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Research Papers

Do the Golden-winged Warbler and Blue-winged Warbler Exhibit Species-specific Differences in their Breeding Habitat Use?

La Paruline à ailes dorées et la Paruline à ailes bleues montrent-elles des différences propres à l'espèce dans l'utilisation de leur habitat de reproduction?

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ABSTRACT. We compared habitat features of Golden-winged Warbler (*Vermivora chrysoptera*) territories in the presence and absence of the Blue-winged Warbler (*V. cyanoptera*) on reclaimed coal mines in southeastern Kentucky, USA. Our objective was to determine whether there are species specific differences in habitat that can be manipulated to encourage population persistence of the Golden-winged Warbler. When compared with Blue-winged Warblers, Golden-winged Warblers established territories at higher elevations and with greater percentages of grass and canopy cover. Mean territory size (minimum convex polygon) was 1.3 ha (se = 0.1) for Golden-winged Warbler in absence of Blue-winged Warbler, 1.7 ha (se = 0.3) for Golden-winged Warbler coexisting with Blue-winged Warbler, and 2.1 ha (se = 0.3) for Blue-winged Warbler. Territory overlap occurred within and between species (18 of n = 73 territories, 24.7%). All Golden-winged and Blue-winged Warblers established territories that included an edge between reclaimed mine land and mature forest, as opposed to establishing territories in open grassland/shrubland habitat. The mean distance territories extended from a forest edge was 28.0 m (se = 3.8) for Golden-winged Warbler in absence of Blue-winged Warbler, 44.7 m (se = 5.7) for Golden-winged Warbler coexisting with Blue-winged Warbler, and 33.1 m (se = 6.1) for Blue-winged Warbler. Neither territory size nor distances to forest edges differed significantly between Golden-winged Warbler in presence or absence of Blue-winged Warbler. According to Monte Carlo analyses, orchardgrass (*Dactylis glomerata*), green ash (*Fraxinus pennsylvanica*) seedlings and saplings, and black locust (*Robinia pseudoacacia*) saplings were indicative of sites with only Golden-winged Warblers. *Sericea lespedeza*, goldenrod (*Solidago* spp.), clematis vine (*Clematis* spp.), and blackberry (*Rubu*s spp.) were indicative of sites where both species occurred. Our findings complement recent genetic studies and add another factor for examining Golden-winged Warbler population decline. Further, information from our study will aid land managers in manipulating habitat for the Golden-winged Warbler.

RÉSUMÉ. Nous avons comparé les caractéristiques de l’habitat dans des territoires de Paruline à ailes dorées (*Vermivora chrysoptera*) avec ou sans la présence de la Paruline à ailes bleues (*V. cyanoptera*) sur des terrains restaurés à la suite de l’exploitation du charbon dans le sud-est du Kentucky (É-U). Notre objectif était de déterminer s’il existe des différences d’habitat propres à chacune de ces espèces qui permettraient un aménagement visant à favoriser la persistance de la Paruline à ailes dorées. Comparée à la Paruline à ailes bleues, la Paruline à ailes dorées établit des territoires à des altitudes plus élevées qui sont caractérisés par un recouvrement supérieur des strates herbacée et arborescente. La superficie moyenne des territoires (polygone minimum convexe) était de 1,3 ha (erreur type = 0,1) pour la Paruline à ailes

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dorées en l'absence de la Paruline à ailes bleues; 1,7 ha (erreur type = 0,3) pour la Paruline à ailes dorées en sympatrie avec la Paruline à ailes bleues; et 2,1 ha (erreur type = 0,3) pour la Paruline à ailes bleues. Des recoupements de territoires ont été observés pour une même espèce et entre les deux espèces (18 de 73 territoires, soit 24,7 %). Toutes les parulines à ailes dorées et à ailes bleues ont défendu des territoires incluant une interface entre la zone minière restaurée et la forêt mature plutôt que d'établir leur territoire en plein dans les prairies ou arbustaies. La distance moyenne des bordures de territoires par rapport à l'interface la plus proche était de 28,0 m (erreur type = 3,8) pour la Paruline à ailes dorées en l'absence de la Paruline à ailes bleues, 44,7 (erreur type = 5,7) pour la Paruline à ailes dorées en sympatrie avec la Paruline à ailes bleues et 33,1 m (erreur type = 6,1) pour la Paruline à ailes bleues. Ni la dimension des territoires ni la distance à la forêt n'étaient significativement différentes entre la Paruline à ailes dorées avec ou sans la présence de la Paruline à ailes bleues. D'après des simulations de Monte-Carlo, le dactyle pelotonné (*Dactylis glomerata*), les semis et gaulis de frêne rouge (*Fraxinus pennsylvanica*), ainsi que les gaulis de robinier faux-acacia (*Robinia pseudoacacia*) étaient des indicateurs de sites occupés uniquement par la Paruline à ailes dorées. *Sericea lespedeza*, tandis que les verges d'or (*Solidago* spp.), les clématites (*Clemati*s spp.) et les mûriers (*Rubus* spp.) étaient des indicateurs de sites où les deux espèces de paruline étaient présentes. Nos résultats viennent compléter des études génétiques récentes et suggèrent un facteur supplémentaire à étudier afin de déterminer les causes de la diminution des effectifs de Paruline à ailes dorées. De plus, nos travaux aideront les gestionnaires de territoires à aménager l'habitat en faveur de la Paruline à ailes dorées.

Key Words: *Blue-winged Warbler; distance to forest edge; Golden-winged Warbler; habitat differences; Kentucky; reclaimed mines; territory size; Vermivora chrysoptera; Vermivora cyanoptera; Vermivora pinus*

INTRODUCTION

The Golden-winged Warbler (*Vermivora chrysoptera*; Fig. 1) is experiencing dramatic population declines and has been extirpated in parts of its historic range (Gill 1980, Confer 1992*a*, Confer 1992*b*, Sauer et al. 2005). As such, the Golden-winged Warbler is listed as a "species of management concern" by the U.S. Fish and Wildlife Service (USFWS) and is on the Partners-in-Flight Continental Watchlist (Rich et al. 2004). Like many other birds, the Golden-winged Warbler is threatened by the loss of early successional habitat (Hunter et al. 2001, Donovan et al. 2002, Brennan and Kuvlesky 2005). Golden-winged Warbler populations are negatively affected by range expansion of the closely related Blue-winged Warbler (*V. cyanoptera*; Fig. 2) and nest parasitism by the Brown-headed Cowbird (*Molothrus ater*; Gill 1980, 1997, Coker and Confer 1990, Confer 1992*a*, Hunter et al. 2001, Confer et al. 2003, Gill 2004, Buehler et al. 2007, Vallender et al. 2007).

The Golden-winged Warbler historically inhabited the eastern U.S. and was largely allopatric from the Blue-winged Warbler, which occurred primarily west of the Appalachian Mountains (Short 1963). The ancestral habitat of the Golden-winged Warbler was likely early successional habitat that resulted from wind, fire, and beaver (*Castor canadensis*) imbedded in otherwise forested landscapes (Short 1963, Hunter et al. 2001). The ancestral habitat of the Blue-winged Warbler is largely unknown, however, Short (1963) suggested occurrence along forest edges adjacent to prairies. Landscape-level deforestation and abandonment of farm fields likely facilitated the eastward expansion of the Blue-winged Warbler into Golden-winged Warbler range and of the latter species into the northeast (Short 1963, Gill 1980). These species now occur sympatrically in early successional, human disturbed sites such as abandoned farm fields, power line rights-of-way, logged forests, and reclaimed mines. However, coexistence is often fleeting and in many areas the arrival of the Blue-winged Warbler is followed by Golden-winged Warbler extirpation (Short 1963, Gill 1980, Confer 1992*b*, Canterbury et al. 1993). These local extirpations are typically attributed to interspecific competition and genetic dilution through hybridization. Although the availability of disturbed sites is decreasing in some regions because of successional advancement

Fig. 1. Golden-winged Warbler (*Vermivora chrysoptera*) in Kentucky, Photo: Laura Patton

of farm fields and reforestation, early successional habitat resulting from coal mining is increasing in the southern part of the Golden-winged Warbler's range.

Reclaimed mines in the Midwestern U.S. have become increasingly important for grassland nesting birds such as the Henslow's Sparrow (*Ammodramus henslowii*), Grasshopper Sparrow (*A. savannarum*), and Dickcissel (*Spiza americana*; Bajema et al. 2001, DeVault et al. 2002, Monroe and Ritchison 2005). Lacki et al. (2004) documented the expansion of several grassland bird species into reclaimed mines in Indiana. In Kentucky, the Grasshopper Sparrow, Henslow's Sparrow, and Blue Grosbeak (*Guiraca caerulea*) historically occurred in the central and western part of the state but expanded onto eastern reclaimed mines after forested mountains were converted to grasslands (Mengel 1965, Ciuzio 2002, Palmer-Ball 1996). The Golden-winged Warbler was first observed in Kentucky in July of 1944 on Black Mountain (~1264 m) where a small population persisted (Mengel 1965). Thereafter, observations of Golden-winged Warblers were sporadic at high elevation sites on Black, Pine, and Cumberland Mountains and nesting was not documented in Kentucky until this study (Patton 2007). In recent years, the Golden-winged Warbler was observed at lower elevations on reclaimed mines in eastern Kentucky (Palmer-Ball 1996, Patton et al. 2004). In 2003, 16 Golden-winged Warblers were documented via the Golden-winged Warbler Atlas Project (Cornell Lab of Ornithology 2003), which led to this study of breeding habitat characteristics.

Much of the research related to the decline of the Golden-winged Warbler has focused on hybridization with the Blue-winged Warbler (Gill 1997, Shapiro et al. 2004, Dabrowski et al. 2005, Vallender et al. 2007). Although understanding the genetic challenges that face the species is important, improving habitat conditions for the Golden-winged Warbler in newly colonized areas such as those found in eastern Kentucky is also valuable, particularly where the Blue-winged Warbler is absent. Identification of interspecific associations and habitat characteristics at landscape, territory, and nest site scales are keys in determining whether Golden-winged Warbler populations can be promoted while discouraging encroachment by the Blue-winged Warbler (Buehler et al. 2007). Our objectives were to (1) quantify territory-scale characteristics of Golden-winged Warbler and Blue-winged Warbler breeding habitat on reclaimed mines, and (2) compare biotic and abiotic habitat characteristics within territories of the Golden-winged Warbler and Blue-winged Warbler.

Fig. 2. Blue-winged Warbler (*Vermivora cyanoptera*) in Kentucky, Photo: Laura Patton

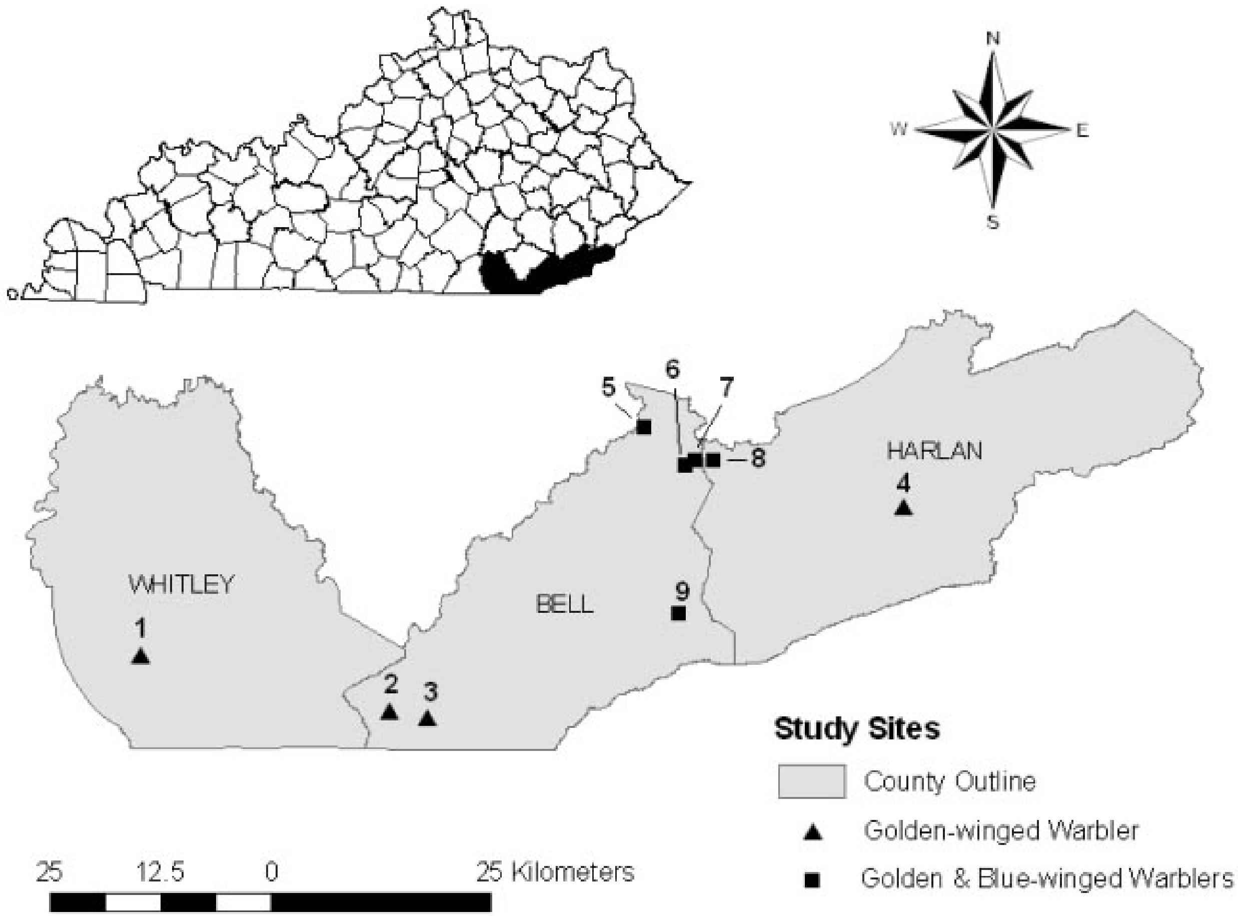
METHODS

Study Area

We conducted our study during 2004 and 2005 on nine sites in Harlan, Bell, and Whitley counties in southeastern Kentucky, USA (Fig. 3). Four sites had no Blue-winged Warblers, and five sites had both species. Two sites, one with only Golden-winged Warblers and one with both species, were added in 2005. Study sites were selected from Golden-winged Warbler Atlas Project surveys (Cornell Lab of Ornithology 2003, Patton et al. 2004), as well as ground and aerial exploration. All study sites were on landscapes that had been previously mined for coal via contour-mining or mountaintop removal. At the time of our study, all sites were between 10 and 25 years postreclamation. Patchy vegetation, steep slopes, and disturbances including timber harvest, cattle grazing, and mining equipment operation were common on all study sites. Elevation ranged from 426 to 912 m above mean sea level.

The study area was located in the eastern Kentucky coalfield (Kentucky Foundation 2002). Mining created linear openings and large expanses of grasslands and shrublands in an otherwise forested region. Reclamation efforts on reclaimed mines in Kentucky predominantly consisted of introduction of non-native plants such as fescue (*Festuca* spp.), sericea lespedeza (*Lespedeza cuneata*), bird's-foot trefoil (*Lotus corniculatus*), clovers (*Trifolium* spp.), and black alder (*Alnus glutinosa*; Jones 2005). Mines were also reclaimed with black locust (*Robinia pseudoacacia*), a native tree species (Jones 2005). Mixed-mesophytic forests dominated areas surrounding our study sites (Jones 2005). This forest type is composed of a combination of deciduous and evergreen tree species including oaks (*Quercus* spp.), hickories (*Carya* spp.), maples (*Acer* spp.), yellow-poplar (*Lireodendron tulipifera*), American beech (*Fagus grandifolia*.), American basswood (*Tilia americana*), and eastern hemlock (*Tsuga Canadensis*), whereas chestnut oak (*Q. prinus*), Virginia pine (*Pinus virginiana*), short-leaf pine (*P. echinata.*), and pitch pine (*P. rigida*) occupy ridge-tops, southwestern facing slopes, and areas with rocky shallow soils (Braun 1950, Leopold et al. 1998).

Fig. 3. The study area was within a 3-county portion of southeastern Kentucky. The nine sites included four where the golden-winged warbler occurred and the blue-winged warbler was absent; Williamsburg (1), Fonde (2), Tower (3), and Coalgood (4), and five sites where both species occurred; Beverly (5), Begley 3 (6), Begley 1 (7), Bigfoot (8), and Coldstone (9).



Dominant vegetation on our study sites included tall fescue (*F. elatior)*, timothy (*Phleum pratense*), orchardgrass (*Dactylis glomerata*), sericea lespedeza, goldenrod (*Solidago* spp.), blackberry (*Rubus* spp.), clematis (*Clematis* spp.), morning-glory (*Ipomoea spp.*), autumn-olive (*Elaeagnus umbellata*), black locust, green ash (*Fraxinus pennsylvanica*), and maple.

The spring climate of eastern Kentucky is temperate and mildly humid with average temperatures of approximately 13°C, 18°C, and 22°C in April, May, and June, respectively (Kentucky Climate Center 2007*a*). Rainfall from 1895 to 2004 averaged approximately 9.7, 11.2, and 10.9 cm during these months, respectively (Kentucky Climate Center 2007*b*).

Banding and monitoring

We attracted territorial male Golden-winged Warblers and Blue-winged Warblers with recorded songs produced by the Cornell Lab of Ornithology, captured them in mist-nets, and banded them with a unique combination of plastic colored bands (Avinet, Inc.) and a USFWS metal band. Bird banding was permitted by the Kentucky Department of Fish and Wildlife Resources (KDFWR), the USFWS, and under Institutional Animal Care and Use Committee Protocol # 00690A2004, University of Kentucky. We delineated territories by flagging trees and other vegetation where we observed birds singing, perching, and feeding. We visited study sites twice per week from the last week in April to mid-June and observed birds from dawn until late morning when singing decreased. Each territory was monitored ≥6 times throughout the breeding season to ensure that study birds were not transients or shifting territories. Each monitoring bout lasted approximately 30 to 50 minutes. We alternated the order that territories were monitored to minimize time of day effects on activity (Shields 1977, Bibby et al. 2000). We revisited all flagged bird locations and recorded their latitude / longitude (North American Datum 1983) using a Global Positioning System (GPS) receiver.

Territory characteristics

To describe Golden-winged Warbler and Blue-winged Warbler habitat use in relation to forest edges, we calculated the linear distances from bird locations outside the forest edge to the nearest forest edge. This was performed with the Auto Add Lines program (Environmental Systems Research Institute 2005 modified by D. Vichitbandha of the KDFWR) in ArcGIS 9.0 (ESRI 2004). We identified forest edges as the dark contrast with the lighter colored adjacent grassland/shrubland areas and digitized them at a map scale of 1:4500 from digital photo imagery captured in 2004 (Kentucky Geography Network 2005). We averaged the distances of all bird locations outside the forest to nearest forest edge for each territorial male. We performed a one-way analysis of variance (SAS Institute 2001) to identify potential differences in distance to forest edge among territories of Golden-winged Warblers in the absence of Blue-winged Warblers, Golden-winged Warblers coexisting with Blue-winged Warblers, and Blue-winged Warblers.

We used Hawth’s Analysis Tools (Beyer 2004) in ArcGIS to create minimum convex polygons (MCP) for each male territory. We included all locations from the breeding season in the MCP analyses (Barg et al. 2005, Börger et al. 2006). We used MCPs over other methods, i.e., adaptive kernel, because we wanted to delineate maximum territory size for each male. Although MCPs can grossly overestimate territory size (Kernohan et al. 2001), they are a reasonable method for our application. An overestimation of territory size provided a liberal recommendation to land managers regarding the amount of transition zone between forest and shrubland needed to support breeding populations of Golden-winged Warblers on reclaimed surface mines. We used a one-way analysis of variance (SAS Institute 2001) to identify potential differences in territory size among Golden-winged Warblers at sites without Blue-winged Warblers, Golden-winged Warblers coexisting with Blue-winged Warblers, and Blue-winged Warblers. We estimated territory overlap as the percent each individual territory overlapped with another territory. We arcsine transformed the percentages of overlap to improve normality (Bonham 1989). We used a Kruskal-Wallis test (Program R v. 10.1, R Foundation for Statistical Computing 2009) to identify potential differences in territory overlap among the three species groups.

Within-territory characteristics

We sampled structural and vegetative characteristics in 10 randomly selected, 5 m-radius circular plots in each Golden-winged and Blue-winged Warbler territory (Klaus and Buehler 2001, Remes 2003, DeBoer and Diamond 2006). Plots of this size are more efficiently and accurately sampled than larger plots (Bonham 1989). Additionally, an increased number of smaller plots, rather than fewer larger plots, better reflect the patchy nature of local vegetation (Bonham 1989), a characteristic of reclaimed surface mines. We collected habitat data from mid-June to mid-July in 2004 and 2005 after territory mapping was completed.

Habitat measurements in each plot included slope, aspect, elevation, vegetation density, shrub height, canopy cover, tree basal area, aggregate sapling height, number of seedlings, and percent of ground covered by grass, forb, and shrub. We recorded slope with a clinometer to the nearest percent. We determined aspect with a compass to the nearest degree. We recorded elevation (m) with a GPS (North American Datum 1983) or altimeter (Suunto Escape203 model).

We measured vegetation density at the center of each 5 m-radius plot with a 3.4 cm x 3.4 cm x 2.4 m wooden picket painted with alternating 1 dm black and white bands (modified from Robel et al. 1970, Griffith and Youtie 1988). We took 16 readings, four at each cardinal location of the plot, facing the Robel pole 1 m above the ground and 4 m from the pole. We averaged these readings to yield one value per plot. We recorded shrub height (m) as the mean height of all shrubs in a plot measured by a combination of visual estimates and Robel readings. We recorded percent canopy cover at the plot center with a spherical densiometer facing each cardinal direction and averaged the readings to yield one value per plot.

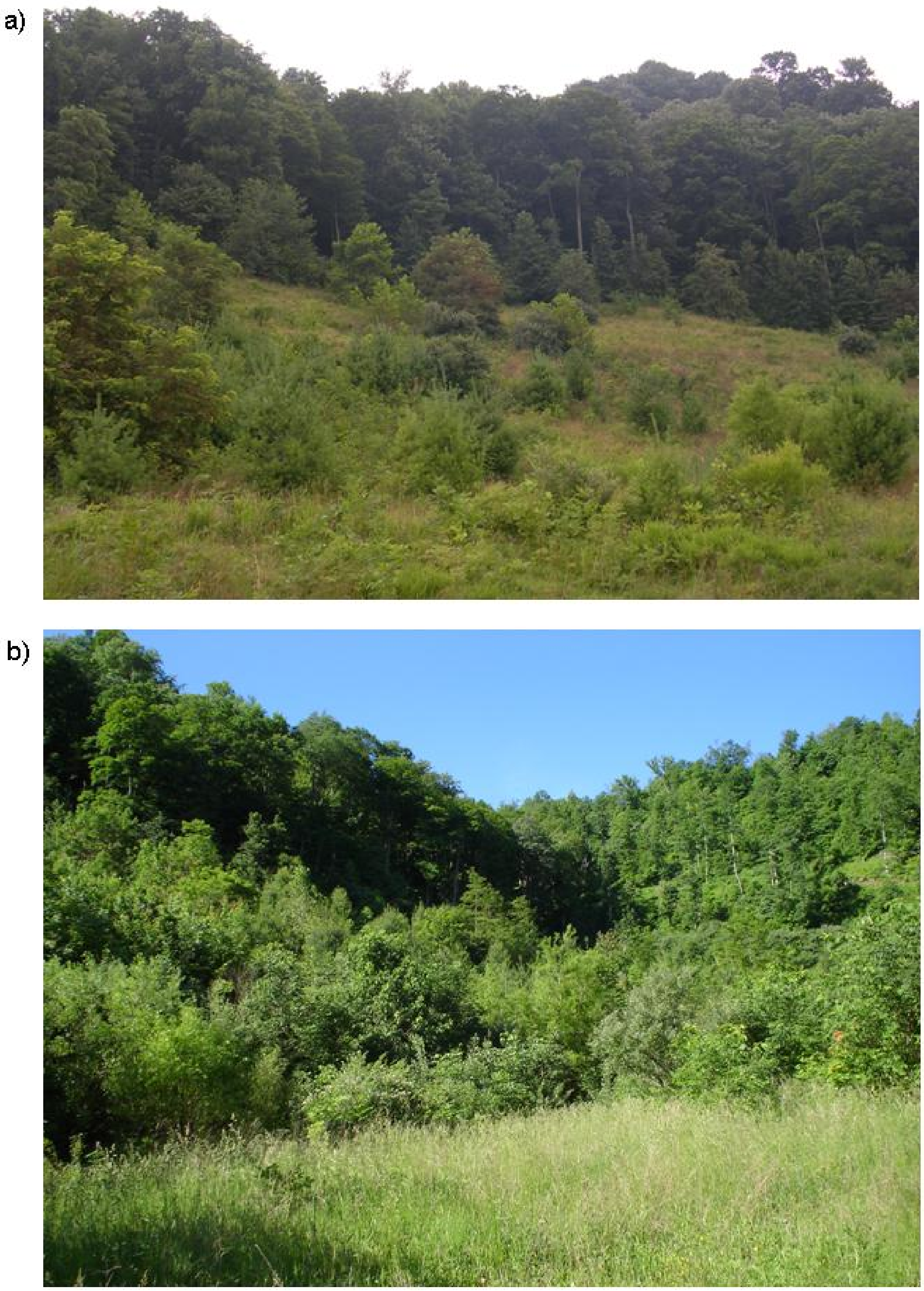
We measured the diameter at breast height, measured at a height of 1.37 m above the ground, of each tree ≥10 cm (Will 1986, Klaus and Buehler 2001, Hudman and Chandler 2002) and computed the basal area for each plot (Avery and Burkhart 1983). We used a clinometer to measure the height of each tree within a plot. We determined aggregate sapling height by recording the number of saplings, <10 cm dbh, >1 m tall, and visually estimating their heights (Klaus and Buehler 2001). We recorded the species of all trees and saplings, and the number and species of all seedlings, <1 m tall (Klaus and Buehler 2001). We visually estimated the percentage of ground covered by grasses, forbs, and shrubs for each plot and recorded the dominant species.

We arcsine transformed the percentages of slope, canopy cover, grass, forb, and shrub to improve normality (Bonham 1989) and square root transformed the number of seedlings per plot (Sokal and Rohlf 1969). We transformed aspect data according to McCune and Grace (2002) to reflect Heat Load Index, which is a measure of solar radiation along the northeast-southwest axis. We summed the heights of all saplings in each plot to yield a single value of aggregate height, an indicator of density that is more reliable than other measures, such as number of saplings or average height of saplings (Fei et al. 2006). We pooled data across years because we considered plots sampled in the same areas in both seasons independent due to annual structural changes in habitat (Winter et al. 2005). We observed black locust trees in territories from the first season that had fallen by the second season, and the substantial growth that was documented over time (Fig. 4) would indicate some amount of growth between seasons.

We used a multivariate analysis of variance (MANOVA) to assess whether our 12 measured habitat variables could distinguish between three species groups (Program R v. 10.1, R Foundation for Statistical Computing). The three species groupings were designated as: 0 = Blue-winged Warbler territories in areas with the Golden-winged Warbler, 1 = Golden-winged Warbler territories in areas with the Blue-winged Warbler, or 2 = Golden-winged Warbler territories in areas without the Blue-winged Warbler. The MANOVA was followed by a series of one-way analysis of variances (ANOVAs) on the 12 habitat variables (Program R v. 10.1) to identify which variables were most useful in making this distinction among the groupings. Variables that were significant at $p < 0.15$ within the ANOVA were included in a linear discriminant analysis (Program R v. 10.1; package MASS; Venables and Ripley 2002). The criteria of $p < 0.15$ for variable entrance into the discriminant analysis falls within the range (0.1 - 0.25) recommended by Costanza and Afifi (1979). Variables with pooled within-class standardized canonical coefficients of >0.4 or <-0.4 were considered sufficiently important in separating the groupings. Class means were used to identify the specific relationship of variables to species groupings. Overall accuracy and kappa statistic were calculated to assess whether the discriminant analysis model classified significantly better than chance (Titus et al. 1984). For all analyses, the data were analyzed at the territory level to maximize the independence of our samples.

We used Indicator Species Analyses in PC-ORD (McCune and Mefford 1999) to categorize grass, forb, shrub, vine, tree, sapling, and seedling genera as specific to either Golden-winged Warbler sites or sites where both species occurred. We used the Monte Carlo test to determine the statistical significance of indicator values (Dufrêne and Legendre 1997, McCune and Mefford 1999). We considered indicators significant at $p < 0.01$ due to the high number of genera in most of the analyses. We used 1000 randomizations in the Monte Carlo test. Even if genera were significant at $p < 0.01$, we did not consider them to be meaningful indicators

Fig. 4. a) Photo of high elevation (average 738m) Golden-winged Warbler-only site taken in 2003, Photo: Laura Patton. b) Same site in 2010, when a Blue-winged Warbler was documented for the first time since surveys for these species began in 2003. The site has experienced significant growth in shrub and sapling cover, Photo: Laura Patton



unless they had indicator values of at least 25, meaning that a genus was present in at least 50% of the samples in one of the groups (Dufrêne and Legendre 1997).

RESULTS

Territory characteristics

Twenty-five Golden-winged Warbler territories were delineated at sites where the Blue-winged Warbler was absent. Forty-eight territories were delineated at sites where both species occurred, i.e., 26 Golden-winged Warbler, 22 Blue-winged Warbler. Mean MCP territory size was 1.3 ha (se = 0.1) for Golden-winged Warblers in absence of Blue-winged Warblers, 1.7 ha (se = 0.3) for Golden-winged Warblers coexisting with Blue-winged Warblers, and 2.1 ha (se = 0.3) for Blue-winged Warblers. There was no difference in territory size among the three species groupings (df = (2,70), F = 2.65, P = 0.08; Table 1).

Territory overlap occurred within and between species (18 of n = 73 territories, 24.7%). At sites with only Golden-winged Warblers, four territories overlapped (4 of n = 25, 16%), the overlap ranging from 0.7% to 17%. Eight Golden-winged Warbler territories at sites with coexisting Blue-winged Warblers (8 of n = 26, 30.7%) overlapped with either a Blue-winged Warbler territory (n=4) or Golden-winged Warbler territory (n=4), and the overlap ranged from 1.5% to 57%. Six Blue-winged Warbler territories (6 of n = 22, 27.2%) overlapped with another Blue-winged Warbler territory (n=2) or a Golden-winged Warbler territory (n=4), and the overlap ranged from 0.4% to 48%. There was no difference in territory overlap among the three species groupings (df = (2,70), H = 2.18, P = 0.33; Table 1).

All Golden-winged and Blue-winged Warblers established territories that included an edge between reclaimed mine land and mature forest, as opposed to establishing territories in open grassland/shrubland habitat. The mean distance territories extended from a forest edge was 28 m (se = 3.8) for Golden-winged Warblers in absence of Blue-winged Warblers, 44.7 (se = 5.7) for Golden-winged Warblers coexisting with Blue-winged Warblers, and 33.1 (se = 6.1) for Blue-winged Warblers. There was no difference in the distance the territories were from forest edge among the three species groupings (df = (2,70), F = 2.78, P = 0.07; Table 1).

Within-territory characteristics

The multivariate analysis of variance indicated that our habitat variables were useful in separating the three species groupings ($F_{2,70}$ = 1.69, Λ=0.56, P = 0.041). The one-way analysis of variance models identified three variables at p <0.15 to include in the linear discriminant analysis. The three variables were elevation, percent canopy cover, and percent grass. The first canonical axis of the linear discriminant analysis accounted for 90% variation between the three groups. All three variables loaded heavily on this first canonical axis 1 (Table 2). Class means on the canonical variables (Table 3) indicated that this first axis represents a contrast between the territories of Golden-winged Warblers without Blue-winged Warblers and Blue-winged Warblers that co-occurred with Golden-winged Warblers. Traits of Golden-winged Warblers that co-occurred with Blue-winged Warblers were intermediate along the axis. When compared with Blue-winged Warblers, Golden-winged Warblers established territories at higher elevations, with a greater percentage of grass cover and canopy cover (Table 1). The overall accuracy of our linear discriminant model in classifying territory types was 0.60. The kappa statistic confirmed that the model classified territories 40% (se= 0.086; CI 95% 0.231-0.575) better than chance.

According to Monte Carlo analyses, species that were indicative of sites with only Golden-winged Warblers were orchardgrass (IV = 33.0, p = 0.009), green ash seedlings (IV = 37.0, p = 0.001) and saplings (IV = 35.5, p = 0.001), and black locust saplings (IV = 33.2, p = 0.001). Species indicative of sites with both Golden-winged Warblers and Blue-winged Warblers included sericea lespedeza (IV = 47, p = 0.005), goldenrods (IV = 46.1, p = 0.009), clematis vine (IV = 28.2, p = 0.003), and blackberry (IV = 42.7, p = 0.002).

DISCUSSION

Our analyses revealed few differences in breeding habitat characteristics between the Golden-winged Warbler and Blue-winged Warbler on reclaimed surface mines in southeastern Kentucky. The

Table 1. Means of territory characteristics grouped by Golden-winged Warblers in the absence of Blue-winged Warblers (GWWA-only), Golden-winged Warblers coexisting with Blue-winged Warblers (GWWA with BWWA), and Blue-winged Warblers coexisting with Golden-winged Warblers (BWWA).

	ANOVA		GWWA-only (n=25)		GWWA with BWWA (n=26)		BWWA (n=22)	
Variable	$F_{(2,70)}$	p	Mean ± se	range	Mean ± se	range	Mean ± se	range
Territory-level								
Distance to forest edge (m)	2.78	0.07	28.0 ± 3.8	1.74 - 80.8	44.7 ± 5.7	7.9 - 109.1	33.1 ± 6.1	5.2 - 139.4
Territory Size (ha)	2.65	0.08	1.3 ± 0.1	0.3 - 2.8	1.7 ± 0.3	0.2 - 5.8	2.1 ± 0.3	0.7 - 6.7
% Territory Overlap †	2.18§	0.33	1.3 ± 0.9	0.7 - 17.0	7.8 ± 3.2	1.5 - 57.0	5.8 ± 3.0	0.4 - 48.0
Within-territory-level								
Elevation ‡	3.19	0.047	648.1 ± 28.1	486.8 - 903.7	629.8 ± 10.4	480.6 - 717.5	577.6 ± 16.9	442.0 - 681.1
% Grass †‡	2.52	0.087	42.2 ± 3.8	11.0 - 75.0	35.7 ± 2.4	8.5 - 59.5	34.6 ± 1.8	16.8 - 50.8
% Canopy Cover †‡	2.58	0.083	44.8 ± 4.4	9.9 - 83.3	33.0 ± 3.1	12.6 - 78.5	34.1 ± 3.5	12.4 - 59.4
% Shrub†	1.55	0.219	17.4 ± 2.1	5.9 - 46.4	22.6 ± 2.5	0.6 - 54.2	20.2 ± 2.0	6.8 - 42.1
Aspect	1.45	0.240	0.5 ± 0	0.3 - 1.0	0.5 ± 0	0.3 - 0.7	0.5 ± 0	0.2 - 0.6
% Slope†	1.37	0.259	26.6 ± 3.6	0 - 71.6	20.3 ± 2.4	1.6 - 50.8	24.7 ± 2.4	4.1 - 45.6
Agg. Sapling Height	0.74	0.480	28.9 ± 5.8	5.1 - 120.7	23.9 ± 3.3	2.1 - 74.8	21.9 ± 2.3	3.8 - 36.8
Shrub Height	0.52	0.597	1.1 ± 0.1	0.4 - 1.8	1.2 ± 0.1	0.3 - 1.8	1.2 ± 0.1	0.8 - 2.0
% Forb†	0.47	0.626	40.0 ± 3.4	14.5 - 73.8	40.6 ± 2.0	13.0 - 63.0	44.1 ± 1.6	30.3 - 61.0
Tree Basal Area	0.48	0.618	2.1 ± 0.4	0 - 8.4	1.6 ± 0.3	0 - 5.2	2.0 ± 0.4	0.1 - 6.4
Vegetation Density	0.34	0.713	0.71 ± 0	0.4 - 1.2	0.7 ± 0	0.4 - 1.2	0.7 ± 0.03	0.5 - 1.0
Number of Seedlings†	0.25	0.775	13.1 ± 3.7	0.3 - 74.4	11.0 ± 3.9	0.5 - 93.4	11.0 ± 1.9	1.0 - 40.4

†Data presented are untransformed for easier reference to the reader
‡ Variables differed among species groupings ($p < 0.15$) and were included in Discriminant Analysis
§ H-statistic from Kruskal-Wallis test

Table 2. Variable loadings of territory characteristics on canonical axes obtained from a linear discriminant analysis used to distinguish three species groupings on reclaimed surface mines in southeastern Kentucky: 1) Golden-winged Warblers in the absence of Blue-winged Warblers; 2) Golden-winged Warblers coexisting with Blue-winged Warblers; and 3) Blue-winged Warblers coexisting with Golden-winged Warblers.

Variable	Canonical 1	Canonical 2
Elevation†	0.735	0.766
% Canopy Cover†	0.437	-0.654
% Grass Cover†	0.704	-0.198

† Variables with canonical coefficients of > 0.4 or < -0.4 were considered sufficiently important in separating the groupings.

Golden-winged and Blue-winged Warblers monitored during our study occupied habitat on reclaimed mine land composed of patches of herbaceous plants, shrubs, and saplings that were adjacent to mature forest edges (Figs. 4a and 5). Other studies throughout the range of the Golden-winged Warbler have also documented an association of this species with forest edge. For example, most Golden-winged Warbler territories in north-central New York included a forest edge (Confer et al. 2003). In Pennsylvania, Golden-winged Warbler territories occurred in 60 m wide utility rights-of-way traversing forests or small (1 ha) clearcuts that were adjacent to older forests (Kubel 2005). The majority of Golden-winged and Blue-winged Warbler nests located on our study sites were placed near forest edges or at the peripheries of sapling groves (Patton 2007). Similar findings were reported in the Cherokee National Forest, Tennessee, where Golden-winged Warblers typically placed nests on the edges of regenerating forests and herbaceous openings (Klaus and Buehler 2001).

Golden-winged Warbler association with forest edge is likely indicative of the early successional habitat within which the species evolved. Prior to the availability of human-created disturbance habitat such as farmland abandonment, utility right-of ways, reclaimed surface mines, and timber harvests, Golden-winged Warblers likely nested in beaver, wind, and fire disturbed areas in otherwise forested landscapes (Short 1963, Hunter et al. 2001). Plant communities resulting from these were small in scale or heterogeneous with respect to degree of disturbance (Hunter et al. 2001). As such, Golden-winged Warblers breeding in these communities would not have been far from a mature forest edge.

Forest edges may increase the availability of singing perches that optimize mate attraction. Rossel (2001) found that song perches of Golden-winged Warblers occurred in the upper portions of larger trees that were close to the forest edge. Forest edges may also benefit the Golden-winged Warbler via the close proximity of nesting material such as grape vine bark and oak leaves, which were commonly used for nest material by both species on our sites and elsewhere (Confer 1992*a*; L. Patton *unpublished data*). On one occasion, we observed a female Golden-winged Warbler fly repeatedly from her nest site to a single tree on a forest edge approximately 80 m away to collect grape vine bark. Dense vegetation characteristic of forest edges also may provide important foraging opportunities for adults and young during the postfledging period (Kubel 2005). Golden-winged Warbler broods in Pennsylvania were often observed using dense cover in forests bordering clearcuts and utility rights-of-way during the postfledging period (Kubel 2005). Finally, McCollin (1998) suggested that a

Table 3. Class means obtained from a linear discriminant analysis using elevation, % grass cover, and % canopy cover to distinguish three species groupings on reclaimed mines in southeastern Kentucky. Golden-winged Warblers = GWWAs; Blue-winged Warblers = BWWAs.

Territory Type	Grouping Code	Canonical 1	Canonical 2
BWWAs with GWWAs	0	-1.288 ± 0.133	-0.278 ± 0.146
GWWAs with BWWAs	1	0.003 ± 0.080	0.781 ± 0.174
GWWAs without BWWAs	2	1.028 ± 0.101	-0.359 ± 0.190

unique microclimate along forest edges may affect habitat selection in birds. Golden-winged and Blue-winged Warblers may seek a microclimate that is unique to the forest edge in terms of wind, temperature, and moisture gradients. To our knowledge, these microclimate features have never been quantified for Golden-winged Warbler breeding habitat, and should be incorporated into future studies.

The importance of developing effective management protocols that facilitate breeding habitat segregation between the Golden-winged Warbler and Blue-winged Warbler appears to be more imperative than ever considering the recent finding of range-wide cryptic hybridization between these two species (Vallender et al. 2009). Our study revealed differences in habitat characteristics between Golden-winged Warbler and Blue-winged Warbler breeding territories including elevation, canopy cover, and grass cover. Although few differences in habitat were identified, these characteristics are important because they may affect nesting success of Golden-winged Warblers and the occurrence of Blue-winged Warblers. The Golden-winged Warblers in this study occupied similar elevations as the Blue-winged Warbler. However, it also occurred at higher elevations where the Blue-winged Warbler was absent (Fig. 6). Elevation was important to Golden-winged Warbler density and nesting success in West Virginia whereby higher nesting success occurred at higher elevations in areas of sympatry with the Blue-winged Warbler (R. Canterbury, *personal communication*). Although the Blue-winged Warbler has expanded to higher elevations throughout its range (Canterbury et al. 1993, Gill 2004), elevational separation appears to be maintained in some cases such as in New York, Tennessee, and Pennsylvania (Confer and Knapp 1981, Bulluck 2007, Larkin and Grata 2009). Consequently, even in areas where the colonization front of the Blue-winged Warbler has passed, high elevation refugia for the Golden-winged Warbler may still exist.

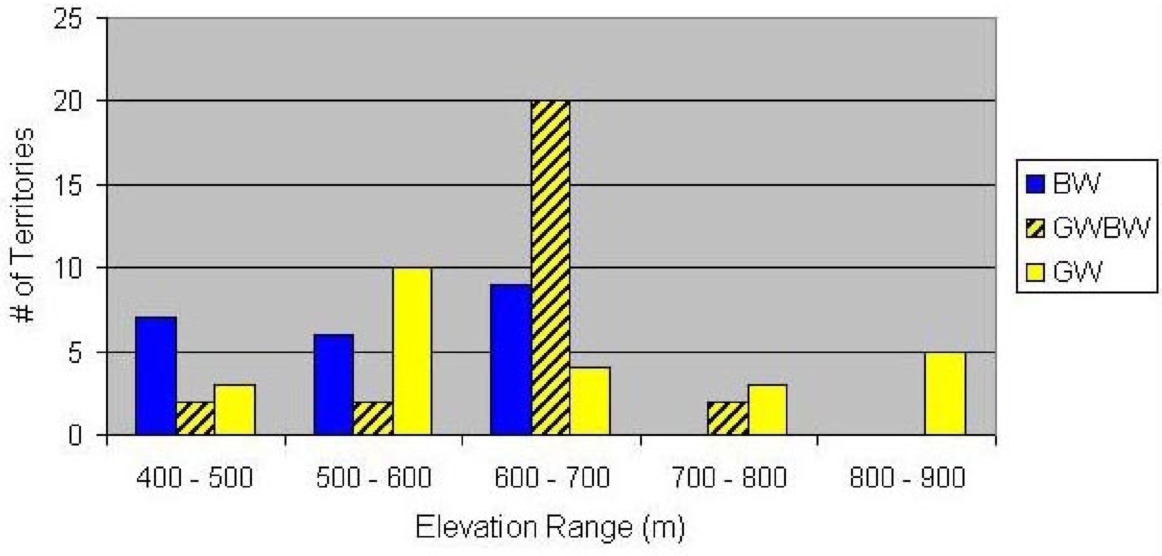
Bulluck (2007) defined high quality Golden-winged Warbler habitat in Tennessee to be >580m in elevation. In Kentucky, the Blue-winged Warbler was largely absent from counties in which our four Golden-winged Warbler-only study sites were located, at elevations on average of 533, 728, 738, and 890 m (Palmer-Ball 1996; KDFWR species information data 2009). Since the publication of the Kentucky Breeding Bird Atlas (Palmer-Ball 1996), observations of Blue-winged Warblers have increased across southeastern Kentucky (KDFWR species information data 2009). It remains to be seen how the Blue-winged Warbler will continue to expand into this region, and whether it will colonize higher elevation sites where the Golden-winged Warbler is currently isolated. Since the completion of our study, the Blue-winged Warbler colonized a low elevation, i.e., average 533 m, study site where only the Golden-winged Warbler occurred (P. Hartman, University of Kentucky, *personal communication*). By 2009, Blue-winged Warblers had replaced nearly all Golden-winged Warblers. Interestingly, this site is only <80 km from higher

Fig. 5. Stand of black locust along forest edge, Photo: Laura Patton

elevation sites in Tennessee where the Blue-winged Warbler has been rare at sites occupied by the Golden-winged Warbler (Bulluck 2007). Just recently, during the 2010 Golden-winged Warbler Atlas Project, a Blue-winged Warbler was documented at one of our high elevation study sites, average 738 m, where previously only the Golden-winged Warbler had been observed since surveys began in 2003 (L. Patton, *personal observation*). The site has experienced significant growth in shrub and sapling cover since this study was initiated in 2004 (Fig. 4). It is unclear whether the Blue-winged Warbler would have expanded to this elevation even if habitat had been maintained at an early successional state, or whether succession made this area more attractive to the Blue-winged Warbler. It will be informative to monitor the extent to which the Blue-winged Warbler can colonize higher elevation sites in this region and also whether phenotypically pure Golden-winged Warbler populations at higher elevations already contain introgressed individuals, as has been documented in Tennessee (Vallender et al. 2009). If higher elevation sites are maintained without the Blue-winged Warbler, they may serve as sites for the Golden-winged Warbler to minimize hybridization, and thus provide important habitats that can be managed for the maintenance of genotypically pure Golden-winged Warbler populations (Buehler et al. 2007, Vallender et al. 2007).

In our study, Golden-winged Warbler territories at sites unoccupied by Blue-winged Warblers had greater canopy cover compared with those of Golden-winged Warblers and Blue-winged Warblers at sites occupied by both species. Based on the

Fig. 6. Elevational distribution of territories of Golden-winged Warblers in absence of Blue-winged Warblers (GW) and coexisting Golden-winged (GWBW) and Blue-winged Warblers (BW).



results of our study and those from studies conducted elsewhere, maintaining an appropriate amount of tree cover within the early successional matrix, away from the forest edge, appears to be a requisite for use as breeding habitat by Golden-winged Warblers. Specifically, too little tree cover and too much tree cover both result in early successional sites not being used by breeding Golden-winged Warblers (Huffman 1997, Cumming 1998, Klaus and Buehler 2001). Residual basal area was lower (median=10m²/ha) in harvested stands occupied by Golden-winged Warblers than those unoccupied by Golden-winged Warblers (median = 40m²/ha) in the southern Appalachian Mountains (Klaus and Buehler 2001). Golden-winged Warbler in central Pennsylvania often used residual overstory trees in the interior portions of clearcuts as song perches (Kubel 2005). The amount of residual trees in harvested stands influenced the occurrence of Golden-winged Warblers in Manitoba, whereby stands with few or no residual trees were unoccupied by the species (Cumming 1998). Additionally, Huffman (1997) noted that regenerating aspen stands with residual trees were used by breeding Golden-winged Warblers in Minnesota, but recommended that residual canopy cover should not exceed 25%. Kubel (2005) hypothesized that availability of residual trees is most important when the size of a harvested stand exceeds the area of a typical Golden-winged Warbler territory (0.6-2.7 ha). For example, if a harvested stand is large enough to incorporate several territories, but no residual trees are present, then the interior portions of the harvested area will be unsuitable as Golden-winged Warbler breeding habitat. As such, territories will be restricted to the periphery of the harvested stand, and the full potential of the stand to support breeding Golden-winged warblers will not be achieved. If this hypothesis holds true, many expansive areas of reclaimed surface mines lack this important component of Golden-winged Warbler breeding habitat. Only one study has examined the effect of tree cover on Golden-winged Warbler reproductive success (Confer et al. 2003). Confer et al. (2003) reported that tree cover had a small, but significant, negative effect on Golden-winged Warbler nesting success in old field habitats in central New York. However, if greater tree cover leads to Golden-winged Warbler isolation from the negative effects of hybridization with Blue-winged Warblers, a small reduction in nesting success may be an appropriate trade-off.

Our analysis also revealed that grass cover was greater in Golden-winged Warbler territories at sites unoccupied by Blue-winged Warblers compared with those of Golden-winged Warbler and Blue-winged Warbler at sites where both species coexisted. This finding is consistent with the findings from studies elsewhere. Golden-winged Warbler territories in central New York had greater amounts of herb cover compared with Blue-winged Warbler territories, and herbaceous cover was positively correlated with clutch size (Confer et al. 2003). Sites used by the Golden-winged Warbler in Pennsylvania had greater amounts of goldenrod than similar sites not occupied by the species (Kubel 2005). Additionally, reclaimed mines occupied by Golden-winged Warblers in Tennessee had thick herbaceous cover maintained by periodic arson fires, and Golden-winged Warbler nests were placed in areas with greater amounts of grasses and forbs than available non-nest sites (Bulluck 2007).

Although we detected a relationship between increased grass cover in Golden-winged Warbler territories at sites where the Blue-winged Warbler was absent, there may be a threshold of herbaceous cover at which Golden-winged Warbler nesting success is negatively affected via nest predation and parasitism (Dion et al. 2000, Confer et al. 2003). Although grass cover may provide increased concealment around nests and thus can guard against predation and increase nest success (Martin and Roper 1988, Winter et al. 2005), dense ground cover, such as that created by tall fescue, may conceal small terrestrial predators from avian predators (Orians and Wittenberger 1991, Dion et al. 2000). In New York, Golden-winged Warbler nest parasitism by Brown-headed Cowbirds was positively correlated with percent herbaceous cover (Confer et al. 2003). Moreover, this threshold value may easily be reached on reclaimed surface mines because fescue, a dense mat-forming grass, is often planted for erosion control. Nonetheless, this may not be applicable to our study area in eastern Kentucky because the landscape is mostly forested, and Brown-headed Cowbirds were rarely observed during our study. Further, no evidence of nest parasitism was found on our study sites (Patton 2007). Additionally, the Brown-headed Cowbird was not recorded on point counts during a 2-year study on the Yellow-breasted Chat (*Icteria virens*) on reclaimed mines in eastern Kentucky (Ciuzio 2002) and was rare on reclaimed mines in Indiana (DeVault et al. 2002). Nest parasitism by the Brown-headed Cowbird was low for several species of grassland songbirds on reclaimed mines in Indiana (Galligan et al. 2006), and in logged forests in Tennessee and North Carolina (Klaus and Buehler 2001). Consequently, the effects of nest parasitism by the Brown-headed Cowbird in this region may not be as great as in other portions of the Golden-winged Warbler's range (Coker and Confer 1990, Confer 1992*a*, Confer et al. 2003, Buehler et al. 2007).

Common plant species on all of our study sites were fescue, timothy grass, morning-glory, and maple. Our analyses identified plant species that were indicative of sites only occupied by the Golden-winged Warbler. These included orchardgrass, green ash seedlings, and green ash and black locust saplings. Lespedeza, goldenrods, blackberry, and clematis vine were indicator species at sites with Golden-winged and Blue-winged Warblers. Black locust, green ash, blackberry, and orchardgrass were also reported as prevalent in areas occupied by the Golden-winged Warbler in other studies (Will 1986, Klaus and Buehler 2001). Black locust could be important to the Golden-winged Warbler because it is heavily browsed by insects including the locust borer (*Megacyllene robiniae*) and various caterpillars (U.S. Department of Agriculture, Forest Service 1990, Galford 1997). We often observed Golden-winged Warblers gleaning insects from the leaves of black locust. Black locust is a short-lived tree because it is highly susceptible to insect damage by the locust borer and heart rot fungi (*Phellinus rimosus* or *Polyporus robiniophilus*; U.S. Department of Agriculture, Forest Service 1990, U. S. Department of Agriculture, Natural Resources Conservation Service 2007). This could potentially benefit the Golden-winged Warbler in terms of the presence of snags for singing perches, and by prolonging the duration of time a site provides early successional habitat suitable for Golden-winged Warbler occupancy. As such, we recommend black locust be a significant component of reclamation planting mixtures on surface mines where Golden-winged Warbler conservation is a priority. This is particularly true along forest-reclaimed mine land edges where black locust plantings could result in substantial amounts of Golden-winged Warbler habitat in a relatively short amount of time.

CONCLUSION

The Golden-winged Warbler shares southeastern Kentucky reclaimed mines with bird species that are on the decline elsewhere including Yellow-breasted chat, Eastern Towhee (*Pipilo erythrophthalmus*), and Grasshopper Sparrow (Brennan and Kuvlesky 2005). Reclaimed mines are appealing for the conservation of the Golden-winged Warbler and other species of early successional habitats because succession is retarded compared with forest openings and old fields (Burger 1999, DeVault et al. 2002). Mosaics of forests, shrublands, and grasslands characteristic of reclaimed mine lands in eastern Kentucky offer land managers opportunities to improve conditions for the Golden-winged Warbler and several grassland and forest edge species. As such, state wildlife agencies and other conservation groups should work to enroll private landowners in state and federal habitat assistance programs that provide funding and on-the-ground technical assistance to those who wish to improve habitat for a variety of wildlife. Additionally, we urge the development of partnerships between game and nongame oriented organizations to merge and strengthen efforts that facilitate biodiversity and conservation of regionally imperiled species like the Golden-winged Warbler (Brennan and Kuvlesky 2005). Finally, the creation of Golden-winged Warbler breeding habitat on reclaimed mine lands in the Appalachian Coal Region may be enhanced and accelerated by a recent multigroup partnership intended to promote the recovery of forests on mine lands in the region. The Appalachian Regional Reforestation Initiative (ARRI) is a cooperative effort by the States of the Appalachian Region with the Federal Office of Surface Mining to encourage restoration of high quality forests on reclaimed coal mines in the eastern U.S. (Angel et al. 2005). Partnerships like ARRI have the potential to create or enhance significant amounts of early successional habitat on more than 280,000 ha of reclaimed mine land in the eastern U.S.

Our findings complement recent genetic studies and add another factor for examining Golden-winged Warbler population decline. Further, information from our study will aid land managers in manipulating habitat for the Golden-winged Warbler. Habitat manipulation on high elevation reclaimed mines could reduce the chances of competition, hybridization, and genetic introgression between Golden-winged Warbler and Blue-winged Warbler. Management to promote the Golden-winged Warbler should prioritize higher elevations along forest edges rather than open grasslands. Early successional transition zones should extend within an average of 50 m from the forest edge and should extend parallel along the forest edge as far as is feasible. In fragmented areas, as many forest edges as possible should be targeted for manipulation. Such management may support more breeding pairs of Golden-winged Warblers, and thus increase fitness as a result of clustered breeding (Ahlering and Faaborg 2006). Based on the patterns revealed in our study, a mixture of grasses and forbs (~40% cover) should be promoted to facilitate Golden-winged Warbler occupation. Habitat should also be manipulated to include scattered mature trees (basal area = 2-8 m^2/ha) beyond the forest edge, and aggregate sapling heights up to 45 m/5 m^2. Although heavy shrub cover should be discouraged, an average of 20% will likely help create the patchy habitat that the Golden-winged Warbler appears to favor.

There were numerous patches of early successional habitat along forest edges in this study where the Golden-winged Warbler and Blue-winged Warbler were absent or failed to return in subsequent breeding seasons. Several of these sites had advanced to young forests, including midstory hardwood growth and heavy shrub cover. In these areas, periodic prescribed burning or mechanical removal of shrubs could be effective. Burns conducted during mid-January to mid-March can promote growth of herbaceous vegetation in the spring, are less likely to destroy nests of breeding birds, and can increase insect abundance (Yarrow and Yarrow 1999). Late summer burns may also stimulate forb cover while reducing woody stems (Harper 2007). Habitat may also be manipulated through disking, which promotes forb cover, and use of herbicides to manipulate the percentages of grass, forb, and woody cover (Harper 2007). Some sites had forest edges that abruptly changed to grassland with little or no intermediate transition zone, resulting in a hard edge. There were also hollow-fills, or large sloped openings, adjacent to our study sites that were reclaimed solely with herbaceous vegetation. These hard edges and openings could be improved by planting patches of herbaceous vegetation, shrubs, and saplings.

It is encouraging that the Golden-winged Warbler has colonized available habitat on reclaimed surface coal mines in southeastern Kentucky. Nonetheless, further examination of their use of reclaimed mines as breeding habitat is necessary to determine whether these human-created disturbed sites support source or sink populations (Pulliam 1988, Remes 2003). Specifically, we recommend that future studies examine Golden-winged Warbler nesting success and associated habitat characteristics on reclaimed mines to further aid in the creation of conservation approaches that facilitate the species recovery.

Responses to this article can be read online at:
http://www.ace-eco.org/vol5/iss2/art2/responses/

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LITERATURE CITED

Ahlering, M. A., and J. Faaborg. 2006. Avian habitat management meets conspecific attraction: if you build it, will they come? *Auk* **123**:301-312.

Angel, P., V. Davis, J. Burger, D. Graves, and C. Zipper. 2005. The Appalachian regional reforestation initiative. *Forest Reclamation Advisory* **1**:1-2.

Avery, T. E., and H. E. Burkhart. 1983. *Forest measurements.* Third edition. McGraw-Hill, New York, New York, USA.

Bajema, R. A., T. L. DeVault, P. E. Scott, and S. L. Lima. 2001. Reclaimed coal mine grasslands and their significance for Henslow's sparrows in the American Midwest. *Auk* **118**:422-431.

Barg, J. J., J. Jones, and R. J. Robertson. 2005. Describing breeding territories of migratory passerines: suggestions for sampling, choice of estimator, and delineation of core areas. *Journal of Animal Ecology* **74**:139-149.

Beyer, H. L. 2004**.** *Hawth's Analysis Tools for ArcGIS.* [online] URL:http://www.spatialecology.com/htools.

Bibby, C. J., N. D. Burgess, D. A. Hill, and S. H. Mustoe. 2000. *Bird census techniques.* Second edition. Academic Press, San Diego, California, USA.

Bonham, C. D. 1989. *Measurements for terrestrial vegetation.* John Wiley & Sons, New York, New York, USA.

Börger, L., N. Franconi, G. De Michele, A. Gantz, F. Meschi, A. Manica, S. Lovari, and T. Coulson. 2006. Effects of sampling regime on the mean and variance of home range size estimates. *Journal of Animal Ecology* **75**:1393-1405.

Braun, E. L. 1950. *Deciduous forests of eastern North America.* Hafner, New York, New York, USA.

Brennan, L. A., and W. P. Kuvlesky, Jr. 2005. North American grassland birds: an unfolding conservation crisis? *Journal of Wildlife Management* **69**:1-13.

Buehler, D. A., A. M. Roth, R. Vallender, T. C. Will, J. L. Confer, R. A. Canterbury, S. Barker Swarthout, K. V. Rosenberg, and L. P. Bulluck. 2007. Status and conservation priorities of golden-winged warbler (*Vermivora chrysoptera*) in North America. *Auk* **124**:1439-1445.

Bulluck, L. P. 2007. *Golden-winged warbler (Vermivora chrysoptera) demographics and habitat use and the potential effects of land use change on golden-winged and cerulean warblers (Dendroica* *cerulea) in the Cumberland Mountains of Tennessee.* Dissertation, University of Tennessee, Knoxville, Tennessee, USA.

Burger, J. A. 1999. Academic research perspective on experiences, trends, constraints, and needs related to reforestation of mined land. Pages 63-74 *in* K. C. Vories, and D. Throgmorton, editors. *Proceedings of enhancement of reforestation at surface coal mines: technical interactive forum.* 23-24 March 1999, U.S. Department of the Interior, Office of Surface Mining and Coal Research Center, Southern Illinois University, Fort Mitchell, Kentucky, USA.

Canterbury, R. A., D. M. Stover, and T. C. Nelson. 1993. Golden-winged warblers in southern West Virginia: status and population ecology. *Redstart* **60**:97-106.

Ciuzio, E. A. 2002. *Do restored elk affect bird communities in eastern Kentucky?* Thesis, University of Kentucky, Lexington, Kentucky, USA.

Coker, D. R., and J. L. Confer. 1990. Brown-headed cowbird parasitism on golden-winged and blue-winged warblers. *Wilson Bulletin* **102**:550-552.

Confer, J. L. 1992*a*. Golden-winged warbler. Pages 1-16 *in* A. Poole, and F. Gill, editors. *Birds of North America*. Academy of Natural Sciences, Philadelphia, Pennsylvania, USA, and American Ornithologists' Union, Washington, D.C., USA.

Confer, J. L. 1992*b*. Golden-winged warbler, *Vermivora chrysoptera*. Pages 369-383 *in* K. J. Schneider, and D. M. Pence, editors. *Migratory nongame birds of management concern in the Northeast.* U.S. Department of the Interior, Fish and Wildlife Service, Newton Corner, Massachusetts, USA.

Confer, J. L., and K. Knapp. 1981. Golden-winged warblers and blue-winged warblers: the relative success of a habitat specialist and a generalist. *Auk* **98**:108-114.

Confer, J. L., J. L. Larkin, and P. E. Allen. 2003. Effects of vegetation, interspecific competition, and brood parasitism on golden-winged warbler (*Vermivora chrysoptera*) nesting success. *Auk* **120**:138-144.

Cornell Lab of Ornithology. 2003. Golden-winged warbler atlas project. [online] URL: http://birds.cornell.edu/gowap/.

Costanza, M. C., and A. A. Afifi. 1979. Comparison of stopping rules in forward stepwise discriminant analysis. *Journal of American Statistical Association* **74**:777-785.

Cumming, E. E. 1998. *Distribution and habitat associations of Golden-winged Warblers in Duck, Mountain, Riding Mountain, and Porcupine Hills, Manitoba, 1998.* The Canadian Wildlife Service-Forest Bird Research Program, Saskatoon, Saskatchewan, Canada.

Dabrowski, A., R. Fraser, J. L. Confer, and I. J. Lovette. 2005. Geographic variability in mitochondrial introgression among hybridizing populations of golden-winged (*Vermivora chrysoptera*) and blue-winged (*V. pinus*) warblers. *Conservation Genetics* **6**:843-853.

DeBoer, T. S., and D. D. Diamond. 2006. Predicting presence-absence of the endangered golden-cheeked warbler (*Dendroica chrysoparia*). *Southwestern Naturalist* **51**:181-190.

DeVault, T. L., P. E. Scott, R. A. Bajema, and S. L. Lima. 2002. Breeding bird communities of reclaimed coal-mine grasslands in the American Midwest. *Journal of Field Ornithology* **73**:268-275.

Dion, N., K. A. Hobson, and S. Lariviere. 2000. Interactive effects of vegetation and predators on the success of natural and simulated nests of grassland songbirds. *Condor* **102**:629-634.

Donovan, T. M., C. J. Beardmore, D. N. Bonter, J. D. Brawn, R. J. Cooper, J. A. Fitzgerald, R. Ford, S. A. Gauthreaux, T. L. George, W. C. Hunter, T. E. Martin, J. Price, K. V. Rosenburg, P. D. Vickery, and T. B. Wigley. 2002. Priority research needs for the conservation of Neotropical migrant landbirds. *Journal of Field Ornithology* **73**:329-339.

Dufrêne, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monograhs* **67**:345-366.

Environmental Systems Research Institute (ESRI). 2004. *ArcGIS version 9.0*. ESRI, Redlands, California, USA.

Environmental Systems Research Institute (ESRI). 2005. *Auto Add Lines*. ESRI, Redlands, California, USA.

Fei, S., P. J. Gould, K. C. Steiner, and J. C. Finley. 2006. Aggregate height – a composite measure of stand density for tree seedling populations. *Forest Ecology and Management* **223**:336-341.

Galford, J. R. 1997. *The locust borer.* Forest Insect and Disease Leaflet 71, U.S. Department of Agriculture, Forest Service, Washington, D.C., USA. [online] URL: http://www.na.fs.fed.us/spfo/pubs/fidls/locust/locust.htm.

Galligan, E. W., T. L. DeVault, and S. L. Lima. 2006. Nesting success of grassland and savanna birds on reclaimed surface coal mines of the Midwestern United States. *Wilson Journal of Ornithology* **118**:537-546.

Gill, F. B. 1980. Historical aspects of hybridization between blue-winged and golden-winged warblers. *Auk* **97**:1-18.

Gill, F. B. 1997. Local cytonuclear extinction of the Golden-winged warbler. *Evolution* **51**:519-525.

Gill, F. B. 2004. Blue-winged warblers (*Vermivora pinus*) versus golden-winged warblers (*Vermivora chrysoptera*). *Auk* **121**:1014-1018.

Griffith, B., and B. A. Youtie. 1988. Two devices for estimating foliage density and deer hiding cover. *Wildlife Society Bulletin* **16**:206-210.

Harper, C. A. 2007. Strategies for managing early succession habitat for wildlife. *Weed Technology* **21**:932-937.

Hudman, S. P., and C. R. Chandler. 2002. Spatial and habitat relationships of red-eyed and blue-headed vireos in the southern Appalachians. *Wilson Bulletin* **114**:227-234.

Huffman, R. D. 1997. *Effects of residual overstory on bird use and aspen regeneration in aspen harvest sites in Tamarac National Wildlife Refuge, Minnesota.* Thesis, West Virginia University, Morgantown, West Virginia, USA.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. *Wildlife Society Bulletin* **29**:440-455.

Jones, R. L. 2005. *Plant Life of Kentucky.* University Press of Kentucky, Lexington, Kentucky, USA.

Kentucky Climate Center. 2007*a*. Eastern temperature. [online] URL: http://kyclim.wku.edu/climate/climDiv_viewer.htm.

Kentucky Climate Center. 2007*b*. Eastern precipitation. [online] URL: http://kyclim.wku.edu/climate/climDiv_viewer.htm.

Kentucky Foundation. 2002. Timeline of Kentucky coal. [online] URL: http://www.coaleducation.org/coalhistory/default.htm.

Kentucky Department of Fish and Wildlife Resources (KDFWR). 2009. *Blue-winged Warbler species information*. Kentucky Department of Fish and Wildlife Resources, Kentucky, USA. [online] URL: http://www.kdfwr.state.ky.us/kfwis/speciesInfo/speciesInfo.asp

Kentucky Geography Network. 2005. *Farm Services Agency and National Agricultural Imagery Program Digital Ortho Photo Imagery for Kentucky 2004.* [online] URL: http://kygeonet.ky.gov/metadataexplorer.

Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 126-168 *in* J. J. Millspaugh, and J. M. Marzluff, editors. *Radio Tracking and Animal Populations.* Academic Press, San Diego, California, USA.

Klaus, N. A., and D. A. Buehler. 2001. Golden-winged warbler breeding habitat characteristics and nest success in clearcuts in the southern Appalachian mountains. *Wilson Bulletin* **113**:297-301.

Kubel, J. E. 2005. *Breeding ecology of golden-winged warblers in managed habitats of central Pennsylvania.* Thesis, Pennsylvania State University, State College, Pennsylvania, USA.

Lacki, M. J., J. L. Fitzgerald, and J. W. Hummer. 2004. Changes in avian species composition following surface mining and reclamation along a riparian forest corridor in southern Indiana. *Wetlands Ecology and Management* **12**:447-457.

Larkin, J. L., and J. Grata. 2009. Golden-winged warbler conservation initiative – Pennsylvania. Final Report. Pennsylvania Department of Conservation and Natural Resources, Harrisburg, Pennsylvania, USA.

Leopold, D. J., W. C. McComb, and R. N. Muller. 1998. *Trees of the central hardwood forests of North America.* Timber Press, Portland, Oregon, USA.

Martin, T. E., and J. J. Roper. 1988. Nest predation and nest-site selection of a western population of the hermit thrush. *Condor* **90**:51-57.

McCollin, D. 1998. Forest edges and habitat selection in birds: a functional approach. *Ecography* **21**:247-260.

McCune, B., and J. B. Grace. 2002. *Analysis of Ecological Communities.* MjM Software Design, Gleneden Beach, Oregon, USA.

McCune, B., and M. J. Mefford. 1999. *PC-ORD: Multivariate Analysis of Ecological Data.* Version 4. MjM Software Design, Gleneden Beach, Oregon, USA.

Mengel, R. M. 1965. *The birds of Kentucky.* Allen Press, Lawrence, Kansas, USA.

Monroe, M. S., and G. Ritchison. 2005. Breeding biology of Henslow's sparrows on reclaimed coal mine grasslands in Kentucky. *Journal of Field Ornithology* **76**:143-149.

Orians, G. H., and J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. *American Naturalist* **137**:29-49.

Palmer-Ball, B., Jr. 1996. *The Kentucky breeding bird atlas.* University Press of Kentucky, Lexington, Kentucky, USA.

Patton, L. L. 2007. *Comparative ecology of the golden-winged warbler and blue-winged warbler on reclaimed mines in southeastern Kentucky.* Thesis, University of Kentucky, Lexington, Kentucky, USA.

Patton, L. L., S. Vorisek, and J. L. Larkin. 2004. Golden-winged and blue-winged warbler on reclaimed mines in eastern Kentucky. *Kentucky Warbler* **80**:73-75.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. *American Naturalist* **132**:652-661.

R Foundation for Statistical Computing. 2009. *Program R Version 2.10.1.* R Foundation for Statistical Computing, Vienna, Austria.

Remes, V. 2003. Effects of exotic habitat on nesting success, territory density, and settlement patterns in the blackcap (*Sylvia atricapilla*). *Conservation Biology* **17**:1127-1133.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Iñigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. *Partners in Flight North American Landbird Conservation Plan.* Cornell Lab of Ornithology. Ithaca, New York, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management* **23**:295-297.

Rossel, C. R., Jr. 2001. Song perch characteristics of golden-winged warblers in a mountain wetland. *Wilson Bulletin* **113**:246-248.

SAS Institute. 2001. *The SAS System for Windows Version 8*. SAS Institute, Cary, North Carolina, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. *The North American breeding bird survey, results and analysis 1966-2005.* Version 6.2.2006, U.S. Geological Survey, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Shapiro, L. H., R. A. Canterbury, D. M. Stover, and R. C. Fleischer. 2004. Reciprocal introgression between golden-winged warblers (*Vermivora chrysoptera*) and blue-winged warblers (*V. pinus*) in eastern North America. *Auk* **121**:1019-1030.

Shields, W. M. 1977. The effect of time of day on avian census results. *Auk* **94**:380-383.

Short, L. L. 1963. Hybridization in the wood warblers *Vermivora pinus* and *V. chrysoptera*. Pages 147-160 *in Proceedings of the 13th International Ornithological Congress.* 1962, Ithaca, New York, USA.

Sokal, R. R., and F. J. Rohlf. 1969. *Biometry.* W. H. Freeman and Company, San Francisco, California, USA.

Titus, K., J. A. Mosher, and B. K. Williams. 1984. Chance-corrected classification for use in discriminant analysis: ecological applications. *American Midland Naturalist* **111**:1-7.

U.S. Department of Agriculture, Forest Service. 1990. *Silvics of North America: 1. Conifers; 2. Hardwoods.* Agriculture Handbook 654. [online] URL: http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2007. *PLANTS Database.* [online] URL: http://plants.usda.gov.

Vallender, R., R. J. Robertson, V. L. Friesen, and I. J. Lovette. 2007. Complex hybridization dynamics between Golden-winged and Blue-winged Warblers *(Vermivora chrysoptera* and *V. pinus)* revealed by AFLP, microsatellite, intron and mtDNA markers. *Molecular Ecology* **16**: 2017-2029.

Vallender, R., S. L. VanWilgenburg, L. P. Bulluck, A. M. Roth, R. A. Canterbury, J. L. Larkin, and I. J. Lovette. 2009. Extensive rangewide mitochondrial introgression indicates substantial cryptic hybridization in the Golden-winged Warbler (*Vermivora chrysoptera*). *Avian Conservation and Ecology - Écologie et conservation des oiseaux* **4**(2): 4. [online] URL: http://www.ace-eco.org/vol4/iss2/art4/

Venables W. N., and B. D. Ripley. 2002. *Modern applied statistics with S.* Springer-Verlag, New York, New York, USA.

Will, T. C. 1986. *Behavioral ecology of species replacement: blue-winged and golden-winged warblers in Michigan.* Dissertation. University of Michigan, Ann Arbor, Michigan, USA.

Winter, M., D. H. Johnson, and J. Faaborg. 2005. Variability in vegetation effects on density and nesting success of grassland birds. *Journal of Wildlife Management* **69**:185-197.

Yarrow, G. K., and D. T. Yarrow. 1999. *Managing wildlife.* Sweetwater Press, Birmingham, Alabama, USA.