CHANGES IN EARLY-SUCCESSIONAL HARDWOOD FOREST AREA IN FOUR BIRD CONSERVATION REGIONS ACROSS FOUR DECADES

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ABSTRACT

Early successional hardwood forests constitute important breeding habitat for many migratory songbirds. Declines in populations of these species suggest changes in habitat availability either on the species' wintering grounds or on their early successional breeding grounds. We used Forest Inventory and Analysis data from 11 states across four decades to examine changes in early successional (small-diameter) hardwood forests in four Bird Conservation Regions (BCRs) where migratory songbirds of interest have exhibited population declines: Appalachian Mountains, Central Hardwoods, Piedmont, and Southeastern Coastal Plains. We hypothesized that 1) proportional to the amount of timberland on the landscape, hardwood area in the four BCRs of interest has remained stable across the four decades studied and 2) proportional to the total amount of hardwood timberland on the landscape, the area of small-diameter hardwood forest in the four BCRs of interest has declined across the four decades studied. In the Central Hardwood BCR, proportional hardwood area declined slightly (P=0.0033), while in the Southeastern Coastal Plain, proportional hardwood area remained stable (0.2705). The Appalachian Mountains and Piedmont experienced increases (P=<0.0001). Total timberland area and proportional area of early successional forests across the entire sample of interest remained stable from the 1970s through the 1980s, experienced an increase in the 1990s, then declined in the 2000s (P<0.0001)—a pattern reflected in the individual BCRs. Implications of our findings are discussed.

INTRODUCTION

Early-successional, or small-diameter, hardwood forests constitute an important habitat component for many wildlife species, including numerous migratory songbird and game animal species. Historically, natural and anthropogenic disturbances like fire, insects and disease, domestic and wild animal grazing, and storms helped to create and maintain early successional habitat in the central hardwoods, Appalachian, and Piedmont regions (Lorimer 2001). Lorimer and White (2003) estimate that in the pre-settlement hardwood forests of the northeast the average proportion of the landscape occupied by early successional habitat was between 1-3 percent, with some coastal pine/oak forests exhibiting proportions of 10 percent or higher. Following European settlement, land clearing for agriculture, development and commercial timber management replaced fire as primary disturbances in the hardwood forests of Eastern North America, resulting in widespread areas of early-successional habitat reaching proportions of as much as 75 percent of the forested landscape by the late 19th and early 20th centuries (Lorimer and White 2003).

More recently, some studies suggest that forests throughout the central and northern hardwood regions are maturing, resulting in a reduction in the amount of early successional habitat on the landscape (Trani 2001, Brooks 2003, Oswalt and Turner 2009). Lorimer and White (2003) and Brooks (2003) suggest that, for the northeastern United States, the proportion of forest that is early-successional may be nearing pre-settlement levels following the widespread clearing that occurred during settlement and expansion.

Early successional hardwood forests constitute important breeding habitat for many migratory songbirds of concern like the golden-winged warbler (Vermivora chrysoptera), prairie warbler (*Dendroica discolor*), chestnut-sided warbler (*D. pensylvanica*), and Bewick's wren (*Thryomanes bewickii*), among others. Changes in the availability of early successional habitat are of interest to wildlife managers and ornithologists who are concerned with declines in disturbance-dependent avian species (Hunter and others 2001, DeGraaf and Yamasaki 2003). Mitchel and others (2001) found that birds associated with early successional habitat respond to changes in habitat availability at a landscape scale, and inferred that the extent of contiguous habitat may be limiting for those populations. Declines in populations of these species suggest changes in habitat availability either on the species' wintering grounds or on their early successional breeding grounds. Regional patterns

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of change in early successional habitat are, therefore, important for understanding the role that declining small-diameter forest area may play in changing populations of breeding songbirds.

We used Forest Inventory and Analysis (FIA) data from 11 states across four decades to examine changes in early successional (small-diameter) hardwood forests in portions of four bird conservation regions where migratory songbirds of interest have exhibited population declines: Appalachian Mountains, Central Hardwoods, Piedmont, and Southeastern Coastal Plains. We hypothesized that 1) proportional to the amount of timberland on the landscape, total hardwood area in the four BCRs of interest has remained stable across the four decades studied and 2) proportional to the total amount of hardwood timberland on the landscape, the area of small-diameter hardwood forest in the four BCRs of interest has declined across the four decades studied.

METHODS

Data from the USDA Forest Service national FIA Database (FIADB) were compiled and analyzed to examine the status and trends of small diameter hardwood forests among four decadal time periods (1970s, 1980s, 1990s, and 2000s) within four Bird Conservation Regions of interest. The sample population was defined by intersecting the outline of Bird Conservation Regions (BCRs) of interest with FIA plot locations in 11 states using ESRI ArcGIS (figure 1). Four BCRs were of interest in this study: Central Hardwoods, Southeastern Coastal Plain, Appalachian Mountains, and Piedmont. FIA plots were located on the map using actual coordinates collected in the field, with the exception of plot locations in Missouri and West Virginia, where FIA "perturbed and swapped" locations were used (see Bechtold and Patterson 2005 for detailed documentation of FIA inventory methods, and LaPointe 2005 for an explanation of fuzzed and swapped coordinates). Not all states were available for all years, and survey years varied among states. States, survey periods, and numbers of plots used in this analysis are given in table 1.

Data were aggregated to the county level for analysis, and counties were used as the sample unit (Fei and Steiner 2007, Oswalt and Turner 2009). The total timberland area in hectares (TTA), total hardwood timberland area (THA), and total small-diameter hardwood timberland area (TSD) were calculated for each Decade-State-BCR-County combination. Sample area and size differed through time; therefore, area estimates were normalized for analysis by converting raw numbers to proportions, yielding the proportion of total timberland area that was hardwood (PTTA), the proportion of total timberland area that was small-diameter hardwood (PTSD), and the proportion of total hardwood timberland that was small-diameter (PTHA). Concerns that the use of proportions might produce erroneous results with regards to changes in avian habitat if raw TTA and raw TSD both experienced declines but PTSD remained stable were relieved by Smith and others (2009), who showed that in the regions encompassing the BCRs of interest, timberland area has remained stable or increased since the mid-1970s. Hardwood stands were identified as those falling within a pre-selected set of FIA forest-type groups containing primarily hardwood species (table 2). Small-diameter (seedling/sapling) stands were identified using the FIA variable STNDSZCD, which defines small diameter stands as: Stands with an all live stocking value of at least 10 (base 100) on which at least 50 percent of the stocking is trees less than 12.7 cm in diameter (U. S. Forest Service 2009). Analyses of variance were used determine changes in PTTA, PTSD, and PTHA over time across the whole study area and by BCR. Proportions were arcsin-transformed to improve normality. Means were back-transformed for reporting purposes. Generalized least square means were compared among decades for each ANOVA.

RESULTS

HYPOTHESIS 1

Proportional to the amount of timberland on the landscape, hardwood area in the four BCRs of interest has remained stable across the four decades studied.

Hardwood area trends, as a proportion of total timberland, varied by BCR and time. In the Appalachian Mountain BCR, PTTA increased between the 1970s and 1990s, and then increased again between the 1990s and 2000s ($p<0.0001$; figure 2). The Central Hardwoods experienced a moderate increase in PTTA from 1970 to 1980 (88.0 ± 1.9 and 89.3 ± 0.8), followed by a gradual decrease in 2000 to levels statistically lower than 1980, but comparable to 1970 (86.2 ± 0.9; $p=0.0033$). The Southeastern Coastal Plains BCR PTTA remained stable across all four decades ($p= 0.2705$). The PTTA increased in the Piedmont BCR between the 1980s and 1990s ($p<0.0001$). Timberland in the Appalachian Mountains and Central Hardwood BCRs was predominately hardwood, and contained the highest proportion of hardwood to softwood timberland in the study (91.2 ± 4.1 and 86.2 ± 0.9 percent in the 2000s, respectively). In comparison, the Piedmont BCR sample area was composed of approximately 60.8 ± 1.4 percent hardwood area, while the Southeastern Coastal Plain BCR was only 39.1 ± 1.1 percent hardwood area.

HYPOTHESIS 2

Proportional to the total amount of hardwood timberland on the landscape, the area of small-diameter hardwood forest in the four BCRs of interest has declined across the four decades studied.

Proportionally, the area of small-diameter hardwood timberland across the entire sample of interest remained stable from the 1970s to the 1980s (27.0 ± 0. 7 and 26.8 ± 0.7 percent, respectively), increased in the 1990s to 32.3 ± 0.8 percent, then declined in the 2000s to 21.7 ± 0.6 percent ($p<0.0001$; figure 3). In the Appalachian Mountains BCR, no differences occurred from the 1970s to the 1980s (18.0 ± 1.3 and 16.0 ± 0.9 percent, respectively), but small-diameter area increased in the 1990s to 19.6 ± 1.4 percent of hardwood timberland before declining precipitously to 11.7 ± 0.9 percent in the 2000s ($p<0.0001$; figure 4). Small-diameter hardwood area was stable in the Central Hardwoods BCR from the 1970s through the 1990s (23.8 ± 2.2, 21.5 ± 1.2, and 21.8 ± 1.8 percents, respectively) but declined to 9.1 ± 0.6 percent of total hardwood timberland area in the 2000s ($p<0.0001$). In the Piedmont BCR, small-diameter area experienced no significant changes ($p=0.1329$). Small-diameter area increased in the Southeastern Coastal Plain between the 1970s and 1980s (34.7 ± 1.0 and 38.3 ± 1.1 percent of hardwood timberland area, respectively), reached a peak in the 1990s at 43.7 ± 1.0 percent, then declined back to pre-1990s levels in the 2000s (36.7 ± 1.1 percent, $p<0.0001$).

DISCUSSION

In contrast to our original hypothesis that the hardwood proportion of timberland area remained stable from the 1970s to the 2000s in the BCRs studied, total hardwood area actually increased in the Appalachian Mountains and Piedmont BCRs and remained stable, overall, in the Central Hardwoods and Southeastern Coastal Plain BCRs. Because of the stability of the total timber resource, and the relative stability of the overall hardwood resource, we were able to focus on the proportion of that resource that was small-diameter habitat.

Declines in early successional stands as a proportion of the overall hardwood resource were most notable in the Central Hardwood and Appalachian Mountain BCRs with 15 and 6 percent declines from the 1970s to the 2000s, respectively. Current proportions of early-successional forest for the Central Hardwoods and Appalachian Mountains appear to be similar to presettlement levels for the upper Midwest and Northeast, but possibly much lower than presettlement levels for the central hardwoods region as reported by Lorimer (2001), though that study used different definitions of early successional forests, different regional boundaries, and included both softwood and hardwood forests, savannas, and prairies. Comparisons with presettlement landscapes are also confounded by overall changes in forest area that occurred with the onslaught of development. Oswalt and Turner (2009) studied the Appalachian Hardwood Region (similar to, but distinct from the Appalachian Mountains BCR), and also note that total diameter distributions of hardwood trees shifted to larger diameter classes between the 1980s and 2000s (Oswalt and Turner 2009).

In contrast to the Central Hardwoods and Appalachian Mountains BCRs, while we noted proportional declines from the 1990s to the 2000s in the Southeastern Coastal Plain BCR, there was no net change from the 1970s and small-diameter stands still comprised between 34 and 36 percent of total hardwood timberland. The Piedmont and Southeastern Coastal Plain BCRs may experience more natural disturbance from hurricanes and associated fire and storms than the northern and central interior forests, or a larger proportion of timberland in the Piedmont and Southeastern Coastal Plain may be affected by commercial timber harvests, resulting in a larger proportion of small-diameter forests. However, overall hardwood forest area (and, subsequently, small-diameter hardwood forest area) is lowest in both of these predominately pine and mixed oak/pine regions than in the Central Hardwoods and Appalachian Mountains regions.

The loss of early successional hardwood forest habitat on the landscape is suggested as one potential reason for declining migratory songbird populations that typically rely on small-diameter forests for a portion of their lifecycle (Richardson and Brauning 1995, Nolan and others 1999, Gill and others 2001, Klaus and Buehler 2001). In a study examining bird population status in three of these BCRs, we found that most of the scrub-shrub birds as a group were declining significantly (Franzreb and others in press). Thus, it is particularly concerning that we found significant declines in small-diameter forests in the two BCRs that contained the largest proportion of hardwood timberland investigated in this study. However, factors beyond overall area loss may be playing a role in avian species declines. For example, although our study addresses declines in landscape-scale early successional hardwood forest area, it does not address shifts in tree, shrub, or herb species composition since the 1970s. Changes in the dominant vegetation occupying small-diameter stands may affect the structure of breeding habitat and available food sources, which may, in turn, impact populations (Lynch and Whigham 1984). This paper and other papers addressing landscape-level changes in small-diameter forest (e.g. Trani and others 2001) also fail to take into account the distribution of small-diameter forests in relation to the overall forest matrix, and in relation to surrounding land uses. Overall changes in the forest matrix, particularly patch size, may also play an important role in avian population dynamics (Lynch and Whigham 1984).

Early successional forests as defined in this paper may not adequately represent changes in habitat used by disturbance dependent birds on the landscape. For example, this study does not assess changes in scrub-shrub habitat that would not meet the FIA definition of forestland. Additionally, some species that depend on early successional structure for breeding may be able to make use of relatively small canopy gaps or multi-storied forests that may not be captured within the definition of "small-diameter stand size" utilized in this paper.

The FIA program has undergone many changes since the 1970s, including switching from measuring plots using a variable-radius prism plot design to a fixed-radius annual remeasurement plot design, changing plot remeasurement cycles, fluctuating plot lists, and changes in definitions and estimation methods (Bechtold and Patterson 2005). These changes have accompanied the transition of FIA from a series of regional programs to a nationally consistent program that is comparable from state to state across regional boundary lines. Therefore, some changes noted in the paper may be due in part to changing FIA methodologies, though we anticipate that those influences are minimal.

CONCLUSIONS

Data from FIA suggest that early successional habitat in hardwood forests of the Central Hardwoods, Appalachian Mountains BCRs have declined since the 1970s, despite a stable or increasing hardwood timberland resource, and that Piedmont and Southeastern Coastal Plain BCR hardwood forests have declined since the 1990s, but are similar to areas noted in the 1970s. These declines are concerning with regards to disturbance-dependent migratory songbird populations that have been declining over the last several decades. However, multiple factors may also play a role in avian population declines, and changes in other types of early successional habitat that were not captured in this study, like scrub-shrub habitat, prairies, and small canopy gaps may be affecting populations.

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Table 1—States, years, and number of plots used for each decadal time period

Decade	1970s	1980s	1990s	2000s
State/Year	Alabama 1972	Alabama 1982	Alabama 1990	Alabama 2008
	Arkansas 1978	Arkansas 1988	Arkansas 1995	Arkansas 2007
	Georgia 1972	Georgia 1989	Georgia 1997	Georgia 2008
	Mississippi 1977	Kentucky 1988	Mississippi 1994	Kentucky 2007
	North Carolina 1974	Mississippi 1987	North Carolina 1990	Mississippi 2006
	South Carolina 1978	North Carolina 1984	South Carolina 1993	North Carolina 2007
	Tennessee 1980	South Carolina 1986	Tennessee 1999	South Carolina 2007
	Virginia 1977	Tennessee 1989	Texas 1992	Tennessee 2007
		Virginia 1985	Virginia 1992	Virginia 2008
		Missouri 1989		Missouri 2008
		West Virginia 1989		West Virginia 2006
Total Number of Plots	28,367	39,611	31,596	31,733

Table 2—Forest Inventory and Analysis forest type codes and definitions used for data selection

FIA Forest Type Code	Forest Type	FIA Forest Type Code	Forest Type
400	Oak/Pine group	510	Scarlet oak
401	Eastern white pine/northern red oak/white ash	511	Yellow-poplar
402	Eastern redcedar/ hardwood	512	Black walnut
403	Longleaf pine/oak	513	Black locust
404	Shortleaf pine/oak	514	Southern scrub oak
405	Virginia pine/southern red oak	515	Chestnut oak/black oak/scarlet oak
406	Loblolly pine/hardwood	516	Cherry/white ash/yellow-poplar
407	Slash pine/hardwood	517	Elm/ash/black locust
409	Other pine/hardwood	519	Red maple/oak
500	Oak/hickory group	520	Mixed upland hardwoods
501	Post oak/blackjack oak	800	Maple/beech/birch group
502	Chestnut oak	801	Sugar maple/beech/yellow birch
503	White oak/red oak/hickory	802	Black cherry
504	White oak/red oak/hickory	805	Hard maple/basswood
505	Northern red oak	809	Red maple/upland
506	Yellow-poplar/white oak/northern red oak	905	Pin cherry
507	Sassafras/persimmon	962	Other hardwoods
508	Sweetgum/yellow-poplar	971	Deciduous oak woodland
509	Bur oak	976	Miscellaneous woodland hardwoods

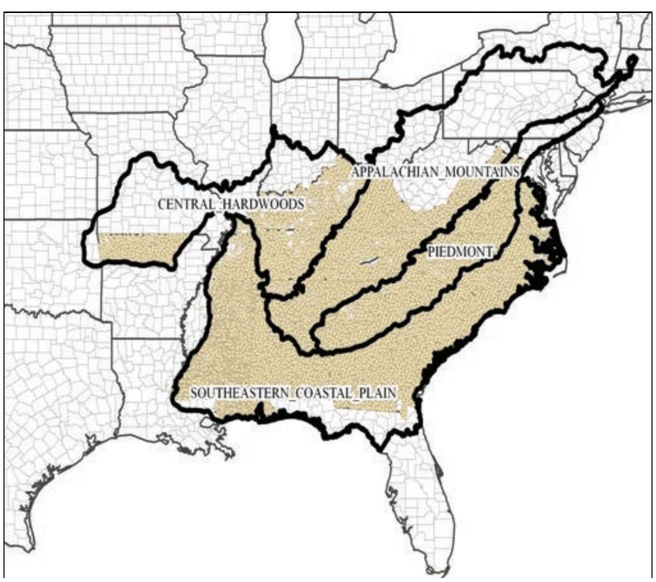

Figure 1—Bird Conservation Regions and plots (approximate locations) used in this study.

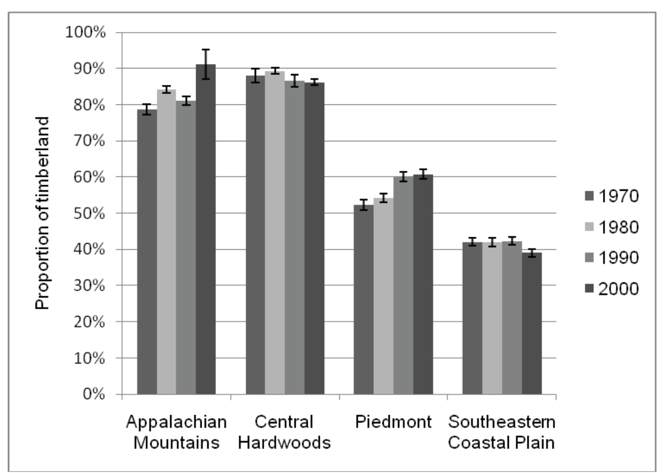

Figure 2—Proportion (±1 s.e.) of timberland in selected hardwood forest types by BCR and time (all size classes).

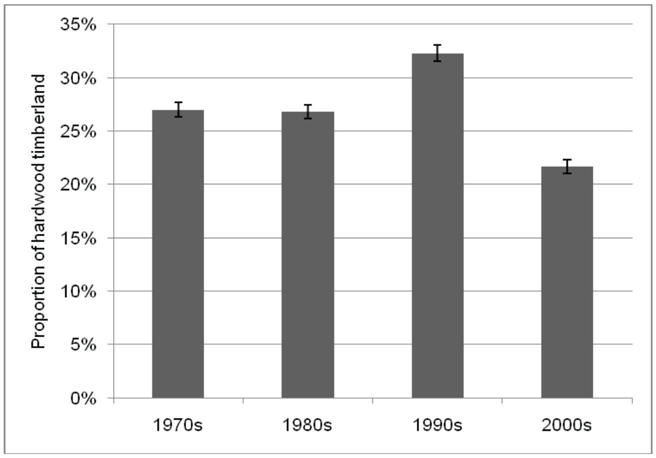

Figure 3—Proportion (±1 s.e.) of all hardwood timberland that is small-diameter.

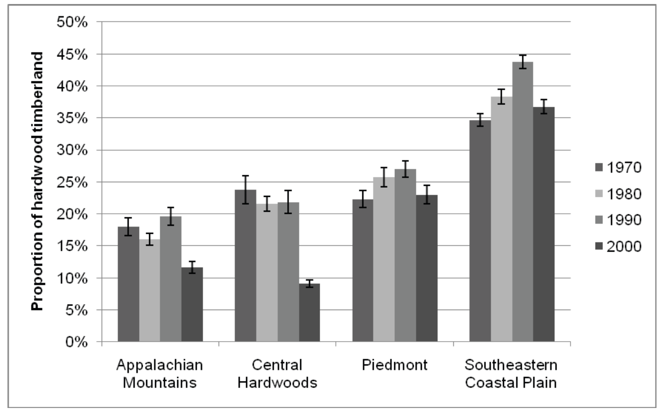

Figure 4—Proportion (±1 s.e.) of hardwood timberland that is small diameter by BCR and time.