# SILVICULTURE FOR A DECLINING SPECIES, CERULEAN WARBLER: 10-YEAR RESULTS OF A PILOT STUDY IN THE MISSISSIPPI ALLUVIAL VALLEY

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**Abstract**—We report on the current status of a long-term study of Cerulean Warbler (*Setophaga cerulea*) response to silviculture on a 58-ha tract in Desha County, Arkansas. The work involved a 10 year pre-manipulation monitoring of the birds on the tract, followed by implementation of a split plot comparison of alternative treatments, each applied to a randomly selected half of the original plot. We present results of the alternative treatments on warbler species occurrence, distribution and standing crop of canopy and subcanopy trees, and composition and abundance of advanced regeneration resulting from the manipulation applied in 2002-2004. Basal areas in the area managed by the Cerulean Warbler prescription were higher than those in area managed by a standard prescription. Advanced regeneration did not meet company standards for favored species on nearly 2/3 of the company treated area and almost 90 percent of the area treated with the Cerulean Warbler prescription. Interpretation of these values was complicated by lingering effects of a devastating 1994 ice storm. This necessarily unreplicated study serves as a pilot for later evaluation of a Cerulean Warbler silvicultural treatment. It is a cautionary tale because continuing decline of the Cerulean Warbler population introduces an unknown amount of uncertainty into interpretation of the response of the birds to the experimental manipulation; no Cerulean Warblers were recorded on the plot in the most recent survey. The study provides a basis to consider trade-offs in management for a resource that may be dominated by extra-ownership effects beyond the manager's control or manipulation.

## INTRODUCTION

Silviculture for Songbirds, the practice of managing forests to produce specific habitats for bird communities of interest, is usually practiced as a process in which a prescription designed to produce specific forest products is applied to stands of interest and the response of birds to the habitats resulting from the manipulations is monitored as a design output. The process is a well-respected one, a reasonable basis for adaptive management applications (Powell and others 2000), and one that works especially well for targeting community or guild responses. In the case of particularly vulnerable species, of which the Cerulean Warbler (*Setophaga cerulea*) is certainly one (Buehler and others 2013, Hamel 2000, US Fish and Wildlife Service 2006), the importance of silviculture to the continued existence of the species is well-recognized (Boves and others 2013, Buehler and others 2008, Hamel 2005) among other actions (Buehler and others 2006). For such vulnerable species as the Cerulean Warbler, a management approach directly tailored to the biology of the species may be more useful than one based simply on monitoring avian response to standard silvicultural prescriptions.

The current report is the third in a series depicting an experimental silviculture prescription designed to produce habitat conditions identified from observations of the behavioral ecology of Cerulean Warbler (Hamel and others 2006, Hamel and others 2010). Our objective is to evaluate the response of the birds to the treatment over a 10-year entry cycle, and to compare the standing crop of trees and advanced regeneration at the end of the cycle. Our work has been a necessarily unreplicated study as no other suitable study sites were available in the physiographic province in which we work.

## METHODS

### Study Area Location and Recent History

The study area is a 58-ha (143 acres) portion of a larger 130-ha (320 acres) management unit on properties managed by Anderson Tully Co. (ATCO), a division of The Forestland Group, in Desha County., Arkansas (33° 44' 42" N, 91° 9' 30" W, fig. 1). Primary management of

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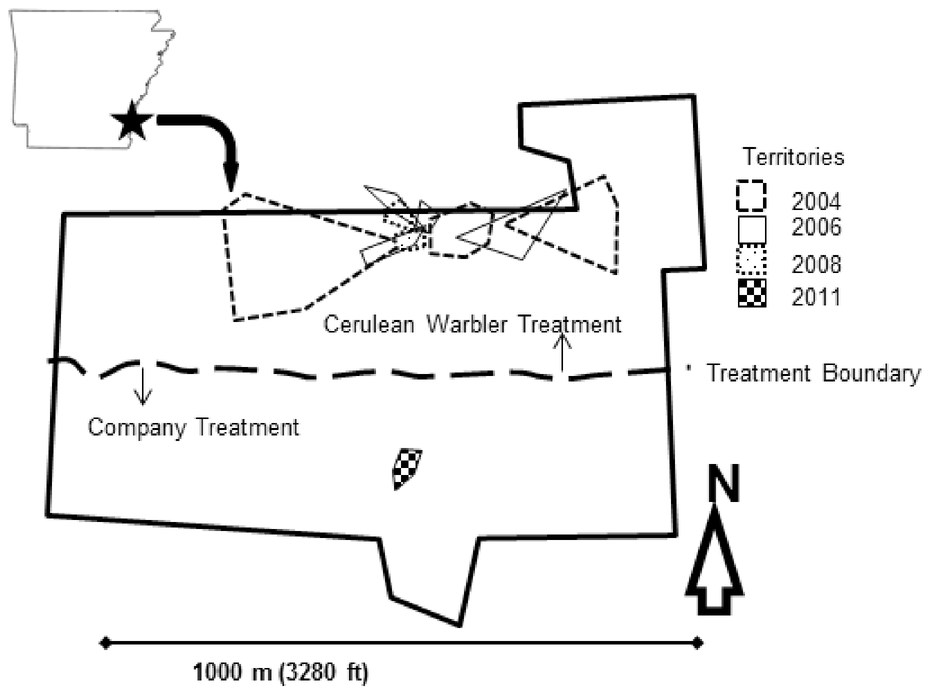


Figure 1—Cerulean Warbler study site in Desha County, Arkansas, USA.

the unit is for large sawtimber products of bottomland hardwoods. After the harvest entry into the unit in 1991, which was conducted according to standard company prescription, the study area was removed from the management portfolio of the company to enable study of behavioral ecology of Cerulean Warbler on it. As such, the study area was not available for company salvage logging activities subsequent to a devastating 1994 ice storm that affected much of a 20 county area in Arkansas and adjacent Mississippi. The storm created extensive damage to the forest canopy of the study area with heavier damage to the midstory than overstory trees of the stand (Christopher A. Woodson, U.S. Fish and Wildlife Service, 101 Park DeVille Drive, Suite B, Columbia, MO 65203, unpublished analyses).

Forest vegetation of the study area is bottomland hardwoods of the riverfront hardwoods subtype (Hodges 1997, Johnson 1973), characterized by American sycamore (*Platanus occidentalis*), eastern cottonwood (*Populus deltoides*), American elm (*Ulmus americana*), sweet pecan (*Carya illinoiensis*), green ash (*Fraxinus pennsylvanica*). Soils in the study area are of Sharkey-Commerce-Coushatta association (Gill and others 1972), which are young silt loam soils in new meanders of the Mississippi River. The study area and adjacent company lands in Desha County are within the Mississippi River batture lands.

The study area, one of three in a larger study of Cerulean Warbler behavioral ecology (Hamel 2005), is near the extreme southern end of the breeding range of the species. The others are in Shelby and Lauderdale Counties. in Tennessee.

## Treatments

For a complete description of treatments and site conditions, please see Hamel and others (2006, Hamel and others 2010). Treatments applied in the study, defined in Hamel and others (2006), are abstracted as follows.

**Company Treatment**—This partial cutting prescription involved elements of improvement cutting, thinning, and regeneration cutting. It involved harvesting overstory trees to reduce mortality, improve species composition and spacing, and increase growth of the residual stand. It further involved cutting midstory trees to remove poorly formed shade tolerant species in order to release advanced regeneration and encourage the establishment and growth of additional shade intolerant regeneration of desirable species.

**Cerulean Warbler Treatment**—This partial cutting prescription was a modification of the standard prescription, involving elements of improvement cutting, thinning, and regeneration cutting. The prescription differed from the standard prescription in that fewer trees were removed from the shade tolerant midstory.

### Avian Sampling

We conducted territory mapping of Cerulean Warbler, Northern Parula (*Setophaga americana*), American Redstart (*S. ruticilla*), Yellow-throated Warbler (*S. dominica*), Hooded Warbler (*S. citrina*), Swainson's Warbler (*Limnothlypis swainsonii*), as well as daily tallies of all bird species observed on the study area during breeding season visits. Sample sizes by year were as follows: 2004 (5 samples), 2005 (1), 2006 (8), 2007 (1), 2008 (4), 2011 (3), 2012 (8), 2013 (8), 2014 (1). Anticipated fieldwork in 2010, as well as half of that in 2011, and portions in other years could not be conducted because flooding precluded access to the study site. Sampling consisted of walking surveys by observers (authors Smith or Hamel) on predetermined routes through the study area, during which encountered individuals were marked on maps. Territory maps were prepared from the field maps; a territory was assigned to the area where a male bird was recorded on at least three visits in a year. Results from these territory maps depict the composite response of the Cerulean Warbler to the treatments. In addition to the mapped locations, associated observations of behavior of the birds were used to interpret Cerulean Warbler use of the treatments. The composite map of the response of the birds to the treatments (fig. 1) was evaluated by visual inspection.

### Vegetation Sampling

We measured the forest vegetation of the study area after the 2013 growing season at two scales. Measurements of canopy vegetation were made at regularly spaced intersections of a 50x50m grid of the study area (N = 260). Grid intersections on the border between the two treatments were assigned alternately to Company Treatment or Cerulean Warbler Treatment systematically from a random starting point. At each such intersection, a variable-radius sample was taken using a 6.9-$m^2$/ha (30 $ft^2$ per acre) basal area factor sampling device (JIM-GEM® Cruz-All, Forestry Suppliers, Inc., Jackson, MS). Each apparent in-tree was identified to species, and its crown class dominant, co-dominant, intermediate, suppressed), diameter at 1.4 m (4.5 ft) above ground level, height using a hypsometer (Haglöf, Långsele, Sweden) , presence of vines in the canopy, and distance and azimuth from the grid point were recorded. After fieldwork was completed, the record of diameters was screened to remove trees from the sample whose center was farther from the grid point than the limiting distance of the basal area factor for the measured diameter. The sample measurements were summarized into density and basal area data for individual species, for different shade tolerance classes (Burns and Honkala 1990), and by ATCO Market Classes (table 1). Resulting summaries for the two treatments were compared using t-tests, with significance accepted at experiment-wide Bonferroni-corrected $\alpha$ = 0.05.

Advanced regeneration developed or promoted as a result of the treatments in this study was measured at 0.0004 ha (0.001 acre, "milacre") fixed radius plots. All stems less than 10.2 cm (4 in) diameter in these plots were tallied to species and recorded in one of two categories, those (a) shorter and (b) taller than 1.4 m (4.5 ft). These plots were located as follows: one plot was superimposed on each grid intersection and the other two plots were sited 12.5 m (41 ft) away from that center plot. In grid locations within the two treatments these plots were located east and west of the intersection. For gridpoints on the border of the treatments, the two plots were placed north and south of the intersection. In addition to these tallies, stems 10-15 cm (4-6 in), and 15-25 cm (6-10 in) dbh were tallied in 0.008 ha (0.02 acre) fixed radius plots centered on the grid intersections.

A variety of locations and plot sizes was necessary to characterize the advanced regeneration in three ways. The first of these ways dealt only with the stems tallied in the milacre plots, and involved stem densities summarized to species, to shade tolerance category, and to ATCO Market Class (table 1). The second set of characterizations involved calculation of advanced regeneration score (Johnson 1980) for each grid intersection. The regeneration score was determined via averaging the tally of stems measured on the three milacre plots and stems 10-25 cm were summarized from the single 0.008 ha plot at the intersection. These tallies all were standardized to stems per 0.01 acre plot required by the Johnson (1980) method, and scaled by the factors published in the Johnson (1980) protocol into a composite regeneration-points-per-plot basis. The third set of characterizations was applied to tally of stems as in the Johnson (1980) method, applied only to the ATCO Market Class A species. A composite density estimation was calculated from these data as follows,

$$\text{Johnson Points} = (\text{Stems} < 4.5 \text{ ft tall/ac})/6 + (\text{stems} > 4.5 \text{ ft tall/ac})/2 + (\text{stems} > 4\text{" dbh/ac}). \quad (1)$$

### Statistical Treatment

Regeneration data compiled in these categories were analyzed as follows. The milacre data were analyzed with SAS/STAT software, Version 9.2 of the SAS System for Windows using Proc GLIMMX generalized linear mixed models for Poisson distributed data (© SAS Institute Inc. 2009) and treatments tested

**Table 1—Basal area of canopy trees recorded on Cerulean Warbler study area, Desha Co., AR, after 2013 growing season. Asterisks indicate species whose abundance differed between the treatments at P = 0.05 after Bonferroni correction for simultaneous multiple species comparisons (ATCO – Company Treatment, CERW – Cerulean Warbler Treatment)**

| Tree Species | Shade tolerance | ATCO Market Class | Treatment ATCO | | Treatment CERW |
|---|---|---|---|---|---|
| | | | N = 123 | | N = 137 |
| | | | mean basal area ± s.e., $m^2$/ha ($ft^2$/ac) | | |
| boxelder, *Acer negundo* | Tolerant | C | 3.1 ± 0.5 | | 3.6 ± 0.5 |
| | | | (13.5 ± 2.2) | | (15.7 ± 2.2) |
| red maple, *Acer rubrum* | Moderate | B | 0.1 ± 0.1 | | 0.1 ± 0.1 |
| | | | (0.4 ± 0.4) | | (0.4 ± 0.4) |
| sweet pecan, *Carya illinoiensis* | Intolerant | A | 0.9 ± 0.2 | | 0.9 ± 0.2 |
| | | | (3.9 ± 0.9) | | (3.9 ± 0.9) |
| sugarberry, *Celtis laevigata* | Moderate | B | 5.4 ± 0.6 | ** | 11.1 ± 0.8 |
| | | | (23.5 ± 2.6) | ** | (48.3 ± 3.5) |
| dogwood, *Cornus drummondi* | — | D | 0.1 ± 0.1 | | - |
| | | | (0.4 ± 0.4) | | - |
| persimmon, *Diospyros virginiana* | Tolerant | B | 0.1 ± 0.1 | | - |
| | | | (0.4 ± 0.4) | | - |
| green ash, *Fraxinus pennsylvanica* | Moderate | A | 2.5 ± 0.4 | | 4 ± 0.6 |
| | | | (10.9 ± 1.7) | | (17.4 ± 2.6) |
| sweetgum, *Liquidambar styraciflua* | Intolerant | A | 2 ± 0.4 | ** | 0.2 ± 0.1 |
| | | | (8.7 ± 1.7) | ** | (0.9 ± 0.4) |
| sycamore, *Platanus occidentalis* | Intolerant | A | 1.6 ± 0.4 | | 1.9 ± 0.3 |
| | | | (7 ± 1.7) | | (8.3 ± 1.3) |
| cottonwood, *Populus deltoides* | Intolerant | A | 0.2 ± 0.1 | | 0.1 ± 0.1 |
| | | | (0.9 ± 0.4) | | (0.4 ± 0.4) |
| overcup oak, *Quercus lyrata* | Intolerant | B | 0.1 ± 0.1 | | - |
| | | | (0.4 ± 0.4) | | - |
| Nuttall oak, *Quercus nuttallii* | Intolerant | A | 0.1 ± 0.1 | | - |
| | | | (0.4 ± 0.4) | | - |
| baldcypress, *Taxodium distichum* | Moderate | C | 2 ± 0.5 | | 4.1 ± 0.8 |
| | | | (8.7 ± 2.2) | | (17.9 ± 3.5) |
| American elm, *Ulmus americana* | Moderate | B | 1.7 ± 0.3 | | 2.4 ± 0.4 |
| | | | (7.4 ± 1.3) | | (10.5 ± 1.7) |
| **Total** | | | **19.7 ± 1.1** | ** | **29.1 ± 1.1** |
| | | | **(371 ± 5)** | ** | **(479 ± 5)** |

for significance at α = 0.05. Data from the Johnson (1980) characterization as well as the composite ATCO Market Class A trees were modeled with the method of Krishnamoorthy and others (2011) to assess of the adequacy of advanced regeneration.

## RESULTS

### Avian Sampling

Surveys were conducted frequently enough in 2004, 2006, 2008, 2011, 2012, and 2013 to map territories on and adjacent to the study area. Female Cerulean Warblers were associated with the males in the surveys in 2004, 2006, and 2008, suggesting that breeding occurred; however, no nests were discovered. In all years save 2011, territories were located in the Cerulean Warbler Treatment area (fig. 1). During the survey in 2011, cut short by flooding, one singing male was found three times during April in the Company Treatment area. In 2012-2014, no Cerulean Warblers were found in the study area.

### Vegetation Sampling

**Canopy Vegetation**—Mean canopy basal area ten years after treatment was significantly greater ($t = 6$, 258 df, $P < 0.0001$; fig. 2) on the Cerulean Warbler Treatment area (29 ± 1.1 $m^2$/ha; 479 ± 5 $ft^2$per acre, n=137 plots; quadratic mean diameter 27.7 cm, 10.9 in) than that on the Company Treatment area (19.7 ± 1.1 $m^2$/ha; 371 ± 5 $ft^2$ per acre, n=123 plots; quadratic mean diameter 26.0 cm, 10.2 in). Individuals of 14 tree species were recorded in the canopy (table 1). Basal area of two of these species differed significantly at the comparison-wide α = 0.05. Sugarberry (*Celtis laevigata*) was more abundant on the Cerulean Warbler Treatment ($t = 5.4$, df= 258, $P < 0.0001$); and sweetgum (*Liquidambar styraciflua*) was more abundant on the Company Treatment ($t = 4.9$, df= 258, $P < 0.0001$). These two species were responsible for the significant differences between treatments by shade tolerance class as well (fig. 3); sweetgum is shade intolerant, while sugarberry is moderately tolerant of shade. The treatments were different in basal area by ATCO Market Class only for Class B species, also because of the large difference in sugarberry basal area (fig. 4).

**Advanced Regeneration**—Ten years after the application of the treatments, estimated total advanced regeneration measured on milacre plots was abundant; Company Treatment 3537 ± 155 stems/ha (1432 ± 62 stems per acre), n = 368; Cerulean Warbler Treatment 3507 ± 148 stems/ha (1420 ± 59 stems per acre), n = 412. The treatments did not differ significantly by generalized linear mixed model with Poisson distributed data ($F_{1, 778} = 0.02$, $P = 0.89$). Seedlings and saplings of 14 tree species were identified on these plots (table 2), in which mean abundance of three species, boxelder (*Acer negundo*; $t = 6.2$, df=778, $P < 0.0001$), sugarberry ($t = 7.3$, df=778, $P < 0.0001$), and sweetgum ($t = 6.3$, df=778, $P < 0.0001$) differed between the treatments by

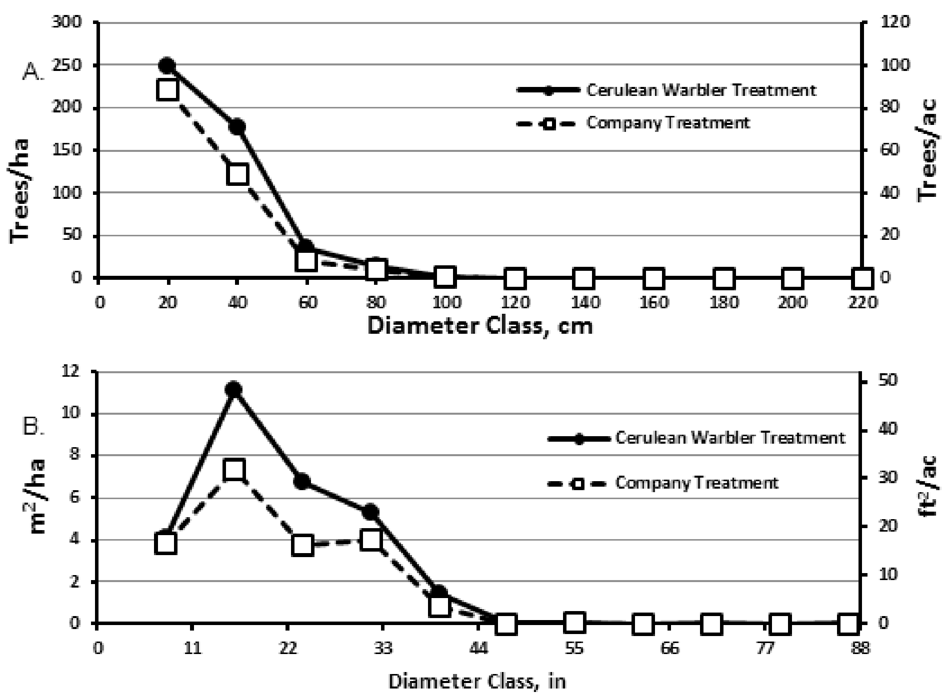


Figure 2—Diameter class distributions of tree density (upper) and basal area (lower) on the Cerulean Warbler study site measured after 2013 growing season.

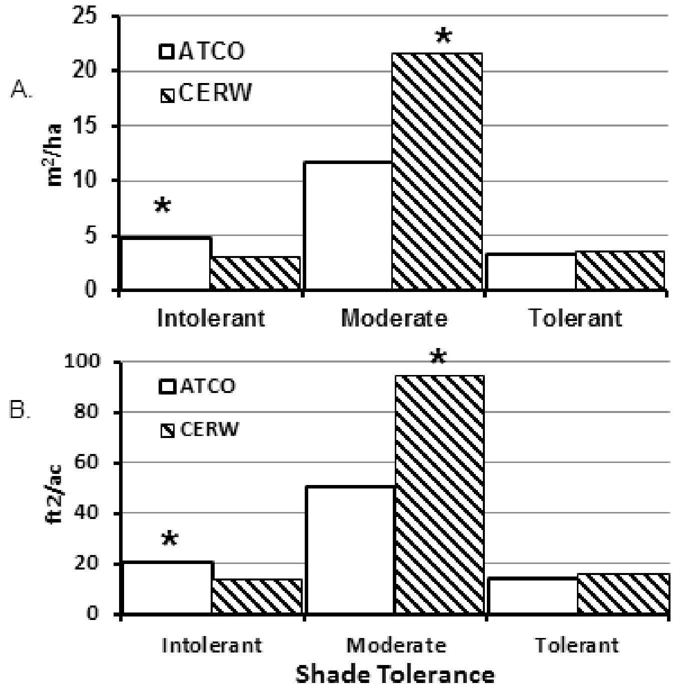


Figure 3—Forest canopy basal area distribution by shade tolerance classes, Cerulean Warbler study area, Desha Co., AR, after 2013 growing season. A. Basal area expressed in $m^2$/ha; B. Basal area expressed in $ft^2$/ac. Asterisks indicate that treatments differ at P = 0.05. ATCO – Company Treatment; CERW – Cerulean Warbler Treatment.

t-test after Bonferroni correction to comparison-wide α = 0.05.

The distribution of advanced regeneration between the treatments differed for each shade tolerance class modeled by the generalized linear mixed models approach; the Company Treatment produced more shade intolerants [709 ± 72 stems/ha (287 ± 29 stems per acre), n = 368; $F_{1, 760}$ = 21.16, P < 0.0001] and more shade tolerants [1383 ± 99 stems/ha (560 ± 40 stems per acre), n=368; $F_{1, 760}$ = 37.23, P < 0.0001] than the Cerulean Warbler Treatment [intolerants 331 ± 44 stems/ha (134 ± 18 stems per acre), tolerants (672 ± 62 stems/ha (272 ± 25 stems per acre), n=412]. The Cerulean Warbler Treatment produced more advanced regeneration of moderate shade tolerance [2507 ± 124 stems/ha (1015 ± 50 stems per acre), n= 412; $F_{1, 760}$ = 36.3, P < 0.0001] than did the Company treatment [1509 ± 104 stems/ha (611 ± 42 stems per acre), n = 368]. Advanced regeneration of the desired species in the ATCO Market Class A was more abundant in the Company Treatment [855 ± 77 stems/ha (346 ± 31 stems per acre), n = 368; $F_{1, 760}$ = 18.42, P < 0.0001] than in the Cerulean Warbler Treatment [454 ± 52 stems/ha (184 ± 21 stems per acre), n = 412].

In comparison to the tolerance intervals modeled from milacre samples using methods in Krishnamoorthy and others (2011) for ATCO Market Class A species, the Company Treatment produced at least 500 stems/ha (200 stems per acre) throughout the treatment, while barely 10 percent of the Cerulean Warbler Treatment produced the desired abundance of advanced regeneration (fig. 5). A further comparison using the same modeling approach to the composite of data from milacre and 0.008 ha plots yielded a similar result (fig. 6) relative to a 250 stems/ha (100 stems per acre) criterion density of Market Class A stems.

Results of the examination of the advanced regeneration on the two treatments using the Johnson (1980) points system indicated that 72 percent of the plots on the Company Treatment, and 56 percent of the plots on the Cerulean Warbler Treatment, contained sufficient advanced regeneration to be considered stocked. By comparison, 21 percent of plots on the Company Treatment, and 8 percent of plots on the Cerulean Warbler Treatment, were stocked with sufficient advanced regeneration of desirable Market Class A species.

## DISCUSSION

Several reservations must be raised about this study. It was unreplicated, so uncontrolled differences between the treatments may have produced the observed

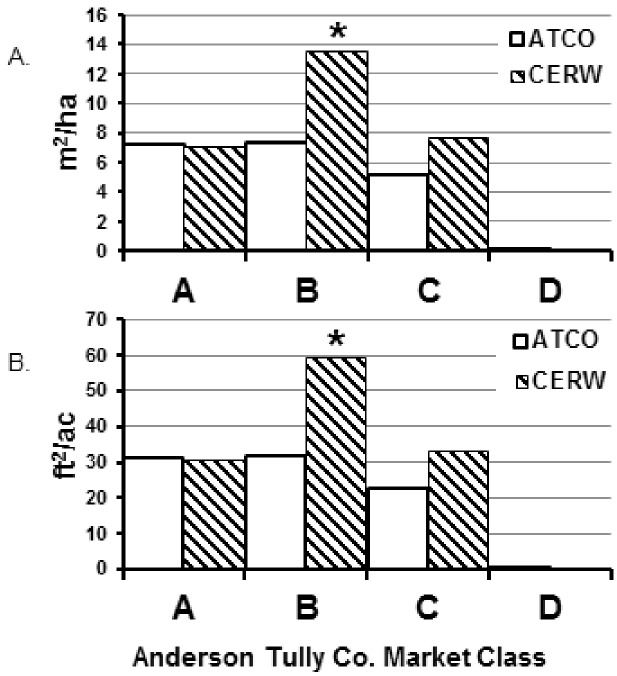


Figure 4—Forest canopy basal area distribution by Anderson Tully Market Class, Cerulean Warbler study area, Desha Co., AR, after 2013 growing season. A. Basal area expressed in $m^2$/ha; B. Basal area expressed in $ft^2$/ac. Asterisks indicate treatments differ at P = 0.05. ATCO – Company Treatment; CERW – Cerulean Warbler Treatment.

**Table 2—Advanced regeneration recorded on Cerulean Warbler study area, Desha Co., AR, after 2013 growing season. Asterisks indicate species whose abundance differed between the treatments at P = 0.05 after Bonferroni correction for simultaneous multiple species comparisons (ATCO – Company Treatment, CERW – Cerulean Warbler Treatment)**

| Tree Species | Shade tolerance | ATCO Market Class | Treatment ATCO | | Treatment CERW |
|---|---|---|---|---|---|
| | | | N = 368 | | N = 412 |
| | | | mean stems/ha, (stems/ac) | | |
| boxelder, *Acer negundo* | Tolerant | C | 1235 (500) | ** | 576 (233) |
| red maple, *Acer rubrum* | Moderate | B | 7 (2.7) | | 12 (5) |
| sweet pecan, *Carya illinoiensis* | Intolerant | A | 148 (60) | | 156 (63) |
| sugarberry, *Celtis laevigata* | Moderate | B | 846 (342) | ** | 1805 (731) |
| persimmon, *Diospyros virginiana* | Tolerant | B | 60 (24) | | 30 (12) |
| green ash, *Fraxinus pennsylvanica* | Moderate | A | 181 (73) | | 144 (58) |
| honeylocust, *Gleditsia triacanthos* | Intolerant | D | - | | 6 (2) |
| sweetgum, *Liquidambar styraciflua* | Intolerant | A | 271 (111) | ** | 12 (5) |
| red mulberry, *Morus rubra* | Tolerant | C | 40 (16) | | 66 (27) |
| sycamore, *Platanus occidentalis* | Intolerant | A | 161 (65) | | 138 (56) |
| water oak, *Quercus nigra* | Intolerant | B | 47 (19) | | 12 (5) |
| Nuttall oak, *Quercus nuttallii* | Intolerant | A | 74 (30) | | 6 (2) |
| baldcypress, *Taxodium distichum* | Moderate | C | 34 (14) | | 30 (12) |
| American elm, *Ulmus americana* | Moderate | B | 430 (174) | | 516 209) |
| **Total** | | | **3537 (1432)** | | **3507 (1420)** |

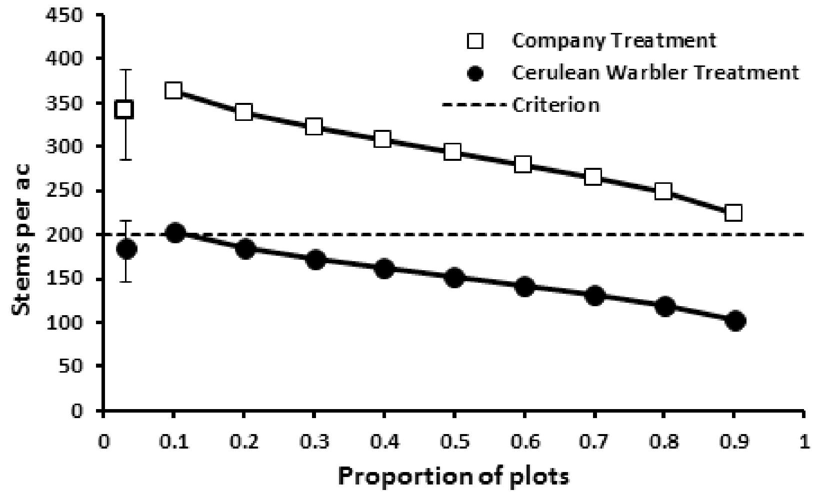


Figure 5—Proportion of milacre advanced regeneration measurement plots expected to meet 200 stems/ac (500 stems/ha) criterion abundance of Anderson Tully Co. Market Class A species in treatments on Cerulean Warbler study area in Desha Co., AR, measured during 2013 growing season (Company Treatment n = 368, Cerulean Warbler Treatment n = 412). Connected symbols reflect model estimates (Krishnamoorthy and others 2011) based upon actual values, whose means ± 95 percent confidence intervals are shown in the separate symbols

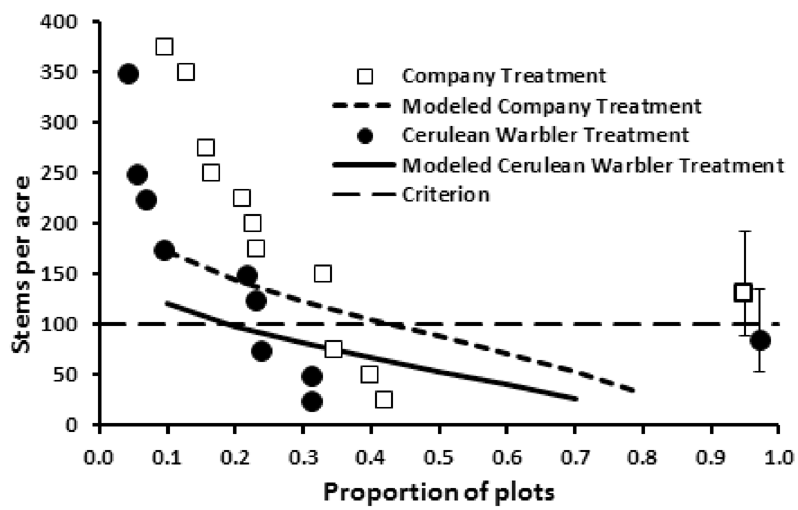


Figure 6—Proportion of 0.02 ac advanced regeneration composite measurement plots expected to meet 100 stems/ac (247 stems/ha) criterion abundance of Anderson Tully Co. Market Class A species in treatments on Cerulean Warbler study area in Desha Co., AR, measured during 2013 growing season (Company Treatment n = 123, Cerulean Warbler Treatment n = 137). Symbols are actual measurements. Lines reflect model estimates (Krishnamoorthy and others 2011) based upon actual values, whose means ± 95 percent confidence intervals are shown in the separate symbols on the right edge of the graph. Note that only 19 percent of plots in the Cerulean Warbler Treatment area and 45 percent of plots in the Company Treatment area are expected to meet criterion abundance, despite the fact that the mean values do not differ significantly from criterion.

results. Also, global Cerulean Warbler populations declined during the study, suggesting that factors external to the study may have affected response by the birds to an unknown degree. The duration of the study itself exposed the plot to effects of a severe ice-storm that impeded management actions carried out on other affected company lands. Severe flooding prevented visitation to the area in more than one year of the study.

Having raised these cautions, several encouraging results were observed. First, as Cerulean Warbler pairs were present on the Cerulean Warbler Treatment area in three sampling sessions, 2004-2008, the prescription designed for the Warbler is provisionally successful. Our work lasted longer than that of Boves and others (2013) and may have reflected some of the source-sink and ecological trap effects they postulated. The concentration of territories in the same area, and the positive association of territory size with distance from a common center point during the study begs further study.

Forest canopy and advanced regeneration resulting from the treatments were consistent with the prescriptions applied, and provide some indication of the trade-offs required in this habitat production between suitable habitat for the Cerulean Warbler and maintenance of sawtimber production into the future on the same lands.

## CONCLUSIONS

1. The treatments produced forest stand conditions consistent with the prescriptions applied.
2. The Cerulean Warbler Treatment intended to produce habitat for Cerulean Warbler was used consistently by the birds for a portion of the study; the Company Treatment was used only incidentally by the birds.
3. This unreplicated pilot study offers guidance for more substantive later work in Mississippi River Alluvial Valley forests.
4. Behavioral ecology of Cerulean Warbler merits continued examination.

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## LITERATURE CITED

Boves, T.J.; Buehler, D.A.; Sheehan, J. [and others]. 2013. Emulating natural disturbances for declining late-successional species: a case study of the consequences for Cerulean Warblers (*Setophaga cerulea*). PLoS ONE. 8(1): e52107. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0052107. [Date accessed: April 28, 2015].

Buehler, D.A.; Giocomo, J.J.; Jones, J. [and others]. 2008. Cerulean Warbler reproduction, survival, and models of population decline. Journal of Wildlife Management. 72: 646-653.

Buehler, D.A.; Hamel, P.B.; Boves, T.J. 2013. Cerulean Warbler *Setophaga cerulea*. Revised. In: Birds of North America online. Poole, A., ed. Ithaca, NY: Cornell Lab of Ornithology. http://bna.birds.cornell.edu/bna/species/511/articles/introduction. [Date accessed: April 28, 2015].

Buehler, D.A.; Welton, M.J.; Beachy, T.A. 2006. Predicting Cerulean Warbler habitat use in the Cumberland Mountains of Tennessee. Journal of Wildlife Management. 70: 1763-1769.

Burns, R.M.; Honkala, B.H., tech. cords. 1990. Silvics of North America: Vol. 1. Conifers; Vol. 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture. 877 p.

Gill, H.V.; Larance, F.C.; Cloutier, H.; Long, H.W. 1972. Soil survey of Desha County, Arkansas. Washington, DC: U. S. Department of Agriculture Soil Conservation Service. In cooperation with: Arkansas Agricultural Experiment Station. 50 p. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. [Date accessed: April 24, 2015].

Hamel, P.B. 2000. Cerulean Warbler status assessment. St. Paul, MN: U.S. Department of Interior, Fish and Wildlife Service. 141 p. http://www.fws.gov/midwest/es/soc/birds/cerw/pdf/cerw-sa.pdf. [Date accessed: April 28, 2015].

Hamel, P.B. 2005. Suggestions for a silvicultural prescription for Cerulean Warblers in the Lower Mississippi Alluvial Valley. In: Ralph, C.J.; Rich, T.D., eds. Bird conservation implementation and integration in the Americas: proceedings of the third international partners in flight conference, 20-24 March 2002, Asilomar Conference Grounds, CA. Gen. Tech Rep. PSW 191. Albany, CA: U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station: 567-575.

Hamel, P.B.; Staten, M.; Wishard, R. 2006. Initial Cerulean Warbler (*Dendroica cerulea*) response to experimental silvicultural manipulations, Desha County, Arkansas. In: Connor, K.F., ed. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS 92. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 3-9.

Hamel, P.B.; Staten, M.; Wishard, R.; Smith, C.G., III. 2010. Cerulean Warbler response to silvicultural manipulations on managed forestland in Desha County, Arkansas, third year results. In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS 121. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 475-479.

Hodges, J.D. 1997. Development and ecology of bottomland hardwood sites. Forest Ecology and Management. 90: 117-125.

Johnson, R.L. 1973. Oak-gum-cypress in the Midsouth. In: Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture Forest Service, Division of Timber Management Research: 98-101.

Johnson, R.L. 1980. New ideas about regeneration of hardwoods. In: Proceedings of Hardwood Regeneration Symposium. Atlanta, Ga., Jan 29, 1980. Forest Park, GA: Southeastern Lumber Manufacturers Association: 17-19.

Krishnamoorthy, K.; Yanping Xia; Fang Xie. 2011. A simple approximate procedure for constructing binomial and poisson tolerance intervals. Communications in Statistics. 40: 2243-2258.

Powell, L.A.; Lang, J.D.; Conroy, M.J.; Krementz, D.G. 2000. Effects of forest management on density, survival, and population growth of wood thrushes. Journal of Wildlife Management. 64: 11-23.

SAS Institute Inc. 2009. SAS/STAT ® 9.2 User's Guide, Second Edition. Cary, NC: SAS Institute Inc. 7869 p. http://support.sas.com/documentation/cdl/en/statug/63033/HTML/default/viewer.htm#statug_glimmix_a0000001405.htm. [Date accessed: May 13, 2015].

U.S. Department of the Interior, Fish and Wildlife Service. 2006. "Endangered and threatened wildlife and plants; 12-month finding on a petition to list the Cerulean Warbler (*Dendroica cerulea*) as threatened with critical habitat." Federal Register. 71.234: 70717-70733.