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Avian population trends in the vulnerable montane forests of the Northern Appalachians, USA

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Abstract Declines in bird populations are an important issue facing conservationists. Although studies have documented bird declines in a variety of lowland habitats, montane habitats are generally under represented in these investigations. Nevertheless, montane habitats are vulnerable because of their restricted geographic distribution as well as their exposure to environmental stressors such as atmospheric deposition and climate change. We surveyed birds at 768 points on 42 transects in montane spruce-fir forests the White Mountains of New Hampshire from 1993–2003. We detected 17,479 individuals of 73 species during this period, of which 10 were abundant enough for analyses. Of these 10 species, three exhibited significant population declines during the survey period: Yellow-bellied Flycatcher (*Empidonax flaviventris*), Bicknell's Thrush (*Catharus bicknelli*) and Magnolia Warbler (*Dendroica magnolia*). Two of these species (Yellow-bellied Flycatcher and Bicknell's Thrush) are considered ecological indicator species for montane spruce-fir forest. Declines in these species are an indication that recent concern on the part of conservationists about montane spruce-fir forest and the birds that inhabit them are justified. Our observation that these trends were not reflected in the National Breeding Bird Survey (BBS) analyses, and that one high priority species, the Bicknell's Thrush, did not occur on BBS routes in New Hampshire during the survey period, argues for the importance of continued efforts to monitor these habitats.

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Introduction

Bird declines have been the subject of concern for conservationists in North American for over a century (Peterjohn et al. 1995). During this period, declines have been reported for a variety of bird species from various habitat types (Rappole 1995). This work has resulted in renewed efforts to document changes in bird populations, and to investigate the potential causes of these trends (e.g. Hagan and Johnston 1992). One issue that has become evident is the under-representation of some habitats in these investigations, including northeastern montane forests (Bystrak 1981).

Montane spruce-fir forest in the northern Appalachians is occupied by a distinct avifauna from the surrounding lowland habitats (Able and Noon 1976), which includes species of high conservation concern such as the Bicknell's Thrush (Rich et al. 2004; scientific names in Table 1). Montane spruce-fir forests are also ecologically vulnerable. Because of their position on the tops or sides of mountains, this type of habitat is limited in geographic extent and occurs in isolated patches separated by valleys characterized by very different vegetation types (Atwood et al. 1996). Montane spruce-fir habitats are also subject to a variety of environmental stressors. Atmospheric deposition affects the vegetation in which birds forage and nest (Miller-Weeks and Smoronk 1993), and also results in bioaccumulation of toxins that might reduce survival and fecundity (Rimmer et al. 2005). Finally, the fact that montane spruce-fir habitats occur towards the tops of mountain ranges make them vulnerable to future habitat constriction resulting from climate change (Atwood et al. 1996).

In recognition of the fact that montane spruce-fir forests are under represented in regional bird monitoring efforts, as well as the vulnerability of these habitats to degradation, we undertook the analysis of data collected by the White Mountain National Forest as part of a standardized bird monitoring program implemented in 1993 to track bird populations in this vulnerable habitat. In this paper, we present the results of our analyses of the first decade of these monitoring data to provide information on the status of bird populations in montane spruce-fir forests.

Methods

Study area

This study was conducted in the New Hampshire section of the White Mountain National Forest, which is located in the northern Appalachian Mountains (Fig. 1). The White Mountain National Forest consists of 330,000 ha of federally owned land located in the states of New Hampshire and Maine, USA, of which 47,000 ha are designated wilderness and the remainder is managed for recreation, wildlife habitat, timber and other natural resources Sampled elevations ranged from 740–1,470 m asl. The area is characterized by warm, wet summers and cold winters with deep snow. The landscape surrounding the study area is extensively forested (>90%). No active timber management takes place in montane spruce-fir forest on the White Mountain National Forest, which encompasses the study area, but the area is heavily used for non-motorized recreation, chiefly backpacking and skiing.

Table 1 The results (standard errors and 90% confidence intervals) of non-linear regressions on aggregate counts of birds in montane spruce-fir forest in the White Mountains of New Hampshire for the years 1993–2000 and 2003, as well as for the years 1993, 1995–2000

Species	1993–2000 and 2003		1993, 1995–2000	
	Trend (SE) 90% CI	*N*	Trend (SE) 90% CI	*N*
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	**0.92 (0.019)** 0.89–0.96	536	**0.95 (0.026)** 0.89–0.99	1149
Winter Wren (*Troglodytes troglodytes*)	1.02 (0.058) 0.91–1.13	883	1.05 (0.101) 0.85–1.26	1876
Swainson's Thrush (*Catharus ustulatus*)	1.07 (0.051) 0.98–1.17	683	1.08 (0.094) 0.89–1.27	1273
Bicknell's Thrush (*Catharus bicknelli*)	**0.93 (0.033)** 0.87–0.99	261	**0.93 (0.033)** 0.86–0.99	604
Myrtle Warbler (*Dendroica coronata*)	0.99 (0.023) 0.94–1.03	992	0.97 (0.025) 0.92–1.02	2246
Magnolia Warbler (*Dendroica magnolia*)	0.99 (0.023) 0.95–1.04	342	**0.94 (0.016)** 0.91–0.97	710
Blackpoll Warbler (*Dendroica striata*)	1.01 (0.023) 0.96–1.05	1075	0.98 (0.020) 0.95–1.02	2463
Pine Siskin (*Carduelis pinus*)	0.77 (0.199) 0.40–1.15	127	0.74 (0.233) 0.27–1.21	554
Dark-eyed Junco (*Junco hyemalis*)	1.04 (0.030) 0.99–1.10	736	1.03 (0.039) 0.95–1.11	1512
White-throated Sparrow (*Zonitricia albicollis*)	1.05 (0.022) 1.01–1.09	1106	1.01 (0.023) 0.96–1.06	2151

Trend values >1 are increases, and <1 are declines. Trends significant at $\alpha = 010$ are presented in bold

Bird surveys

Birds were surveyed using 5-min unlimited distance point counts from 1993–2000 and in 2003 at 768 points on 42 transects located along hiking trails in montane spruce-fir forest and in krummholz. Transects provided broad coverage of the study area, and were located on nearly all of the mountain and ridge systems and most of the trails on which montane spruce fir forest occurred within the White Mountain National Forest. All surveys were conducted between 0500 and 1100 h EST on days with no precipitation. Each survey point was visited once per year during the month of June, the height of the breeding season, and points were located ≥250 m apart along transects to increase independence (Ralph et al. 1995).

Trend analysis

We analyzed bird trends using an aggregate analysis in which a single fit is obtained using a total count for each year aggregated over the transects. We chose this approach over the often used route-regression technique (which fits a trend for each transect and then uses a

Fig. 1 Map of eastern United States with inset indicating the location of 42 transects surveyed for birds in montane spruce-fir habitat on the White Mountains of New Hampshire, 1993–2000, 2003. The shaded area represents the boundaries of the White Mountain National Forest Transect locations are indicated by triangles (▲)

weighted average of the transect-specific trends; see Geissler and Sauer 1990) because the route-regression method assumes that transects are randomly located, an assumption that was not satisfied by our sampling scheme. Furthermore, the data were relatively sparse for many species, and thus we encountered problems fitting trends for individual transects. Instead, we considered the transects as fixed, and used an aggregate analysis, which directly fits an overall trend defined for the region associated with the surveyed transects. This appeared to have little effect on the trend estimates for at least one species, Bicknell's Thrush, for which trends were identical between route-regression and the aggregate analysis.

Not all transects were run in every year and not all points within a transect were visited over different years when the transect was run. In carrying out the analysis, we have to ensure that the same transects, and points within transects, were included over all years. This procedure guarantees the use of compatible totals over years and precludes the nature and magnitude of the trend being an artifact of unequal sampling over years. We tried this in two ways: first using all the survey years to provide an analysis for the longest time period but with fewer transects per year; and then excluding the two years with the fewest transects and analyzing the remaining data for 1993, 1995–2000. This process represents a compromise between the greatest temporal coverage (9 seasons over an 11 year period), which had a relatively low number of transects per year (16), and less temporal coverage (7 seasons over an 8 year period) with the greatest number of transects (39).

Once a common set of transects and points was designated, the total count in year y, denoted C_y, was obtained for the transects/points involved. We fit the standard trend model, with $E(C_y) = a * b^y$, where E denotes the expected value and the coefficient b represents the trend. This analysis was done using non-linear regression (via PROC NLIN in SAS) with a weight that corresponds to the variance of the count being proportional to what it would be if C was distributed Poisson. This approach is equivalent to using the estimating equation approach of Link and Sauer (1994), which is the most commonly employed method for fitting this model. We were unable to model observer effects because high observer turnover (only 23% participated >1 year) did not permit the separation of observer versus year effects.

We investigated the adequacy of the model both through residual analyses and by fitting a nonparametric curve (using LOESS in SAS). Our model appeared to fit the data well. We also examined the residuals to check for serial correlation, both plotting residuals over time and plotting the current versus past residual. There was no clear indication of serial correlation. Statistical significance of the trends was determined on the basis of non-overlap of confidence intervals with one. Because the consequences of failing to detect a decline in populations of these bird species was potentially serious, we assessed the statistical significance of trends based on 90% confidence intervals (Askins et al. 1990; Bart et al. 2004).

The results of our analyses were compared with the results of the North American Breeding Bird Survey (BBS), which were obtained from the US Geological Survey website (http://www.mbr-pwrcusgsgov/bbs/trend/tf00html). The BBS is conducted by volunteer observers, who together survey approximately 2,539.4-km survey routes in New Hampshire by stopping along each route at 0.8 km intervals and recording all birds seen or heard during a three minute interval (Bystrak 1981). Significance of trends from the BBS were based on $\alpha = 0.10$.

Results

Bird communities

We detected 9,245 individuals of 64 species in the analysis of all years (1993–2000 and 2003), and 17,479 individuals of 73 species in the analyses of the years 1993, 1995–2000. Of these, we selected the 10 most abundant species (≥100 detections; Table 1), which accounted for >80% of all individuals detected during the study.

Bird trends

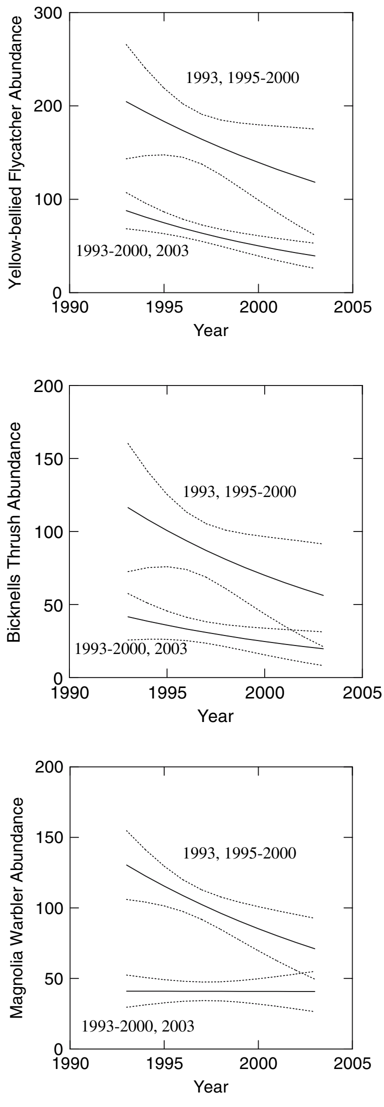
Two species exhibited significant declines in the White Mountains for both the entire data set and the years 1993, 1995–2000 (Yellow-bellied Flycatcher and Bicknell's Thrush; Fig. 2). In addition, Magnolia Warblers declined for the analysis of 1993, 1995–2000, but not for the analysis of all years.

There was little agreement between the population trends we calculated and the trends from the BBS for New Hampshire for the same time period. Two of the species that exhibited significant negative trends in our analyses (Yellow-bellied Flycatcher and Magnolia Warbler) did not exhibit any significant change in the BBS analyses. One species, the Bicknell's Thrush, did not occur on BBS routes in New Hampshire. Finally, when we considered all trends regardless of statistical significance, only 33% of the species exhibited trends in the same direction in both our analyses and the BBS analyses.

Discussion

Widespread reports of declines in North American bird populations have caused concern among conservationists in recent decades (Rappole 1995); however there has been limited systematic monitoring effort in eastern montane forests, so the status of populations of birds in these habitats has up to this point been largely a matter of conjecture. Bird

Fig. 2 Fitted curves and 90% CIs for bird trends of species exhibiting significant trends for either the analyses of 1993, 1995–2000 or all years 1993–2000, 2003 surveyed in montane spruce-fir areas of the White Mountains of New Hampshire



populations are known to fluctuate under ordinary circumstances, and thus it is possible that population declines observed in a given area could represent part of these normal fluctuations rather than the response of populations to a single common factor or event (Holmes and Sherry 2001). Although our results do not provide definitive proof that these species are experiencing serious, long-term declines, the magnitude of these declines (≥4%/yr) and our observation that all of the significant population trends were negative suggest that the allocation of additional monitoring and conservation resources to these species and their habitat merits serious consideration.

Our findings have added significance because one of these species, the Bicknell's Thrush, is identified by the North American Bird Conservation Initiative as one of the Highest Priority Landbirds in the Atlantic Northern Forest (Dettmers 2003). Furthermore, two of the three species that declined over the study period are considered ecological indicator species for montane spruce-fir habitat in the new White Mountain National Forest Plan (US Forest Service 2005). Ecological indicator species are selected to represent a larger community and serve as a gauge of overall ecosystem health. Our observation that these indicator species are declining suggests that closer examination of the factors potentially affecting this ecosystem and appropriate intervention should be a high priority for conservationists and managers.

Our observation that the Yellow-bellied Flycatcher, Bicknell's Thrush and Magnolia Warbler are declining in the White Mountains is consistent with other studies of these species. Bicknell's Thrushes have disappeared from several island and coastal locations in Canada during the 20th century (Nixon 1999) as well as from low-mountain sites in the United States (Atwood et al. 1996). Similarly, of long-term studies reporting significant changes in Magnolia Warblers, all three reported declines (Hall 1984; Stewart 1987; Hill and Hagan 1991). Magnolia Warblers are reported to occur in high densities in early-successional habitats and decline in numbers as stands mature (Hall 1994). Although we do not have information on habitat changes at our study sites over time, successional changes are a possible explanation for changes in Magnolia Warbler populations. With the exception of the BBS (discussed above) no long-term studies other than ours have been conducted on breeding populations of Yellow-bellied Flycatchers, however Hussel et al. (1992) reported significant declines in numbers for this species at migratory stopover sites in the Great Lakes region from 1961–1988.

Identifying the likely causes of population declines is particularly difficult in the case of Neotropical migrants because their populations are affected by events during the breeding season, migration and wintering seasons (Sillett and Holmes 2002). Nearly all of the montane spruce-fir forest in our study area is reserved from active forest management, and there was no significant ski area or wind power development in the study area over the course of the study period, however these montane spruce-fir habitats are still subject to a variety of anthropogenic stressors. For example, acid deposition potentially affects both the structure of the habitat by causing tree mortality (Miller-Weeks and Smoronk 1993), as well as leaching calcium from the soil (DeHayes et al. 1999). The depletion of calcium from the soil results in lower calcium availability in invertebrate prey, which may affect egg formation and productivity, and has been implicated in the decline of Wood Thrushes (*Hylocichla mustelina*), particularly in highland areas with thin and poorly buffered soils (Hames et al. 2002).

In addition to its effects on calcium availability, acidification also promotes the conversion of inorganic mercury (Hg) to toxic methylmercury (MeHg). Bioaccumulation of mercury is known to affect reproduction and survival of birds in aquatic habitats (Chan et al. 2003) and has been reported in the Bicknell's Thrush (Rimmer et al. 2005); however it is not known whether the levels reported from Bicknell's Thrushes approach toxicity thresholds for this species.

Additionally, montane birds may be vulnerable to global climate change because of the potential effects of temperature increases on the ecology and habitat used by these species. Changes in summer temperature projected to occur this century, could eventually reduce the availability of spruce-fir habitat for Bicknell's Thrush by over 95% (Rodenhouse et al. in press), and thus climate change is potentially a serious threat for montane bird species in the long term. The increase in temperature over our study period is relatively small, however ($\approx$0.20°C; Hayhoe et al. 2006), and thus it is unlikely that habitat changes due to climate change over this period were responsible for the trends we observed.

Finally, recreational use is another potential contributor to declines in bird populations. National Forests experienced a 12% annual increase in visitation between 1965 and 1994

(Cole 1996), and the White Mountain National Forest had nearly 7 million visitors in 2005 (US Forest Service 2006). Of these visitors to the White Mountain National Forest, about 31,400 visited the backcountry. Studies indicate that some birds avoid recreational trails (Miller et al. 1998; Gutzwiller and Anderson 1999) and might even experience higher nest predation in more heavily used areas (Miller et al. 1998).

All of the three species that declined are Neotropical migrants, species that breed to the north and winter to the south of the tropic of cancer (Rappole 1995). Comparisons of population trends between migratory and resident forest species typically report that declines are more pronounced in migrants (Terborgh 1989; Askins et al. 1990). These results have been cited as evidence that migrants are particularly vulnerable, perhaps due to some shared aspect of their reproductive biology, such as lower reproductive output (Whitcomb et al. 1981). Alternatively, migrant populations might be affected by migratory stop-over or wintering habitat effects (Rappole 1995). Studies of Bicknell's Thrushes, Yellow-bellied Flycatchers and Magnolia Warblers during the non-breeding season do indicate that all of them occur in mature forest habitats, and in some cases appear to prefer forest over anthropogenically altered disturbed or fragmented habitats (Rappole and Morton 1985; Ornat and Greenberg 1990; Askins 1992; Rappole et al. 1992; Rappole 1995; Rimmer et al. 2001). Clearly, reports of habitat use on the breeding and wintering grounds are not sufficient evidence to identify where habitat limitation occurs, however it does serve to remind us of the need to consider the entire life cycle of these species.

There was poor agreement between our results for the White Mountains and the results of the BBS data for New Hampshire. A possible explanation for this is the fact that our data were collected from a restricted portion of the state, whereas the BBS coverage is broader. In addition, the high altitude of the White Mountains results in more terrain inaccessible by the roadside surveys used in the BBS analyses, effectively eliminating the overlap between the BBS and our survey areas. In any case, these results appear to confirm our suspicion that bird trends in montane spruce-fir areas are not adequately covered by existing national bird survey programs. Further evidence of this is the fact that one of the species that exhibited significant trends in our analyses was not detected by the BBS in New Hampshire during the survey period (Bicknell's Thrush).

Conservation implications

Declines in these species are an indication that recent concern on the part of conservationists and managers about montane spruce-fir forests and the birds that inhabit them are justified. We recommend that investigations of the factors responsible for these population declines should be undertaken. Our observation that these trends were not reflected in the Breeding Bird Survey (BBS) analyses, and that one high priority species, the Bicknell's Thrush, did not even occur in the BBS data, argues for the importance of continued efforts to monitor these habitats.

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