BIRD SPECIES' RESPONSES TO POST MINE RECLAMATION IN ALABAMA – A PRELIMINARY ANALYSIS[1]

Richard R. Borthwick[2] and Yong Wang

Abstract. Surface mining transforms landscapes and ecosystem functions through the removal of vegetation and soil. Losses of vegetation correlate with declines, displacement, and transformations of songbird communities. Mine reclamation is a legislative requirement that can influence wildlife communities. The purpose of this study was to examine the avian community responses to mine reclamation practices and, as a proxy, assess the potential benefits and limitations of current reclamation approaches. Avian point counts were carried out at 202 plots on mined and surrounding non-mined areas throughout the Shale Hills Region of Alabama. These mines were reclaimed across a 26 year time-frame and using a variety of reclamation techniques. Six of the thirty-six bird species observed in high enough densities for detailed analysis showed differences of interest between reclaimed and random non-mined sites. Two species showed negative density responses: Carolina Chickadees (*Poecile carolinensis*), Hooded Warblers (*Setophaga citrina*). Conversely, densities of Field Sparrows (*Spizella pusilla*), Gray Catbirds (*Dumetella carolinensis*), Pine Warblers (*Setophaga pinus)*, and Prairie Warblers (*Setophaga discolor*) responded positively to mine reclamation. We found that most mine reclamation in the Shale Hills Region of Alabama tended to shift habitat towards open canopy, edge, and grassland habitats. Though our study area tended to have fairly open forest structures (average basal areas around 13 m^2/ha and average canopy closures around 50%), species that responded negatively were often associated with older sites with more closed canopies. Reclamation techniques should incorporate diverse canopy vegetation and thick mid-story cover to promote more complex vertical forest structure.

Additional Key Words: reclamation, diversity, abundance, habitat, succession.

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Introduction

Coal mining results in large landscape changes as soils and vegetation are removed, and is managed federally through the Surface Mining Control and Reclamation Act (SMCRA, 2006). Alabama state legislation also protects mined lands through bonds to ensure they are restored to pre-development characteristics or better (Alabama Surface Mining Commission (ASMC) Administrative Code, 2013). In the state, approximately 30,500 ha (over 75,000 acres) were permitted for surface coal mining from 1980 to 2005, based on records from the Jasper, Alabama office of the ASMC, and the value of reclamation is left to some broad interpretations. Focal issues for reclamation are site stabilization, restoration of the original contours, and re-vegetation (SMCRA, 2006). Focus on soil erosion and vegetation coverage means reclamation can be approved without consideration for other biota (Mummey et al., 2002a, b; Burger et al., 2011; Buehler and Percy, 2012). Even in this specific focus, reclamation may not appropriately meet long-term vegetation objectives (Holl, 2002). Surface coal mines in Alabama are expected to persist as they provide continued economic growth and stability (Young et al., 2012).

Burger (2011) defined four periods of reclamation: tree-planting by hand, grassland, shrub/scrub, and the Forest Reclamation Approach (FRA) (Angel et al., 2005). Sites surveyed in the Shale Hills Region (SHR) of the southwest end of the Cumberland Plateau, were predominantly restored with loblolly pine (*Pinus taeda* Linnaeus) plantations; grassland and shrub/scrub techniques were used secondarily. The FRA was employed least frequently, but each approach has merit depending on management objectives (Vogel, 1973; Rudgers and Orr, 2009; Burger, 2011). Reclamation approaches that provide early-successional habitats contribute positively to some wildlife such as Henslow's Sparrow (*Ammodramus henslowii*) (Bajema and Lima, 2001) and white-tailed deer (*Odocoileus virginianus*) (Buehler and Percy, 2012). However, many birds of conservation concern in Alabama, including the Cerulean Warbler (*Setophaga cerulean*) (Buehler et al., 2006; Buehler et al., 2008), Red-cockaded Woodpecker (*Picoides borealis*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), and some Nearctic-Neotropical migrants, are associated with large diameter trees and higher canopies not normally observed in early successional habitats.

Changes to forested areas can shift habitat availability and bird communities (James and Wamer, 1982; Hardt and Forman, 1989; Bolger et al., 1991; Winter et al., 2000; Bajema and Lima, 2001; Herzog et al., 2001; Galligan et al., 2006; Wickham et al., 2007; and Loss et al., 2009). This study compared the avian community structure between non-mined sites and reclaimed mine sites to examine bird response to reclamation. Birds often are used to study mine reclamation success as they can respond quickly to changes to the environment (Bolger et al., 1991; Julliard et al., 2006; Devictor et al., 2008), be influenced by mining practices, and are relatively easily detected.

Purpose of the Study

The purpose of this study was to understand the impact of mine reclamation on avifauna observed breeding in the SHR by exploring the following:

1) How do avian species densities respond favorably or negatively to mine reclamation?

2) What specific species benefit from current reclamation practices, and which are poorly addressed?

We hypothesized that species associated with early successional habitat for nesting and breeding should be more abundant at previously mined sites as canopy openings, and early-successional mid-story vegetation ought to be prevalent, and avian species associated with mature forest characteristics should have lower densities at the reclaimed mine sites.

Methods

This study took place in the Shale Hills sub-region (SHR) of the Cumberland Plateau (Fig. 1), a primarily forested landscape (~41-80%; Iverson et al., 1994) with a temperate climate characterized by hot summers (maximum-mean 32º C), mild winters (minimum-mean 1º C), and approximately 1400 mm of precipitation per year (Smalley, 1979). The SHR comprises the southern-most foothills of the Cumberland Plateau, topographically defined by rolling hills, not the higher elevation ridgelines and plateaus observed to the north (Lemke et al., 2012). The SHR falls along the line where the Coastal Plain and Cumberland Plateau physiographic regions meet (University of Alabama, 2012), resulting in shallow shale seams.

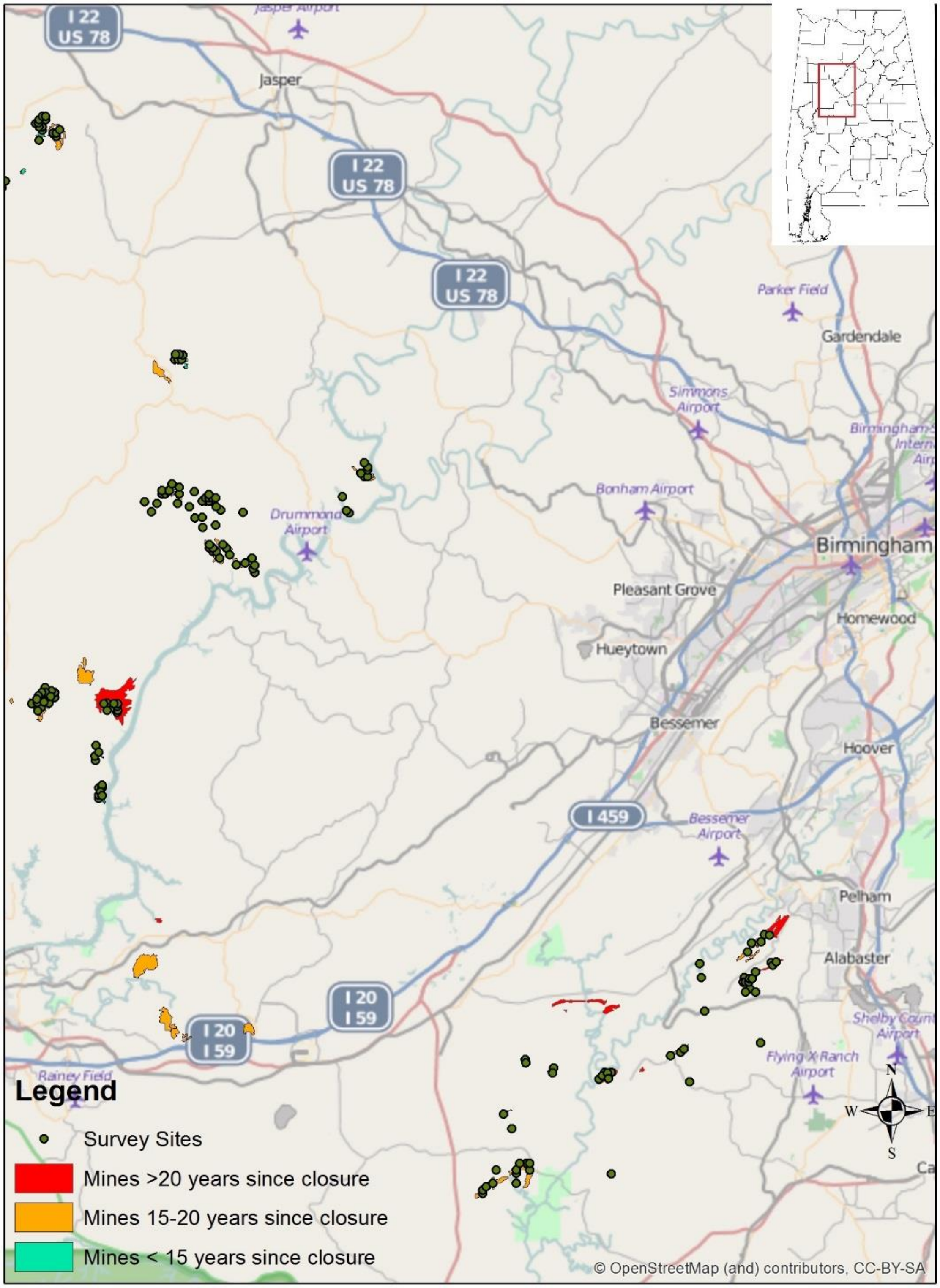


Figure 1. Overview map of the Shale Hills Region with the approximate regional location identified in red within the inset of Alabama. Colored polygons indicate mine permit areas while points indicate sample locations.

Mine Selection

We selected twenty-seven small-scale, area and contour mines, permitted after 1977 and closed by 2008. This time frame was chosen to ensure that all study mines were permitted after the implementation of SMCRA (in 1977) and closed five years prior to this study to provide sufficient time for reclamation (ASMC, 2012).

Non-mined sites were adjacent to reclaimed mine sites, and were actively managed (i.e. forestry or agriculture), but were not mined. The non-mined sites were distributed across three wildlife management areas (WMAs) within the project area: Wolf Creek WMA, Mulberry Forks WMA, and Cahaba River WMA.

Sampling Plot Selection

We generated plots using Generalized Random Tessellation Stratified (GRTS) design, using ArcGIS 10 (ESRI, 2011). This allowed flexibility in sampling (Stevens & Olsen, 2004; Lemke et al., 2012). We spaced plots greater than 250 m from each other (Ralph et al., 1995), and maximized distribution within each mine footprint. Habitat data from plots surveyed in a previous study (Lemke et al., 2012) were made available, and we used these within the permitted mine area of a focal mine. We randomly selected non-mined plots using GRTS within the polygons of selected state WMAs within the project area and compared with digital records for pre-1977 mine footprints (ASMC, 2012).

In total, we selected 202 plots with 172 at reclaimed mine sites and 30 from non-mined sites. This discrepancy in effort ensured that mine variation, based on differences in reclamation type, time since reclamation, mine size and mine type, was accounted for. Conversely, non-mined sites were distributed across wildlife management areas with similar land-use objectives. Due to these differences in landscape variation, we avoided a site-specific exploration of habitat variation and focused instead on comparing bird communities within the major landscapes. We surveyed plots for habitat and bird-community data. We collected habitat data using a modified James and Shugart (1971) method with fixed radius plots (11.4 m). At each plot, we collected data on woody vegetation consisting of tree-species, percent live canopy, and diameter at breast height (DBH) within the 11.4 m plot. Additionally, we took four readings from plot center using a densiometer in each of the cardinal directions, and averaged them for percent canopy closure and percent mid-story cover. Lastly, we recorded percent ground cover and number of forbs species present within 1 m^2 of plot center.

We collected data for eight habitat variables: percent conifer, percent ground cover, percent mid-story cover, percent canopy closure, percent live canopy, number of species of forbs, average basal area, and total trees per plot. These align with primary forest-structure factors influencing songbird distributions (James and Wamer, 1982).

Avifauna Surveys

Bird surveys were completed from May 1-June 30 in 2013 and 2014 using point-counts with distance estimation (Ralph et al., 1995; Buckland et al., 2001). Surveys commenced within 15 minutes of sunrise (U.S. Naval Observatory's Astronomical Applications Department sunrise and set for Birmingham, AL, http://aa.usno.navy.mil/data/docs/RS_OneYear.php), and persisted for a minimum of four hours after sunrise (Lynch, 1995), ending about 10:30. After arriving at the point, investigators waited for two minutes before beginning the survey to allow avifauna activities to settle (Rosenstock et al., 2002). Buckland et al. (1993) found that point-counts are better suited to multiple species investigations in patchy terrain than transects. Investigators estimated radial distances for bird detections from the plot center and classified them into one of four distance categories (minimum recommended by Rosenstock et al., 2002): <20 m, 20-50 m, 50-100 m, and >100 m in an unlimited detection radius.

Bird surveys consisted of three five-minute interval point-counts (15 minutes total) to ensure completeness of detections (Lynch, 1995) and to allow for the calculation of detection probabilities (Alldredge et al., 2007). We recorded the following for each detection: species, distance from plot center, activity, sex (generally assumed to be male for singing individuals but ranked as unknown where uncertainty existed), time of first detection, and in which intervals the individual was detected. Only audio detections were used for abundance estimates. Multiple individuals of a species were confirmed through simultaneous calls or visual observations. We randomly selected 12% of the sites to be repeated in 2013 and 2014 to compare annual differences; the years were statistically similar and therefore combined for all subsequent analyses.

Statistical Analysis

We examined the between year difference of avian density using a paired sample t-test. With species that showed significant annual differences, we completed a general linear model (GLM) to evaluate if the differences were habitat related, year related, or related to a year-habitat interaction. Because there was no way to segregate non-mined lands by time, and because they were generally similar in land-use and forest composition while mined lands were widely variable, there was not a logical and cohesive method to test differences in habitat features and avian community between the reclaimed mine sites and non-mined sites, so we used an independent sample t-test, both unadjusted and with a modified Bonferroni adjustment (Holm, 1979). We calculated avian density estimates through the Detect and Distance software packages within the R environment by assessing estimates for both distance and removal models (Miller et al., 2014; Solymos et al., 2014). The Distance package consistently provided the lowest AIC values with no co-variates, and was therefore used to estimate species densities. Prior to calculating density estimates, a double-observer approach (Nichols et al., 2000) was used with each investigator to determine individual detection probabilities, and these were applied prior to modelling abundance estimates. All statistical tests were declared significant if $P < 0.05$, with the exception of by-species comparisons which used an adjusted P-value as described by Holm (1979), and means are reported with standard errors.

Results

Across two years, 78 species of birds were observed with 36 species having more than 10 individuals detected (Table 3). All 78 species were used for annual comparisons, the 36 well-represented species were used for all other analyses. Number of bird observations per plot were similar between the two years when all species were combined (Fig. 2) (2013 mean = 12.3 ± 0.71 and 2014 mean = 13.1 ± 0.57; paired t-test = 1.79, df = 22, $p = 0.087$).

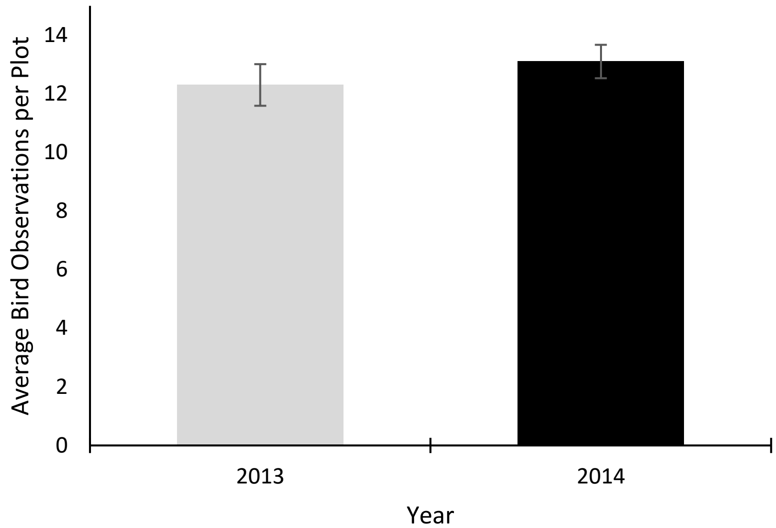
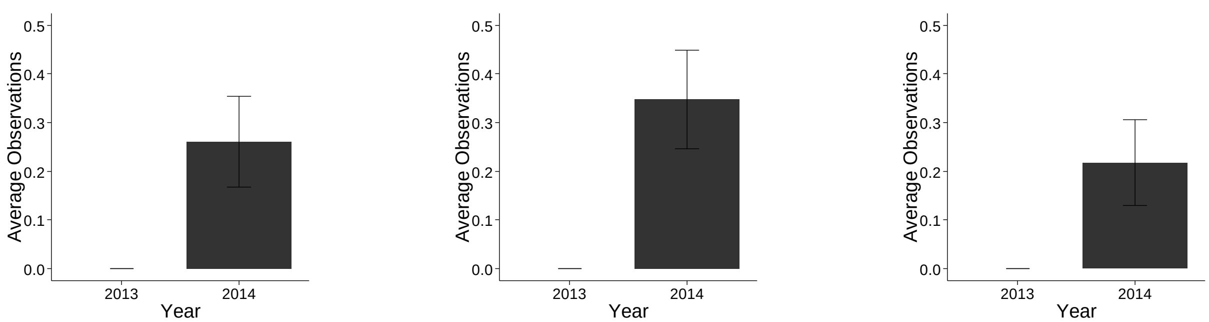


Figure 2: Comparison of 2013 (n=23) and 2014 (n=23) average (±SE) songbird observations per plot for both reclaimed mines and non-mined landscapes in the Shale Hills Region of Alabama. Years were statistically similar (paired t-test, $t_{(\alpha=0.025,22)} = 1.79$, df = 22, $p = 0.087$).

When comparisons were done by species for the 12% subset of repeated sites, three species were not observed in 2013 but were observed in 2014, and had significant differences across years (Fig. 3 a-c): Pileated Woodpecker (*Dryocopus pileatus*, *P*=0.011), Blue Grosbeak (*Passerina caerulea*, *P* = 0.0024), and Downy Woodpecker (*Picoides pubescens*, *P*=0.022).



a) Pileated Woodpecker (*P* = 0.011) **b)** Blue Grosbeak (*P* = 0.0024) **c)** Downy Woodpecker (*P* = 0.022)

Figure 3: Comparison of average individuals observed per plot (~5 ha) during breeding bird surveys in the Shale Hills Region of Alabama for Pileated Woodpecker (*Dryocopus pileatus*), Blue Grosbeak (*Passerina caerulea*), and Downy Woodpecker (*Picoides pubescens*) between 2013 (n=23) and 2014 (n = 23). Error bars are standard error. *P* values were based on paired sample t-test.

Because these three species had annual differences, they were tested with a GLM using all detection values, not only the 12% of sites that were repeated, for an interaction effect, a year effect, and treatment effect. All three species showed no interaction effect, and no treatment effect when combining all detections (Table 1). Because there was no interaction effect, these species were included for analysis.

Table 1. Assessment of the treatment and year effects for three target species from 2013-2014 breeding birds surveys in the Shale Hills Region of Alabama. Focal species are as follows: Pileated Woodpecker (*Dryocopus pileatus*), Blue Grosbeak (*Passerina caerulea*, and Downy Woodpecker (*Picoides pubescens*).

Year	**M or NM**[ᵃ]	**Pileated Woodpecker**	**Blue Grosbeak**	**Downy Woodpecker**
2013	Mined	0.21 ± 0.07	0.01 ± 0.08	0.01 ± 0.08
2014	Mined	0.28 ± 0.08	0.60 ± 0.09	0.13 ± 0.09
2013	Not Mined	0.13 ± 0.17	0.03 ± 0.18	0.03 ± 0.18
2014	Not Mined	0.10 ± 0.32	0.40 ± 0.26	0.20 ± 0.30
Effect - *P*		Year – 0.181 Treatment – 0.104 Interaction – 0.583	**Year – 0.000***** Treatment – 0.630 Interaction – 0.205	**Year – 0.000***** Treatment – 0.397 Interaction – 0.557

[a]M = Mined and NM = Non-Mined

We evaluated how vegetation differed, on average, between reclaimed mine sites and non-mined sites (Table 2). Mid-story cover was significantly higher at non-mined sites (43.8% ± 1.06) than reclaimed mine sites (18.6 ± 1.06), and the percentage of conifer trees in the canopy composition was significantly lower (19.1% ± 1.45) at non-mined sites than reclaimed mine sites (61.9% ± 1.45).

Table 2: Average habitat values for reclaimed mine sites and non-mined sites in the Shale Hills Region of Alabama, based on a modified James and Shugart (1971) methodology. Significant differences at < 0.05 level of probability are in bold. P values are based on the independent sample t-test.

Habitat	**Non-mined Mean**	**Mined Mean**	**SE**	**P**
Percent Conifer	**19.1**	**61.9**	**1.45**	**0.003**
Ground Cover	42.1	49.3	1.14	0.537
Live Canopy	41.0	41.3	0.91	0.972
Forbs	3.8	4.1	0.09	0.745
Average Basal Area	13.6	12.3	0.26	0.622
Mid-story Cover	**43.8**	**18.6**	**1.06**	**0.027**
Canopy Closure	53.2	44.0	0.94	0.334

Total Trees/plot	51.4	67.5	4.02	0.693

Unadjusted contrasts between mined and non-mined sites showed significant differences, either positive (+) or negative (-), in bird density of eight species: Carolina Chickadee (*Poecile carolinensis*) (-), Chipping Sparrow (*Spizella passerine*) (+), Field Sparrow (*Spizella pusilla*) (+), Gray Catbird (*Dumetella carolinensis*) (+), Hooded Warbler (*Setophaga citrina*) (-), Pine Warbler (*Setophaga pinus*) (+), Prairie Warbler (*Setophaga discolor*) (+), and Red-headed Woodpecker (*Melanerpes erthyrocephalus*) (-), while adjusted p-values from a modified Bonferroni calculation showed only two significant differences: Hooded Warbler (-) and Prairie Warbler (+) (Table 3). Most species that responded positively to mines were early-successional, open-area, or pine dependent species. Conversely, species that responded negatively to mines were generally mature-forest associated species. Avian diversity was not significantly different across mined and non-mined sites, though it was slightly lower in non-mined sites (1.91 ± 0.008) than reclaimed mine sites (2.04 ± 0.008).

Discussion and Management Implications

Species-specific density estimates aligned with other estimates from a territory mapping study in the vicinity (Carpenter et al., 2011). Diversity, though lower in both habitats than anticipated, showed differences across landscapes with mined landscapes being more diverse than non-mined. This discrepancy is likely a consequence of both mature forest birds being poorly represented throughout the study region, particularly in many of the currently practiced reclamation techniques at the time frame investigated, but also of the importance of post-disturbance early successional vegetation structure for a wide berth of species. Habitat variables were generally distributed as expected, but due to the large variation across mine-reclamation types and time-scale, the variance within this data set is large. The results indicate that reclamation is poorly restoring canopy diversity and mid-story density, two valuable habitat components for many avian species (James and Wamer, 1982).

Table 3: Average species densities per 10 hectares during 2013-2014 breeding bird surveys. Densities are compared between reclaimed mine sites and non-mined sites in the Shale Hills Region of Alabama. Species with significant differences at the modified Bonferroni level of probability are in bold.

Species	Species Latin Names	Species Code	Non-mined Mean	Mined Mean	SE	P
Acadian Flycatcher	*Empidonax virescens*	ACFL	0.40	0.28	0.003	0.679
American Crow	*Corvus brachyrhynchos*	AMCR	1.51	1.17	0.002	0.067
Blue Grosbeak	*Passerina caerulea*	BLGR	0.19	0.52	0.003	0.187
Blue Jay	*Cyanocitta cristata*	BLJA	0.57	0.38	0.002	0.296
Blue-gray Gnatcatcher	*Polioptila caerulea*	BGGN	5.13	5.40	0.021	0.896
Brown Thrasher	*Toxostoma rufum*	BRTH	1.14	1.87	0.013	0.598
Carolina Chickadee	*Poecile carolinensis*	CACH	5.90	3.47	0.011	0.028*
Carolina Wren	*Thryothorus ludovicianus*	CARW	0.61	1.14	0.004	0.212
Chipping Sparrow	*Spizella passerine*	CHSP	0.11	0.22	0.004	0.012*
Common Yellowthroat	*Geothlypis trichas*	COYE	1.12	1.59	0.008	0.551
Downy Woodpecker	*Picoides pubescens*	DOWO	0.09	0.12	0.001	0.728
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	0.24	0.52	0.004	0.508
Eastern Phoebe	*Sayornis phoebe*	EAPH	0.89	0.7	0.003	0.495
Eastern Towhee	*Pipilo erythryphthalmus*	EATO	1.60	2.71	0.007	0.14
Field Sparrow	*Spizella pusilla*	FISP	0.77	1.89	0.005	0.018*
Gray Catbird	*Dumetella carolinensis*	GRCA	0.27	1.64	0.006	0.024*
Hooded Warbler	***Setophaga citrina***	**HOWA**	**2.64**	**0.98**	**0.005**	**0.002**
Indigo Bunting	*Passerina cyanea*	INBU	4.67	6.24	0.01	0.116
Mourning Dove	*Zenaida macroura*	MODO	0.28	0.50	0.002	0.141
Northern Cardinal	*Cardinalis cardinalis*	NOCA	4.32	3.20	0.006	0.072
Northern Flicker	*Colaptes auratus*	NOFL	0.14	0.17	0.001	0.765
Northern Mockingbird	*Mimus polyglottos*	NOMO	0.68	0.61	0.004	0.838
Pileated Woodpecker	*Dryocopus pileatus*	PIWO	0.19	0.41	0.001	0.084
Pine Warbler	*Setophaga pinus*	PIWA	2.74	4.67	0.007	0.005*
Prairie Warbler	***Setophaga discolor***	**PRAW**	**2.17**	**5.74**	**0.008**	**0.000**
Red-bellied Woodpecker	*Melanerpes carolinus*	RBWO	0.19	0.21	0.001	0.851
Red-eyed Vireo*	*Vireo olivaceus*	REVI	4.71	3.33	0.008	0.098
Red-headed Woodpecker	*Melanerpes erythrocephalus*	RHWO	0.24	0.06	0.001	0.011*
Scarlet Tanager	*Piranga olivacea*	SCTA	0.22	0.16	0.001	0.614
Summer Tanager	*Piranga rubra*	SUTA	0.76	0.66	0.004	0.786
Tufted Titmouse	*Baelophus bicolor*	TUTI	0.72	0.70	0.003	0.918
White-breasted Nuthatch*	*Sitta carolinensis*	WBNU	0.26	0.14	0.001	0.415
Wild Turkey	*Meleagris gallopavo*	WITU	0.01	0.01	0	0.981
Wood Thrush*	*Hylocichla mustelina*	WOTH	0.28	0.11	0.001	0.081
Worm-eating Warbler*	*Helmitheros vermivorum*	WEWA	2.61	1.32	0.009	0.151
Yellow-breasted Chat	*Icteria virens*	YBCH	1.69	2.47	0.005	0.117
Overall Diversity**			1.91	2.04	0.008	0.11

*These species showed significant differences at an unadjusted $\alpha = 0.05$.

**This is a Shannon-Weaver (1948) diversity index and is not in birds/ha, it is simply an index value.
P values are based on independent sample t-test while significance is based on Bonferroni adjustments.

After adjusting the p-value tolerance, using a modified Bonferroni, only two species were considered significant: Hooded Warbler and Prairie Warbler. Although, initially, at $\alpha = 0.05$, eight avian species had significant differences between landscapes (starred in Table 3). These eight species were considered for biological and ecological relevancy in landscape differences, and the following species are explored in more detail below: Carolina Chickadee (-), Field Sparrow (+), Gray Catbird (+), Hooded Warbler (-), Pine Warbler (+), and Prairie Warbler (+). The Red-headed Woodpecker and Chipping Sparrow were so poorly represented in both landscapes, that differences observed likely bear no ecological relevance on treatments as these species appear to be sparsely distributed within the study area. Alternatively, the remaining six species had density differences that seem dependent on micro-habitat variation, a consideration that requires further study.

Carolina Chickadees were densely distributed throughout the region, but were less common on mined lands than non-mined lands. Work by Anderson and Shugart (1974) showed that Carolina Chickadee are negatively associated with slope and light penetration, but positively correlated with shrub density and foliage biomass. These findings align with our findings that non-mined landscapes tended to have more mid-story thus increasing foliage biomass, shrub density, and decreasing light penetration. Additionally, Hooded Warblers were found to generally associate with a dense shrub layer (Anderson and Shugart, 1974), which corresponds with our habitat relationships. These species densities responded negatively to reclaimed mine sites. Conversely, the remaining four species were more abundant on reclaimed surface mines. Field Sparrows are linked to old fields, brushy pastures, and sparse forests (Hunter et al., 2001) which, though poorly reflected in the habitat means, may be very prevalent on recently reclaimed surface mines. Similarly, Prairie Warblers tend to be associated with regenerating and disturbed stands (Hunter et al., 2001). Gray Catbirds are mixed-habitat species common along edge interfaces (Yahner, 1988), and these environments are created along mine perimeters. Pine Warblers are affiliated, in general, with thin understory cover, and dense, conifer dominated, high canopies (Anderson and Shugart, 1974), so it was not surprising that densities corresponded very appropriately with percent conifer, which significantly differed across landscapes. 'Negative' respondent species were generally associated with mature forests, canopy diversity or thick mid-story cover, while 'positive' respondent species were associated with more open mixed-habitats.

Species that are generally associated with mature forests were poorly represented throughout the study area, though our findings indicate anecdotally higher densities on non-mined landscapes. Contextually, the study area has been historically vegetated (Iverson et al., 1994), and mature forest species are declining. Management efforts to increase vertical complexity are likely to aid the diversification of avian communities both on reclaimed surface-mined and non-mined lands. This may not be an appropriate conservation concern for all regions, as much of the central Midwest is suffering precipitous grassland bird declines (Sauer and Link, 2011).

Management Implications

Much of the mine reclamation in the SHR has focused on compacted leveling of the excavated area, distribution of approved seed mixes, and the planting of monoculture pine plantations. Though cost effective and helpful to certain early-successional avian species, many species associated with mature forests showed negative trends in density. It is worth noting that densities of mature forest species were low throughout the region; further exploration is required to determine if other resource management is compounding this issue or if it is geographically unique. Further study is also required to determine how these species may respond across reclaimed mines.

Although mining reclamation is adequately restoring habitat for a range of local species, even surpassing non-mined landscapes in many regards, current practices in both forest-types could improve to increase structural complexity to increase densities of bird species associated with mature forests. Currently, even mature-forest-dwelling species that have known links to early successional habitat in post-breeding phases had lower-trending densities on mined lands (Marshall et al., 2003). This stresses the importance of prolonging subsequent disturbance in or adjacent to these areas beyond the 26 year time frame, at least at times, to ensure that the mature-forest bird community is also appropriately managed.

These study findings are limited to their geographic region and to small-scale surface mines, and should not be considered appropriate for larger mines, mines at higher elevations, latitudes, longitudes, or in different ecotypes.

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