>100 m from clearcut). Few studies have addressed these questions experimentally and none have done so on management units >300 ha. Several species appear to have reduced densities around habitat edges (King et al. 1996, Porneluzi and Faaborg 1999, Manolis et al. 2000), but this effect has not been clearly documented with experimental evidence, and some results suggest that there is less of a negative effect within mature contiguous forest (Duguay et al. 2001, Moorman et al. 2002, Rodewald 2002). Lastly, few studies have looked at the effect of timber stand improvement (TSI) practices on forest-breeding birds. This practice leads to structural changes in the forest that are likely to affect forest bird use of TSI stands. Our study objectives were to determine at a local-scale (≤13 ha) the effects of 1) clearcuts, 2) clearcut edge (buffer), and 3) timber stand improvement on Ozark breeding birds.

STUDY AREA

We used 6 of the original 9 MOFEP large study sites that ranged in size from 312 ha to 512 ha within the Current River and Peck Ranch Conservation Areas in Carter, Reynolds, and Shannon counties (91°01′ to 91°13′W and 37°00′ to 37°12′N). Our study sites were located in the Ozark hills of south-central Missouri, a region that was 84% forested with mature upland oak-hickory and oak-pine forest communities (Xu et al. 1997). The structure and composition of the contemporary Ozark forest were largely the result of heavy harvest during the late 1800s and early 1900s, followed by a period of widespread wildfire coupled with overgrazing, then a prolonged period of fire suppression. These activities reduced shortleaf pine (*Pinus echinata*)

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and allowed dominance of oaks (*Quercus* spp.) and hickories (*Carya* spp.) in overstory (Krusekopf et al. 1921, Galloway 1961, Cunningham and Hauser 1989, Guyette and Kabrick 2002). In 1995, these sites were free from harvest manipulation for ≥40 years, had forest of similar structure and age, and had minimal edge (Sheriff 2002). Most overstory trees on the sites ranged 50–70 years old (Brookshire and Dey 2000). This forest supported Acadian flycatcher (*Empidonax virescens*), ovenbird (*Seiurus aurocapilla*), worm-eating warbler (*Helmitheros vermivorus*), Kentucky warbler (*Oporornis formosus*), wood thrush (*Hylocichla mustelina*), red-eyed vireo (*Vireo olivaceus*), scarlet tanager (*Piranga olivacea*), summer tanager (*Piranga rubra*), indigo bunting (*Passerina cyanea*), and others (Clawson et al. 1997). The MOFEP sites were managed under MDC Forest Land Management Guidelines (MDC 1986), which were based on a multiple-use, sustained-yield forest management concept.

Missouri Department of Conservation managed forested land to meet multiple objectives, such as timber harvest, watershed protection, wildlife habitat, and recreation. Even-aged management used clearcut harvest with a cutting rotation of 80–100 years per site, resulting in a regulated harvest of 10–15% of the trees per entry on a 15-year period. Timber stand improvement culled poor quality trees and increased growing space for residual trees (Kabrick et al. 2002). Forest managers set aside 10% of site forest area as old growth (not to be included in harvest rotation). The goal of even-aged management was to create a multi-aged, multi-level structure forest with the following composition: 10% regeneration (saplings and sprouts), 20% small trees (6–14 cm dbh), 30% pole-timber (14–29 cm dbh), and 40% saw-timber (>29 cm dbh). After one rotation, stands (3–13 ha) would have trees of similar age regenerated from clearcut, although over a large management unit, structure would resemble the target composition. At each harvest entry for even-aged sites, managers decided which stands would be treated with clearcut harvest, TSI, or left alone until the next entry.

METHODS

Within MOFEP, we used 3 large management compartments (sites) that we randomly assigned to even-aged management and 3 sites assigned to no harvest. We examined the effects of clearcut by partitioning areas at each of the 3 even-aged sites into disturbance classes: clearcut, buffer (0–100 m from clearcut), and interior (>100 m from clearcut). We delimited buffer and interior at 100 m from clearcut because Porneluzi and Faaborg (1999) found reduced use by ovenbird of habitat 0–100 m from edge. We contrasted these areas of disturbance to the sites assigned to no harvest and used the original MOFEP block structure to pair sites of no harvest and even-aged management. We based the 3 blocks on proximity and similarity of sites. This design produced 3 replicates for each disturbance category. We used the block as a random effect and the disturbance as a fixed effect. For responses to the first harvest entry (harvested in 1996), we examined changes in territory density between the precut period 1991 to 1995 and the post-cut period 1997 to 2000. Timber stand improvement was done in both even-aged buffer and interior. We chose to evaluate TSI only in interior to minimize confounding between responses to clearcut and to TSI. Managers performed TSI on 33.7% of the area at site 3, 16.7% at site 5, and 6.8% at site 9.

Data Collection

We selected 5 mature forest-dwelling focal species (Acadian flycatcher, ovenbird, worm-eating warbler, Kentucky warbler, and wood thrush) and 4 early successional focal species (hooded warbler [*Wilsonia citrina*], indigo bunting, prairie warbler [*Dendroica discolor*], and yellow-breasted chat [*Icteria virens*]). We selected these because 1) they were territorial and vocal, allowing estimates of their densities via spot mapping; 2) their nests were generally accessible for monitoring of reproductive success; and 3) we had comparable data on abundance and demography of these species from fragmented habitats in prior or concurrent studies (Clawson et al. 1997).

We determined bird territory locations by spot-mapping (Anonymous 1970) during the precut period (1991–1995) and during the postcut period (1997–2000). To survey the study sites, we divided each entire study site into seven adjoining spot-mapping plots, each of which was approximately 45 ha in size. We surveyed each plot 10 times from mid-May through the end of June. Trained field assistants spent 3–4 hours each morning, beginning at dawn, spot-mapping an entire plot. Field assistants surveyed plots in rotation to avoid observer bias. We recorded locations of all observed birds on enlarged topographic maps of the plot. We created a new map for each plot visit. To identify territories, we created yearly composite maps for each species on each site (all plots combined), with all detections color-coded by census date. We defined a territory as a cluster of ≥3 detections from 3 different census dates. R. L. Clawson interpreted all composite maps and manually mapped centers of detection clusters as approximate territory centers.

Data Analysis

For even-aged sites, we used ArcView Geographic Information System (GIS) 3.2 to calculate the shortest distance from clearcut edge to each territory center for each focal species and year (we assigned territories within a clearcut a distance of zero). We used these distances to characterize each territory as being in our disturbance categories: clearcut, buffer, or interior. We calculated densities as territories per 100 ha (TPHH) by species and year for even-aged site disturbance categories and for no harvest sites. We further classified even-aged interior territories as being in or out of TSI areas. For each focal species, we performed split-plot analysis of variance for repeated measures (Milliken and Johnson 1984) with disturbance and block as main effects, year as the repeated effect, and postcut territory densities as dependent variables.

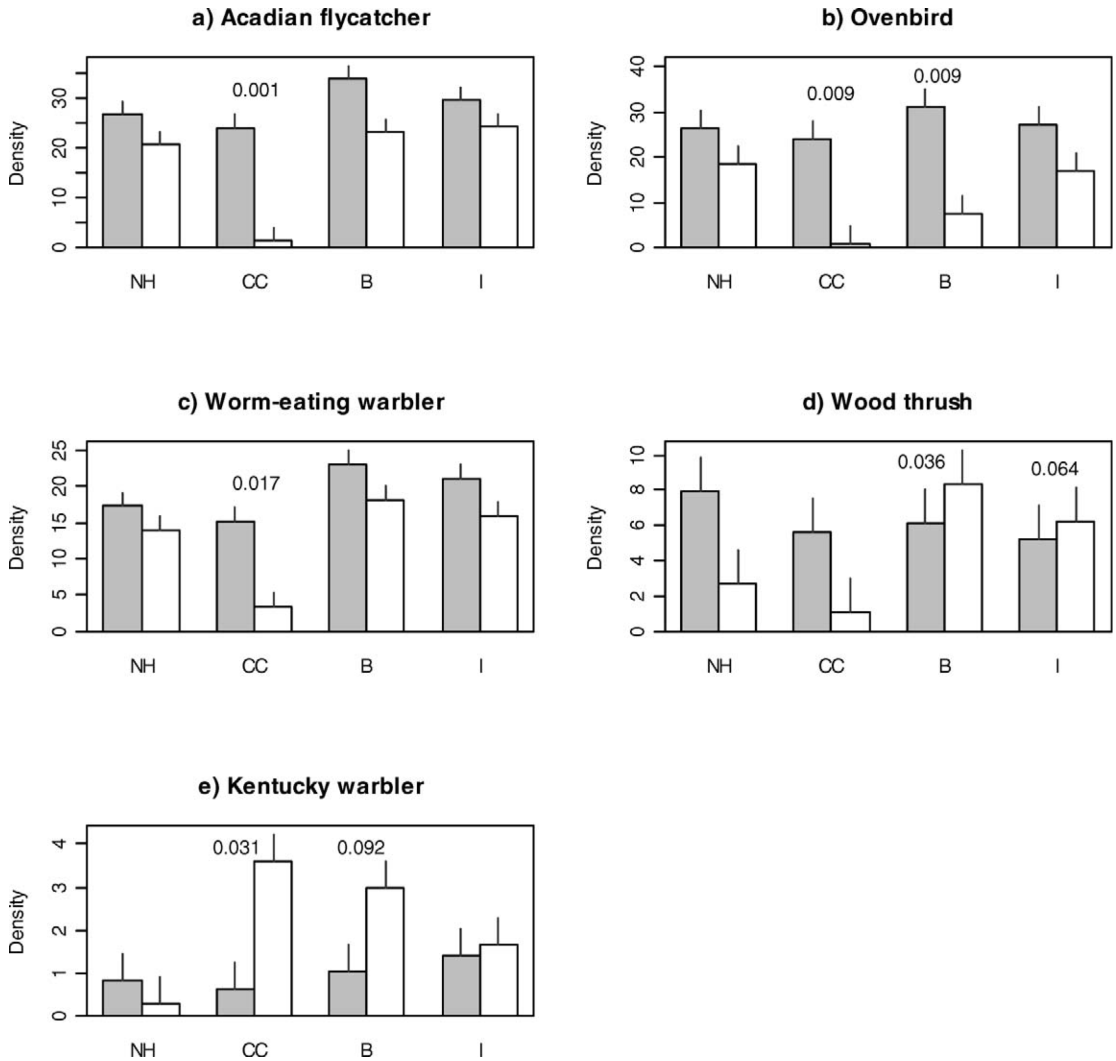

Figure 1. Mean mature forest-dwelling breeding bird territories per 100 ha in the Missouri Ozark Forest Ecosystem Project by precut (1991–1995, shaded) and post-cut (1997–2000, not shaded) period and by disturbance category (NH: no harvest, CC: even-aged clearcut, B: even-aged buffer 0–100 m around clearcuts, and I: even-aged interior >100 m from clearcuts). We calculated densities from spot-map data collected in Carter, Reynolds, and Shannon counties of Missouri, USA, from mid-May through the end of June. Significant contrasts to density changes in the no harvest treatment are indicated with *P*-values above each disturbance ($\alpha = 0.1$). Error bars represent standard errors.

On the disturbance by year interaction, we adjusted degrees of freedom and *P*-values for unequal correlation and unequal variance among random variables (Milliken and Johnson 1984). For mature forest-dwelling species (Acadian flycatcher, ovenbird, worm-eating warbler, Kentucky warbler, and wood thrush), these analyses showed no significant disturbance by year interactions ($P > 0.14$), which indicated that disturbance effects were consistent among years, and allowed us to proceed with a simpler randomized block model on changes between precut and postcut territory density means. We contrasted each disturbance level to no harvest. To increase statistical power, we used $\alpha = 0.10$ for all tests.

To examine the effects of TSI, we categorized each territory center of the even-aged interior as being in or out of TSI. We tested for changes in proportions of territories in TSI between precut and postcut using logistic regression models (Agresti 1990) that included effects for sites and period (precut or postcut).

RESULTS

All 5 of our focal mature forest-dwelling bird species had significant changes in density (precut to postcut) between disturbance categories (Fig. 1). In clearcut, Acadian flycatcher densities decreased 16.8 TPHH (SE = 2.6, Fig. 1a) relative to change in no harvest (block effect: mean sq [MS] = 24.27; disturbance effect: $F_{3,6} = 19.74$, mean sq error [MSE] = 9.97, $P = 0.002$); ovenbird densities decreased 15.7 TPHH (SE = 4.1; Fig. 1b) relative to no harvest (block effect: MS = 298.15; disturbance effect: $F_{3,6} = 8.31$, MSE = 25.19, $P = 0.015$); and worm-eating warbler densities decreased 8.4 TPHH (SE = 2.6; Fig. 1c) relative to no harvest (block effect: MS = 8.05; disturbance effect: $F_{3,6} = 4.22$, MSE = 9.96, $P = 0.063$). Also in clearcut, the wood thrush density decrease was similar to no harvest (contrast:

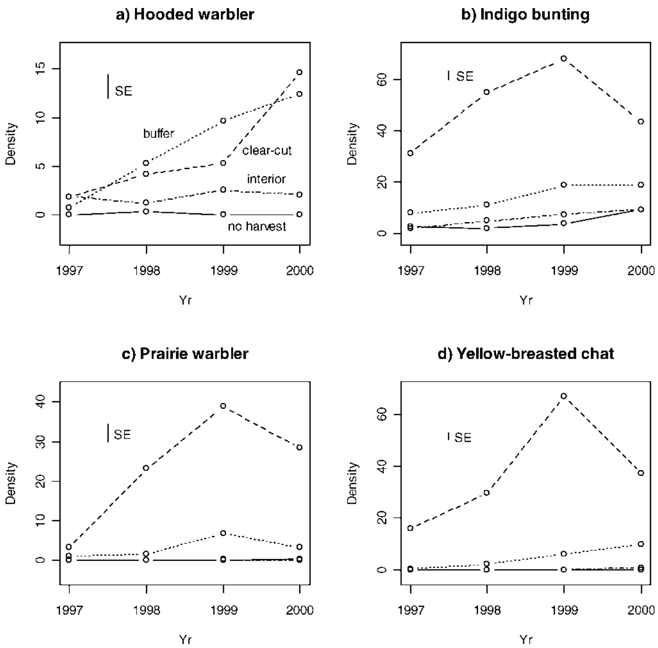

Figure 2. Postcut mean early successional breeding bird territories per 100 ha in the Missouri Ozark Forest Ecosystem Project by year and disturbance category (no harvest, even-aged clearcut, even-aged buffer 0–100 m around clearcuts, and even-aged interior >100 m from clearcuts). We calculated densities from spot-map data collected in Carter, Reynolds, and Shannon counties of Missouri, USA, from mid-May through the end of June. Error bars represent standard errors.

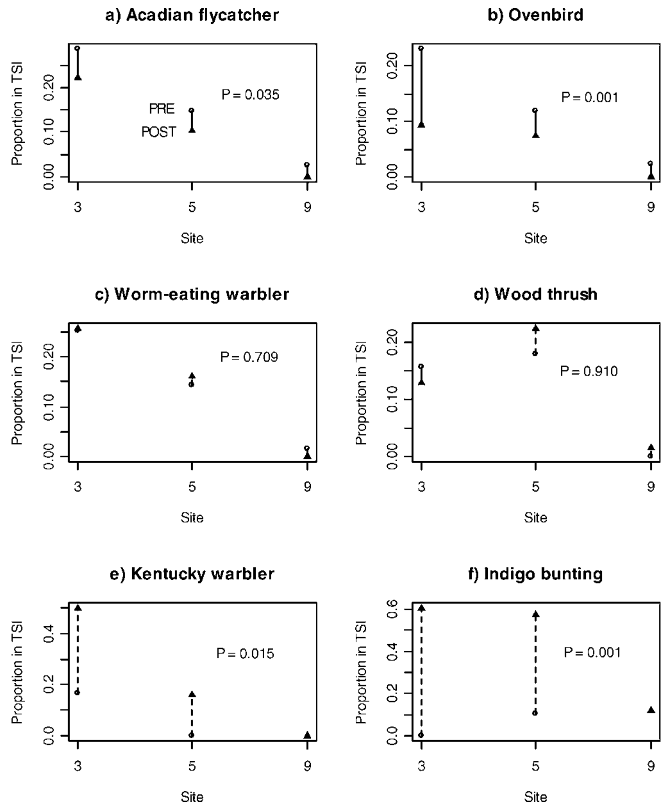

Figure 3. Proportions of breeding bird territories in timber stand improvement (TSI) areas of interior (>100 m from clearcuts) on the Missouri Ozark Forest Ecosystem Project by precut (1991–1995, circle) and postcut (1997–2000, triangle) period and experimental even-aged site. We calculated proportions from spot-map data collected in Carter, Reynolds, and Shannon counties of Missouri, USA, from mid-May through the end of June. Period effect *P*-values are from logistic regressions. Solid lines show decreases and dashed lines show increases.

0.63 TPHH, SE = 2.8; Fig. 1d; block effect: MS = 22.44; disturbance effect: $F_{3,6} = 3.79$, MSE = 11.38, $P = 0.078$) and Kentucky warbler densities increased 3.5 TPHH (SE = 1.3; Fig. 1e) relative to no harvest (block effect: MS = 0.52; disturbance effect: $F_{3,6} = 3.23$, MSE = 2.35, $P = 0.103$).

Among early successional species, precut mean densities were zero for hooded warbler and low for indigo bunting (1.68 TPHH, SE = 0.36), prairie warbler (0.03 TPHH, SE = 0.02), and yellow-breasted chat (0.11 TPHH, SE = 0.05). During postcut, hooded warbler densities did not differ among disturbance categories (block effect: MS = 120.6; disturbance effect: $F_{3,6} = 2.74$, MSE = 51.1, $P = 0.136$; disturbance by yr interaction: $F_{9,18} = 1.73$, MSE = 17.7, adjusted-$P = 0.225$; Fig. 2a). Disturbance effects on indigo bunting densities varied among years (block effect: MS = 231.3; disturbance effect: $F_{3,6} = 25.9$, MSE = 205.8, $P = 0.001$; disturbance by yr interaction: $F_{9,18} = 4.19$, MSE = 40.8, adjusted-$P = 0.025$; Fig. 2b), where the largest difference between clearcut and no harvest occurred in 1999 (contrast: 64.4 TPHH, SE = 7.4). Likewise, disturbance effects on prairie warbler densities varied among years (block effect: MS = 243.6; disturbance effect: $F_{3,6} = 6.9$, MSE = 217.4, $P = 0.022$; disturbance by yr interaction: $F_{9,18} = 2.73$, MSE = 57.2, adjusted-$P = 0.100$; Fig. 2c), and the largest difference between clearcut and no harvest occurred in 1999 (contrast: 38.9 TPHH, SE = 8.1). Also, yellow-breasted chat density disturbance effects varied among years (block effect: MS = 244.2; disturbance effect: $F_{3,6} = 24.5$, MSE = 157.2, $P = 0.001$; disturbance by yr interaction: $F_{9,18} = 14.81$, MSE = 22.6, adjusted-$P = 0.001$; Fig. 2d), where the largest difference between clearcut and no harvest occurred in 1999 (contrast: 66.7 TPHH, SE = 6.1).

In buffer areas, ovenbird was the only species with strong density reduction (contrast to no harvest: −15.7 TPHH, SE = 4.1; Fig. 1b). Also in buffer, wood thrush densities increased 7.4 TPHH (SE = 2.8; Fig. 1d) and Kentucky warbler increased 2.5 TPHH (SE = 1.3; Fig. 1e).

In the interior areas, wood thrush was the only mature forest-dwelling species to show increased density at interior areas after cutting (contrast to no harvest: 6.2 TPHH, SE = 2.8; Fig. 1d). Our focal early successional species did not have density differences between interior and no harvest (Fig. 2).

Because TSI was not evenly applied among sites, we looked at the proportions of bird territories in TSI area during precut and compared those to proportions during postcut. The proportion of territories in TSI zones decreased after cutting for Acadian flycatcher ($\chi^2_1 = 4.44$; Fig. 3a) and ovenbird ($\chi^2_1 = 10.74$; Fig. 3b). Proportions did not change for worm-eating warbler ($\chi^2_1 = 0.14$; Fig. 3c) and wood thrush ($\chi^2_1 = 0.01$; Fig. 3d). Proportions increased for Kentucky warbler ($\chi^2_1 = 5.96$; Fig. 3e) and indigo bunting ($\chi^2_1 = 25.69$; Fig. 3f).

DISCUSSION

Within even-aged management sites, the direct effects of clear cutting on bird species were mixed. In clearcut, Acadian flycatcher, ovenbird, worm-eating warbler, and wood thrush had density decreases >75%, although the wood thrush decrease was similar to its decrease at no harvest control sites. For Acadian flycatcher, mid-canopy nesting sites were lost. For ovenbird and worm-eating warbler, canopy removal (Kabrick et al. 2002) coupled with the subsequent increase in density of ground level vegetation and woody debris (Grabner and Zenner 2002) probably contributed to the observed declines. In contrast, Kentucky warbler was attracted to thickets in regenerating forest (Zenner et al. 2006) and increased 470%.

Prior to cutting, most early successional species were not nesting on even-aged management sites, but densities increased in clearcut areas after cutting. Oak stumps sprouted as dense clumps in which yellow-breasted chat, prairie warbler, and indigo bunting nested. Through 2001 to 2005, prairie warbler and yellow-breasted chat densities declined (R. Clawson, MDC, unpublished data) when dense stems >1 m in height dominated tree regeneration.

For our study, cutting was synchronized and limited to once every 10–15 years, leading to pulses of early successional bird use. If even-aged management is applied across the Ozarks, timing of cuts should be offset to allow early successional species consistent availability of breeding habitat. Clearcuts ranged in size from 1 ha to 13 ha and averaged 5.4 ha (SD = 3.3 ha) in size. The maximum density and diversity of early successional birds occurred on cuts of ≥8 ha (Brito-Aguilar 2005). Future cuts of these sizes are likely to produce positive effects on early successional bird species.

Among the species we examined, ovenbird was the only species with >75% density reduction in buffer areas. The area of effect on ovenbird is at least as large as the combination of clearcut and buffer areas, which can extend to 35% of a management site. Ovenbird have reduced abundance (Wenny et al. 1993, Porneluzi and Faaborg 1999) and reduced nest success (Hagan et al. 1996, King et al. 1996, Manolis et al. 2002) around habitat edges, even in heavily forested landscapes. If ovenbird conservation is a management concern, then consolidating the 12% harvest of even-aged management into fewer, larger cuts (8–13 ha) will reduce the amount of area in buffer and potentially reduce the overall effect on ovenbird.

Among the other mature forest-dwelling species in buffer, Kentucky warbler densities increased 189% and wood thrush increased 36%. Both of these species differ from ovenbird in their requirement for greater density of ground level vegetation (Hoover and Brittingham 1998, Hunter et al. 2001). Perhaps wood thrush was attracted to buffer areas for proximity to postfledging habitat in clearcuts (Anders et al. 1997, Pagen et al. 2000, Marshall et al. 2003.) However, most species appear to make use of regenerating clearcut for postfledging habitat and were not similarly attracted to buffer.

The effects of TSI varied among study species. Reduction of canopy in TSI (Kabrick et al. 2002) might have negative effects on Acadian flycatchers, whereas increase of ground level vegetation might negatively impact ovenbirds. By contrast, those same characteristics draw Kentucky warblers and indigo buntings into TSI. In the future, if managers wish to diminish the cumulative effects of disturbance, they could offset the timing of TSI from harvest by 7 years to reduce the negative effect on ovenbirds. After TSI, canopy gaps will grow closed by 1.9 m in 7 years (Johnson et al. 2002), making TSI stands more useful to ovenbirds at the time of clear cutting.

The first harvest entry created landscapes with 12% of area in early succession, 23% in mature forest buffer, and 65% in mature forest interior. Even-aged management will continue with harvest entries on 15-year intervals. After 100 years with 7 harvest entries, the landscape in even-aged management will be a mosaic of stands 15 years apart in age with each age class covering approximately 12% of the area. After the next harvest entry in 2011, the mosaic will approximately consist of 12% early succession, 12% regeneration ≥15 years old, 23% mature forest buffer, and 53% interior. Then, mature forest-dwelling birds that do not use 15-year-old regeneration could face further decrease of total breeding habitat. Thompson et al. (1992) found no difference between breeding Acadian flycatcher densities in areas of clearcut after 20 years of regeneration (pole and sawtimber) and in areas of no harvest, but densities in sapling regeneration 11–20 years old were low (0.9 TPHH, SE = 0.6). Regeneration from the first harvest entry will still have low Acadian flycatcher densities when additional mature timber is removed in clearcuts of the second harvest entry. We hypothesize that breeding Acadian flycatcher habitat will be further reduced for ≥5 years following the next harvest entry. For other species, more information is needed to make projections on impacts of future conditions. Future research in MOFEP will be able to determine the age of regeneration when breeding birds return to clearcut stands and evaluate cumulative effects of even-aged management.

MANAGEMENT IMPLICATIONS

We recommend combining adjoining stands to keep clearcut sizes between 8 ha and 13 ha to reduce negative effects on ovenbirds by cutting. We suggest a 7-year offset between the timing of clear cutting and TSI to reduce their combined effects on ovenbirds. Also, timing of clearcuts across the Ozarks should be offset to allow early successional species consistent availability of breeding habitat. Even-aged management can be changed at small spatial and temporal scales to reduce effects on ovenbirds and improve habitat availability for early successional species.

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