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Original research article

Measuring the effectiveness of conservation programs for shrubland birds

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HIGHLIGHTS

- We measured the amount of shrubland habitat in a typical eastern US state.
- Most shrubland habitat resulted from commercial logging.
- For 15 priority species an average of 20% were supported by deliberate conservation.
- Conservation efforts supported 47% of field sparrows and 49% indigo buntings.
- Deliberate shrubland management is an important supplement to commercial activities.

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ABSTRACT

Disturbance-dependent habitats such as grasslands and shrublands are declining in many regions. To mitigate these declines, government agencies are using anthropogenic disturbances like logging and mowing to mimic natural ones. Because these programs can be costly or controversial, measuring their effectiveness is important. Here, we evaluate the conservation effectiveness of shrubland management for 15 bird species in Massachusetts, USA. Because shrublands are constantly changing in extent and location, we suggest that the key measure of conservation effectiveness should be how managed areas contribute to habitat availability. We used remotely-sensed data to assess the total area of shrublands in Massachusetts and consulted managers and a timber-harvest database to determine contributions of management by government agencies and non-governmental conservation organizations. We calculated species-specific habitat availability based on the habitat relationships of individual bird species. The area of potential habitat for shrubland birds in Massachusetts averaged 35,000 ± SD of 11,300 ha. Of this total, an average of 20% ± 15% exists because of management by government and NGOs. Management was most important for birds that nest primarily in uplands and avoid wetlands. We conclude that active management by government agencies and NGOs provides a substantial proportion of shrubland habitat in Massachusetts. With habitat on private property being lost to development or succession, active management will be even more important in the future.

1. Introduction

Disturbance-dependent habitats and their constituent plants and animals are increasingly imperiled (Litvaitis, 1993; Askins, 2000, 2001; Brawn et al., 2001). Seven of the 11 endangered songbirds in the contiguous U.S. require disturbed

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habitats, and 79% of the most endangered ecosystems nationwide are disturbance-dependent (Noss et al., 1995; U.S. Fish and Wildlife Service, 2006). Historically, floods, wildfires, beavers, and insect outbreaks maintained disturbance-dependent habitats (DeGraaf and Miller, 1996; Askins, 2000). Today, these disturbances are often suppressed because they threaten human health or property. As a result, state and federal land-management agencies and non-governmental conservation organizations (hereafter ''NGOs'') are using anthropogenic disturbances such as logging, prescribed fire, and mowing to replace natural disturbance regimes. Managers using these techniques now treat thousands of hectares each year in the eastern U.S. (Oehler, 2003).

Habitat management can be costly because of the specialized equipment and personnel needed. For example, mechanically removing woody plants in old fields costs \$80 to \$486 ha^{-1} (Oehler, 2003). Because disturbance-dependent habitats are ephemeral, they require frequent treatment to maintain their distinctive ecological characteristics (Thompson and DeGraaf, 2001; DeGraaf and Yamasaki, 2003). Using disturbance as a management tool can be controversial because of concerns about aesthetics, forest fragmentation, and fires (Askins, 2001). The increasing scarcity of conservation funds and public concerns about management activities necessitate that we evaluate the effectiveness of management for early-successional habitats.

For disturbance-dependent organisms, however, evaluating the conservation benefits of managed areas can be complicated. Early-seral patches are in constant flux because of succession, and the locations and total area of habitat are always changing (Bormann and Likens, 1979; Askins, 2000). Despite criticisms (Soule and Sanjayan, 1998), conservation targets are often based on the *proportion* of a habitat under protection (Svancara et al., 2005; Tear et al., 2009). However, this approach does not lend itself to managed habitats. Proportional targets do not make sense if the overall area of habitat available is declining, as shrublands are in this area (e.g. Bradshaw and Hannon, 1992; Litvaitis, 1993; Swetnam, 1993). In the northeastern U.S., for instance, disturbance-dependent grasslands and shrublands are currently declining (Askins, 2000). Proportional targets would dictate, nonsensically, that the area of habitat needing protection is becoming smaller as a result. Alternatively, the area protected per se can be used to judge conservation effectiveness (Brooks et al., 2004; Chape et al., 2005). This measure can be problematic because of the difficulty in objectively determining how much habitat is necessary to preserve biodiversity (Fahrig, 2001; Wilhere, 2008).

We suggest that, for disturbance-dependent organisms, the criterion for the effectiveness of management efforts should be how habitat availability would change in the absence of management (Ferraro and Pattanayak, 2006). This criterion is suitable regardless of current habitat extent. When the habitat is abundant, managed areas may make little contribution to habitat availability, and management will be less necessary. When the habitat is rare, even a small managed area can provide substantial benefits. Thus, one can only evaluate benefits of managed areas in light of regional habitat availability (e.g. Buffum et al., 2011).

Here, we conduct a conservation evaluation of management efforts for shrubland-breeding birds in Massachusetts. We focus on Massachusetts because it, like other parts of the northeastern U.S., has suffered significant losses of shrublands to forest regeneration and suburban development in recent decades (Litvaitis, 1993; Askins, 2000; Trani et al., 2001; DeNormandie et al., 2009). In this region, the area of early-successional forest has decreased by 89% since the 1950's (Schlossberg and King, 2007). As a result, populations of most shrubland birds are declining as well (Hagan et al., 1992; Hunter et al., 2001). To stem these declines, government agencies and conservation organizations are actively creating and maintaining shrublands, which we define as open-canopied habitats with varying amounts of woody cover. We collected data from a variety of sources to determine the extent of shrubland management by government agencies and NGOs in Massachusetts. Our goal was to determine, for several bird species, how shrubland availability would change in the absence of government and NGO management programs.

2. Methods

We conducted a conservation assessment for 15 bird species common in Massachusetts shrublands (Table 1). Our assessment had three steps: (1) We estimated the total area of shrublands in Massachusetts; (2) We collected data on areas managed as shrublands by state and federal government agencies and NGOs; (3) For each species, we compared the area of shrubland habitat in the state with the area created through management to determine the contribution of managed areas to that species' conservation.

2.1. Estimating total shrubland cover in Massachusetts

Our study area was mainland Massachusetts, which excludes Dukes and Nantucket Counties. To estimate total cover of shrublands, including natural and anthropogenic shrublands owned by private landowners, government, and NGOs, we used geographic information system (GIS) data from the Commonwealth of Massachusetts. The 2005 Land Use layer is based on aerial photos captured in 2005 and classified into 33 categories indicating natural habitat or type of development (MassGIS, 2009). Four land use categories potentially included shrublands: (1) ''Brushland/successional'' included several types of shrublands; (2) ''Open land'' included abandoned agricultural fields among other open habitats; (3) ''Powerline/utility'' comprised rights-of-way where shrubby vegetation is often encouraged over trees that could interfere with power lines (Confer and Pascoe, 2003; King et al., 2009a); (4) ''Non-forested wetlands'' included two types of shrubby habitat: shrub swamps and bogs (see Brewer, 1967; Van Velzen, 1980; Ewert, 1982).

Table 1
Estimated density (birds/ha) of focal bird species in Massachusetts shrublands, by habitat category.

Species	Wetlands	Rights-of-way	Uplands
Alder flycatcher (*Empidonax alnorum*)	3.04	0.17	0.56
Gray catbird (*Dumetella carolinensis*)	1.07	0.95	1.49
Cedar waxwing (*Bombycilla cedrorum*)	2.09	0.55	2.04
Yellow warbler (*Setophaga petechia*)	1.59	0.05	0.10
Chestnut-sided warbler (*Setophaga pensylvanica*)	0.74	1.80	1.97
Prairie warbler (*Setophaga discolor*)	0.00	1.24	1.63
Black-and-white warbler (*Mniotilta varia*)	0.65	1.09	2.99
Common yellowthroat (*Geothlypis trichas*)	4.97	1.99	2.54
Eastern towhee (*Pipilo erythrophthalmus*)	0.01	1.08	1.92
Field sparrow (*Spizella pusilla*)	0.00	0.60	0.72
Song sparrow (*Melospiza melodia*)	2.28	0.22	0.82
Swamp sparrow (*Melospiza georgiana*)	3.44	0.00	0.00
White-throated sparrow (*Zonotrichia albicollis*)	0.23	0.10	1.01
Indigo bunting (*Passerina cyanea*)	0.06	0.66	0.58
American goldfinch (*Spinus tristis*)	2.58	0.84	1.33

"Open land" is a catch-all category for non-forested habitats that do not fit into other categories. On the basis of field experience at sites classified as "open land" and consultation with experts who helped develop the MassGIS habitat categories, we determined that 50% of the area in this category could be considered shrubland habitat (D. Goodwin, J. Scanlon, personal communication). Thus, we reduced the total are of "open land" by 50% in our calculations.

The minimum mapping unit for MassGIS' 2005 Land Use coverage was 0.4 ha. Many shrubland birds, however, are edge- or area-sensitive, and patches as small as 0.4 ha may be too small for many species (Annand and Thompson, 1997; Costello et al., 2000; Chandler et al., 2009a). We used results form two recent reviews to assess avian responses to patch size and edges (Schlossberg and King, 2007, 2008). Responses to edges are relevant because edge avoidance in birds is correlated with avoidance of small patches (Parker et al., 2005). Of our 15 focal species, 12 showed evidence for edge avoidance or avoidance of patches smaller than 1 ha. For two species (yellow warbler and swamp sparrow), we found no relevant studies, and for the remaining species (gray catbird), we found no evidence of edge avoidance and no studies of area sensitivity. Given the strong preponderance of evidence that birds avoid patches smaller than 1 ha, we set 1 ha as the minimum patch size for calculations of shrubland habitat in Massachusetts.

Many shrubland birds have specialized habitat requirements (Probst et al., 1992; Askins, 2000; Bulluck and Buehler, 2006; Schlossberg et al., 2010). Thus, for each bird species, we restricted the GIS dataset to shrubland types where birds typically breed. To determine which habitats focal bird species utilized, we analyzed avian count data from beaver wetlands, utility rights-of-way, managed old fields, regenerating clearcuts, scrub oak (*Quercus ilicifolia*), and pitch-pine (*Pinus rigida*) barrens in Massachusetts (see Chandler et al., 2009b; King et al., 2009a,b; Schlossberg et al., 2010, for details). These habitats make up the vast majority of shrublands in the state (Schlossberg and King, 2007). We used N-mixture models of avian abundance to estimate densities of each bird species in each habitat (Royle, 2004). We used these density estimates to restrict GIS data on Massachusetts shrublands to areas likely to be used by each species, as described below.

The habitat categories used by MassGIS to describe shrublands were broad. For instance, the "brushland/successional" category included a variety of successional stages and cover types. Because the MassGIS categories did not correspond to traditional descriptions of shrubland habitats (Lorimer, 2001), we had to make some simplifying assumptions to predict habitat used by each species. First, we divided shrubland habitats into three broad categories: uplands (the "open land" and "brushland successional" categories in the MassGIS dataset), wetlands ("non-forested wetlands"), and utility rights-of-way ("powerline/utility"). To estimate how birds use these habitats, we mapped our density estimates for birds in Massachusetts shrublands onto those three categories. We used our field data from beaver ponds to estimate abundance in wetlands; the distribution of wetland subtypes (bog, shrub swamp, etc.) in our beaver pond sample was nearly identical to the statewide distribution of non-forested wetlands (unpublished data). Similarly, we mapped density estimates from rights-of-way onto the "powerline/utility" GIS category. For upland habitats, our estimated abundance for each species was the mean abundance in four upland habitats: regenerating clearcuts, old fields, scrub oak, and pitch-pine barrens. These four habitats make up the vast majority of upland shrublands in Massachusetts (Schlossberg and King, 2007).

Our goal was to identify the total area of potential habitat in the state for each bird species. We define potential habitat as areas where we expect a species' abundance to be at least 10% of the maximum abundance in wetlands, uplands, or utility rights-of-way. The 10% threshold was chosen arbitrarily to ensure that all areas capable of supporting even modest bird populations were included in the analysis. For each species, we excluded habitats from the MassGIS dataset where density estimates were less than 10% of the maximum in the three categories. For instance, we excluded uplands ("open land" and "brushland/successional") and rights-of-way from potential habitat of yellow warblers because estimated density in those two habitats was less than 10% of estimated density in wetlands (Table 1). We explored consequences of using threshold values besides 10% of maximum abundance as the basis for potential habitat (see Results).

In utility rights-of-way, abundances of many birds vary with corridor width (King et al., 2009a). For each bird species whose potential habitat included rights-of-way, we restricted the area of this habitat to the range of widths likely to be used by that species. We re-analyzed data from King et al. (2009a) and used N-mixture models to model linear, quadratic,

Table 2
Data sources used to estimate the extent of managed shrublands in Massachusetts.

Agency/Program	Years of data	Source
Natural Resources Conservation Service (NRCS)		
Wildlife Habitat Incentive Program	2005–2009	Beth Scheier, NRCS
	1998–2004	Extrapolation from recent data
MA Division of Fisheries and Wildlife (DFW)		
Landowner Incentive Program	2004–2009	Tracy Grazia, DFW
Uplands Program, silviculture	1990–2009	Ben Mazzei, DFW
Uplands Program, mechanical	1997–2009	Ben Mazzei, DFW
	1990–1997	Extrapolation from recent data
MA Dept. of Conservation and Recreation (DCR)		
Forestry programs	2004–2008	David Goodwin, DCR
	1989–2003	Timber harvest database
US Army Corps of Engineers	1984–2003	Timber harvest database
Towns/localities	1984–2003	Timber harvest database

sigmoid, and null (slope = 0) effects of right-of-way width on the abundance of each species. We used Akaike's information criterion to determine which type of curve fit best. For each bird, we used abundance equations from the N-mixture models to identify the range of widths where each species' predicted density was at least 10% of the maximum in rights-of-way. To determine the distribution of widths of Massachusetts rights-of-way, we used GIS to place 200 random points in rights-of-way throughout the state. Two points were in a power plant or substation, so we took 1% as our estimate for the area of such facilities and reduced total right-of-way area by 1% in our calculations. At each random point we measured corridor width, the shortest line through the point that connected both edges of the right-of-way. We used the distribution of widths in our random sample as our estimate of the distribution of right-of-way widths in the state. We determined the proportion of right-of-way sample points that was within each species' predicted range of widths and multiplied that proportion by the total area of rights-of-way in the state to estimate potential habitat in this category.

2.2. *Estimating shrubland cover created by government and NGOs*

To estimate the area of shrublands created by conservation programs, we contacted managers and accessed a large timber-harvest database. We were aided in identifying agencies and programs involved in shrubland management by our extensive contacts with state and federal agencies, NGOs, and localities in Massachusetts, developed over a decade of research (Table 2). In each case, we contacted the relevant manager(s) and requested information about the area managed as shrublands through silviculture, fire, or mechanical/chemical treatment from 1990–2009. We used this time window because clearcuts provide shrubland habitat for approximately 20 years before a closed canopy forms (Aber, 1979; Schlossberg and King, 2009). For old fields, 20 years may be conservative, as these habitats sometimes remain in an early-successional state for longer (Evans, 1978; Keever, 1983). If data from 1990–2009 were unavailable, we used the most recently available 20-year period (Table 1). We intentionally used conservative criteria in estimating the extent of shrublands created by government and NGOs (see below). Thus, if our results have any bias, it should be against finding an important contribution of managed areas to shrubland availability in Massachusetts.

For some agencies, data on silvicultural treatments were not available for the entire 20 years. Additionally, we lacked data on silvicultural treatments by the federal government and individual towns. To fill in missing years, we obtained estimates for silvicultural treatments from a database of all Forest Cutting Plans (FCPs) in Massachusetts compiled by Kittredge et al. (2009). For each timber harvest larger than 25,000 board feet or 50 cords, the state requires landowners to submit an FCP, including location, harvest area, and silvicultural treatment. Because FCPs are required by law, we were not concerned about under reporting, and are confident these values represent the majority of silvicultural activity in the study area (Kittredge et al., 2009). We excluded harvests smaller than 1 ha, as these create little early-successional habitat (see above). For the remaining harvests, we totaled harvest areas by year, treatment, and ownership (state, federal, local, private). We restricted timber harvests to three silvicultural techniques that create early-successional habitat by removing all or most of the canopy: clearcut, seed tree, and shelterwood.

Where agencies did not have the full 20 years of data on mechanical treatments, we consulted with managers to determine whether the area treated annually could be extrapolated back in time to fill in missing years. If so, we used the annual rate of habitat creation in the data from that agency as our estimate for missing years. Where projects funded by one agency were implemented by another, we made sure not to count those areas twice.

We adjusted the data on managed areas to reflect habitat usage patterns for each focal bird. First, for species whose potential habitat did not include uplands, we set the area of managed habitat to 0. Because of restrictions on modifying wetlands and difficulties in working in wet terrain, essentially all shrubland management in Massachusetts occurs in uplands. Thus, species that do not use upland habitats receive little or no benefit from management programs.

Second, we adjusted the area of shelterwood cuts in the FCP database. Shelterwoods make up the vast majority of silvicultural treatments in managed areas, but these treatments typically retain 30 to 60% canopy cover after the first or second cuts. Many shrubland birds are less abundant in shelterwood cuts than in clearcuts, and whether or not shelterwood cuts can be considered shrublands is questionable (King and DeGraaf, 2000). We used data from field studies to determine the relative usage of shelterwoods and clearcuts by our focal species. We considered clearcuts a control for effects of canopy cover. Two published studies compared abundances of birds in shelterwoods and clearcuts in the eastern U.S. (Annand and Thompson, 1997; King and DeGraaf, 2000). We compiled data from those studies, and for each species, we divided abundance in shelterwood cuts by abundance in clearcuts; in every case abundance was greater in clearcuts. The resulting quotient was the relative value of shelterwood habitat. Two bird species appeared in both published studies; for these species, we simply averaged the quotients from each study. Two additional species did not appear in either study. For these species, we averaged quotients from the other species and used this value to estimate the relative value of shelterwoods. We multiplied the relative value of shelterwoods for each species by the area of managed shelterwoods in the state to produce a final estimate for managed contributions to that species' habitat.

2.3. Data analysis

For each bird species, we determined the relative contribution of government- and NGO-managed areas by dividing the area of managed habitats by that species' potential habitat in the state. We also determined the effects of altering the 10% threshold for inclusion as potential habitat by examining scenarios with thresholds of 5% and 20% of maximum abundance for potential habitat. For each scenario, we used t-tests, with data paired by bird species, to compare the contribution of managed areas under the alternative scenario and the original 10% threshold.

To validate our estimates of statewide potential habitat, we compared avian population estimates based on potential habitat with population estimates based on Breeding Bird Survey (BBS) data. The BBS is an annual, road-based count of birds at random locations throughout the U.S. Methods developed by Rosenberg and Blancher (2005) allow estimation of regional bird populations by adjusting BBS data for detectability. Schlossberg and King (2007) used these methods on BBS data from Massachusetts from 1996 to 2005 to estimate statewide bird populations for focal species. In addition, we used our potential habitat calculations to estimate statewide bird populations. For each species, we simply multiplied the estimated density in each of the three habitat categories by the potential area of that habitat in Massachusetts and summed results to estimate population size. We calculated the linear correlation between the population estimates based on BBS data and our estimates based on potential habitat. Because estimates for different species varied over two orders of magnitude, we log-transformed data before analysis. A positive relationship with the BBS data would indicate that potential habitat is approximating actual bird populations estimated with an independent set of field observations.

One potential problem with our analysis is that data on managed habitats used 2009 as a baseline while GIS data on shrublands statewide dated from 2005. We believe that this 4-year discrepancy should have little effect on our overall results. Though shrubland habitat is declining in Massachusetts, the rate of loss is approximately 1% year^{-1} (DeNormandie et al., 2009). As discussed above, our estimates of the importance of managed habitats in Massachusetts may be biased slightly low but should be sufficiently accurate for making general conclusions.

3. Results

The estimated area of potential habitat for shrubland birds in Massachusetts averaged 35,000 ha $\pm$ SD of 11,300 ha (range = 18,100 to 48,800 ha) for 15 bird species (Table 3). The estimated area of avian habitats managed by government and NGOs was 6,500 $\pm$ 3,400 ha (range = 0 to 11,100 ha). The proportional contribution of managed areas to statewide shrubland habitat averaged 20 $\pm$ 15% (range = 0 to 49%). When we reduced the threshold for inclusion as potential habitat to 5% of maximum abundance, the proportional contribution of managed areas decreased non-significantly to 18 $\pm$ 13% ($t_{14} = 1.09, P = 0.29$). Similarly, when we increased the threshold for inclusion as potential habitat to 20% of maximum abundance, the proportional contribution of managed areas increased very slightly, with new mean 20 $\pm$ 16% ($t_{14} = -0.07, P = 0.94$).

Population estimates based on BBS data and our estimates based on potential habitat had a strong, positive correlation ($r_{15} = 0.74, p = 0.003$; Fig. 1). Alder flycatcher proved a significant outlier in this relationship. This species is uncommon in eastern Massachusetts, so its BBS-predicted population was much lower than the population estimate based on potential habitat. When we removed alder flycatcher from the dataset, the correlation between the two sets of population estimates was even stronger ($r_{14} = 0.87, p < 0.001$).

4. Discussion

Our results show that, on average, 20% of the habitat of shrubland birds in Massachusetts exists because of management by government or NGOs. The focal species in our study declined at an average rate of 2.4% per year between 1980 and 2007 in Massachusetts (Sauer et al., 2008). Shrubland habitat has been declining for decades in the Northeast, and habitat loss is the most likely cause of declining bird populations (Litvaitis, 1993; Schlossberg and King, 2007). Without regular disturbance, most managed areas would cease to be suitable for shrubland birds within a relatively short time because of succession (Schlossberg and King, 2009). Thus, any loss of managed habitats could worsen population trends of shrubland birds. Recent

Table 3
Potential habitat and areas managed by government and NGOs for shrubland birds in Massachusetts.

Species	Potential habitat (ha)				Government- and NGO-managed habitat (ha)				Proportion managed
	Wetlands	Rights-of-way	Uplands	Total	Old fields	Clearcuts/seed tree	Shelter-wood	Total	
Alder flycatcher	23,327	0	14,202	37,529	744	2,929	0	3,673	0.10
Gray catbird	23,327	9,388	14,202	46,917	744	2,929	0	3,673	0.08
Cedar waxwing	23,327	5,767	14,202	43,296	744	2,929	7,441	11,114	0.26
Yellow warbler	23,327	0	0	23,327	0	0	0	0	0.00
Chestnut-sided warbler	23,327	9,904	14,202	47,433	744	2,929	4,252	7,925	0.17
Prairie warbler	0	7,941	14,202	22,143	744	2,929	3,189	6,862	0.31
Black-and-white warbler	23,327	9,807	14,202	47,336	744	2,929	6,909	10,582	0.22
Common yellowthroat	23,327	8,961	14,202	46,490	744	2,929	1,063	4,736	0.10
Eastern towhee	0	9,825	14,202	24,027	744	2,929	3,189	6,862	0.29
Field sparrow	0	6,318	14,202	20,520	744	2,929	6,378	10,051	0.49
Song sparrow	23,327	0	14,202	37,529	744	2,929	4,464	8,138	0.22
Swamp sparrow	23,327	0	0	23,327	0	0	0	0	0.00
White-throated sparrow	23,327	0	14,202	37,529	744	2,929	3,189	6,862	0.18
Indigo bunting	0	3,904	14,202	18,106	744	2,929	4,783	8,456	0.47
American goldfinch	23,327	11,241	14,202	48,770	744	2,929	4,464	8,138	0.17

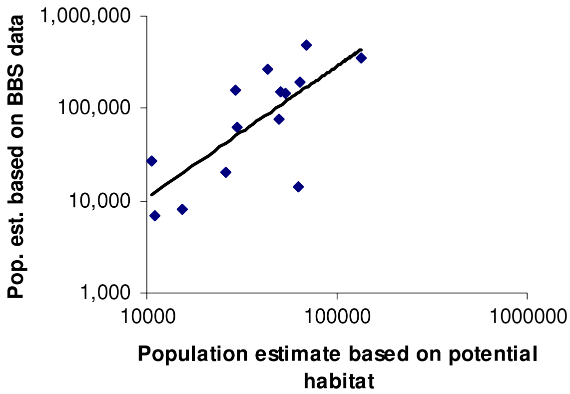

Fig. 1. Comparison of population estimates for shrubland birds in Massachusetts based on BBS data and potential habitat calculations. Least-squares regression line is shown.

efforts to restrict active management in Massachusetts could reduce the amount of silviculture on state lands and have deleterious consequences for shrubland bird populations.

Our results raise the issue of whether the current level of shrubland management is sufficient to maintain populations of shrubland birds. Shrubland habitat in Massachusetts is being lost to development at a rate of roughly 1% per year (DeNormandie et al., 2009). The amount of wood harvested on private property has changed little in recent decades, but future development may reduce timber harvests (McDonald et al., 2006). Thus, one can argue that merely maintaining the current extent of shrublands in Massachusetts will require increased efforts by government agencies and NGOs. We suggest that, at a minimum, Massachusetts set a goal of maintaining the current level of shrubland management for the foreseeable future. Buffum et al. (2011) made a similar recommendation, reasoning that such a target would permit conservationist to gauge the effectiveness, over time, of the status quo.

The benefits of management varied substantially by species. Upland specialists in our sample, (field sparrow, eastern towhee, indigo bunting, and prairie warbler), benefit more from active management than species that use wetlands. In fact, roughly half of the habitat for field sparrow and indigo bunting in Massachusetts exists because of active management. By contrast, wetland specialists such as yellow warbler and swamp sparrow benefit little from shrubland management because these birds are rare in upland habitats where management occurs. Finally, widespread species such as common yellowthroat and gray catbird use a variety of different shrubland types and, therefore, appear less dependent on active management than some other species that utilize managed areas.

The estimate that 20% of avian shrubland habitats in Massachusetts exists due to active management may underestimate the actual importance of these areas. Shrublands managed by government and NGOs are likely of higher quality than shrublands on private property, so losses of managed habitats could have disproportionate effects on birds. Clearcuts, for instance, are nearly twice as extensive on public or NGO-owned lands as on private property in Massachusetts. Because clearcuts lack a canopy, they provide better shrubland habitat than partial-cutting methods that retain canopy cover, and abundances of shrubland birds are higher in clearcuts than in partial cuts (Annand and Thompson, 1997; King and DeGraaf, 2000). Thus, public lands, with their relatively high level of clearcutting, are providing habitat largely unduplicated by private logging. Similarly, mechanically treated areas such as old fields mowed by the Department of Fish and Wildlife are important for many bird species. Compared to silvicultural habitats, old fields have relatively high cover of herbaceous vegetation and pioneer shrubs and vines, and many birds are more abundant in old fields than regenerating forests (Askins, 2001; Bulluck and Buehler, 2006; King et al., 2009b). Though estimates of the total extent of old fields are not available for Massachusetts, in our experience large (>1 ha) old fields are uncommon outside of managed areas.

We consider this analysis to be a preliminary estimate of the proportion of shrubland habitat managed by government and NGOs. Ideally, we would have used habitat-specific abundances of birds to determine the proportion of statewide bird populations that occur on managed habitats. In reality, GIS data on shrubland cover in Massachusetts was insufficiently detailed for us to estimate densities on a patch-by-patch basis. Thus, we had to make several assumptions about habitat usage by shrubland birds. While one could question the assumptions we used, our overall goal was to define statewide shrubland habitat broadly and managed areas more narrowly. The 10% threshold for potential habitat led us to likely include areas with relatively low numbers of shrubland birds as part of a species' habitat. By contrast, we adjusted coverage of managed shelterwoods to reflect species' usage of that habitat. Thus, our overall strategy should have biased our results against finding an important contribution of managed areas. The 20% estimate for this contribution should, therefore, be considered a lower-end estimate.

The 10% threshold used to define potential habitat was arbitrary, but two lines of evidence support our definition of potential habitat. First, we found a strong, positive relationship between avian population estimates for Massachusetts based on our definition of potential habitat and estimates based on BBS data. These two sets of population estimates were generated completely independently, so the positive correlation validates our estimates of potential habitat. Second, when we used thresholds of 5% or 20% of maximum abundance to define potential habitat, we found essentially no difference in the contribution of managed areas to shrubland habitat. This suggests that our results are robust to the specific definition of potential habitat used in our study.

5. Conclusions

Determining how much land was being managed as shrublands required us to contact numerous agencies and officials; in many cases determining who had the relevant data and how to access it was not straightforward. Currently, the Commonwealth of Massachusetts is developing a management database that would track all land management activities by state agencies. Such a database will be highly valuable, allowing improved coordination of management efforts among agencies and NGOs, and providing easier access to data on management efforts. We strongly encourage the creation of such management databases at the state and federal level. Such databases, combined with ever-improving GIS data on habitat extent, could allow management agencies to continuously monitor how their actions are affecting habitat availability and allocate conservation spending were it is needed most.

The "methods" outlined in this paper provide a straightforward way to conduct such conservation evaluations. We recommend that other states and regions use method similar to ours to assess the conservation benefits of management for shrublands and other early-successional habitats. Oehler (2003) reported that Northeastern states were managing a total of 18,712 ha of grasslands and shrublands per year. Given the costs of these efforts and the scarcity of conservation funding, determining how these efforts are benefiting shrubland animals is important. Similarly, we suggest that researchers revisit the contribution of managed areas in Massachusetts every several years. In Massachusetts, losses of natural habitats to development and changes in funding for shrubland management could change the proportional contribution of managed areas to avian shrubland habitats. Therefore, we suggest regularly revisiting the conservation evaluation conducted here to update the conclusions and determine if management efforts should be changed.

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