Suggestions for a Silvicultural Prescription for Cerulean Warblers in the Lower Mississippi Alluvial Valley[1]

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Abstract

Conservation of species with high Partners in Flight concern scores may require active habitat management. Cerulean Warbler (*Dendroica cerulea*) occurs at low numbers in the Lower Mississippi Alluvial Valley in the western part of its breeding range. A study of the breeding ecology of the species was initiated in 1992 on three sites there. Characteristics of individual trees used by the birds have been measured in detail. Elements of the vegetation utilized by male Cerulean Warblers, by female Cerulean Warblers, and as nests have been identified. A silvicultural prescription designed to produce these elements is being prepared as an experimental manipulation of habitats for the birds. The development of this suggested silvicultural prescription offers an example for development of similar prescriptions for other forest canopy dwelling bird species. One difficulty may be in assessing the response of the birds to the treatments when the available habitat exceeds the amount needed to support the spatial needs of the local small population, whether the measured response is one of abundance or of productivity. This is because the response may be smaller than can be detected by the experimental design used to conduct the experiment; available birds may not be numerous enough to produce a detectable response.

Key words: adaptive management, bottomland hardwoods, forest canopy, habitat management, habitat selection, mature forest, Parulidae.

Management Background

Land managers use objectives as central to the process of forest, wild land, and recreation management (e.g. Morrison et al. 1992). Put in a more colloquial way, "It isn't management unless you do it on purpose (Tony Melchiors, pers. comm.). Conservation work on priority bird species, such as those with high Partners in Flight concern scores (Carter et al. 2000), often seems to have an implied objective of "protection by purchase" thereby maintaining the habitat in perpetuity safe from habitat degradation. Especially true is this mindset when it comes to species of later successional stands, to species of older forests. An implicit "protection is necessary" focus frequently develops

Priority species may occur in places that have been managed for other purposes; presence of the species may be facilitated by past management or merely may be serendipitous. Thus, the occurrence of species of interest was not necessarily an objective of the management that produced the habitats in which they occurred. This is an important point, because the occurrence of the species of interest is thus a by-product of management directed toward some other objective. When we measure "habitat" of a species under such circumstances (e.g. Cerulean Warbler [*Dendroica cerulean*]; Kahl et al. 1985, Hamel 1992, Robbins et al. 1992, Gabbe et al. 2002) we measure the outcomes of management for objectives other than ideal habitat for the birds. Hence, the presence of suitable habitat has an unknown relationship to the initial management objectives for the property. In other cases, occupied habitat has resulted from secondary succession following cessation of agricultural or pasture land use (Oliarnyk and Robertson 1996); in these cases also, the succession was a result of a process other than purposeful forest management designed to produce habitat for a species.

Many species have habitat requirements that are not fully understood because of interactions with disturbance patterns and regional and physiographic differences in plant communities. Our conservation action is based on the hope that the unknown past is a good predictor of the unknown future. For yet another group of species, we perceive their continued existence to be in jeopardy, and we wish to ameliorate the jeopardy. For some of these species, continued existence has been jeopardized by past activities. Continued existence of other species is threatened by current activities as we understand their effects. For other species uncertainty about future population status is a result of ignorance of habitat requirements rather than past harm or current threat. We are saddled with the responsibility of assigning each species to a category of one to whom harm has occurred, one for whom threats are real, or one for whom the threats are simply unknown.

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Cerulean Warbler (CERW), a Nearctic breeding, neotropic wintering, wood warbler (Robbins et al. 1992) is a species with such an uncertain future. The species breeds in forests of broadleaved trees in the eastern deciduous forest biome of the United States and southeastern Canada, where its center of abundance lies in the Ohio River valley (Hamel 1998, Rosenberg et al. 2000). The diet is primarily insects (Bent 1953). Populations of the species are believed to be declining or to have declined substantially during the past 35 years or so (Hamel 2000). Typical breeding habitat for the species is mature hardwood forest, and the birds are believed to be associated with large trees (Hamel 1992, 2000). Heterogeneous three-dimensional structure of the canopy within the forest is believed to be of particular importance to the birds (Lynch 1981, Hamel 2000, Jones et al. 2001). The birds occur in an environment that has been subject to a wide variety of land use changes and management strategies, on a host of scales, against a backdrop of potential climate change, in a context of rapidly increasing human population and technological capability, on both its North American breeding and South American nonbreeding grounds.

The species is one that appears regularly on lists of species that need protection (Hamel 1998). One set of suggested habitat characteristics is that of Kahl et al. (1985 in Hamel 1992), who noted habitat around song perches of CERWs to include 50-150 stems/ha >30 cm dbh, under a closed canopy (mean 85 percent cover, never <65 percent) at least 18 m tall, with a moderate number (1,030 - 2,800) of wood stems <2.5 cm dbh, and low density (<175/ha) of dead stems 2.5 - 9.9 cm dbh. Extensive study of CERWs in the northeastern part of the species range in southern Ontario (Oliarnyk and Robertson 1996, Jones and Robertson 2001) indicated that the birds use areas for nesting with complex forest canopies heterogeneous horizontally as well as vertically, and that the birds use a variety of tree species for nesting at the local scale.

Long ago, Widmann (1907) noted that the CERW was among the most abundant breeding warblers in the bottomland forests of the Sunken Lands of southeastern Missouri in the Lower Mississippi Alluvial Valley (LMAV). At present, the species is unrecorded in these same environments by the Breeding Bird Survey (Sauer et al. 2001). Priority land use in these environments is row crops. Forest land use is a distant competitor with agriculture (Allen et al. 2001). Forests are present in the LMAV chiefly as a result of agricultural subsidy programs such as the Wetland Reserve or Conservation Reserve, or flooding regimes that make agriculture unprofitable. The modest understanding of the tract size associations of CERWs in this landscape has catapulted the species into a role of flagship species for afforestation efforts (Mueller et al. 1999).

My purpose here is to outline the breeding biology in relation to habitat of the species, to indicate possible implications of this biology for forest management, and to suggest an approach to purposeful management of habitats for this species in the LMAV. Nowhere has specific action been taken consciously to produce habitat for the species although some experimental tests are currently underway (D. A. Buehler, pers. comm.). Because of the apparent dependence of the species upon locations with a particular constellation of forest features, purposeful management may be a requirement for the species' long-term persistence. No study of the production of habitat for CERWs has been conducted anywhere.

Methods

Study Areas

Three areas were selected for study of the breeding biology and habitat use of CERW in the LMAV. Sites were selected as representative of the habitats of CERWs in the LMAV. The work reported here began in 1992 and continues to the present. Each site was located in the unimpeded floodplain of the Mississippi River, subject to annual flooding. Each was a tract of forest well in excess of the 1600 ha reported to be the minimal size of tract in which the species occurred in these environments (Robbins et al. 1992). The sites had varied management history, lay in slightly different areas of the floodplain, and were dominated by slightly different forest communities. Two were in public and one in private ownership. Each area was marked at the intersections (grid points) of a 50 x 50-m grid.

Chickasaw National Wildlife Refuge is an 8,000-ha tract in Lauderdale County, Tennessee (35º 48' 56" N 89º 38' 52" W). Presently in public ownership since the late 1980's, the tract is managed by the U.S. Fish and Wildlife Service. The tract was owned and managed for sawtimber trees (diameters exceeding 27 cm) using single-tree and group selection practices (management techniques that produce small contiguous groups of trees of similar size and age and favored species) by the Anderson Tully County prior to public acquisition. Within this tract a 50-ha study site (N = 231 grid points) was located in the middle of the floodplain on a low flat and adjacent natural levee bordering a tributary to the Mississippi River. Forest here was dominated by sugarberry (*Celtis laevigata*), Nuttall oak (*Quercus nuttallii*), overcup oak (*Q. lyrata*), and sweet pecan (*Carya illinoensis*).

Desha Delta Hunt Club, in Desha County, Arkansas (33º 44' 39" N 91º 09' 31" W) is part of a 15,000-ha continuous tract of forest in the batture land of the Mississippi River. It is owned and managed by the

Anderson Tully County for sawtimber using single-tree and group selection practices. Within this area a 54-ha study site (N = 260 grid points) was located on ridge and swale topography close to the Mississippi River. Forest here was dominated by sugarberry, boxelder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), with a smaller amount of sycamore (*Platanus occidentalis*), and baldcypress (*Taxodium distichum*).

Meeman Shelby Forest State Park and Wildlife Management Area (35º 19' 46" N 90º 03' 40" W), is a unit of the Tennessee State Park system, in Shelby County, Tennessee. This 3800-ha area is part of a contiguous tract of forest that extends from the top of the bluff at the eastern edge of the Mississippi River floodplain to the bank of the river three km west. A 56-ha study area (N = 261 grid points) was located here at the toe of the bluff on a small alluvial fan produced by a creek that drains adjacent uplands. Portions of this area were harvested early in the past century, and parts of if were agricultural fields at that time as well. Forest here was dominated by cottonwood (*Populus deltoides*), boxelder, and sugarberry, as well as other species.

Behavioral Ecological Activities

CERWs were studied on the three study areas using spot-mapping, focal animal behavior sampling, and timed nest watches. The data resulting from focal animal sampling formed the primary basis for this report. Individual, usually unmarked, male or female CERWs were located by observers at predetermined portions of the study areas visited in a systematic fashion. These individual birds were followed through the forest for varying periods. Where possible, birds were selected *a priori* for observation. Often, however, and especially in the case of female birds, selection of focal animals was opportunistic. Individual trees in which the birds were observed were identified to species, their diameter at breast height (dbh, 1.5 m), height, and crown class were measured, and attachment of lianas noted; and trees were marked with numbered aluminum tags. Date, time, gender and individual identity of focal bird were noted, as well as height in the tree and activity in which the bird was engaged. Subsequent measures were made at timed, one-minute intervals. Because of the density of the foliage and the frequent perch changes by the birds, most observation sequences consisted of a single entry.

Tree species use was estimated for the birds by selecting the first entry for each gender for a given date-time observation sequence. Tree use was summarized by tree species, crown class, and diameter class, for female and for male CERWs. Tree species represented by at least 10 entries for females or for males were submitted to analysis. This criterion permitted evaluation of use vs. availability for 17 species of trees, representing 94 percent of the sample of use by females (N = 821 trees) and 97 percent of the sample of trees used by males (N = 2468 trees). These species represented 82 percent of the total number of trees available, and 78 percent of the total basal area of trees on the study areas. Use vs. availability was calculated from chi-square statistics, significance accepted at P = 0.05, corrected by a Bonferroni procedure for the 34 tests conducted (Rice 1989).

Nest trees (N = 68) were measured, as were those of the behavioral use, with addition of specific measures of height of the nest, distance and direction of the nest from the bole of the tree, and distance of the nest from the distal end of the branch in which it was placed. Distance of the nest from the bole, and distance from the distal end of the branch were summed into a measure of the crown radius of the tree at the nest, the nest radius. Nest radii for 16 of the nests were compared with projected crown radii using the equations of Goelz (1996), who developed equations for the average crown radii of open-grown trees. Crown radii of open-grown trees can be considered to be approaching the maximum for the species (Goelz 1996). Goelz (1996) presented no estimation equation for crown radius of *Acer negundo*; this tree species accounted for 14 CERW nests. Null expectation that observed nest radius would be less than predicted crown radius of open-grown trees of the same species and diameter was tested with a paired t-test. Null expectation arose in part because the nest trees were forest grown trees, and because no *a priori* reason existed to expect nests to be placed at the height at which the maximum crown radius of the nest tree was achieved.

Distance from nest to the edge of the nearest canopy gap was measured for a subset of the nests and for an equal number of randomly selected grid points. A canopy gap was defined as an opening in the canopy at least 10 m^2 in area. Gap distances were analyzed with analysis of variance statistics on square-root transformed data, with study area and nature of the measure (nest or random point) as main effects.

Tree species availability was estimated for each of the sites from a series of variable-radius-plot samples taken at grid point intersections. Measures identical to those of trees in the focal animals sample were made for each tree selected using a 6.889 m^2/ha basal-area-factor angle gauge. Number of trees was estimated for each sampled tree by use of a weighting factor. The weighting factor was the number of trees/ha calculated from the sampling area associated with the tree diameter/selection device combination. Shade tolerance of the trees was taken from Meadows and Stanturf (1997). Comparison of use and availability were conducted with chi-square statistics, testing the null hypothesis that use did not differ from that expected on the basis of availability. Significance was accepted at P = 0.05, after Bonferroni correction for the number of tree species in the test.

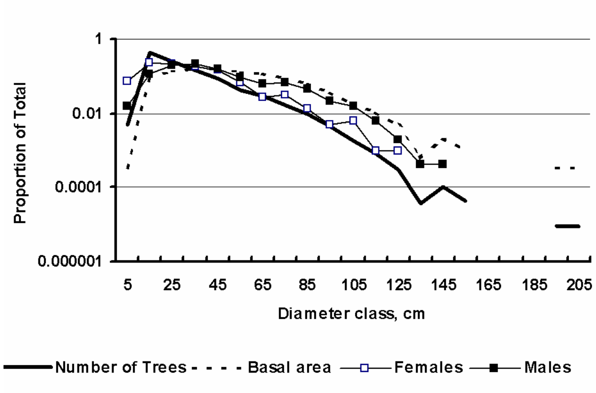

Figure 1— Use of trees by Cerulean Warblers in the Lower Mississippi Alluvial Valley. For number of trees and basal area, quantity graphed is the proportion of the total weighted value measured on sample plots that fell into the particular diameter class. For Cerulean Warbler use, quantity graphed is the proportion of the total number of trees used by that gender that fell into the particular diameter class. Sample sizes for the birds are N = 3690, for the study areas N > 200,000.

Habitat Modeling

Habitat measurements at grid intersection points included measurements made for the tree species availability measures above, plus estimates of canopy cover, and ground cover. Using the data on tree species locations from the focal animal sampling, grid points were assigned to groups as CERW habitat or non-habitat. Models of vegetation structure characterizing habitat utilization were constructed for these two groups using logistic regression. Separate models of habitat utilization were estimated for each of the study areas. Model results were then applied as predictors of habitat and non-habitat to other study areas than the one from which they were developed. Because these logistic regression models failed to predict habitat occupancy outside the study area from which they were developed, they will not be discussed further here.

Results

Trees Selected by the Birds

Use of Trees by Diameter Class

CERWs, particularly the males, used large trees more frequently than their availability in the stands (*fig. 1*). For males, use frequency exceeded available frequency for all diameter classes 35 cm and larger (P < 0.05). For females, use frequency exceeded available frequency in 7 of 10 diameter classes 35 cm and larger, a result that did not differ from expected. When use frequency by diameter class was compared separately for number of trees by species and species basal area, female CERWs appeared to use trees in proportion to the number of trees in the stands, while male CERWs appeared to use trees in proportion to their basal area in the stands (*fig. 1*).

Use of Trees by Crown Class

Female CERWs at Chickasaw NWR disproportionately used trees in the suppressed crown class (*table 1*). Male CERWs disproportionately used trees in the dominant and codominant crown classes. Nest trees were placed disproportionately in dominant and codominant trees as well.

Use of Trees by Shade Tolerance Class

Male CERWs on Chickasaw NWR disproportionately used shade intolerant trees and underused shade tolerant trees (*table 2*). Female CERWs used trees without regard for shade tolerance. Distribution of nests was similar to that of use by males.

Table 1— *Cerulean Warbler use of trees by crown class, Chickasaw National Wildlife Refuge, Lauderdale County, Tennessee. Expected values for these comparisons in the table (not shown) were based upon distribution of weighted number of trees sampled on 231 plots on the Chickasaw NWR Cerulean Warbler study area. Notation as "Low" or "High" indicates that the number of trees in that cell is Higher or Lower than expected at P = 0.05, by chi-square test.*

Tree use/crown class	Females	Males	Nests	Total
Dominant/codominant	47	189	14	240
	Low	High	High	
Intermediate	58	116	4	178
	Low	Low		
Suppressed	107	115	1	223
	High	Low	Low	
Total[a]	212***	420***	19***	651

[a] *P < 0.05, ** P < 0.01, *** P < 0.001

Table 2— *Cerulean Warbler use of trees by shade tolerance class, Chickasaw National Wildlife Refuge, Lauderdale County, Tennessee. Expected values for these comparisons in the table (not shown) based upon distribution of weighted number of trees sampled on 231 plots on the Chickasaw NWR Cerulean Warbler study area. Notation as "Low" or "High" indicates that the number of trees in that cell is Higher or Lower than expected at P = 0.05, by chi-square test.*

Tree use/shade tolerance class	Female	Male	Nest	Total
Intolerant	57	189 High	4 High	250
Moderately Tolerant	78	146	5	229
Tolerant	96	115 Low	8 Low	219
Total[a]	231 NS	928***	17***	698

[a] * P < 0.05, ** P < 0.01, *** P < 0.001, NS = not significant.

Use of Trees by Species

Male use exceeded availability by number of trees in eight of 17 cases, and was significantly lower than expected for four species (*table 3*). Female use exceeded availability by number of trees in four cases, and was significantly lower than expected once (*table 3*). Male use exceeded availability by basal area in seven of 17 cases, and was significantly lower than expected for three species (*table 4*). Female use exceeded availability by basal area in five cases, and was significantly lower than expected twice (*table 4*). Both sexes overused *Celtis laevigata*, *Acer negundo*, *Platanus occidentalis*, *Liquidambar styraciflua*, *Carya illinoensis*, and *Ulmus americana*. Both underused *Fraxinus pennsylvanica* and *Taxodium distichum*. Male use exceeded availability for *Populus deltoides* and *Diospyros virginiana*, while females used *Ulmus rubra* less often than expected. For *Quercus nuttallii*, male use exceeded availability by number of trees, and female use was significantly lower than expected on the basis of basal area.

Nest-Site Characteristics

CERWs in the LMAV chose nest trees of at least moderately shade intolerant species for 43 of 68 nests. Nests at Chickasaw NWR were often far from the bole of the tree (mean = 6.8 ± 1.0 m from the bole, N = 15). A comparison of measured nest radius with predicted crown radius was possible for 16 nest trees of five species (*table 5*). Mean value of nest radius did not differ from that predicted by Goelz (1996) for open-grown trees of that species and diameter, indicating that CERWs chose long limbs as nest substrates. Analysis of variance of distance to nearest gap for 54 nest sites on the three LMAV study sites and 54 randomly selected points from these areas ($F_{5,102,df} = 21.73$, $R^2 = 0.52$, $P < 0.01$) indicated significant differences among sites but not, however, between nest sites and random points for any study area (*table 6*).

Discussion

The predominant tree used by a male CERW is canopy dominant or codominant of a wide variety of species and often a shade intolerant species. My interpretation of the preponderance of higher frequency use vs. availability was that the birds used a wide variety of tree species, rather than they required these species, similar to the interpretations of Jones and Robertson (2001) and Oliarnyk and Robertson (1996) for a CERW population in southern Ontario. Results of such tests should probably be viewed with caution, as they may not be portable from one area to another. For example, Gabbe et al. (2002) report that CERWs prefer to use the relatively rare kingnut hickory (*Carya laciniata*) on their Illinois study area. Because *C. laciniata* accounted for 5 percent of the importance value of trees on the Meeman Shelby Forest study area, CERW use of that tree was expected to be 5 percent; but CERWs there did not use the tree. Consistent overuse by both male and female CERWs of boxelder was an indicator of the prevalence of the species in bottomland hardwoods, especially on the Meeman Shelby Forest study area, where the trees achieved large size. In bottomland hardwoods, boxelder is an indicator of past disturbance to the forest canopy (J. Goelz, pers. comm.). The significant underuse of certain tree species was perhaps more easy to explain than overuse. Underuse of *Taxodium distichum* by males (and failure to observe any use by females) was a clear indication that CERWs in bottomland hardwoods were using areas that were less prone to flooding than were those in which baldcypress grew. A similar interpretation was suggested by the underuse of *Fraxinus pennsylvanica* in proportion to its basal area.

Table 3— *Tree species availability and use by Cerulean Warblers in the Mississippi Alluvial Valley. Availability determined on the basis of weighted number of trees of the species in the stands. Expected values for the chi-square comparison calculated as the proportion of total number of trees available in that tree species* total number of trees used by that gender of Cerulean Warbler.*

Tree species	Proportion of trees available	Female use (N)	Female use (χ^2)	Female difference[a]	Male use (N)	Male use (χ^2)	Male difference[a]
Acer negundo	0.14	192	59.0	High	433	29.5	High
Acer rubrum	0.022	12	1.93		29	11.4	Low
Acer saccharinum	0.021	28	6.1		29	10.8	High
Carya illinoensis	0.037	57	23.1	High	174	74.3	High
Celtis laevigata	0.28	199	3.77		438	89.93	Low
Diospyros virginiana	0.0051	10	exp < 5		32	30.13	High
Fraxinus pennsylvanica	0.062	48	0.16		145	0.41	
Juglans nigra	0.0017	0	exp < 5		16	exp < 5	
Liquidambar styraciflua	0.039	62	28.6	High	184	81.6	High
Platanus occidentalis	0.020	36	23.1	High	279	1062	High
Populus deltoides	0.012	0	exp < 5		130	338.4	High
Quercus lyrata	0.028	22	0.034		67	0.047	
Quercus nuttallii	0.031	34	3.19		211	244.	High
Quercus pagodaefolia	0.00020	0	exp < 5		12	exp < 5	
Taxodium distichum	0.026	0	exp < 5		22	28.4	Low
Ulmus americana	0.041	37	0.37		84	2.7	
Ulmus rubra	0.056	20	14.6	Low	55	50	Low
Total	0.81	757			2340		
Critical value, χ^2, 1 df, at P = 0.05 after Bonferroni correction			10.12	4 High 1 Low		10.12	8 High 4 Low

[a]High or Low indicates that the observed use was significantly higher or lower than expectation.

The data here show that the predominant tree used by a female CERW was a tree in a suppressed crown position, apparently without regard for species or shade tolerance. This pattern of use appeared to differ from the pattern of use by male CERWs. This result, however, must be viewed with considerable caution. Female CERWs were very difficult to observe, and these results may be biased. The opportunity to observe the primarily silent females may have occurred only when the birds were close to the ground, and hence more likely to be seen in suppressed crowns. Differences in use by males and females of *Quercus nuttallii* with respect to number of trees (males used more often than expected) and basal area (females used less often than expected) may have indicated that males selected larger trees and females selected trees without regard to their size.

Taken together, the results for the gap distance measures and nest radius vs. crown radius comparison may be instructive for development of a silvicultural prescription. CERW nests were not located closer to gaps. Nest to gap distance measures (*table 6*) were much less than those reported by Oliarnyk and Robertson (33 ± 5 m; 1996). They were, however, similar to those recorded by Jones et al. (14.9 ± 3 m; 2001) prior to ice-storm disturbance of their Ontario study site. Subsequent to ice-storm disturbance, nest to gap distance in the Ontario site decreased to 3 ± 0.4 m, a value close to that recorded from the Desha Delta Hunt Club site in this study (*table 6*). Nest radii of CERW nest trees reported by Jones et al. (5.8 - 7.4 m; 2001) is likewise similar to the value observed in this study. Nest radii of CERW nest trees in the LMAV did not differ from expected crown radii of open-grown trees. Open-grown trees, however, express what might be considered the maximum possible crown radius, for which purpose Goelz (1996) chose them. Thus, CERW nests may have been placed in locations where the nest trees, at least on the side where the nest was located, were in an equivalent position with respect to available sunlight, as would be open-grown trees. Failure to detect differences in distance to gap between nest sites and random points indicated that, in the LMAV, the birds were found in areas where more habitat was available than was being used by the birds. This is the first demonstration of an association between CERW nesting and nearness to canopy gaps at some earlier time in the life of a nest tree in the LMAV.

Table 4— *Tree species availability and use by Cerulean Warblers in the Mississippi Alluvial Valley. Availability determined on the basis of basal area of the tree species in the stands. Expected values for the chi-square comparison calculated as the proportion of basal area available in that tree species* total number of trees used by that gender of Cerulean Warbler.*

Tree species	Proportion of basal area available	Female use (N)	Female use (χ^2,)	Female difference[a]	Male use (N)	Male use (χ^2)	Male difference[a]
Acer negundo	0.06	192	396	High	433	521	High
Acer rubrum	0.01	12	0.92		29	0.096	
Acer saccharinum	0.02	28	4.9		29	12.7	Low
Carya illinoensis	0.04	57	15.2	High	174	49.2	High
Celtis laevigata	0.14	199	52.9	High	438	17.3	High
Diospyros virginiana	0.0057	10	exp < 5		32	22.7	High
Fraxinus pennsylvanica	0.098	48	13.2	Low	145	39	Low
Juglans nigra	0.0020	0	exp < 5		16	exp < 5	
Liquidambar styraciflua	0.045	62	16.4	High	184	46.3	High
Platanus occidentalis	0.050	36	0.57		279	199	High
Populus deltoides	0.057	0	exp < 5		130	0.86	
Quercus lyrata	0.038	22	2.70		67	7.63	
Quercus nuttallii	0.094	34	24.2	Low	211	1.95	
Quercus pagodaefolia	0.00067	0	exp < 5		12	exp < 5	
Taxodium distichum	0.051	0	exp < 5		22	86.7	Low
Ulmus americana	0.024	37	15.5	High	84	10.7	High
Ulmus rubra	0.029	20	0.59		55	3.74	
Total	0.78	757			2340		
Critical value, χ^2, 1 df, at P = 0.05 after Bonferroni correction			10.12	5 High 2 Low		10.12	7 High 3 Low

[a] High or Low indicates that the observed use was significantly higher or lower than expectation.

Table 5— *Comparison of measured crown radius at the nest (nest radius) of Cerulean Warbler nest trees from three study areas in the Lower Mississippi Alluvial Valley with crown radius calculated for open-grown trees using procedures in Goelz (1996).*

Tree Species	N	Mean nest radius (m)	SE	Mean calculated crown radius (m)	SE	Mean difference (m)	SE
Carya illinoensis	4	9.2	1.63	7.3	0.41	-1.91	1.73
Fraxinus pennsylvanica	5	5.2	1.02	6.6	0.44	0.98	1.01
Liquidambar styraciflua	3	6.3	0.88	7.3	0.82	2.00	0.29
Populus deltoides	2	4.5	1.50	7.4	0.65	2.45	2.38
Quercus nuttallii	2	7.2	0.75	10.4	0.81	1.71	0.96
Mean value	16	6.2	0.53	7.7	0.28	0.72	0.68

Table 6— *Distance to nearest canopy gap for Cerulean Warbler nests in the Lower Mississippi Alluvial Valley. Values in columns marked with different letters indicate significantly different values in ANOVA.*

	Nest to Gap			Random point to Gap		
Site	**N**	**Mean Distance (m)**	**SE**	**N**	**Mean Distance (m)**	**SE**
Chickasaw NWR	14	20.16 A	1.97	14	20.58 A	3.22
Desha Delta Hunt Club	19	4.15 B	0.80	19	4.13 B	1.21
Meeman Shelby Forest State Park	21	26.09 A	2.01	21	30.94 A	3.65
Gap distance category mean		14.95	3.43		16.44	5.00

Rudiments of a Silvicultural Prescription

These suggestions are offered to land managers and others interested in CERWs to stimulate a dialogue about the production of breeding habitat for this species. They are made for stands of bottomland hardwood trees in the LMAV. Because similarities of habitat use and some characteristics of habitat between LMAV and Ontario sites (see above) exist, it is tempting to extend the suggested application of the prescription to the habitats of the species elsewhere as well.

To produce habitat for CERWs, silvicultural activities must accomplish at least the following, within the context of a tract of land extensive enough (Hamel 2000) to accommodate breeding by the species:

1. Produce large sawtimber trees, which have large, expansive crowns, approaching those of open grown trees of similar diameter.

2. Emphasize production of such large individuals of both shade intolerant and shade tolerant species.

3. Locate these trees in situations in which large shade intolerant dominant trees overtop large individuals of shade tolerant species in close proximity to each other, creating opportunity for trees in both dominant and suppressed canopy positions to develop long limbs.

4. Grow these trees in such a way that over the course of the rotation numerous gaps are present throughout the stand to stimulate growth of long limbs with abundant foliage.

No specific suggestions are available from this analysis for the question of how much canopy cover is necessary. The presence of unused habitat in all three study areas in the LMAV precludes making such a determination. Options to produce these structural elements both through even-aged and uneven-aged silvicultural systems exist. The apparent association between nesting habitat for these birds and canopy gaps (Hamel 2000) further suggests that repeated stand entry to conduct intermediate treatments during the course of a rotation will be necessary. It is unlikely that gap-phase succession based solely upon individual tree-fall can develop sufficient heterogeneity in space to maintain habitat without some more extensive disturbance (Hunter et al. 2001; J. Goelz, pers. comm.). Satisfactory metrics for specifying the three-dimensional structure of the canopy appropriate to this species are not available. Articulation of a silvicultural prescription to produce that structure must await that specification.

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