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CERULEAN WARBLER (*SETOPHAGA CERULEA*) RESPONSE TO CHANGES IN FOREST STRUCTURE IN INDIANA

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Resumen. **– Respuesta de la Reinita Cerúlea a cambios en estructura forestal en el estado de Indiana en los E.E.U.U.** – La Reinita Cerúlea (*Setophaga cerulea*), paseriforme Neotropical, ha sufrido una declinación en su tamaño poblacional durante las últimas cuatro décadas. Como consecuencia, ha sido catalogada como "En Peligro" en el estado de Indiana, Estados Unidos, y es considerada globalmente como especie de "conservación preocupante". En los últimos cinco años (2007-2011), nuestra investigación se ha enfocado en cómo las poblaciones de la Reinita Cerúlea responden a los cambios del ambiente como resultado de diferentes prácticas de manejo del bosque en sus áreas de anidación. Como parte del Experimento en Ecosistemas de Madera Fina, un estudio experimental de gran escala y a largo plazo (100 años) sobre los impactos del manejo del bosque en plantas y vida silvestre, monitoreamos las poblaciones de la Reinita Cerúlea durante el periodo pre-tratamiento (2007 & 2008) y pos- tratamiento (2009 – 2011). En 2011, se inició un estudio sobre la biología de anidación. El área de estudio consiste de seis sitios con tratamiento y tres sitios control, todos ubicados dentro de nueve unidades de manejo en los bosques estatales de Yellowwood y Morgan – Monroe en el sur de Indiana. Las poblaciones de la Reinita Cerúlea respondieron positivamente (+75%) a sitios con tratamientos de edades uniformes y negativamente (-38%) a sitios con tratamientos de edades no uniformes en base al número de detecciones luego de la cosecha. También hubo un incremento (+62%) en el número de detecciones de la Reinita Cerúlea en los sitios control entre los años antes y después del tratamiento. El éxito de anidación fue mayor en los sitios control (41%) comparados con los sitios de tratamiento de edad uniforme (33%) y los de edad no uniforme (22%); sin embargo, estas diferencias no fueron significativas.

Abstract. – The Cerulean Warbler (*Setophaga cerulea*), a Neotropical migratory songbird, has declined in population size during the last four decades. As a consequence, it is listed as "Endangered" in the state of Indiana, USA, and is considered a species of "conservation concern" globally. For the last five years (2007-2011), our research has focused on how Cerulean Warbler populations respond to changes in their environment as a result of different forest management practices on their breeding grounds. As part of the Hardwood Ecosystem Experiment, a large scale and long term (100 years) experimental study of forest management impacts on plants and wildlife, we monitored Cerulean Warbler populations during pre-treatment (2007 & 2008) & post-treatment (2009-2011) years. In 2011, we initiated a breeding biology study. Our study area consisted of six treatment & three control sites, all located within nine management units in the Yellowwood and Morgan-Monroe state forests of southern Indiana. Cerulean Warbler populations responded positively (+75%) to even-aged treatment sites and negatively (-38%) to uneven-aged treatment sites as determined by the number of detections after harvest. There was also an increase (+62%) in the number of Cerulean Warbler detections in the control sites between pre- and post-treatment years. Nesting success was highest in control sites (38%) compared with even-aged (35%) and uneven-aged (22%) sites; however, these differences were not significant.

Key words: Cerulean Warbler, *Dendroica cerulea, Setophaga cerulea*, Relative Abundance, Nesting Success, Response To Silviculture.

INTRODUCTION

Cerulean Warblers (*Setophaga cerulea)* are small migratory songbirds that breed in the Northeastern and Midwestern portions of North America and winter on the slopes of the Andes (Robbins *et al.* 1992, Hamel 2000). For the last 40 years, this species has declined at an annual rate of 4.1% (Sauer *et al.* 2008), the steepest decline of any North American Parulid (Jones *et al.* 2008). As a consequence, it is listed as a top priority species for conservation action by Partners in Flight (Hamel *et al.* 2004) and listed as "Vulnerable" by the International Union for Conservation of Nature (Birdlife International 2004). It was petitioned for listing as a threatened species under the Endangered Species Act (U.S. Fish & Wildlife Service 2002) but the petition to list was later denied as the action was not warranted (U.S. Fish & Wildlife Service. 2006). In Indiana, the Cerulean Warbler is listed as endangered.

Cerulean Warblers prefer large tracts of mature deciduous forest (Hamel 2000). On the breeding grounds in the Midwest, specifically Indiana, Cerulean Warblers generally are associated with forests featuring a heterogeneous forest structure with multiple canopy layers created by multi-age stands of trees, and appear to prefer large dominant trees within their territories (Jones & Islam 2006, Roth & Islam 2008). These forests are typically dominated by oaks (*Quercus* spp.) and hickories (*Carya* spp.) in the uplands with beech *(Fagus grandifolia*), northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and white ash (*Fraxinus americana*) as common mesic species in ravines (Homoya *et al.* 1985). These forests are characterized by canopy gaps that are created naturally through tree fall or fire, or anthropogenically from old logging roads and forest clearings. Several authors have also noted that Cerulean Warblers are associated with canopy gaps in other parts of the breeding range and that these gaps are likely of importance to the species (Oliarnyk & Robertson 1996, Hamel 2000, Bosworth 2003, Weakland & Wood 2005, Wood *et al.* 2006, Bakermans & Rodewald 2009).

A parallel study by the Cerulean Warbler Technical Group on response of this species to different forest treatments was conducted in Ohio, West Virginia, Kentucky, and Tennessee (Dawson *et al.* this 2012, Larkin *et al.* 2012). In another study in West Virginia, Cerulean Warblers were present at a lower abundance and frequency in 15-18 year old regenerating clearcut stands compared to 70-80 year old mature second-growth forests (Wood *et al.* 2005). In southern Indiana, Cerulean Warbler habitat needs appeared to be supported by a 20-30 year cutting cycle combined with uneven-age management and timber stand improvement practices (Register & Islam 2008). Cerulean Warbler response to experimental habitat manipulation has been identified as an important research priority (Hamel *et al.* 2004) in order to determine, in particular, specific characteristics of vegetation structure preferred by the birds and how to produce these vegetative characteristics on the landscape.

The Hardwood Ecosystem Experiment (HEE, see http://www.heeforeststudy.org/), a large scale and long term (100 years) experimental study of forest management impacts on plants and wildlife, was initiated in southern Indiana in 2006. The HEE is a research collaboration between the Indiana Department of Natural Resources, Purdue University, Ball State University, Indiana University of Pennsylvania, Indiana State University, Drake University, and The Nature Conservancy. The goal of this experiment is to understand social and ecological impacts of long-term forest management on public and private lands in Indiana and in the broader Central Hardwoods Region. The primary objective is to develop even and uneven-

aged silvicultural systems that maintain oak-dominated forest communities and landscapes. Nine management units (303-483 ha in size with 200 ha core) were randomly selected in Morgan-Monroe (9716 ha) and Yellowwood state forests (9444 ha) in southern Indiana (Fig. 1). Six of nine management units received one of two types of silvicultural treatments in 2008. Three units (1, 7 & 8) received single tree selection with patch cutting to create uneven-aged forests (Fig. 1). These units each received eight cuts, which created openings ranging from 0.4 to 2 ha, dispersed across ridges, north and south slopes, and bottomlands. Three units (3, 6 & 9) were treated with both shelterwood and clearcut harvests with the intent to create even-aged forests (Fig. 1). Shelterwood and clearcut harvested areas each received four cuts per unit. Shelterwood harvests removed forest canopy ranging from 45 to 53 m^2/ha of basal area. Two 4 ha shelterwood harvests and two 4 ha clearcuts, applied to each of the three units, occurred on slopes in each cardinal direction. The three remaining units (2, 4 & 5) did not receive silvicultural treatment and served as controls (Fig. 1). All management units were comparable in tree structure and composition, and were characterized by ridgetops with steep, narrow drainages. For this study, 2007 and 2008 represent pre-treatment years, and 2009, 2010, and 2011 represent post-treatment data.

Our objectives were to (1) measure Cerulean Warbler relative abundance in study areas before and after forest treatments were applied and (2) monitor breeding success during the third year after harvest. We hypothesized that Cerulean Warblers would occur in greater abundance in management

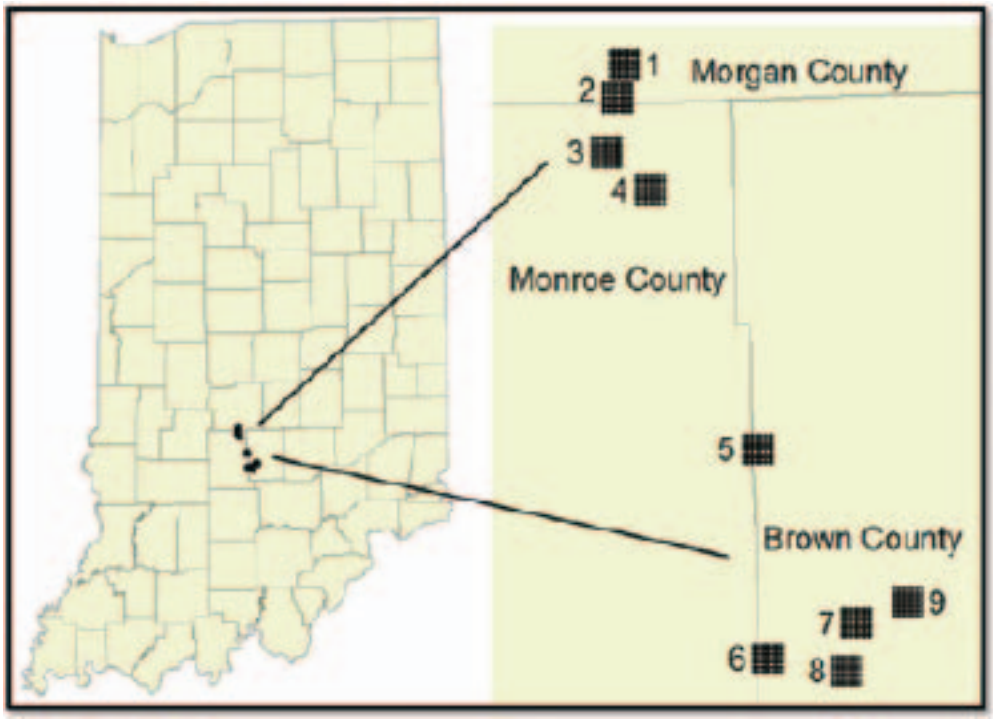

FIG. 1. Location of nine study sites within Morgan, Monroe, and Brown counties in southern Indiana.

units receiving forest treatments that removed fewer trees from the landscape, thereby creating multiple canopy openings known to be attractive to this species.

METHODS

We established four study sites (1.96 km^2 each) in Morgan-Monroe State Forest and five study sites (1.96 km^2 each) in Yellowwood State Forest in the core of each management unit. We conducted 100-m fixed radius point count surveys during the month of May from 2007-2011, once at every site each year. Every study site had seven linear transects with seven points, for a total of 49 points for each survey. Points were spaced 200 m apart to minimize duplicate sampling as male Cerulean Warblers were found to broadcast their songs approximately 100 m (Jones *et al.* 2000, Hamel *et al.* 2009). Surveys were conducted from approximately 05:30 to 10:30 EST and none was initiated during periods of rain, wind, or any other phenomenon that would prevent vocalizations from being heard. We surveyed each point for a total of 5 minutes. The first 2 minutes were spent listening for singing males. This was followed by a minute of Cerulean Warbler song broadcasting via audio cassette or MP3 player and speaker to elicit a vocal response from any males in the immediate area. The last 2 minutes were spent listening without playback (Falls 1981). When a male Cerulean Warbler was detected, we recorded both distance and compass direction from the survey point to prevent the same individual from being counted more than once during the 5 minute period. To eliminate potential bias on the sequence and date that units were sampled each year, we used a random numbers table to determine the order in which the study sites were surveyed from first to last.

Territory mapping was conducted in May and June of 2011. Whenever a Cerulean Warbler was observed singing repeatedly from a tree, we marked the tree with flagging tape and recorded the coordinates (Universal Transverse Mercator/UTM) of the tree location, using a Garmin GPS 76 handheld Global Positioning System (GPS) unit. Territories were considered to be completely mapped when a range of 5-12 trees were flagged. Whenever possible, we revisited known territories multiple times before final demarcation was determined. GPS coordinates were imported into ArcMap to create territory polygons using the minimum convex polygon method.

Nest searching commenced in May and June of 2011 in conjunction with territory mapping. Direct observation of a female on a male's territory and her general behavior often exposed the location of the nest. Additionally, we followed mated males and used audible clues such as "whisper singing" when they were in close proximity to a nest. Once nests were found, they were monitored from the ground using binoculars and spotting scopes once every two to three days from incubation to fledging. We defined a successful nest where at least one nestling fledged, an unsuccessful nest as one that failed, and unknown as the number of territories that were monitored for signs of nesting but no nests or fledglings were found. We defined nesting success as follows: Successful nests/unsuccessful nests + unknown.

One-way Analysis of Variance (ANOVA) was performed to determine if there was any difference in the number of Cerulean Warbler detections among even-aged (shelterwood/clearcut), uneven-aged (single tree selection with patch cutting), and control sites prior to harvest (2007 & 2008). Post-harvest comparisons of ANOVA data will be presented elsewhere. Percent change in relative abundance was computed by taking the average relative abundance for the two pre-treatment years and comparing these values with the average relative abundance for the three post-treatment years for each group. A

chi-square goodness-of-fit test was conducted to determine if there was any significant difference in nesting success among the three groups. We used Minitab 16 for all statistical tests. Significant differences were accepted at $\alpha = 0.05$ probability.

RESULTS

Over the five-year period, we detected a total of 576 male Cerulean Warblers on our point counts (94 in 2007, 124 in 2008, 135 in 2009, 93 in 2010, and 130 in 2011). There was no significant difference in the number of Cerulean Warbler detections ($F_{2,15} = 2.57$, $P = 0.110$) among the three groups (even-age, uneven-age, & control) for the two combined pre-treatment years (2007 & 2008). The number of detections between pre- and post-harvest years increased in even-aged sites (75%), decreased in uneven-aged sites (38%), and increased in control sites (62%, Fig. 2).

Of 101 Cerulean Warbler territories that were monitored intensively for nesting activity in 2011, 31 territories had either a nest that fledged young or fledglings were observed in the territory, and these territories were considered successful. Although nesting success differed among even-aged (14/40 = 35%), uneven-aged (8/37 = 22%), and control (9/24 = 38%) sites, these differences were not statistically significant (Pearson $\chi^2 = 2.303$, df = 2, $P = 0.316$).

DISCUSSION

The strength of our study is the Before-After Control-Impact design which allows us to make comparisons against pre-harvest data. Our prediction that Cerulean Warblers would occur in greater abundance in sites with small openings created by uneven-age harvest was not

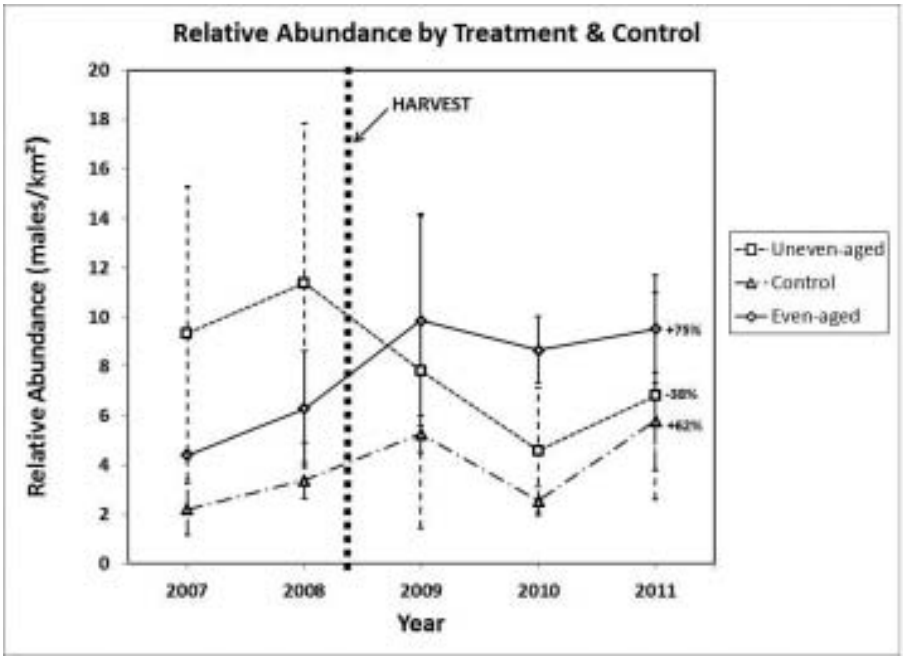

FIG 2. Relative abundance estimates of Cerulean Warblers in response to silvicultural treatments in southern Indiana, 2007-2011.

supported. Based on relative abundance estimates in the three year post-harvest period, sites in management units that received clearcuts and shelterwood treatments attracted more Cerulean Warblers compared to sites in units that received single tree selection with patch cutting. Past research has suggested that Cerulean Warblers are attracted to disturbances in the canopy (Bosworth 2003, Weakland & Wood 2005) but the size and extent of these disturbances has not been established. Annual monitoring of Cerulean Warbler populations in the management units will determine if the response to these openings continues as clearcuts and other harvested areas regenerate over time.

A study conducted in southern Indiana found no significant difference in the number of Cerulean Warbler detections among stands 2-30 years old (single tree selection and a combination of group and single tree selection) and unharvested reference sites (stands 35-100+ years old; Register & Islam 2008). In contrast, in a study in West Virginia, Wood *et al.* (2005) found that Cerulean Warblers occurred in greater abundance in 70-80 year mature forests than in 15-18 year old stands that received clearcuts and two-age harvests. Though statistically not significant, Cerulean Warblers were detected almost 5 times in greater abundance in the two-age harvest stands than in the clearcut stands (Wood *et al.* 2005).

Even though control sites had higher nesting success (38%) than either of the treatment sites (even-aged-35%, uneven-aged-22%), there was no significant difference in nesting success. Openings created by clearcuts and shelterwood treatments not only attracted Cerulean Warblers when they first arrived to breed, but provided areas next to which males established territories, attracted and paired with females, and raised young. Our findings, however, are preliminary and are based on one year of reproductive data. Continued monitoring of reproductive output at these forest treatment sites will determine if these sites attract Cerulean Warblers only to serve as "Ecological Traps", with increased predator and brood parasite populations resulting in lower Cerulean Warbler productivity as suggested by a study in Tennessee (Boves 2011), or if small openings are indeed beneficial to this species.

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