Adaptive forest management to improve habitats for Cerulean Warbler

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Abstract: Cerulean Warbler (*Dendroica cerulea*, Aves: Parulidae) is a Neotropical migratory bird with a declining population. These birds are a focal species of the U.S. Fish and Wildlife Service, and listed as Vulnerable to Extinction by the International Union for the Conservation of Nature. Thus, the birds properly may be considered to be a conservation reliant species. Since 2001, the Cerulean Warbler Technical Group has been engaged in investigations and discussions to bring together the appropriate natural history, scientific approach, and management expertise to address the thorny problems posed by a species with declining populations that uses advanced stages in forest succession and mature hardwood forests of eastern North America. The species' predilection to use topographic edges in the central Appalachians further creates potential for conflict between habitat management for the species and mountaintop removal coal mining activities. We are developing a set of adaptable, and adaptive, guidelines for use by silviculturists and other land managers to address objectives of habitat maintenance and production for this species in concert with other management objectives, including timber production. Using data on distribution by forest type, successional stage, and stand stocking information, we describe Cerulean Warbler habitats and suggest certain silvicultural practices that we believe will benefit the species in different forest types. We further describe an on-going large-scale silvicultural experiment and other field tests in which these suggested practices and others are being evaluated to assess their utility as producers of habitat for the species.

Keywords: Cerulean Warbler Technical Group, Conservation-reliant species, *Dendroica cerulea,* stand stocking

INTRODUCTION

Cerulean Warbler (*Dendroica cerulea*, Aves: Parulidae; Photo above shows a breeding male) is a Nearctic Neotropical migratory bird with a declining population (Link and Sauer 2002; Robbins et al. 1992). These birds are a focal species of the U.S. Fish and Wildlife Service (cf. Ruley 2000, U.S. Fish and Wildlife Service 2002), and listed as Vulnerable to Extinction by the International Union for the Conservation of Nature (Birdlife International 2004). Habitat destruction, due directly or indirectly to human activities, is usually listed as a primary cause of the decline of the species (Robbins et al. 1992, Hamel 2000a). Thus, Cerulean Warbler properly may be considered to be a conservation-reliant species (Scott et al. 2005). Scott et al. (2005) use the term "conservation-reliant" to indicate an endangered species whose future is entirely dependent upon the application of specific conservation activities. I wish to extend the sense of that concept to include a species like the Cerulean Warbler that is not legally identified as endangered, but whose future is in doubt, and for which the necessity and potential effectiveness of appropriate conservation action to maintain populations is clear.

Management or conservation guidelines are clearly needed to produce and sustain habitats for the species. Currently, however, insufficient information is available to promulgate a reliable set of these guidelines. My purpose here is thus to review the biology of the species in such a way that potential management hypotheses can be developed, and then to outline an adaptive course of action to develop functional management guidelines provide habitat. This

contribution is confined to management of breeding habitats, because our understanding of them is better than that of nonbreeding habitats, and because reproduction occurs here and that sets the annual rate of population increase and therefore the ultimate population size. Recent evidence (Jones et al. 2004, Buehler et al. in review) suggests that more powerful effects on population result from low survival, of both adults and juveniles, than from fecundity, however, indicating that the ultimate conservation of the species depends on locations and parts of the life cycle that occur outside the North American breeding habitat.

THE FRAMEWORK

Understanding the conservation need, the ornithological peculiarities of the species, and the forestry context in which conservation of this particular species is destined to occur, requires a melding of concepts whose basis lies in these separate fields, but whose combination is crucial to the future of this species. Ornithology contributes empirical knowledge and theory concerning the behavior of the birds, its relation to habitat, foraging patterns, predators, nest parasites, and external factors such as the perils of migration. A central contribution to the discussion derived from ornithological practice is the notion of forest fragmentation and its effect on the birds. This is a spatial dimension occurring at a landscape scale that is of demonstrated importance to the conservation of this species but inconsequential to standard silvicultural practice.

Forestry contributes a detailed appreciation of the inexorable growth of trees through of time and the capacity of skilled practitioners to use this growth, to groom it toward specific targets of vegetation structure, and to utilize the by-products of this grooming to underwrite the costs inherent in achieving the desired structure. The ornithology and forestry meet in the expression of the desired structure, derived from ornithological observation and expressed in terms of forestry, with the expression of the process involved in producing that structure, derived from silvicultural knowledge and expressed in terms of ornithological outcome.

Conservation is the outcome, the future in which the application of forestry techniques to achieve the structure determined ornithologically to be beneficial to this species, results in the persistence and increase of the population to an acceptable level. The North American Landbird Conservation Plan (Rich et al. 2004) established a target level as twice the population estimated to occur in 1995. Because the knowledge of the precise habitat structure requisite to this outcome is limited, both in terms of landscape configuration, as well as horizontal and vertical vegetation distribution within stands, the process of carrying out conservation of Cerulean Warbler must be an adaptive one, both locally and regionally.

STUDY SPECIES

Most of our knowledge of Cerulean Warblers has come from the study of breeding male birds. These are the most obvious individuals of the species, as they are highly vocal. Therefore, our appreciation for the habitat utilization by these birds is based strongly upon observations of only one sex (Barg et al. 2006). If female Cerulean Warblers use different criteria to select habitats, we risk developing silvicultural prescriptions that provide ideal habitat for male birds but do not provide crucial elements for the females. For this reason, as well as others that will be obvious, it is premature at this time to state precise management prescriptions.

It is appropriate, however, to use what we know about the males to guide development of a management strategy that identifies differences between male and female habitat needs, and then incorporates both into the ultimate guidelines that result from the process. Hamel and Rosenberg (in press) developed a hierarchical description from large to small scale to express features of Cerulean Warbler breeding habitat, which will be followed loosely here.

Landscape Context

The important concept that populations occurring within a forest stand can be affected by factors associated with the landscape in which the stand is located, is a one that has fundamental importance to ornithological practice (cf. Robbins et al. 1989). While the application of this idea in ornithology is extensive, it is of less utility to silvicultural practice, where the vicinity of a growing tree is conveniently considered to be a radius approximately that of the tallest trees in the stand. Perhaps the clearest parallel in forestry concerns relationships between mills and the forest tracts which supply them. With respect to Cerulean Warblers and other migratory birds, the concept of landscape context is usually expressed in terms of habitat fragmentation (Morrison et al. 1992, Robinson et al. 1995).

Habitat fragmentation usually means that as habitat area is reduced, the capacity of a habitat to support a population is degraded beyond the extent of decline in area. The practical effect of the process of fragmentation is that as populations decline they become confined to larger and larger patches of habitat. This appears to be happening to Cerulean Warblers which are confined to very large tracts of forest (>4000 ha) in the southwest portion of the range, but occupy a much wider array of tract sizes in the north and northeast portions of the range (Rosenberg et al. 2000; Hamel and Rosenberg in press). The precise mechanism by which Cerulean Warbler occurrence within tracts is reduced beyond the simple area of the tracts in the southern and western parts of the range is a topic of great concern for the species that has not been resolved. Practically speaking, it means that potentially useful habitat is not occupied because it is too close to the hard, external edge of existing forest patches (Bosworth 2003). Similarly, it suggests that increases in patch size and in proportion of forest in the landscape will be beneficial to Cerulean Warbler (Twedt and Loesch 1999, Twedt et al. 2006). The implication of this understanding is that, to the extent that breeding habitat limits this species' population, a distinct portion of that limitation derives from the landscape outside the breeding territory.

Occurrence by Forest Region and Forest Cover Type

Breeding habitats of the Cerulean Warbler are concentrated in the Central Hardwoods Forest Region as defined by Fralish (2003; Fig. 1, Fig. 2). The birds occupy a variety of forest types and topographic positions, a fact that has created consternation among those attempting to understand its habitat utilization patterns and preferences. Because this understanding is a prerequisite to developing site- or region-specific management prescriptions, attention must be paid to improving and generalizing this understanding. Toward this end, a working hypothesis for the habitat utilization of the species may be that these birds are primarily associated with Central Hardwoods forest types. In the Central Hardwoods Region the birds are widely distributed among upland types (Eyre 1980), with an emphasis on both mesic situations for nest site selection (Nicholson 2004), and more exposed or steep situations for territory location

(Weakland and Wood 2005). The birds also occur along streams and in floodplains, where they are associated with tall forest with some distinct vertical structure within the vegetation.

Outside the Central Hardwoods region, the birds are associated with tree species characteristic of Central Hardwoods types, as these occur within other regions. This seems particularly true in the northern part of the range, where the birds occur in upland oak-hickory stands on south-facing slopes, and are not as strongly associated with stands of typical Northern Hardwoods types (K.V. Rosenberg, pers. comm.). They are, however, frequently associated with wetland situations in which beaver (*Castor canadensis*) or other agents have created the heterogeneous vertical structure that permits male birds to establish song perches from which their relatively weak song can be heard for longer distances than in closed forests. In upland forests in the Northern Hardwoods, Cerulean Warbler territories may depend upon individual trees of species with open crowns or which leaf-out late in the season, such as hickories, *Carya* sp. (Oliarnyk and Robertson 1996, Barg et al. 2006).

In the Southern Hardwoods Region in the southwestern portion of the range, from which the birds have been largely extirpated, Cerulean Warblers also occur in two distinct habitats. First, the birds occupy bottomland forests on particularly rich soil, where the canopy is especially tall and the structure of the vegetation is vertically heterogeneous. In these situations, the vegetation structure itself provides the openings, both vertically within the canopy profile and horizontally within the stand, from which the males can sing. Second, the birds occur in upland sites, preferentially at topographic breaks, such as near the top edge of a bluff, where vertical structure provided by vegetation is enhanced by topography.

The wide variety of cover types used suggests that something other than tree species composition is crucial to understanding breeding habitat. Nevertheless, the suggestions of Robbins et al. (1992) that certain species, e.g. *Ulmus americana*, are important, and the demonstration of the importance of *Carya* sp. in certain localities stress that certain tree species may be locally important.

Stand Structure

No student of Cerulean Warbler can avoid noticing the importance of vertical vegetation structure to the occurrence of these birds, presumably because male birds choose locations for song perches where open spaces within the canopy improve the broadcast characteristics of their songs (Barg et al. 2006, Woodward 1997). These situations may result from tall dominant trees extending above the general canopy level, from spacing between trees in the stand, from openings within the canopy of large trees, from vines hanging from tree crowns, or because of the phenological characteristics of leaf-out. Stands in which the warbler occurs always contain tall trees (Wilson 1811; Hamel 2000b), often of large to very large diameter, with a complex vertical structure. The stands may be dense and shrub-covered near ground level, but then open to a taller canopy of mid and overstory trees. Alternatively, the stands may be open at ground level and the midstory almost closed with a taller canopy of dominant and codominant trees towering above the midstory. Openings, or spaces, between the dominant trees there create a heterogeneous vertical structure over the closed midstory. Barg et al. (2005) provide extensive details on the spatial heterogeneity within breeding territories in Ontario. In bottomlands and

other sites with low relief, the birds occur only in stands where the canopy is horizontally and vertically heterogeneous, in situations in which the song perches of the males can have good broadcast possibilities for the songs. Song perch trees typically are of larger diameter than those within territories and territories are typically found in portions of stands with larger trees than is usual for the stand (Robbins et al. 1992).

In uplands, particularly where slopes are steep, the birds may occur in stands that have a more closed canopy. In these situations the heterogeneity of vertical vegetation structure is provided by the topography itself. For example, in the Appalachians the birds occur on ridgetops, and atop highwalls overlooking abandoned strip mine benches as well.

Within stands, Cerulean Warblers may occur in association with edges of one sort or another, such as along river courses (Robbins et al. 1998), but the situation is complex and as yet unresolved. Certain workers associate the birds with canopy gaps (Nicholson 2004); others do not (Jones 2000, Barg et al. 2006). Occurrence is associated with forest disturbance by a number of workers (Hunter et al. 2001, Rodewald 2004, Stoleson 2004, Wood et al. 2005), yet the effect of disturbance in the short term can be negative (Jones et al. 2001). An objective comparison of nest to gap distances among MAV sites yielded no particular association (Hamel 2005).

In contrast to the use of a variety of cover types, the consistency with which observers associate the birds with a complex vertical structure suggests that particular local structure or some specific process is critical to production of Cerulean Warbler habitat. Determining that structure or process is an important goal for research on this species.

Territory and Nesting Microhabitat

Studies of nest sites have been conducted across the breeding range of the Cerulean Warbler. The most extensive of these have been done on the periphery of the range, in Ontario in the north (Oliarnyk and Robertson 1996, Jones and Robertson 2001), Illinois (Vanderah 1993, Vanderah and Robinson 1995), and Indiana (Islam and Basile 2002, Islam and Roth 2004) and Michigan (Rogers 2006) on the west, and the Mississippi Alluvial Valley (MAV) in the south (Hamel et al. 1998). Important work has come from eastern Tennessee (Nicholson 2004, Buehler in press) and West Virginia (Weakland and Wood 2005, Wood et al. 2005), but demographic data from the core of the range in the Ohio Hills of southeastern Ohio and western West Virginia are still forthcoming.

Cerulean Warbler nests are located in a variety of situations in deciduous trees of a plethora of species (Hamel 2000b). Rogers' (2006) description of the nest site is a good one. Usually the nest is placed on a horizontal branch, often just proximal to a bifurcation. The nest frequently is placed under a small canopy or umbrella of leaves, either from twigs of the nest tree or from vines, such as Virginia Creeper (*Parthenocissus quinquefolia*). Typically, though not always, the nest is located above a space in the canopy that may be from 1 to 20m tall. Female Cerulean Warblers often drop vertically from the nest through this gap before flying horizontally to feeding locations. This behavior is characteristic of the species, and was first called "bungee-dropping" by Glendy Vanderah (pers. comm.). In spite of the importance of vertical structure to the species, vegetation configuration around nest sites is itself quite variable (Fig. 3).

Our understanding of the difference between nest sites and song perches gives insights into the difference between male and female Cerulean Warbler habitat selection. It cannot give us a complete understanding, however, because it is not yet clear if nest sites are chosen solely by the females or jointly by the pairs. In the MAV, the trees selected for nests and those used as song perches overlap. Some nest trees are clearly trees that males would not choose as primary song perches, while others are trees in which the breeding males concentrate their singing activities. Female Cerulean Warblers are very difficult to observe, and so distinguishing between male and female behavior in regards the choice of nest trees is difficult. If interpreted incorrectly, the implications for a management prescription for Cerulean Warbler habitat are profound. For example, in bottomlands, Cerulean Warbler males generally choose large, dominant or codominant cottonwoods (*Populus deltoides*), sycamores (*Platanus occidentalis*), green ashes (*Fraxinus pennsylvanicus*), or cherrybark (*Quercus pagoda*) or Nuttall oaks (*Q. nuttallii*) for their song perches (Hamel 2005). Nests, however, are often placed in more shade-tolerant boxelders (*Acer negundo*) and elms (*Ulmus americana*). A silvicultural prescription that emphasized production of high quality sawtimber of the trees preferred by males, and by timber buyers, might well produce excellent male Cerulean Warbler habitat, at the expense of female habitat.

Stand Stocking

Stocking is a concept with wide understanding in and utility to forest managers such as the membership of the Society of American Foresters, but one whose application to ornithology is much less widespread. Consequently, it deserves some elaboration for that important portion of the audience. Ernst and Knapp (1985) is a useful place to begin. Stocking is a measure of the space occupied by growing trees in a forest stand, in relation to the amount of space that would be occupied were the canopies of the trees utilizing all available light or growing space. Stocking depends upon two parameters, the density of trees and the basal area, or cross-sectional area of woody stems at breast height, of trees in the stand. In Cerulean Warbler range, these parameters are expressed in English units in the U.S., as trees per acre and ft^2 per acre, and in metric units in Canada, as trees per ha and m^2 per ha. Stocking charts generally assume that all trees are the same diameter, or mathematically convert them to a common quadratic mean diameter, the diameter of the tree of average basal area in the stand. The stand density and basal area are then used to relate existing conditions to those that would obtain for a stand of that density and basal area, were all the trees of equal diameter. Stocking permits us to look at the current condition of a stand and imagine its future, in the sense that reasonably well-understood functional relationships between density and basal area, expressed as the so-called "A"- and "B"-lines of stocking relate to the capacity of the trees in the stand to fully occupy the growing space. In this terminology, 100% stocking is considered the "A-line", a point at which growing space is fully occupied and at which crowding of the crowns is beginning to occur. The "B-line" represents usually the minimal stocking from which full occupancy of the site in the future is assured; alternatively, this can be viewed as the target stand density after thinning the stand has occurred (Putnam et al. 1960, Goelz 1995). Over time, without intervention, a stand of trees will move toward a higher stocking level. Thus, if Cerulean Warbler vegetation structure occurs a t a particular range of stocking levels, that structure will persist for only a limited period of time within a stand, absent some disturbance. Our one published estimate of stand stocking for

Cerulean Warbler habitat is that of Kahl et al. (1985) who identify the fairly narrow window of 65-85% stocking.

As an attempt to express Cerulean Warbler breeding habitat in strictly silvicultural terms, I have taken data from the study sites on which I work in the MAV, as well as some from three additional study areas, in Indiana (Islam and Basile 2002, Islam and Roth 2004), in Pennsylvania (S. Stoleson, pers. comm..), and in Ohio (A. Rodewald, pers. comm.), and summarized stand characteristics of these study sites in terms of the appropriate stocking charts. The stocking chart for the Indiana, Pennsylvania, and Ohio sites is the standard chart of Gingrich (1967), while that for the MAV sites is the chart of Goelz (1995).

In the MAV sites, the stands are well stocked, perhaps even overstocked, and characterized by a large quadratic mean diameter (Fig. 4). No clear relationship appears to exist between the average stocking of the stand and the stocking of the immediate vicinity of the nest sites. This may indicate that managing stands for diverse vertical and horizontal structure with a given stocking level and relatively high diameter will provide the variety of situations conducive to nest site selection.

In the Indiana sites, stocking levels between Cerulean Warbler use and nonuse areas are similar, but in each case the birds were using a portion of the stand with a higher quadratic mean diameter than was typical of randomly selected portions of the stand (Fig. 5). In the Pennsylvania data, stands subjected to shelterwood cuts, stands adjacent to shelterwoods, and uncut stands were measured. Cerulean Warblers occurred in stands with lower stocking and higher quadratic mean diameter (Fig. 6). Biologically, this suggests that the birds were using areas in which fewer larger trees occurred, and avoiding stands where larger numbers of smaller stems were characteristic. Silviculturally, the birds were found in stands that had been subjected to shelterwood cutting. In the Ohio study sites, Cerulean Warbler abundance appeared to be related to stocking level, and in a regular way (Fig. 7). Cerulean Warbler numbers were higher in stands with lower stocking (Fig. 8), although the small sample size and variability among stands precludes conclusive test.

In each of these cases, in Indiana, Pennsylvania, and Ohio, the occurrence of the birds is associated with space within the stand, available growing space as indicated by stocking levels well below the fully stocked condition. The available space might thus be a measure of the birds association with heterogeneous structure within the stand, both vertically and horizontally.

From these few examples, stand stocking appears to be a useful measure on which ornithologists and silviculturists can collaborate in developing a management prescription for the Cerulean Warbler. This is predicated on finding appropriate stocking levels for Cerulean Warblers and integrating these with goals of production forestry that are compatible with them. It will be possible, I believe, to do this in a way in which Cerulean Warbler management can be integrated into standard forestry practice.

Critical to the success of this integration will be clear ornithological specification of the habitat needs of breeding females as well as males, and indeed of juvenile birds as these differ from those of the adults. The necessary caveat to this process is the recognition that developing

and applying silvicultural prescriptions for breeding habitat will only improve the breeding habitat. To the extent that our assumption that population limitation is due to breeding habitat is not correct, we will be unable to assure conservation of the species by breeding habitat improvement alone.

APPROACH TO PROBLEM SOLUTION

In response to the observed decline in numbers of the Cerulean Warbler, and obvious importance of forests of large sawtimber trees to the species, the Cerulean Warbler Technical Group (CWTG) was formed in 2001 in Knoxville, TN. The group subsequently met in Shepherdstown, WV, in 2002, to develop a focused, coherent, and comprehensive approach to the conservation of the species. This led to the development of a Cerulean Warbler Conservation Initiative, through which the CWTG has begun to address the significant information and conservation needs of this species. The CWTG strives to include all stakeholders with interests, financial or otherwise, in the future of the species, in developing workable conservation solutions for the birds (Hamel et al. 2004).

In light of the scarcity of information on Cerulean Warbler breeding habitat requirements, particularly within the core of the birds range, an experiment to assess Cerulean Warbler response to silviculture was devised and implemented at study areas in Kentucky, Ohio, Tennessee, and West Virginia. The experiment is a replicated, randomized complete block designed habitat manipulation. The treatments are intended to address the combined silvicultural need to create advance regeneration within stands and the ornithological need to provide diverse vertical vegetation structure for breeding Cerulean Warblers. The treatments are thus varying intensities of canopy removal: control – 0% removal, light – removal cutting to leave approximately 75-80 ft^2 basal area per acre; intermediate - removal cutting to leave approximately 55 ft^2 basal area per acre; and heavy - removal cutting to leave approximately 20 ft^2 basal area per acre. Stocking levels can be inferred by reference to Figures 5, 6, and 7, but cannot be specified without information on quadratic mean diameter. Details of the treatment protocol are presented in an Appendix.

Study sites are generally sawtimber stands with closed canopy, in landscapes that are primarily forested (i.e., > 70% forest within 10 km). The treatment area is 10 ha with an equal sized buffer around the treatment plot. Study sites were initially selected in 2004, and have to date received two years of pretreatment sampling for avian community and vegetation characteristics. Harvest treatments currently are being implemented.

Other groups are also interested in development of specific habitat management prescriptions for forest songbirds. The Missouri Ozark Forest Ecosystem Project (MOFEP, http://mofep.mdc.mo.gov/ visited 7 September 2006), an outstanding example, is a long-term study initiated in 1991. In Indiana, the Partnership for Sustainable Working Forests includes a team of researchers from Purdue University, Indiana University, Indiana State University, and Ball State University. They are involved in a project called the "Hardwood Ecosystem Experiment," on state forestry lands in Indiana; the possibility of including the Hoosier National Forest exists. The state is concerned about the lack of oak regeneration on their lands. The overall aim of this long-tern (8 years) study is to initiate a large-scale experimental study of

forest management, and its impacts on a wide variety of selected species. As in the Cerulean Warbler Conservation Initiative, a before-after control design with multiple treatments from light to heavy canopy removal and subsequent burning are involved (K. Islam, pers. comm.).

Adaptive model

This experimental design was based upon the assumption that Cerulean Warbler breeding habitat needs include extensive forest and heterogeneous vertical canopy structure within that forest. We further assumed that forest canopies today are in general too closed and lack the required vertical heterogeneity for the species, and that forest management may be used to enhance habitat for Cerulean Warblers. The observed responses of the birds will aid in development of specific management prescriptions.

My general hypothesis is that Cerulean Warbler response to the light treatments will likely be positive initially as the treatment reduces stocking level and creates space between existing crowns in the stand, but that in the longer term the light treatment will not present good habitat as the canopy will close relatively soon after the treatment. Response to the intermediate treatment may be positive initially, if the effect of the treatment is similar to the light treatment, or negative initially, if the effect is similar to that of the heavy treatment. Either way, I expect that this treatment will probably provide good breeding conditions for the birds for a longer period of time than will the light treatment. Increased spacing between trees resulting from the reduced stocking level will create a more favorable situation for song broadcast by males, as in the light treatment. Increased light levels in the stand beyond those produced by the light treatment will permit additional crown development and increased vegetation within the profile, which may also increase nest site opportunities. Both of these results will persist in the intermediate treatments longer than in the light treatments. Response to the heavy treatment will initially be negative, because the stocking level will be too low and the stands too open. As the stands respond to the treatment over time, however, the increase in crown size occasioned by growth into the open space, and the development of a more diverse midstory by ingrowth of trees in the spaces created between the residual stems will both serve to increase future potential of the stands as breeding habitat for Cerulean Warblers. The birds thus may increase in number and probably experience higher nesting success, though perhaps only after a period of time, say after 10 years post-treatment. Alternatively, the effect of one or more of these treatments may be to create so much space within the stands that the birds abandon them for an extended period of time.

Implications of this experiment for Cerulean Warbler management guidelines must thus await a sufficient period of time to allow the effects of the treatments to be expressed in terms of population size and demographic response. If the initial effect of certain of the treatments is severe, and bird numbers fall, this may be only a temporary response. The birds' use of the modified habitat types will lag behind the response of the vegetation to the treatment. Consequently, development of final management guidelines will require at least 15 years.

Conservation needs of Cerulean Warbler are present-day, however, and cannot be put on hold while the requisite data is gathered from this experiment. During the interim the CWTG hopes to stimulate the participation of additional partners who are willing to share their lands and

their harvest records. It will be possible to use such historical records of harvest, coupled with past and current measures of populations of Cerulean Warbler and other important forest songbirds, to obtain valuable information which can be used to adaptively develop silvicultural guidelines in the intermediate time period (Hamel and Dunning 2000).

CONCLUSION

The long-term conservation of the Cerulean Warbler, as for so many other forest birds, requires collaboration among those interested in the birds as well as those interested in forest management. We assume that the activities of the CWTG and the silvicultural treatments described in this paper will further this cooperation, and provide a continuing means to improve it. Although legitimate concerns have been expressed that factors operating during the non-breeding season may contribute significantly to population regulation of this species, the ultimate population size cannot be greater than that which the breeding grounds are capable of producing. Thus the future of the species depends vitally on the capacity of forest managers, especially in the Central Hardwoods, to produce habitats in which the species can thrive. It is also necessary to observe that improving breeding habitat can in the long term only address population limitations that occur as a result of breeding habitat limitation. To the extent that factors outside the breeding season control population size or trend, those factors also must be addressed in a comprehensive conservation plan.

ILLUSTRATIONS

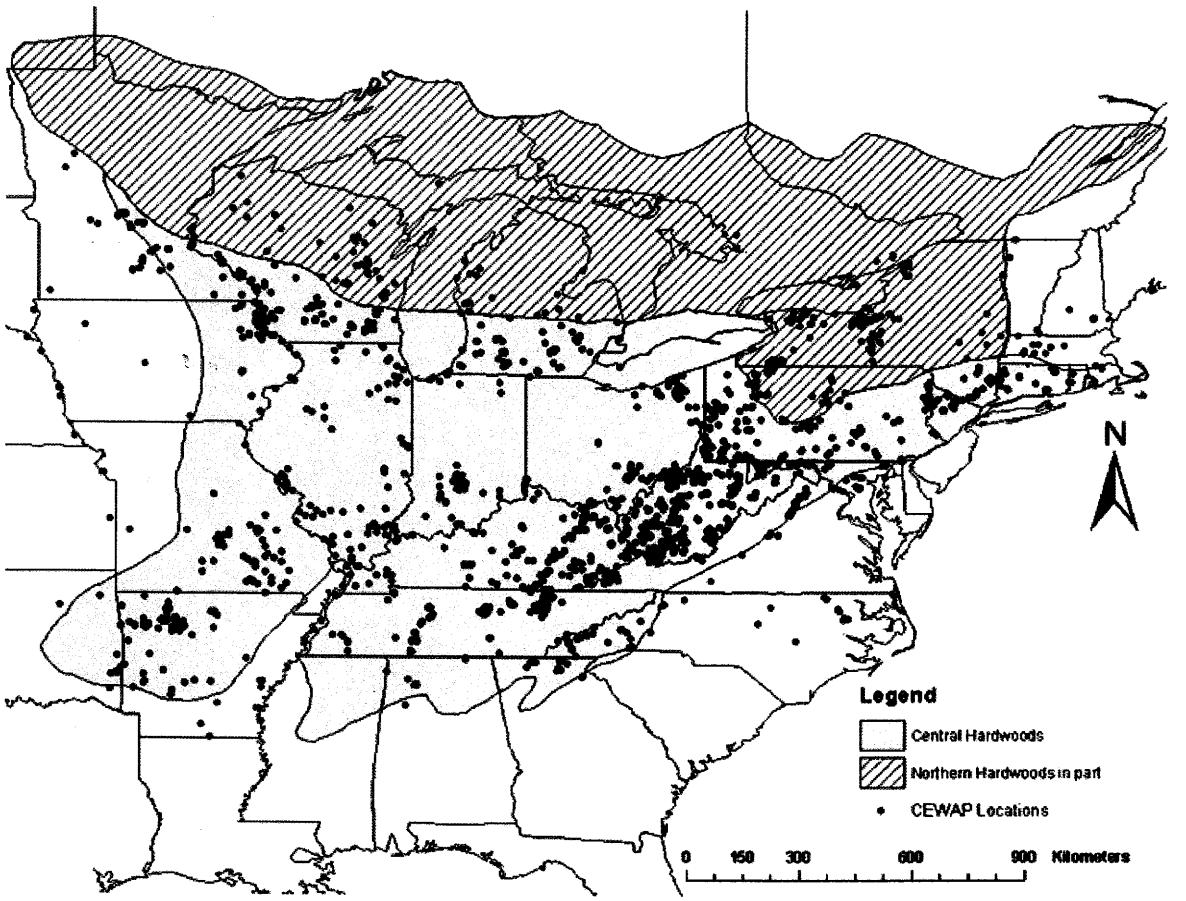

Figure 1. Breeding range of the Cerulean Warbler, indicated by locations identified in the Cerulean Warbler Atlas Project (CEWAP; Rosenberg et al. 2000), and its relation to the Central and Northern Hardwoods Regions of Fralish (2003).

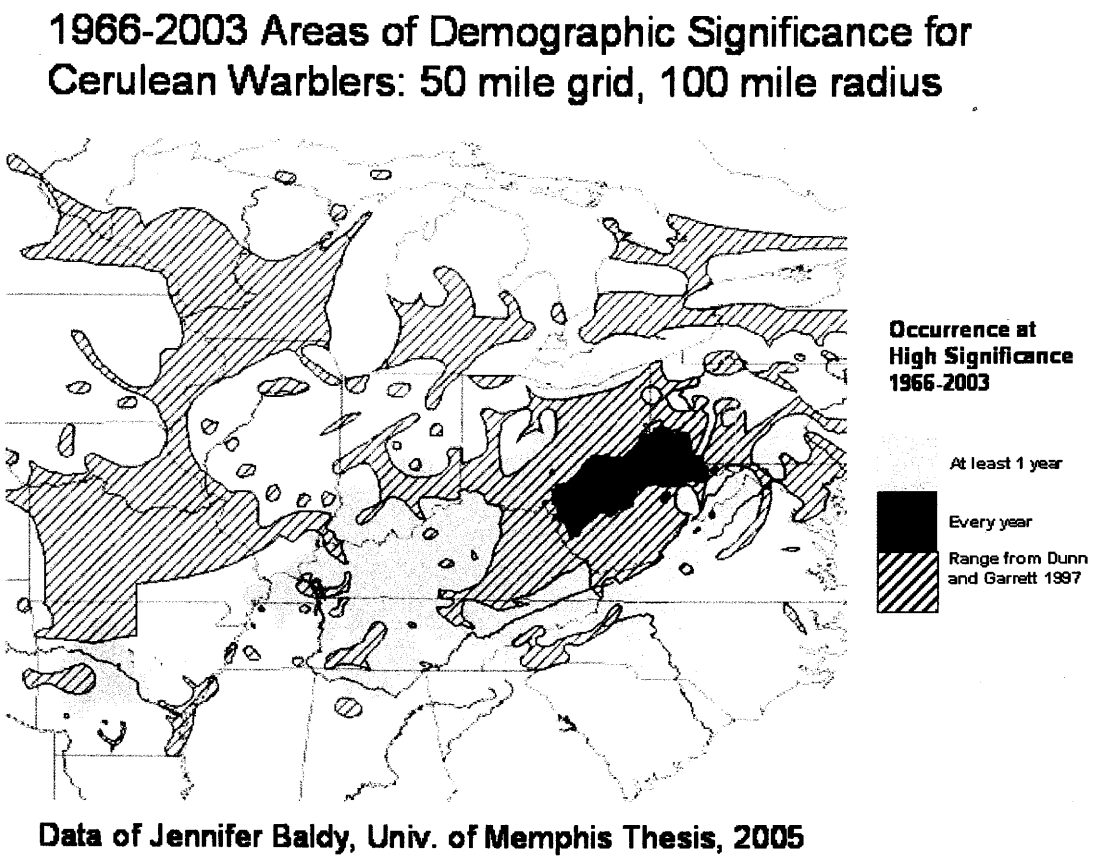

Figure 2. Breeding range of Cerulean Warbler, showing the portions of the range in which the birds occurred at higher than expected rate of occurrence in at least one year or in every year of BBS data 1966-2003. This latter area is one objective estimate of the "Core" of the breeding range. Data from Baldy (2005) and Dunn and Garrett (1997).

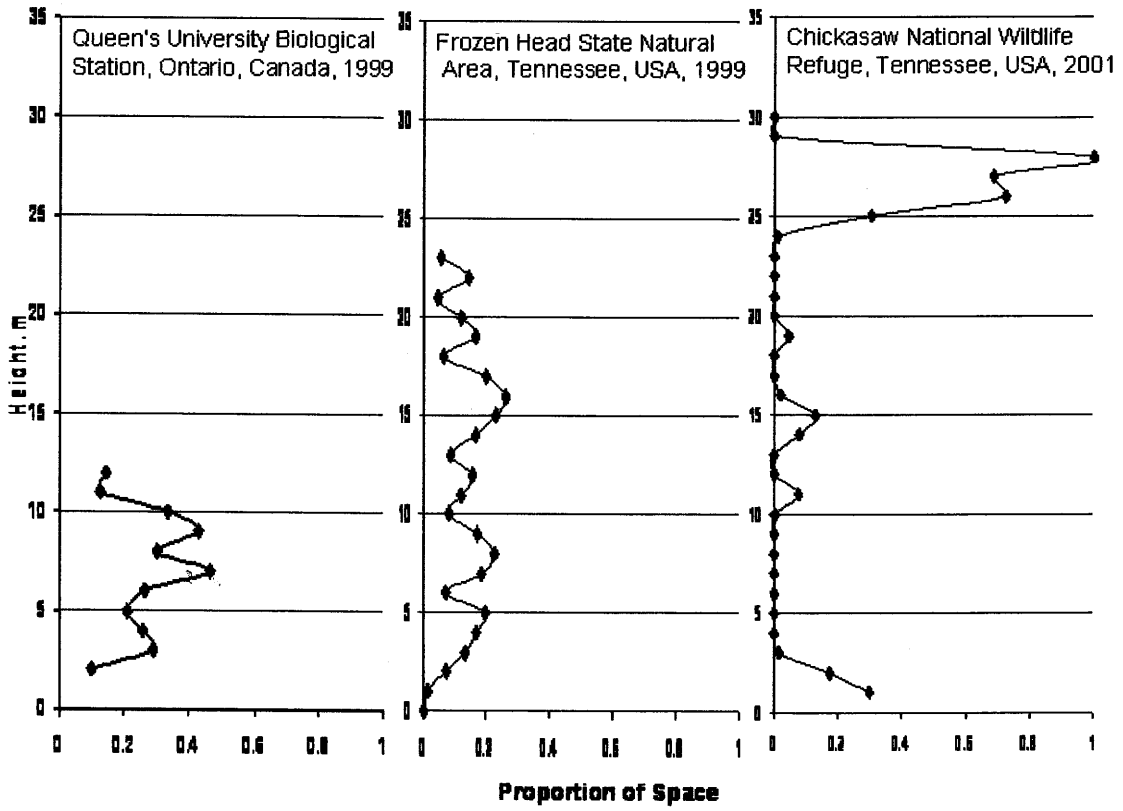

Figure 3. Comparison of vertical distribution of vegetation at selected Cerulean Warbler nest sites in three different portions of the range, all measured with identical protocol using laser rangefinder. Lines indicate proportion of horizontal space occupied by vegetation, in 1m intervals, within a 5-m diameter circle centered beneath the nest.

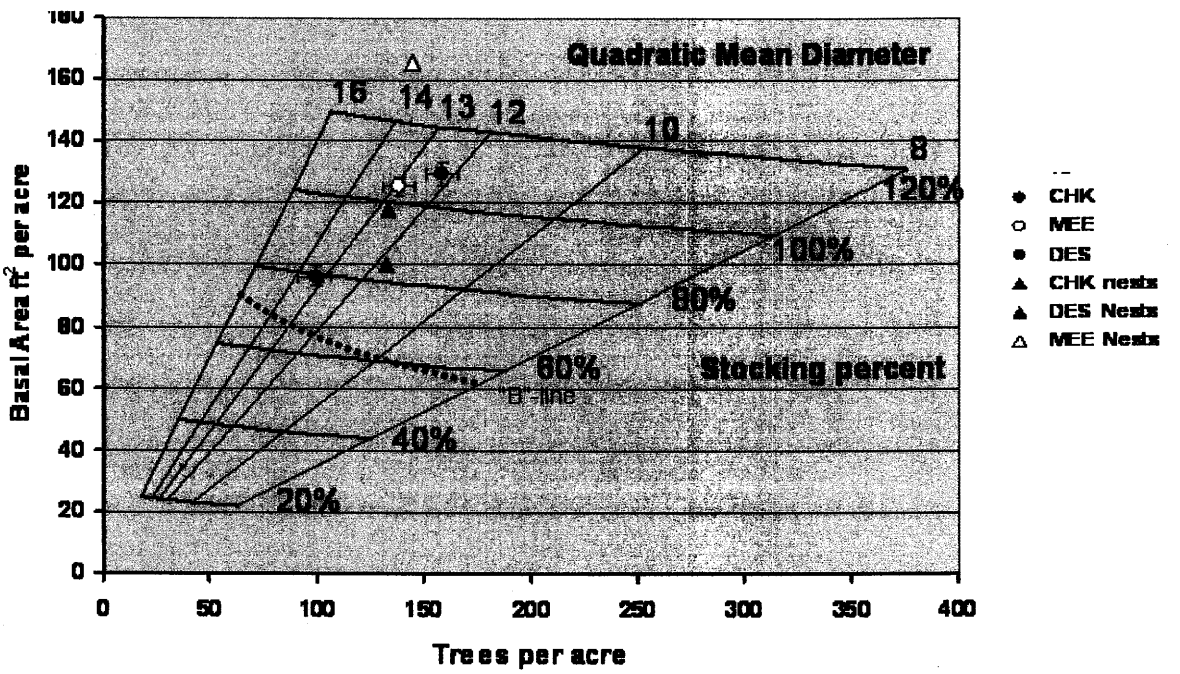

Figure 4. Stocking of Cerulean Warbler study sites in the Mississippi Alluvial Valley, in which basal area per acre and trees per acre observed on Cerulean Warbler study sites are depicted on the stocking chart for bottomland hardwoods compiled by Goelz (1995). Circles indicate average stocking of grid points in the stands, with 1 s.e. error bars; triangles indicate average stocking of plots taken directly under nest sites. Sites are CHK – Chickasaw National Wildlife Refuge, Lauderdale Co., TN; DES – Desha Delta Hunt Club, property of Anderson Tully Co., Desha Co., AR; and MEE – Meeman Shelby Forest State Park and Wildlife Management Area, Shelby Co., TN.

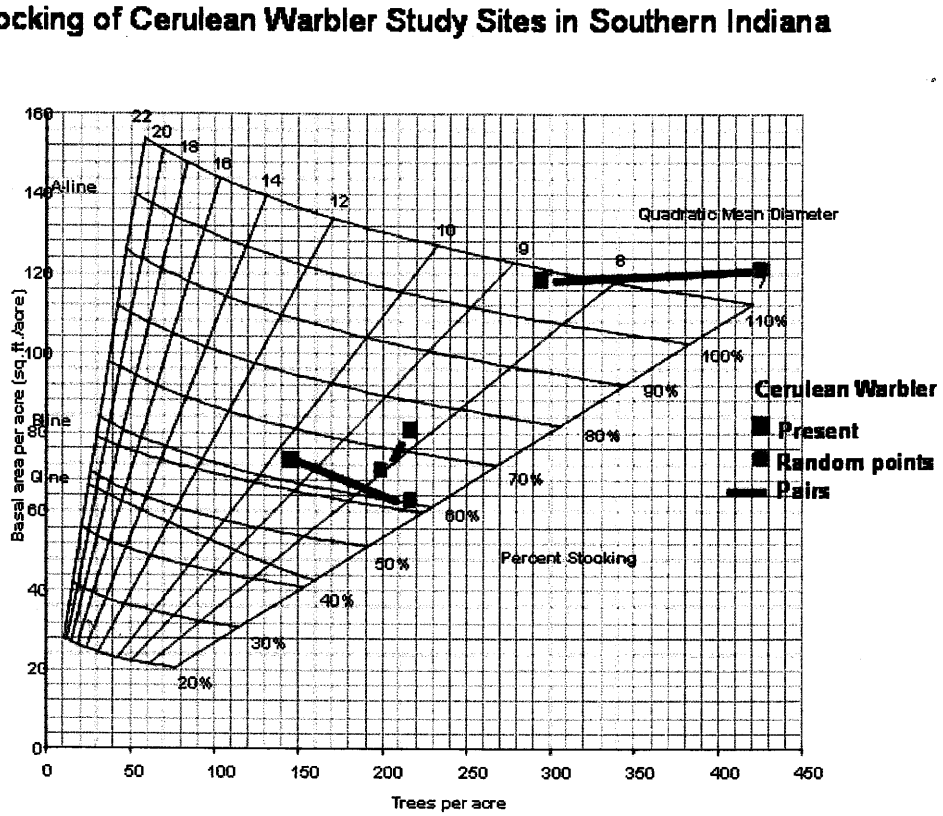

Figure 5. Stocking of Cerulean Warbler study sites in southern Indiana, in which basal area and tree density of study sites are depicted on the stocking chart of Gingrich (1967) for Central Hardwoods. Data from Islam and coworkers, in reports to US Fish and Wildlife Service.

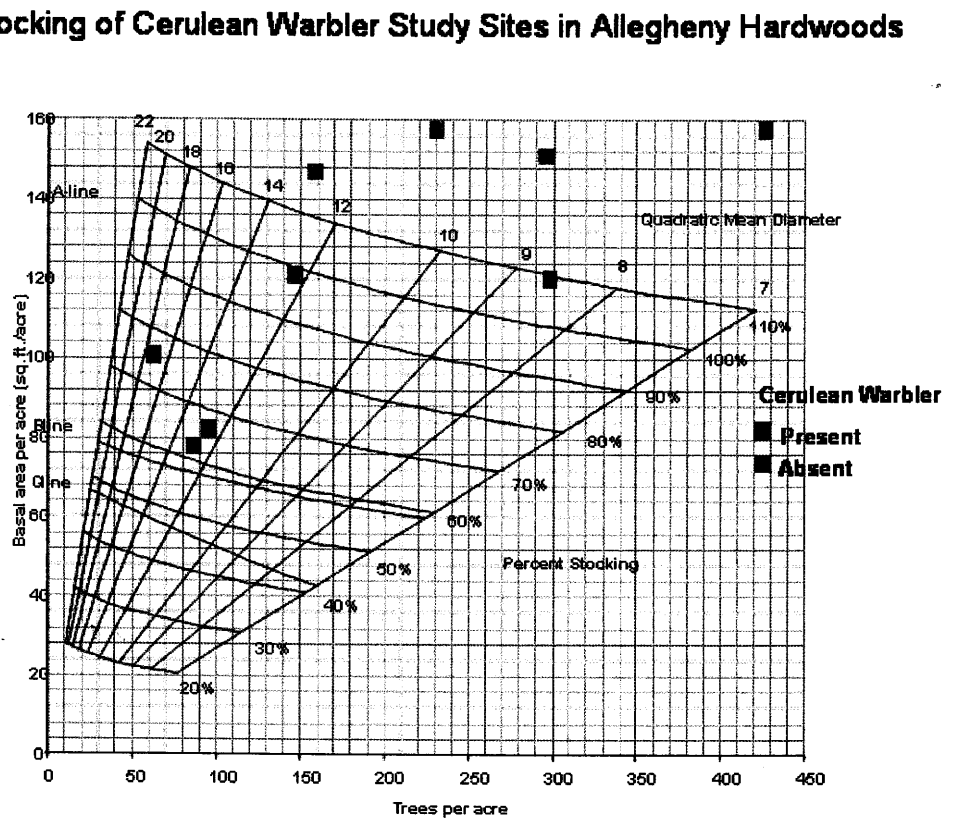

Figure 6. Stocking of Cerulean Warbler study sites in Pennsylvania, in which basal area and tree density on study sites are depicted on the stocking chart of Gingrich (1967) for Central Hardwoods. Data from Scott Stoleson, pers. comm.

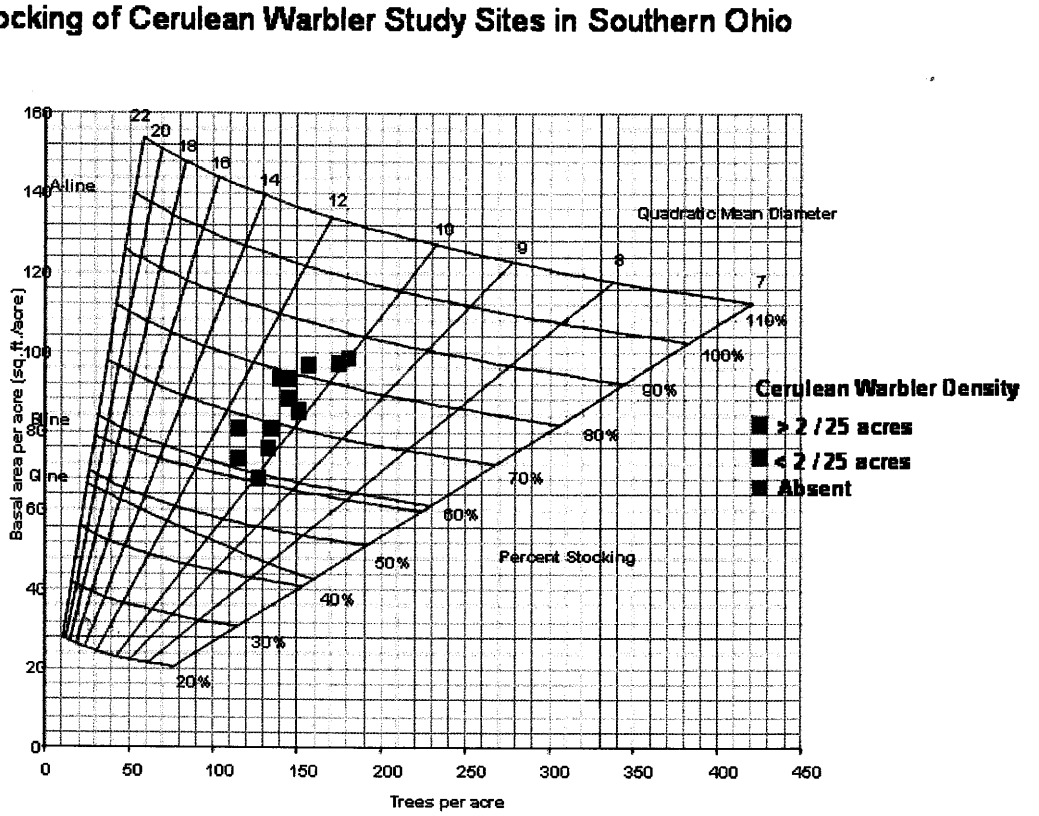

Figure 7. Stocking of Cerulean Warbler study sites in southern Ohio, in which basal area and tree density on study sites are depicted on the stocking chart of Gingrich (1967) for Central Hardwoods. Data from Amanda Rodewald, pers. comm.

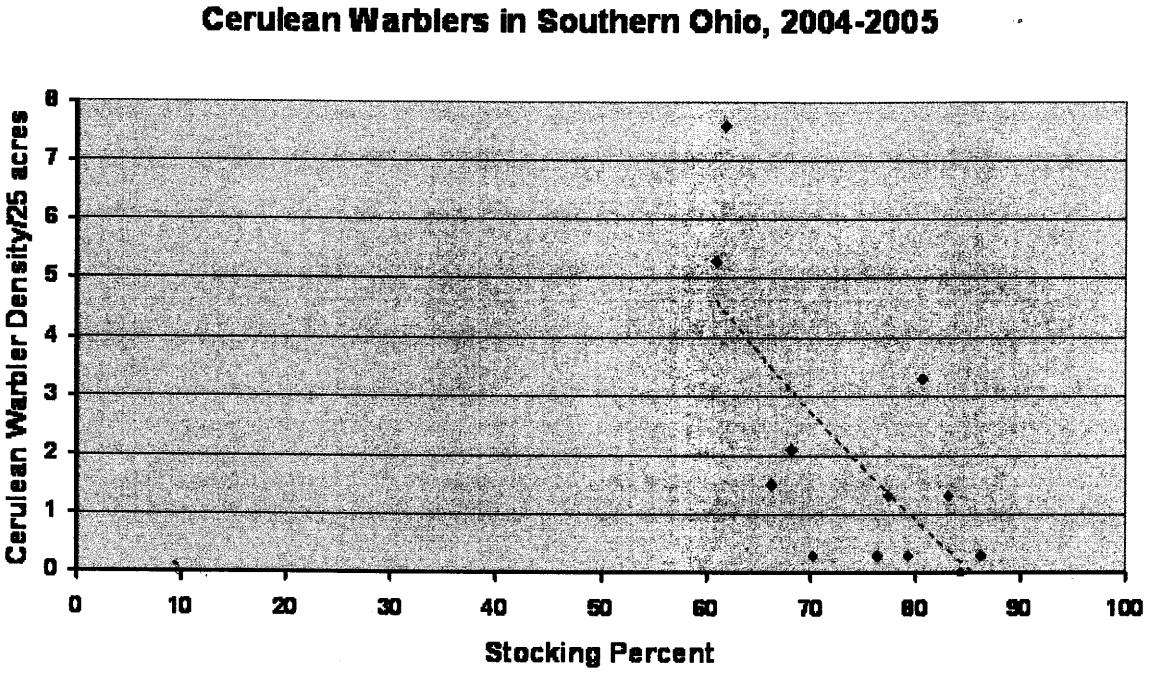

Figure 8. Density of territorial Cerulean Warblers in relation to stocking of study sites in southern Ohio, in which observed basal area and tree density on study sites were used with formulae of Gingrich (1967) for Central Hardwoods to calculate stocking. Data from Amanda Rodewald, pers. comm. Dotted line suggests logarithmic fit to the data.

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Appendix

Forest Management Research Project
Treatment Implementation Guidelines
January 30, 2006

Control: The control stand will remain untreated through the conclusion of the project or at least until August 2008, preferably August 2009. This includes any form of harvest, prescribed burning, or application of herbicides.

Light Treatment: Between August 15, 2006 and April 1, 2007 this stand should be harvested by removing enough of the overstory to leave approximately 75–80 sqft BA/acre (17.2-18.3 m^2/ha). The removal can be a combination of timber stand improvement and value extraction. However, the residual stand should be evenly stocked (i.e., removals should be well-spaced) and the removals should not be strictly a thinning from above as would occur in a diameter limit cut, although such a cut with a high limit (i.e., ≥18" DBH) would give us very similar results and would not be a problem. The marking objective should be designed to roughly mimic a single-tree selection harvest as commonly practiced in the region in question.

Intermediate Treatment: Between August 15, 2006 and April 1, 2007 this stand should be harvested by removing enough of the overstory to leave approximately 55 sqft BA/acre (12.6 m^2/ha). The removal should be conducted such that the residual stand is comprised almost entirely of well-spaced dominants and co-dominants. All other commercial stems (i.e., > 6" DBH) should be felled. The marking objective should be designed to roughly mimic a shelterwood harvest as commonly practiced in the region in question. The cut should NOT be a heavy diameter-limit type harvest. Clearfelling of all stems 2" DBH or larger should be completed within the same time frame as the harvest.

Heavy Treatment: Between August 15, 2006 and April 1, 2007 this stand should be harvested by removing virtually all of the overstory, leaving only approximately 20 sqft BA/acre (4.6 m^2/ha). Residual stems should be well-spaced and be comprised of dominants and co-dominants. All other commercial stems (i.e., > 6" DBH) should be felled. The marking objective should be designed to roughly mimic a deferment or "modified-shelterwood" harvest as commonly practiced in the region in question. Clearfelling of all stems 2" DBH or larger should be completed within the same time frame as the harvest.

All Treatments: No additional timber harvests, burning, or application of herbicides should occur for the remainder of the study or through August 2008, preferably August 2009. This restriction should apply to at least a 50 yard buffer, preferably to a 200 yard buffer. All decks should be located OUTSIDE of the stands if possible. Road and skid trail construction within treatment stands should be minimized.

Treatments should be 25 +/- 2 acres in size when completed.