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A spatial analysis of forest management and its contribution to maintaining the extent of shrubland habitat in southern New England, United States

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ABSTRACT

Conservation organizations in the northeastern United States (US) recommend forest clearcutting to create shrubland habitat, which is required by many wildlife species with declining populations. The planning of habitat management programs is hampered by a lack of information on the current extent of shrubland habitat and the current rate of forest clearcutting that creates shrubland habitat. We addressed these information gaps by using a combination of automated and manual approaches to determine the extent and spatial configuration of shrubland habitat and recent forest clearcuts. We focused on the state of Rhode Island because (a) it is representative of the northeastern US in terms of the prevalence of private ownership of forests, and the ongoing decline in the populations of many shrubland wildlife species; (b) federal, state and private conservation groups are actively promoting clearcuts to create shrubland habitat; (c) many state-wide GIS databases are available; and (d) the spatial extent of the state made our results both generalizable and politically relevant. Our fine-scale mapping allowed a detailed analysis of shrubland distribution in conjunction with other available GIS layers that facilitates identification of priority areas for habitat management. We found that the extent of upland shrubland in non-coastal areas is decreasing by at least 1.5% annually. Considering the lack of consensus about conservation targets for the amount of shrubland, we propose that conservation organizations attempt to stabilize rather than expand the extent of shrubland habitat. This approach would provide an opportunity to assess whether the current extent of shrubland is sufficient to maintain reduced but stable wildlife populations that require this habitat. We propose a coordinated forest management program with targets for increased forest management on conservation lands. We found that the average patch size of shrubland created by recent clearcuts is large enough for most shrubland bird species, but too small for the New England cottontail (*Sylvilagus transitionalis*), which has been proposed for threatened and endangered status.

1. Introduction

Conservation of shrubland habitat in the northeastern United States (US) is an important priority because it is relatively rare and is required by many wildlife species (DeGraaf et al., 2006; RIDEM, 2005). Shrubland, which is also referred to as scrub–shrub, brush or thickets, is dominated by shrubs or trees less than 5 m tall with a dense understorey. Most shrubland habitat in the region is ephemeral, developing after agricultural abandonment or forest disturbance and reverting to more mature forest types within a few decades, although it persists longer in coastal areas when exposed to salt spray (Latham, 2003). The plant species composition of shrubland depends on the type and scale of disturbance and other factors, and can include both early and late successional species (Lorimer, 2001).

Hurricanes, beaver (*Castor canadensis*) activity, and episodic outbreaks of pests and pathogens have historically created new shrubland by destroying large areas of forest in the northeastern US (Foster and Aber, 2004). Between 1930 and 1955, forest fires affected most forests in Rhode Island and had a major impact on species composition (Brown, 1960). Hurricanes capable of blowing down entire forest stands occur on average every 75 years in southern New England (Boose et al., 2001). For example, during the 1938 hurricane, the town of Lincoln Rhode Island experienced blowdowns of more than 23,000 m^3 of timber (Peirce, 1968), which represented more than 450 m^3 per hectare. Climate change is expected to increase the intensity of hurricane wind speeds and increase the size of forest blowdowns (Busby et al., 2008).

Anthropogenic activity has also created new shrubland. The extent of shrubland in New England increased dramatically after the decline of agriculture in the late 19th century as abandoned fields

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succeeded to shrubland (Foster and Aber, 2004). This decline in agriculture in New England occurred because farmers were unable to compete with farms in the Midwest (Irland, 1999). The scope of this decline was especially dramatic in southern New England where, for example, more than 85% of the land farmed in Rhode Island in 1850 was abandoned by 1965 (Hooker and Compton, 2003). The extent of shrubland in southern New England was also maintained in the first half of the 20th century by widespread extraction of firewood (Lorimer, 2001).

In the late 20th century, the extent of shrubland in New England started a long period of decline as existing areas of shrubland matured into forests and only small amounts of new shrubland were created (Foster and Aber, 2004). The transition from shrubland to forest was well documented in Rhode Island and was typical for the region. By 1965 the process of agricultural abandonment was largely complete and farmland covered only 10% of the state (Hooker and Compton, 2003). Due to better fire control, forest fires no longer created new areas of shrubland (NIFC, 2010). The dominant size class of forests in the state changed from sapling–seedling in 1972 (Peters and Bowers, 1977) to poletimber in 1985 (Alerich, 2000) and sawtimber in 1998 (Alerich, 2000), and the volume of standing timber was five times higher in 2009 than it had been in 1953 (Butler and Payton, 2009; Ferguson and McGuire, 1957). Recent trends in the extent of shrubland in the state are less clear: some studies indicate that shrubland extent has stabilized since1985 (Butler and Payton, 2011) while others studies indicate a continuing decline (Novak and Wang, 2004).

Shrubland habitat is important for many wildlife species in the region. Schlossberg and King (2007) classified 41 species of birds as characteristic of New England shrublands – this definition excludes those species which are incidental in shrublands. One third of the 60 native terrestrial mammals in the northeastern US prefer shrubland habitat, and three mammal species are obligate users (Fuller and DeStefano, 2003), including the New England cottontail (*Sylvilagus transitionalis*) which has been proposed for threatened and endangered status (Litvaitis et al., 2006). Shrubland also provides habitat for rare butterflies and moths (Wagner et al., 2003), rare reptiles (Litvaitis, 2003) and many rare plants (Latham, 2003). Thus, conservation of shrubland habitat is an important priority for many federal and state management agencies as well as non-government organizations (NGOs).

Many studies have linked recent declines in populations of wildlife species in the northeastern US to the loss of shrubland habitat (Blomberg et al., 2009; Endrulat et al., 2005; DeGraaf and Yamasaki, 2003; Foster and Aber, 2004). The populations of 14 shrubland bird species significantly declined in southern New England between 1996 and 2006, whereas populations of only four species significantly increased (Schlossberg and King, 2007). Declining populations of the New England cottontail, a native obligate user of shrubland habitat, prompted the United States Fish and Wildlife Service (USFWS) in 2004 to begin formal consideration of the species for threatened or endangered status (Litvaitis et al., 2006) Thus, the rarity of shrubland habitat in the northeastern US along with the declines in wildlife that depend on this habitat has focused the attention of conservation agencies on how to most effectively manage public and private lands to increase shrubland habitat.

Forest clearcutting, which involves removing the entire tree community to encourage the natural regeneration of both shade tolerant and intolerant species, is generally considered the most effective method for creating shrubland habitat (DeGraaf and Yamasaki, 2003; Litvaitis, 1993; Schlossberg et al., 2010). However, there is often public opposition to clearcutting due to concerns about the visual impact of clearcuts and the potential loss of habitat for species which require mature forests (Askins et al., 2007; Berlick et al., 2002; Costello et al., 2000). Therefore, conservation agencies should only promote clearcutting as part of coordinated, science-based programs which maximize the wildlife benefits of clearcuts while minimizing the negative impacts.

In order for conservation agencies to plan effective habitat management programs it is critical to know the current extent and spatial distribution of shrubland habitat. However, this information is currently not available – several land use/land cover studies have estimated the area of shrubland but provide conflicting estimates. The general problem is that shrubland is classified in a variety of ways and few standard metrics are used. Conservation planners also need to know how much forest management is currently taking place and how much of the forest management is resulting in new shrubland habitat. The average patch size of shrubland created by forest management is important because many wildlife species cannot persist in patches below a threshold size (Chandler et al., 2009; DeGraaf et al., 2006). However, information on forest management activities is limited: environmental organizations monitor forest management activities on their own land, but little monitoring takes place on private land, which includes most forest land in the region.

In this study we attempted to fill information gaps which limit the ability of conservation organizations to plan early successional habitat management programs. These same information gaps are common elsewhere and we describe an approach that is generally applicable to other regions for determining the extent of shrubland and forest management. Our specific objectives were to (a) estimate the current area and spatial distribution of shrubland and assess whether it is stable, increasing or decreasing; and (b) estimate the current area and spatial distribution of forest management and assess its impact on maintaining shrubland habitat. Our fine-scale mapping allowed a detailed analysis of shrubland distribution and patch size that in turn provides conservation organizations and private landowners the appropriate spatial context in which to identify priority areas for habitat management.

2. Methodology

2.1. Study area

The study covered the state of Rhode Island, which has a total land area of 270,654 ha (Alerich, 2000) bordering the Atlantic Ocean between 71°7′ W and 71°53′ W, and 41°8′ N and 42°1′ N (Fig. 1). Rhode Island is one of six states in New England, and one of three states in southern New England. Forests covered 52% of the state as of 2009, with dominant species being *Acer rubrum*, *Pinus strobus*, *Quercus velutina*, *Quercus rubra*, *Quercus coccinea*, and *Quercus alba* in descending order of total volume (Butler and Payton, 2011). We focused on the state of Rhode Island because (a) it is representative of the northeastern US in terms of the prevalence of private ownership and the ongoing decline in the populations of many shrubland wildlife species; (b) federal, state and private conservation groups are actively promoting clearcuts to create shrubland habitat (AFA, 2010; Oehler, 2003; TNC, 2010; USFWS, 2008); (c) many state-wide GIS databases are available; and (d) the spatial extent of the state made our results both generalizable and politically relevant.

2.2. Analysis of existing studies

We reviewed eight studies that provide data on shrubland habitat to develop the methodology for the rest of the current study (Table 1). Four studies provided estimates for upland[1]

[1] We refer to upland as all land that is not classified as wetland, regardless of elevation.

Fig. 1. Location of study area.

Table 1
Land cover land use studies in Rhode Island.

Abbreviation	Full name	Years	Type of shrubland estimated	Data and documentation
C-CAP	Coastal Change Analysis Program. National Oceanic and Atmospheric Administration	1995 2000 2005	Upland shrubland Wetland shrubland	Data available from: http://www.csc.noaa.gov/index.html
FIA	Forest Inventory and Analysis Program. US Forest Service	1954 1972 1984 1998 2007	Combined upland and wetland shrubland	Data and summary reports available from: http://www.fia.fs.fed.us/
Kupa–Whitman	Land-cover Types of Rhode Island: an ecological inventory. Kupa, J.J. and Whitman, W.R.	1962	Upland shrubland, Wetland shrubland	Summary report: Kupa and Whitman (1972). Maps georeferenced but not digitized
MacConnell	Remote sensing land use and vegetative cover in Rhode Island. MacConnell, W.P.	1970	Wetland shrubland	Summary report: MacConnell (1974). Maps not georeferenced or digitized
NLCD	National Land Cover Data Set. US Geological Survey and US Environmental Protection Agency	1992 2001	Upland shrubland	Data available from: http://www.epa.gov/mrlc/change.html
Novak–Wang	Effects of suburban sprawl on RI forests: LANDSTAT View from 1972–1999. Novak, A.B. and Wang, Y.Q.	1972 1985 1999	Upland shrubland	Data provided by authors. Summary report: Novak and Wang (2004)
NWI	National Wetland Inventory	2004	Wetland shrubland	Data available from: http://www.fws.gov/wetlands/Data/DataDownload.html
RILU	Land Use of Rhode Island. Statewide Planning Program, RI Department of Administration	1988 2005 2003/04	Upland shrubland	Data available from: http://www.edc.uri.edu/rigis/

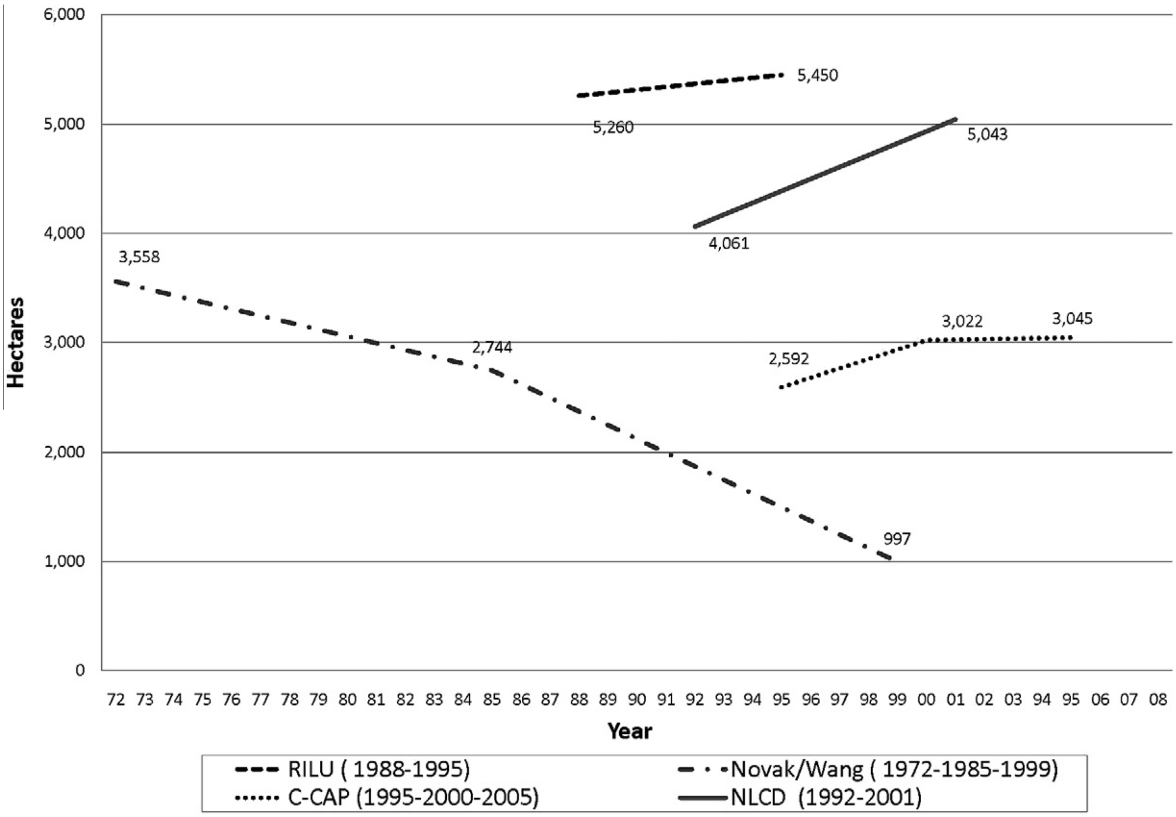

Fig. 2. Estimates of trends in the area of upland shrubland in Rhode Island. Data sources are provided in Table 1.

shrubland in Rhode Island for two or more years, but these studies reported conflicting trends and very different estimates of the area of upland shrubland (Fig. 2). These conflicting trends result from the difficulty in detecting the small patches of shrubland (<0.5 ha) prevalent in the region, and the general problem that "shrubland" is classified in a variety of ways. For example, the Land Use of Rhode Island (RILU) distinguished between shrubland and forest on the basis of canopy density; the Coastal Change Analysis Program (C-CAP) and the National Wetlands Inventory (NWI) distinguished on the basis of tree height. The Forest Inventory and Analysis (FIA) distinguished between including "seedling/sapling" which is assumed to represent shrubland (Chandler et al., 2009; Litvaitis, 2003; Trani et al., 2001), and forest on the basis of tree diameter. In addition, the studies delineated wetland and upland areas differently, which had a significant impact on the area of upland shrubland. Our review concluded that none of the studies conducted during the past decade provides a reliable estimate of the extent of shrubland habitat.

Many wildlife studies utilize data from FIA, which divides forests into five stand size classes including "seedling/sapling" which is assumed to represent shrubland (Chandler et al., 2009; Litvaitis, 2003; Trani et al., 2001). However, FIA data are not appropriate for estimating the seedling/sapling class at the scale of Rhode Island because the small number of inventory plots in this category results in sampling errors (SE) of up to 39% (Alerich, 2000). Furthermore, the FIA seedling/sapling class, which has a maximum diameter of 12.6 cm, includes forest stands that are too mature for shrubland birds in the northeastern US (Schlossberg and King, 2007).

RILU 2003/04 provides the best estimate of the current extent of upland shrubland in Rhode Island due to its high resolution, use of recent imagery, and accuracy. However, a visual analysis revealed that the RILU 2003/04 automated method for identifying shrubland underestimated the area of shrubland by misclassifying areas of shrubland as forest. Furthermore, RILU 2003/04 cannot be used to detect trends in conjunction with RILU 1988 and RILU 1995 due to the methodological change in 2003 from manual to automated delineation, which had a large impact on delineating areas of shrubland.

2.3. Estimating the area of 2008 shrubland

Given the problems outlined above with existing databases, we used automated and manual approaches to map the extent of shrubland in Rhode Island. All polygons classified as shrubland or powerlines by RILU 2003/04 and as shrubland by NWI were combined using ArcGIS versions 9.x and 10 (Environmental Systems Research Institute, Redlands, CA). The status of each polygon was checked using high resolution 2008 true color digital imagery (15 cm pixel size), and the polygon boundaries were redrawn if needed at a scale of 1:2000. Additional polygons of shrubland that were falsely classified as forests were identified by systematically examining the 2008 imagery using a fishnet grid at the scale of 1:3000 and delineating polygons at a scale of 1:2000. This process was facilitated by only displaying areas classified as forest in RILU 2003/04. The same process was repeated to identify areas of shrubland falsely classified as non-forest. Extensive ground ruthing was carried out in coastal areas where it is harder to distinguish shrubland from forest. The new shapefile for 2008 shrubland was used in conjunction with other layers available in the Rhode Island Geographic Information System (RIGIS)[2] to analyze the ownership pattern, protection status, distribution by town, and area of wetland vs. upland shrubland. When calculating the patch size of shrubland, small patches less than 0.04 ha were excluded.

[2] See: http://www.edc.uri.edu/rigis/.

2.4. Analysis of forest clearcuts

To estimate the current area and spatial distribution of forest management in our study area, we mapped the area of forest that was clearcut between 1997 and 2003/04 and was not used for construction of houses, roads or other semi-permanent infrastructure by 2008. This time frame was selected based on the availability of orthophotography and land use datasets. An initial set of potential clearcuts during the period was identified by detecting a change in land use from "forest" in RILU 1995 to "brush" in RILU 2003/04. Each polygon was checked with the 1997 and 2003/04 imagery to verify that forest management actually took place during the period, and the polygon boundaries were redrawn to match the actual area of forest management at a scale of 1:2000. Additional clearcuts were identified by systematically examining the 2003/04 imagery for Rhode Island using a fishnet grid at a scale of 1:3000, and delineating polygons at a scale of 1:2000. This process was facilitated by only displaying areas classified as forest in RILU 2003/04. The status of all clearcuts was checked with 2008 imagery, and all clearcuts that showed signs of construction were deleted or subdivided to eliminate the areas of construction. The 2008 status of the remaining clearcuts was classified as either "shrubland," "agriculture," "pasture," "recreation," or "other land use." The new dataset for forest clearcuts was used in conjunction with other GIS layers to analyze the ownership pattern, protection status, prevalence of clearcuts in wetlands, and type of forest which had been clearcut. When calculating the patch size of clearcuts, small patches less 0.04 ha were excluded.

2.5. Delineation of coastal buffer

The study delineated a coastal buffer to distinguish areas dominated by coastal shrubland from areas dominated by other types of shrubland. Coastal shrubland is a unique shrubland community that undergoes limited succession due to the impact of salt spray (Enser and Lundgren, 2006; Latham, 2003). The current study defined the coastal buffer as all areas within 1 km of the coast plus all portions of Block Island. The coastal buffer, which includes upland and wetland areas, represents 16% of the land area of Rhode Island.

2.6. Maintenance of upland shrubland

An analysis was conducted to determine whether the area of upland shrubland habitat is being maintained by the current amount of forest management in combination with other sources of gain and loss of shrubland. The analysis covered the non-coastal upland areas of RI which represent 76% of the land area of Rhode Island and 98% of all forest clearcuts. Wetland forests in Rhode Island are generally not actively managed due to their strong protection status, and the area of wetland shrubland is relatively stable because successional trends are partially balanced by regression caused by increases in water levels (Golet and Parkhurst, 1981). The analysis excluded the coastal buffer because estimating the rate of succession for shrubland in the coastal buffer would be speculative. Furthermore, the survey of forest management activities found that very little clearcutting is done in coastal areas.

The annual loss of shrubland resulting from succession to forest was estimated by first calculating the percentage of 2008 shrubland that had originated from clearcuts rather than as regeneration on abandoned fields or open areas. Pre-2008 condition was determined using the RILU 1995 dataset. Shrubland originating from forest management was assumed to persist as shrubland for 10–15 years before reverting to forest, whereas shrubland originating from abandoned agriculture or open areas was assumed to persist as shrubland for 30–50 years (DeGraaf and Yamasaki, 2003). Separate high and low assessments were conducted based on the minimum and maximum persistence values. The area of shrubland under powerlines, which is permanently maintained as shrubland, were excluded from the calculation of the annual loss of shrubland, but not from the total area of shrubland.

The annual gain of shrubland from forest management was estimated by using the new data set on forest clearcuts created between 1997 and 2003/04 which were classified as producing shrubland in 2008. The annual loss of shrubland to non-forest land use (e.g., developed, agriculture, pasture, etc.) and the annual gain of shrubland from non-forest land use were extracted from C-CAP, which was considered to be the best source of supplementary data despite its lower resolution due to its recent imagery and direct estimates of both upland and wetland forest and shrubland.

3. Findings

3.1. Forest clearcuts

The area of forest clearcut between 1997 and 2003/04 which did not exhibit signs of residential or commercial construction by 2008 was distributed throughout the state, but almost exclusively in non-coastal upland areas (Fig. 3 and Table 2). For more detailed maps of the extent of forest management and shrubland, see Buffum (2011). Fifty two percent of the area of forest clearcut was producing shrubland in 2008, whereas the remaining clearcut area had been converted to non-forest land uses such as recreation (21%), agriculture (11%), pasture (10%) or other land uses (5%). Ninety five percent of the clearcut area producing shrubland was located on land which had been forested in 1995. Sixty three percent of the area of forest clearcuts producing shrubland was located on land with no conservation status.

3.2. Shrubland in Rhode Island

Upland and wetland shrubland is widely distributed throughout the state, but with a higher concentration in coastal areas (Fig. 4 and Table 3). Non-coastal uplands had the lowest coverage of shrubland. The mean patch size of upland shrubland in coastal areas was double that in non-coastal areas. Sixty two percent of shrubland in Rhode Island was located on land which does not have conservation status.

3.3. Maintenance of upland shrubland

We used our new datasets on the extent of shrubland and forest clearcuts to assess whether additional clearcutting is required to maintain the current extent of shrubland (2008) in conjunction with other sources of loss or gain of shrubland. Two assessments were carried out, based on the high and low estimates of the persistence of shrubland (DeGraaf and Yamasaki, 2003). Most of the loss of shrubland resulted from succession of shrubland to forest, while most of the gain of shrubland resulted from forest clearcuts. Both assessments concluded that the current amount of forest management is not adequate to maintain the existing area of shrubland in conjunction with other sources of loss or gain of shrubland, and that the extent of shrubland will decrease unless the amount of forest clearcutting is increased (Table 4).

4. Discussion

4.1. Current extent of shrubland

Our study provided the first detailed study of the extent and spatial distribution of shrubland in the state since 1962 (Kupa

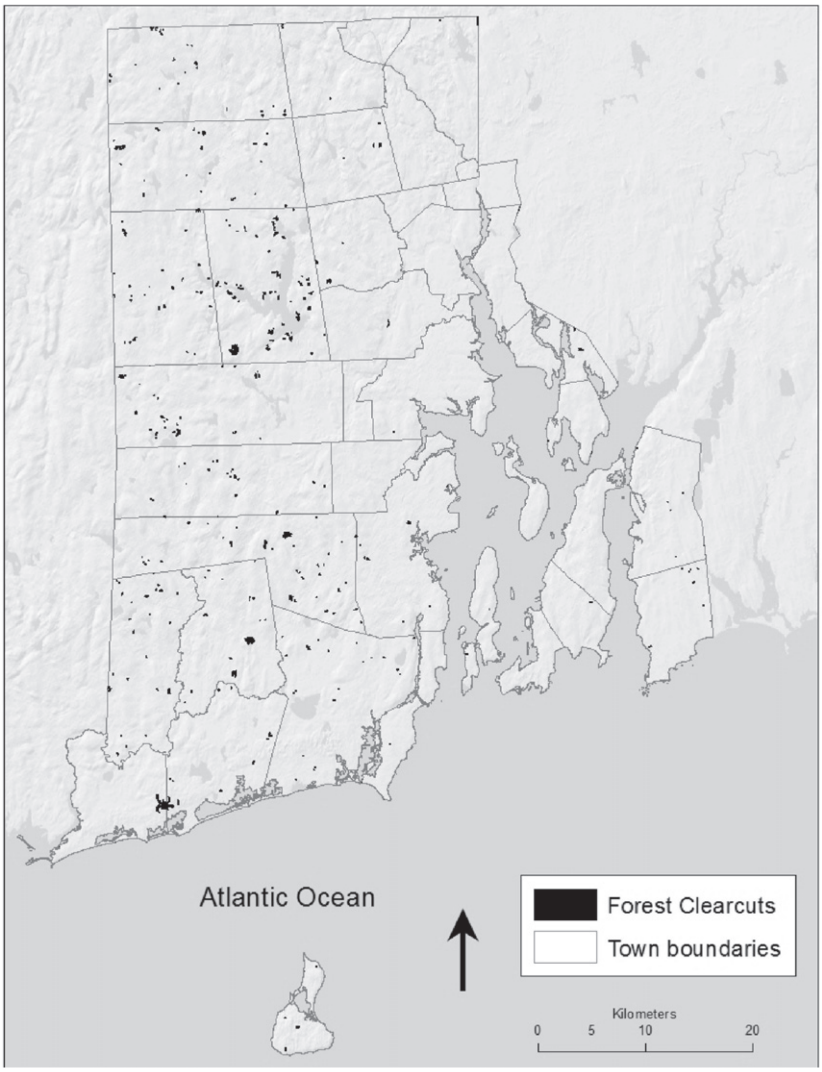

Fig. 3. Area of forest clearcut in Rhode Island 1977–2003/04.

Table 2
Area of forest clearcut (1997–2003/04) in Rhode Island which produced shrubland by 2008.

Land category	Clearcut area (ha)	Percent of all clearcut area (%)	Patches >0.04 ha (expressed in ha)		
			Mean patch size	Maximum patch size	Number of patches
Non-coastal upland	308.6	97.7	1.2	17.6	249
Non-coastal wetland	0.5	0.2	0.1	0.1	2
Coastal upland	6.7	2.1	3.3	6.3	2
Coastal wetland	0.00	0.00	–	–	0
Subtotal non-coastal	309.1	97.9	1.3	17.6	248
Subtotal coastal	6.7	2.1	3.3	6.3	2
Subtotal upland	315.3	99.8	1.3	17.6	249
Subtotal wetland	0.5	0.2	0.1	0.1	2
Total	315.8	100.0	1.2	17.6	256

and Whitman, 1972). The use of manual and automated methods was labor intensive, but our fine-scale mapping allowed a detailed analysis of shrubland distribution in conjunction with other available GIS layers that facilitates identification of priority areas for habitat management.

Our estimate of shrubland (2008) is roughly comparable to the FIA forest inventory data, despite the high FIA sampling error for this category (Alerich, 2000), but higher than the estimates of all land use/land cover studies conducted during the past 20 years, some of which only quantified upland shrubland or all shrubland (Table 5). In addition to the difficulty for remote sensing to differentiate between shrubland and forest, the difference between the estimates is partially the result of (a) different approaches for distinguishing between upland and wetland areas, and (b) different approaches for distinguishing between coastal shrubland and forest. For example, our estimate of the extent of upland shrubland is double that of C-CAP, but when the coastal buffer is excluded and a standard methodology for delineating wetlands is applied (based on NWI), the C-CAP estimate is higher (3552 ha) than our estimate (2575 ha).

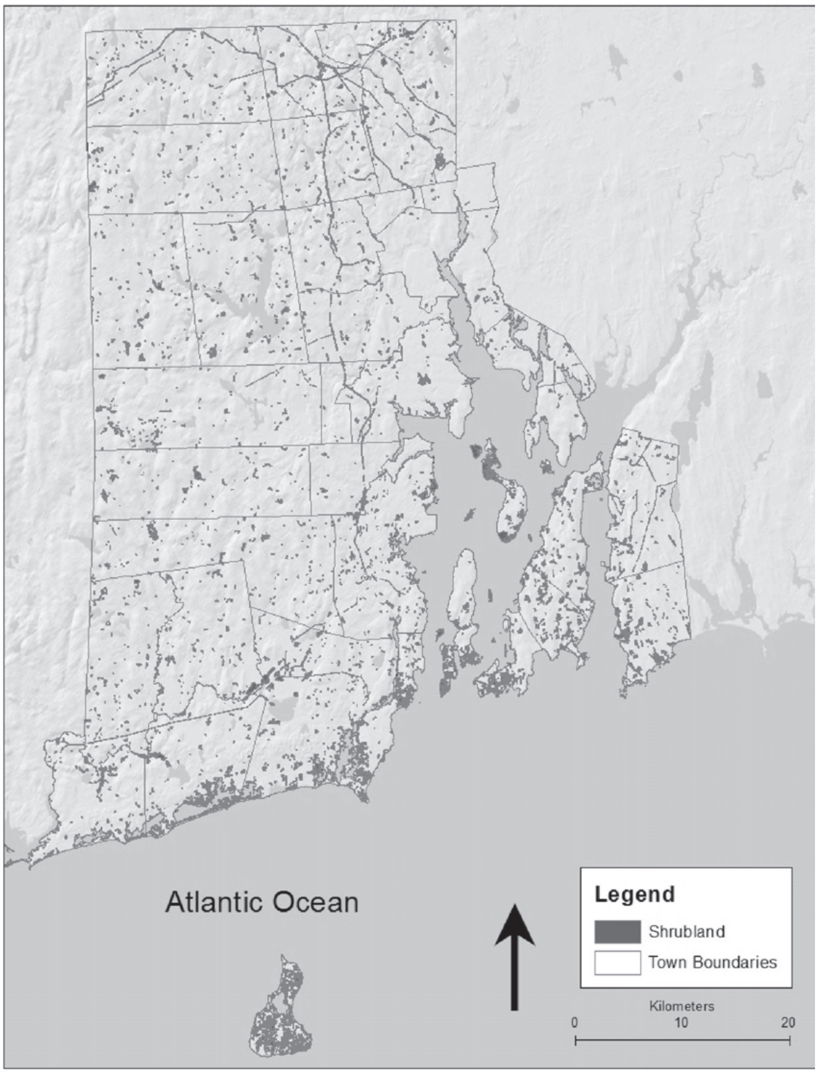

Fig. 4. Shrubland in Rhode Island (2008).

Table 3
Extent of shrubland in Rhode Island, 2008.

	Total land area (ha)[a]	Shrubland area (ha)		Percent of all shrubland (%)	Percent land in shrubland (%)	Patches >0.04 ha (expressed in ha)		
		Total	Under powerlines			Mean patch size	Maximum patch size	Number of patches
Non-coastal upland	202,828	2789	2209	31.3	1.4	1.22	41	2281
Non-coastal wetland	21,255	2227	558	24.9	10.5	1.6	105	1393
Coastal upland	39,320	3297	34	36.9	8.4	2.64	91	1250
Coastal wetland	3751	608	9	6.8	16.2	0.86	36	698
Subtotal non-coastal	224,083	5017	2768	56.2	2.2	1.82	105	2759
Subtotal coastal	43,072	3906	42	43.8	9.1	3.18	92	1228
Subtotal upland	242,149	6087	2243	68.2	2.5	1.75	91	3476
Subtotal wetland	25,006	2836	567	31.8	11.3	1.37	105	2064
Total	267,154	8923	2810	100	3.3	2.27	105	3919

[a] Excludes freshwater rivers and lakes.

4.2. Distribution of shrubland

We found that the shrubland coverage is not equally distributed in the state. Shrubland covers 16.2% of the land area in coastal wetlands, but only 1.4% in non-coastal uplands. The prevalence of shrubland in coastal areas is fortunate, as coastal shrubland provides critical food supplies for migratory landbirds (Parrish, 1997; Smith et al., 2007). However, the small portion of land

Table 4
Amount of clearcutting required to maintain the existing extent of upland shrubland in non-coastal areas of Rhode Island.

	Shrubland persistence	
	High[a]	Low[a]
Annual loss and gain of shrubland		
Loss of shrubland from succession to forest – for shrubland originating from abandoned agriculture (ha $year^{-1}$)	−16	−26
Loss of shrubland from succession to forest – for shrubland originating from cleared forest (ha $year^{-1}$)	−73	−110
Loss of shrubland to non-forest land use (ha $year^{-1}$)[b]	−5	−5
Gain of shrubland from forest clearcuts (ha $year^{-1}$)[c]	47	47
Gain of shrubland from non-forest land use (ha $year^{-1}$)[b]	5	5
Total change in area of shrubland		
Change in area of shrubland (ha $year^{-1}$)	−42	−89
Change in area of shrubland (percent $year^{-1}$)	−1.5%	−3.2%
Amount of clearcutting required to maintain current shrubland extent (2008)		
Area of clearcuts required (ha $year^{-1}$)	89	136
Area of clearcuts required as a percentage of 1997–2003 clearcuts (%)	188	288

[a] High persistence model assumes succession to forest within 50 years for shrubland originating from abandoned agriculture and 15 years for shrubland originating from cleared forest. Low persistence model assumes 30 and 10 years respectively.
[b] Based on supplementary data from C-CAP.
[c] Based on 1997–2003 levels of clearcuts that produced shrubland by 2008.

Table 5
Estimates of upland shrubland in Rhode Island (ha).

	All shrubland	Upland shrubland
Present – 2008	8923	6087
Coastal Change Analysis Program (C-CAP) – 2006	6194	3044
Forest Inventory and Analysis (FIA) – 1999	8620	–
Forest Inventory and Analysis (FIA) – 2008	7952	–
Kupa–Whitman – 1962	13,294	–
National Land Cover Data Set (NLCD) – 2001	–	5042
Land Use of Rhode Island (RILU) – 2003	–	2749
Wang/Novak – 1999	–	997

covered by upland shrubland in non-coastal areas, which represent 67% of the land area of Rhode Island, indicates a potential problem for the many species that depend on this habitat (Table 3).

4.3. Patch size

The average patch size of the clearcuts during the study period which were producing shrubland in 2008 was greater than the average patch size of existing shrubland, indicating that forest management is not lowering the average patch size of shrubland. This is important because some wildlife species cannot persist in patches of shrubland below a threshold size (Chandler et al., 2009; DeGraaf et al., 2006). There is not yet consensus on the minimum patch size required by shrubland birds. Askins et al. (2007) concluded that 0.6 ha patches provide habitat for most shrubland specialists in southern New England, whereas Schlossberg and King (2007) recommended larger openings of at least 1 ha. The average patch size of the 1997–2003 clearcuts exceeds both of these recommendations, which suggests that the average size of clearcuts does not need to be increased to provide habitat for shrubland birds. Furthermore, patches greater than 1 ha are relatively abundant (Fig. 5). However, the persistence of the New England cottontail is tenuous because current forest management is not creating enough large clearcuts to maintain habitat for this species which prefers patches larger than 10 ha (Litvaitis, 2001; Litvaitis et al., 2006).

4.4. Trends in extent of shrubland

Our two assessments of changes in the extent of upland non-coastal shrubland, based on high and low estimates for shrubland persistence, indicate that the extent of shrubland is decreasing annually by 1.5–3.2%. Clearcuts were the major source of new shrubland habitat, but the intensity of recent forest management has been too low to maintain the shrubland extent. There are many reasons why the intensity of forest management has decreased in recent decades, but Berlick et al. (2002, p. 17) conclude that “deep seated philosophical objections to harvesting” are likely the greatest barrier to more intensive forest management in southern New England.

A comparison of our estimate (2008) to historical estimates of shrubland in the state also suggests a continuing decline of shrubland. We estimate that shrubland (2008) represents 3.3% of the total land area of the state, which is lower than the 1962 estimate of 5.0% (Kupa and Whitman, 1972), and presumably much lower than in the early 1900s when the area of shrubland peaked (DeGraaf and Yamasaki, 2003).

Some of the loss of shrubland can be attributed to land clearing for development, which has reduced the area of forest in the state since 1963 (RIDEM, 2010). However, our estimate for the loss of shrubland is much higher than estimates for the loss of forest area, which reportedly declined by only 0.6% per year between 1985 and 2009 (Butler and Payton, 2009). This indicates that most of the loss of shrubland is due to succession of shrubland to forest. As a result, the ratio of shrubland to forest is gradually decreasing. In 1962, shrubland represented 7.2% of the total forested area of the state (Kupa and Whitman, 1972), whereas our estimate (2008) indicates that shrubland represents only 5.2% of the total forested area.

4.5. Targets for creation of shrubland habitat

There is a notable lack of consensus on what should be the target amount of shrubland habitat in southern New England. Some wildlife biologists have proposed large scale forestry interventions to increase the extent of shrubland. For example, Dettmers and Rosenberg (2000) proposed addressing population objectives for priority shrubland bird species by maintaining shrubland on 10% of forests in southern New England, which is almost double our estimate of the current extent (2008) of 5.2%. Williamson (2008) proposed a much more ambitious program of maintaining shrubland and young forest on 27% of forests in Rhode Island to restore shrubland bird populations to 1970 levels. Schlossberg and King (2007) argued for increasing the extent of shrubland habitat, but they concluded that setting specific population or habitat targets for maintaining viable populations of shrubland birds is premature due to limited understanding of their ecology.

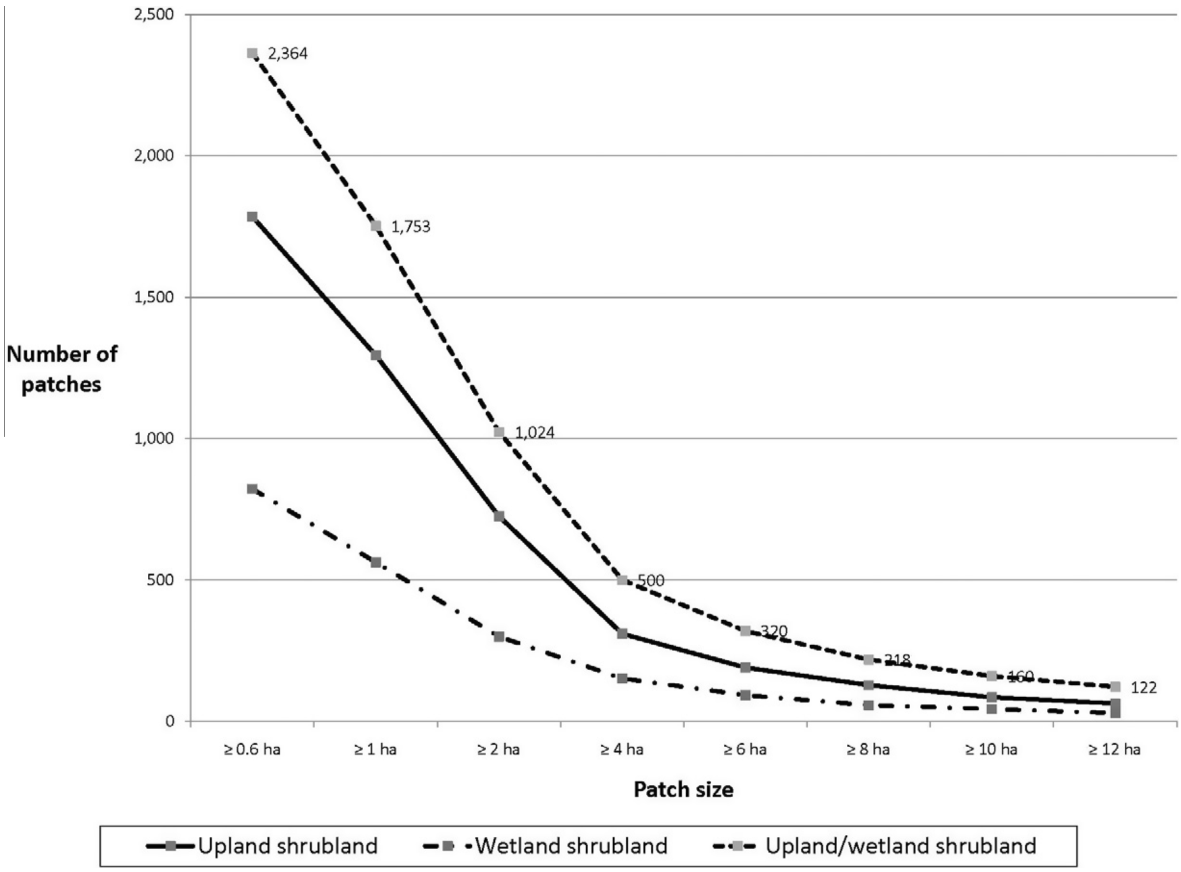

Fig. 5. Distribution of shrubland by patch size in Rhode Island (ha).

Considering the lack of consensus about conservation targets for the amount of shrubland, we propose the more conservative approach of attempting to stabilize rather than expand the extent of shrubland habitat. This approach would provide an opportunity to assess whether the current extent of shrubland is sufficient to maintain reduced but stable wildlife populations that require this habitat. Ongoing monitoring of wildlife populations would be critical to make this assessment. This approach would also limit the negative impacts of forest management on wildlife species that require large contiguous patches of mature forest. For example, mature forest bird species in southern New England require ten times as much habitat as shrubland birds (Dettmers and Rosenberg, 2000).

4.6. Management Recommendations

We recommend that conservation of shrubland in non-coastal upland areas be given high priority. Shrubland covers only 1.4% of the land area in non-coastal upland areas, whereas coverage is six times higher in coastal uplands, seven times higher in non-coastal wetlands, and 11 times higher in coastal wetlands. Even though most forest management takes place in non-coastal uplands areas, the extent of shrubland in this region is decreasing annually by at least 1.5%.

Our analysis indicates that maintaining the current extent of shrubland in non-coastal upland areas of Rhode Island would require increasing the area of clearcuts that produce shrubland by 190–290% (Table 4). We recommend the higher target, which would require harvesting less than 0.1% of forested area in the state each year. Over time, the harvesting target could be met largely by private landowners, who are already implementing most forest management in the state. However, in order to launch this program rapidly and in a coordinated manner, we propose achieving the target initially on conservation properties owned by state and federal agencies, environmental organizations and land trusts. This would require clearcutting 0.3% of the upland forests on conservation land each year. Harvesting at this level for 20 years would only impact 6% of the forested land on conservation properties. Decisions about where to clear forests would have to be based on well-documented datasets that provide information on the spatial extent, patch size, and trends in habitat conversion of shrubland and forests.

We recommend the establishment of an advisory committee to encourage the expansion of forest management activities on conservation land. The advisory committee, which would include representation of state and federal agencies, environmental organizations and land trusts, would monitor progress towards achieving targets for habitat creation on conservation land. At the same time, outreach programs should encourage greater involvement of private landowners in creating shrubland habitat. Landowners with limited land holdings should be encouraged to create small clearcuts of at least 0.6 ha, which provide habitat for most shrubland birds. Conservation organizations and landowners with larger land holdings should create larger clearcuts where possible, as they are an efficient means of increasing the overall area of shrubland and are preferred by species such as the New England cottontail. Locating clearcuts near existing shrubland, powerline rights of way or wetland forests will increase the potential of small clearcuts to meet the needs of area-sensitive species. Furthermore, expanding existing patches of shrubland and creating clearcuts on the periphery of forest patches will increase the area of shrubland without significantly reducing the size of large forest patches that are essential habitat for many species of plants and animals.

Our findings highlight the critical contribution of powerline maintenance to shrubland habitat. We classified 82% of the powerline areas as shrubland, excluding agriculture and developed areas. Powerlines provide suitable habitat for many shrubland birds (Askins, 1994; Confer and Pascoe, 2003; King and Byers, 2002), although there is concern that the long narrow shapes may have a negative impact on nest success (Kubel and Yahner, 2008; Weldon and Haddad, 2005). Power utilities have pioneered approaches such as selective cutting followed by herbicide application to increase the persistence of shrubland habitat (Tefft, 2006). Maintaining the current extent of shrubland without the contribution of powerline management would require clearing an additional 113 ha per year, which would require increasing the current rate of forest management by 500%. Fortunately 78% of the powerlines are located in non-coastal upland areas where shrubland coverage is the least.

We recognize that our proposed harvesting target would not necessarily stabilize the extent of shrubland habitat over the long term. Over 40% of the existing shrubland in the state originated from abandoned agriculture land. Since less agriculture land is currently being abandoned, the portion of shrubland originating from abandoned agriculture will gradually decline, reducing the average persistence of shrubland and increasing the area of annual clearcuts required to maintain the current extent of shrubland. However, this will be partially countered by the increasing susceptibility of the maturing forests to wind damage, which will accelerate the creation of new shrubland in the coming decades. Furthermore, climate change is expected to increase Atlantic hurricane wind speeds, which may cause larger blowdowns which would create more shrubland (Busby et al., 2008). Thus harvesting targets will need to be updated regularly based on the most current data on the extent of shrubland habitat.

5. Conclusions

A goal of this study was to determine if forest management being implemented by conservation organizations and private landowners is maintaining the current extent and patch size of shrubland habitat required by wildlife species. Our results suggest that this is not the case, and the extent of shrubland will continue to decline without active management, leading to the loss of habitat for many wildlife species. Considering the lack of consensus about conservation targets for the amount of shrubland, we propose that conservation organizations attempt to stabilize rather than expand the extent of shrubland habitat. This approach would provide an opportunity to assess whether the current extent of shrubland is sufficient to maintain reduced but stable wildlife populations that require this habitat. We propose a coordinated forest management program with targets for increased forest management on conservation lands.

Measuring the amount of shrubland and temporal patterns of change in this type of successional habitat are problematic because existing land cover data are unable to accurately distinguish between forest and shrubland and detect the small patches of shrubland that are common in the region. This limits the ability of conservation organizations to plan effective habitat management programs. The methodology used in this study provides a means to collect valuable information on the extent of shrubland habitat and forest clearcuts that facilitates identification of priority areas for forest management.

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References

AFA, 2010. Forest Conservation in 2009: A Farm Bill Progress Report. American Forest Foundation, Washington.

Alerich, C., 2000. Forest Statistics for Rhode Island: 1985 and 1998. Resource Bulletin NE-149. US Departure of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA.

Askins, R.A., 1994. Open corridors in a heavily forested landscape: impact on shrubland and forest-interior birds. Wildlife Society Bulletin 22, 339–347.

Askins, R.A., Zuckerberg, B., Novak, L., 2007. Do the size and landscape context of forest openings influence the abundance and breeding success of shrubland songbirds in southern New England? Forest Ecology and Management 250, 137–147.

Berlick, M.M., Kittredge, D.B., Forest, D.R., 2002. The Illusion of Preservation – A Global Environmental Argument for the Local Production of Natural Resources. Harvard Forest Paper 26. Harvard University, Petersham, Massachusetts.

Blomberg, E.J., Tefft, B.C., Endrulat, E.G., McWilliams, S.R., 2009. Predicting landscape-scale habitat distribution for ruffed grouse *Bonasa umbellus* using presence-only data. Wildlife Biology 15, 380–394.

Boose, E.R., Chamberlin, K.E., Foster, D.R., 2001. Landscape and regional impacts of hurricanes in New England. Ecological Monographs 71 (1), 27–48.

Brown, J.H., 1960. The role of fire in altering the species composition of forests in Rhode Island. Ecology 41, 310–316.

Buffum, B., 2011. Can Forest Management Maintain the Extent of Shrubland Habitat in Rhode Island? A Spatial Analysis. University of Rhode Island, Department of Natural Resources, Kingston, RI. Available from: <http://nrs.uri.edu/ce/ProjectReports.html>.

Busby, P.E., Motzkin, G., Boose, E.R., 2008. Landscape-level variation in forest response to hurricane disturbance across a storm track. Canadian Journal of Forest Research 38, 2942–2950.

Butler, B.J., Payton, B., 2009. Rhode Island's Forest Resources, Res. Note NRS-96. US Departure of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA.

Butler, B.J., Payton, B., 2011. Rhode Island's forest resources, 2009. Res. Note NRS-96. U.S. Departure of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, PA.

Chandler, R.B., King, D.I., Chandler, C.C., 2009. Effects of management regime on the abundance and nest survival of shrubland birds in wildlife openings in northern New England, USA. Forest Ecology and Management 258, 1669–1676.

Confer, J.L., Pascoe, S.M., 2003. Avian communities on utility rights-of-ways and other managed shrublands in the northeastern United States. Forest Ecology and Management 185, 193–205.

Costello, C.A., Yamasaki, M., Pekins, P.J., Leak, W.B., Neefus, C.D., 2000. Songbird response to group selection harvests and clearcuts in a New Hampshire northern hardwood forest. Forest Ecology and Management 127, 41–54.

DeGraaf, R.M., Yamasaki, M., 2003. Options for managing early-successional forest and shrubland bird habitats in the northeastern United States. Forest Ecology and Management 185, 179–191.

DeGraaf, R.M., Yamasaki, M., Leak, W.B., Lester, A.M., 2006. Technical Guide to Forest Wildlife Habitat Management in New England. University Press of New England, Hanover.

Dettmers, R., Rosenberg, K.V., 2000. Partners in Flight Landbird Conservation Plan: Physiographic Area 9: Southern New England. Partners in Flight. Available from: <http://www.partnersinflight.org/bcps/pifplans.htm>.

Endrulat, E.G., McWilliams, S.R., Tefft, B.C., 2005. Habitat selection and home range size of ruffed grouse in Rhode Island. Northeastern Naturalist 12 (4), 411–424.

Enser, R.W., Lundgren, J.A., 2006. Natural Communities of Rhode Island. Rhode Island Natural History Survey, Kingston, RI. Available from: <http://www.rinhs.org/wp-content/uploads/ricommclass.pdf>.

Ferguson, R.H., McGuire, H.R., 1957. The Timber Resources of Rhode Island. Northeastern Forest Experiment Station, Forestry Service, US Department of Agriculture, Upper Darby, PA.

Foster, D.R., Aber, J.D., 2004. Forests in Time: the Environmental Consequences of 1,000 years of Change in New England. Yale University Press, New Haven.

Fuller, T.K., DeStefano, S., 2003. Relative importance of early-successional forests and shrubland habitats to mammals in the northeastern United States. Forest Ecology and Management 185, 75–79.

Golet, F.C., Parkhurst, J.A., 1981. Freshwater wetland dynamics in South Kingstown, Rhode Island, 1939–1972. Environmental Management 5, 245–251.

Hooker, T.D., Compton, J.E., 2003. Forest ecosystem carbon and nitrogen accumulation during the first century after agricultural abandonment. Ecological Applications 13, 299–313.

Irland, L., 1999. The Northeast's Changing Forest. Harvard University Press, Persham, Massachusetts.

King, D.I., Byers, B.E., 2002. An evaluation of powerline rights-of-way as habitat for early-successional shrubland birds. Wildlife Society Bulletin 30, 868–874.

Kupa, J.J., Whitman, W.R., 1972. Land-cover Types of Rhode Island: an Ecological Inventory. URI Agricultural Experiment Station Bulletin 409. University of Rhode Island, Kingston, RI.

Kubel, J.E., Yahner, R.H., 2008. Quality of anthropogenic habitats for Golden-winged Warblers in central Pennsylvania. The Wilson Journal of Ornithology 20 (4), 801–812.

Latham, R.E., 2003. Shrubland longevity and rare plant species in the northeastern United States. Forest Ecology and Management 185, 21–39.

Litvaitis, J.A., 1993. Response of early successional vertebrates to historic changes in land use. Conservation Biology 7, 866–873.

Litvaitis, J.A., 2001. Importance of early successional habitats to mammals in eastern forests. Wildlife Society Bulletin 24, 466–473.

Litvaitis, J.A., 2003. Are pre-Columbian conditions relevant baselines for managed forests in the northeastern United States? Forest Ecology and Management 185, 113–126.

Litvaitis, J.A., Tash, J.P., Litvaitis, M.K., Marchand, M.N., Kovach, A.I., Innes, R., 2006. A range-wide survey to determine the current distribution of New England cottontails. Wildlife Society Bulletin 34, 1190–1197.

Lorimer, C.G., 2001. Historical and ecological role of disturbance in eastern North American forests: 9000 years of change. Wildlife Society Bulletin 29, 425–439.

MacConnell, W.P., 1974. Remote Sensing Land Use and Vegetative Cover in Rhode Island. Bulletin No. 200, July 1974. Cooperative Extension Service, University of Rhode Island, Kingston, RI.

NIFC, 2010. Wildland Fire Statistics Year-to-Date by State (2005–2009). National Interagency Fire Center, Boise, Idaho. Available from: <http://www.nifc.gov/fire_info/fire_stats.htm>.

Novak, A.B., Wang, Y.Q., 2004. Effects of suburban sprawl on Rhode Island's forests: a Landsat view from 1972 to 1999. Northeastern Naturalist 11, 67–74.

Oehler, J.D., 2003. State efforts to promote early-successional habitats on public and private lands in the northeastern United States. Forest Ecology and Management 185, 169–177.

Parrish, J.D., 1997. Patterns of frugivory and energetic condition in nearctic landbirds during autumn migration. The Condor 99, 681–697.

Peirce, E.S., 1968. Salvage Programs Following the 1938 Hurricane. University of California, Regional Oral History Office, Berkely, CA.

Peters, J., Bowers, T., 1977. Forest Statistics for Rhode Island. USDA Forest Service Resource Bulletin NE-49. USDA Forest Service, Upper Darby, PA.

RIDEM, 2005. Rhode Island's Comprehensive Wildlife Conservation Strategy. Division of Fish and Wildlife, State of Rhode Island Department of Environmental Management, Providence, RI. Available from: <http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/swgplan.pdf>.

RIDEM, 2010. Rhode Island Forest Resources Assessment and Strategies – a Path to Tomorrow's Forests. Department of Environmental Management, Division of Forest Environment, North Scituate, Rhode Island. Available from: <http://www.dem.ri.gov/programs/bnatres/forest/index.htm>.

Schlossberg, S., King, D.I., 2007. Ecology and Management of Scrub–shrub Birds in New England: A Comprehensive Review. Natural Resources Conservation Service, Resource Inventory and Assessment Division, Beltsville, Maryland.

Schlossberg, S., King, D.I., Chandler, R.B., Mazzei, B.A., 2010. Regional synthesis of habitat relationships in shrubland birds. Journal of Wildlife Management 74, 1513–1522.

Smith, S.B., McPherson, K.H., Backer, J.M., Pierce, B.J., Podlesak, D.W., McWilliams, S.R., 2007. Fruit quality and consumption by songbirds during autumn migration. The Wilson Journal of Ornithology 119, 419–428.

Tefft, B.C., 2006. Managing shrublands and old fields. In: Oehler, J.D., Covell, D.F., Capel, S., Long, B. (Eds.), Managing Grasslands, Shrublands, and Young Forest Habitats for Wildlife: A Guide for the Northeast. The Northeast Upland Habitat Technical Committee, Massachusetts Division of Fisheries and Wildlife, Westborough, MA. Available from: <http://www.wildlife.state.nh.us/Wildlife/Northeast_Hab_Mgt_Guide.htm>.

TNC, 2010. Tillinghast Pond Management Area. The Nature Conservancy, Providence, RI. Available from: <http://www.nature.org/wherewework/northamerica/states/rhodeisland/preserves/art26509.html>.

Trani, M.K., Brooks, R.T., Schmidt, T.L., Rudis, V.A., Gabbard, C.M., 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29, 413–425.

USFWS, 2008. Rhode Island National Wildlife Refuge Complex – 2008–09 Annual Habitat Work Plan. US Fish and Wildlife Service, Charlestown, RI. Available from: <http://www.fws.gov/trustompond/management.html>.

Wagner, D.L., Nelson, M.W., Schweitzer, D.F., 2003. Shrubland Lepidoptera of southern New England and southeastern New York: ecology, conservation, and management. Forest Ecology and Management 185, 95–112.

Weldon, A.J., Haddad, N.M., 2005. The effects of patch shape on indigo buntings: evidence for an ecological trap. Ecology 86 (6), 1422–1431.

Williamson, S., 2008. Bird conservation region 30: New England/mid-Atlantic Coast. In: Kelley, J., Williamson, S., Cooper, T.R. (Eds.), American Woodcock Conservation Plan. Wildlife Management Institute, Cabot, Vermont, pp. 138–147. Available from: <http://timberdoodle.org>.