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Analysis of combined data sets yields trend estimates for vulnerable spruce-fir birds in northern United States

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ABSTRACT

Continental-scale monitoring programs with standardized survey protocols play an important role in conservation science by identifying species in decline and prioritizing conservation action. However, rare, inaccessible, or spatially fragmented communities may be underrepresented in continental-scale surveys. Data on these communities often come from decentralized, local monitoring efforts that differ in their goals and survey protocols. We combine 16 point count datasets, controlling for differences in protocol and detection probabilities to estimate regional trends for 14 spruce-fir forest bird species across Northeastern and Midwestern United States, a vulnerable community threatened by numerous anthropogenic stressors and widely considered a priority for conservation. Our analyses indicated that four species considered as ecological indicators for this community, Bicknell's Thrush (*Catharus bicknelli*), Magnolia Warbler (*Setophaga magnolia*), Blackpoll Warbler (*Setophaga striata*) and Yellow-bellied Flycatcher (*Empidonax flaviventris*), each exhibited significant declines. Olive-sided Flycatcher (*Contopus cooperi*), a species of concern in parts of its range, and two additional species for which no previous concern existed, the Evening Grosbeak (*Coccothruastes vespertinus*) and the Gray Jay (*Perisoreus canadensis*), each also showed significant overall declines. Five out of nine species with sufficient data for analyses from Northeastern and Midwestern surveys showed significant differences in trends between these regions. Spruce-fir obligate species were more likely to decline significantly than species that use spruce-fir in addition to other habitat types. These results demonstrate the value of combining disparate data sources for analyzing regional patterns of population trends to confirm and extend conservation concern for some species and identify others for which additional attention may be needed.

1. Introduction

Monitoring of plant and animal populations and their environments is a fundamental component of conservation science (Nichols and Williams, 2006; Lovett et al., 2007). Long-term monitoring data can be used to identify species in decline, track the spread of invasive species, assess the effectiveness of management practices, and understand species' responses to environmental disturbances (Niemi and McDonald, 2004; Marsh and Trenham, 2008; Lindenmayer and Likens, 2009). For birds, the most extensively monitored animal taxon on the planet, continental-scale monitoring programs such as the North American Breeding Bird Survey (BBS; Sauer et al., 2014) have been invaluable in assessing population trends and assigning conservation priorities (Robbins et al., 1989; Sauer and Droege, 1992; Rich et al., 2004). However, rare, inaccessible, or spatially fragmented habitats may be underrepresented in road-side continental-scale surveys (Hanowski and Niemi, 1995). Data on bird assemblages that breed in these habitats therefore come from decentralized, local, and sometimes ad hoc monitoring efforts that differ in their goals and protocols (Marsh and Trenham, 2008). In such cases, when data from larger geographic scales is absent, local data collected using a diversity of methodologies and at shorter time scales can be combined to estimate long-term trends in abundance (Houlahan et al., 2000; Loh et al., 2005; Van Strien et al., 2013; Pagel et al., 2014). Such

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analyses allow local conservation and management considerations to be placed in broader geographic contexts (Houlahan et al., 2000). Here, we combine local and regional point count survey data, controlling for inter-survey differences in protocol and detection probabilities (Sólymos et al., 2013a), to estimate population trends for a group of spruce-fir forest birds.

Vulnerable and threatened spruce-fir forest birds of the upper Midwestern and Northeastern regions of the United States are an example of an assemblage that is poorly covered by continental-scale monitoring programs. High-elevation spruce-fir forests occur on the tops and sides of mountains on steep, difficult terrain, and accessibility is largely limited to hiking or ski trails. Low-elevation spruce-fir forests are dense and boggy with few roads to interior patches. The BBS often misses species that breed largely in these inaccessible forests. For example, the Bicknell's Thrush (*Catharus bicknelli*), a globally vulnerable species (IBTCG, 2010) and an indicator of montane spruce-fir habitat (US Forest Service, 2006), has not been detected on a BBS route in the United States since 1996 (Sauer et al., 2014). As a result, little information exists regarding long-term population trends of spruce-fir birds at broad geographic scales (Niven et al., 2004; King et al., 2008). Spruce-fir forest birds in the United States are affected by anthropogenic development (Glennon and Porter, 2005; Zlonis and Niemi, 2014), commercial timber harvests (Titterington et al., 1979), defoliation from episodic insect pest outbreaks (Venier and Holmes, 2010), atmospheric deposition of environmental toxins (Rimmer et al., 2005), and may be especially vulnerable to modern climate change (Atwood et al., 1996; Rodenhouse et al., 2008; Ralston and Kirchman, 2013). Spruce-fir forest ecotones may already be shifting upwards in elevation (Beckage et al., 2008). Birds at their southern periphery are shifting their distribution northward (Zuckerberg et al., 2009), occupying unsuitable habitats (DeLuca, 2013), and suffering losses in reproductive success as a result of modern warming (Waite and Strickland, 2006). Climate change may also be causing an increase in occupancy of an important nest predator, the red squirrel (*Tamiasciurus hudsonicus*), in montane spruce-fir forests (Rimmer et al., 2001; DeLuca, 2013). It is therefore important to establish population baselines for these climate vulnerable species, especially at their southern periphery.

Because of heightened conservation concern for this assemblage, several organizations have established monitoring programs that specifically target spruce-fir birds, some of which have now been implemented for over two decades. For example, the Vermont Center for Ecostudies, the White Mountain National Forest (WMNF), and the Wildlife Conservation Society each coordinate long-term survey programs in montane forests or low-elevation boreal spruce bogs (US Forest Service, 2006; Scarl, 2011; Glennon, 2014). In addition, several National Forests, Parks, and Wildlife Refuges throughout the Northeast and upper Midwest have endeavored to monitor spruce-fir forest bird species on local or regional scales (Howe and Roberts, 2005; King et al., 2008; Johnson, 2012; Zlonis et al., 2013; Faccio and Mitchell, 2014). Our goal was to combine and collectively analyze these datasets for the first time in order to estimate broad scale trends in abundance.

2. Methods

2.1. Study area

We describe spruce-fir forests of the eastern United States as forested landscapes in which spruce (red spruce [*Picea rubens*], white spruce [*P. glauca*] and/or black spruce [*P. mariana*]) and balsam fir (*Abies balsamea*) are dominant or codominant. This is a catch-all definition and includes a variety of habitat types (Eyre, 1980; Pastor and Mladenoff, 1992; Sperduto and Nichols, 2011; Edinger et al., 2014) covering over 5 million ha in the upper Midwest (Minnesota, Wisconsin, Michigan; hereafter 'Midwest'), and Northeast (New York, Vermont, New Hampshire, Maine; hereafter 'East'; US Forest Service, 2010; Fig. 1). These Midwestern and Eastern regions correspond closely to physiographic strata used in previous analyses of regional avian trends (Sauer and Droege, 1992; Sauer et al., 2014) and used by Partners in Flight as conservation units (Rich et al., 2004). The Midwestern region of the present study corresponds to the "Boreal Hardwood Transition" physiographic area, and the Eastern region consists primarily of the "Adirondack Mountains" and "Spruce-Hardwood Forests" areas (following Partners in Flight terminology). At forested wetland sites, black spruce dominates with tamarack (*Larix laricina*) and little or no fir. Lowland sites with drier soils are composed of red spruce, balsam fir and occasionally white spruce, or white pine (*Pinus strobus*). In the Midwest, upland spruce-fir forests include varying amounts of quaking aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). In the mountainous east, spruce-fir dominates at mid to high elevations and can contain mountain paper birch (*Betula cordifolia*) and mountain ash (*Sorbus americana*). At higher elevations, spruce and broadleaf species decrease in abundance and mountain forests can be nearly pure stands of balsam fir. Due to their ecological distinctiveness and vulnerability, spruce-fir forests have been recognized as a key component of regional biodiversity across Northeastern and Midwestern United States.

2.2. Species selection

We constructed a list of avian spruce-fir forest obligates and associates by consulting authoritative sources that provide matrices of 'preferred' or 'utilized' habitat types for birds in the Midwest (Robbins, 1991) and East (DeGraaf and Yamasaki, 2001). We defined spruce-fir forest 'obligates' as species that prefer and utilize only spruce-fir forest types. We defined spruce-fir 'associates' as species that prefer spruce-fir, but also utilize other forest types. These inclusion criteria excluded a number of species that can be common in spruce-fir forests but do not 'prefer' them and are also broadly distributed in other forest types. Further, we considered only passerines for analysis, as detection of non-passerines during point count surveys can be low. We characterized 18 passerines as either spruce-fir obligates ($n = 8$), or associates ($n = 10$; Table 1). Our list is largely coincident with target species of boreal bird surveys (King et al. 2008; Scarl, 2011; Glennon, 2014), and includes several species considered ecological indicators for high-elevation spruce-fir forest (Bicknell's Thrush, Magnolia Warbler [*Setophaga magnolia*] and Yellow-bellied Flycatcher [*Empidonax flaviventris*]; US Forest Service, 2006). Four species on our list, Bay-breasted Warbler (*Setopahaga castanea*), Rusty Blackbird (*Euphagus carolinus*), White-winged Crossbill (*Loxia leucoptera*), and Pine Siskin (*Carduelis pinus*) were excluded entirely from analyses because of insufficient data, leaving 6 obligates and 8 associates in our analysis.

2.3. Point count data

Point count data were obtained from 16 monitoring programs (hereafter 'programs') throughout the spruce-fir forest zone of the Midwestern and eastern United States (Fig. 1; Online Appendix Table A1). Point counts took place within the period from 1989 to 2013 and varied across programs in temporal (mean: 13 years; range: 2–24 years) and spatial coverage (median: 3269 km^2; range: 159–426,059 km^2; Online Appendix Table A1). All surveys included in our analyses are standard single-observer