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Winter bird use of harvest residues in clearcuts and the implications of forest bioenergy harvest in the southeastern United States

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ABSTRACT

Increased market viability of harvest residues gleaned for forest bioenergy feedstocks may intensify downed wood removal, particularly in intensively managed forests of the Southeast. Downed wood provides food and cover for many wildlife species, including birds, yet we are aware of no study that has examined winter bird response to experimentally manipulated, operational-scale woody biomass harvests. Further, little research has investigated avian use of downed wood following timber harvests. As such, our objectives were to: (1) evaluate effects of varying intensities of woody biomass harvest on the winter bird community and (2) document spatial associations between winter bird species and available habitat structure, including downed wood, in regenerating stands. In January and February of 2012–2014, we surveyed birds using a modified version of spot-mapping in six woody biomass removal treatments in North Carolina, USA ($n = 4$ regenerating stands). Treatments included clearcut harvest followed by: (1) traditional woody biomass harvest with no biomass harvesting guidelines; (2) 15% retention with harvest residues dispersed; (3) 15% retention with harvest residues clustered; (4) 30% retention with harvest residues dispersed; (5) 30% retention with harvest residues clustered; and (6) no woody biomass harvest (i.e., reference). We tested for treatment-level effects on avian relative abundance (overall and individual species), species diversity and richness, and counts of winter birds detected near ($\sim$1 m from pile), in, or on branches of downed wood piles and calculated proportional avian habitat use of harvest residues and vegetation in regenerating stands. In 69 visits over three winters, we observed 3352 birds in treatments. In 2013, counts of birds detected in piles were greater in the no biomass harvest and 30% clustered treatments than the no biomass harvesting guidelines treatment. In 2012 and 2013 combined, mourning dove (*Zenaida macroura*) had greater relative abundance in the no biomass harvest treatment compared to the 15% dispersed treatment and was more often detected within 1 m of downed wood piles than in vegetation. We counted more winter birds in and near adjacent forest edge than in treatment interiors each year. Overall, we detected minimal treatment effects on winter bird relative abundance and no effects on species diversity and richness. Relative abundance of winter birds increased over time as vegetative cover established in regenerating stands. Our results suggest woody biomass harvests in intensively managed pine forests had no effect on the winter bird community, but winter birds used harvest residues. Further, vegetation structure and composition, rather than availability of harvest residues, primarily influenced winter bird use of regenerating stands.

1. Introduction

Renewable energy development has increased worldwide in response to sociopolitical interests in alternative energy production, economics, and policy (Pimentel, 2008; IPCC, 2011; Creutzig et al., 2014; Erakhrumen, 2014). Forest bioenergy is an expanding

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renewable energy technology of interest (Milbrandt, 2005; Mayfield et al., 2013). Intensively managed forests can produce vast amounts of woody biomass, including merchantable roundwood and harvest residues, the latter of which may be used as a feedstock for forest bioenergy production to generate heat, electricity, and biofuels (Parikka, 2004). Currently, woody biomass is an important feedstock for production of wood pellets (Sikkema et al., 2011), co-generated electricity (i.e., coal and woody biomass simultaneously burned; Annamalai and Wooldridge, 2001), combined heat and power systems (Dornburg and Faaij, 2001), and, to a lesser extent, liquid transportation biofuels (United States Department of Agriculture (USDA), 2007; Forisk Consulting, 2013).

In the southeastern United States (hereafter "Southeast"), approximately 22% of timberland is planted forest (Oswalt et al., 2014), much of which is intensively managed, making the region a center of forest bioenergy development (Mayfield et al., 2013). The Southeast currently is the largest global exporter of wood pellets, and wood pellet production in the region is predicted to increase to meet growing market demands driven by European Union renewable energy mandates (Forisk Consulting, 2013; Goh et al., 2013; Galik and Abt, 2015). The Southeast also is experiencing more rapid development of forest bioenergy-production facilities (e.g., woody biomass power plants) than anywhere else in the world (Mendell and Lang, 2012; REN21, 2013). Additionally, the USDA has predicted nearly 50% of second generation biofuels required to meet United States biofuel mandates by 2022 will be supplied by forests of the Southeast (USDA, 2010).

Reductions of downed wood via woody biomass harvests could affect forest ecosystems and wildlife communities (Perschel et al., 2012; Evans et al., 2013). Downed wood influences nutrient retention and water dynamics (Harmon et al., 1986; Fraver et al., 2002) and provides food and cover for wildlife (Lanham and Guynn, 1996; Whiles and Grubaugh, 1996) in forests. Thus, downed wood plays critical roles in forest ecosystem function and integrity (Harmon et al., 1986; Janowiak and Webster, 2010; Riffell et al., 2011). During final harvests, gleaning of low-value harvest residues via woody biomass harvesting occurs when volumes of downed wood are high (i.e., immediately following a major disturbance like clearcutting; Harmon et al., 1986; Grodsky et al., 2016). Further, intensive woody biomass harvests may remove large quantities of residual downed wood (Fritts et al., 2014). Therefore, woody biomass harvests may diminish food and cover resources for wildlife dependent on downed wood immediately following forest disturbance.

Concerns regarding potential effects of woody biomass harvests on forest ecosystems and sustainability have led to development of non-regulatory biomass harvesting guidelines (BHGs) for natural and intensively managed forest types in several forested regions of the United States (e.g., Southeast – Perschel et al., 2012). BHGs specify target volumes of downed wood to be retained on the forest floor to maintain biological diversity and site productivity (Ranius and Fahrig, 2006; Perschel et al., 2012). In general, BHGs are based on the assumption that wildlife universally respond positively to increased volumes of downed wood (i.e., more downed wood is better than less; Harmon and Hua, 1991). However, responses to downed wood may differ among wildlife species. Further, suggested volumes and spatial arrangements of downed wood vary among regional BHGs, and BHGs have limited technical underpinnings due to a paucity of empirical support. Therefore, research is needed to determine effects of woody biomass harvests and implementation of BHGs on forest ecosystem sustainability and wildlife habitat.

Our study was part of an interdisciplinary research project that assessed sustainability of woody biomass harvests and efficacy of BHGs at maintaining biodiversity. We aimed to complement concurrent studies of breeding bird (*see* Grodsky, 2016) and amphibian and reptile, shrew, and rodent (*see* Fritts, 2014; Fritts et al., 2015, 2016) responses to woody biomass harvests in intensively managed forests of the Southeast by using winter birds as study organisms. The Southeast supports a diversity of winter birds, including residents and short-distance winter migrants (Hamel, 1992). Winter birds often are an overlooked component of the bird community of the region, especially in intensively managed forests. Yet, winter birds may serve ecological roles as granivores and seed dispersers in regenerating stands (e.g., Rost et al., 2010). Further, winter bird habitat use is a relevant issue for addressing year-round avian conservation. For example, evidence suggests that successful breeding of resident birds is affected by availability of winter vegetation structure (DellaSalla et al., 1996) and winter can be the critical, limiting season influencing avian survival (Chambers and McComb, 1997).

In the Southeast, several winter bird species are known to use downed wood (Hamel, 1992; Lohr et al., 2002), especially coarse woody debris (CWD; debris ⩾7.6 cm in diameter for a length of at least 91 cm; Woodall and Monleon, 2008). CWD may trap seeds dispersed by surface flow or wind and subsequently provide locally abundant food resources for granivores (Loeb, 1996; Sharitz, 1996), potentially including granivorous birds. CWD also harbors high densities of invertebrate prey (Hanula et al., 2006; Castro and Wise, 2010). Thus, insectivorous winter birds may center their foraging around CWD when winter temperatures are warm enough for invertebrate activity (i.e., >40 °F). CWD piles maintain a relatively stable thermal environment (Loeb, 1996), and winter birds may use CWD as thermal and escape cover (Lima, 1993).

Few studies have addressed relationships between winter birds and downed wood, avian response to experimental manipulations of harvest residues, or winter bird use of recent clearcuts (herein "regenerating stands"; Lanham and Guynn, 1996; Riffell et al., 2011). The dearth of research on winter bird use of harvest residues, coupled with the lack of empirical data guiding BHGs, indicate that studies of winter bird response to harvest residue removal following woody biomass harvests are warranted. Thus, our primary objectives were to: (1) evaluate effects of varying intensities of woody biomass harvest on the winter bird community and (2) document spatial associations between winter bird species and available habitat structure, including downed wood, in regenerating stands.

2. Methods

2.1. Study area and design

We examined winter birds in four regenerating stands (hereafter "blocks") in Beaufort County, North Carolina (35.6104°N, 76.8613°W) within the Coastal Plain Physiographic Region of the Southeast. All four blocks [70.5 ± 6.1 (mean ± SE) ha] were intensively managed forests planted with loblolly pine (*Pinus taeda*) seedlings and managed by Weyerhaeuser Company. Blocks were managed for sawtimber production and were commercially thinned twice before final harvest at 32–39 years old. The study area primarily consisted of pine plantations of various ages (86%), and the surrounding area included agriculture, forest, and limited rural housing (Homyack et al., 2016). Average winter temperature of the study area was 8.61 °C. Soils were predominantly loam and silt loam.

During clearcut harvest in November 2010 through February 2011, we implemented woody biomass removal treatments (herein "treatments") at each block. We used a randomized complete-block experimental design, dividing each block into the following six treatments [area = 11.7 ± 0.5 (mean ± SE) ha; range = 8.4–16.3 ha]: (1) clearcut with a traditional woody biomass harvest and no BHGs implemented (NOBHGS); (2) clearcut with 15% retention of harvest residues evenly dispersed throughout the treatment (15DISP); (3) clearcut with 15% retention of harvest residues clustered in large piles throughout the treatment (15CLUS); (4) clearcut with 30% retention of harvest residues evenly dispersed throughout the treatment (30DISP); (5) clearcut with 30% retention of harvest residues clustered in large piles throughout the treatment (30CLUS); and (6) clearcut with no woody biomass harvest (i.e., clearcut only; NOBIOHARV), which served as a reference. We defined harvest residues as non-roundwood stems, pine tops, and limbs traditionally considered non-merchantable prior to the advent of forest bioenergy-driven woody biomass markets.

In each treatment, all standing pines merchantable as roundwood were cut and transported to a logging deck with a grapple skidder. For the NOBHG treatments, we instructed loggers to glean all harvest residues they deemed merchantable as woody biomass. For the NOBIOHARV treatments, pine roundwood was harvested; however, we instructed loggers to fell and leave all other stems (i.e., primarily midstory hardwoods) not harvested as roundwood and pine tops and limbs.

To implement the four treatments emulating BHGs, we used ArcGIS (ESRI, Redlands, California, USA) to delineate retention areas that represented either 15% or 30% of the total treatment area. Prior to clearcut harvest, we located retention areas using a hand-held Garmin Rino global positioning system (Olathe, Kansas, USA) and flagged boundaries. We retained all hardwoods not merchantable as roundwood and other pine residues in retention areas. Retention areas were clearcut after loggers harvested 85% or 70% of the non-retention treatment areas, and harvest residues from retention areas were redistributed throughout the treatment unit with a grapple skidder. In retention treatments, loggers spread retained harvest residues from retention areas evenly throughout the DISP treatments or in randomly placed piles throughout the CLUS treatments. Because we created treatments by distributing harvest residues with a grapple skidder, individual piles of harvest residues in the CLUS and NOBIOHARV treatments were approximately the size of one grapple load (volume $\approx 36.19\ m^3\ ha^{-1}$; Fritts et al., 2014). Harvest residues from the non-retention areas and the entire NOBHG treatment were chipped at the logging deck during harvest.

In the winter of 2010–2011, site preparation followed clearcut harvest and treatment implementation. Blocks were sheared using a V-shaped blade, bedded into continuous, mounded strips of soil approximately 3 m wide and <1 m tall, and planted with loblolly pine seedlings during the fall-winter of 2011–2012 at a density of $\approx$1100 trees ha^{-1}. Shearing moved retained woody biomass into the 3-m space between pine beds (i.e., inter-bed space). Consequently, woody biomass was rearranged following shearing into long, linear rows in inter-bed space parallel to planted pine rows. However, volume of woody biomass in treatments was largely unaltered by site preparation and discrete clusters of debris were maintained in the interbed space (Fritts et al., 2014). Blocks were treated with the following two post-harvest herbicide applications of imazapyr (Chopper©, BASF, Raleigh, North Carolina, USA) for herbaceous weed control: (1) a broadcast application (applied by helicopter) one year after harvest and (2) a banded application (applied only to pine seedlings in bedded rows) two years after harvest. Blocks and treatments were bordered by drainage ditches ($\sim$1 m wide) containing vegetation that was unaffected by site preparation and thus more developed than vegetation in treatments. A logging road ($\sim$3.7 m wide) separated each side of most sites and adjacent forest stands, which typically fell into two age classes: (1) young ($\sim$10 years old) and (2) mature ($\sim$30 years old). Snags were rare on all blocks.

2.2. Avian sampling and habitat use

We surveyed winter birds using a modified version of spot-mapping (Bibby et al., 1992; Lohr et al., 2002) along uniformly distributed, continuous strip transects in treatments from 1 January to 28 February, 2012–2014. Transects were 25 m from all block edges, 50 m apart from one another, and ran the entire length of the blocks (i.e., from one end to the other); number of transects per block varied by block width. During each winter field season, an observer continuously walked along transects, surveyed birds 25 m to either side of transect lines, and recorded the number of birds within each treatment, in drainage ditches (see Section 2.1), and $\sim$10 m into adjacent forest stands (herein "adjacent forest edge"). The observer recorded the spatial location, movements (i.e., with directional arrows), and species of each detected bird on maps of treatments. For each detection, the observer also recorded (when applicable) whether the bird was on the ground within $\sim$1 m of a downed wood pile (herein "near pile"), within a downed wood pile (herein "in pile"), or on branches protruding from a downed wood pile (herein "on branch of pile"). For each detection, we estimated distance to the nearest drainage ditch or adjacent forest edge and assigned detections to one of three distance classes: (1) 1–25 m; (2) 25–50 m; and (3) $\geqslant$50 m; distance class assignments were independent of transect spacing.

A single observer sampled each of the four blocks and treatments therein 3 times in 2012, 6 times in 2013, and 8 times in 2014. The observer conducted one survey of all treatments in one entire block between sunrise and 1000 h on mornings with no precipitation and winds <25 km/h. The observer started each survey route at a random corner of each block and alternated the order in which blocks were surveyed to eliminate potential temporal and directional biases. Because we surveyed winter birds 25 m to either side of transect lines in relatively open areas consisting primarily of low-lying grasses (when vegetation was present), we assumed detection probability in treatments was near 100% (Diefenbach et al., 2003; Plush et al., 2013). Additionally, spot mapping allowed us to track winter bird movements (e.g., flushes) after initial detections, which minimized double-counting of individuals.

2.3. Quantifying harvest residues

During a concurrent study, Fritts et al. (2014) measured scattered and piled downed wood in each treatment within each block using the line-intersect sampling (LIS) technique (Van Wagner, 1968) and a visual encounter method, respectively (*see* Fritts et al., 2014 for detailed methods). To generate total volume of downed wood ($m^3\ ha^{-1}$) for each treatment, they summed volume of piled downed wood estimated from the visual encounter method and volume of scattered downed wood estimated using the LIS method.

2.4. Quantifying vegetation

We did not characterize habitat characteristics in 2012 because blocks had minimal vegetation due to intensive site preparation and young stand age. In February of 2013 and 2014, when vegetation was well-established in regenerating stands, we estimated vertical vegetation structure, maximum vegetation height, groundcover (i.e., cover < 1 dm off the forest floor), and horizontal vegetation cover (i.e., cover $\geqslant$ 1 dm off the forest floor) at three (2013) and six (2014) systematically distributed vegetation plots in each treatment. At each vegetation plot, we established three, 10-m transects along which we measured vegetation at 10, 1-m increments (i.e., 30 total sampling points/vegetation plot). We oriented the first transect based on a random bearing and oriented the remaining two transects 120° to either side (USDA, 2007). As an index of vertical structure, we counted the number of times any vegetation type (forb, grass, woody shrubs and vines) touched any decimeter increment along a 2-m-tall, 4.8-cm-diameter rod at 30 sampling points (Moorman and Guynn, 2001). Maximum vegetation height for each vegetation plot was the maximum decimeter increment (up to 2 m) at which we recorded a vegetative hit for each of the 30 sampling points. We recorded common groundcover types (bare ground, coarse woody debris, grass, and litter) that touched anywhere from the bottom through the first 1-dm increment of the rod. We recorded horizontal vegetation cover types (forb, grass, and woody shrubs and vines) that touched anywhere above the 1-dm increment of the rod. We indexed percent cover of each groundcover and horizontal vegetation type at each vegetation plot by dividing the number of sampling points where the rod touched each ground or horizontal vegetation type by 30 and multiplying by 100.

2.5. Statistical analyses

We calculated annual relative abundance as the count of individual birds detected per treatment in each block divided by number of visits per block for each year for all winter bird species combined (i.e., all species with $\geqslant 1$ detection per year), each species with $\geqslant 30$ detections per year, and two wren species [Carolina wren (*Thryothorus ludovicianus*) and house wren (*Troglodytes aedon*)] that have documented relationships with downed wood (Hamel, 1992). We chose the minimum sample size of 30 detections to ensure inclusion of all relatively common winter bird species in regenerating stands. For each treatment in each block, we calculated species richness and derived the Shannon-Weaver index of diversity (herein "species diversity"; Shannon and Weaver, 1949) for the entire winter bird community using the *diversity* function in the R package "vegan" (Oksanen et al., 2012) and used these metrics as response variables. To avoid bias induced by edge effects, we only included winter bird detections recorded $\geqslant 25$ m from all drainage ditches and adjacent forest edges in analyses. We excluded winter birds observed on logging decks because logging decks were excluded from treatment implementation.

To test for treatment-level effects on winter birds, we ran generalized linear models (GLMs) with a Gamma distribution, using winter bird (i.e., all winter birds and each species) relative abundance (i.e., count/effort), species diversity, and species richness as response variables. For relative abundance analyses, we used treatment, block, and year as independent, explanatory variables; for species diversity and richness analyses, we analyzed each year separately and used treatment and block as independent, explanatory variables. To generate a standardized metric to represent the spatial associations of winter birds with piles of downed wood in treatments, we divided the count of all winter birds detected near, in, or on branches of piles, respectively, by number of visits to each block for each year. We then used these relative counts of winter birds detected near, in, or on branches of piles as response variables and treatment and block as independent, explanatory variables in GLMs (Gamma distribution) for each year. Because the Gamma distribution requires positive values, we added half the value of the smallest positive observation to each data point with an original value of 0 when at least one value of 0 occurred in a dataset for a response variable. We assumed overdispersion when the residual deviance divided by the residual degrees of freedom was >1.5. When we detected overdispersion, we corrected for it by applying a negative binomial regression model (Venables and Ripley, 2002). For the categorical variables treatment and year, we performed *post-hoc* Tukey's pair-wise comparisons of means for all models using general linear hypothesis testing (*glht* function; single-step method) in the R package "multcomp" (Hothorn et al., 2013).

We examined use of available habitat structure (i.e., downed wood piles versus vegetation) by commonly encountered winter bird groups in regenerating stands. Specifically, we calculated the proportion of detections near, in, or on branches of downed wood piles or in vegetation for commonly encountered winter bird groups, including wrens (Carolina wren and house wren), mourning dove (*Zenaida macroura*), and sparrows [savannah sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*), and swamp sparrow (*Melospiza georgiana*)]. We summarized these proportions descriptively. We also determined winter bird distribution across a gradient of edge proximity spanning from adjacent forest edges and drainage ditches inwards to the interior of regenerating stands. For each year, we compared total winter bird counts among adjacent forest edge and drainage ditches (see Section 2.1), and distance classes away from adjacent forest edges and drainage ditches (i.e., 1–25 m, 25–50 m, and >50 m) using Pearson's Chi Squared Goodness of Fit Tests.

We compared yearly vegetation structure and composition among treatments using randomized complete block design analyses of variance (ANOVAs). After confirming normality and homogeneity of variances using Shapiro-Wilks and Bartlett tests, respectively, we ran ANOVAs using index of each groundcover type (i.e., bare ground, coarse woody debris, grass, and litter), index of each horizontal vegetation cover type (i.e., forb, grass, and woody shrubs and vines), vertical vegetation structure, and maximum vegetation height for each treatment in each block per year as dependent variables, and treatment and block as fixed effects. We arcsine square-root transformed percentile variables, but untransformed means and standard errors are reported. We conducted all analyses using statistical software program R (version 3.1.0; R Core Team, 2014). We set $\alpha = 0.05$.

3. Results

In the winters of 2012–2014, we counted 9618 birds of 52 species, of which 3352 (35%) occurred in treatments (i.e., $\geqslant 25$ m from drainage ditches and adjacent forest edge; *see* Appendix A). In 2012, mourning dove was the most commonly encountered species in treatments (37%; Table 1). Sparrows, including savannah sparrow, song sparrow, and swamp sparrow, collectively comprised 67% and 88% of winter bird counts in treatments in 2013 and 2014, respectively (Table 1).

There were few treatment effects on winter bird metrics (Table 1). Neither species diversity nor richness differed among treatments in any year. Mourning dove relative abundance (2012 and 2013 combined) was greater in the NOBIOHARV treatment than in the 15DISP treatment. In 2014, field sparrow relative abundance was greater in the NOBHGS treatment than in other treatments, with the exception of the 30CLUS treatment. Apart from mourning dove (2012 and 2013 combined) and field sparrow (2014), we detected no treatment effects on relative abundance of the winter bird community or individual species. However, winter bird relative abundances typically increased from 2012 to 2013, whereas differences in winter bird relative abundances between 2013 and 2014 were not as large (Table 1). Sparrow species were rare in 2012; relative abundance of swamp sparrow increased from 2013 to 2014, and relative abundance of Carolina wren, species richness, and species diversity all peaked in 2013 (Table 1).

In general, counts of winter birds near, in, or on branches of downed wood piles did not differ among treatments (Table 2). In 2013, counts of winter birds detected in piles were greater in the NOBIOHARV and 30CLUS treatments than in the NOBHGS treatment. In all years, we detected fewer winter birds in piles than near

Table 1
Mean ± SE of Shannon-Weaver index of diversity and species richness, and relative abundance (counts per treatment unit/# visits per block each year) of winter birds recorded in six woody biomass removal treatments within regenerating stands ($n = 4$), January and February, 2012–2014, Beaufort County, North Carolina. With the exception of Carolina Wren and House Wren, we only included winter bird species with ⩾30 detections per year in our species-specific analyses. Treatments included: (1) no Biomass Harvesting Guidelines (NOBHGS); (2) 15% woody biomass retention distributed evenly throughout the treatment unit (15DISP); (3) 15% woody biomass retention in piles (15CLUS); (4) 30% woody biomass retention distributed evenly throughout the treatment unit (30DISP); (5) 30% woody biomass retention in piles (30CLUS); and (6) no woody biomass harvest (NOBIOHARV). Different letters indicate significant differences among treatments or years; years were pooled for analyses. N/A indicates insufficient sample size. Scientific names of winter bird species available in appendices.

	Year	Woody biomass removal treatment					
		NOBHGS	15DISP	15CLUS	30DISP	30CLUS	NOBIOHARV
Community metric							
Shannon-Weaver (H)	2012	0.40 ± 0.26	0.70 ± 0.25	1.00 ± 0.18	1.06 ± 0.17	0.37 ± 0.37	0.51 ± 0.36
	2013	1.85 ± 0.11	1.84 ± 0.04	1.88 ± 0.10	1.89 ± 0.14	1.87 ± 0.14	1.80 ± 0.08
	2014	1.15 ± 0.17	1.06 ± 0.16	1.19 ± 0.26	0.98 ± 0.27	1.04 ± 0.11	1.21 ± 0.05
Species richness (N)	2012	2.00 ± 0.71	2.25 ± 0.75	3.00 ± 0.58	3.75 ± 0.63	2.00 ± 1.00	2.25 ± 0.95
	2013	9.00 ± 1.29	9.75 ± 0.25	9.50 ± 1.44	9.75 ± 1.89	10.25 ± 1.70	8.75 ± 0.63
	2014	6.25 ± 1.25	5.50 ± 1.32	6.00 ± 0.41	6.00 ± 1.35	4.50 ± 1.19	6.25 ± 0.63
Relative abundance							
All birds	2012^{b}	2.42 ± 1.24	1.42 ± 0.70	2.00 ± 0.56	3.42 ± 0.96	2.83 ± 1.08	3.08 ± 1.16
	2013^{a}	6.30 ± 1.47	8.37 ± 1.03	7.13 ± 0.73	7.22 ± 0.65	10.84 ± 4.41	6.99 ± 0.93
	2014^{a}	9.28 ± 1.15	10.84 ± 3.29	11.50 ± 2.22	9.19 ± 0.96	11.72 ± 4.73	9.81 ± 1.42
Carolina wren	2012^{b}	0.17 ± 0.17	0	0.42 ± 0.32	0.17 ± 0.17	0.33 ± 0.33	0.17 ± 0.17
	2013^{a}	0.32 ± 0.07	0.28 ± 0.08	0.32 ± 0.12	0.58 ± 0.17	0.43 ± 0.12	0.42 ± 0.17
	2014^{c}	0.03 ± 0.03	0.06 ± 0.04	0	0.06 ± 0.04	0.06 ± 0.06	0.09 ± 0.06
House wren	2012^{ab}	0	0.08 ± 0.08	0	0.08 ± 0.08	0	0.17 ± 0.17
	2013^{a}	0.04 ± 0.04	0.08 ± 0.04	0.08 ± 0.04	0.08 ± 0.04	0.12 ± 0.04	0.12 ± 0.04
	2014^{a}	0.13 ± 0.05	0.09 ± 0.06	0.16 ± 0.08	0.31 ± 0.17	0.09 ± 0.09	0.16 ± 0.06
Field sparrow	2012	N/A	N/A	N/A	N/A	N/A	N/A
	2013	N/A	N/A	N/A	N/A	N/A	N/A
	2014	1.19 ± 0.58^{a}	0.22 ± 0.15^{bc}	0.03 ± 0.03^{c}	0.09 ± 0.06^{bc}	0.78 ± 0.51^{ab}	0.22 ± 0.11^{bc}
Mourning dove	2012^{a}	0.75 ± 0.55^{ab}	0.17 ± 0.10^{b}	0.17 ± 0.10^{ab}	0.92 ± 0.57^{ab}	1.42 ± 1.20^{ab}	2.33 ± 1.31^{a}
	2013^{b}	0.16 ± 0.07^{ab}	0^{b}	0.42 ± 0.21^{ab}	0.04 ± 0.04^{ab}	0.16 ± 0.12^{ab}	0.17 ± 0.10^{a}
	2014	N/A	N/A	N/A	N/A	N/A	N/A
Savannah sparrow	2012	N/A	N/A	N/A	N/A	N/A	N/A
	2013	1.14 ± 0.41	1.39 ± 0.44	1.05 ± 0.10	0.82 ± 0.45	0.80 ± 0.28	0.61 ± 0.12
	2014	0.22 ± 0.18	2.59 ± 2.51	1.03 ± 0.78	0.22 ± 0.22	2.94 ± 2.85	0.88 ± 0.60
Song sparrow	2012	N/A	N/A	N/A	N/A	N/A	N/A
	2013	1.34 ± 0.30	2.06 ± 0.37	1.34 ± 0.36	1.62 ± 0.20	2.21 ± 0.44	1.96 ± 0.30
	2014	1.66 ± 0.24	1.88 ± 0.37	2.09 ± 0.54	1.53 ± 0.42	1.59 ± 0.39	2.25 ± 0.30
Swamp sparrow	2012	N/A	N/A	N/A	N/A	N/A	N/A
	2013^{b}	0.73 ± 0.18	1.28 ± 0.04	0.92 ± 0.24	0.76 ± 0.08	1.39 ± 0.44	0.82 ± 0.25
	2014^{a}	5.19 ± 0.97	5.25 ± 1.06	6.94 ± 1.00	6.22 ± 0.96	6.03 ± 1.87	5.44 ± 0.87
Yellow-rumped warbler	2012	N/A	N/A	N/A	N/A	N/A	N/A
	2013	0.17 ± 0.12	0.56 ± 0.16	0.15 ± 0.06	0.32 ± 0.14	0.27 ± 0.12	0.42 ± 0.22
	2014	N/A	N/A	N/A	N/A	N/A	N/A

Table 2
Counts of all winter bird detections near (i.e., ∼1 m from pile), in, or on branches of piles of downed wood per visit (mean ± SE) recorded in six woody biomass removal treatments within regenerating stands ($n = 4$), January and February, 2012–2014, Beaufort County, North Carolina. Treatments included: (1) no Biomass Harvesting Guidelines (NOBHGS); (2) 15% woody biomass retention in piles (15CLUS); (3) 15% woody biomass retention distributed evenly throughout the treatment unit (15DISP); (4) 30% woody biomass retention in piles (30CLUS); (5) 30% woody biomass retention distributed evenly throughout the treatment unit (30DISP); and (6) no woody biomass harvest (NOBIOHARV). We analyzed counts from each year independently. Different letters indicate significant differences among treatments.

Location	Year	Woody biomass removal treatment					
		NOBHGS	15DISP	15CLUS	30DISP	30CLUS	NOBIOHARV
Near pile	2012	3.00 ± 1.35	3.25 ± 0.63	4.50 ± 0.96	4.00 ± 0.58	4.00 ± 1.47	3.75 ± 1.31
	2013	8.00 ± 1.08	5.25 ± 1.11	6.50 ± 1.55	4.00 ± 0.91	5.25 ± 1.70	8.00 ± 1.78
	2014	3.50 ± 1.50	1.75 ± 0.48	3.75 ± 1.80	2.00 ± 0.71	3.25 ± 1.38	4.75 ± 1.44
In pile	2012	0.75 ± 0.48	0.50 ± 0.29	1.00 ± 0.41	1.25 ± 0.25	1.25 ± 0.63	2.75 ± 1.03
	2013	0.50 ± 0.29^{b}	1.00 ± 1.00^{ab}	1.75 ± 0.75^{ab}	1.75 ± 0.48^{ab}	4.50 ± 1.32^{a}	4.50 ± 1.04^{a}
	2014[A]	N/A	N/A	N/A	N/A	N/A	N/A
On branches of pile	2012	2.00 ± 0.91	1.75 ± 0.48	3.00 ± 0.58	3.75 ± 0.75	1.00 ± 0.41	4.25 ± 2.21
	2013	9.00 ± 2.27	8.50 ± 3.20	11.25 ± 2.56	7.00 ± 2.45	14.25 ± 1.93	11.25 ± 3.42
	2014	0.50 ± 0.29	1.00 ± 0.71	1.00 ± 0.41	2.25 ± 1.03	1.25 ± 0.48	2.75 ± 1.55

[A] Our ability to detect birds in piles was severely limited by 2014 because developing vegetation in interbeds made it difficult to determine whether a bird flushed into or out of piles of downed wood.

piles or on branches of piles (Table 2). For all years, we frequently detected Carolina wren and house wren in piles. Relative to other winter bird species in regenerating stands, we recorded a high number of counts near piles for the following species: dark-eyed junco (*Junco hyemalis*), mourning dove, and palm warbler (*Setophaga palmarum*) in 2012; chipping sparrow (*Spizella passerina*) and mourning dove in 2013; and mourning dove and northern bobwhite (*Colinus virginianus*) in 2014. In 2012, we most often detected eastern bluebird (*Sialia sialis*) and song sparrow on branches of piles.

Among the most commonly encountered winter bird groups, wrens and sparrows more frequently used vegetation than downed wood in regenerating stands, whereas doves were more often detected on the ground within 1 m of downed wood piles than in or among vegetation (Fig. 1). Winter bird counts differed among distance to edge categories in 2012 (χ^2 = 114.19, DF = 3, P = <0.01), 2013 (χ^2 = 619.04, DF = 3, P = <0.01), and 2014 (χ^2 = 1303.59, DF = 3, P = <0.01), and we counted more winter birds in adjacent forest edge, drainage ditches, and ⩽25 m from drainage ditches and adjacent forest edge than in treatments (i.e., ⩾25 m from drainage ditches and adjacent forest edge) each year (Fig. 2).

Volume of harvest residues in treatment plots was shown to accurately match that of our original experimental design, which emulated target percentages of harvest residue retention proposed in BHGs (Fritts et al., 2014). Fritts et al. (2014) calculated the following volumes (m^3 ha^{-1}) of harvest residues in each treatment: NOBHGS = 20.65 ± 1.45; 15DISP = 40.80 ± 13.11; 15CLUS = 37.76 ± 9.42; 30DISP = 55.75 ± 12.49; 30CLUS = 55.17 ± 12.49; NOBIOHARV = 108.20 ± 20.05. Most vegetation structure and composition metrics did not differ among treatments in 2013 or 2014 (Table 3). Grass ground cover was greater in the 15CLUS treatments than in the 15DISP treatments in 2013 and greater in the 30CLUS treatments than in the 30DISP or NOBIOHARV treatments in 2014. In 2013, vegetative cover of grass was greater in the NOBHGS and 15CLUS treatments than in the 15DISP treatments. Although results of ANOVAs indicated differences in vertical vegetative structure among treatments for 2013 and 2014, pair-wise comparisons of treatment means revealed no significant differences. In 2013, ground cover was mostly comprised of bare ground and grass, whereas grass alone was the most dominant ground cover in 2014. Additionally, grass comprised most of the horizontal vegetation cover in both 2013 and 2014.

4. Discussion

Our results suggest woody biomass harvests in regenerating stands within intensively managed forests of the Southeast had little effect on the winter bird community. After testing response of winter birds to experimental removal of downed wood in mature (between 40 and 50 years old) loblolly pine forests of the Southeast, Lohr et al. (2002) also found downed wood removal had no effect on the winter bird community. In contrast, Rost et al. (2010) documented a significant, positive relationship between constructed piles of downed wood and abundance of seed-dispersing, winter birds in harvested and burned Mediterranean pine forests, but no winter bird response to dispersed woody biomass. Although the winter bird community in our study was unaffected by volume and distribution of retained harvest residues, we demonstrated that downed wood may play an ecological role as winter bird habitat complementary to that of vegetation in regenerating stands. However, vegetation structure and composition, rather than availability of downed wood, primarily influenced winter bird abundance in regenerating stands.

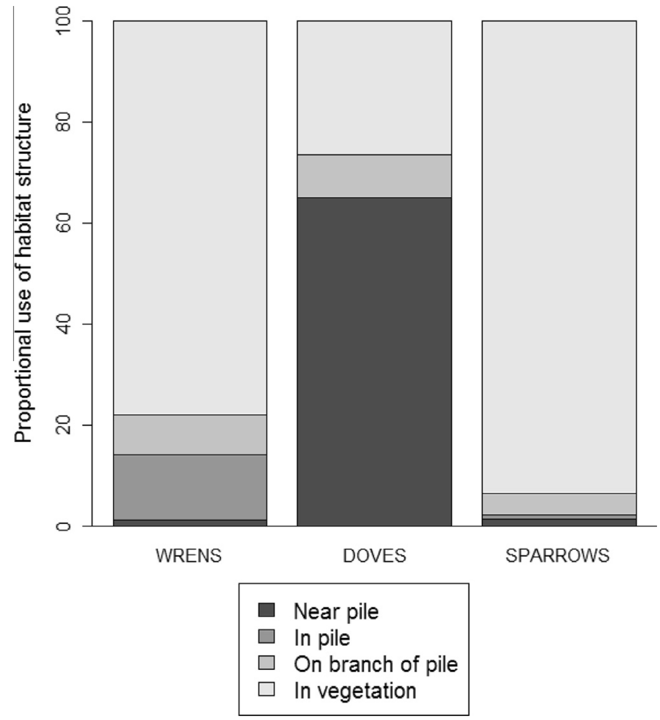

Fig. 1. Proportional use of habitat structure, including harvest residue piles [i.e., downed wood; near (within 1 m), in, and on branches of piles by wrens, mourning dove, and sparrows in regenerating stands (n = 4), January and February, 2012–2014, Beaufort County, North Carolina. WRENS = Carolina wren and house wren (2012–2014); DOVES = mourning dove (2012 and 2013 only); SPARROWS included savannah sparrow, song sparrow, and swamp sparrow (2013 and 2014). Only detections recorded ⩾25 m from edge were included. Scientific names of winter bird species available in appendices.

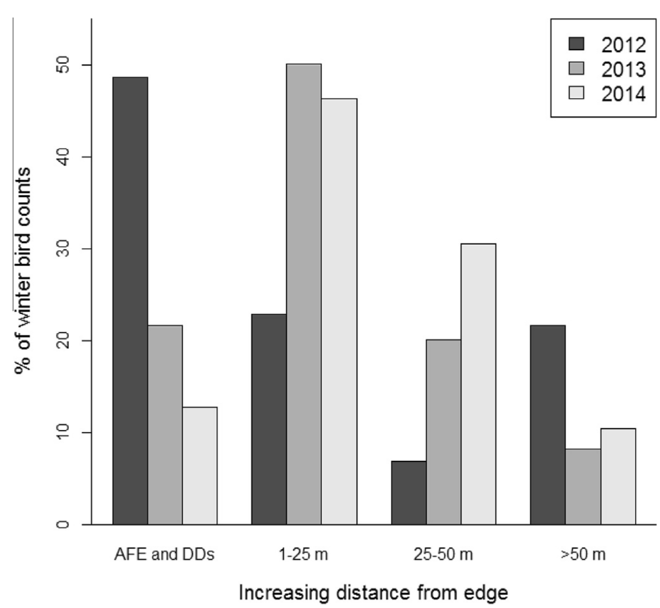

Fig. 2. Yearly variation in percentage of winter bird counts in adjacent forest edge (AFE; up to ~10 m into stands) and drainage ditches (DDs), and distance classes away from drainage ditches and adjacent forest edge (1–25 m, 25–50 m, and ⩾50 m) in intensively managed pine plantations, January and February, 2012–2014, Beaufort County, North Carolina.

Operational and economic realities affecting forest harvesting at the time our experiment was implemented may have resulted in relatively high volumes of retained harvest residues following

Table 3
Winter habitat variables[A] (mean ± SE) estimated in six woody biomass removal treatments within regenerating stands ($n = 4$) in February, 2013 and 2014, Beaufort County, North Carolina. Treatments included: (1) no Biomass Harvesting Guidelines (NOBHGS); (2) 15% woody biomass retention in piles (15CLUS); (3) 15% woody biomass retention distributed evenly throughout the treatment unit (15DISP); (4) 30% woody biomass retention in piles (30CLUS); (5) 30% woody biomass retention distributed evenly throughout the treatment unit (30DISP); and (6) no woody biomass harvest (NOBIOHARV). Winter habitat covariates for each treatment in each site were compared using randomized complete block design ANOVAs with treatment and block as fixed effects. Different letters indicate significant differences among treatments.

Covariate	Woody biomass removal treatments						Treatment		Block	
	NOBHGS	15DISP	15CLUS	30DISP	30CLUS	NOBIOHARV	$F_{5,16}$	P_{trt}	$F_{3,16}$	P_{rep}
Ground cover (%)										
Bare ground (2013)	39.17 ± 6.24	45.00 ± 2.44	33.33 ± 3.58	38.89 ± 1.71	35.00 ± 4.46	40.56 ± 4.11	1.18	0.37	3.92	0.03
Bare ground (2014)	26.81 ± 5.91	28.06 ± 4.01	26.67 ± 4.50	30.00 ± 2.97	25.83 ± 5.49	27.08 ± 3.49	0.35	0.87	16.26	<0.01
Litter (2013)	10.56 ± 2.80	17.22 ± 45.28	13.06 ± 2.65	7.50 ± 1.82	15.28 ± 2.37	13.06 ± 3.82	2.42	0.09	13.40	<0.01
Litter (2014)	11.25 ± 2.07	16.67 ± 3.25	16.11 ± 1.50	17.92 ± 4.22	10.83 ± 1.82	18.19 ± 2.39	1.19	0.36	1.46	0.27
Grass (2013)	37.78 ± 4.21[ab]	24.44 ± 4.73[b]	43.06 ± 2.13[a]	34.72 ± 6.03[ab]	35.28 ± 4.93[ab]	27.50 ± 3.82[ab]	3.14	0.04	5.59	<0.01
Grass (2014)	52.78 ± 6.52[ab]	46.67 ± 5.56[ab]	50.42 ± 5.35[ab]	40.97 ± 6.23[b]	55.00 ± 6.87[a]	41.39 ± 3.68[b]	4.93	<0.01	32.67	<0.01
CWD (2013)	6.67 ± 1.52	7.50 ± 0.72	7.50 ± 1.49	12.50 ± 2.43	8.06 ± 2.50	13.61 ± 3.41	1.98	0.14	3.78	0.03
CWD (2014)	8.06 ± 1.25	7.36 ± 1.01	7.08 ± 0.80	9.31 ± 41.20	7.08 ± 1.20	11.11 ± 1.95	1.05	0.43	1.63	0.23
Vegetative cover (%)										
Forb (2013)	9.94 ± 2.68	11.11 ± 4.55	3.61 ± 1.64	11.39 ± 3.43	10.28 ± 1.86	11.67 ± 1.00	2.03	0.13	3.55	0.04
Forb (2014)	16.11 ± 4.68	16.67 ± 5.60	12.92 ± 2.65	20.00 ± 5.00	10.83 ± 3.40	21.81 ± 4.05	2.23	0.11	14.30	<0.01
Grass (2013)	58.06 ± 5.86[a]	34.17 ± 7.84[b]	63.89 ± 3.96[a]	55.56 ± 6.07[ab]	54.72 ± 5.87[ab]	44.44 ± 7.87[ab]	4.43	0.01	7.25	<0.01
Grass (2014)	75.14 ± 4.30	73.33 ± 4.45	73.33 ± 4.24	70.00 ± 7.28	81.53 ± 4.28	67.36 ± 4.39	2.40	0.09	15.02	<0.01
WSV (2013)	3.89 ± 0.62	2.78 ± 1.15	3.33 ± 1.04	3.89 ± 0.28	5.56 ± 0.40	6.11 ± 1.78	1.78	0.18	2.86	0.07
WSV (2014)	22.08 ± 1.46	20.14 ± 3.43	19.03 ± 1.65	24.72 ± 3.61	22.92 ± 2.15	30.83 ± 4.39	1.39	0.28	0.66	0.59
VVS (2013)	4.28 ± 0.53	2.63 ± 0.48	4.20 ± 0.12	4.43 ± 0.71	4.09 ± 0.57	2.99 ± 0.42	2.93	0.05	5.35	0.01
VVS (2014)	4.35 ± 0.25	3.89 ± 0.28	3.91 ± 0.26	3.58 ± 0.33	4.47 ± 0.39	3.55 ± 0.18	3.43	0.03	10.66	<0.01
MVH (2013)	5.31 ± 0.52	3.44 ± 0.65	5.22 ± 0.12	5.75 ± 0.62	5.30 ± 0.68	3.92 ± 0.53	3.28	0.04	4.58	0.02
MVH (2014)	7.39 ± 0.39	7.02 ± 0.06	6.88 ± 0.48	7.21 ± 0.35	7.52 ± 0.16	7.08 ± 0.27	0.40	0.84	0.67	0.58

[A] CWD = coarse woody debris; WSV = woody shrub/vine; VVS = vertical vegetative structure; MVH = maximum vegetation height.

woody biomass harvest. Specifically, intensities of woody biomass harvests at the sites may have been restricted due to technological limitations of harvest equipment and disparities between costs of harvesting biomass relative to its market value may have diminished operator effort. Recent studies in the Southeast have shown that even the most intensive, unrestricted experimental woody biomass harvests leave relatively large volumes of harvest residues on the landscape (Homyack et al., 2013; Fritts et al., 2014). For example, a concurrent study at the blocks showed that the minimum volume of harvest residues retained in a treatment plot was $16.28\ m^3\ ha^{-1}$ (7.81 tons ha^{-1}; Fritts et al., 2014), which exceeded by over three-fold the Forest Guild's BHGs for the Coastal Plain physiographic region (Perschel et al., 2012). Therefore, current levels of woody biomass harvest in the Southeast may retain volumes of harvest residues above the threshold needed to sustain winter bird populations, if a threshold even exists.

Some previous studies suggested breeding birds negatively responded to experimental decreases in downed wood (e.g., Lohr et al., 2002), and our finding of minimal winter bird response to harvest residue removal relative to that of breeding birds coincides with results from other studies (*see* Riffell et al., 2011). Differences between breeding and winter bird response to downed wood removal may be related to the suite of species occurring in each season or differences in the amount of downed wood necessary to meet foraging versus nesting requirements (Hutto and Gallo, 2006; Riffell et al., 2011). Additionally, birds typically are non-territorial during winter and thus are unlikely to be as strongly tied to a particular habitat element (Lohr et al., 2002). However, Carolina wrens are territorial year-round (Simpson, 1985; Strain and Mumme, 1988), and we detected no response to woody biomass removal treatments by this species.

Knowledge of avian use of downed wood remains underdeveloped (Lanham and Guynn, 1996; Seibold et al., 2015), yet our records of spatially explicit, winter bird counts recorded near, in, or on branches of downed wood piles, coupled with field observations, indicate that several winter bird species use downed wood extensively during winter. Based mainly on anecdotal information on breeding birds and natural history studies in the Southeast, Hamel (1992) cited nine species of birds associated with downed wood. We commonly recorded Carolina and house wrens in piles of downed wood, verifying observations by Hamel (1992) and Lanham and Guynn (1996) that wrens are closely associated with downed wood. Indeed, greater counts of winter birds detected in piles within treatments maintaining greater volumes of harvest residues in 2013 coincided with peak relative abundance of Carolina wren among years. Additionally, we recorded many other bird species associated with downed wood previously unlisted by Hamel [(1992); *see* Appendix B]. We notably recorded several sparrow species (e.g., savannah sparrow, song sparrow, and swamp sparrow) using downed wood, indicating that downed wood may provide habitat structure in regenerating stands for some overwintering sparrows. However, sparrows used vegetation structure far more than downed wood in regenerating stands.

Although no studies have directly addressed mechanisms behind winter bird use of downed wood, our results support previous studies that inferred downed wood is used by winter birds for perching and cover (Shackleford and Conner, 1997; Laven and Mac Nally, 1998; Hagan and Grove, 1999; Lohr et al., 2002). Prior to vegetation establishment, we frequently detected eastern bluebird perching on branches of downed wood piles, and observed this species pouncing on grounded prey [e.g., crickets (Gryllidae)] from these vantage points (S. Grodsky, *pers. obs.*). Similar interrelationships between downed wood perches and foraging have been recorded for European robin (*Erithacus rubecula*; Rost et al., 2010) and several Australian robins (*Petroica* spp.; Mac Nally et al., 2001). Winter bird use of downed wood perches decreased as maximum vegetation height increased from 2013 to 2014, potentially indicating structural height more so than perch type (i.e., downed wood versus vegetation) dictates winter bird perch selection. Yet, at least during early stand development, perches provided by retained harvest residues may have facilitated predator vigilance among winter birds in regenerating stands (Lohr et al., 2002). Additionally, we frequently observed winter birds, including sparrows, flush into piles of downed wood rather than nearby clumps of grasses when vegetation was present (S. Grodsky, *pers. obs.*), potentially supporting the hypothesis that some passerines prefer woody cover when threatened (Lima, 1993). However, our ability to account for birds using downed wood as cover was limited by 2014 because developing vegetation in interbeds made it nearly impossible to determine whether a bird flushed into or out of piles of downed wood. Although we did not explicitly test functionality of harvest residues as thermal cover, some winter birds (e.g., sparrows) may have used roosted in downed wood because of the warmer, thermal environment relative to vegetation.

Our results also indicate winter birds may have used downed wood for the abundant insect prey and seeds it can harbor (Jabin et al., 2004; Ulyshen and Hanula, 2009; Castro and Wise, 2010). During each year of our study, we commonly detected ground-gleaning granivores (e.g., mourning dove) near piles. In this case, granivorous birds may be concentrating their feeding around piles of downed wood, which may in turn be damming seeds during pre- (seeds sourced from adjacent stands) and post-vegetation establishment (seeds sourced within stands). Loeb (1996) hypothesized that seed-damming capabilities of downed wood may attract mammalian granivores to downed wood structure for feeding. Based on our results, the same idea may apply to some granivorous winter birds, especially mourning dove. We detected mourning dove near piles more often than in vegetation, potentially suggesting that seed availability near downed wood influenced habitat use by this species. Further, granivorous birds concentrating their attention downward while feeding also could benefit from the cover downed wood provides from diurnal raptors overhead (Mac Nally et al., 2001). In 2012, we frequently detected palm warbler, an insectivore, on the ground near piles, and, for most detections, this species was actively foraging (S. Grodsky, *unpublished data*). Therefore, some ground-foraging insectivores may take advantage of highly abundant and easily accessed invertebrate prey resources associated with downed wood, especially prior to vegetation establishment (Lohr et al., 2002). Unlike in more northern latitudes, winter temperatures in the Southeast often are mild enough to support invertebrate activity (i.e., >40 °F).

Most woody biomass harvests in the Southeast are predicted to occur on private, intensively managed forests in association with clearcutting (Riffell et al., 2011), which has implications for avian use of regenerating stands beyond woody biomass harvest alone. Dynamic, successional trajectories of vegetation in regenerating stands and spatiotemporal implications of managed forest landscapes (i.e., a mosaic of variably aged stands, retained stands, and other features) inevitably will affect winter birds in conjunction with woody biomass harvests. Birds frequently associate with vertical structure in the form of vegetation (MacArthur and MacArthur, 1961) and snags (Fischer and McClelland, 1983; Lanham and Guynn, 1996). We detected more birds each year in and within 25 m of drainage ditches and adjacent forest edge likely because edge maintained greater vegetative complexity than the interiors of regenerating stands for the duration of our study. Further, many winter birds likely moved between adjacent forest stands and regenerating stands, taking advantage of resources available in each. In contrast, sparrows most often used the interior of regenerating stands, but only after grasses were present as early successional vegetation cover. Considering these points and the fact that winter bird relative abundance markedly increased from pre- to post-vegetation establishment, vegetation in and surrounding the study sites likely had a marked effect on winter bird use of regenerating stands. Thus, we suggest that, in most cases involving woody biomass harvests following clearcutting in intensively managed forests, the relationship between birds and vegetation structure and composition and landscape juxtaposition will outweigh any effects of harvest residue retention in regenerating stands.

5. Conclusion

Winter birds largely were unaffected by current levels of woody biomass harvest in intensively managed forests, suggesting that implementation of current BHGs is potentially unnecessary with respect to winter birds in the Southeast. Winter birds responded to successional changes in vegetation structure and composition more so than availability of downed wood. Yet, many winter bird species used harvest residues, potentially indicating that downed wood is a valuable habitat component in young forests. Additional research on mechanistic value of downed wood to winter birds in regenerating stands is warranted. Although current levels of woody biomass harvest in the Southeast leave considerable volumes of harvest residues on the landscape, technological advances in harvest machinery or increases in the market value of woody biomass could result in intensified removal of downed wood. If future woody biomass harvests intensify, leading to a substantial decrease in harvest residue retention relative to current levels on our study sites, we recommend that winter bird response to woody biomass harvests be re-evaluated to inform and update BHGs, if necessary.

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Appendix A

Number and location of winter birds observed in regenerating stands ($n = 4$) and surrounding edge, January and February, 2012–2014, Beaufort County, North Carolina. Regenerating stands and treatments therein were bordered by drainage ditches (~1 m wide) containing vegetation which was unaffected by site preparation and thus more developed than vegetation in treatments. Locations in treatments included: Interior = ⩾50 m from drainage ditches and adjacent forest edge (AFE); Moderate = 25–50 m from drainage ditches and AFE; and Short = 1–25 m from drainage ditches and AFE. A logging road (~3.7 m wide) separated each side of most regenerating stands and adjacent forest stands, which typically fell into two age classes: (1) young (~10 years old) and (2) mature (~30 years old).

Common name	Scientific name	Interior	Moderate	Short	Drainage ditch	AFE (mature)	AFE (young)	Total
American crow	*Corvus brachyrhynchos*	0	0	0	0	15	15	30
American goldfinch	*Spinus tristis*	4	1	6	4	0	41	56
American kestrel	*Falco sparverius*	2	1	0	1	0	0	4
American robin	*Turdus migratorius*	2	9	0	0	6	1	18

Appendix A (*continued*)

Common name	Scientific name	Interior	Moderate	Short	Drainage ditch	AFE (mature)	AFE (young)	Total
Bluejay	*Cyanocitta cristata*	0	0	0	0	1	7	8
Brown creeper	*Certhia americana*	0	0	0	0	1	0	1
Brown-headed nuthatch	*Sitta pusilla*	0	0	0	0	3	0	3
Brown thrasher	*Toxostoma rufum*	0	0	0	0	2	0	2
Carolina chickadee	*Poecile carolinensis*	1	4	3	1	33	11	53
Carolina wren	*Thryothorus ludovicianus*	34	49	114	36	61	18	312
Chipping sparrow	*Spizella passerina*	0	84	411	48	4	2	549
Cooper's hawk	*Accipiter cooperii*	1	0	0	2	0	0	3
Dark-eyed junco	*Junco hyemalis*	35	37	91	44	2	4	222
Downy woodpecker	*Picoides pubescens*	0	0	0	0	3	0	3
Eastern bluebird	*Sialia sialis*	18	25	47	24	5	2	123
Eastern phoebe	*Sayornis phoebe*	6	8	6	11	0	1	32
Eastern towhee	*Pipilo erythrophthalmus*	8	7	35	23	78	58	209
Field sparrow	*Spizella pusilla*	22	79	141	107	5	13	367
Fox sparrow	*Passerella iliaca*	0	0	0	0	5	0	5
Golden-crowned kinglet	*Zonotrichia atricapilla*	0	0	0	0	2	3	5
Gray catbird	*Dumetella carolinensis*	0	0	2	1	1	4	8
Great blue heron	*Ardea herodias*	0	0	0	2	0	0	2
Great horned owl	*Bubo virginianus*	0	0	0	0	1	0	1
Hairy woodpecker	*Leuconotopicus villosus*	0	0	0	0	10	0	10
Hermit thrush	*Catharus guttatus*	0	0	1	2	9	2	14
Henslow's sparrow	*Ammodramus henslowii*	0	0	1	0	0	0	1
House wren	*Troglodytes aedon*	16	31	74	9	0	0	130
Killdeer	*Charadrius vociferus*	11	0	0	0	0	0	11
Marsh wren	*Cistothorus palustris*	0	0	1	0	0	0	1
Merlin	*Falco columbarius*	0	0	1	0	0	0	1
Mourning dove	*Zenaida macroura*	72	44	138	20	3	13	291
Northern bobwhite	*Colinus virginianus*	0	45	122	0	0	0	167
Northern cardinal	*Cardinalis cardinalis*	0	0	15	11	15	9	50
Northern flicker	*Colaptes auratus*	0	0	0	2	14	4	20
Northern mockingbird	*Mimus polyglottos*	0	0	1	9	4	6	20
Palm warbler	*Setophaga palmarum*	8	18	26	11	4	4	71
Pileated woodpecker	*Hylatomus pileatus*	0	0	0	0	11	3	14
Pine warbler	*Setophaga pinus*	0	0	0	0	33	1	34
Red-bellied woodpecker	*Melanerpes carolinus*	0	0	0	0	13	0	13
Red-shouldered hawk	*Buteo lineatus*	0	0	0	0	0	1	1
Red-tailed hawk	*Buteo jamaicensis*	0	0	0	0	1	2	3
Red-winged blackbird	*Agelaius phoeniceus*	17	7	32	0	0	0	86
Ruby-crowned kinglet	*Regulus calendula*	0	0	4	1	4	4	13
Savannah sparrow	*Passerculus sandwichensis*	98	300	349	68	0	0	815
Song Sparrow	*Melospiza melodia*	201	417	849	314	9	21	1811
Sparrow spp.	n/a	64	217	423	26	0	45	775
Swamp sparrow	*Melospiza georgiana*	341	930	1462	129	7	6	2875
Tufted titmouse	*Baeolophus bicolor*	0	0	0	0	16	0	16
Wilson's snipe	*Gallinago delicata*	4	3	2	0	0	0	9
Winter wren	*Troglodytes hiemalis*	0	1	4	0	1	0	6
White-crowned sparrow	*Zonotrichia leucophrys*	0	1	1	4	0	0	6
White-throated sparrow	*Zonotrichia albicollis*	3	4	26	38	14	11	96
Yellow-rumped warbler	*Setophaga coronata*	9	40	90	69	33	21	262
Unknown shorebird	n/a	3	2	0	0	0	0	5
Unknown wren	n/a	1	3	4	1	0	0	9
Total		984	2368	4485	1019	429	333	9618

Appendix B

Total counts of winter birds detected near (i.e., ~1 m from pile), in, or on branches of piles of downed wood in regenerating stands ($n = 4$), January and February, 2012–2014, Beaufort County, North Carolina.

Common name	Scientific name	Near pile	In pile	On branch of pile	Total
Carolina wren[a]	*Thryothorus ludovicianus*	5	23	18	46
Chipping sparrow	*Spizella passerina*	462	0	7	469
Dark-eyed junco	*Junco hyemalis*	102	13	29	144
Eastern bluebird	*Sialia sialis*	0	0	48	48
Eastern phoebe	*Sayornis phoebe*	0	0	11	11
Eastern towhee	*Pipilo erythrophthalmus*	1	2	6	9
Field sparrow	*Spizella pusilla*	1	0	13	14
House wren[a]	*Troglodytes aedon*	0	19	8	27
Killdeer	*Charadrius vociferus*	10	0	0	10
Mourning dove	*Zenaida macroura*	139	0	30	169
Northern bobwhite	*Colinus virginianus*	27	0	0	27
Northern cardinal	*Cardinalis cardinalis*	3	1	0	4
Northern mockingbird	*Mimus polyglottos*	0	0	1	1
Palm warbler	*Setophaga palmarum*	11	0	10	21
Savannah sparrow	*Passerculus sandwichensis*	36	0	55	91
Song Sparrow	*Melospiza melodia*	23	27	133	183
Swamp sparrow	*Melospiza georgiana*	9	18	60	87
Wilson's snipe	*Gallinago delicata*	7	0	0	7
White-crowned sparrow	*Zonotrichia leucophrys*	1	0	2	3
White-throated sparrow	*Zonotrichia albicollis*	12	0	3	15
Yellow-rumped warbler	*Setophaga coronata*	53	0	14	67
Total		902	104	447	1453

[a] Bird species previously listed as downed-wood associated by Hamel (1992).

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