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Spatial characteristics of early successional habitat across the Upper Great Lakes states

Brian G. Tavernia [a,*], Mark D. Nelson [b], James D. Garner [b], Charles H. Perry [b]

[a] The Nature Conservancy, Colorado Field Office, 2424 Spruce Street, Boulder, CO 80302, USA
[b] USDA Forest Service, Northern Research Station, 1992 Folwell Avenue, St. Paul, MN 55108, USA

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ABSTRACT

Creation and management of early successional forest (ESF) is needed to halt and reverse declines of bird species dependent on pioneering plant species or young forests. ESF-dependent bird species require specific structural forest classes and are sensitive to forest age (a surrogate for forest structure), patch size, proximity to patch edges, and the juxtaposition of forest age classes. To date, ESF conservation plans have relied on spatially inexplicit data, lacking patch and landscape metrics, to set habitat goals and to track habitat trends. In a previous study, we used Landsat time series stacks and a vegetation-change-tracker algorithm to track forest canopy disturbances and subsequent regrowth from 1990 to 2009 across the Upper Great Lakes Young Forest Initiative region. Based on canopy disturbance histories, we assigned forest age classes to forest classes of the National Land Cover Database of 2011. In the present study, we used this spatial product to assess areas, patch and edge metrics, and land protection statuses of deciduous-mixed forest and woody wetland age classes. We defined ESF using four 5-year-age classes (1–5, 6–10, 11–15, 16–20 years old) and their aggregate (1–20 years old) whereas forest >20 years old was referred to as 'persisting'. Aggregated across 5-year-age classes, ESF of deciduous-mixed forest covered 3.4% and 0.9% of Bird Conservation Regions (BCR) 12 (Boreal Hardwood Transition) and 23 (Prairie Hardwood Transition), respectively, whereas woody wetland ESF constituted 1.0% and 0.2% of the same BCRs. For both deciduous-mixed forest and woody wetlands, ESF often occurred in patches ⩾1 ha, but most ESF also occurred near patch edges created by adjacencies with persisting forest. Most ESF fell on lands with an unprotected or unknown protection status regardless of forest class. Regionally, ESF covered less area, occurred in smaller patches and nearer to edges, and more often fell on lands of unprotected or unknown protection status in BCR 23 than in BCR 12. Our results advance ESF conservation by providing insight into spatial characteristics that influence habitat quality and by establishing a baseline for habitat management planning and monitoring.

1. Introduction

Early-successional forest (ESF), defined here to include areas dominated by either pioneer plant species or young forest (Lorimer, 2001), is used by many bird species at different times during their annual cycles (Schlossberg and King, 2008; Streby et al., 2011). Disrupted natural disturbance regimes (e.g., fire suppression), changing timber management practices (e.g., uneven-aged forest management), and land-use conversion (e.g., forest to urban) have contributed to long-term declines in abundance of ESF and ESF-associated bird species in several sub-regions of the eastern U.S. (Trani et al., 2001; King and Schlossberg, 2014). To stabilize and restore populations of ESF-dependent bird species, natural resource managers require information about the amount, distribution, and trends of ESF to create habitat management plans and to evaluate their successes.

Linkages between birds and vegetation associations, such as ESF, defined by plant species composition, successional stage, or structure can be used for regional bird habitat assessments (Trani et al., 2001; Beaudry et al., 2010), but habitat is not synonymous with vegetation associations (Hall et al., 1997). Regional habitat assessments can be refined by applying constraints representing specific habitat requirements at local (e.g., sapling height), patch (e.g., patch size), and landscape (e.g., proximity of forest and old fields) scales (Dwyer et al., 1983; Beaudry et al., 2010). ESF-dependent bird species respond to forest age classes (Schlossberg

* Corresponding author.
E-mail addresses: btavernia@gmail.com (B.G. Tavernia), mdnelson@fs.fed.us (M.D. Nelson), jamesdgarner@fs.fed.us (J.D. Garner), charleshperry@fs.fed.us (C.H. Perry).

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and King, 2009) associated with specific structural characteristics, the juxtaposition of forest age classes (e.g., Streby et al., 2015), forest patch sizes (e.g., Annand and Thompson, 1997), and proximity to patch edges (e.g., Fink et al., 2006). One example of forest composition and age class association is provided by the Canada Warbler (*Cardellina canadensis*), a species preferring 6–20-year-old deciduous or mixed forests with exposed song perches and well-developed understories as breeding habitat (Hagan et al., 1997; Reitsma et al., 2010). ESF-dependent bird species, such as the Golden-winged Warbler (*Vermivora chrysoptera*), might also use multiple forest age classes to meet life history needs (e.g., Streby et al., 2015), and thus, benefit from the juxtaposition of age classes.

Based on a literature review, Schlossberg and King (2007) suggested that scrub–shrub birds might be absent or less abundant in patches less than 1 ha in size whereas they might be insensitive to increasing patch size beyond 4 ha. Scrub–shrub habitat was defined as areas possessing no or little tree canopy and dense shrubs and saplings within the first 2 m above ground and included, e.g., ESF created through even-aged forest management (Schlossberg and King, 2007). The same researchers conducted a meta-analysis and found that several scrub–shrub bird species had higher abundances in clearcut interiors (>60 m from edge) than near edges between clearcuts and mature forests (<30 m from edge) (Schlossberg and King, 2008). Failure to account for forest age class, age class juxtaposition, patch size, or proximity to edge effects will lead to overestimates of habitat area available to ESF-associated bird species and biased assessments of progress toward meeting habitat management goals. For example, tree canopy disturbances may increase ESF area, but the value of this habitat to American Woodcock (*Scolopax minor*) may be reduced if it abuts urban areas, a cover class shown to be negatively correlated with the abundance of male woodcocks (Dwyer et al., 1983).

Managers often lack information to simultaneously address local, patch, and landscape features over large spatial extents and long periods for bird species (Tirpak et al., 2009; Beaudry et al., 2010). The USDA Forest Service's Forest Inventory and Analysis (FIA) program, a national-level inventory and monitoring program, reports detailed information on forest composition and structure (Woudenberg et al., 2010). This information can be used to assess forest habitat classes and microhabitat conditions from as far back as the 1960's to present day for much of the U.S. Nevertheless, FIA sample and plot designs do not provide spatially explicit data regarding forest patch or landscape characteristics (e.g., patch adjacency) (Woudenberg et al., 2010).

With respect to spatially explicit data, our assessment of ESF requires data on all of the following characteristics: forest composition classes and nonforest land cover classes, structural stages spanning 1–20 years of forest age, spatially explicit patches as small as 1 ha, and distances to edge as short as 30 m; thus, a geospatial dataset having 30-m spatial resolution or finer is required to address ESF patch and landscape characteristics. The following paragraph provides a brief summary of the predominant, nationally-available, geospatial datasets that address one or more, but not all of the ESF characteristics for bird species.

The National Land Cover Database of 2011 (NLCD2011) (Homer et al., 2015) is a moderate spatial resolution (30-m) data set that permits patch and landscape metrics to be quantified for forest compositional classes (e.g., deciduous, evergreen, and mixed forest). However, NLCD2011 does not attribute woody wetlands with forest compositional classes, nor does it include information about forest age or related structural attributes (e.g., tree diameter, height) important to defining ESF habitat. The LANDFIRE program makes available a 30-m spatial resolution product that maps year of forest disturbance during the fourteen year period, 1999–2012 (LANDFIRE, 2012), but this product omits ESF of 15–20 years of age. The National Biomass and Carbon Dataset (NBCD; Kellndorfer et al., 2004) provides a 30-m geospatial data set of basal area-weighted canopy height as of the year 2000, from which structural characteristics (and possibly stand age) can be inferred, but NBCD omits ESF that originated after 2000. Forest stand age data are available from Pan et al. (2011), but the coarser spatial resolution associated with this dataset (250 m or 1 km) is inappropriate for analyzing small patches and edge distances. A nationwide 30-m geospatial dataset of forest disturbance is available for the period 1986–2010 (Goward et al., 2015), but this dataset does not include attributes of forest composition. We are unaware of any single geospatial dataset for the western Great Lakes region that simultaneously captures forest composition, age, patch, and landscape metrics at 30-m spatial resolution.

The Upper Great Lakes Young Forest Initiative (YFI) is working to stabilize and eventually increase the amount of ESF habitat found in Bird Conservation Regions (BCR) 12 (Boreal Hardwood Transition) and 23 (Prairie Hardwood Transition) within the states of Michigan, Wisconsin, and Minnesota, USA. YFI is intended to benefit a broad suite of wildlife species dependent on ESF habitat. Its current habitat goals are derived from the American Woodcock Conservation Plan (Cooper, 2008; Kelley et al., 2008) and have as a fundamental objective restoring American Woodcock densities to those observed during the early-1970s (Cooper, 2008; Kelley et al., 2008). Updates to YFI habitat goals are dependent on new input provided by cooperators and an improved understanding of species' habitat needs. Evolution of the YFI habitat goals will be aided by the development of species-specific plans and habitat goals, such as those recently released for the Golden-winged Warbler (Roth et al., 2012).

To further inform future YFI planning efforts, our objective was to use a novel spatial data set to quantify total area, juxtaposition, patch size, and proximity to patch edges of ESF age classes at different spatial scales and temporal intervals. These spatial features are applicable to a broad suite of ESF-dependent species rather than being species-centric (Hunter et al., 2001; Schlossberg and King, 2007, 2008). We also assessed the occurrence of ESF age classes on lands with different conservation protection statuses, and we used these data to suggest future opportunities for ESF creation and maintenance. Our assessment establishes a baseline of ESF conditions for management planning and for monitoring progress toward management goals with the ultimate objective of stabilizing and growing ESF-limited bird populations.

2. Methods

2.1. Study region description

The YFI region includes the U.S. portions of BCRs 12 and 23 that fall within the states of Michigan, Minnesota, and Wisconsin (Fig. 1). BCRs are defined based on shared bird communities, habitats, and natural resource management issues (Matteson et al., 2009). The American Woodcock is a popular game bird throughout the region, and other priority, ESF-dependent bird species common to both BCRs include Golden-winged Warbler, Field Sparrow (*Spizella pusilla*), and Black-billed Cuckoo (*Coccyzus erythropthalmus*) (Knutson et al., 2001; Matteson et al., 2009). BCR 12 contains coniferous and northern hardwood forests, nutrient-poor soils, and many lakes, bogs, and other water bodies formed through river overflows (U.S. NABCI Committee, 2000). Following European settlement, anthropogenic influences have resulted in the exploitation of timber and natural resources, conversion of land for agricultural purposes, wetland loss, reduced tree species richness, and some urbanization (Matteson et al., 2009). Historically, BCR 23 transitioned from prairies in the west and south to beech-maple forests in the north and east, and oak savannas occurred