PLANT STRUCTURE OF HOODED AND KENTUCKY WARBLER BREEDING SITES IN REGENERATING FOREST

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Much of the forest in the Eastern Piedmont has lost its woody understory and herbaceous layers due to browsing by white-tailed deer (*Odocoileus virginianus*) simplifying the structure of the forest. Either the understory layers are missing or the native plants have been replaced by invasive plants that do not support a healthy native fauna. Populations of native animals that depend on a complex forest structure are declining at an unsustainable rate due to these changes (Robbins et al. 1989, McShea et al. 1995). Breeding neo-tropical migrant birds are especially at risk. Kentucky Warblers (*Oporornis formosus*) and Hooded Warblers (*Wilsonia citrina*) both nest in large, mature deciduous forest with dense woody understory (C. Lynch & Whigham 1984; Robbins et al. 1989). Hooded Warblers prefer thicket forming shrubs as nesting substrates (Bent 1953, Kilgo et al. 1996a). Kentucky Warblers also require a dense herbaceous layer for foraging and nesting (Kilgo et al. 1996b). In the core habitat of Southern bottomland forest, Kentucky Warblers prefer tree-fall gaps scattered within forest with denser canopy coverage (Kilgo et al. 1996). Studies of plant associations in preferred nesting patches were made in the bottomland hardwood forest of South Carolina (Kilgo et al. 1996a, b, Sargent et al. 1997) and in the Appalachian physiographic region (McShea et al. 1995, Howlett, J. S., and B. J. Stutchbury. 1996). In an analysis of the forest types used by breeding Kentucky Warblers in north-western Virginia, a negative correlation between suitable Kentucky Warbler breeding habitat and white-tailed deer density was found (McShea et al. 1995). If population declines in these species are to be reversed, the native understory and herbaceous layers must be restored through deer herd reduction that allows native plants to grow and compete with invasive plants. The critical

question for deer management programs is: when has the forest recovered enough to support bird species that need a complex forest structure to successfully breed? To answer this question, we studied the plant structure of known nesting patches of Kentucky and Hooded Warblers in the northern Piedmont physiographic region, which is the northern edge of the breeding range for Kentucky and Hooded Warblers.

Study Area and Methods

This study examined the forest structure at two sites, The Ted Stiles Preserve at Baldpate Mountain (TSPBM) in Mercer County, New Jersey (primarily managed by Mercer County Park Commission and co-owned by the state of New Jersey, Mercer County, Hopewell Township and Friends of Hopewell Valley Open Space) and the Northern Stony Brook Preserve (NSBP) in Mercer and Hunterdon Counties, New Jersey (owned and managed by D&R Greenway Land Trust, Inc.), where vigorous white-tailed deer hunting programs have allowed regeneration of a native understory and created habitat favorable for breeding Kentucky and Hooded Warblers. Both locations were in the Sourland Mountains in the central New Jersey Piedmont physiographic region. The measured vegetation structure of breeding territories for Kentucky and Hooded Warblers was compared to that of random points previously measured in both study sites and 35 additional sites across central and northern New Jersey to help understand why both bird species are declining as breeding birds in the region.

Determination of breeding bird sites**:** Breeding territories used in this study were determined during two censuses at TSPBM and one census at NSBP. The routes where GPS points were taken to identify breeding / vegetation measurement locations were based on the 2010 breeding maps for each bird species (See Appendix B for breeding census details). GPS points for

Hooded Warblers were taken where males were singing on territory in 2010. GPS points for Kentucky Warblers were taken where males were singing on territory in 2010 and documented breeding locations from previous surveys (2007 - 2009). The inclusion of past breeding locations was necessary for Kentucky Warblers because of the limited number of breeding pairs in 2010. At TSPBM, GPS points were taken on 22 June 2010 along the Ridge Trail, the NW Loop Trail, and the Copper Hill Trail in a 7 hr 46 min census and on 23 June 2010 along the Summit Trail and the road to Strawberry Hill loop and the NW Loop in a 4 hr census.

Vegetation measurements: Measurements of the woody understory vegetation within the deer browse zone, herbaceous vegetation and forest canopy were performed on 20 and 29 September, 2010 at TSPBM and 1 October 2010 at NSBP to avoid disturbing active nests. A total of 42 locations were sampled; 32 at TSPBM and 10 at NSBP. At TSPBM, six sites were overlapping Hooded and Kentucky Warbler breeding territories, eighteen sites were Hooded Warbler breeding territories only and eight were Kentucky Warbler breeding territories only. At NSBP, six sites were Hooded Warbler breeding territories only and four sites were Kentucky Warbler breeding territories only. All vegetation sample locations were pre-determined to coincide with breeding bird locations (see above).

Woody understory vegetation (i.e., shrubs and tree saplings) was measured using the "forest secchi" method (M. Van Clef, unpublished data). Since 2004, this method has been utilized by sixteen natural land managers across 35 sites in central and northern New Jersey to guide deer management programs. The forest secchi is a modification of similar white board methods used to estimate vegetation density. A 1 m x 1 m white foam board was evenly divided into a 16-cell

grid using black tape. The number of obstructed cells (partially or completely) was recorded at a distance of 10 m from the center point of a sampling location. Total, native and non-native cover was recorded separately. For each location, four readings were taken (i.e., the four cardinal compass directions) and averaged to create a single measurement per location. The white board was held 40 cm (1.31 feet) above the ground (top of board reached 1.4 m or 4.59 feet above ground). [Note: In past experience, deer begin to 'notice' woody vegetation greater than six inches tall. Therefore, sites with a history of high deer densities tend to have very low cover of woody plants taller than the lowest height of the board (i.e., 40 cm).]. Herbaceous cover was measured using a 0.25-m^2 quadrat. Measurements were taken at the same locations utilized for the forest secchi board (i.e., 10 m from the sample location center point in each of the four cardinal compass directions) by laying the quadrat on the ground. The percent cover for total, native and non-native herbaceous cover (includes forbs and ferns only) was visually estimated in 5% increments. The forest canopy density was estimated using a concave densiometer. For each sampling location, four measurements were taken (i.e., the four cardinal compass directions). The average of the four readings represents the sampling locations estimated forest canopy cover.

Results

Sample locations for each study site are depicted in Maps 1 and 2. Woody understory and canopy data are summarized in Figure 1 and summary tables for all measured parameters are provided in Appendix A. Tables in Appendix A are presented for TSPBM and NSBP both individually and combined, Hooded Warbler breeding sites and Kentucky Warbler breeding sites (Note: Some breeding sites have both Hooded and Kentucky Warblers). For comparative

purposes, previously collected data are reported for randomly selected forest health monitoring points at TSPBM, NSPB and 35 sites studied in central and northern New Jersey.

The average total woody understory cover at breeding bird locations was approximately 97% at both TSPBM and NSBP. Native species cover was over 82% at breeding locations within both study sites, while non-native species cover was approximately 37 and 56% at TSPBM and NSBP, respectively. The native cover averaged 87% in the highest quality habitat at TSPBM (defined as sample locations with at least three adjacent breeding Warbler territories).

The combined averages for study sites showed higher total (97 vs. 41%), native (84 vs. 21%) and non-native (41 vs. 24%) woody understory cover relative to 35 sites located in central and northern New Jersey (M. Van Clef, unpublished data). The total understory cover in randomly selected locations previously measured at TSPBM was approximately 63% (vs. 97% at measured breeding locations). The native woody understory at randomly selected points was over 60% lower than at breeding locations (22 vs. 83%) and non-native cover was over 25% higher (64 vs. 37%). The total understory cover in randomly selected locations previously measured at NSBP was approximately 63% (vs. 97% at measured breeding locations). The native understory at randomly selected locations was nearly 50% lower than at breeding locations (38 vs. 86%). Unlike TSPBM, non-native cover was approximately 25% lower at randomly selected locations than at known breeding locations (30 vs. 56%).

The herbaceous cover at both study sites was relatively sparse. TSPBM had an average cover of approximately 5% (4% native and 1% non-native) and herbs were present in 41% of plots. NSBP had an average herbaceous cover of approximately 2% (only native species were present) and herbs were present in only 15% of plots. The average herbaceous plant coverage was above 10% in only seven of 42 sampling locations across both study sites.

Forest canopy density was greater than 94% at both study sites with no difference found between the Hooded and Kentucky Warbler breeding sites.

Discussion

In agreement with the previous studies cited above, our study found that Kentucky and Hooded Warblers required a dense understory of thicket forming species to breed. There is not an agreement on shade density requirements for Kentucky Warblers in the literature. Chapman (1907) described the Kentucky Warbler as a bird of more open overgrown thickets but Bent (1957) described the bird as liking deep shade and overgrown thickets. A study of nesting sites in a bottomland hardwood forest indicated that Kentucky Warblers prefer tree-fall gaps in densely shaded forest (Kilgo et al 1996). We found neither a difference in forest canopy density requirements for the two warbler species nor a requirement for a dense herbaceous layer for breeding Kentucky Warblers.

The native thicket forming understory utilized by Kentucky and Hooded Warblers was predominately or entirely spicebush (*Lindera benzoin*) at 39 of 42 locations across both study sites. Several locations had relatively high amounts of Blackhaw (*Viburnum prunifolium*), one NSBP Hooded Warbler location had a predominantly American beech (*Fagus grandifolia*) sapling understory, one TSPBM location had a mixed tree sapling understory interspersed with non-native autumn olive (*Elaeagnus umbellata*) and another TSPBM location had a mixed tree sapling understory with some spicebush. These latter two locations were sub-prime breeding territories on the periphery of high quality habitat and were approximately twice the size of higher quality breeding territories and probably would not have been used if the adjacent high-quality territories had not been saturated with breeding Hooded Warblers (subordinate male

Warblers, usually first year breeders, are known to use subprime habitat if adjacent high quality habitat is saturated).

The primary non-native understory component at both study sites was Multiflora rose (*Rosa multiflora*). In the breeding territories, most of the Multiflora rose was being overgrown by spicebush and was generally in poor health due to excessive shading (e.g., premature loss or yellowing of leaves). Both species of birds tolerated Multiflora rose if spicebush cover was high. Adjacent areas where Multiflora rose was observed to overtop lower growing spicebush were not being used for breeding. Autumn olive (*Elaeagnus umbellata*) was establishing in core forest areas where canopy cover was relatively low, while linden viburnum (*Viburnum dilatatum*) was invading open and closed forest areas. Linden viburnum was particularly problematic because it can survive in shaded conditions and permanently overtop spicebush. The difference in overall woody coverage between nesting and non-nesting sites suggested that overall woody cover, especially native cover, was inadequate for successful breeding of these bird species at many non-nesting measured sites.

It is possible that the reported 'requirement' for open canopy may actually be a requirement for very dense woody understory growth that is often associated with open forests. At both study sites, the shade tolerant spicebush was the dominate understory species, which may account for incongruities between previous studies and this current study related to canopy density requirements. It is also possible that areas with dense spicebush became more dense following past forestry activities and have persisted to the present day due to their shade tolerance. Additional investigation is required to determine the relationships between past and current canopy coverage, development and/or maintenance of native understory density, and deer

density relative to habitat suitability for Kentucky and Hooded Warblers. The reported association of Kentucky Warblers with more open canopied tree gaps within denser canopied forests (Kilgo et al. 1996) does not appear to be universal and their association appears to be more heavily dependent upon dense woody understory structure (which may or may not be associated with past canopy thinning).

The herbaceous layer coverage was sparse not exceeding 5%. Christmas fern (*Polystichum acrostichoides*), black cohosh (*Cimicifuga racemosa*), white snakeroot (*Ageratina altissima*), Solomon's seal (*Polygonatum pubescens*), and jumpseed (*Polygonum virginianum*) were found in the herbaceous layer of several breeding territories of both Hooded and Kentucky Warblers. Three Kentucky Warbler breeding territories had hog-peanut (*Amphicarpa bracteata*), smartweed (*Polygonum* sp.), or enchanter's nightshade (*Circaea lutetiana*). Two Hooded Warbler breeding territories had white wood aster (*Eurybia divaricata*) or partridge-berry (*Mitchella repens*) in the herbaceous layer.

While we did not find a dense herbaceous layer, we observed that the vegetation within 40 cm of the ground (i.e., below the forest secchi board measurements) was dominated by lower branches of mature shrubs and shrub/tree seedlings, which appears to preclude dense herbaceous cover but met bird habitat requirements. For future studies, an evaluation of the herbaceous layer combined with woody vegetation less than 40 cm in height may provide a better representation of suitable Kentucky Warbler habitat than herbaceous cover measurements alone. The requirement for a dense herbaceous layer by Kentucky Warblers appeared to be interchangeable with dense growth of lower branches of mature spicebush suggesting that the low cover structure was more important than the species composition.

Differences in vegetative structure at known bird breeding locations compared to randomly selected locations at both study sites revealed the patchiness of native understory recovery following deer herd reduction. Throughout TSPBM, there were many non-breeding areas with very high densities of Multiflora rose that reached 2 to 3 m tall. These same locations generally included large amounts of heavily deer-browsed spicebush that cannot grow taller than 0.5 to 1 m in height, which eliminated their ability to suppress the Multiflora rose and provide suitable nesting habitat. The reasons for observed patchiness in deer browse effects have not been determined, but attempts to elucidate this phenomenon will be important for land managers across the state and throughout the region. Factors that could be considered for further investigation include distance to adjacent properties where hunting is less effective at reducing deer populations (e.g., core areas at TSPBM seem relatively healthy relative to edges of the site) and past land uses that may impede growth of native species relative to invasive species (e.g., formerly plowed lands have severely altered soil structure that appears to favor 'weeds' and past forestry practices may have altered growth rates for native and non-native species).

To guide deer management programs, previously utilized thresholds for woody understory density using the forest secchi method were arbitrarily set at > 70% total / native vegetation and < 5% non-native vegetation to acknowledge that a dense shrub layer consisting almost exclusively of native species is expected in a healthy forest. This study suggests that overall density should be higher than 70% (> 95%), but that much higher levels of non-native cover (up to 56%) were tolerated by Kentucky and Hooded Warblers when co-occurring native understory species are dominant (> 85%).

The vigorous deer management programs at both study sites allowed the establishment of dense, native understory growth and provided rarely observed habitat for Kentucky and Hooded

Warblers. However, success has not been universal across the entirety of either study site and additional deer herd reduction is required both on site and within adjacent areas to compensate for lingering impacts associated with very large deer populations, past land uses and current invasive species infestations.

In conclusion, Hooded and Kentucky Warblers required a dense understory to breed but tolerated non-native plants when native plants dominated and defined the understory structure. In the central New Jersey Piedmont, spicebush thickets met the breeding requirements of these birds. Multiflora rose was tolerated if it was being thinned and overgrown by spicebush, but rose dominated understory thickets were not utilized for breeding even when they formed a very dense understory. The requirement for a dense herbaceous layer by Kentucky Warblers appeared to be interchangeable with dense growth of lower branches of mature spicebush.

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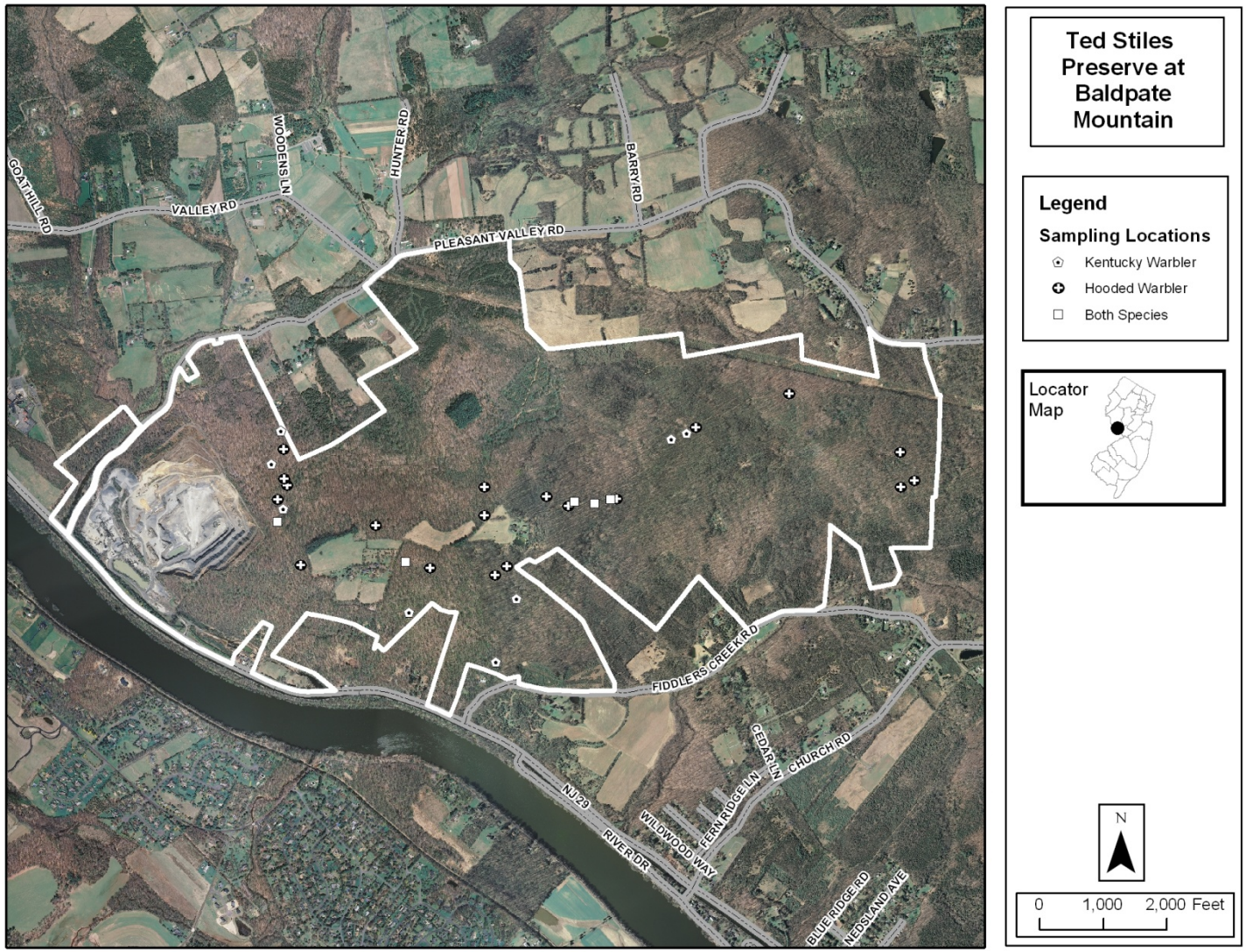
Map 1. Ted Stiles Preserve at Baldpate Mountain



Map 2. Northern Stony Brook Preserve

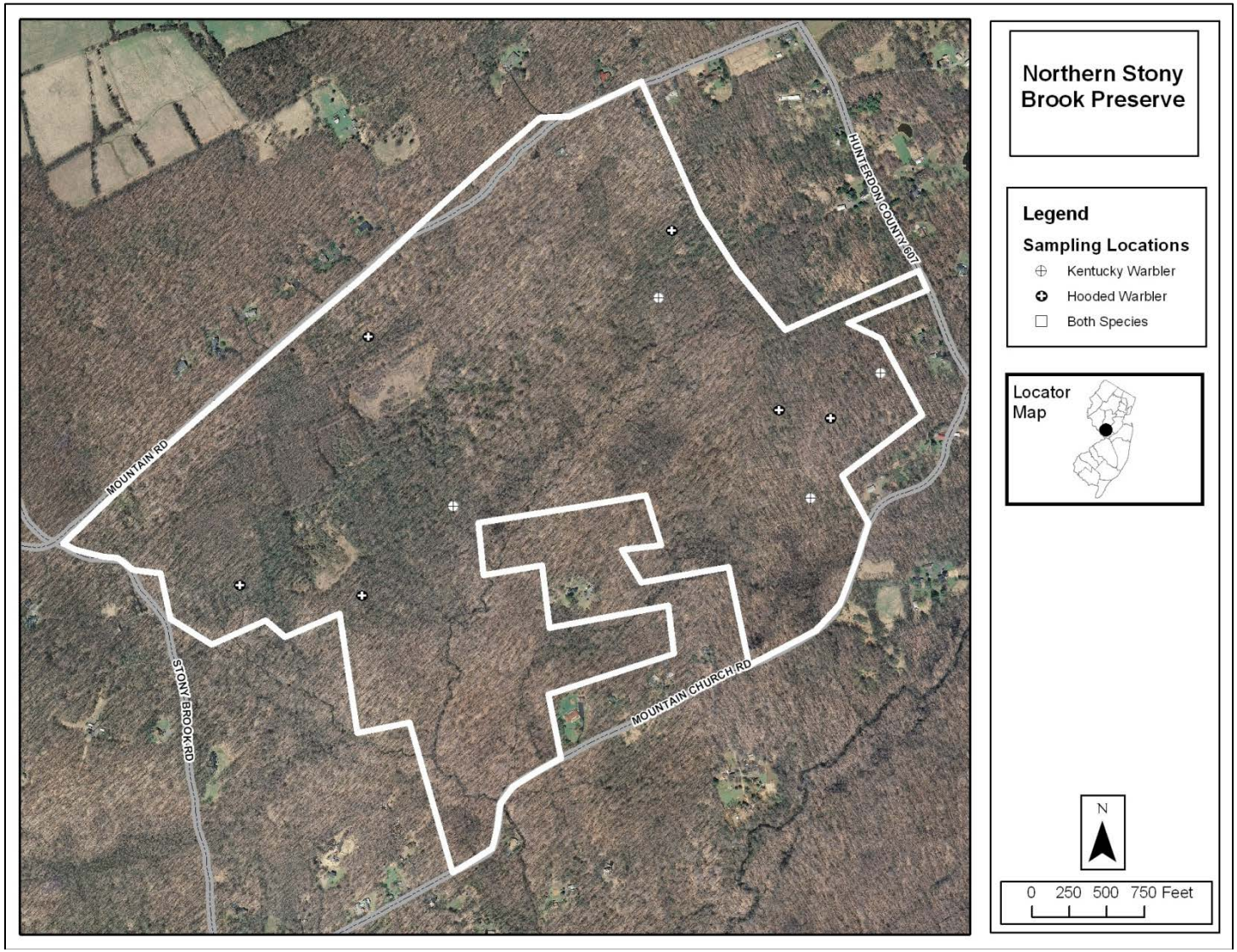
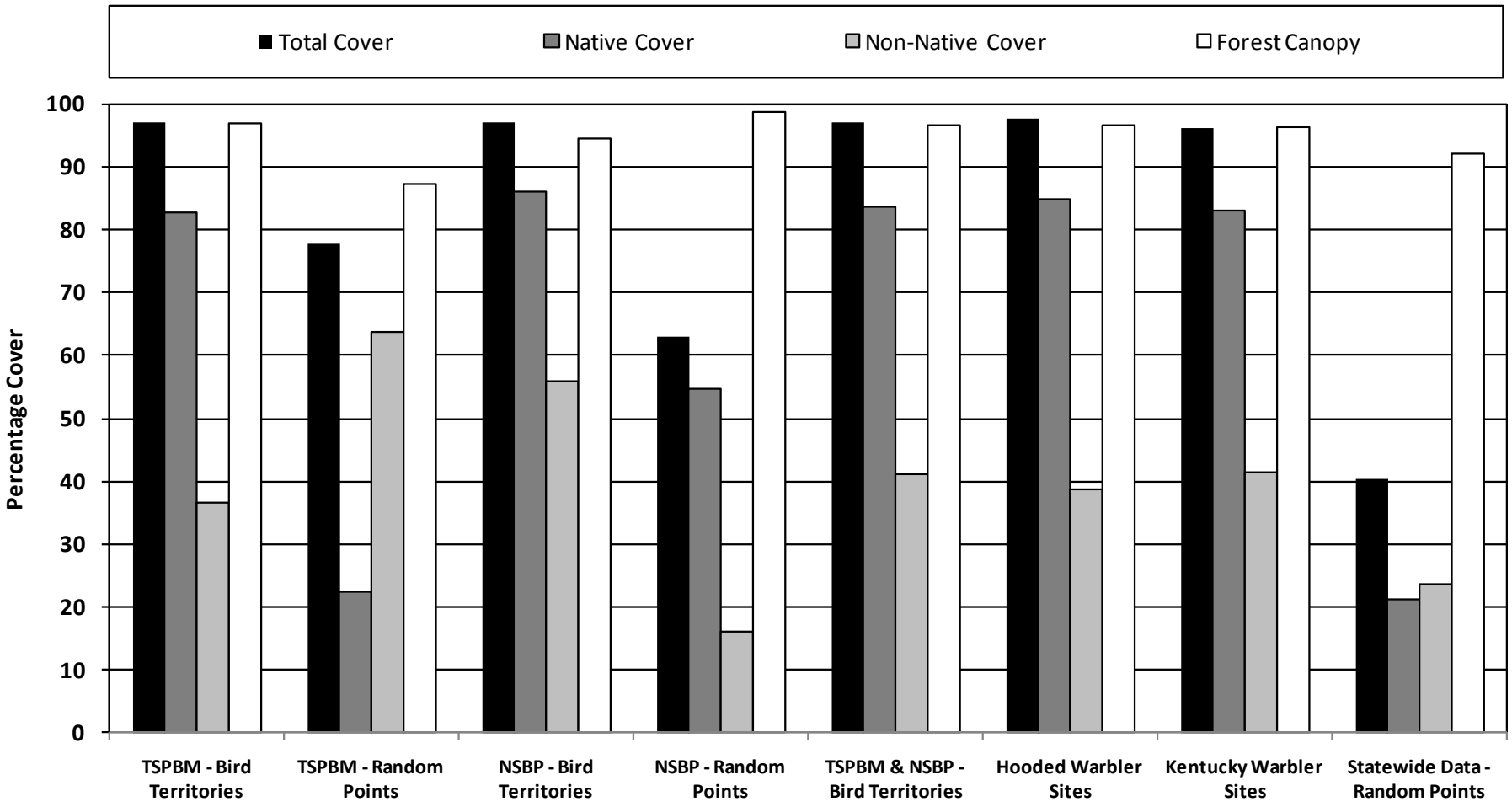


Figure 1. Summary of Woody Understory and Canopy Cover Measurements



Appendix A. Summary of Measured Vegetation Parameters

Kentucky Warbler Points (17 points)
Fall 2010

Woody Understory via Forest Secchi*

Average Percentage of Cells Obstructed (Total)	96.0
Average Percentage of Cells Obstructed (Native)	83.1
Average Percentage of Cells Obstructed (Non-Native)	41.5

Herbaceous Cover via Quadrat (% cover)

Average Percentage Cover within Quadrat (Total)	6.8
Average Percentage Cover within Quadrat (Native)	5.4
Average Percentage Cover within Quadrat (Non-Native)	1.3

Herbaceous Cover via Quadrat (Frequency)

Average Percentage of Qudrats with Herbs Present (Total)	39.7
Average Percentage of Quadrats with Herbs Present (Native)	32.4
Average Percentage of Quadrats with Herbs Present (Non-Native)	16.2

Forest Canopy

Average Tree Canopy Cover (Total)	96.2

* Cells Obstructed denotes a cell that is wholly or partially covered by woody vegetation

Northern Stony Brook Preserve (10 points)
Fall 2010

Woody Understory via Forest Secchi*

Average Percentage of Cells Obstructed (Total)	96.9
Average Percentage of Cells Obstructed (Native)	85.9
Average Percentage of Cells Obstructed (Non-Native)	55.8

Herbaceous Cover via Quadrat (% cover)

Average Percentage Cover within Quadrat (Total)	1.9
Average Percentage Cover within Quadrat (Native)	1.9
Average Percentage Cover within Quadrat (Non-Native)	0.0

Herbaceous Cover via Quadrat (Frequency)

Average Percentage of Qudrats with Herbs Present (Total)	15.0
Average Percentage of Quadrats with Herbs Present (Native)	15.0
Average Percentage of Quadrats with Herbs Present (Non-Native)	0.0

Forest Canopy

Average Tree Canopy Cover (Total)	94.6

* Cells Obstructed denotes a cell that is wholly or partially covered by woody vegetation

Appendix A. Summary of Measured Vegetation Parameters (continued)

Baldpate Mountain and Northern Stony Brook Preserve (42 points)
Fall 2010

Woody Understory via Forest Secchi*

Average Percentage of Cells Obstructed (Total)	96.9
Average Percentage of Cells Obstructed (Native)	83.5
Average Percentage of Cells Obstructed (Non-Native)	41.2

Herbaceous Cover via Quadrat (% cover)

Average Percentage Cover within Quadrat (Total)	5.2
Average Percentage Cover within Quadrat (Native)	4.1
Average Percentage Cover within Quadrat (Non-Native)	1.1

Herbaceous Cover via Quadrat (Frequency)

Average Percentage of Qudrats with Herbs Present (Total)	35.1
Average Percentage of Quadrats with Herbs Present (Native)	25.6
Average Percentage of Quadrats with Herbs Present (Non-Native)	17.3

Forest Canopy

Average Tree Canopy Cover (Total)	96.5

* Cells Obstructed denotes a cell that is wholly or partially covered by woody vegetation

Appendix A. Summary of Measured Vegetation Parameters (continued)

Hooded Warbler Points (30 points)
Fall 2010

Woody Understory via Forest Secchi*

Average Percentage of Cells Obstructed (Total)	97.5
Average Percentage of Cells Obstructed (Native)	84.8
Average Percentage of Cells Obstructed (Non-Native)	38.6

Herbaceous Cover via Quadrat (% cover)

Average Percentage Cover within Quadrat (Total)	6.0
Average Percentage Cover within Quadrat (Native)	5.0
Average Percentage Cover within Quadrat (Non-Native)	1.1

Herbaceous Cover via Quadrat (Frequency)

Average Percentage of Qudrats with Herbs Present (Total)	38.3
Average Percentage of Quadrats with Herbs Present (Native)	25.8
Average Percentage of Quadrats with Herbs Present (Non-Native)	20.0

Forest Canopy

Average Tree Canopy Cover (Total)	96.7

* Cells Obstructed denotes a cell that is wholly or partially covered by woody vegetation

Kentucky Warbler Points (17 points)
Fall 2010

Woody Understory via Forest Secchi*

Average Percentage of Cells Obstructed (Total)	96.0
Average Percentage of Cells Obstructed (Native)	83.1
Average Percentage of Cells Obstructed (Non-Native)	41.5

Herbaceous Cover via Quadrat (% cover)

Average Percentage Cover within Quadrat (Total)	6.8
Average Percentage Cover within Quadrat (Native)	5.4
Average Percentage Cover within Quadrat (Non-Native)	1.3

Herbaceous Cover via Quadrat (Frequency)

Average Percentage of Qudrats with Herbs Present (Total)	39.7
Average Percentage of Quadrats with Herbs Present (Native)	32.4
Average Percentage of Quadrats with Herbs Present (Non-Native)	16.2

Forest Canopy

Average Tree Canopy Cover (Total)	96.2

* Cells Obstructed denotes a cell that is wholly or partially covered by woody vegetation

Appendix B. Censuses of Breeding Territories Used to Determine GPS Routes

Breeding territories on TSPBM were mapped in ten censuses on the Ridge Trail and adjacent loops and six censuses on the Summit Trail loop from 11 May to 30 June 2010 with a total of 96 hrs spent mapping. Five censuses of the Summit Trail loop also included the first 0.5 mile of the NW loop to access the breeding areas earlier in the morning than the territories could be reached from the Ridge Trail. At NSBP, GPS points were taken on 24 June 2010 along the Yellow, Blue, Red-Orange, and Green Trails in a 5 hr 31 min census. The breeding territories at NSBP were mapped in six censuses from 19 May until 24 June 2010 with a total of 28 hrs spent mapping.