CHAPTER FIVE

Space and Habitat Use of Breeding Golden-winged Warblers in the Central Appalachian Mountains*

Mack W. Frantz, Kyle R. Aldinger, Petra B. Wood, Joseph Duchamp, Timothy Nuttle, Andrew Vitz, and Jeffery L. Larkin

Abstract. Spot-mapping, or recording locations of observed use by territorial songbirds, is often used to delineate core breeding territories. However, a recent radiotelemetry study in Minnesota found that male Golden-winged Warblers (*Vermivora chrysoptera*) occurring in high-density populations used resources outside their spot-mapped territories. We compared differences in space use and quantified vegetation characteristics in territories and home ranges of individual male Golden-winged Warblers that we monitored using both spot-mapping and radiotelemetry. Our study sites in Pennsylvania and West Virginia had lower population density than in Minnesota. We recorded 524 telemetry locations among 12 male Golden-winged Warblers in Pennsylvania and 488 telemetry locations among seven males in West Virginia. Telemetry-delineated home ranges (100% and 50% minimum convex polygons [MCPs]) were two to four times larger than spot-mapped territories. Spot-mapped territories had minimal overlap among individual males, but home ranges had extensive space-use overlap in both the number and amount of MCP overlap among several males. Forty percent of telemetry locations were outside of spot-mapped territories. Sapling abundance was greater in home ranges (mean 22.5 saplings ± 2.1 SE) than spot-mapped territories in Pennsylvania (11.8 ± 1.9). In managed pastures of West Virginia, tree abundance was greater in home ranges (7.3 trees ± 0.8) than spot-mapped territories (1.9 ± 0.6). More telemetry locations than spot-mapped locations occurred in forest in both states, and telemetry locations were closer to intact forested edges of shrublands than spot-mapped locations in West Virginia. On several occasions, we observed radiomarked individuals >200 m (maximum of 1.5 km) from their MCP spot-mapped territory boundaries. Why Golden-winged Warblers leave their spot-mapped territories is unknown, but our observations suggest foraging, forays for extra-pair mating, and reconnaissance for postbreeding movements as possible motives. Our results from areas with low Golden-winged Warbler territory densities are similar to patterns reported for a high-density population in Minnesota. Ultimately, spot-mapping alone does not accurately reflect space use of Golden-winged Warblers during the breeding season, nor does it characterize all cover types used even in areas

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with relatively low territory densities. Current conservation plans for Golden-winged Warblers that are based on habitat characteristics measured within spot-mapped territories or at the landscape scale may not adequately incorporate space use at intermediate spatial scales of clusters of territories or home ranges.

Key Words: extra-territorial movement, foraging, radiotelemetry, spot-mapping, territory.

In the central Appalachian Mountains of Pennsylvania and West Virginia, population numbers of Golden-winged Warblers (*Vermivora chrysoptera*) have declined ~8% per year during 1966–2011 (Sauer et al. 2012), due in part to decline of shrubland cover types (Yahner 2003). Implementation of recently developed management guidelines for the creation of shrubland that supports breeding Golden-winged Warblers is a conservation priority (A. M. Roth et al., unpubl. plan). The primary foundation for these guidelines is avian and vegetation data collected at the scale of the spot-mapped territory where bird use areas are delineated by recording locations of song perches.

Breeding habitat requirements of songbirds are often studied by quantifying resource use within spot-mapped breeding territories (Confer et al. 2003, Roth and Lutz 2004, Bulluck and Buehler 2008), but recent telemetry studies suggest that individuals access important habitat components outside their defended territories (Anich et al. 2009, Streby et al. 2012). In Minnesota, at a study area with one of the highest known breeding densities of Golden-winged Warblers (~1 territory/ha), telemetry-delineated territories were three times larger than territories delineated by spot-mapping (Streby et al. 2012). Given the potential for conservation plans to be less effective if based solely on spot-mapping (Streby et al. 2012), potential differences between techniques need to be examined in other regions of the breeding distribution where territory densities are lower. Ultimately, determining the propensity for Golden-winged Warblers to use areas outside their spot-mapped breeding territories, and the characteristics of those areas, will be important for informing regional habitat management guidelines.

We used radiotelemetry and spot-mapping to examine habitat and space use of territorial male Golden-winged Warblers in the central Appalachian Mountains region of Pennsylvania and West Virginia. Unlike a recent study in Minnesota, our study occurred in areas with low nesting densities of Golden-winged Warblers (1 pair/10 ha in Pennsylvania; J. Larkin, unpubl. data; 1.4/10 ha in West Virginia; K. Aldinger, unpubl. data). By comparing areas used by Golden-winged Warblers in their home ranges to areas within spot-mapped territories, we can address whether spot-mapping is missing important aspects of Golden-winged Warbler habitat use. Our objectives were to (1) compare estimates of Golden-winged Warbler space use based on radiotelemetry versus spot-mapping, and (2) quantify vegetation characteristics of telemetry and spot-mapped-delineated areas at micro- and macrohabitat scales.

METHODS

Study Area

We conducted our study during May–July 2011 at two study areas in north-central Pennsylvania, and during May–July 2012 at two study areas in Randolph and Pocahontas counties, West Virginia. All study areas were within the Appalachian Mountains Bird Conservation Region (BCR 28). Study areas in Pennsylvania were in Bald Eagle State Park and Sproul State Forest. Bald Eagle State Park (41.033°N, 77.600°W) study sites were located at ~200 m elevation within the Ridge and Valley Province (Briggs 1999). We monitored Golden-winged Warblers at six study sites across a 219-ha portion of the park that was comprised of managed and natural shrublands, and remnant closed-canopy forest patches. Nonnative shrubs such as bush honeysuckle (*Lonicera* spp.), autumn-olive (*Elaeagnus umbellata*), and multiflora rose (*Rosa multiflora*) dominated the plant community. The most common native woody species included red osier dogwood (*Cornus sericea*), gray dogwood (*C. racemosa*), arrowwood viburnum (*Viburnum dentatum*), blackberry (*Rubus* spp.), elm (*Ulmus* spp.), black walnut (*Juglans nigra*), hawthorn (*Crataegus* spp.), and ash (*Fraxinus* spp.).

Study sites at Sproul State Forest (41.233°N, 77.700°W) were located at ~610 m in the

Appalachian Mountains High Plateau (Briggs 1999). We monitored Golden-winged Warblers at three study sites across 270 ha of a 1,619-ha area burned by an arson fire in 1990. Most forest stands in Sproul State Forest were mature (80–100 years old), closed-canopied forest that lacked the structural characteristics used by nesting Golden-winged Warblers. Rather, breeding Golden-winged Warblers in our study area were associated with disturbance-generated plant communities adjacent to older forests (80–100 years old) including areas influenced by timber harvests, wildfire, and abandoned natural gas wells (Larkin and Bakermans 2012). Shrubland cover available to breeding Golden-winged Warblers was characterized by a patchy mosaic of saplings, shrubs, herbaceous openings, and scattered trees (approx. basal area: 2.3–9.2 m^2/ha). Regenerating forests in the burned areas were dominated by a mosaic of native species including blackberry, blueberry (*Vaccinium* spp.), mountain laurel (*Kalmia latifolia*), sweet fern (*Comptonia peregrina*), hay-scented fern (*Dennstaedtia punctilobula*), sassafras (*Sassafras albidum*), birch (*Betula* spp.), black locust (*Robinia pseudoacacia*), red maple (*Acer rubrum*), and chestnut oak (*Quercus prinus*).

Study sites ($n = 6$) in Pocahontas ($n = 3$; 38.317°N, 80.083°W) and Randolph counties ($n = 3$; 38.917°N, 79.733°W), West Virginia were fenced pastures 7–179 ha and 800–1,200 m in elevation. Five sites were grazed annually by cattle and horses (0.3–1.3 animal units/ha) between 15 May and 1 October, maintaining shrubland vegetation. One site had not been grazed since 1970 (W. A. Tolin, pers. comm.). All sites were characterized by a patchy mosaic of grasses, herbaceous vegetation, blackberry, shrubs, and scattered saplings and canopy trees (>10 cm dbh) surrounded by intact forest, defined as contiguous closed canopy comprised of sawtimber (>25 cm dbh), and generally lacking the dense understory vegetation characteristic of shrubland areas. Grass cover dominated the central portions of all sites, where livestock grazing was most intense, and transitioned into shrub–scrub cover and intact forest toward the fenced perimeter. Dominant species within areas dominated by shrubland vegetation included sweet vernal grass (*Anthoxanthum odoratum*), velvet grass (*Holcus lanatus*), meadow fescue (*Festuca elatior*), goldenrod (*Solidago* spp.), common cinquefoil (*Potentilla simplex*), Virginia strawberry (*Fragaria virginiana*), devil's darning needles (*Clematis virginiana*), hawthorn (*Crataegus* spp.), autumn-olive, shrubby St. John's wort (*Hypericum prolificum*), multiflora rose, naturalized apple (*Malus* spp.), black locust, white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), and sugar maple (*Acer saccharum*).

Capture and Handling

Between 1 May and 1 July, we captured male Golden-winged Warblers using targeted mist netting with song playback and a warbler decoy (Anich et al. 2009). We fitted captured individuals with a metal U.S. Geological Survey leg band and a unique combination of 1–3 color bands for identification purposes. Additionally, we fit large-bodied males ≥10 g in Pennsylvania ($n = 12$) and ≥9 g in West Virginia ($n = 7$) with a VHF radio transmitter (BD-2N [0.43 g] or LB-2X [0.31 g], Holohil Systems Ltd., Carp, ON). We attached radio transmitters to the interscapular region with a glue-on method that required ~5 min of handling time (Frantz 2013) and allowed the transmitter to fall off during the prebasic molt and prior to migration (Pyle 1997). The transmitter units constituted <5% of a Golden-winged Warbler's mass.

Territory and Home-Range Delineation

We refer to areas that we delineated via the spot-mapping technique as *spot-mapped territories*. We refer to areas repeatedly traversed by an individual and all extra-territorial movements (Kenward 2001) detected via radiotelemetry as *home ranges*. We considered movements outside the spot-mapped territory to be extra-territorial, but we recognize that some movements outside the spot-mapped territory might have been within an individuals' true song territory (Streby et al. 2012).

We used spot-mapping to delineate territories for all radiomarked and color-banded males at our study sites for Golden-winged Warblers, Blue-winged Warblers (*V. cyanoptera*), and hybrids (referred to collectively as *Vermivora* spp.). We followed individual color-banded males every other day through visual observations of feeding, perching, and singing. Monitoring all *Vermivora* spp. allowed us to account for space use overlap with males that neighbored our radiomarked Golden-winged Warblers. Golden-winged Warblers, Blue-winged Warblers, and hybrids appeared to behaviorally treat each other as conspecifics on our study sites. All observations were marked with flagging tape and we recorded each location using Garmin eTrex and GPSMAP 60CSx global positioning system units (accurate to <5 m). We spot-mapped territories for each color-banded male during 30–60-min sampling periods between 05:00 and 19:00 Eastern Standard Time (EST; Barg et al. 2005). Like Streby et al. (2012), our methods differed from Barg et al. (2005) in that we recorded each location only once regardless of how long we observed the bird there. We recorded ≥5 spot-mapping locations per visit and we varied time of observation periods among days (mean 11.0 ± 1.0 SE days per territory, range 6–17 days).

We collected radiotelemetry data every other day to alternate with spot-mapping days for the life of each transmitter using the homing method (Mech 1983, White and Garrott 1990). We approached each radiomarked Golden-winged Warbler on foot based on radio signal strength until we observed the bird feeding, perching, or singing, but we did not approach close enough to perceptibly influence their behavior (Vitz and Rodewald 2010). If we were unable to observe a bird without influencing its behavior, we approached the perceived location from several directions to triangulate the individual's location (Anich et al. 2009). We conducted telemetry monitoring between 05:00 and 19:00 EST. We varied the order and time of day that we monitored individual radiomarked Golden-winged Warblers to prevent any time-of-day effects on activity (Shields 1977). To ensure that telemetry locations were biologically independent, we used a sampling interval long enough to allow an individual to move from any point in its territory to any other point (Lair 1987, Holzenbein and Marchinton 1992, McNay et al. 1994, Silva-Opps and Opps 2011). As such, we allowed at least 1 min (although typically 2–10 min) to elapse between consecutive locations.

Vegetation Sampling

As part of a larger study, we placed vegetation sampling points within spot-mapped territories using a standardized protocol developed by the Golden-winged Warbler Working Group (modification of protocol in appendix [AP-16] of A. M. Roth et al., unpubl. plan). The protocol was used throughout the Golden-winged Warbler breeding range for consistent habitat description (Buehler et al. 2007). Using a systematic random sampling design, we established transects through each spot-mapped territory and sampled vegetation within 1- and 5-m radius plots at ≥30 points per territory (Figure 5.1). We did not sample vegetation directly at the locations where we observed Golden-winged Warblers during spot-mapping surveys to keep protocol for the larger study. Anich et al. (2012) found that habitat features differed between used and random locations within home ranges of Swainson's Warblers (*Limnothlypis swainsonii*) and concluded that sampling at random points may not accurately describe used habitat features (Anich et al. 2012). However, sampling many random points at the small spatial scale of the spot-mapped territory best characterizes the patchy vegetation typically used by Golden-winged Warblers (Bonham 1989, Confer et al. 2003). We also sampled vegetation outside of spot-mapped territories at points where we observed Golden-winged Warblers via telemetry. We sampled habitat characteristics within home ranges at all telemetry locations ≥12 m outside the spot-mapped territory to allow a buffer between spot-mapped territories and home ranges and prevent overlap of measured areas. We did not sample vegetation at telemetry locations that overlapped with spot-mapped territories. We conducted vegetation sampling at each telemetry location within a 1-m radius plot centered at the location, four additional 1-m radius plots 5 m away from the center plot, one in each cardinal direction, and one 5-m radius plot centered at the telemetry location.

Within each 1-m radius plot, we visually estimated percent cover of vegetation (i.e., grass, forbs, ferns, and goldenrod), shrubs <1 m tall, shrubs >1 m tall, saplings (<10 cm dbh), and percent canopy cover. We visually estimated percent cover of woody ground cover, vines, bare ground, and litter in West Virginia only, and nonvegetation (bare ground and litter) in Pennsylvania. Our visual estimates should be considered indices comparing spot-mapped locations and telemetry locations. Visual estimation of vegetation cover can produce both reliable and unreliable results (Kercher et al. 2003, Helm and Mead 2004, Symstad et al. 2008), but is cost effective and valid for managers to apply across large scales (Cook et al. 2010). All visual estimates were made by a single observer in Pennsylvania, and teams were trained in West

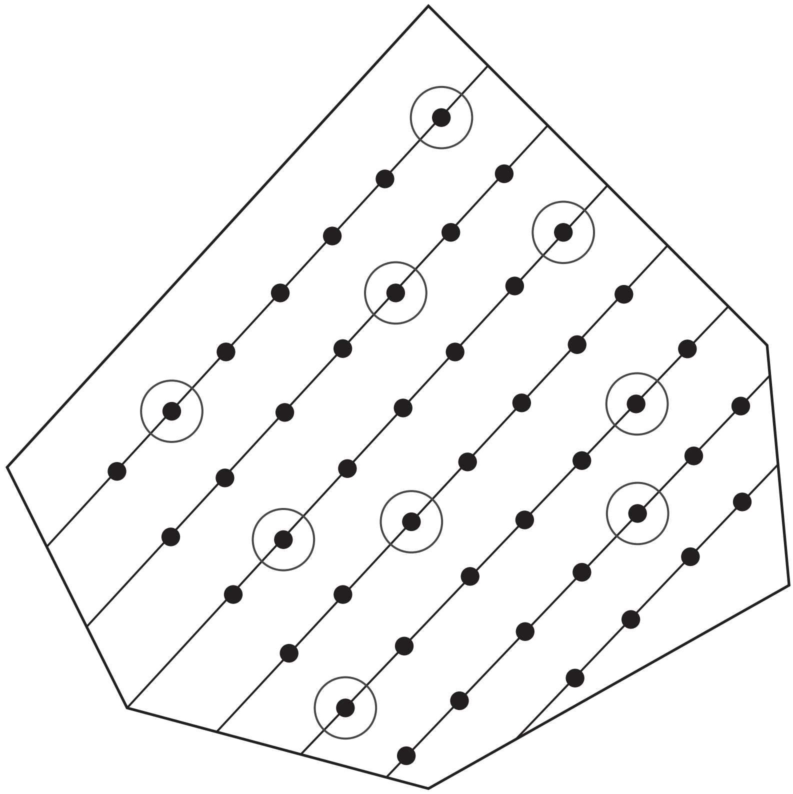

Figure 5.1. Vegetation sampling design for a hypothetical Golden-winged Warbler territory with random transects (lines) and 1-m radius vegetation sampling plots (black dots) and 5-m radius sampling plots (large circles). For each radiomarked male, we averaged habitat variables across all vegetation plots within the spot-mapped territory and across all vegetation plots at home-range telemetry locations that were outside the spot-mapped territory.

Virginia by the same observer using a standard collection protocol to limit bias in visual estimates among observers.

We measured distance from a plot center to a microedge as a change in vegetation height or composition. We also measured the number of snags within 11.3 m and live trees (>10 cm dbh) using a 2.5 m^2/ha (10 ft^2/ac) prism from each plot center. On the 5-m radius plots, we counted shrubs ≥1 m tall and saplings. We measured distance from plot center to the nearest intact forested edge as defined in the study area description using a measuring tape, rangefinder, or ArcMap Geographic Information System (GIS) (ver. 10; ESRI 2011). We defined forested edge as the edge of the forest canopy forming an interface between intact forest and nonforest (shrubland) cover types. We assigned locations of radiomarked Golden-winged Warblers within forested cover types negative distances and locations on an intact forested edge a distance of 0 m.

To examine macrohabitat characteristics, we assigned a cover type as shrubland or forest to each spot-mapped and telemetry location. We defined shrubland as nonforested, shrub–scrub cover with sparse canopy trees and with an herbaceous understory of forbs and grasses. We classified contiguous, closed-canopy areas with ≥0.25-ha of trees (>10 cm dbh) as forest. If the 0.25 ha circular buffer around a location was not completely forested and contained shrubland cover, then that location was not classified as forest.

Data Analysis

We delineated spot-mapped territories and home ranges using 100% and 50% minimum convex polygons (MCPs; see Chandler 2011) in GIS.

Although MCPs tend to overestimate home-range size (White and Garrot 1990), we used polygons to ensure maximum quantification of area needed to support male Golden-winged Warblers, to be consistent with other Golden-winged Warbler studies that have used spot-mapping and MCPs (Patton et al. 2010; Chapter 7, this volume), and to be consistent with recent radiotelemetry studies conducted on Golden-winged Warblers at other sites (Chandler 2011, Streby et al. 2012). Our spot-mapped territories may have excluded parts of the "real" territory (Streby et al. 2012) but can be considered an approximate estimate of the principal defended areas of the breeding territory used by Golden-winged Warblers (Anich et al. 2009).

We used Selected Cores Analysis in Ranges 7 (Anatrack, Wareham, UK) with the recalculated Ac (RAc) peel center method to determine which points were removed for 50% MCPs because the method reselects the area of densest locations after the farthest radio location is excluded (South et al. 2008). We tested data for normality and applied a $\log_{10}$ transformation to nonnormal data prior to analysis (Zar 2010). We used a paired t-test for normal data or an analogous nonparametric Wilcoxon Signed Rank test when the log transformation did not normalize the data to determine if there were size differences between home ranges and spot-mapped territories.

For each radio-marked male Golden-winged Warbler's spot-mapped territory and home range, we used the intersect tool in GIS to measure the amount of area overlap with all neighboring spot-mapped *Vermivora* territories (Patton et al. 2010). In addition, we counted the number of spot-mapped *Vermivora* territories that overlapped each individual's spot-mapped territory and home range. We used a nonparametric Wilcoxon Signed Rank test to compare the amount of area overlap (in ha) and number of territories that overlapped each individual's spot-mapped territory and home range.

For each radiomarked male, we averaged habitat variables across all vegetation plots within the spot-mapped territory and across all vegetation plots at home-range telemetry locations that were outside the spot-mapped territory. We tested habitat variables for normality and used an appropriate transformation prior to analysis if needed. We used a paired t-test or nonparametric Wilcoxon Signed Rank test to compare averaged habitat variable measurements between spot-mapped territories and home ranges. We used Holm's (1979) correction to control experiment-wise error rate when conducting multiple comparisons [$\alpha/(n - 1)$; $P < 0.003$]. We compared distance to intact forested edge between Golden-winged Warbler use locations in spot-mapped territories and home ranges using a paired t-test or nonparametric Wilcoxon Signed Rank test. Forest patches were smaller (typically <2 ha) and more scattered throughout the landscape at Bald Eagle State Park than at Sproul State Forest in Pennsylvania. Therefore, we conducted a Wilcoxon Signed Rank test only on individuals from our study sites on the Sproul State Forest ($n = 9$) where intact forest surrounded the shrublands and was easy to classify this cover type at a large spatial scale.

We examined macrohabitat characteristics of areas used by Golden-winged Warblers by comparing the number of locations within shrubland or forest at all spot-mapped and telemetry locations using a χ^2-test of independence. We compared only use of each cover type between the two monitoring methods and not use relative to availability (Streby et al. 2012). We used National Land Cover Dataset 2001 Percent Tree Canopy Version 1.0 to assess canopy cover within a 90 m × 90 m window around each location (Homer et al. 2004). We used Focal Statistics in GIS, ground truthing, and review of aerial (years 2011 and 2012) 1- and 0.5-m resolution photographs in ArcMap to classify all locations.

RESULTS

We recorded 524 telemetry and 439 spot-mapped locations for 12 male Golden-winged Warblers in Pennsylvania, and 488 telemetry and 616 spot-mapping locations for seven males in West Virginia. Collectively, we recorded 20–155 locations per Golden-winged Warbler (mean 53.3 ± 6.6 locations). We spot-mapped for 6–17 days (mean 11.0 ± 1.0 days) and conducted radiotelemetry for 3–13 days (mean 8.0 ± 1.0 days) for each individual. For 100% territory MCPs we used 19–49 (37 ± 3) and 33–178 (88 ± 19) spot-mapped locations per individual in Pennsylvania and West Virginia, respectively. For 100% home-range MCPs we used 20–63 (43 ± 4) and 25–155 (70 ± 16) telemetry locations per individual. Out of all telemetry locations collected, 40% of home-range locations fell outside their respective male's spot-mapped territory.

TABLE 5.1

Size comparisons of radiomarked Golden-winged Warbler spot-mapped territories and home ranges using 50% and 100% MCPs, and number and area overlap of neighboring Vermivora *spot-mapped territories that overlapped with the 100% MCP spot-mapped territories and 100% MCP home ranges of radiomarked Golden-winged Warblers in Pennsylvania (n = 12) and West Virginia (n = 7) during 2011 and 2012, respectively.*

		Radiomarked, spot-mapped territory			Radiomarked home range		
Metric	State	Mean	±SE	Range	Mean	±SE	Range
Territory size (ha):							
100% MCP	PA	1.7	0.2	0.65–3.69	6.3	1.7	1.40–19.76
	WV	2.4	0.5	0.79–4.77	11.8	6.2	2.27–47.99
50% MCP	PA	0.3	0.1	0.12–0.69	0.5	0.1	0.13–1.03
	WV	0.3	0.1	0.13–0.63	0.6	0.1	0.20–1.28
Number of neighboring spot-mapped territories overlapped	PA	0.7	0.3	0–3	2.1	0.6	0–6
	WV	1.0	0.2	0–2	2.4	1.1	0–9
Area of neighboring spot-mapped territories overlapped (ha)	PA	0.2	0.1	0.00–0.54	1.3	0.4	0.00–4.53
	WV	0.4	0.2	0.00–1.18	2.6	1.7	0.00–12.48

Spot-Mapped Territory versus Home-Range Size

Among radiomarked males, home ranges (100% MCPs) were larger than spot-mapped territories in Pennsylvania (1.40–19.76 ha; t-test: $t_{11} = 4.16$, $P = 0.002$) and West Virginia (2.27–47.99 ha; Wilcoxon Signed Rank test: $Z_7 = -2.37$, $P = 0.018$; Table 5.1). Core home ranges (50% MCP) also were larger than core spot-mapped territories (50% MCP) in Pennsylvania (0.13–1.03 ha; $t_{11} = 2.34$, $P = 0.039$) and West Virginia (0.20–1.28 ha; $t_6 = -2.75$, $P = 0.033$). Although core areas (50% MCPs) averaged two times larger when delineated by telemetry than spot-mapping (Table 5.1), a majority of telemetry and spot-mapped core areas overlapped (15 of 19 individuals; Figure 5.2).

Spot-Mapped Territory versus Home-Range Overlap

Spot-mapped territories of individual males rarely overlapped territories of neighboring males (0–3 overlapping territories, Table 5.1), but home ranges of individual males overlapped up to nine spot-mapped territories (Figure 5.3). In Pennsylvania and West Virginia, spot-mapped territories were overlapped twice as often by other home ranges than they were by other spot-mapped territories. The difference was statistically significant in Pennsylvania ($Z = -2.23$, $P = 0.026$), with a similar nonstatistically significant trend in West Virginia ($Z = -1.63$, $P = 0.102$). In terms of overlap with neighboring spot-mapped territories, home ranges of radiomarked males overlapped six times more area than spot-mapped territories of radiomarked males (Pennsylvania: $Z = -2.50$, $P = 0.013$; West Virginia: $Z = -2.20$, $P = 0.028$, Table 5.1). Most of the overlapping territories were Golden-winged Warblers (33 of 39 total overlaps), but one Blue-winged Warbler in West Virginia and five hybrids (two in West Virginia and three in Pennsylvania) were included as overlapping radiomarked individuals.

Habitat Characteristics of Spot-Mapped Territories and Home Ranges

We sampled vegetation at 163 and 126 telemetry locations that occurred outside spot-mapped territories in Pennsylvania and West Virginia, respectively. In Pennsylvania, there were fewer saplings in spot-mapped territories than home ranges ($t_{11} = -3.81$, $P = 0.003$; Table 5.2). In West Virginia, there were three times as many trees in home ranges as in spot-mapped territories ($t_6 = -5.31$, $P = 0.002$; Table 5.2). Distance to intact forested edge in West Virginia was shorter for telemetry locations (14.3 m ± 8.0) than for spot-mapped locations (44.8 m ± 6.7; $t_6 = 2.92$, $P = 0.012$). Distance to intact forested edge in Pennsylvania did not differ between telemetry locations (139.5 m ± 22.7) or spot-mapped locations (141.1 m ± 25.3; $Z = 0.059$, $P = 0.952$).

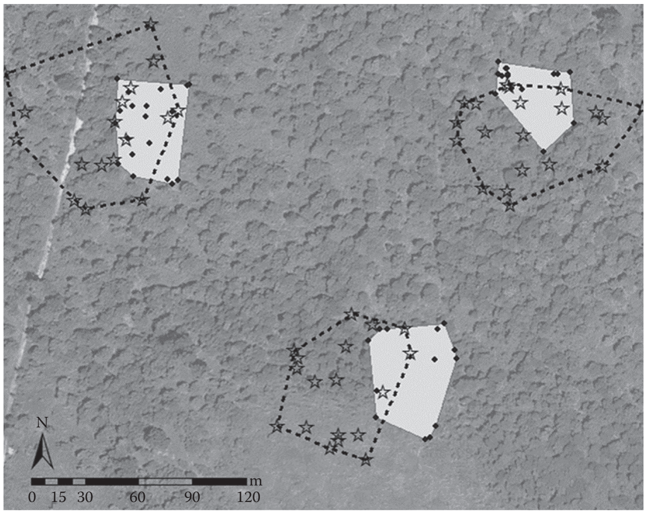

Figure 5.2. An example of overlapping spot-mapped (light gray) and telemetry-based (dashed polygon) core areas (50% MCPs) in Pennsylvania, with spot-mapped locations (circles) and home-range locations (stars) indicated. Core areas were on average two times larger when delineated by telemetry than spot mapping, and the majority of telemetry and spot-mapped core areas overlapped in Pennsylvania and West Virginia (15 of 19 individuals).

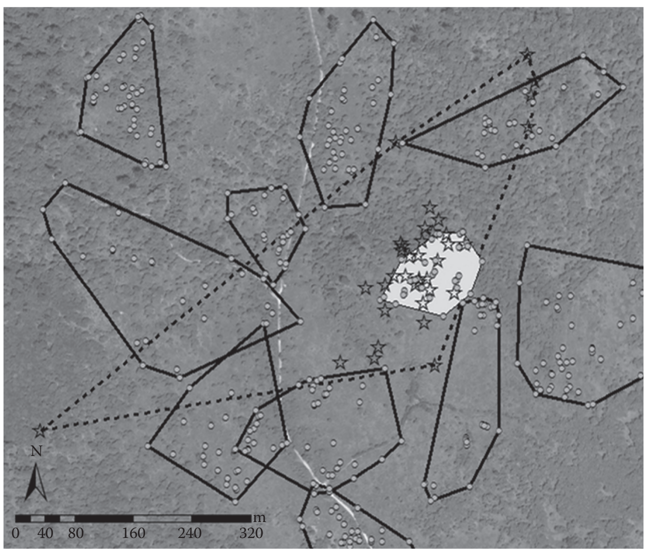

Figure 5.3. A spot-mapped territory (light gray) and home range (dashed polygon) for an individual male Golden-winged Warbler in Pennsylvania. The individual's spot-mapped territory did not overlap with other *Vermivora* spp. spot-mapped territories (hollow polygons), but his home range overlapped with portions of spot-mapped territories of six other individuals. Spot-mapped territory locations are represented as circles and home-range locations as stars.

Locations in Forest versus Shrubland Cover Types

A higher proportion of telemetry locations than spot-mapped locations occurred in forest in Pennsylvania (χ^2 = 9.36, df = 1, P = 0.002) and West Virginia (χ^2 = 9.91, df = 1, P = 0.002). In Pennsylvania, one spot-mapped location for one individual was in forest, whereas 10 telemetry locations representing four of 12 individuals were in forest. In West Virginia, two spot-mapped locations representing two of seven individuals were located in forest, whereas 12 telemetry locations

TABLE 5.2
Vegetation sampled within Golden-winged Warbler spot-mapped territories and outside territories in home ranges at study sites in Pennsylvania and West Virginia during 2011 and 2012, respectively.

	Pennsylvania				West Virginia			
	Spot-mapped territory (n = 12)		Home range (n = 12)		Spot-mapped territory (n = 7)		Home range (n = 7)	
Habitat variable	Mean	± SE	Mean	± SE	Mean	± SE	Mean	± SE
Grass (%)	5	1	4	1	29	3	21	3
Forbs (%)	7	2	2	<1	27	2	26	3
Ferns (%)	18	2	19	2	<1	<1	1	<1
Rubus spp. (%)	39	4	30	2	7	3	7	1
Goldenrod (*Solidago* spp.: %)	6	1	4	1	17	3	9	2
Woody Cover (%)	—	—	—	—	4	1	7	2
Litter (%)	—	—	—	—	10	2	20	2
Vine (%)	—	—	—	—	2	2	1	<1
Non-vegetation (Bare Ground + Litter) (%)	12	2	17	2	—	—	—	—
Bare Ground (%)	—	—	—	—	5	1	9	2
Shrub <1 m (%)	11	2	12	1	4	<1	7	2
Shrub >1 m (%)	4	1	11	2	7	1	10	2
Sapling (%)	9	2	14	2	2	1	3	1
Canopy cover (1-m scale: %)	15	3	24	3	6	4	31	7
Distance to microedge (m)	1.3	0.1	1.1	0.1	2.2	0.3	2.6	0.6
No. trees	1.8	0.6	3.1	0.5	1.9	0.6	**7.3***	**0.9***
No. Snags	0.1	0.1	0.4	0.1	0.0	0.0	0.3	0.1
No. of shrubs	8.2	3.5	9.2	2.5	11.0	1.7	15.5	1.6
No. of saplings	11.9	2.5	**20.7***	**2.9***	7.3	3.2	6.5	1.6
Distance to intact forested edge (m)	141.1	25.3	139.5	22.7	44.8	6.7	**14.3***	**8.0***

After Holm's correction, we considered P-values to be significant when <0.003. Values in bold and starred (*) were statistically significantly different from each other.

representing four of seven individuals were in forest. Overall, three of 1,055 spot-mapped locations and 22 of 1,012 telemetry locations were classified as forest (Table 5.3). Moderate amounts of high canopy cover at a 90 m × 90 m scale (71% ± 3 Pennsylvania; 68.5% ± 4 West Virginia) occurred at forest locations resulting in presence of shrub, sapling, and herbaceous ground cover at 1- and 5-m plot scales (Table 5.3). Distance to shrubland edge was low (mean 45.9 m ± 4.0; Table 5.3).

DISCUSSION

Golden-winged Warblers in low nesting-density populations in Pennsylvania and West Virginia regularly used areas outside their spot-mapped territories, with 40% of all telemetry locations occurring outside spot-mapped territories. MCP size differences between spot-mapped and telemetry-based techniques were similar to those reported in a high-density population in Minnesota (Streby et al. 2012), although we cannot make direct comparisons between the results of these studies due to differences in field methods and data analyses. However, both our study and Streby et al. (2012) concluded that spot-mapping was limited in its utility to accurately represent space use and movements of Golden-winged Warblers.

Songbird home ranges have been reported to be 1.4–8 times larger than breeding territories

TABLE 5.3

Vegetation characteristics at forested locations where Golden-winged Warblers were observed during spot mapping or via radiotelemetry in Pennsylvania and West Virginia during 2011 and 2012, respectively.

	Pennsylvania		West Virginia	
	Forested locations (*n* = 10)		Forested locations (*n* = 11)	
Habitat variable	Mean	±SE	Mean	±SE
Grass (%)	1	<1	9	2
Forbs (%)	2	1	34	3
Ferns (%)	6	2	2	1
Rubus spp. (%)	4	2	2	1
Goldenrod (*Solidago* spp.: %)	1	<1	<1	<1
Woody Cover (%)	—	—	11	3
Litter (%)	—	—	27	3
Vine (%)	—	—	1	<1
Non-vegetation (Bare Ground + Litter) (%)	45	5	—	—
Bare Ground (%)	—	—	14	3
Shrub <1 m (%)	23	4	7	2
Shrub >1 m (%)	18	3	2	1
Sapling (%)	17	3	5	1
Canopy cover (1-m scale: %)	51	6	76	3
Distance to microedge (m)	0.8	0.1	5.4	0.9
No. trees	6.0	1.0	12.6	1.2
No. Snags	0.6	0.2	0.8	0.3
No. of shrubs	12.6	4.5	31.1	8.3
No. of saplings	30.0	10.0	7.6	3.1
Distance to intact forested edge (m)	51.0	7.2	41.3	3.8

Vegetation data represent 21 of 25 forested locations from eight of nine individuals. We did not collect microhabitat vegetation data at the forested spot-mapped locations (*n* = 3) or at one telemetry location within a spot-mapped territory.

(Hanski and Haila 1988, Leonard et al. 2008, Anich et al. 2009). Home ranges of Golden-winged Warblers based on telemetry locations in our study (6.3–11.8 ha) averaged three-to-four times larger than each individual's spot-mapped territory (1.7–2.4 ha) and were larger than other reported values for Golden-winged Warbler spot-mapped territory size (Confer 1992, Rossell et al. 2003, Patton et al. 2010). For example, one radio-marked Golden-winged Warbler in Pennsylvania traveled 1.6 km outside his spot-mapped territory in late afternoon but was observed back in his spot-mapped territory the following morning (Frantz 2013). Our results are consistent with Streby et al. (2012), who found that Golden-winged Warbler telemetry-delineated home ranges were larger than telemetry-based song territories in Minnesota. Our telemetry-delineated home ranges (Pennsylvania: 6.3 ± 1.7 ha; West Virginia: 11.8 ± 6.2 ha, 100% MCP) were two-to-four times larger than spot-mapped territories (Pennsylvania: 1.7 ± 0.2 ha; West Virginia: 2.4 ± 0.5 ha). However, Streby et al. (2012) also found that telemetry-based song territories (0.45 ± 0.08 ha) were three times larger than spot-mapped song territories (0.16 ± 0.02 ha) in Minnesota. Therefore, comparisons based on spot-mapping between our study and that of Streby et al. (2012) suggest that territories may be considerably larger in low-density populations. Territory size often is inversely related to population density (Maher and Lott 2000), where territories and home ranges are expected to be smaller in areas with more intraspecific competition (Pons et al. 2008, Anich et al. 2010).

Core use areas based on 50% MCPs are generally considered the most important part of an animal's home range (Burt 1943, Samuel and Green 1988) because food and other critical resources often are patchily distributed throughout the landscape (Powell et al. 1997). Avian breeding territories vary in size, but usually represent areas of high use within a larger home range (Harris et al. 1990). Core areas (50% MCPs) for the Golden-winged Warblers we monitored were larger when delineated by telemetry than spot-mapping in almost all cases (16 out of 19 males). However, telemetry and spot-mapped core areas usually overlapped (15 out of 19 cases), suggesting that both methods can reliably delineate the core use areas of territories. Conversely, spot-mapping was less effective at completely characterizing space use of breeding Golden-winged Warblers compared to telemetry. The disparity in estimates of space use resulting from spot-mapped versus telemetry-based methods is important to consider in efforts to create and maintain high quality Golden-winged Warbler breeding habitat across their breeding distribution.

The high overlap among individual home ranges in our study suggests that areas between spot-mapped territories are shared by neighboring Golden-winged Warblers and may provide foraging grounds that do not appear to be defended (Williams 1990). In Pennsylvania, we observed three territorial males foraging in the same area within a 10-m radius circle with no apparent aggressive behavior; two of the males were outside their spot-mapped territories and one was on the periphery of his spot-mapped territory (Frantz 2013). We recognize that MCPs can overestimate the amount of overlap by including areas that a bird may never visit (Barg et al. 2005). However, given the many factors that influence home-range boundaries (Anich et al. 2010, 2012), and that spot-mapping underestimates territory size of Golden-winged Warblers (Streby et al. 2012), it is possible that even more overlap occurred between neighboring Golden-winged Warblers than what we documented.

Spot-mapped territories of neighboring Golden-winged Warblers had little overlap, whereas telemetry-delineated home ranges had extensive overlap with spot-mapped territories (Streby et al. 2012, our study). Movements of male Golden-winged Warblers into other males' breeding territories or home ranges may have been motivated by potential opportunities for extra-pair matings (Frantz 2013). In Ontario, ~30% of Golden-winged Warbler nestlings were the result of extra-pair copulations, occurring in 55% of all nests (Vallender et al. 2007).

Forest cover is important for breeding Golden-winged Warblers at a landscape scale (A. M. Roth et al., unpubl. plan), and the same appears true at the home-range scale. We observed Golden-winged Warblers in forested patches more often using radiotelemetry than through spot-mapping, although visits to forest cover were still relatively rare (25 of 2,067 total spot-map and telemetry locations; 1.2%). The forest cover at locations where we observed radiomarked Golden-winged Warblers were of various stand ages (20–110 years) and typically contained canopy gaps, especially in Pennsylvania, resulting in heterogeneous vegetative structure. Moderate amounts of high canopy cover suggested the presence of canopy disturbance that allowed growth of shrub, sapling, and herbaceous ground cover.

Movements into forest could serve as reconnaissance to identify areas where adults would bring dependent young as fledglings use forest cover in higher proportion than available (Chapter 8, this volume). A radiomarked Golden-winged Warbler male attending fledglings in West Virginia progressively ventured farther into surrounding closed-canopy forest away from its spot-mapped territory. Thus, implementing management activities that result in a diverse array of forest stand conditions will benefit efforts to create and maintain Golden-winged Warbler breeding habitat in the Appalachian region.

Our results inform Golden-winged Warbler monitoring and conservation strategies. Partners in Flight detection distance for population estimates of Golden-winged Warblers was 200 m (Rosenberg and Blancher 2005), which was later determined to be 100–150 m in nonopen cover types (Kubel and Yahner 2007, Aldinger and Wood 2015). Given that many of our telemetry locations were >200 m away from spot-mapped territories, locations where singing males were detected may only be loosely associated with their breeding territories. Furthermore, current conservation plans for Golden-winged Warblers are based on habitat relationships derived solely from spot-mapped territories and lack consideration of an intermediate spatial scale between the territory and landscape scale (Bakermans et al. 2011; A. M. Roth et al., unpubl. plan). Consideration of an intermediate spatial scale may benefit Golden-winged Warbler monitoring and conservation.

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