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EFFECTS OF LANDSCAPE CHANGE
ON GOLDEN-WINGED AND BLUE-WINGED WARBLERS
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Katherine. J. Kahl

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EFFECTS OF LANDSCAPE CHANGE ON GOLDEN-WINGED AND BLUE-WINGED WARBLERS IN MICHIGAN

By

Katherine J. Kahl

A THESIS

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ABSTRACT

EFFECTS OF LANDSCAPE CHANGE ON GOLDEN-WINGED AND BLUE-WINGED WARBLERS IN MICHIGAN

By

Katherine J. Kahl

The objective of this research was to compare changes in landscapes over time where Golden-winged and Blue-winged Warblers were present and absent in the lower peninsula of Michigan. To do this, the landscape composition (land cover types within the landscape) and landscape structure (degree of fragmentation of land cover types) along Breeding Bird Survey (BBS) routes where both species were present were examined and compared to routes where they were absent in 1978, 1993, and 2000. Differences in landscape composition and structure around 46 BBS routes were compared using classified land cover data from 1978, 1993, and 2000. A GIS was used to create a 400-meter buffer around BBS routes. Total area and area-perimeter ratios for 12 landscape composition and 12 landscape structure variables were calculated within each buffered area. Principal components analysis explained covariation patterns across multiple landscape composition and structure variables. Analysis of variance was used to test the significance of each principal component. Results show that both Golden-winged and Blue-winged Warblers are moving northward. Potential causes of range shift for the Golden-winged Warbler may be due to increased human influence and increased fragmentation of land cover types they find favorable. Blue-winged Warblers may not be as negatively affected by these factors.

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INTRODUCTION

The Golden-winged Warbler (*Vermivora chrysoptera*) is among the highest-ranked species for conservation in the Northeast, Southeast, and Midwest regions of the United States (Barker and Rosenberg, 2000). Over the last three decades, the Golden-winged Warbler has declined by 7.7% annually within its breeding range while the Blue-winged Warbler (*V. pinus*), a congener, has only declined by 4.4% annually in the southern portion of its range (Sauer *et al.*, 1999). Both species are currently under United States Fish & Wildlife Service contracted status assessment to determine whether they should be Federally listed as threatened or endangered (Confer and Tupper, 2000; T. Will, Bird Conservation Biologist, pers.comm.). There has been no published research on the status of Michigan Golden-winged and Blue-winged Warbler populations since 1986 (Will, 1986).

The Golden-winged Warbler is an insectivorous, ground-nesting, Neotropical migratory songbird that breeds in the northeastern United States and Canada, with its largest populations concentrated in habitats along the Appalachian mountain range and the U.S.-Canadian border. Michigan, Wisconsin, Minnesota, New York, Pennsylvania, Vermont, West Virginia, and Ontario have some of the largest breeding populations (National Geographic Society 1987; Brewer *et al.*1991) (Fig. 1.1). Golden-winged Warblers are associated with early successional patches of herbaceous cover, shrubs and scattered trees that are often bordered by a forested edge. This habitat often results from fire, logging, or abandoned farmland. They can also be found along marshes and bogs with forested edge (Confer, 1992).

The Blue-winged Warbler is similar in behavior, vocalization, and body size, and is known to compete with the Golden-winged Warbler for resources. Also a Neotropical migratory songbird and a ground-nester, the Blue-winged Warbler breeding range lies slightly southwest of the Golden-winged Warbler range (Fig. 1.2). Shrubby, early-successional habitat is favored (Dunn and Garrett, 1997; Confer, 1992). Range expansion for more than a century was aided by increased amounts of abandoned farmland and forest clear-cuts providing the necessary early- to mid-successional habitat (Berger, 1958; Confer and Knapp, 1981; Will, 1986). More recently, increased urban sprawl and succession of abandoned farmland and old field cover types have resulted in habitat loss for the species.

Hybridization occurs where the two species breeding ranges overlap (Fig. 1.3) producing a first cross (F_1) between the Golden-winged and Blue-winged Warbler called the Brewster's Warbler (*V. leucobronchialis*). The less common Lawrence's Warbler, (*V. lawrencii*) is the second cross (F_2) between either parent species and a Brewster's Warbler (Curseon *et al.*, 1994; Dunn and Garrett, 1997). Both hybrids are fertile, although their fitness may be low and potentially negatively affecting population sizes of both species with increased hybridization (Confer, 1992). Both hybrids sing either parent species song, or a garbled version of it, and have distinctive although variable plumage markings. There is debate as to whether hybrids can accurately be visually differentiated from Blue-winged Warblers (Parkes, 1951; Short, 1963; Ficken and Ficken 1968a,b; Gill and Murray 1972; Gill 1980, 1997; Confer and Larkin, 1998).

Specific causes of Golden-winged Warbler decline within the breeding range are often attributed to competition and hybridization with the Blue-winged Warbler.

However, the mechanism by which hybridization may favor the Blue-winged Warbler is not yet understood (Confer, 1992). Arrival and expansion of the Blue-winged Warbler in an area is frequently associated with the decline of the Golden-winged Warbler (Gill, 1980; Confer, 1992). However, they have not been proven to be the direct cause of the extinction of local Golden-winged Warbler populations (Gill *et al.*, 2001). Golden-winged Warbler decline is known to be caused in large part by factors such as habitat loss due to succession and human influences.

Behaviorally dominant Blue-winged Warblers may displace Golden-winged Warblers from optimal habitat in central Michigan (Will, 1986). However, in other geographic areas of the breeding range, Golden-winged Warblers dominate Blue-winged Warblers (Confer, 1992) or Blue-winged Warblers do not exclude Golden-winged Warblers from optimal nesting territories (Confer and Larkin, 1998).

Much of today's research on Golden-winged and Blue-winged Warbler populations focuses on hybridization of these two species and the potential negative effects on the success of "true" populations of each species. Understanding how hybridization is affecting population dynamics and therefore range shift must be explored to accurately assess where species populations are located, in what abundance, and the patterns of reproduction for each species and hybrids. The information needed first, however, relates to understanding the particular habitat type characteristics that each species is selecting for or against. Understanding the local and landscape-level patterns of habitat selection within the possible matrix of habitat choices within the landscape is a necessary first step for conservation agencies as well as for the knowledge base of avian ecology.

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FIGURES

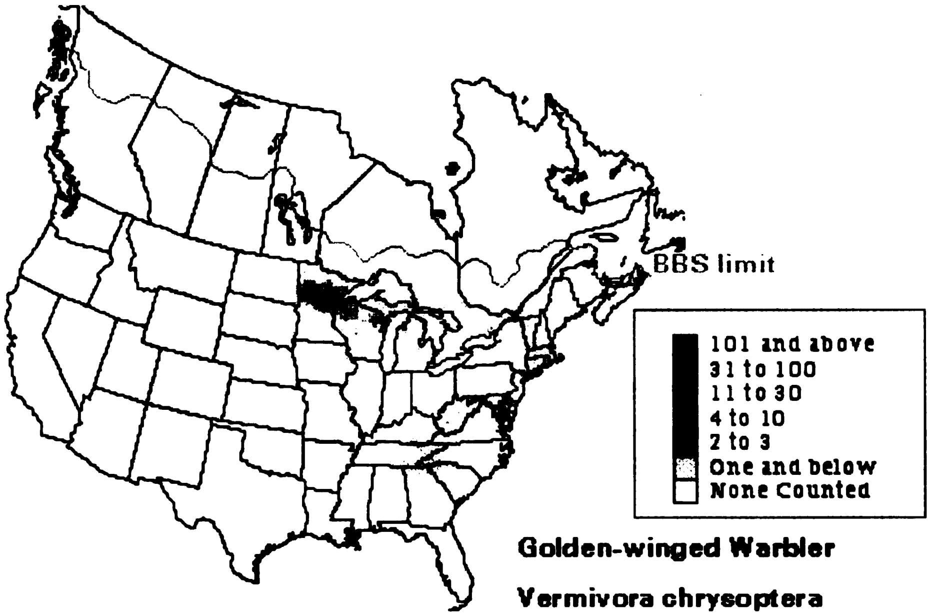


Figure 1.1 Golden-winged Warbler distribution map. Map taken from National Breeding Bird Survey data results collected between 1985 and 1992.

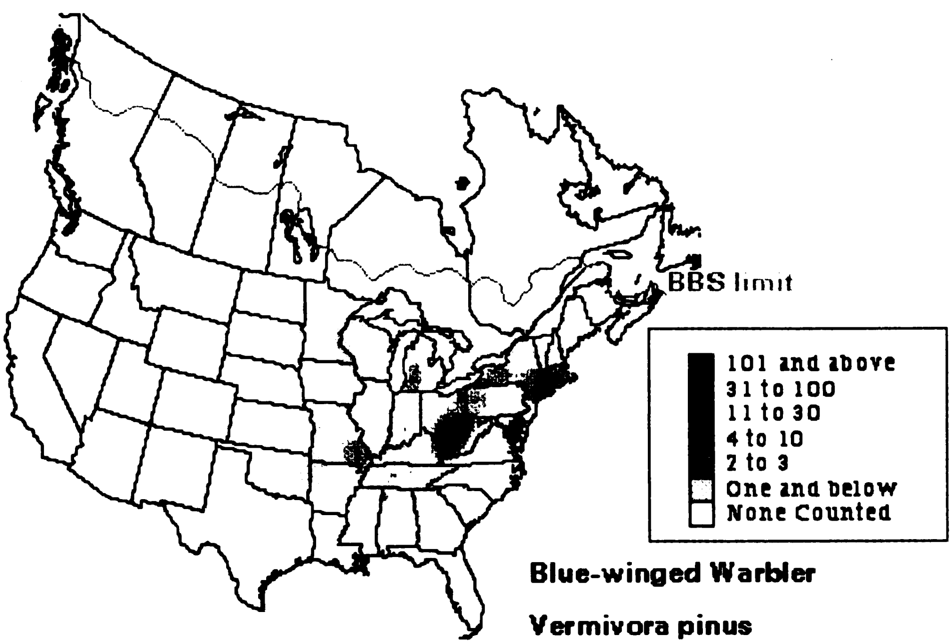
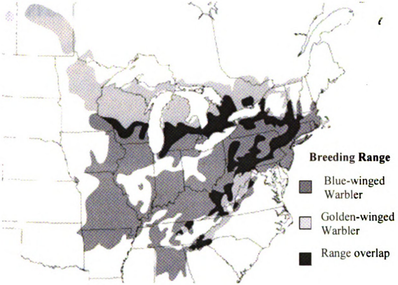


Figure 1. 2. Blue-winged Warbler distribution map. Map taken from National Breeding Bird Survey data results collected between 1985 and 1992.



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EFFECTS OF LAND COVER CHANGE ON GOLDEN-WINGED AND BLUE-WINGED WARBLERS IN MICHIGAN

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Abstract. The objective of this research was to compare changes in landscapes over time where Golden-winged and Blue-winged Warblers were present and absent in the lower peninsula of Michigan. To do this, the landscape composition (land cover types within the landscape) and landscape structure (degree of fragmentation of land cover types) along Breeding Bird Survey (BBS) routes where both species were present were examined and compared to routes where they were absent in 1978, 1993, and 2000. Differences in landscape composition and structure around 46 BBS routes were compared using classified land cover data from 1978, 1993, and 2000. A GIS was used to create a 400-meter buffer around BBS routes. Total area and area-perimeter ratios for 12 landscape composition and 12 landscape structure variables were calculated within each buffered area. Principal components analysis explained covariation patterns across multiple landscape composition and structure variables. Analysis of variance was used to test the significance of each principal component. Results show that both Golden-winged and Blue-winged Warblers are moving northward. Potential causes of range shift for the Golden-winged Warbler may be due to increased human influence and increased

fragmentation of land cover types they find favorable. Blue-winged Warblers may not be as negatively affected by these factors.

Key words: Golden-winged Warbler, Blue-winged Warbler, landscape ecology, breeding range, Michigan, area-perimeter ratio.

INTRODUCTION

Human alteration of land cover can cause changes in landscape composition and structure that result in loss of biodiversity. For many Neotropical migratory songbird species, loss in land cover diversity may lead to geographical shifts in their breeding ranges. Globally, breeding ranges for many birds and mammals are beginning to shift to the north (Parmesan and Yoke, 2003). These geographical changes in breeding range location may be the result of shifts in the geographic locations of favorable habitats within the landscape. Habitat is defined as the resources and conditions present in an area that affect occupancy by a species (Morrison, 2002). Many different habitats may be are contained within a landscape. Landscapes are defined as spatially heterogeneous areas (Morrison, 2002). The term landscape will be discussed as a large-scale area, and as perceived by Golden-winged and Blue-winged Warblers.

The boundaries of the Golden-winged Warbler (*Vermivora chrysoptera*) range are shifting northeastward, abundance is decreasing within the breeding range, (Confer and Larkin, 1998) and the total area of the geographic range is shrinking (Gill, 1980; Will, 1986; Brewer, 1991). Blue-winged Warbler (*V. pinus*) abundance is declining, although not quite as sharply, and its breeding range is expanding as it spreads northeastward (Short, 1962; Gill and Murray, 1972; Confer and Knapp, 1979). For the Golden-winged

Warbler and the Blue-winged Warbler, the cause of their northeastward shifts could be one or a combination of the following: changes in landscape structure and composition of breeding range, Golden-winged Warbler competition with the potentially dominant Blue-winged Warbler for resources, or climate change.

If loss of suitable landscape composition and/or landscape structure is the reason Golden-winged and Blue-winged Warblers are shifting north and becoming locally extinct at the southern edges of the breeding range, what is happening at local and broad-scale levels at those edges? Populations at the edges of the range may be especially affected by human alteration of landscapes if they have already been reduced to low numbers by previous environmental changes (Maurer and Taper, 2002). Loss of habitat due to human alteration may be one of the main causes for overall population decline and potentially for range shift. Therefore we need to consider the way in which species react to their environment where increased human influence is present.

Population dynamics within a species geographic range are complex. Species are not evenly distributed within their range. Rather, population abundance follows a spatial pattern determined by availability of suitable habitat within a range (Brown, 1984; Hengeveld, 1990; Maurer and Taper, 2002). Patches of high species abundance exist where resources are most favorable and tend to be positioned toward the central part of the range, with other localized patches of suitable habitat radiating around and away from the central region until abundance declines to zero toward the edges of the range (Maurer and Taper, 2002; Brown et al., 1995; Maurer and Villard, 1994; Lawton, 1993). As increased anthropogenic disturbance affects the southern edges of the range boundaries, species may tend to move northward into habitats that have not been as disturbed. These northern landscapes may have slightly different habitat compositions, making large-scale conservation efforts for the species difficult. Are individuals of each species choosing these new areas because they prefer the habitat within the landscape(s), or are these new areas of their ranges "second choice" because they have been pushed out of previous areas of their range due to anthropogenic influences or competition?

Global climate change may be playing a role in these shifts (Root *et al.*, 2003). Global average temperatures have increased by approximately 0.6° C in the past decade and already many birds and mammals have responded by changing their movement patterns (Root *et al.*, 2003, Parmesan *et al.*, 2003). Paired with other ecological stressors, the increased, rapid warming trend could completely change bird community dynamics over time. However, this issue is not the focus of this study. Rather, examining how landscapes have changed and consequently, how the species' presence and absence have changed within the landscape, is the focus at hand.

This said, studying areas and patterns of local abundance and local extinction allows us to better understand how landscape structure and composition affect species habitat selection and movement patterns. Proactively monitoring and correlating changes in habitat with species abundance over time is an effective way to estimate the future distribution of a species and in which geographic areas conservation efforts should be focused.

The objective of this research is to compare changes in landscapes over time where Golden-winged and Blue-winged Warblers are present and absent. To do this, landscape structure and composition of BBS routes in the lower peninsula of Michigan that were inhabited by these warblers during 1978, 1993, and 2000 were examined and compared to similar BBS routes in all years that were not used by the species.

METHODS

To identify landscapes used by Golden-winged and Blue-winged Warblers in 1978, 1993, and 2000, standardized surveys conducted in each year were used. North American Breeding Bird Surveys (BBS) are conducted during the peak of the nesting season, primarily in June in Michigan. Each route is 39.4 km (24.5 miles) long, with 50 stops located at 0.8 km (0.5 mile) intervals along the route. A three-minute point count is conducted at each stop, during which the observer records all birds heard or seen within a 0.4 km (0.25 mile) radius of the stop (USGS Patuxent Wildlife Research Center, http://monitoring2.er.usgs.gov/bbs/).

Michigan BBS route data for 46 active routes in the lower peninsula were hand-digitized by the Kalamazoo Nature Center research department using GPS points taken at each stop by the individuals that survey these routes (Fig 1.a.). Michigan was in the process of digitizing their BBS routes at the start of this research. At that time, 46 out of the 57 routes in the lower peninsula were completed, therefore setting the number of routes I was able to use. Changes in landscape composition and structure were analyzed along these 46 routes using a classified land cover data source for each year: 1978, 1993, and 2000. To assess change in land cover over time, classified images for 1978 were compared to 1993 in the northern lower peninsula, and for 1978 and 2000 in the southern lower peninsula. I calculated land cover change in the northern lower peninsula using 19 routes and in the southern lower peninsula using 27 routes. The decision to use two different land cover classifications from two different years for the second time period was brought about by the lack of a single, current, classified coverage of the entire state.

Michigan Resource Information System (MIRIS) images provided classified land cover data for 1978. Coverages were derived by county from 1:24,000 scale color-infrared and black-and-white aerial photographs and used to identify 52 land cover classes (MIRIS, http://www.ciesin.org/datasets/mirisbase/mirisbase-home.html).

Classified land cover data for the northern lower peninsula in 1993 and the southern lower peninsula in 2000 were obtained from the Michigan Department of Natural Resources (MDNR) and were developed for the Michigan Gap Analysis Project (http://www.dnr.state.mi.us/spatialdatalibrary/metadata/2000_slp_landcover.htm; http://www.dnr.state.mi.us/spatialdatalibrary/metadata/lu1993_nlp_mgr.htm). Land cover for both 1993 and 2000 were derived from classification of Landsat Thematic Mapper imagery and used to identify 32 land cover classes for 1993 and 30 classes for 2000. Data for these two years are in the Michigan Georef coordinate system with a 30-meter resolution.

Since the original classifications for 1978, 1993, and 2000 coverages were each categorized differently and each had a different number of classes, land cover classification systems for each coverage were matched to MDNR "Current Use Inventory Classification System Definitions" standards so that land cover change could be uniformly assessed between years (Michigan Department of Natural Resources, 1981; http://www.crs.msu.edu/pdf/lclu/CUI.pdf). Matching classifications produced 20 common, aggregated land cover classes that were used for all years to note correlated landscape composition and structure trends in the data and to recognize which cover classes were pertinent to focus on for this study (Table 1). These 20 classes were further aggregated to 12 classes, increasing the integrity of the data by merging similar classes that had less data to those with sufficient data (Table 1). These classes were used for all statistical analysis of landscape composition and structure variables. A variable measuring diversity, or heterogeneity, of land cover types along BBS routes was calculated using a Shannon-Weaver Index (Zar, 1996) with all 20 cover classes.

Using GIS, a 400-meter "buffer" was placed around each of the BBS routes (200 meters on each side of the route, ends of routes rounded). This buffer distance signified the detectable range of birds from a BBS route. A distance of 400m is recommended by the Golden-winged Warbler Atlas Project (which also studies Blue-winged Warblers) for use in point count surveys designed to detect these species (S. Barker, Golden-winged Warbler Project Coordinator, pers. comm.). The buffer was used to clip out land cover around BBS routes from classified coverages. Within each clip, I calculated the total area and perimeter of each land cover class polygon. I dissolved common land cover class boundaries so that a single, total area could be calculated for adjacent polygons of the same cover class, for each cover class. Polygon areas and perimeters for each land cover class were summed for each clipped BBS route for each time period.

For each landscape variable, two measurements were taken: landscape composition (total area) and landscape structure (area-perimeter ratios). Landscape composition refers to the different cover classes that make up the landscape. Landscape structure is defined as the spatial configuration of land cover classes (i.e., size and shape of cover class patches in relationship to each other on the landscape). Cover class refers to the classification given to a particular land cover type; the land cover as interpreted by a photo-interpreter. Land cover refers to what is interpreted to be on the ground, not necessarily what the land is *used* for (by humans). Landscape composition was assessed for the area of each land cover class around each BBS route per year using 1978, 1993, and 2000 classified coverages. Landscape structure was assessed for each land cover class in each time period by calculating the ratio of area to perimeter for every polygon of each land cover class along a BBS route. When a cover class was not found along a route, its area was entered as zero for that route, therefore making the area to perimeter ratio equal to zero. I chose only non-zero area-perimeter ratios to use for structural variable analysis. A high area to perimeter ratio for agricultural land would indicate large, continuous tracts of agriculture around a route. A small area to perimeter ratio would indicate smaller, more fragmented patches of agriculture around a route. An additional landscape structure class, heterogeneity, was added to note diversity of land cover along routes and used to see how it was associated with routes where species were present and where they were absent.

STATISTICAL ANALYSIS

In addition to the univariate analysis described in the previous section, changes in the landscape were also measured using multivariate analysis. Principal component analysis (PCA) summarizes covariation among multiple variables (composition and structure) so that patterns of covariation can be seen in the grouped land cover types that are associated with the resulting principal components. Principal components analysis gave a summary of the variance associated with landscape variables across BBS routes, whereas correlations may have gone unseen using only univariate analysis. Instead of basing conclusions on responses of single variables, PCA allows shows many factors responding to a combination of landscape composition and structure variables. It ranks variables on a gradient of positive to negative scores so that response can be viewed in an ordered, landscape context and more complete conclusions may be drawn.

Principal components analysis was run for all 12 landscape composition variables to look for variance among habitat classes on routes where Golden-winged and Blue-winged Warblers were present and where they were absent in 1978 and 1993 or 2000. Each land cover type was scored and "ranked" along the positive to negative gradient. For example, if a land cover class was positively associated with routes where species were present, it was correlated with presence when all compositional variables were analyzed for species presence-absence associations over time; that land cover class was significantly associated with routes where the species was present in 1978 and/or 1993 or 2000.

Golden-winged and Blue-winged Warblers may not only be looking for a particular habitat type while selecting a territory, they are also keying in on habitat structure. Analysis of area-perimeter ratios for each cover type in 1978 and 1993 or 2000 examined differences in patch size, or degree of fragmentation, along routes and how those differences compared to where species were present and absent. Principal components analysis was calculated for all non-zero habitat structure variables and heterogeneity to examine how the variance between area-perimeter ratios for land cover classes, or the degree of fragmentation for all land cover types, differed along routes between 1978 and 1993/2000 and where species were present and absent.

To see how both landscape composition and structure differed along routes over time and how it affected where species were present and absent, the 12 composition classes, five landscape structure variables that had non-zero area values, and heterogeneity were analyzed together using PCA.

Analysis of variance (ANOVA) was performed on all univariate and multivariate landscape variables. This test measured the relationships between all variables and the two factors, year (1978 and 1993/2000) and species presence-absence (Golden-winged and Blue-winged Warbler). This test was used to identify significant ($p<0.05$) interactions or main effects between a landscape variable and one or both factors. Significant univariate results were used to add support to significant findings in multivariate relationships.

Analysis of variance was run separately for the first eight of 12 principal components for the 12 composition variables, on the 5 landscape structure variables and heterogeneity, and for the first eight of 12 combined composition and structure variables. Results provided information on the statistical significance of each principal component and therefore the "ranking" of land cover composition and structure variables associated with routes where species were present and absent. Significant components were used to make conclusions about how land cover around BBS routes differed over time and where Golden-winged Warblers were present and absent.

For example, when a particular principal component for landscape structure variables showed a statistically significant interaction between year and species presence, it was implied that land cover on routes where the species was present was significantly different for the two years and that therefore the structure of the land cover classes positively associated with the component may have had a significant effect on the presence of the species.

In 1978, Golden-winged Warblers were observed on BBS routes throughout the state, although they were absent on many of the southern lower peninsula routes (Fig. 1.b.). In 1993, Golden-winged Warblers were seen only in the northern lower peninsula and not at all on southern lower peninsula routes, indicating a northward shift. Therefore a land cover comparison for in the northern lower peninsula was made between routes in 1978 and 1993 (Fig. 1.b). Blue-winged Warblers were recorded on BBS routes throughout the state in 1978, 1993, and in 2000. Although a northward shift in their occurrence can be seen (Fig 1.c). Land cover comparison for Blue-winged Warblers was made between 1978 and 1993 in the northern lower peninsula and between 1978 and 2000 for the southern lower peninsula.

Analyses were done in SAS (SAS Institute Inc., 1999). Mean total area and perimeter of each landscape composition and structure class was calculated separately for all BBS routes across years.

RESULTS

Differences among routes with and without Golden-winged Warblers

There was a significant interaction between year (1978, 1993) and Golden-winged Warbler for compositional land cover variables along routes associated with principal component 1 (Fig. 2). Noting the gradient of association on the y-axis and the compositional land cover variables associated with it, routes with agriculture, open land, and urban land covers were associated with absence of Golden-winged Warblers in 1978. Routes with water and deciduous and coniferous forests were associated with presence in 1978. Note absence was associated with human-influenced land cover and presence was associated with more “natural” land cover we would expect to find Golden-winged

Warblers near. In 1993, routes where Golden-winged Warblers were present and absent converged on the gradient; there were not distinguishable differences along the gradient among land cover classes on routes where species were present and absent. Golden-winged Warblers were just as likely to be on a route with agriculture, open land, and urban land cover classes as on routes with more water, deciduous forest and coniferous forest, suggesting that the landscape became more homogeneous over time. Data suggest that in 1993 Golden-winged Warblers were present in landscapes with more agriculture *or* open land *or* urban land cover and also on routes with less water, deciduous forest, and coniferous forest. It is not possible to tell which land cover types are most "important" to Golden-winged Warblers from this graph.

Total mean agricultural land cover on routes showed a significant main effect for Golden-winged Warbler presence absence (Fig. 3). This graph indicates that Golden-winged Warblers were not responding positively agricultural cover, with regard to the convergence in figure 2. Golden-winged Warblers were found on routes with low areas of agriculture regardless of year. There was a slight increase in presence, but it was not significant. Therefore, because increased presence on routes in 1993 was likely not due to agriculture cover, presence must have had more to do with the context of open land and/or urban land cover classes were associated with on routes from 1978 to 1993.

Significant landscape structure variables for principal component 3 were different on routes where Golden-winged Warblers were present and where they were absent (Fig. 4). There was a significant main effect for Golden-winged Warbler presence-absence, indicating only that there was a difference between GW presence and absence. Golden-winged Warblers were found in landscapes with high area-perimeter ratios for agriculture and deciduous forest and absent on routes with high area-perimeter ratios for shrub and herbaceous covers. This suggests that they were present on routes with agriculture and deciduous forest cover classes, but only if they were fragmented.

Landscape composition and structure associated with principal component 1 had a significant interaction for Golden-winged Warbler presence and year (1978-1993)(Fig. 5). Agriculture composition as well as the area-perimeter ratios for agriculture, shrub and herbaceous cover were high where on routes where Golden-winged Warblers were absent in 1978. Coniferous and deciduous forest composition, nonforested wetland composition, and heterogeneity classes had low principal component scores and were associated with routes where Golden-winged Warblers were present in 1978. In 1993, there was a convergence in composition and structure variables on routes where Golden-winged Warblers were present and absent. Routes where Golden-winged Warblers were present in 1993 had more heterogeneity associated with them than they did in 1978. This may suggest that Golden-winged Warblers are choosing more heterogeneous landscapes.

In 1978, there was a distinct difference in presence-absence. In 1993, there was a convergence toward more complex landscapes with less overall agriculture. Because heterogeneity was the most heavily weighted variable in the PCA, this suggests that Golden-winged Warblers were present in more complex landscapes in 1993 than in 1978. However, Golden-winged Warblers were also absent in those same landscapes, but likely for different reasons. Note that there was a bigger change in absence from 1978 to1993 than in presence. The convergence in landscapes indicate that Golden-winged Warblers were associated with low agriculture landscapes, but other human-related components in the landscape may be part of the reason Golden-winged Warblers were choosing the routes too. Agricultural land cover within the landscape may be undergoing increased change due to other human-influenced uses (i.e. urban and open land increase).

In 1978, Golden-winged Warblers were present on routes in both the southern and northern lower peninsula (Fig. 1.b). In 1993, they were only present in the northern lower, but recorded throughout the northern region. However, in 2000, only one northern route among the routes I sampled had Golden-winged Warblers present on it. My results show that routes where Golden-winged Warblers were present consistently had little agricultural land cover associated with them. When agriculture was present, it was often highly fragmented. Routes in 1978 were less fragmented overall, and had more "natural" cover classes associated with them.

Differences among routes with and without Blue-winged Warblers

There was a significant main effect for Blue-winged Warbler presence-absence on routes with herbaceous land cover (Fig 6). Blue-winged Warblers were absent on routes with large areas of herbaceous cover and present on routes with smaller areas of herbaceous cover. The opposite would be expected since Blue-winged Warblers are thought to use early successional classes like this one.

There was a significant interaction between year (1978 and 1993) and Blue-winged Warbler presence-absence shown by principal component 2 for landscape composition variables (Fig. 7). Routes that were positively associated with herbaceous, urban, and nonforested wetland cover classes had Blue-winged Warblers on them in 1978. Routes that had scrub-shrub wetland, deciduous forest, and agricultural land cover had few Blue-winged Warblers present on them in 1978. Note that in 1993, Blue-winged Warblers were present in landscapes that contained agriculture and absent on routes that did not.

A significant interaction for year (1978, 2000) and Blue-winged Warbler presence-absence on southern routes, (principal component 7, Fig. 8) showed some land cover classes that were associated with presence on northern routes in 1978 (Fig.7) to be associated with absence on southern routes in 1978. In both 1993 (north, Fig. 7) and 2000 (south, Fig. 8), there was a change on routes that Blue-winged Warbler presence and absence were associated with. Blue-winged Warbler presence was associated with agriculture in the south in 2000. However, it was associated with urban land cover as well. In the north, presence was also associated with agriculture. This indicates that Blue-winged Warblers did not seem to be as disturbed by human- influenced landscapes as Golden-winged Warblers were. Landscapes seemed to be changing away from what Golden-winged Warbler presence was associated with, but Blue-winged Warblers did not seem to be affected in the same way by landscape changes.

When only looking at significant main effects for year, changes in land cover between 1978 and 1993 or 2000 showed the most change on routes where Blue-winged Warblers were present. Increases in urban landscapes and decreases in agricultural land in the southern lower peninsula seem to have been the biggest changes on these routes.

DISCUSSION

This study shows that landscape characteristics associated with the presence and absence of Golden-winged and Blue-winged Warblers were different in1978 and 1993 in the northern lower peninsula BBS routes and in 1978 and 2000 in the southern lower peninsula BBS routes.

Routes in the southern lower peninsula showed increased presence of Blue-winged Warblers from 1978 to 1993 (Fig 1.c). By 2000 however, it appears that Blue-winged

Warblers had pushed northward slightly. The possibility that competition for territories or mates with Golden-winged Warblers has caused Golden-winged Warblers to move north is supported by the fact that in 2000 no Golden-winged Warblers were recorded on BBS routes in the southern lower peninsula and only one route in the north had a Golden-winged Warbler recorded on it. Routes in the southern lower peninsula are more heavily-dominated by human-influenced land cover classes than in the northern regions. Golden-winged Warblers may be retreating northward to find these more secluded and less fragmented landscapes. Blue-winged Warblers may be benefiting from Golden-winged Warblers deserting the southern edges of their range, and thus moving northward as well, retracting the southern edges of their ranges too. These ideas give support to a human-driven cause for northward range shift. It could also be true that Blue-winged Warblers are out-competing Golden-winged Warblers for resources and pushing them northward. Regardless, data from these routes, which may not be a complete representative sample of the Michigan landscape, but is a good "first look", suggest that both species are moving northward.

With increased human-influenced land cover classes associated with absence of Golden-winged Warblers, the idea that human alteration of landscapes in Michigan are at least partially to blame for the decline of the species and the northward breeding range shift toward more ideal land cover within landscapes is supported. Those landscapes associated with Golden-winged Warbler presence have declined in the southern lower peninsula from 1978 to 2000. This would help to explain a northward shifting of the southern boundaries of the range. It is possible that these landscape changes could be enhancing the ability for Blue-winged Warblers to move into northern areas. This in turn could be increasing the opportunity for competition with the Golden-winged Warbler.

I previously stated that the Blue-winged Warbler was decreasing 4.4% within the southern portion of its breeding range. Note that this statement is not necessarily indicative of the entire breeding range. Populations in the southern portion of the range may be declining, but if the range as a whole is indeed shifting northward, populations in the northern portions of the range may be increasing. However, data to show this is not available at this time. Michigan is within the central to northern portion of the Blue-winged Warbler range. Populations may be, or may be becoming, larger here than we realize. Consider too, that Michigan is within the central to southern portion of the Golden-winged Warbler range, therefore it would make sense that populations are smaller and may continue to get smaller if Michigan doesn't have the quality of habitat that northern regions may have. Golden-winged Warblers may be moving northward in search of better quality habitat or it may be getting "pushed" northward by the Blue-winged Warbler

Landscapes associated with Golden-winged Warbler presence in 1978 were more indicative of landscapes one would expect to find them in than they were in 1993. This suggests a degradation of landscape quality for the species over time. Although these species may prefer cover types that indeed are present in the landscape in any given year, the proximity to and context of the ideal cover types must be in "natural" mosaics for the birds to find them favorable.

Factors such as the presence of Blue-winged Warblers, predation, and Brown-headed Cowbird (*Molothrus ater*) parasitism are natural factors associated with Golden-winged

Warbler decline (Confer, 1992). These factors may be exacerbated in landscapes subjected to increased human-alteration. Understanding the human-induced factors that contribute to decline, such as habitat alteration and loss of landscape diversity, may allow for more ecologically informed decisions in developing urban and suburban landscapes. The more we knowledge we have on a local and state-wide levels, the more it can be applied to the large scale picture of what is happening with these birds. Management agencies need to be aware of the population dynamics and what may be causing decline and range shift so that they can prepare management plans with this information in mind. Global warming threatens to be a contributing factor to many changes in population dynamics. Continued rates of consumption of ozone-depleting substances by our increasing population will likely continue this warming trend. The consequences on population dynamics, such as northward range shift, will heighten and make conservation of important landscapes harder to predict as we become more unsure of species response to changing plant and animal communities.

Land cover characteristics on routes where Golden-winged Warblers were present and absent showed significant changes from 1978 to 1993 and 2000. Generally these changes indicated that the large differences between where they were present and where they were absent in 1978 had disappeared in 1993 or 2000; the routes with land cover composition and structure their presence was associated with were just as likely to be associated with their absence over time.

The landscapes occupied by Golden-winged Warblers in 1978 were much more indicative of the "natural" landscapes we tend to associate them with than were the landscapes occupied in 1993. This indicates that the quality of Michigan landscapes has deteriorated for Golden-winged Warblers over time. However, Blue-winged Warblers don't seem to be as negatively affected by these changes as Golden-winged Warblers.

Future Research

Land cover changes along BBS routes analyzed in this study have provided a picture of landscape change patterns on only a small portion of these species' ranges in Michigan. Additional contemporary data on the distribution of these species in Michigan, as well as historic and current land cover data, are needed for a more thorough analysis of effects of land cover change over time on patterns of Golden-winged and Blue-winged Warbler distribution.

To supplement the spatial limitations of using BBS routes located along secondary roads, as this is likely not the best place to survey for Golden-winged and Blue-winged Warbler populations, it would be useful to have supplementary land cover data from "control routes" in other parts of the state to be able to truly assess land cover change in Michigan. The "control routes" would be the same geographic distance (25 miles) as BBS routes, with random turns (i.e not straight lines) and would be located in randomly selected geographic areas for example. Selecting areas that are not along secondary roads may give a more diverse and realistic representation of Michigan land cover and thus Michigan land cover change.

Each year, more Golden-winged Warblers are observed in the upper peninsula of Michigan. Including BBS routes in the upper peninsula and/or other supplementary data on these species would add greater understanding to both land cover change in Michigan as well as Golden-winged and Blue-winged Warbler population dynamics.

A new state-wide land cover classification has been released by the MDNR (April, 2003). Classification of raw Landsat satellite imagery, or other finer-scaled types of imagery, are other options that could be accessed for additional land cover information. Both of these options will provide further opportunity to more uniformly assess land cover change from 1978 to the present.

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Table 1. Landscape Composition and Structure Classes.

Original (19 + heterogeneity) and aggregated (12 + heterogeneity) land cover class descriptions for 1978, 1993, and 2000 images using MIRIS codes. Classes used to analyze structure and composition of the landscape associated with differences in Golden-winged and Blue-winged Warbler presence-absence.

TABLES

Table 1. Landscape Composition and Structure Classes.
Original (19 + heterogeneity) and aggregated (12 + heterogeneity) land cover class descriptions for 1978, 1993, and 2000 images using MIRIS codes. Classes used to analyze structure and composition of the landscape associated with differences in Golden-winged and Blue-winged Warbler presence-absence.

MIRIS Code	Class Label	Aggregated Class
1100	Urban (residential)	1100
1200	Commercial, service, industrial, transportation, institutional	1100
1700	Extractive (mining, quarry)	1100
1900	Open land, outdoor recreation, parks, cemeteries	1900
2100	Agriculture (cropland, confined feeding, permanent pasture)	2100
2200	Vineyard, orchard ornamental	2100
3100	Herbaceous cover	3100
3200	Shrub cover	3200
4110	Northern hardwoods	4110
4120	Dominant oak/hickory	4110
4130	Dominant aspen, white birch and associates	4110
4140	Lowland hardwoods (ash, elm, soft maple, cottonwood, balm-of-Gilead, aspen, birch)	4110
4210	Pine (white, red, jack, scotch, white spruce, black spruce, balsam fir, Douglas fir, larch, hemlock, managed Christmas tree plantations (scotch, Douglas fir, blue spruce, white pine)	4210
4230	Lowland conifers (cedar, black spruce, tamarack, balsam fir-white spruce, balsam fir, jack pine)	4210
5000	Water (stream, lake, reservoir, Great Lakes)	5000
6110	Wooded wetlands	6110
6120	Scrub, shrub wetland	6120
6220	Nonforested wetland (aquatic bed, emergent, mud flats)	6220
7000	Barren (beach, riverbank, sand dune, exposed rock)	7000

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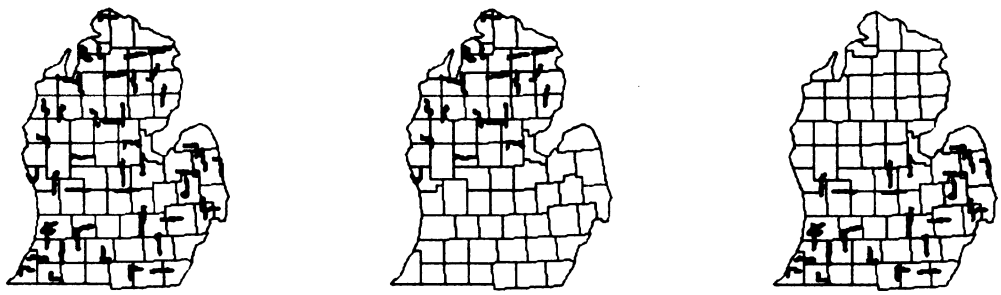
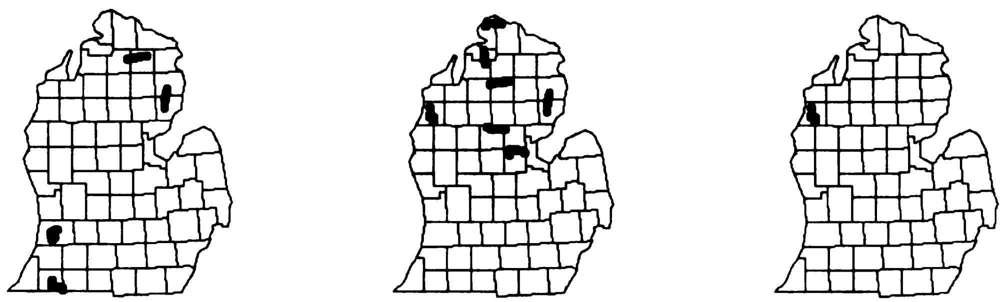
Figure 8. Landscape composition and structure variables. Significant interaction between year and Blue-winged Warbler: 1978-2000 (F=4.63, df_1= 1, df_2=36, p=0.0382)

FIGURES



1.a 1978 Routes 1993 NLP Routes 2000 SLP routes



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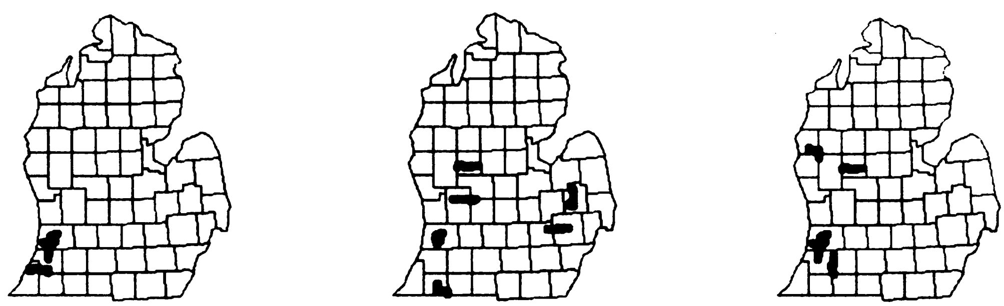

1.c 1978 BW present 1993 BW present 2000 BW present

Figure 1. Routes with and without Golden-winged and Blue-winged Warblers
1.a. BBS routes surveyed in 1978, 1993, and 2000.
1.b. Golden-Winged Warblers were present in the northern- and southern lower peninsulas in 1978, recorded on some routes in the northern lower peninsula in 1993, and not found on any southern lower peninsula routes in 2000. Land cover change was assessed between 1978 and 1993 on routes in the northern lower peninsula where Golden-winged Warblers were present and absent.
1.c. Blue-winged Warblers present on routes for 1978, 1993, and 2000. Land cover was analyzed between routes for 1978 and 1993 on routes in the northern lower peninsula where Blue-winged Warblers were present and absent and around routes for 1978 and 2000 for the southern lower peninsula where Blue-winged Warblers were present and absent.

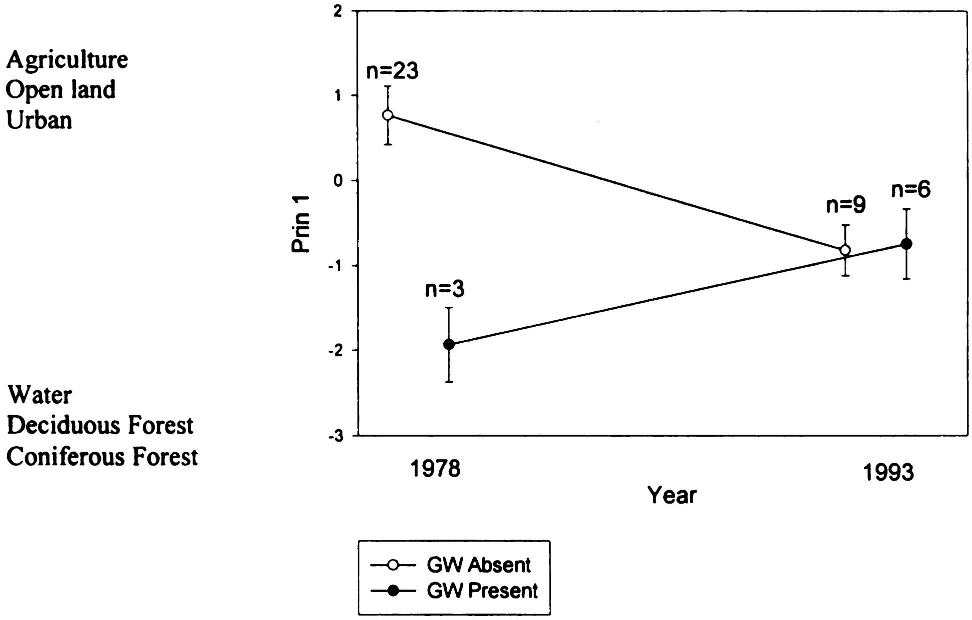

Figure 2. Landscape composition variables: Golden-winged Warbler. Significant interaction between year and Golden-winged Warbler occurrence: 1978-1993 (F=6.00, df_1=1, df_2=37, p=0.0192). Sample sizes (number of routes sampled) are shown for each year for all graphs.

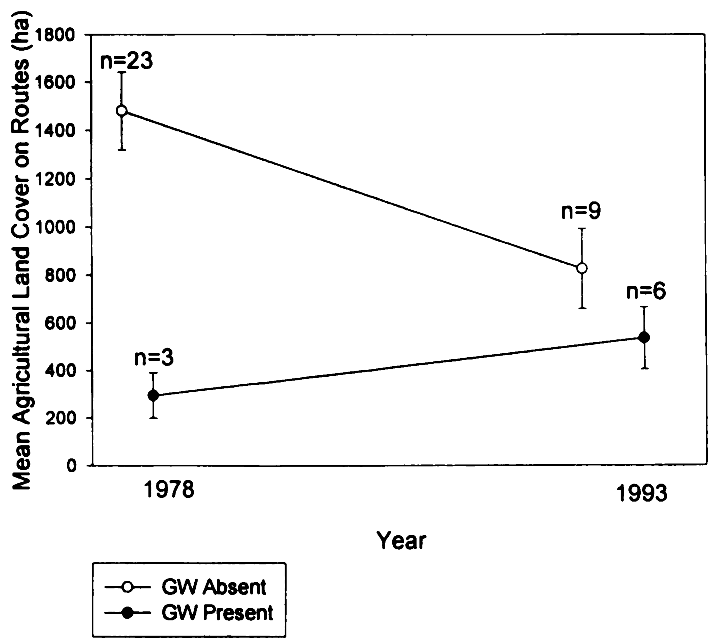

Figure 3. Univariate landscape composition variables. Significant main effect for Golden-winged Warbler: 1978-1993 (F=7.52, df_1=1, df_2=38, p=0.009).

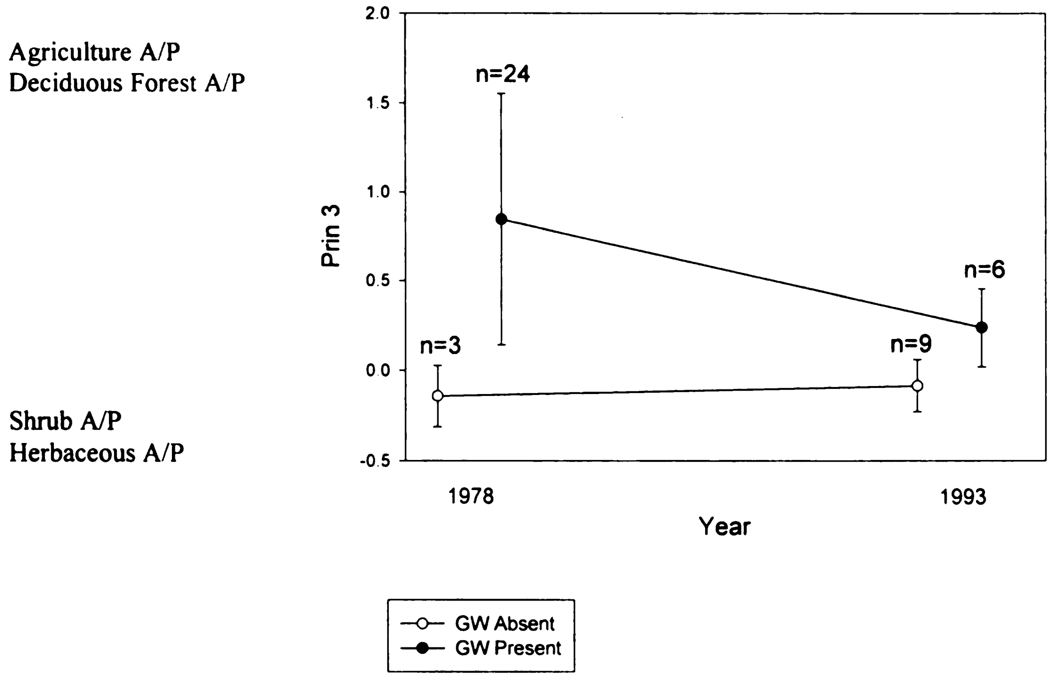

Figure 4. Landscape structure variables. Note significant main effect for Golden-winged Warbler: 1978-1993 (F=4.60, df_1=1, df_2=36, p=0.0387)

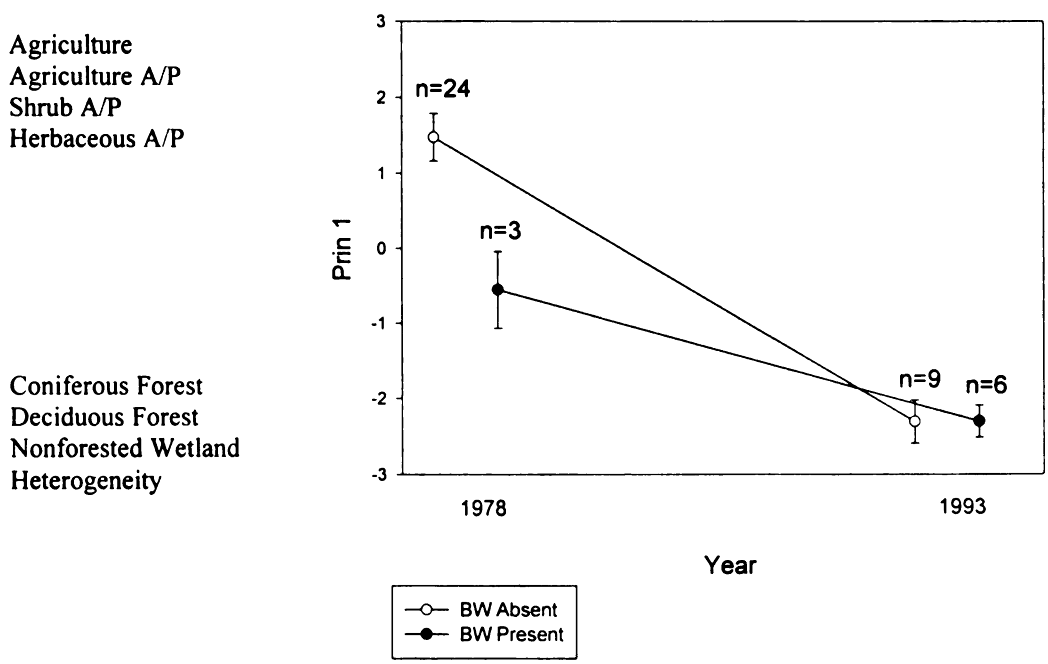

Figure 5. Landscape composition and structure variables. Note significant interaction between Golden-winged Warbler and year: 1978-1993 (F=6.0, df_1=1, df_2=37, p=0.0192)

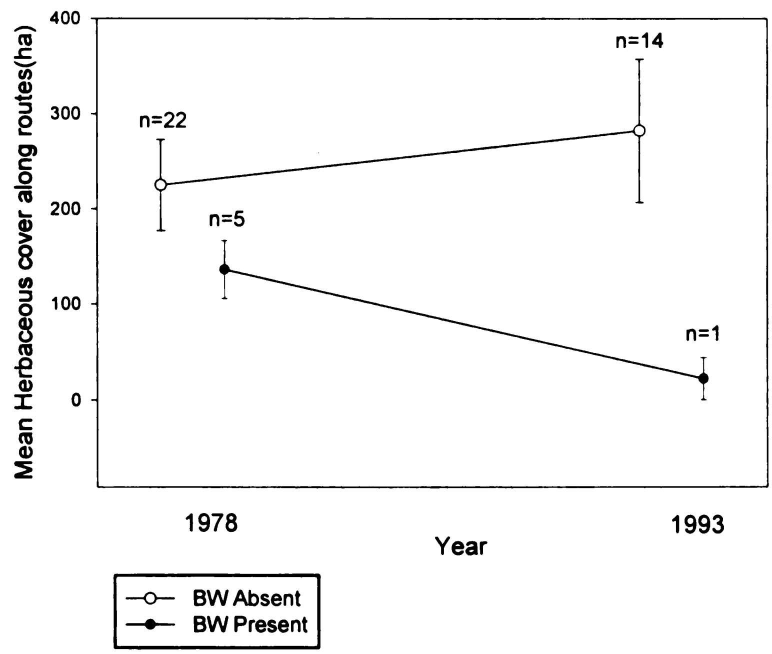

Figure 6. Herbaceous landscape composition. Significant main effect for Blue-winged Warbler: 1978-1993 (F= 5.02, df_1=1, $df2$=38, p=0.0310)

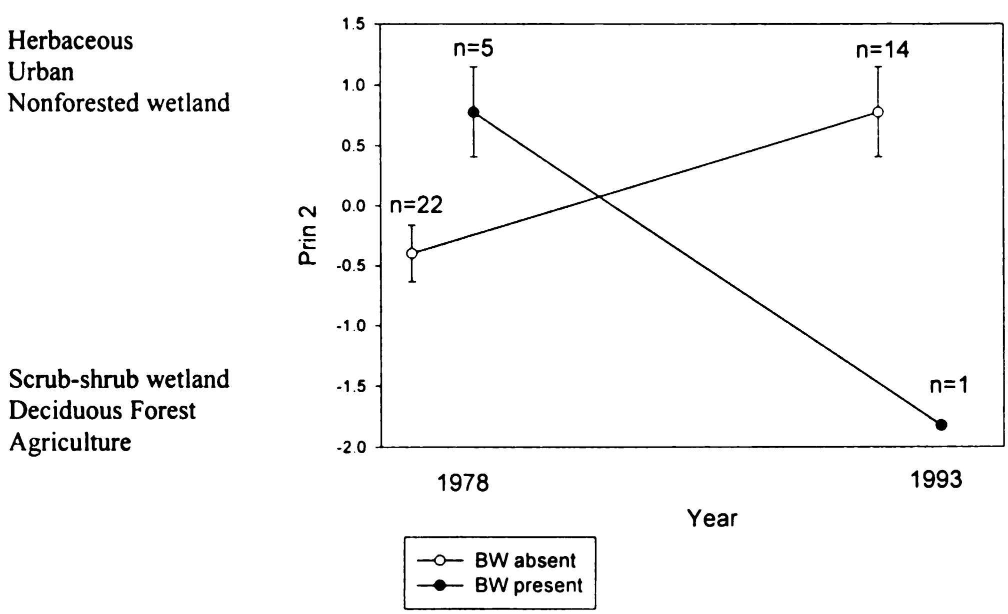

Figure 7. Landscape composition variables: Blue-winged Warbler. Significant interaction between year and Blue-winged Warbler: 1978-1993 (F= 4.63, df_1=1, df_2=36, p= 0.0382)

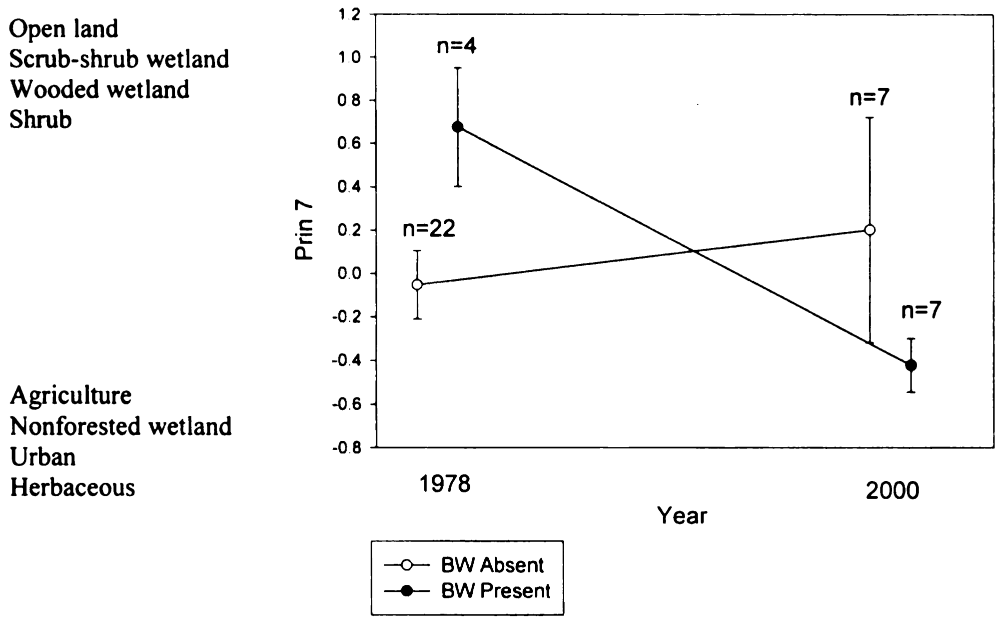

Figure 8. Landscape composition and structure variables. Significant interaction between year and Blue-winged Warbler: 1978-2000 (F=4.63, df_1= 1, df_2=36, p=0.0382)

APPENDIX A

APPENDIX A. PCA eigenvector values for significant results

Figure 5. PC 1	
Landscape Structure and Composition Variables	**Eigenvector Value**
Heterogeneity	-0.458
Urban	0.012
Openland	0.160
Agriculture	0.373
Herbaceous	-0.087
Shrub	0.121
Deciduous	-0.237
Coniferous forest	-0.319
Water	-0.126
Wooded wetland	0.146
Scrub-shrub wetland	-0.032
Nonforested wetland	-0.146
Urban AP	0.297
Agriculture AP	0.401
Deciduous AP	0.162
Herbaceous AP	0.302
Shrub AP	0.330

Figure 7: PC 2	
Landscape Composition	**Eigenvector Value**
Urban	0.471
Open land	0.151
Agriculture	-0.291
Herbaceous	0.048
Shrub	0.089
Deciduous forest	-0.058
Coniferous forest	0.181
Water	0.059
Wooded wetland	0.191
Scrub-shrub wetland	0.025
Nonforested wetland	0.450
Barren	0.391

Figure 2: PC 1	
Landscape Composition Variable	**Eigenvector Value**
Urban	0.471
Open land	0.150
Agriculture	-0.291
Herbaceous	0.480
Shrub	0.089
Deciduous forest	-0.058
Coniferous forest	0.181
Water	0.059
Wooded wetland	0.191
Scrub-shrub wetland	0.025
Nonforested wetland	0.450
Barren	0.391

Figure 4: PC 4	
Landscape Structure Variables (area-perimeter ratios; AP)	**Eigenvector Value**
Heterogeneity AP	-0.197
Urban AP	0.453
Agriculture AP	0.398
Deciduous forest AP	0.428
Herbaceous AP	0.451
Shrub AP	0.460