Full length article

Effects of silvicultural treatments on Cerulean Warbler (*Dendroica cerulea*) abundance in southern Indiana

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**ARTICLE INFO**

Article history:

Received 13 July 2007

Accepted 21 February 2008

Keywords:

Cerulean Warbler

*Dendroica cerulea*

Silviculture

Uneven-age management

Selective logging

**ABSTRACT**

The Cerulean Warbler (*Dendroica cerulea*), a once common summer inhabitant and breeder in southern Indiana, has declined at both the local and continental population levels. Because Cerulean Warblers tend to nest in large deciduous trees, they are especially at risk due to deforestation of mature tree stands. Few studies have examined the effects of specific silvicultural practices (i.e., group and single tree selection harvesting methods) on the distribution and abundance of the Cerulean Warbler. During the summers of 2005 and 2006, Cerulean Warblers were surveyed within the Morgan-Monroe and Yellowwood state forests, as well as the Hoosier National Forest in southern Indiana. Three treatment types were surveyed; unharvested reference sites (stands 35-100+ years old) were compared with single tree selection treatments and treatments where a combination of group and single tree selection was used (stands 2-30 years old). Mean bird abundance was estimated from bird surveys to determine if trends exist between silvicultural regimes and Cerulean Warbler abundance. Cerulean Warblers were located in all treatment types, with no significant differences (*p* = 0.654) in abundance among treatment types examined (unharvested – 0.36, single tree – 0.46, group and single tree combination – 0.36). These results suggest that uneven-age management practices, such as single tree and group selection harvesting, provide suitable breeding habitat for Cerulean Warblers.

1. Introduction

The Cerulean Warbler (*Dendroica cerulea*) has become a bird of increasing conservation concern and focus. This species is listed as vulnerable by IUCN (*Birdlife International, 2004*). Once a common summer inhabitant and breeder in south-central and southeastern Indiana (*Branner, 1998*), it has declined at both the local and continental population levels (*Hamel, 1998, 2000; Hands et al., 1989; Robbins et al., 1992*). In Indiana, the Cerulean Warbler is now listed as a “species of special concern” (*Hamel, 1998*). Although this offers no government supported protection for this small Neotropical migrant, it has called attention to the need for research and conservation efforts (*Hamel, 1998*).

Between 1966 and 1987, Cerulean Warbler populations experienced declines greater than any other North American wood warbler (*Robbins et al., 1992*), averaging a 3.4% annual decrease based on North American Breeding Bird Survey data (*Hamel, 1998; Robbins et al., 1992*). Within this same time period Cerulean Warbler populations in Ohio and Indiana declined 3.6% and 2.7% per year, respectively (*Hands et al., 1989*).

The breeding range of the Cerulean Warbler extends from the Mississippi Alluvial Valley north into southern Ontario, Canada, and spans from Illinois in the west to New York in the east (*Hamel, 2000*). Habitat fragmentation and loss of overall habitat within this range is often blamed for the decline of Cerulean Warbler populations (*Hamel, 1998, 2000; Robbins et al., 1992*). Because Cerulean Warblers tend to nest high in large deciduous trees that are found in expansive, unfragmented, interior tracts of forest (*Hamel, 2000*), they are especially at risk due to deforestation of the deciduous, mature forests during the past 200 years. Clearing of land for agricultural use and the prevalence of urban sprawl during the past century quickly replaced much of the forestsed landscape (*Robbins et al., 1992*).

The effects of silvicultural practices on the distribution and abundance of the Cerulean Warbler is relatively unknown. Recommended prescriptions for optimal breeding habitat include: (a) protecting trees on large, lowland tracts of deciduous forests, (b) longer rotation management to permit tree maturation, (c) uneven-age management, (d) techniques that favor canopy gaps, and (e) even-age management combined with long rotations (*Flashpohler, 1993; Hamel, 2000; Hands et al., 1989; Lynch, 1981; Oliarnyk and Robertson, 1996*). Limited published information is available on the species’ response to forest management activities. In West Virginia, *Wood et al. (2005)* examined Cerulean Warbler...
abundance in 15–18-year-old regenerated clear-cut stands, as well as two-age harvest stands. They detected more Cerulean Warblers in regenerated 15–18 year two-age (uneven-age) versus clear-cut stands (even-age), but the differences were not significant. When these two treatments were compared to 70–80 year unharvested control sites, Cerulean Warbler abundance was greater in unharvested control areas than in clear-cut stands, but there were no differences between the mature control stands and 15–18 year regenerated two-age treatments. We provide additional insight by comparing Cerulean Warbler abundance in specific uneven-age treatments (i.e., group and single tree selection) to unharvested reference sites in other regions.

Our specific objectives were: (1) to determine if Cerulean Warbler abundance is greater in mature stands of trees with fewer associated edges, as in the Deam Wilderness Area of the Hoosier National Forest, than in selectively harvested stands in the Morgan-Monroe and Yellowwood state forests, (2) to compare bird abundance within the state forests between single tree selection harvesting practices and practices using a combination of single tree and group selection, and (3) to determine if a correlation exists between bird abundance and the number of years since a harvest had occurred.

2. Methods

2.1. Study area

The study was conducted from May through July of 2005 and 2006 within the Morgan-Monroe and Yellowwood state forests, and within the Charles C. Deam Wilderness Area of the Hoosier National Forest (Fig. 1). Both the state forests and the Deam Wilderness area of the Hoosier National Forest are comparable in tree structure and composition, where the overstory consists mainly of hickory and oak species (Indiana State Forest, USDA Forest Service, unpublished data). Morgan-Monroe and Yellowwood state forests are approximately 9716 ha and 9444 ha, respectively. Beginning in the 1960s, both the Morgan-Monroe and Yellowwood state forests have been harvested using single tree selection and group selection practices on 20–30 year cutting cycles (Jenkins and Parker, 1998). Currently, both forests are actively managed for harvesting in delineated sub-units of land called ‘tracts’. Surveyed tract sizes were variable and ranged in size from 9 to 65 ha, with an average tract size of approximately 34 ha. The average stand age is 17 years of age.

In the Hoosier National Forest, clear cutting was the predominant harvesting method from the late 19th century into the 20th century. The Charles C. Deam Wilderness Area of the Hoosier National Forest was officially established in 1982, and is located in Brown and Monroe counties. This area is approximately 5261 ha. Although forest harvest history within the Deam Wilderness Area is variable, there has been no commercial harvesting since at least 1966. The average stand age of surveyed tracts within the Hoosier National Forest is 98 years of age.

2.2. Bird survey

Study plots consisted of a $7 \times 7$ (1.96 km$^2$) grid with survey points 200 m apart from one another, recorded in Universal Transverse Mercator (UTM) using a Global Positioning System unit. This grid was applied to 7 of 10 study sites, arranged in seven north–south transect lines. Survey grids on the remaining three sites (all within the Morgan-Monroe and Yellowwood state forests) had to be reduced in size due to private property boundaries (1.52, 1.12, and 0.8 km$^2$ in size). Male Cerulean Warblers were located, both visually and aurally, by song presence at each survey point as we traversed transects. Seven minutes were spent at every survey point. The number of minutes spent at each survey point was varied to ensure an adequate number of minutes at each point, allowing for a more comprehensive survey of the area.
point. After an initial observation period of 3 min, a playback of conspecific male song recordings was used to elicit a vocal response (Falls, 1981). These recordings were played for approximately 1 min followed by an additional 3 min of observations without playback. Surveys took place between 05:30 and 10:30 h of each day beginning 1st May and ending no later than 30th May, as males began to establish territories and were most vocal. Surveys were not conducted on days when rain or high winds prevented vocalizations from occurring or being heard.

2.3. Silvicultural analysis

Records of past harvesting that included when, where, and how trees were harvested, as well as topographic maps of the study area were obtained from the Indiana Department of Natural Resource and the Hoosier National Forest. The history of three silvicultural practices within the study grids was examined: (a) unharvested control sites (regeneration in stands is 35–100+ years old), (b) single tree selection sites (regeneration in stands is 2–30 years old), and (c) sites containing a combination of single tree and group selection (regeneration in stands is 2–30 years old). Group selection openings, which are small pockets of harvested trees within a forested landscape, ranged in size from 0.2 to 1.4 ha. Geographic Information System layers were generated for Cerulean Warbler detections within the forest tracts based on methods of harvesting and time of harvest. Shapefiles of Cerulean Warbler point detections were overlaid on state and national forest maps to determine if current forest structure throughout the study site is correlated with the distribution and abundance of Cerulean Warblers.

Due to the nature of state forest management, harvested tracts were of varying ages and sizes. Therefore, treatment areas were analyzed proportionally by calculating weighted means, based on the number of survey points that fell within each treatment. Mean bird abundance was estimated from bird surveys for each of the three forest types.

Statistical tests were performed at alpha level 0.05, and data for 2005 and 2006 were combined. An analysis of variance (ANOVA) was used to test for differences in mean number of birds between single tree and the combination of single tree and group selection treatment types, as well as areas of no harvest. Also, years since harvest was studied to determine if Cerulean Warbler presence might be more abundant in older forest tracts due to increased canopy height and increased complexity in vertical structure that occurs as a disturbed forest develops (Spies, 1997). Since these data had a non-normal distribution, a Spearman’s rank correlation was used to determine if any correlation existed between number of bird detections and years since harvest among all surveyed tracts.

3. Results

A total of 157 Cerulean Warblers were detected over 2 years. There were no significant differences in Cerulean Warbler abundance among the three treatment types examined (Tables 1 and 2). In the state forests, there were no statistically significant differences in Cerulean Warbler abundance between the two uneven-age treatments (Tables 1 and 2). And, finally, no correlation was revealed between number of bird detections and years since harvest for any of the tracts surveyed within our study grids ($r_s = -0.139, p = 0.128, \text{Fig. 2}$).

4. Discussion

Although overall Cerulean Warbler abundance estimates were low, birds were detected in all three forest treatment types examined. Years since harvest also was not a predictor of bird abundances. These conclusions support the hypothesis that sustainable forestry practices (i.e. uneven-age management), such as those currently conducted in Yellowwood and Morgan-Monroe state forests, can and do provide Cerulean Warblers with suitable breeding habitat.

Many studies have concluded that Cerulean Warblers utilize areas around canopy gaps (Wood and Wood, 2005; Hamel, 2000; Oliarnyk, 1996; Oliarnyk and Robertson, 1996). Uneven-age treatments such as single tree selection likely mimic natural canopy gaps that occur in mature forests (Flashpohler, 1993), as well as maintain an adequate number of the large trees necessary for Cerulean Warbler territory establishment and nesting (Jones and Islam, 2006; Islam et al., 2006). Although our study examined specific uneven-age treatment types, and a broader age difference between forests (2–100+ years), the conclusions are similar to those of Wood et al. (2005), who found no significant differences in Cerulean Warbler abundance between unharvested control stands and two-age treatments (15–18 years old). However, clear-cut treatments differed significantly in bird detections from control stands (Wood et al., 2005), and while clear-cut treatments were not examined in our study, it is obvious that they result in immediate habitat loss for Cerulean Warblers and other interior forest dwelling birds that may take years to regenerate.

Although group selection practices offer an alternative to clear-cut methods, forested edges are still produced as a result of these openings. Edge areas are attractive to brood-parasitic

### Table 1
Mean number of Cerulean Warbler (*Dendroica cerulea*) males detected per survey points across forest treatment types in southern Indiana

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$x \pm$ S.D.</th>
<th>$N$ survey points</th>
<th>$f$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature/unharvested</td>
<td>0.36 ± 0.64</td>
<td>204</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single tree</td>
<td>0.46 ± 0.81</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group and single tree selection</td>
<td>0.36 ± 0.70</td>
<td>179</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.39 ± 0.68</td>
<td>424</td>
<td>0.420</td>
<td>0.654</td>
</tr>
</tbody>
</table>

Data for 2005 and 2006 were combined and results of ANOVA are reported.

### Table 2
Data table illustrating the percentage of Cerulean Warbler (*Dendroica cerulea*) detections per silviculture treatment type during 2005 and 2006 in southern Indiana

<table>
<thead>
<tr>
<th>Study year</th>
<th>Treatment type</th>
<th>No. of survey points per treatment</th>
<th>No. of detections per treatment</th>
<th>% Detections per treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Single tree</td>
<td>41</td>
<td>6</td>
<td>14.6</td>
</tr>
<tr>
<td></td>
<td>Group and single tree</td>
<td>179</td>
<td>27</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td>Mature/unharvested</td>
<td>204</td>
<td>38</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>424</td>
<td>71</td>
<td>18.6</td>
</tr>
<tr>
<td>2006</td>
<td>Single tree</td>
<td>41</td>
<td>5</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>Group and single tree</td>
<td>179</td>
<td>44</td>
<td>24.6</td>
</tr>
<tr>
<td></td>
<td>Mature/unharvested</td>
<td>204</td>
<td>37</td>
<td>18.1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>424</td>
<td>86</td>
<td>18.1</td>
</tr>
</tbody>
</table>
Brown-headed Cowbirds (Molothrus ater) and other nest predators that may reduce survivorship of forest dwelling birds such as the Cerulean Warbler (Brittingham and Temple, 1983). Through a simulated model of uneven-age management, Thompson (1993) found that edges produced through multiple, small group selection openings could reduce fecundity in forest-interior dwelling bird species, but the model predicted even greater decreases in bird populations resulting from clear-cut treatments, due to the dramatic change in forest structure. Furthermore, in southern Indiana cowbird parasitism is not isolated to areas of active forest management. Even in mature tracts of forest such as the Deam Wilderness Area, Brown-headed Cowbirds parasitized two out of nine Cerulean Warbler nests located over a 2-year period (Islam et al., 2006). This suggests that, despite increased risk of edge effects from multiple smaller openings, group selection treatments may provide a better alternative to traditional clear-cut treatments for maintaining Cerulean Warbler populations.

Longer rotations support the large, mature trees critical for Cerulean Warbler habitat (Jones and Robertson, 2001; Hamel, 1998; Flashpholer, 1993). In Morgan-Monroe and Yellowwood state forests, Cerulean Warbler habitat needs appear to be supported by 20–30 year cutting cycles combined with uneven-age management and timber stand improvement practices. Evans and Fischer (1997) suggested that timber stand improvement involving the removal of trees of low quality may be an important technique for the enhancement of Cerulean Warbler habitat.

5. Conclusion

Uneven-age silviculture treatments in southern Indiana forests appear to be compatible with Cerulean Warbler breeding habitat needs. In Ontario, Canada, Cerulean Warblers were not only found to occur in forests that had been selectively cut, but Cerulean Warbler reproductive success also did not differ significantly in these areas compared to unmanaged areas (Oliarnyk, 1996). Studies of nesting success within Morgan-Monroe and Yellowwood state forests will be necessary to determine whether or not forests that have been selectively logged are also viable source populations of Cerulean Warblers.

Acknowledgements

We thank the Amos W. Butler Audubon Society, the Ball State University Chapter of Sigma Xi, and the Ball State Office of Academic Research and Sponsored Programs for providing financial support for this project. We would especially like to thank April Howard, Kelly Jones, Kirk Roth, and Erin Arnold for their help both in and out of the field. Dr. Jim Jones offered a great deal of statistical support, and Jim Allen, Dave Vadas, Ben Hubbard, and Dale Weigel also provided much assistance in determining placement of survey plots, obtaining GIS shapefiles, and gathering information on silviculture records. One of the figures was modified with the assistance of Angela Gibson. This manuscript has greatly improved by the comments and suggestions of two anonymous reviewers and the editor.

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