Ecology and Conservation Biology of the North American Wood Turtle (Glyptemys insculpta) in the Central Appalachians

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Abstract

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Ecology and Conservation Biology of the North American Wood Turtle (Glyptemys insculpta) in the Central Appalachians

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My study presents information on summer use of terrestrial habitat by IUCN “endangered” North American Wood Turtles (*Glyptemys insculpta*), sampled over four years at two forested montane sites on the southern periphery of the species’ range in the central Appalachians of Virginia (VA) and West Virginia (WV) USA. The two sites differ in topography, stream size, elevation, and forest composition and structure. I obtained location points for individual turtles during the summer, the period of their most extensive terrestrial roaming. Structural, compositional, and topographical habitat features were measured, counted, or characterized on the ground (*e.g.*, number of canopy trees and identification of herbaceous taxa present) at Wood Turtle locations as well as at paired random points located 23-300m away from each particular turtle location.

First, I report and discuss basic morphometric and activity area data of the VA and WV turtles. Chapter two uses a nine-year dataset of adult WV Wood Turtles to estimate population size, population growth rate (lambda), and survivorship with open population Cormack-Jolly-Seber and Pradel models in program MARK. My third chapter assess Wood Turtle thermal ecology by examining three data sets of environmental and turtle temperatures: 1) temperatures

in three different microhabitat types (unshaded by ground cover [exposed], under vegetation [UV], under litter [UL]) recorded by iButtons at arrays throughout the two study sites; 2) ground temperatures at the locations of radio-tracked individuals and their paired random points measured within 300 meters and 30 minutes of each other; 3) body temperatures estimated with iButtons attached to the shell bridges of adult Wood Turtles. In the fourth chapter, I examine highly localized conditions resulting from short-term weather patterns and fine-scale microhabitat characteristics by comparing ground-level relative humidity at the locations of radio-tracked Wood Turtles to those at paired random points. I use the GIS-based water balance model developed by Dr. James Dyer to examine landscape conditions (such as water deficit ["DEF"] and actual evapotranspiration ["AET"]) resulting from long-term climate patterns and broad-scale habitat conditions (*e.g.*, topographical aspect and soil types).

The final two chapters are the heart of my dissertation. Vegetation was identified, measured, counted, or characterized in plots at 640 locations (394 in VA, 246 in WV), evenly distributed between adult turtle and random points. Importance values for overstory trees ≥ 10cm dbh were calculated in $400m^2$ plots; herbaceous plant taxa were identified in $400m^2$ and $1m^2$ plots; woody seedling taxa were identified in 1 m^2 plots; forest types were specified at the $400m^2$ plot and stand (5-20ha) scales. I used the R program "indicspecies", paired logistic regression, and classification and regression trees (CART) to analyse these data. Over thirty herbaceous and woody seedling taxa were indicators for Wood Turtle presence at the $400m^2$ and/or $1m^2$ scales at the VA and WV study sites. I used a series of conditional logistic regressions to quantify habitat use of Wood Turtles at multiple scales across a range of different forest types. At each of the turtle and random points proportions of ground cover were visually estimated within $1m^2$ plots to assess microhabitat use; structural, compositional, and topographical habitat features were measured in $400m^2$ circular plots to capture meso-scale ecological data; and stand scale (5-20ha) designations of forest type and seral stage were used to assess macro-scale habitat use. I found that Wood Turtles showed a preference for specific environmental conditions: older forest sites with relatively more herbaceous ground cover, large woody debris, canopy openness, and turtle-level obscurity, and with gentler slopes and warmer aspects.

Dedication

For my family, especially my parents, Donald William and Mary Mihailoff Krichbaum, and my friends, especially Sherman Bamford, Shay and Kim Clanton, Lloyd Clayton, Jacques and Ulysses Desportes, Nancy Eckel-Dickenson, Bob Fener, Joe and Jackie Glisson, Joe and Laura Hazelbaker, Allan Hench, Henry C. Familiarus, Jack Hutchinson, Mike Jones, Linda Lee and Andy Mahler, Ernie and Sue Reed, Jody Schaub, Andrew Sterrett, Dwight Worker, and Christina Wulf.

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CHAPTER 5: VEGETATIVE INDICATORS FOR WOOD TURTLE (*GLYPTEMYS INSCULPTA*) HABITAT USE IN CENTRAL APPALACHIAN FORESTS

Introduction

Numerous interacting factors at multiple spatial scales generate structural and compositional heterogeneity in forests (Braun 1950, Runkle 1991b, Franklin *et al*. 2002, McEwan *et al*. 2010). Broad- and fine-scale distributional patterns of understory and overstory forest vegetation result from synergies of site-specific physical conditions, disturbance regimes, and biotic interactions (Watt 1947, Braun 1950, Swanson *et al*. 1988, DeMars and Runkle 1992, Callaway 1997, Pickett and Rogers 1997, Hutchinson *et al*. 1999, Angelstam 2003, Dyer 2006, Dyer 2010, Matlack and Schaub 2011, McEwan and Muller 2011, Chapman and McEwan 2012, Anning *et al*. 2014). Because plants affect environmental conditions and resource availability within areas where animal activities take place, vegetation patches pattern animal habitat use in manifold ways (Doak *et al*. 1992, Baxley and Qualls 2009).

Forests provide not only food resources for resident animal species, but also refugia from predators, osmoregulatory opportunities (such as humid microclimates), thermoregulatory opportunities (shade and basking), cover from elements, reproductive staging areas, and nesting sites. Thus, spatial ecology may not be strongly linked to forage/prey abundance or composition, particularly for taxa such as turtles that do not have high rates of energy expenditure and may be process rather than resource limited (Congdon *et al*. 1989). Though vegetation structure may be a more important driver of animal habitat preference than taxonomic composition (DeGraaf *et al*. 1998, Carter *et al*. 1999, Kearns *et al*. 2006, Waldron *et al*. 2008, McCoy *et al*. 2013), for some chelonians specific floristic composition, not just amounts of general vegetation, may be a factor in microhabitat selection (Del Vecchio *et al*. 2011).

Previous studies have examined habitat use by turtles (Kaufmann 1992a, Kazmaier *et al*. 2001, Compton *et al*. 2002, Refsnider and Linck 2012, McCoy *et al*. 2013), but most deal with vegetation composition and structure with the use of broad-scale cover type categories (*e.g.,* deciduous forest or woodland), few have gone into detail on evidence of preference for specific taxa of trees or forbs (but see Del Vecchio *et al*. 2011, McKnight 2011, McCoard *et al*. 2016b). Habitat is not necessarily synonymous with a vegetative "cover type"; many factors influence habitat selection by animals and a cover type such as "oak-hickory forest" may contain tracts of different ages, species, structural attributes, and microhabitats. At these heterogeneous tracts specific vegetative taxa may be directly preferred as forage or they may be associated with other preferred food resources (such as invertebrate prey) or habitat conditions (*e.g.*, cover or microclimates). For this reason, to be of value for practical conservation application, habitat selection studies of taxa with activity areas of limited extent and fine-scale specificity of preferences, such as small turtles, must be performed at spatial and categorical scales of congruent detail.

The objective of this study was to determine if forest dwelling North American Wood Turtles (*Glyptemys insculpta*) were associating with specific overstory tree taxa and ground floor flora. Identification of such species can serve to identify or predict locations that are suitable habitat for the turtles, *i.e.*, serve as "management indicator species" useful for protecting Wood Turtle populations and their habitat. A better understanding of Wood Turtle spatial ecology, informed by empirical data and statistical analyses, will help focus conservation efforts, especially where commercial logging, recreational activities, road construction, vehicular traffic, and other anthropogenic disturbances may occur (Gardner *et al*. 2007). Due to the heterogeneous nature of forest patches and the Wood Turtles' omnivory, I hypothesized that some sites would be preferred more than others and predicted that a subset of the floristic taxa identified in the field would be correlated with Wood Turtle occurrences. Due to my observations of Wood Turtles at various locations over the course of eight years, I also predicted that most of the floristic taxa correlated with Wood Turtle occurrences would not be hydrophytes.

Focal Species

Wood Turtles (*Glyptemys insculpta*) are amphibious emydids found in deciduous, coniferous, and mixed forests in the northeastern United States (see "Focal Species" in Chapter 1 for more details on their natural history). Wood Turtle foraging and ingestion occur in both terrestrial and aquatic settings, including underwater (Carroll 1999, Krichbaum pers. obs.). As omnivores, they use a wide variety of foods (Strang 1983, Kaufmann 1992, Niederberger and Seidel 1999, Ernst

2001, Compton *et al*. 2002, Walde *et al*. 2003, Ernst and Lovich 2009, Jones 2009, Krichbaum pers. obs.). Turtle habitat use may be in response to fine-scale presence or abundances of litter invertebrates, fungi, or herbs that are distributed non-randomly in the forest (Meier *et al*. 1995, Caldwell 1996, Hanula 1996, Hutchinson *et al.* 1999, Rubino and McCarthy 2003, Van de Poll 2004, Kappes 2006, Gilliam 2007). Strang (1983) and Kaufmann (1995) noted seasonal differences in terrestrial habitat use apparently in response to the variance in availability of fungi, herbs, berries, and slugs.

Though I have few direct personal observations of feeding, I assumed that ground floor plant taxa found at a site may be an important driver of turtle use of those sites. I have observed Wood Turtles feeding, or observed evidence of feeding (such as pieces of foodstuffs on their faces), only 39 times from 2006 to 2015 in VA and WV (*ca*. 4% of my encounters with turtles); these observations took place in March to October from 9:35-20:30. Almost half of these occasions (18) involved herbaceous leaves, with the only identifiable taxon being *Viola* spp. My other foraging observations involved mushrooms (7), earthworms (5), insects (3), slugs or snails (3), fruit (2: blackberries and Skunk Cabbage), and a crustacean (crayfish).

Others have reported Wood Turtles feeding on cinquefoil (*Potentilla* spp.), wood sorrel (*Oxalis* spp.), greenbrier (*Smilax* spp.), Partridgeberry (*Mitchella repens*), Prairie Ragwort (*Senecio plattensis*), violets (*Viola* spp.), fruit of Skunk Cabbage (*Symplocarpus foetidus*), grasses, blueberries (*Vaccinium* spp.), blackberries (*Rubus* spp.), leaves and fruit of strawberries (*Fragaria* spp.), leaves of willows (*Salix* spp.) and alders (*Alnus* spp.) and birches (*Betula* spp.), new growing tips of ferns, moss, algae, fungi (*e.g.*, *Amanita, Boletus, Cortinarius, Russula, Suillus*), invertebrates (*e.g.*, earthworms, slugs, snails, crustaceans, beetles, millipedes, caterpillars, and leeches), carrion, and tadpoles (see pg. 260 of Ernst and Lovich 2009 for literature citations for the above listed foods). Slugs (221 times) and other invertebrates (25), fungi (27), including the genera *Russula* and *Lactarius*, and the leaves of Jewelwort (*I. capensis*) (30) were salient taxa in Jones' (2009) extensive feeding observations in Massachusetts.

Methods

Study Area

My study was set toward the southern edge of the species range in montane forests of Virginia and West Virginia. See "Study Area" in Chapter 1, Fig. 1.1, Tables 5.3-5.5, and Appendix 1 for detailed description of the study area.

Field Procedures

I used radio-telemetry to locate turtles during the summer months when Wood Turtles are most terrestrially active (see "Field Procedures" at Chapter 1 for general information). I compared turtle locations to randomly identified points to to identify habitat use by Wood Turtles. The same habitat features were measured, counted, or characterized on the ground at turtle locations as at paired random points. Each turtle location was paired with a random point designated in the field at a random compass orientation and random distance 23-300m from turtle points; geographic coordinates for these were generated using a Garmin ETrex GPS unit.

These distances represent the spatial range that could easily be within an individual's summer seasonal activity area (*ca*. 0.2-10ha in size), as well as ensuring that random point plots did not overlap turtle plots. Over the four field seasons habitat features were measured, counted, or characterized (such as diameter-breast high (dbh) of canopy trees and slope aspect) at 640 plots (394 in VA, 246 in WV), evenly distributed between adult turtle and random points.

At each turtle and random point I used nested plots ($1m^2$ and $400m^2$) to capture vegetation composition and structure of differentially scaled patches (Barbour *et al*. 1986, Stromberg 1995, Peet *et al*. 1998). In 2011-2014 at each Turtle point, I positioned a square $1m^2$ plot (Daubenmire frame) using the animal's location as the center; the same procedure was followed at random points. To assess microhabitat use, in these plots I visually estimated percent ground cover of forbs, grass, woody vegetation, coarse woody debris, moss, fungi, rock, sand, bare soil, and leaf litter. During 2013-2014 herbaceous plants (non-gramineous) and woody seedlings (those ≤ 25cm in height) were identified to the species- or genus-levels within the $1m^2$ plots to estimate microhabitat compositional preference. Botanical nomenclature herein follows Weakley *et al*. 2012.

To capture meso-scale ecological community data, habitat features for each Wood Turtle location (and paired random site) were measured in $400m^2$ circular plots with the turtle and random points at the center of each plot (11.3m radius = $400m^2$ = 1/25 of a hectare = *ca*. 1/10 of an acre). These plot dimensions can adequately capture representation of understory herbaceous species as well as overstory canopy tree species (Barbour *et al*. 1986, Peet *et al*. 1998) and have been used to identify ecological communities on the GWNF (Coulling and Rawinsky 1999, Fleming and Coulling 2001). In 2011-2013 I identified non-gramineous herbaceous plants to the species- or genus-levels within these 400m^2 plots. In 2011-2014 all trees ≥ 10cm in diameter at breast height ("dbh") were counted, identified, and measured for dbh.

Analytic Procedures

Herbaceous and Woody Seedling Taxa

I used the R package "indicspecies" (R Development Core Team 2015) to examine the herbaceous taxa and woody seedling taxa found at the plots. At both spatial scales (1m^2 and 400m^2), most taxa were found in a limited number of plots. Taxa that are not somewhat common, easily found, and readily identifiable have limited pragmatic utility for management and conservation purposes. Therefore, I reduced the original presence-absence tabulations to datasets for the indicator species analyses at both the 400m^2 and 1m^2 scales that included only those taxa that were found in at least 10% of any of the plot types in a state. The six plot type alternatives for each state used in all the indicator value and association coefficient analyses were: female Wood Turtles = FWT, female random points = FRP, male Wood Turtles = MWT, male random points = MRP, WT = males and females combined, RP = male and female random points combined. The significance level for reported p-values was alpha ≤0.05.

The "indicspecies" computational output includes an indicator value index for each individual taxon that indicates the degree of its association with site groups (*e.g.*, the plot types identified above). Such indices are useful for assessing the predictive values of the taxa as indicators of the conditions prevailing in site groups. This index is the product of two components, denoted A and B (De Cáceres and Legendre 2009): 1) A is the probability that a site belongs to the target group (*e.g.*, MWT) given that the specific herbaceous taxon was found; this is called the "specificity" of the species as an indicator. 2) B is the probability of finding the species in the sites belonging to the individual site group (*i.e.*, the plot types); this component is called the "sensitivity" of the species as an indicator. Hence, in this framework the perfect indicator species would be one that is only found in plots of the target site group (a specificity of 1.00) and that is found in 100% of the target site group plots (a sensitivity of 1.00).

In addition, for the $1m^2$ plots I computed the indicator value index for combinations of two taxa (De Cáceres *et al*. 2012). This procedure evaluated 171 species pair combinations for the $1m^2$ plots in Virginia, and 210 such combinations for West Virginia. The species combinations indicator values among site groups are examined in the same way as for individual taxa (*i.e.*, calculating A and B).

With the "indicspecies" package I also examined the association between the herbaceous species and the turtle plot types by computing Pearson's *phi* coefficient of association (Chytry´ *et al*. 2002). This correlation index is similar to but somewhat different from the indicator value index. It is useful for determining the ecological preferences of species among a set of alternative site groups (in this case the FWT/FRP/MWT/MRP/WT/RP plot types). An advantage of the *phi* coefficient is that it can identify avoidance of a particular taxon through negative values. The computations corrected for the fact that groups had unequal numbers of points.

As described above for the herbaceous taxa, I also used “indicspecies” to examine the woody seedling taxa found at the $1m^2$ plots.

I also computed Pearson’s *phi* coefficient of association between the herbaceous taxa and the forest type groups I designated to the random point $400m^2$ plots. Using tree importance values calculated for each random plot and the forest typing system used by the US Forest Service (USFS undated), I designated a forest type for each plot (*e.g.*, a Chestnut Oak – Scarlet Oak type or a Virginia Pine type). I then aggregated these more finely resolved designations into six more broadly defined forest type groups: oligotrophic oak (Od), sub-mesic oak (Om), dry mixed pine and deciduous (M), pine (P), mesic deciduous (Dm), and mesic mixed pine and deciduous (Mm) (Table 5.3). These six forest type groups were used as the alternative site groups in a coefficient of association analysis.

To ascertain whether Wood Turtles were using wetland or upland habitats I tabulated the hydrophytic status of the taxa used in the analyses. A standard classification system is used for hydrophytes, which are defined as “plants growing in water or on a substrate that is at least periodically deficient in oxygen due to excessive wetness” (Tiner 2006). The presence of various types of hydrophytes is an essential feature for defining wetlands (Tiner 2006). The classifications reflect the frequency of a species' occurrence in wetlands: I) obligate (OBL): >99% of time in wetlands), 2) facultative wetland (FACW): 67□ 99% in wetlands, 3) facultative (FAC): 34-66% (equally likely to occur in wetlands or non-wetlands), 4) facultative upland (FACUP): 1-33% (usually occur in non-wetlands) and 5) upland (UPL): occur in wetlands <1% of the time. Plants in classes 1, 2, and 3 in this scheme are considered to be hydrophytic; the classifications used herein for taxa were taken from Lichvar *et al*. (2014).

Tree Taxa, Forest Types, and Seral Stages

To examine Wood Turtles' affinity for or association with canopy tree species I calculated "importance values" (IVs) for the taxa of trees ≥ 10cm dbh in each 400m^2 plot. Trees of this size generally form the overstory and midstory canopy and are also those that are typically removed during commercial logging operations (being so-called "pole timber" (10-24cm dbh) and "saw timber" (≥25cm dbh)). Importance values can range from 0 to 100 and are a combination of two metrics: the number of trees of a given taxon and the total basal area of each taxon. Basal area is calculated for each tree by dividing its dbh by two, squaring this quotient, and multiplying by *pi* (πr^2), then the basal areas of individuals of a specific taxon are summed within site to give the overall basal area for that taxon. These basal areas for each taxon are compared to the total basal area of all the measured trees in the plot to give a proportionate number for the individual taxa. Similarly, the numbers of individual trees of each taxon are compared to the total number of measured trees in the plot to give a proportionate abundance for the individual taxa. Finally, these two numbers (proportions of basal area and number of trees) are added together, divided by two, and multiplied by 100 to give the importance value of each taxon in the plot. For example, given that there are a total of ten trees in a plot and their total basal area is 10,000cm^2 and five of these trees are Sugar Maples with a total basal area of 3000cm^2, then, the importance value for Sugar Maple in the plot is 40: $(((5/10) + (3000/ 10{,}000))/2) \times 100 = 40$.

Using the tree taxa typically dominant in the forest type groups, as well as taxonomic groupings (*i.e.*, oaks, maples, pines) and mixtures of these groupings (deciduous taxa, mesic taxa, and mixtures of these), I formulated fifteen models that were used in conditional logistic regressions of the importance values for tree taxa at turtle plots (used habitat) versus those at paired random plots (available habitat; Appendix 5). The global model was the one with the smallest number of taxa that accounted for at least 90% of the mean importance value for the total plots in each state. Due to differences in species composition and sample size that resulted in some “failures to converge” for the regression process in R, the final models I ran were slightly modified between Virginia and West Virginia and between sexes. Data for Virginia and West Virginia were analysed separately due to obvious differences in forest composition, and because of the geographic proximity of the study sites I also performed analyses with pooled data. I used the R packages “Survival” for the regressions and “AICcmodavg” for AIC_c values and model averaged coefficients (R Development Core Team 2015).

Using the IVs for the 400m^2 plots, to visually examine habitat preferences I used classification and regression trees (CART) to determine how effectively overstory composition partitioned turtle and random plots. Due to obvious differences in forest composition, data for Virginia and West Virginia were analysed separately. For the CART analyses I constructed trees for each state using pooled male and female data. In the IV datasets for tree constructions, I used only those taxa with an overall mean importance value > 0.8 in any of the four plot types (FWT/FRP/MWT/MRP in each state): 20 taxa in Virginia and 16 in West Virginia (see mean importance values at Table 5.2). Due to differences in species composition and sample size (leading to failures of log likelihood convergence), the final models were slightly modified between Virginia and West Virginia. The model for Virginia contained the following taxa (see Appendix 5 for acronyms): WP+WO+RM+SM+NRO+HICK+CO+BG+VP+SYC+ELM+BW+WA+ TP+SO+BL+BLBIR+SERV+BO+IW; while the model for West Virginia contained: WP+WO+RM+SM+NRO+HICK+CO+BG+VP+SYC+ELM+BW+WA+ BLCH+DW+CEDAR. I identified optimal tree sizes by examining cross-validation graphs that plotted change in relative error against tree size. I simplified the trees using pruning code to find the tree closest to two terminal leaves (equal to the number of categories: WT-RP) with the lowest misclassification rate. I used the R package "rpart" (R Development Core Team 2015).

After tree pruning I calculated a *K* statistic (Dellinger *et al*. 2007) to assess the strength of the optimal trees relative to chance classification: $K = \frac{(A-B)}{(C-B)}$

A = # of actual observations correctly classified by a tree,

B = # of observations correctly classified by chance on average (number of observations divided by number of classification categories),

C = # of observations correctly classified by a perfect tree.

The values of *K* can be used to gauge the strength of the optimal trees (Landis and Koch 1977): < 0 poor, 0-0.20 slight, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 substantial, 0.81-1.00 almost perfect.

To examine forest composition (forest type) and structure (seral stage) at a larger spatial scale than the $400m^2$ plots I used the stand inventory data supplied by the USFS. This database supplies a forest type, age, and site index for every delineated "stand" on the GWNF, stands being generally 5-20ha in size. Most paired turtle and random points were in a delineated GWNF stand; points found in private land inholdings were not used in this analysis. Using the Forest Service categorized forest types for the stands I examined turtle points and random points with G-tests, comparing frequencies of forest type groups of observed (turtle) points with those of expected (random) points; the expected proportions for the turtle points were the proportions calculated from the random point frequencies. In the same way, with the forest type characterizations for the $400m^2$ plots (based on the plots' calculated importance values) I used G-tests to compare frequencies of forest type groups of turtle points (the observed numbers) with those of random points (the expected numbers); the expected proportions for the turtle points were the proportions calculated from the random point frequencies. With G-tests I also examined the turtle and random points by comparing their forest type group characterization at the 400m^2 scale (the observed numbers) with their characterization at the stand scale; the expected proportions for the plots were the proportions calculated from the stand frequencies. I reasoned that if the stand level characterization was accurate for the entire stand (*i.e.*, forest composition was homogeneously distributed), then there should be no difference between the expected and observed frequencies.

All the G-tests were performed in Excel, were two-tailed, used a Williams continuity correction, and had degrees of freedom set for an intrinsic hypothesis because I was using my data to generate expected proportions (McDonald 2014). When the G-test results were significant, exact binomial tests of turtle and random points for specific forest type groups were done in R.

Using the USFS inventory stand ages I categorized the seral stage of stands. Early successional habitat ("esh") were stands aged 0-35 years, mid-successional habitat ("mid-suc.") were those aged 36-75 years, mature stands ("mature") were aged 75 years to the minimum age for old growth for specific forest types ("FT"). Stands were considered "old growth" at a minimum age of 100 years for FT 33; 110 for FT 60; 120 for FTs 42 and 45; 130 for FTs 10, 52, 53, and 54; and 140 years for FTs 9, 41, 50, 56 (age figures from USDA FS 1997) (see Table 5.3 for FT nomenclature and enumeration). Based on personal observation and the ages of adjacent GWNF stands, the private lands in VA were included in the mid-successional and mature data, while those in WV were included in the mature and old growth data. Using the categorized seral stages I examined turtle points and random points with G-tests, comparing frequencies of seral stages of turtle points with those of random points; the expected proportions for the turtle points were the proportions calculated from the random point frequencies.

Results

Forest Types and Seral Stages of Stands and Plots

Though only separated by *ca*. 20km, forest composition clearly differed between the two study sites (Tables 5.1-5.4, Figs. 5.1-5.3); see, *e.g*., the IVs for VRPs and WRPs at Table 5.2. The 400m^2 plots at the VA site were mostly composed of six broad forest type groups: oligotrophic oak (Od), sub-mesic oak (Om), dry mixed pine and deciduous (M), pine (P), mesic deciduous (Dm), and mesic mixed pine and deciduous (Mm), with a small number of points located in two additional types, seeps and brushy (ruderal) habitats. Almost 90% of the total VA turtle and random plots were composed of three forest type groups, Dm (21.8%), Od (31.0%), and Om (37.6%). Plots at the WV site were also mostly composed of the same six broad forest types, with the addition of a small number of points in brushy and Eastern Red Cedar (*Juniperus virginiana*) habitats. Around 81% of the total WV turtle and random plots were composed of three forest type groups, but unlike in VA the most prevalent groups were M (45.1%), P (19.1%), and Om (16.7%).

At the stand spatial scale, turtle and random points occurred in thirteen different forest types, but only one of these occurred in both states, White Oak –

Northern Red Oak – Hickory (FT 53) (Table 5.4). Stands at the VA site were composed of the same forest type groups as the plots, except M stands were absent. Almost 90% of the total VA turtle and random points were in stands composed of the two oak forest type groups, Om (81.0%) and Od (8.6%). Stands at the WV site were composed of just three forest type groups, but unlike in VA there were no points in Od stands, instead, many points were in M and P stands: Om (39.8%), M (35.9%), P (24.3%).

Ninety-five percent of turtle location points were within the 295m buffer zone around the VA main stream. This zone included 560ha of National Forest; these stands comprised 379.6ha (67.8%) of Om, 89.4ha (16.0%) of Od, 26.0ha (5.1%) of M, 24.6ha (4.4%) of Mm, 20.2ha (3.6%) of P, 4.5ha (0.8%) of Dm, 7.1ha (1.3%) of brushy ruderal, and 6.1ha (1.1%) were not given a forest type designation. There were also 26.4ha of private lands without stand data (Fig. 5.4). Ninety-five percent of turtle location points were within a 290m buffer zone around the WV main stream. This zone included 148ha of National Forest; these stands comprised 70.7ha (47.9%) of M, 45.3ha (30.7%) of P, 31.7ha (21.4%) of Om, and 0.07ha (0.04%) of Od. There were 71.5ha of private lands without stand data (Fig. 5.5).

G-tests detected a difference between the frequency of turtle points and random points for forest type groups characterized at the $400m^2$-plot scale (Fig. 5.2) in both WV ($G = 32.06$, $df = 4$, $p < 0.0001$) and VA ($G = 111.13$, $df = 4$, $p < 0.0001$).

A G-test detected no difference between the frequency of turtle points and random points for forest type groups characterized at the stand level in WV ($G = 1.42$, $df = 1$, $p = 0.233$) (Fig. 5.3). In VA, however, there was a difference between the frequency of turtle points and random points for forest type groups characterized at the stand level ($G = 41.18$, $df = 3$, $p < 0.0001$) (Fig. 5.3). Exact binomial tests found the differences to lie with the Mm ($p < 0.00001$) and Od ($p < 0.00001$) forest type groups.

G-tests detected a difference between the frequency of points for forest type groups characterized at the $400m^2$-plot and stand scales in both WV ($G = 361.83$, $df = 5$, $p < 0.0001$) and VA ($G = 596.55$, $df = 5$, $p < 0.0001$) (Fig. 5.6).

Most of the 2011-2014 plots wherein I calculated importance values were in older forest (mature and old growth seral stages) (Table 5.5, Figs. 5.7 & 5.8). In VA, 83.7% of turtle points (males and females pooled) were in stands of older forest, while 70.6% of random points were. One hundred percent of turtle points and random points were in stands of older forest at the WV site, which had no esh or mid-successional stands. In the VA buffer zone, the GWNF stands comprosed 89.4ha (16.0%) of esh, 95.8ha (17.1%) of mid-successional, 247.4ha (44.2%) of mature, and 127.2ha (22.7%) of old growth (Fig. 5.8). GWNF stands in the WV buffer zone comprised 109.5ha (74.1%) of mature and 38.3ha (25.9%) of old growth.

A G-test detected a difference between the frequency of turtle points and random points for seral stages characterized at the stand scale in VA ($G = 21.91$, df

= 2, $p < 0.0001$) (Fig. 5.7). Turtles used esh (exact binomial test, $p = 0.0120$) and mid-successional ($p = 0.0053$) less than was available, while using OG ($p = 0.0042$) more than was available at random; there was no difference of frequency between turtle and random points for the mature seral stage ($p = 0.0960$). Because all the sites in WV were in stands of older forest, I did not test for differences in frequency for seral stages there.

Overstory Trees

Importance values were calculated from 7098 trees ≥10cm dbh at 396 plots (144 female plots and 54 male plots and their paired RP plots) in Virginia and from 5024 trees ≥10cm dbh at 246 plots (74 female plots and 49 male plots and their paired RP plots) in West Virginia. I performed separate analyses for the VA and WV sites because of clear differences between the states in the proportionate composition of overstory trees.

I identified 41 overstory tree taxa; importance values (IVs) were calculated for 39 taxa in Virginia and 31 taxa in West Virginia. In the regression model formulations, I used only those taxa with an overall mean importance value ≥ 0.8 in regression models for any of the four plot types (FWT/FRP/MWT/MRP): 18 taxa in Virginia and 18 in West Virginia. See Tables 5.1-5.3 for tree taxa used in modeling, definitions of acronyms, and importance values. For trees with a dbh ≥ 10cm in $400m^2$ plots in 2011-2014 there was no difference in taxa richness between turtle points and paired random points in either state (Tables 5.6 & 5.7).

Paired Logistic Regression

There was some overlap in the tree taxa that best explain habitat preferences for Virginia females and males (Tables 5.9 & 5.10). Both sexes showed a positive affinity for sites with relatively higher values for Sugar Maple (*Acer saccharum*) and Serviceberry (*Amelanchier* spp.), while both sexes showed a tendency to avoid sites with higher importance values for Chestnut Oak (*Quercus montana*) and Scarlet Oak (*Q. coccinea*). Virginia females showed a positive affinity for sites with higher values for White Oak (*Q. alba*) and White Ash (*Fraxinus americana*), and a tendency to avoid sites with high values for Black Oak (*Q. velutina*). In contrast, Virginia males showed a tendency to avoid sites with higher importance values for White Oak, Red Maple (*A. rubra*), White Pine (*Pinus strobus*), and Ironwood (*O. virginiana*).

Both West Virginia females and males tended to avoid sites with higher importance values for Chestnut Oak (Tables 5.9 & 5.10). West Virginia males also tended to avoid sites with higher importance values for Sugar Maple and White Pine. West Virginia females showed a positive affinity for sites with higher values for Red Maple, Hickories (*Carya* spp.), and Sycamore (*Platanus occidentalis*).

The top two conditional regression models for explaining habitat selection by Virginia females were the mesic deciduous (Dm) and sub-mesic oak (Om) models, with eleven and nine taxa respectively (Table 5.8). The dry mixed pine and deciduous (M) and oaks' taxa models were the top two models for Virginia males, with seven and five taxa respectively. The top two models for West Virginia females were the global (with ten taxa) and mesic species (with six taxa) models. The global (with ten taxa) and dry mixed pine and deciduous (M, with eight taxa) models were the top two models for West Virginia males.

There was limited commonality in the tree taxa that best explain habitat preferences for pooled females or pooled males from both states (Table 5.12). Both sexes showed a tendency to avoid sites with higher importance values for Chestnut Oak and Scarlet Oak. In addition, some taxa were preferred by one sex but avoided by the other, such as with Sugar Maple and Elm. Females showed a tendency to avoid sites with higher importance values for Ironwood and Elm (*Ulmus* spp.), while males exhibited a tendency to avoid sites with higher importance values for Sugar Maple and seven other taxa. Females showed a positive affinity for sites with higher values for White Oak, Sugar Maple, White Ash, and Serviceberry. In contrast, males showed a preference for sites with higher importance values for Elm and Basswood (*Tilia americana*).

The only well-supported model for explaining habitat selection by pooled Virginia and West Virginia females was the mesic deciduous (Dm) model, with ten taxa (Table 5.11). The oaks model (with five taxa) was the best model for pooled Virginia and West Virginia males; the global model (with twelve taxa) was also well supported. The only well-supported model for explaining habitat selection by all Virginia and West Virginia Wood Turtles combined was the global model (Table 5.11).

When all Wood Turtles of both sexes from both states were examined together, only White Ash and Serviceberry were strongly preferred (Table 5.12). The models indicated turtles tended to avoid sites with higher importance values for White Pine, Chestnut Oak, Scarlet Oak, and Northern Red Oak (*Q. rubra*).

CART

The CART results suggest VA Wood Turtles preferred sites with relatively higher importance values for White Ash, Sugar and Red Maples, and White Oak and relatively lower values for Chestnut, Scarlet, and Black Oaks. For WV Wood Turtles the results indicate a preference for sites with relatively higher importance values for Red Maple, Sycamore, and Hickories and lower values for Chestnut Oak and White Pine. These CART results are generally congruent with the conditional logistic regression results.

Virginia. For the Virginia CART, using pooled female and male turtles and their random points, when all three of the initial trees were pruned, only Chestnut Oak and Scarlet Oak were used in tree construction (Fig. 5.9). The pruned trees resulted in 73.4% of points correctly classified by the IV threshold values for CO and SO; $K = 0.47$. Twelve taxa were used in tree construction without priors using the "information" split: all five Oaks (Black, Chestnut, Northern Red, Scarlet, and White), White and Virginia Pine, Red and Sugar Maple, White Ash, Hickories, and Ironwood. Using the "information" split with priors, the taxa used in tree construction were three Oaks (Chestnut, Scarlet, and White), Red and Sugar Maple, White Ash, and Black Birch (*Betula lenta*). When trees were constructed using a “gini” split with priors, the only taxa used were Chestnut and Scarlet Oaks and Red and Sugar Maples.

Because a substantial number of the VA turtle points had a component of Chestnut Oak (63 out of 197), I ran further CART analyses on this subset of data (*i.e.*, turtle plots with CO and their paired random points) to see which taxa partitioned turtle and random points. The model used did not include Chestnut or Scarlet Oaks or taxa with a mean IV less than 1 (see Appendix 5 for acronyms): WP+WO+RM+SM+NRO+HICK+BG+TP+SERV+BO+WA. The taxa used in tree construction using the “information” split without priors and the “gini” split with priors were the same: Sugar Maple, White, Northern Red and Black Oaks, and Hickories. When both of these trees were pruned, only Sugar Maple, White Oak, and Hickories were used in tree construction (Fig. 5.10). The pruned trees resulted in 65.3% of points correctly classified by the IV threshold values; $K = 0.31$.

Using this same data subset I also constructed trees with models that included Scarlet Oak as a variable, but not Chestnut Oak. The taxa used in tree construction using the “information” split without priors and the “gini” split with priors were the same: Sugar Maple, four Oaks (White, Scarlet, Northern Red and Black), and Hickories. When the “information” split tree was pruned, Sugar Maple, White Oak, and Hickories were used in tree construction, while the pruned “gini” tree used Scarlet Oak in addition to those three taxa (Fig. 5.11). The pruned “gini” tree resulted in 69.4% of points correctly classified by the IV threshold values; $K = 0.39$.

West Virginia. For the West Virginia CARTs, using pooled female and male turtles and their paired random points, the taxa actually used in tree construction were the same using the "information" split without priors, the "information" split with priors, and the "gini" split with priors: Red Maple, Chestnut and White Oak, Sycamore, Hickories, and White Pine. When these three trees were pruned, only Red Maple, Hickories, and Sycamore were used in tree construction (Fig. 5.12). The pruned trees resulted in 71.1% of points correctly classified by the IV threshold values for Red Maple, Hickories, and Sycamore; $K = 0.42$.

Though Sycamore was consistently used in tree construction, most of the turtle points did not have a component of Sycamore (107 out of 123). Therefore, I ran further CART analyses on this subset of data (*viz*., the turtle points without Sycamore and their paired random points) to see which taxa classified turtle and random points. The model used did not include Sycamore (see Appendix 5 for acronyms): WP+WO+RM+SM+VP+NRO+HICK+CO+BLCH+ELM+BG+BW+WA. When all three of the initial trees were pruned, only Chestnut Oak and White Pine were used in tree construction (Fig. 5.13).

The pruned information tree resulted in 68.2% of points ($K = 0.36$), and the pruned gini tree 69.2% of points ($K = 0.38$), correctly classified by the IV threshold values for CO and White Pine. These results indicate that Wood Turtles at WV sites without a component of Sycamore preferred sites with relatively lower values for Chestnut Oak and White Pine. The taxa used in tree construction using the "information" split without priors were Red Maple, White, Northern Red and

Chestnut Oaks, Hickories, and Virginia and White Pines. The taxa used in tree construction using the "information" split with priors were the same, with the addition of Black Cherry. The taxa used in tree construction using the "gini" split with priors were Red Maple, White and Chestnut Oaks, and Virginia and White Pines. The initial trees indicated that Wood Turtles at WV sites without a component of Sycamore preferred sites with relatively higher importance values for Red Maple and Hickories.

Herbaceous Flora

400m^2 plots

I recorded 3596 presences of 128 native taxa at 311 plots in VA (with an additional 142 presences of 7 alien species and 214 presences of unknowns) and 1523 presences of 88 native taxa at 159 plots in WV (with an additional 99 presences of 4 alien species and 202 presences of unknowns) in the 400m^2 plots in 2011-2013.

The reduced herbaceous dataset for VA included 40 taxa, as did that for WV (see Table 5.13); of the 53 total taxa 28 were common to both states. Due to these differences in composition, I performed separate analyses for the VA and WV sites. Thirty-eight of the 53 taxa had significant indicator value (p-values ≤ 0.05) for at least one group (Tables 5.13 & 5.14) and 37 taxa had significant *phi* coefficients of association for at least one group (Tables 5.15 & 5.16); thirty-four taxa were useful in both analyses. Virginia had a total of 28 taxa useful as indicators, while WV had 22.

Thirty taxa were indicators for the presence of Wood Turtles (either the FWT, MWT, or FWT+MWT groups) in at least one state (Tables 5.13 & 5.14). Of these 30 taxa, eight were useful in both VA and WV as indicators for pooled males and females: *Amphicarpaea bracteata* (Hog Peanut), *Circaea lutetiana (*Enchanter's Nightshade), *Eurybia divaricata* (White Wood Aster), *Galium triflorum* (Bedstraw), *Oxalis* spp. (Wood Sorrel), *Potentilla* spp. (Cinquefoils), *Viola* spp. (Violets), and the alien *Microstigeum vimineum* (Stiltgrass); with *E. divaricata* (White Wood Aster) and *Oxalis* spp. (Wood Sorrel) having marginally significant p-values in WV (Table 5.14). Three of the 30 WT taxa were ferns: Christmas Fern (*Polystichum arostichoides*) in WV and Sensitive (*Onoclea sensibilis*) and New York (*Parathelypteris noveboracensis*) Ferns in VA. Twenty-seven taxa had significant *phi* coefficients of association for Wood Turtles (Tables 5.5 & 5.16). Most of these were useful in the indicator species analyses, with the addition of White Snake Root (*Ageratina altissima*) and Wild Geranium (*Geranium maculatum*).

Nine taxa ($p < 0.051$) were indicators for random points of one group or another (FRP, MRP, or FRP+MRP; Tables 5.13 & 5.14), suggesting turtles tend to avoid these taxa (see "Study rationale" in Chapter 6). One taxon was a fern, Ebony Spleenwort (*Asplenium platyneuron)*. Many of the nine taxa, such as Trailing Arbutus (*Epigaea repens*), Tick Trefoil (*Desmodium* spp.), and Round-lobed Hepatica (*Anemone americana*), also had significant *phi* coefficients of association for random points (Tables 5.15 & 5.16). In addition, Panicled Hawkwort

(*Hieracium paniculatum*) and Goldenrods (*Solidago* spp.) had significant *phi* values, but not indicator species values for random points.

One taxon was useful in both VA and WV as an indicator for pooled male and female random plots: *Chimaphila maculata* (Spotted Wintergreen). Dittany (*Cunila origanoides*) had marginally significant phi values for FRPs in both states (Table 5.16). Two species, *Uvularia perfoliata* (Perfoliate Bellwort) and the alien *Perilla frutescens* (Beefsteak Plant), were indicators for pooled males and females in WV, but indicators for pooled male and female random plots in VA. Stiltgrass was by far the most common alien herbaceous species, present in 172 plots while the other seven alien taxa pooled occurred in 74 plots.

Some taxa were indicators for turtles at one scale, but not the other; *e.g., Arisaema triphyllum* (Jack-in-the-pulpit)*, Mitchella repens* (Partridgeberry), and Wood Sorrel at the $400m^2$ but not the $1m^2$ scale. Pussytoes (A*ntennaria* spp.) indicated male random points at the $1m^2$ but not the $400m^2$ scale. Some common taxa were useful indicators individually at neither scale; *e.g*., *Dioscorea villosa* (Wild Yam)*, Galium circaezans* (Wild Licorice), and *Packera obovata* (Round-leaved Ragwort). Several taxa presented somewhat contradictory results in that they were indicators for turtles at one scale, but random points at the other scale, with interstate variation as well for the first two: *viz., Gaultheria procumbens* (Teaberry) for WWT $400m^2$ – VFR $1m^2$*, Parthenocissus cinquefolia* (Virginia Creeper) for VMR $400m^2$ phi – WWT $1m^2$, and *Hieracium venosum* (Hawkwort) for WRP $400m^2$ – WMT $1m^2$.

Thirteen of the 30 taxa (43%) that were indicators for turtles (males, females, or M+F) in the 400m^2 plots can be considered hydrophytic (nine of the thirteen were FACW or OBL). Fifteen (29%) of the 53 common plant taxa used in the indicator analyses for the 400m^2 plots were wetland plants (*i.e.*, hydrophytes) (Table 5.13).

In both states in 2011-2013, 400m^2 turtle plots had greater herbaceous taxa richness than did random plots, except for WV males (Tables 5.6 & 5.7, Fig. 5.14). Using pooled males and females: VA paired Wilcoxon signed rank test: $V = 8298$, $p < 0.00001$; WV paired t-test: $t = 4.2659$, $df = 78$, $p < 0.0001$.

Virginia 400m^2. Three groups possessed taxa with significant indicator values: one taxon for the MWT, twenty-one for FWT-MWT, and four for the FRP-MRP group. One additional taxon had a p-value ≤ 0.07 (Table 5.14). Five of the six site groups possessed taxa with significant phi association coefficients, only the MRP group did not. Except for the FWT+MWT group, for which 18 taxa were significantly associated, the other four groups only had one or two associated taxa per group (Table 5.16). For all site groups there was also one more taxon with a p-value < 0.09.

West Virginia 400m^2. There were significant indicators for four groups; one taxon for the FRP group, three for the MWT, thirteen for FWT-MWT, and four for the FRP-MRP. The taxon for FRP was *Desmodium* spp. (Tick Trefoil), while those for the MWT group were *Lycopus* spp. (Buglewort), *Impatiens capensis* (Jewelwort), and *Scuttellaria* spp. (Skullcap). There were also three more taxa with p-values ≤ 0.1 in the FWT-MWT and FRP-MRP groups (Table 5.14).

All six groups possessed taxa with significant *phi* coefficients; two taxa for the FWT group, one for the FRP, three for the MWT, two for the MRP, seven for the FWT-MWT, and two for the FRP-MRP. There were also four more taxa with p-values ≤ 0.1 in the FWT-MWT and FRP-MRP groups (Table 5.16).

1m² plots

I recorded 510 presences of 65 native herbaceous taxa at 246 plots (with an additional 42 presences of 1 alien species and 13 presences of unknowns) in VA and 390 presences of 59 native herbaceous taxa at 152 plots (with an additional 29 presences of 2 alien species and 28 presences of unknowns) in WV in 2013-2014.

The reduced herbaceous dataset for VA included 18 taxa, while that for WV had 20 (Table 5.17). Although the quantities of taxa were similar for each state, only 10 of the 28 total taxa were common to both states. None of the taxa were ferns. Fourteen of the 28 herbaceous taxa had significant indicator value (p-values ≤ 0.05) for at least one group and twelve of these taxa also had significant *phi* coefficients of association for at least one group (Tables 5.17 & 5.18).

Eleven taxa had significant indicator value (p-values ≤ 0.05) for at least one turtle group (FWT, MWT, or FWT+MWT) (Table 5.17). Six taxa were useful for turtle groups in both VA and WV: Cinquefoil, Hog Peanut, Bedstraw (*G. triflorum*), Jewelwort, Violets, and the alien Stiltgrass. The same eleven taxa, except for Blue-stemmed Goldenrod (*Solidago caesia*) which had a marginally significant value, had significant *phi* coefficients of association for turtles (Table 5.18). The eleven taxa useful at the $1m^2$ scale were also useful at the $400m^2$ scale, except for the Blue-stemmed Goldenrod (*Solidago* was not identified to the species level in the $400m^2$ plots) and the two taxa mentioned above with contradictory results between scales (Hawkwort and Virginia Creeper).

Three taxa ($p \leq 0.05$) were indicators for random points of one group or another (FRP or FRP+MRP; Table 5.17) in Virginia. No taxa were indicators for random points in West Virginia, except for Pussytoes, of marginal significance for MRP. By inference, turtles tend to avoid these taxa (see "Study rationale" in Chapter 6). Of the three indicator taxa, Teaberry and Bellworts (*Uvularia* spp.) had significant *phi* coefficients of association for random points (Table 5.18), but Dittany did not; Pussytoes had marginal significance for MRP.

Three of the 11 taxa (27%) that were indicators for turtles were hydrophytic. Five (18%) of the 28 common plant taxa used in the indicator analyses for the $1m^2$ plots were wetland plants (*i.e.*, hydrophytes) (Table 5.17).

In both states in 2013-2014, except for WV females $1m^2$ turtle plots had greater herbaceous taxa richness than did random plots (Tables 5.6 & 5.7, Fig. 5.15).

Virginia $1m^2$. There were significant indicators for three site groups; one taxon for the FRP group, four for the MWT, and seven for the FWT-MWT (Table 5.17). Eleven of these 12 taxa also had significant phi coefficients for the same groups; except *Potentilla* was in the VMT group instead of VWT, and one more taxon (*Solidago caesia*) had a p-value = 0.086 (Table 5.18).

Three groups had significant indicator indices for species pairs. Four taxa were involved for the FWT group, 14 taxa for the MWT group, and 11 taxa for the FWT-MWT group. All of the pairs involved taxa that were significant indicators individually, with the addition of *P. quinquefolia*, *Viola* spp., *A. bracteata, S. caesia, Galium pilosum* (Bedstraw), and *Oxalis* spp. for MWT, *M. vimineum, A. altissima*, *G. triflorum,* and *Solidago* spp. for FWT-MWT, and *I. capensis*, *P. quinquefolia, Viola* spp., and *D. villosa* for FWT. Out of 171 examined combinations, 51 had significant p-values.

West Virginia 1m^2. The only group for which there were significant indicators was the FWT-MWT combination; the taxa involved were Stiltgrass, Violets, and Bedstraw (*G. triflorum*). There were also four more taxa with p-values < 0.09 in the MWT, MRP, and FWT-MWT groups (Table 5.17). Only two groups had significant phi coefficients; the associated taxa were *Potentilla* spp. for the MWT group, and *M. vimineum* for the FWT-MWT combination group. There were also seven more taxa with p-values ≤ 0.10 in the MWT, MRP, and FWT-MWT groups (Table 5.18).

Three groups had significant indicator indices for species pairs. The taxa involved for the MRP group were *Potentilla* spp. and *Antennaria* spp. The taxa involved for the MWT group were *Galium circaezans* (Wild Licorice), *M. vimineum, Viola* spp., *G. triflorum, Potentilla* spp., and *P. quinquefolia*. The taxa involved for the FWT-MWT group were the same three that were significant indicators individually. Out of 210 examined combinations, only eleven had significant p-values.

Woody Seedlings

I recorded 686 presences of 19 native woody seedling taxa in VA (with an additional 2 presences of unknowns) and 230 presences of 10 native seedling taxa (with an additional 4 presences of unknowns) in WV at the $1m^2$ plots in 2013-2014.

The reduced woody seedling dataset for VA included 15 taxa, while that for WV had 10 (Table 5.19). Eight of the 17 total taxa were common to both states. Overall, in the $1m^2$ plots ten taxa had significant indicator value (p-values ≤ 0.05) for at least one group and eight of these ten taxa also had significant coefficients of association for at least one group (Tables 5.19 & 5.20).

The same six taxa (four in VA, two in WV) had significant indicator values as well as significant phi coefficient of association values (p-values ≤ 0.05) for at least one turtle group (FWT, MWT, or FWT+MWT); one was useful in both VA and WV, *Rubus* spp. (blackberries) (Table 5.19). Three taxa had significant indicator value for female + male random point groups; two of these were useful in both VA and WV, Chestnut Oak and *Vaccinium* spp. (blueberries). The same three taxa had significant *phi* coefficient of association values for at least one random point group (FRP or FRP+MRP); only Chestnut Oak was useful in both VA and WV (Table 5.20).

Three of the 8 taxa (37%) that were indicators for turtles were hydrophytic. Five (29%) of the 17 common woody seedling taxa used in the indicator analyses can be considered hydrophytes (they were all "facultative") (Table 5.19).

There was no difference in woody seedling taxa richness between turtle and random points in either state in 2013-2014 (Tables 5.6 & 5.7).

Virginia 1m²

There were significant indicators for four site groups; one taxon each for the FWT and MWT groups, two for the FWT-MWT, and four for the FRP-MRP (Table 5.19). The sole taxon for FWT plots was *Lindera benzoin* (Spicebush) while that for MWT plots was *Ostraya virginiana* (Ironwood). Of significant indicator value for the FWT-MWT group were blackberries and *Smilax* spp. (Greenbrier). Significant indicators for the FRP-MRP sites were Red Maple, Chestnut Oak, Northern Red Oak, and blueberries. As was the case for the indicator value index, four groups had significant phi coefficients: one taxon each for the FWT, MWT, and FWT-MWT groups, and three for the FRP-MRP (Table 5.20). There was also one taxon (*Rubus* spp.) with a p-value = 0.08.

West Virginia 1m²

There were significant indicators for only the MWT and FRP-MRP groups; taxa for MWT plots were *Amelanchier* spp. (Serviceberry) and *Rubus* spp., while those for FRP-MRP plots were Chestnut Oak and blueberries (Table 5.19). Two groups had significant phi coefficients; the taxa for MWT plots were *Amelanchier* spp. and *Rubus* spp., while the significant taxon for FRP plots was *Q. montana* (Table 5.20). There was also one taxon (*O. virginiana*) with a p-value = 0.105.

Herbaceous Richness, Forest Types, Seral Stages, Herbaceous Cover

The herbaceous taxa association analyses for random point 400m^2 plots categorized by forest type groups in each state found few taxa to be indicators for specific forest type groups; of these taxa most were associated with the Mm (6 taxa) or Dm (5 taxa) groups, with one taxon (*Hieraceum paniculatum*) having a significant Pearson's phi coefficient of association for the M group (Table 5.21). There were no indicator taxa for the Od, Om, or P forest type groups.

Most of the 2011-2013 400m^2 plots used in the herbaceous indicator species analyses were in older forest (mature and old growth seral stages), 89.5% of aggregated (both states) turtle points and 77.4% of aggregated random points (Table 5.5). At the WV site, which had no esh or mid-successional stands, 82.3% of turtle points were in mature stands and 17.7% were in old growth, whereas 77.2% of random points were in mature stands and 22.8% were in old growth. In VA, 84.0% of turtle points (males and females pooled) were in stands of older forest, while 65.6% of pooled random points were.

The number of herbaceous taxa in VA random point 400m^2 plots did not differ between seral stages (Fig. 5.16) (ANOVA: $F_{(3,148)} = 0.594$, $p = 0.620$), but the number did differ between forest type groups (Fig. 5.17) (Mm was not used as the sample size was only two): (ANOVA: $F_{(3,146)} = 10.965$, $p < 0.00001$). Mean number of taxa: Dm = 14.1 ± 1.7, M = 6.1 ± 1.7, Mm = 35 ± 0, Od = 7.2 ± 0.6, and Om =

12.1 ± 0.8. TukeyHSD tests (with alpha = 0.0083) found the differences to lie between Dm-M ($p = 0.0075$), Dm-Od ($p = 0.00025$), and Od-Om ($p = 0.00001$).

In contrast, in WV the number of herbaceous taxa in random point 400m^2 plots did not differ between forest type groups (Fig. 5.17) (Od and Dm were not included as the sample size was only three for each): (ANOVA: $F_{(3,69)} = 2.485$, $p = 0.0679$); mean number of taxa: M = 11.9 ± 1.2, Mm = 18.2 ± 3.9, Om = 15.6 ± 1.5, P = 10.8 ± 1.7, Dm = 18.0 ± 2.5, Od = 8.0 ± 2.1.

There was some consistency of pattern among both states (Fig. 5.17). In VA random plots the Od and M forest type groups had the lowest number of herbaceous taxa, while in WV the Od and P plots had the lowest (with M third from the bottom). In both states random plots in Dm or Mm forest types had the highest number of taxa, with Om plots occupying the mid-range of richness. With this in mind, I ran correlation tests and regressions between number of herb taxa in random plots and the importance values of some tree taxa typically associated with the different forest type groups.

For Spearman correlation tests between number of herb taxa and importance values in VA I used Chestnut Oak, Scarlet Oak, and White Ash. Number of herb taxa in a plot and the tree importance value were negatively correlated for SO ($S = 767469$, $p < 0.0001$, rho = -0.364) and less so for CO ($S = 674400$, $p = 0.0146$, rho = -0.199), while WA was positively correlated ($S = 320911$, $p < 0.00001$, rho = 0.429) (Fig. 5.18). However, the regressions using these taxa all had low R^2 values (*ca*. 0.1), indicating that the importance value of a single tree species did not predict much of the variation in herbal richness at sites.

For the WV data I used Chestnut Oak, Virginia Pine, and Sugar Maple. Number of herb taxa in a plot and tree importance value were negatively correlated for both VP ($S = 1008113$, $p < 0.00001$, $rho = -0.371$) and CO ($S = 963726$, $p < 0.0001$, $rho = -0.311$), while SM was positively correlated ($S = 419342$, $p < 0.00001$, $rho = 0.430$) (Fig. 5.19). As in VA, the regressions using these taxa all had low R^2 values (*ca*. 0.1).

In both states in 2011-2014, $1m^2$ turtle plots had significantly more herbaceous cover (forbs and grass combined) than did random plots (Tables 5.6 & 5.7, Fig. 5.20). Amount of herbaceous ground cover had a weak negative correlation with distance from the main streams ($S = 595000$, $p < 0.0001$, $rho = -0.362$).

Discussion

I evaluated relationships between floristic composition and structure and Wood Turtle habitat use. The underlying question for a study such as this is: What life-history requirements are met by the use of a habitat (Beyer *et al*. 2010)? Prudent choices are necessary in order to obtain adequate energy, find refuge from predators, and avoid environmental extremes; these choices and activities may increase or decrease the use of available habitats (Halstead *et al*. 2009, Willems and Hill 2009). Wood Turtles preferred or avoided specific herbaceous and woody taxa and forest types, but these sometimes differed between the states. Both structural and compositional characteristics of forest ground floor habitat may directly affect the turtles' foraging success, vulnerability to or avoidance of predators, and osmo- and thermo-regulatory options; overstory canopy structure and composition may directly affect or indicate these potentialities as well.

Herbaceous and Seedling Taxa

Over thirty herbaceous and woody taxa were indicators for Wood Turtles at the $400m^2$ and/or $1m^2$ scales at these VA and WV study sites (Tables 5.13-5.20), including most of the taxa referenced above (in "Focal Species"). The herbaceous indicator taxa discerned by this study, as well as the overstory tree taxa of note, are found throughout the Wood Turtle's range or at least a large portion of it (Fernald 1950, Newcomb 1977, Burns and Honkala 1990). Localized edaphic, topographic, and moisture conditions determine the presence of these flora at finer spatial scales within their broad-scale distributions (Braun 1950, Cantlon 1953).

There was solid concordance between the results of the indicator species analyses and those of the *phi* coefficient of association analyses (Tables 5.13-5.18). With few exceptions, the same taxa were significant in each methodology, a congruence that militates for the accuracy and usefulness of the results. There was also general concordance between the results of the analyses at the $1m^2$ and $400m^2$ scales. There was limited congruence, however, between the states as to the taxa that indicated preference by Wood Turtles (Tables 5.13 & 5.17). Only eight indicator taxa were common to turtles in both VA and WV at the $400m^2$ or $1m^2$ scales. This evidence suggests habitats composed of different forest types be evaluated separately, even when they are in close geographic proximity. Notwithstanding differences in composition, in both states Wood Turtle plots at both spatial scales had greater herbaceous taxa richness than did random plots (Figs. 5.14 & 5.15), which also was the case at a WV river site (McCoard *et al*. 2016b). Another salient result involved herbaceous cover which was clearly greater at turtle points than random points (Fig. 5.20). It is also noteworthy that the great majority of taxa and presences at my forest sites were of native species.

Another pattern is the relative paucity of wetland species both in the overall herbaceous species lists as well as those that serve as indicators. Though the Wood Turtle is often characterized as a riparian species or denizen of wet areas (see, *e.g.*, McCoard *et al*. 2016b or USDA FS $$$$), they clearly use dry uplands a great deal. Most of the indictors were upland or facultative upland taxa (Tables 5.13, 5.17, 5.19). Many of the species with which the Wood Turtles were commonly associated are found in sites of intermediate soil moisture, while some, such as *Ageratina altissima, C. oreganoides, D. villosa, E. divaricata, G. triflorum, Maianthemum racemosa, M. repens, P. obovata, Polygonatum biflorum,* and *Potentilla* spp. can be regularly found in dry settings (Hutchinson *et al.* 1999, Weakley *et al*. 2012). Because many of the species used in the indicator analyses have somewhat broad habitat niches (at least when within relatively undisturbed forests), it is not surprising that only a limited number were useful as indicators for specific forest type groups (Table 5.21). In Beech-Maple and Maple-Basswood forests in Michigan and Minnesota, Rogers (1981) similarly found broad overlap in herbaceous composition in stands of different forest types.

Only one species was an indicator for random points for both states at the $400m^2$ scale, Spotted Wintergreen (*C. maculata*). In addition, one alien species, Beefsteak Plant, served as an indicator for turtle sites in WV, but for random sites in VA. McCoard and colleagues (2016b) elsewhere in WV also found Bedstraw (*Gallium* spp.) to indicate Wood Turtle sites. One taxon that served as an indicator for female Wood Turtle sites in VA, *Boehmeria cylindrical* (False Nettle), was also preferred by Eastern Box Turtles (*Terrapene carolina*) at a coastal plain site in Maryland (McKnight 2011).

As with the herbs, most of the woody seedling taxa found in turtle plots were facultative upland or upland taxa; only three of the seedling indicator taxa were classified as wetland species (Table 5.19). This is further evidence that Wood Turtles regularly use habitats far outside of riparian or wet areas. Though Spicebush (useful for VA females) prefers moister site conditions (Weakley *et al*. 2012), most of the seedling taxa useful as indicators for Wood Turtles (Ironwood, Greenbriar, Serviceberry, and Blackberry) are found in various types of forested settings (Hutchinson *et al*. 1999, Burns and Honkala 1990, Weakley *et al*. 2012); further indication that Wood Turtles commonly use different types of forest. Turtles may have been feeding on the leaves of seedlings (such as Greenbrier) or on the fruits of species found in the shrub or tree layer (*e.g.*, Serviceberry or Spicebush) that had seedlings in the understory.

Overstory Tree Composition and Structure

The results of the conditional logistic regressions, CARTs, and G-tests were concordant; the same species and species groups consistently showed up as important drivers of habitat preference. Although some general tendencies are apparent, particularly the avoidance of sites with a high component of Chestnut Oak, the somewhat low discriminatory power exhibited by the some of the CARTs (only "fair" K values), the low number of regression coefficients that did not overlap zero, and the fact that most tree taxa were not indicative of habitat partitioning or preference, all signify that Wood Turtles use sites with many different tree taxa and proportions of tree taxa (*i.e.*, different forest types). The indicator species of import (*e.g.*, White and Chestnut Oaks, Red and Sugar Maples, White Pine) as well as the other taxa are broadly distributed in eastern North America and most are found throughout or in large portions of the Wood Turtle's range (see maps in Burns and Honkala 1990 and Turtle Taxonomy Working Group 2017).

In the United States Wood Turtle distribution occurs in the following broad-scale forest type regions as defined by Braun (1950) and Dyer (2006):

Mesophytic Region (VA, MD, DE),

Appalachian Oak Section of the Mesophytic Region (VA, WV, MD, PA, NJ, NY, CN, RI, MA, NH, ME),

Beech – Maple – Basswood Region (PA, NY, WS, MN, IA),

Northern Hardwoods – Hemlock Region (PA, NY, CN, MA, VT, NH, ME),

Northern Hardwoods – Red Pine Region (MI, WS, MN).

As with the herbaceous flora, there is a great deal of overlap of tree species among the different large-scale eco-regions where the Wood Turtle occurs (Ashe 1922, Braun 1950, Newcomb 1977, McNab and Avers 1994, Woods *et al*. 1999, Burns and Honkala 1990, Dyer 2006, McNab *et al*. 2007). Generally, throughout the turtle's range a relatively large number of tree species (16-35) predominate at any particular location (Dyer 2006, Rentch 2006); this study area comports with this pattern (Table 5.2).

Just as at the broadest scale (*i.e*., the regional species distribution level), Wood Turtles at the local scale use a range of different forest types. Overall, at least ten forest types were used at this study area (Table 5.4), though some were used more than others, with the oligotrophic oak sites (Od) in particular being used less than expected based upon their availability (Figs. 5.1 & 5.2). In concordance with this finding, the analyses of individual taxa indicated Wood Turtles tended to avoid sites with high importance values for Chestnut and Scarlet Oaks (Table 5.9, Figs. 5.9 & 5.13). Domination by these taxa is generally indicative of nutrient poor sites (oligotrophic) (Burns and Honkala 1990, Fleming and Coulling 2001, Weakley *et al*. 2012). At plots with a component of Chestnut Oak, the CART results indicated VA Wood Turtles preferred sites with relatively higher importance values for Sugar Maple and White Oak and relatively lower values for Hickories (Fig. 5.10).

The preference for Sugar Maple in VA and Red Maple in WV may have to do with site productivity (higher nutrient availability) and/or moisture regimes. The forests are different in each state, with Red Maple, a generalist, typically found in more mesophytic associations at the WV site, while in VA it is more widespread, being abundant also in drier oligotrophic sites as well as in tracts of both older (mature and old growth) and younger age (early and mid-successional seres). The preference for sites with high importance values for Virginia Pine by WV females may be due in part to the high amounts of grass cover often found in these tracts (cover of 10.7% ± 3.4 in $1m^2$ plots at random point sites with a VP IV > 25 vs. 3.7% ± 0.9 at RP sites with a VP IV < 25; mean grass cover in $1m^2$ plots at WV female turtle points was 9.9% ± 1.8; Fig. 5.21 illustrates an example). Locations with high importance values for White Oak, White Ash, Sugar Maple, Elm, Basswood, and Serviceberry can be mesic or sub-mesic sites that are generally productive (Burns and Honkala 1990, Fleming and Coulling 2001, Weakley *et al.* 2012) and have high herbaceous species richness (Fig. 5.17). In contrast, the turtles' tendency to avoid sites with high importance values for White Pine in WV (Fig. 5.7) may be reflective of types of forest, pine or mixed pine/deciduous, with low productivity and low amounts of grass cover (mean cover in $1m^2$ plots at random points with WP IV > 49.7 was 1.85 ± 0.39 vs. 6.81 ± 1.51 in RPs with WP IV < 49.7); mean amount of grass cover in $1m^2$ turtle plots in WV was 10.46% ± 1.40. As with edible herbaceous flora, the abundance or presence of mushrooms or invertebrate prey or the amounts of ground cover (facilitating avoidance of predators) might also be correlated to the predominance of different tree taxa (*e.g.*, increased earthworm activity on sites with higher pH). The ostensible avoidance by male Wood Turtles of White Oaks and Red Maple in Virginia and of Sugar Maple and White Pine in West Virginia is difficult to reconcile with site conditions where such taxa occur. This result may be a statistical artifact that does not reflect biological necessity.

Forest Types and Seral Stages – Patch Scale

My study exemplifies that the scale at which habitat patches are categorized can be a significant factor in accurately portraying habitat use. When the difference in forest type groups were characterized at the stand scale (patches generally 10-20ha) there were no significant differences between WV turtle and random points, though differences did occur for two of the five groups in VA (Fig. 5.3). Such results could be interpreted as showing that Wood Turtles do not exhibit habitat preferences with regard to types of forest. When forest types were examined at the scale of $400m^2$ plots, however, significant differences between turtle and random points consistently occurred (Fig. 5.2), with turtles exhibiting a preference for mesic deciduous (Dm), mesic mixed pine and deciduous (Mm), and sub-mesic oak (Om), while showing a tendency to avoid tracts of oligotrophic oak (Od) and pine (P). Clearly, simply using easily downloaded forest type characterizations made at the stand spatial scale is not sufficient for inferring habitat selection by an animal with small home ranges or activity areas (0.2-13.3ha for this study, with a mean of 2.3ha for 59 telemetered Wood Turtles during June-August in 2011-2014; see Chapter 1).

If stand-scale characterizations were accurate for entire stands (*i.e.*, within-stand forest composition was homogeneously distributed), then there would be no difference between the observed frequencies of turtle or random points when characterized at the stand or plot scales. Which was not the case; there were consistently different frequencies for points characterized at the two different scales (Fig. 5.4), in large part due to discrepancies within the Om and P forest type groups. In VA, numerous 400m^2 plots within stands characterized as Om were actually Od or Dm, while numerous plots in WV within stands characterized as P were actually M and many of those in stands characterized as Om were actually M, Dm, or Mm. Submergent properties at spatial scales of relevance to Wood Turtle habitat use are not evident at coarse grained stand categorization where pertinent discriminatory details of pattern are lost. While the use of stand-scale or more coarsely defined land cover characterizations may be suitable for modeling Wood Turtle population distribution across broad landscapes, this study indicates a finer resolution is required for ascertaining preferential use of habitats by individuals within populations.

As for coarse-filter structural differences (*viz*., seral stages), Wood Turtles exhibited a tendency to avoid mid-successional and early successional habitat (Figs. 5.7 & 5.8); by esh I refer here to young stands of forest regenerating after logging, not to shrubby or grassy ruderal or natural openings in the forest. Wood Turtles showed a preference for small natural or anthropogenic clearings dominated by shrubs (*e.g*., Autumn Olive (*Elaeagnus umbellata*)) or herbaceous ground cover, including dry as well as moist sites (*i.e*., seeps) (Fig. 5.2). These types of shrubby or grassy clearings with few or no overstory trees are lumped into the early successional rubric under some land cover classifications. However, they are structurally and often compositionally different than young sites of regenerating forest with high stem densities of saplings. Managerial mishaps are possible when relevant distinctions of pattern go unrecognized within categorical coalescence.

Synthesis

This study is consistent with others in finding that Wood Turtles have an affinity for microhabitats with an abundance of herbaceous cover (Compton *et al*. 2002, Akre and Ernst 2006, McCoard 2016a). Such sites can be found far from streams and are not limited to floodplains or riparian areas (this study). For instance, small natural canopy gaps are regularly used by Wood Turtles (Remsburg *et al*. 2006, this study) and are important for sustaining herbal growth, richness, and persistence (Goldblum 1997, Anderson and Leopold 2002). By allowing for a greater range of forest floor light levels and temperature regimes, gaps allow for more floristic richness or abundance and enhanced thermoregulatory opportunities.

The forest growth at a particular site is due to the complex interplay of numerous physical factors, disturbance regimes, and biotic interactions (Ashe 1922, Gleason 1926). Localized factors such as disturbance, elevation, slope, aspect, topographic position, slope configuration, and moisture availability are primary influences on the composition of tree taxa at forested tracts in the Central Appalachians (Lawrence *et al*. 1997). As they mature, seedlings sort out on slopes along gradients of light, moisture, and nutrient availability. For instance, McCarthy *et al*. (1984) found that oak species (*Quercus rubra, prinus*, and *coccinea*) were distributionally replaced based on relative resistance to low soil moisture and nutrients. At montane sites in western Virginia, differences in soil moisture and depth, aspect, and topography explained differences in vegetation on upper and lower slopes (Stephenson and Mills 1999). In an eastern Kentucky deciduous forest, north aspect slopes had higher productivity (McEwan and Muller 2011). Shifts in floristic composition can be particularly facilitated where disturbances occur in the presence of advanced regeneration (tree seedlings that are already present on site) (Goins *et al*. 2013).

In both states, both 400m^2 and 1m^2 turtle plots contained significantly more herbaceous taxa than did random plots (Figs. 5.14 & 5.15). If certain herbaceous plants are an important foraging resource, Wood Turtles may be differentially using forest tracts dominated by different tree taxa. This study provides some evidence that the number of herbaceous taxa in the 400m^2 plots at these VA and WV sites varied with forest type; Fleming and Coulling (2001) reported a similar finding in montane VA, as did Hutchinson and colleagues (1999) in the Appalachian region of SE Ohio. This may be a reason the Wood Turtles tended to avoid sites dominated by Chestnut and Scarlet Oaks or Virginia and White Pines. Perhaps this is a bet-hedging stategy in that at any given time sites with greater herbaceous richness are more likely to have some taxa one can use. However, since forest development is a complex of climatic, topographic, and edaphic influences, complicated by biotic interactions (competition, predation, symbioses) and historical contingency, any correlations which can be discerned involving specific tree and herbaceous taxa must be accepted with reservations.

In West Virginia Rentch and colleagues (2005) found the lowest herbal richness in Chestnut Oak forests; these tracts were associated with acidic conditions, which typify my study sites (Fleming 2012). In Kentucky, oak plots were in the driest most nutrient poor sites, while maple species were in the more mesic and nutrient rich sites (McEwan and Muller 2011). The maple communities had significantly greater richness than the oak communities, though the floristic diversity within these oak or maple communities was indistinguishable over the growing season. During the growing season plants can regenerate the consumed parts, so faunal movements can be curtailed and foraging can continue within the same area for extended periods (Owen-Smith *et al*. 2010). Understory species composition and richness in SE Ohio oak forests were correlated with soil moisture and pH (DeMars and Runkle 1992, Hutchinson *et al*. 1999). The age (seral stage) of forest tracts influences the herbaceous community present there; disturbance sensitive species are underrepresented in secondary forests (DeMars and Runkle 1992, Dyer 2010, Matlack and Schaub 2011). However, in SE Ohio forests Olivero and Hix (1998) found herbaceous plant assemblages to vary between aspects, but not with stand age. Composition in Kentucky forests correlated with light flux and soil moisture related to canopy openness, evaporation, and aspect (Adkison and Gleeson 2004). In Ohio, herb species richness was higher on south aspect slopes, but density was greater on north aspect slopes (Small and McCarthy 2003). Aspect can correlate with pH and other soil fertility measures (McEwan *et al*. 2005). Fine-scale (tens of meters) variation in nitrogen and light availability affects understory communities (Frelich *et al*. 2003). The herbaceous layer responds to disturbances in each of the three major vertical layers in a forest ecosystem, *viz*., the overstory canopy, understory vegetation, and the forest floor and soil (Roberts 2004). As an outcome of timber harvesting, local floristic distributions can be reduced or altered (Meier *et al*. 1995). Some fauna in turn could be forced into smaller fragments of intact forest which could potentially increase interspecific competition or exposure to predators (Hagan *et al*. 1996). Habitat fragmentation and loss may potentially increase or decrease either the frequency or the distance of individual movements (Fahrig 2007). As the above citations make clear, multiple physical factors affect floristic composition and distribution, thus Wood Turtle habitat use can be directly or indirectly influenced as well.

The Wood Turtle data used in this study lack a discrete behavioral context. Although animal behaviors can occur synchronously, *i.e*., multi-tasking (Fortin *et al*. 2004), many behaviors are asynchronous since the habitat characteristics associated with meeting different needs are spatially segregated (Roever *et al*. 2014). Behaviors can have opposing habitat selection patterns, thus obscuring the detection of selection in pooled models (Roever *et al*. 2014). For instance, a patch may provide optimal cover from predators or osmo-regulatory benefits, but sub-optimal provision of food resources (Downes 2001). Selection of food patches can be examined in terms of which plant species are accepted for feeding when encountered (Owen-Smith *et al*. 2010). Precise measures of foraging benefits to Wood Turtles would involve close-range observations on the precise types of plants consumed, their age or condition, estimates of their nutritional value, and the food intake rate.

Though herbaceous taxa richness and cover were positively correlated with White Ash, and VA Wood Turtles showed a preference for sites with high importance values for White Ash, it may be difficult to use this species as a management indicator. When I visited the VA site in the summer of 2016, every mature White Ash I observed was dead. Loss of White Ash due to the Emerald Ash Borer (*Agrilus planipennis*) will open up niche space and cause a shift in tree composition across wide areas of the Turtle's distribution. Based on similar affinities for elevation, soil fertility/pH, and moisture regimes (Burns and Honkala 1990, Mueller 2000), taxa such as Tulip Tree, White Oak, Sugar Maple, Red Maple, Basswood, Black Cherry, Elms, or Cucumber Magnolia (*Magnolia acuminata*) may increase in dominance at sites vacated by White Ash.

It must be remembered that just because a site has high amounts of White Pine or Chestnut or Scarlet Oaks does not mean that Wood Turtles cannot or do not use it; *e.g.*, nearly a third of VA turtle points had a substantial component of CO. In fact, at the plot with the highest importance value for any single tree species, a value of 98 for Chestnut Oak, a Wood Turtle was present. Such sites can have habitat attributes that the turtles prefer, such as LWD, abundant mushrooms, particular forbs, or dense understories. Though the CART analysis results for VA found that *ca*. 70% of the turtle points could be discerned from random points on the basis of the low importance value of Chestnut Oak alone, this still leaves 30%

of the points that were not distinguished. For a rare and vulnerable species this degree of uncertainty is particularly important, meaning that precaution must be exercised when devising forest management prescriptions based on turtle preferential tendencies regarding importance values or forest type groups. There are complexities involved even for a category as ostensibly fine-grained as a forest type utilized by the USFS or other agency; for example, multiple types of “Chestnut Oak forest” can be distinguished by differences in their understory flora (Fleming and Coulling 2001).

This study presents evidence that some forest types are avoided or preferred more than others. If this is indeed factual, one must not automatically conclude that it is acceptable to cut down stands of a relatively avoided forest type (*e.g.*, Chestnut Oak or White Pine). Wood Turtles are labile in their use of sites with different tree taxa and proportions of tree taxa (*i.e.*, different forest types); for example, *ca*. 16% of Wood Turtle plots were pine or oligotrophic oak (Table 5.3). Moreover, the scale at which forests are typically intensively logged (individual tracts of 10-20ha or more) is not the spatial scale at which Wood Turtles typically move about in the summer (*ca*. 1-2 ha). Stands that may be of a non-preferred type can have many inclusions of smaller tracts of preferred forest. So, since forest “stands” are not homogeneous (Fig. 5.6), this scale should not be used when managing Wood Turtle habitat from a silvicultural perspective. If a decision is made that forested tracts of a certain composition can be logged without negative impacts to Wood Turtles because they are of a non-preferred type (*e.g.*, Chestnut Oak or White Pine), such habitat removal must still be accomplished at the appropriate scale, meaning small tracts of individual selection or small group selection, and appropriate time (implemented only during winter months when Wood Turtles are totally aquatic).

Conservation Recommendations

Though often characterized as a riparian species (see, *e.g.*, McCoard 2016b or USDA FS $$$$), Wood Turtles regularly range far afield in dry upland habitats; *ca.* 95% of turtle location points were within 295 meters of the main streams, with some turtles ranging out as far as 500-700m. The understory and overstory analyses of this study clearly show that Wood Turtles in the summer regularly use a broad range of forested upland habitats, not just those nearby streams or dominated by mesic or hydric flora. A 300 meter minimal disturbance zone on both sides of occupied perennial streams would protect areas and conditions essential to their survival. The taxa and factors identified herein can be used for well-informed decisions regarding management practices, protective measures, and habitat enhancement/restoration (*e.g.*, fabrication of small canopy gaps), as well as make predictions as to the suitability of sites as potential or current Wood Turtle habitat.

The findings of this study in the central Appalachians are of particular relevance and applicability across areas with similar ecological conditions, *i.e.*, ecoregions with forests of similar composition (Dyer 2006, McNab *et al.* 2007). Ecoregions by definition share similar species compositions, topography, and climate, thus serve as a reasonable mechanism for extrapolation (Omernik and Bailey 1997). If extrapolation using ecoregional commonality is reasonable for

Wood Turtles, then the results from this study may be applicable to other sites in Virginia, West Virginia, Maryland, Pennsylvania, New York, New Jersey, and Massachusetts. The oak forest habitat deemed to be suitable at the broad-scale that is currently found in these states could also greatly expand in extent under some climate change scenarios (Iverson *et al*. 2008).

An understanding of the ecological processes under which vegetational communities develop is needed in order to determine the effects of management practices upon them and in turn upon Wood Turtles. At any site, multiple successional pathways are possible post-disturbance (Egler 1954, Connel and Slatyer 1977). Various factors are responsible for this (*e.g.*, site-specific physical conditions or the abundance of browsers), but it partially depends upon the starting point (see "initial floristic composition" in Egler 1954, Roberts 2004). For trees in particular this means the existence of a seed bank and advanced regeneration (the seedlings already growing at a particular site). The types and amounts of these are important for determining precisely if or where to subject an area to anthropogenic disturbance.

In recognition of our poor understanding of the precise mechanisms of extirpation, habitat selection, and community development, the results of this study suggest that where Wood Turtle populations occur in this ecoregion simply letting forests within the 300m buffer zones develop mature and old-growth conditions under a natural disturbance regime, regardless of their type, would be the best and least expensive course. Habitat complexity generally increases as forests age

(Franklin *et al*. 2002) and, amongst other benefits, this complexity provides refugia from predators (Finke and Denno 2006). A body of research indicates that canopy gaps, herbaceous vegetation, mushrooms, invertebrate richness or abundance, snags, and large woody debris amounts are generally more abundant in older forest habitats (Whitney and Foster 1988, Meier *et al*. 1995, Greenberg and Forrest 2003, Van de Poll 2004, Ziegler 2004, Webster and Jenkins 2005, Keeton *et al*. 2007, Scheff 2014). For instance, the stand-initiation and stem-exclusion stages of seral development (*sensu* Oliver and Larson 1996) (*i.e*., early successional habitat with high density of saplings) is commonly characterized by a depauperate herbaceous layer (Halpern and Spies 1995, Roberts 2004).

This precautionary approach (Cooney 2004) of minimizing human impacts and allowing old-growth forest conditions to develop through natural processes (*i.e*., restoration by "purposeful inaction", Trombulak 1996) is beneficial to not only Wood Turtles. The flowers, fruits, nuts, leaves, roots, bark, and sap of many of the herbaceous, woody, and fungal taxa found where Wood Turtles occur have significant human nutritional, medicinal, and application value (Angier 1974, Horn and Cathcart 2005, Strauss 2014, United Plant Savers 2017). Aside from their ecological functionality, these non-timber resources can provide significant economic and social benefit without commercial logging taking place. See Chapter 6 and "Small Streams, Springs, and Seepages" and "Hardwood Forests" modules in Mitchell *et al.* (2006) for other general habitat management guidelines.

Prescribed fire has been suggested as a management tool for eastern deciduous forests. Fire may not be necessary, however, for maintaining and regenerating northeastern oak forests and increased frequency of burning could potentially reduce forest herb and shrub diversity (Elliot *et al*. 2004, Matlack 2013). Decay processes generally tend to mesify microsites while fire tends to xerify them (Van Lear 1996). Hence, burning is of concern for Wood Turtles, not only due to the potential for direct mortality (for fires that occur outside of their hibernation period) and the deleterious alteration of forest composition and structure, but also because it tends to make sites hotter, drier and more open, thereby exposing turtles and other small organisms to more predators and desiccation.

The diminishment of the importance value of oaks in some eastern forests is often characterized in a negative light, however, this so-called mesification of forests (resulting in, *e.g*., relatively more maples) can be of benefit to some taxa, including the Wood Turtle (see Figs. 5.1, 5.2, 5.9-5.13). The mesification of oak forests is not ubiquitous, but is a trajectory dependent upon various topographical and ecological gradients (McEwan and Muller 2006, Iffrig *et al*. 2008, Loewenstein 2008). Increased frequency of fires may have allowed oak dominance to expand into mesic sites (White and White 1996). The general increase in mesic conditions over time is considered a natural process ("xerarch succession" in Braun 1950, Foster *et al*. 1996), particularly to be expected after the unnatural expansion of oak domination facilitated by various direct and indirect anthropogenic disturbances at multiple scales (*e.g.*, even-age logging and increased burning) (Foster *et al*. 1996, McEwan *et al*. 2010).

Because Wood Turtles regularly range far afield in dry upland habitats, providing protection to a narrowly delineated stream buffer zone, such as typically used 10-30 meters wide riparian strips (Lee *et al*. 2004, USFS 2004), while at the same time degrading or destroying other used habitat, does little to preserve or enhance populations. In other words, narrow or inadequately protected riparian buffer zones often fail to effectively protect the "core habitat" of Wood Turtles and a host of other species (Semlitsch and Bodie 2003, Crawford and Semlitsch 2007, Sterrett *et al*. 2011). Biologically realistic expansive protected zones are needed to accommodate movements and reduce edge effects such as predation (Burke and Gibbons 1995, Joyal *et al*. 2001, Steen *et al*. 2012); for example, predation on artificial Wood Turtle nests (Rutherford *et al*. 2016) and neonates (Dragon 2015) decreased as distance from rivers increased. Perennial stream courses occupied by Wood Turtles in this and similar ecoregions should be buffered on both sides by at least a 300m minimal disturbance zone in order to mitigate for impacts to Turtle population viability and protect areas and conditions essential to their survival. This 300m zone is a bare minimum as it may not be expansive enough to include extensive pre-nesting movements of females or connectivity to other populations; conversely, in some situations the 300m standard could be reduced due to ownership patterns, topography, or habitat type (*e.g.*, cliffs or already existent agricultural sites).

Table 5.1

Importance values of overstory and midstory (dbh ≥ 10cm) tree taxa present in 400m2 plots at turtle and paired random points

Mean importance values of overstory and midstory (dbh ≥ 10cm) tree taxa present in 400m^2 plots at Wood Turtle points and random points in Virginia and West Virginia during June-August 2011-2014. Values for minor species not shown. VFT = Virginia females (n = 144 [points, not turtles]), VFR = Virginia female random points (n = 144), VMT = Virginia males (n = 53), VMR = Virginia male random points (n = 53), WFT = West Virginia females (n = 74), WFR = West Virginia female random points (n = 74), WMT = West Virginia males (n = 49), WMR = West Virginia male random points (n = 49). "n" refers to numbers of plots, not numbers of individual turtles. See Appendix 5 for common names of trees.

Taxon	VFT	VFR	VMT	VMR	WFT	WFR	WMT	WMR
Acer rubra	15.5	15.0	13.2	19.7	4.4	1.9	4.3	1.0
Acer saccharum	2.7	0.7	5.0	1.8	6.2	2.9	4.2	6.1
Amelanchier spp.	1.4	0.8	0.6	0.4	0.6	0.6	0.4	0.3
Betula lenta	1.6	1.4	0.9	1.3	0.0	0.0	0.0	0.0
Carya spp.	4.0	5.1	4.4	4.0	13.0	9.9	12.6	12.8
Cornus florida	0.0	0.4	0.5	0.5	0.8	0.4	0.4	0.5
Fraxinus americana	7.6	1.7	7.7	3.2	0.4	0.0	1.1	0.4
Liriodendron tulipifera	10.6	10.0	7.0	2.0	0.6	0.0	0.2	0.0
Nyassa sylvatica	5.4	5.7	4.4	4.3	1.1	0.9	0.6	0.1
Ostraya virginiana	0.6	0.6	0.9	1.5	0.5	0.0	0.1	0.0
Pinus rigida	0.4	0.3	0.2	0.2	0.5	0.4	1.1	0.4
Pinus strobus	1.9	1.6	4.2	3.2	26.1	27.7	29.6	36.0
Pinus virginiana	1.0	0.9	4.6	2.5	13.6	16.8	13.2	12.9
Platanus occidentalis	0.4	0.0	0.9	0.0	2.7	0.1	1.3	0.0
Prunus serotina	0.3	0.6	0.2	0.4	1.2	1.0	1.7	0.6
Quercus alba	20.1	12.3	23.7	16.3	17.0	18.0	20.2	16.3
Quercus coccinea	3.6	7.7	4.6	12.4	0.4	0.8	0.0	0.4
Quercus montana	10.6	23.2	6.0	16.6	3.5	8.2	1.2	4.9
Quercus rubra	6.8	6.9	6.2	5.7	4.1	6.1	3.9	6.7
Quercus velutina	1.3	3.0	0.6	2.3	0.3	0.6	0.0	0.0
Robinia pseudo-acacia	1.5	0.9	1.2	0.4	0.0	0.1	1.6	0.0
Tilia americana	0.1	0.4	1.1	0.7	1.0	0.1	0.4	0.1
Ulmus spp.	0.6	0.1	0.9	0.4	0.7	0.1	1.3	0.5

Importance values of tree taxa in 400m² plots at pooled turtle and paired random points in VA and WV

Mean importance values of common overstory and midstory (dbh ≥ 10cm) tree taxa present in $400m^2$ plots at Wood Turtle points and points in Virginia and West Virginia during June-August 2011-2014. Values for minor species not shown. FWT = female turtles (n FRP = female random points (n = 218), MWT = male turtles (n = 102), MRP = male random points (n = 102), VWT = Virginia turt 197), VRP = Virginia random points (n = 197), WWT = West Virginia turtles (n = 123), WRP = West Virginia random points (n = 123 turtle points (n = 320), RP = random points (n = 320). "n" refers to numbers of plots, not numbers of individual turtles. Totals do nc 100 because the IVs of 20 minor taxa were excluded. See Appendix 5 for common names of trees.

Taxon	**FWT**	**MWT**	**FRP**	**MRP**	**VWT**	**WWT**	**VRP**	**WRP**	**WT**	**RP**
Acer rubra	11.8	9.0	10.6	10.6	15.1	4.1	16.2	1.6	10.9	10.6
Acer saccharum	4.1	4.7	1.5	3.8	3.2	5.8	1.0	3.9	4.3	2.2
Amelanchier spp.	1.1	0.5	0.8	0.4	1.2	0.5	0.7	0.5	0.9	0.3
Betula lenta	1.0	0.5	0.4	0.7	1.4	0.0	1.4	0.0	0.9	0.6
Carya spp.	7.2	8.2	6.8	8.1	4.2	13.7	4.8	10.5	7.6	7.2
Cornus florida	0.2	0.5	0.4	0.5	0.1	0.7	0.4	0.4	0.3	0.3
Fraxinus americana	5.2	4.7	1.1	1.6	7.6	0.6	2.0	0.2	5.0	1.3
Liriodendron tulipifera	7.3	3.6	6.3	1.0	9.5	0.5	7.8	0.0	6.1	4.6
Nyassa sylvatica	4.0	2.5	4.1	2.4	5.1	0.9	5.3	0.8	3.5	3.6
Ostraya virginiana	0.6	0.5	1.0	0.7	0.7	0.4	0.8	0.0	0.6	0.9
Pinus rigida	0.5	0.7	0.3	0.4	0.4	0.8	0.3	0.4	0.5	0.3
Pinus strobus	9.5	16.8	10.3	18.9	2.5	27.0	2.0	30.8	11.8	13.1
Pinus virginiana	5.5	8.8	6.4	7.6	2.4	14.2	1.3	16.3	6.6	6.8
Platanus occidentalis	1.3	1.1	0.4	0.0	0.5	1.8	0.0	0.1	1.3	0.3
Prunus serotina	0.7	0.9	0.8	0.6	0.3	1.3	0.6	0.7	0.8	0.4
Quercus alba	18.8	21.7	14.2	16.5	20.7	18.4	13.4	17.1	19.7	14.9
Quercus coccinea	2.6	2.5	5.4	6.9	4.2	0.2	9.2	0.6	2.5	5.9
Quercus montana	8.3	3.8	18.3	11.1	9.1	2.4	21.5	7.8	6.9	16.0
Quercus rubra	5.9	5.0	6.7	6.2	6.7	3.9	6.6	5.9	5.6	6.5
Quercus velutina	1.0	0.3	0.8	1.1	1.1	0.2	2.8	0.5	0.8	0.9
Robinia pseudo-acacia	1.0	1.5	0.3	0.2	1.4	0.6	0.8	0.1	1.1	0.2
Tilia americana	0.3	0.8	0.6	0.4	0.4	0.8	0.5	0.1	0.5	0.5
Ulmus spp.	0.6	1.1	2.0	0.4	0.6	0.4	0.2	0.2	0.8	1.5
Totals	98.5	99.7	99.5	100.0	98.4	99.2	99.6	98.5	99.0	98.9

Table 5.3

Forest type groups of 400m^2 plots at turtle and paired random points

Forest type groups of 400m^2 plots at Wood Turtle points and paired random points in Virginia and West Virginia during June-August 2011-2014 (based on importance values of all trees with dbh $\geq$ 10cm in each plot); for each turtle group row, numbers on top indicate counts of plots of that forest type, with proportions (%) of total plots in each turtle group below. **Forest types used to define groups** (USFS terminology): 3 = White Pine, 10 = White Pine – Upland Hardwoods, 33 = Virginia Pine, 39 = Table Mountain Pine, 41 = Cove Hardwoods – White Pine, 42 = Upland Hardwoods – White Pine, 45 = Chestnut Oak – Scarlet Oak – Yellow Pine, 52 = Chestnut Oak, 53 = White Oak – Northern Red Oak – Hickory, 54 = White Oak, 56 = Tulip Poplar – White Oak – Northern Red Oak, 59 = Scarlet Oak, 60 = Chestnut Oak – Scarlet Oak. **Forest type groups**: Br = brushy (ruderal), Dm = mesic deciduous (includes forest type 56), M = dry mixed pine and deciduous (FTs 10, 42, 45), Mm = mesic mixed pine and deciduous (FT 41), Od = oligotrophic oak (FTs 52, 59, 60), Om = sub-mesic oak (FTs 53, 54), P = pine (FTs 3, 33, 39), Seep = sparse canopy with saturated soil, Ced = Eastern Red Cedar. **Turtle groups:** V = Virginia, W = West Virginia, FT = female turtle locations, FR = female random points, MT = male turtle locations, MR = male random points, WT = turtle locations (males and females pooled), TR = random points locations (points for males and females pooled).

Forest Type Groups

	Br	Dm	M	Mm	Od	Om	P	Seep
VFT	2	49	3	5	25	58	0	2
(n=144)	1.4	34.0	2.0	3.5	17.4	40.3	0	1.4
VFR	1	21	4	1	68	49	0	0
(n=144)	0.7	14.6	2.8	0.7	47.2	34.0	0	0
VMT	4	12	1	4	6	23	2	1
(n=53)	7.5	22.6	1.9	7.6	11.3	43.4	3.8	1.9
VMR	0	4	6	2	23	18	0	0
(n=53)	0	7.5	11.3	3.8	43.4	34.0	0	0
VWT	6	61	4	9	31	81	2	3
(n=197)	3.1	31.0	2.0	4.6	15.7	41.1	1.0	1.5
VTR	1	25	10	3	91	67	0	0
(n=197)	0.5	12.7	5.1	1.5	46.2	34.0	0	0

	Br	Dm	M	Mm	Od	Om	P	Ced
WFT	0	5	33	15	0	11	10	0
(n=74)	0	6.8	44.6	20.3	0	14.9	13.5	0
WFR	0	1	32	6	2	15	16	2
(n=74)	0	1.4	43.2	8.1	2.7	20.3	21.6	2.7
WMT	2	2	21	6	0	8	10	0
(n=49)	4.1	4.1	42.9	12.2	0	16.3	20.4	0
WMR	0	2	25	3	1	7	11	0
(n=49)	0	4.1	51.0	6.1	2.0	14.3	22.5	0
WWT	2	7	54	21	0	19	20	0
(n=123)	1.6	5.7	43.9	17.1	0	15.4	16.3	0
WTR	0	3	57	9	3	22	27	2
(n=123)	0	2.4	46.3	7.3	2.4	17.9	22.0	1.6

Table 5.4

Forest types of stands at turtle and random points

Forest types of stands at turtle points and random points in Virginia and West Virginia during June-August 201 (based on USFS stand inventory); for each row, top numbers indicate counts of points in that forest type, with prop (%) of total points in each turtle group below. **Forest types used to define groups**: 3 = White Pine, 10 = White Upland Hardwoods, 33 = Virginia Pine, 39 = Table Mountain Pine, 41 = Cove Hardwoods – White Pine, 42 = U Hardwoods – White Pine, 45 = Chestnut Oak – Scarlet Oak – Yellow Pine, 52 = Chestnut Oak, 53 = White Northern Red Oak – Hickory, 54 = White Oak, 56 = Tulip Poplar – White Oak – Northern Red Oak, 59 = Scarle 60 = Chestnut Oak – Scarlet Oak. **Forest type groups**: Dm = mesic deciduous (includes forest type 56), M = dry pine and deciduous (FTs 10, 42, 45), Mm = mesic mixed pine and deciduous (FT 41), Od = oligotrophic oak (I 59, 60), Om = mesic oak (FTs 53, 54), P = pine (FTs 3, 33, 39). **Turtle groups:** FT = female turtle locations, FR = random points, MT = male turtle locations, MR = male random points, WT = turtle locations (males and f aggregated), RP = random points locations (points for males and females aggregated).

		Turtle groups											
		Virginia						West Virginia					
Forest types		FT	FR	MT	MR	WT	RP	FT	FR	MT	MR	WT	RP
Dm	56	4	4	0	1	4	5	0	0	0	0	0	0
		3.7	3.1		2.0	2.5	2.8	-	-				
M	10	0	0	0	0	0	0	3	3	2	1	5	4
								3.8	4.2	3.9	2.1	3.9	3.3
	42	0	0	0	0	0	0	24	22	15	18	39	40
								30.4	30.5	29.4	36.7	30.0	33.1
	45	0	0	0	0	0	0	0	2	0	0	0	2
								-	2.8				1.65
Mm	41	4	1	11	4	15	5	0	0	0	0	0	0
		3.7	0.8	22.0	8.2	9.4	2.8	-	-				
Od	52	0	3	1	5	1	8	0	0	0	0	0	0
			2.3	2.0	10.2	0.6	4.5	-	-				
	59	0	2	0	2	0	4	0	0	0	0	0	0
			1.5		4.1		2.3	-	-				
	60	3	8	2	3	5	11	0	0	0	0	0	0
		2.8	6.2	4.0	6.1	3.1	6.2	-	-				
Om	53	75	93	31	29	106	122	32	23	20	25	52	48
		68.8	72.1	62.0	59.2	66.7	68.5	40.5	31.9	39.2	51.0	40.0	39.7
	54	20	16	5	4	25	20	0	0	0	0	0	0
		18.3	12.4	10.0	8.2	15.7	11.2	-	-				
P	3	0	0	0	1	0	1	0	0	0	0	0	0
					2.0		0.6	-	-				
	33	0	0	0	0	0	0	20	22	14	5	34	27
								25.3	30.6	27.5	10.2	26.2	22.3
	39	3	2	0	0	3	2	0	0	0	0	0	0
		2.7	1.6			1.9	1.1						
Point totals		109	129	50	49	159	178	79	72	51	49	130	121

Table 5.5

Seral stage of stands at turtle points and random points

Seral stage of stands at turtle points and random points in Virginia and West Virginia during June-August of 2011-2014 and 2011-2013 (based on USFS stand inventory ages); for each turtle group row, top numbers indicate counts of points in that seral stage, with proportions (%) of total stands in each turtle group below. **Seral stages**: esh = early successional habitat (0-35 years old), mid = mid-successional habitat (36-75 years old), mature = mature forest habitat (76-140 years old, depending on forest type), OG = old-growth forest (> 100-140 years old, depending on forest type). **Turtle groups:** FT = female turtle locations, FR = female random points, MT = male turtle locations, MR = male random points, WT = turtle locations (males and females aggregated), TR = random points locations (points for males and females aggregated). n = number of points in VA, WV.

	Seral stages							
	Virginia				West Virginia			
Turtle group	esh	mid	mature	OG	esh	mid	mature	OG
2011-2014								
FT	7	19	88	30	NA	NA	63	11
(n=144,74)	4.9	13.2	61.1	20.8	-	-	85.1	14.9
FR	16	28	82	18	NA	NA	55	19
(n=144,74)	11.1	19.4	56.9	12.5	-	-	74.3	25.7
MT	4	2	38	8	NA	NA	45	4
(n=52,49)	7.7	3.8	73.1	15.4	-	-	91.8	8.2
MR	6	8	33	6	NA	NA	42	7
(n=53,49)	11.3	15.1	62.3	11.3	-	-	85.7	14.3
WT	11	21	126	38	NA	NA	108	15
(n=196,123)	5.6	10.7	64.3	19.4	-	-	87.8	12.2
TR	22	36	115	24	NA	NA	97	26
(n=197,123)	11.1	18.3	58.4	12.2	-	-	78.9	21.1
2011-2013								
FT	2	19	71	26	NA	NA	37	10
(n=118,47)	1.7	16.1	60.2	22.0	-	-	78.7	21.3
FR	16	25	60	17	NA	NA	33	14
(n=118,47)	13.6	21.2	50.8	14.4	-	-	70.2	29.8
MT	2	1	24	5	NA	NA	28	4
(n=32,32)	6.3	3.3	75.0	15.6	-	-	87.5	12.5
MR	4	7	19	3	NA	NA	28	4
(n=33,32)	12.1	21.2	57.6	9.1	-	-	87.5	12.5
WT	4	20	95	31	NA	NA	65	14
(n=150,79)	2.7	13.3	63.3	20.7	-	-	82.3	17.7
TR	20	32	79	20	NA	NA	61	18
(n=151,79)	13.2	21.2	52.4	13.2	-	-	77.2	22.8

Table 5.6

Floristic richness and cover in plots at turtle and paired random points

Values for floristic richness and cover in plots at turtle points and paired random points in Virginia and West Virginia during June-August; forb and seedling taxa in $1m^2$ plots were counted in 2013-2014, forb taxa in $400m^2$ plots were counted in 2011-2013, herbaceous cover (%) in $1m^2$ plots and tree taxa (≥10cm dbh) in $400m^2$ plots were measured in 2011-2014. Reported in descending order are means, standard errors, and ranges. Herbaceous cover is forb cover and grass cover combined. Site groups: FWT = female Wood Turtles, FRP = female random points, MWT = male Wood Turtles, MRP = male random points.

	Virginia				West Virginia			
Variable	**FWT**	**FRP**	**MWT**	**MRP**	**FWT**	**FRP**	**MWT**	**MRP**
$1m^2$								
Forb taxa	2.72	1.28	4.33	0.92	2.67	2.63	4.42	2.50
	0.27	0.22	0.46	0.32	0.30	0.35	0.47	0.46
	0-9	0-10	0-9	0-9	0-7	0-9	1-8	0-8
Seedling taxa	3.10	3.36	2.83	3.31	1.92	1.69	2.00	1.50
	0.21	0.20	0.30	0.30	0.22	0.19	0.36	0.26
	0-10	0-11	0-7	0-7	0-5	0-5	0-8	0-5
Herbaceous cover	14.6	3.3	14.0	1.3	14.4	8.1	15.9	8.0
	2.05	0.74	2.57	0.65	2.13	1.72	2.35	1.53
	0-100	0-79	0-73	0-28	0-75	0-81	0-76	0-53
$400m^2$								
Forb taxa	14.3	10.2	16.1	9.9	16.7	11.4	16.8	15.1
	0.71	0.64	1.33	1.28	0.95	0.98	1.26	1.23
	0-31	0-35	1-30	2-35	5-33	0-29	5-31	1-29
Tree taxa	5.42	5.69	5.81	5.75	5.68	5.35	5.41	5.12
	0.15	0.14	0.25	0.26	0.15	0.18	0.23	0.18
	1-11	1-10	2-9	2-12	3-9	3-10	3-9	3-8

Table 5.7

Test results comparing floristic variables at turtle and paired random points
Results of paired Wilcoxon signed rank tests and paired t-tests comparing floristic variables obtained at turtle points and random points in Virginia (VA) and West Virginia (WV) during June-August; reported in descending order are *p* values, *V* or *t* statistic values, and degrees of freedom. Forb and woody seedling taxa in 1m^2 plots were counted in 2013-2014, forb taxa in 400m^2 plots were counted in 2011-2013, herbaceous cover (%) in 1m^2 plots and tree taxa (≥10cm dbh) in 400m^2 plots were measured in 2011-2014. FWT = female Wood Turtle points, FRP = female random points, MWT = male Wood Turtle points, MRP = male random points. Comparisons with significant results are in **bold**.

		VA		WV	
		FWT-FRP	MWT-MRP	FWT-FRP	MWT-MRP
1 m^2					
Forb taxa richness	p	**<0.0001**	**<0.0001**	0.360	**0.0012**
	V	1584	431	417	192
Woody seedling taxa	p	0.373	0.198	0.966	0.272
	V	1258	183	477	93
Herbaceous cover	p	**<0.0001**	**<0.0001**	**0.0104**	**0.0026**
	V	4827	74	1465	264
400m^2					
Forb taxa richness	p	**<0.0001**	**0.0064**	**0.00016**	0.165
	V or t	4971	2.92	4.10	1.42
	df		32	46	31
Tree taxa richness	p	0.198	0.715	0.131	0.387
	V	3252	599	1049	474

Table 5.8

Well-supported conditional logistic regression models – using tree importance values Best of fifteen conditional logistic regression models of tree importance values at Wood Turtle sites in Virginia and West Virginia, USA in 2010-2014, based on proportions in 400m^2 plots. Type of model in brackets (see Appendix 5). LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; higher AICc weights denote models that are supported among the set of candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights (listed are those models with a cumulative weight ≥ 0.95). See Appendix 5 for identification of tree acronyms.

Models	**LogLik**	**K**	**ΔAICc**	**AICc weight**	**Cum.wt.**
Virginia females					
WO+NRO+SM+RM+BW+TP+WA+BG+ HICK+BLBIR+ELM	-71.31	11	0	0.61	0.61
WO+CO+NRO+SM+RM+HICK+BG+TP+WA [Om]	-74.42	9	1.91	0.23	0.84
WO+CO+NRO+SO+BO	-79.51	5	3.66	0.10	0.94
WO+CO+SO+BO+BG+HICK	-79.56	6	5.84	0.03	0.97
1 [Null model]	-99.81	0	34.05	0.00	1.00
Virginia males					
WO+CO+NRO+SO+BO [Oaks]	-24.39	5	0	0.34	0.34
CO+SO+BO+BG+HICK+WO	-23.55	6	0.56	0.26	0.60
WP+VP+WO+CO+RM+SO+BG	-22.50	7	0.75	0.23	0.83
WP+CO+SM+RM+WO+BG+WA+TP+SO+ NRO+HICK+VP	-17.33	12	2.57	0.09	0.92
1 [Null model]	-37.43	0	15.48	0.00	1.00
West Virginia females					
WP+WO+CO+SM+RM+BLCH+SYC+ NRO+HICK+VP	-34.45	10	0	0.50	0.50
BW+BLCH+ELM+SM+RM+SYC [Mesic]	-39.21	6	0.52	0.38	0.88
WP+VP+WO+CO+RM+BG+SO+HICK	-39.34	8	5.22	0.04	0.92
WO+CO+NRO+SM+RM+HICK+BG	-40.82	7	5.93	0.03	0.94
RM+SM	-46.42	2	6.42	0.02	0.96
1 [Null model]	-51.29	0	12.09	0.00	1.00
West Virginia males					
WP+VP+CO+SM+RM+WO+BLCH+ ELM+NRO+HICK	-10.40	10	0	0.47	0.47
WP+VP+WO+CO+RM+BG+WA+HICK [M]	-12.89	8	0.06	0.45	0.92
WO+CO+NRO+SM+RM+HICK+BG	-16.02	7	3.96	0.06	0.99
1 [Null model]	-33.96	0	24.60	0.00	1.00

Table 5.9

Best conditional logistic regression model variables – using IVs

Conditional logistic regression model variables that best explain Wood Turtle meso-scale habitat selection based on tree importance values at sites in Virginia and West Virginia, USA in 2010-2014. Measured values are based on counts and dbh of trees in 400-m^2 sampling plots. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero. See Appendix 5 for identification of tree acronyms.

	Measured values (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
Variable	Turtle Plots	Random Plots			
Virginia females					
WO	20.1 ± 1.88	12.3 ± 1.30	0.03 ± 0.01	1.030	1 unit
CO	10.7 ± 1.74	23.2 ± 1.99	-0.02 ±0.01	0.980	1 unit
SO	3.7 ± 0.92	7.7 ± 1.13	-0.02 ±0.01	0.980	1 unit
SM	2.7 ± 0.67	0.7 ± 0.29	0.06 ± 0.03	1.062	1 unit
WA	7.7 ± 1.07	1.7 ± 0.54	0.07 ± 0.02	1.073	1 unit
SERV	1.4 ± 0.37	0.8 ± 0.20	0.07 ± 0.05	1.073	1 unit
BW	0.1 ± 0.06	0.4 ± 0.13	-0.22 ± 0.12	0.803	1 unit
BO	1.3 ± 0.36	3.0 ± 0.50	-0.06 ± 0.03	0.942	1 unit
ELM	0.6 ± 0.15	0.1 ± 0.07	0.20 ± 0.13	1.221	1 unit
Virginia males					
WP	4.2 ± 1.59	3.2 ± 1.08	-0.08 ±0.04	0.923	1 unit
CO	6.0 ± 1.64	16.9 ± 2.55	-0.05 ±0.03	0.951	1 unit
SO	4.6 ± 1.73	12.6 ± 2.49	-0.06 ±0.03	0.942	1 unit
BO	0.6 ± 0.41	2.3 ± 0.75	-0.11 ±0.06	0.896	1 unit
RM	13.2 ± 1.45	19.5 ± 1.86	-0.09 ±0.05	0.914	1 unit
SM	5.0 ± 1.48	1.9 ± 0.83	0.10 ± 0.07	1.105	1 unit
SERV	0.6 ± 0.25	0.4 ± 0.21	0.35 ± 0.20	1.419	1 unit
BL	1.2 ± 0.60	0.4 ± 0.16	0.15 ± 0.11	1.162	1 unit
IW	0.9 ± 0.37	1.4 ± 0.40	-0.22 ±0.14	0.803	1 unit
West Virginia females					
CO	2.1 ± 0.79	9.8 ± 2.77	-0.07 ±0.03	0.932	1 unit
RM	5.2 ± 0.92	2.5 ± 0.84	0.11 ± 0.05	1.116	1 unit
HICK	10.1 ± 2.07	10.3 ± 1.36	0.05 ± 0.02	1.051	1 unit
VP	10.5 ± 2.41	17.9 ± 3.07	0.02 ± 0.02	1.020	1 unit
SYC	3.4 ± 1.59	0.04 ± 0.04	0.40 ± 0.23	1.492	1 unit
West Virginia males					
CO	1.0 ± 0.55	5.2 ± 1.84	-0.62 ± 0.25	0.538	1 unit
SM	5.6 ± 2.23	6.5 ± 2.05	-0.26 ± 0.16	0.771	1 unit
WP	29.1 ± 3.94	38.3 ± 4.13	-0.11 ± 0.10	0.896	1 unit

Table 5.10

Synopsis of best conditional logistic regression model variables – using IVs of various turtle groups
Conditional logistic regression model variables that best explain Wood Turtle meso-scale habitat selection based on taxon importance values at sites in Virginia and West Virginia, USA in 2010-2014. Taxon importance values are based on counts and dbh of trees ≥ 10cm dbh in 400m^2 sampling plots. Model coefficients were obtained through model averaging. An **X** of positive sign denotes variables that are preferred, while a **–X** indicates avoidance. Variables with exes are only those with coefficients that did not overlap zero for that particular site group. See Appendix 5 for identification of tree acronyms.

	Type of Site						
Taxon	VFT	VMT	WFT	WMT	FT	MT	WT
WP		**-X**				**-X**	**-X**
VP						**-X**	
WO	**+X**				**+X**		
CO		**-X**	**-X**	**-X**	**-X**	**-X**	**-X**
SO	**-X**	**-X**			**-X**		**-X**
NRO							**-X**
RM		**-X**	**+X**			**-X**	
SM	**+X**				**+X**	**-X**	
WA	**+X**				**+X**		**+X**
SERV					**+X**		**+X**
HICK			**+X**		**-X**		
BW							
BO	**-X**						
ELM					**-X**		

Table 5.11

Well-supported conditional logistic regression models – using IVs and pooled turtle groups Best of fifteen conditional logistic regression models of tree importance values at combined Wood Turtle sites in Virginia and West Virginia, USA in 2010-2014, based on values in 400m^2 plots. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; higher AICc weights denote models that are supported among the set of candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights (best models are those with a cumulative weight $\geq$ 0.95). See Appendix 5 for identification of tree acronyms.

Model	**LogLik**	**K**	**ΔAICc**	**AICc weight**	**Cum. weight**
Virginia and West Virginia females					
WO+NRO+SM+RM+BW+TP+WA+BG+ HICK+ELM [Dm]	-118.90	10	0	0.91	0.91
WO+CO+NRO+RM+SM+HICK+BG+TP+WA	-122.87	9	5.97	0.05	0.96
1 [Null model]	-151.11	0	43.89	0.00	1.00
Virginia and West Virginia males					
WP+VP+WO+CO+SM+RM+BG+WA+TP+ SO+NRO+HICK	-47.39	12	0	0.50	0.50
WO+CO+NRO+SO+BO [Oaks]	-55.23	5	0.35	0.42	0.93
WO+CO+SO+BO+BG+HICK	-56.55	6	5.11	0.04	0.97
1 [Null model]	-141.40	0	20.98	0.00	1.00
Virginia and West Virginia Wood Turtles					
WP+VP+WO+CO+SM+RM+BG+WA+TP+ SO+NRO+HICK [Global]	-196.41	12	0	0.93	0.93
WO+CO+NRO+RM+SM+HICK+BG+TP+WA	-202.39	9	5.75	0.05	0.98
1 [Null model]	-241.76	0	66.04	0.00	1.00

Table 5.12

Best conditional logistic regression model variables – using IVs and pooled turtle groups Conditional logistic regression model variables that best explain Wood Turtle meso-scale habitat selection based on tree importance values at combined sites in Virginia and West Virginia, USA in 2010-2014. Measured values are based on counts and dbh of trees in 400m^2 sampling plots. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero. See Appendix 5 for identification of tree acronyms.

Variable	**Measured values** (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
	Turtle Plots	Random Plots			
VA and WV females					
WO	18.8 ± 1.37	14.2 ± 1.17	0.02 ± 0.01	1.020	1 unit
CO	8.3 ± 1.22	18.3 ± 1.50	-0.02 ±0.01	0.980	1 unit
SO	2.6 ± 0.62	5.4 ± 0.79	-0.03 ±0.01	0.970	1 unit
SM	4.1 ± 0.70	1.5 ± 0.37	0.05 ± 0.02	1.051	1 unit
WA	5.2 ± 0.75	1.1 ± 0.36	0.08 ± 0.02	1.083	1 unit
SERV	1.1 ± 0.25	0.6 ± 0.17	0.18 ± 0.08	1.197	1 unit
IW	0.6 ± 0.13	1.0 ± 0.26	-0.05 ±0.04	0.951	1 unit
ELM	0.6 ± 0.14	2.0 ± 0.34	-0.12 ±0.04	0.887	1 unit
VA and WV males					
WP	16.8 ± 2.02	18.9 ± 2.33	-0.10 ±0.04	0.905	1 unit
VP	8.8 ± 1.73	7.6 ± 1.61	-0.08 ±0.04	0.923	1 unit
CO	3.8 ± 0.95	11.1 ± 1.64	-0.10 ±0.05	0.905	1 unit
SO	2.5 ± 0.96	6.9 ± 1.46	-0.09 ±0.05	0.914	1 unit
NRO	5.0 ± 1.00	6.2 ± 0.86	-0.09 ±0.06	0.914	1 unit
BO	0.3 ± 0.22	1.1 ± 0.40	-0.10 ±0.06	0.905	1 unit
RM	9.0 ± 1.00	10.6 ± 1.36	-0.11 ±0.05	0.896	1 unit
SM	4.7 ± 0.96	3.8 ± 0.85	-0.12 ±0.05	0.887	1 unit
TP	3.6 ± 0.95	1.0 ± 0.43	-0.07 ±0.05	0.932	1 unit
HICK	8.2 ± 1.21	8.1 ± 1.16	-0.09 ±0.04	0.914	1 unit
ELM	1.1 ± 0.36	0.4 ± 0.15	0.13 ± 0.10	1.139	1 unit
BW	0.8 ± 0.31	0.4 ± 0.20	0.11 ± 0.08	1.116	1 unit
VA and WV Wood Turtles					
WP	11.8 ± 0.96	13.1 ± 1.13	-0.02 ±0.01	0.980	1 unit
CO	6.9 ± 0.89	16.0 ± 1.16	-0.03 ±0.01	0.970	1 unit
SO	2.5 ± 0.52	5.9 ± 0.71	-0.04 ±0.01	0.961	1 unit
NRO	5.6 ± 0.58	6.5 ± 0.55	-0.03 ±0.01	0.970	1 unit
WA	5.0 ± 0.59	1.3 ± 0.30	0.05 ± 0.02	1.051	1 unit
SERV	0.9 ± 0.18	0.3 ± 0.06	0.15 ± 0.06	1.162	1 unit
IW	0.6 ± 0.11	0.9 ± 0.19	-0.04 ±0.03	0.961	1 unit
ELM	0.8 ± 0.15	1.5 ± 0.24	-0.06 ±0.03	0.942	1 uni

Table 5.13

Herbaceous taxa used in indicator species analyses – 400m^2 plots
Taxa used in indicator analyses of herbaceous taxa present in 400m^2 plots at turtle points and random points in V
and West Virginia during June-August 2013-2014. Taxa present in a state are marked with a ✓. Taxa with sigr
indicator values (by themselves, not in combination with other taxa) for a site group are marked with an X (a
0.05); o = an indicator for that site group (0.05 < alpha ≤ 0.11); – = not an indicator; denotations are in the order V
Site groups: FWT = female Wood Turtles, FRP = female random points, MWT = male Wood Turtles, MRP = male r
points. Wetland class: FAC = facultative, FACU = facultative upland, FACW = facultative wetland, OBL = o
wetland, UPL = upland.

			State		Site Groups					
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**FWT**	**FRP**	**MWT**	**MRP**	**FWT+ MWT**	**FR M**
Ageratina altissima	White Snake Root	FACU	✓	✓					X/-	
Agrimonia grypsophela	Agrimony	FACU	✓				X/-			
Alium cernum	Wild Onion	FACU		✓						
Amphicarpaea bracteata	Hog Peanut	FAC	✓	✓					X/X	
Anemone americana	Rnd-lobed Hepatica	UPL		✓						-
Antennaria spp.	Pussytoes	UPL	✓	✓						
Arisaema triphyllum	Jack-in-the-pulpit	FACW	✓						X/-	
Aster spp.	Asters	na	✓	✓					-/X	
Boehmeria cylindrica	False Nettle	FACW	✓						X/-	
Chimaphila maculata	Spotted Wintergrn.	UPL	✓	✓						X
Cicuta maculata	Water Hemlock	OBL	✓						X/-	
Circaea lutetiana	Ench.'s Nightshade	FACU	✓	✓					X/X	
Collinsonia canadensis	Stone Root	FAC	✓						X/-	
Cunila origanoides	Dittany	UPL	✓	✓						X
Desmodium spp.	Tick Trefoil (*glabellum*)	UPL	✓	✓		-/X				
Dioscorea villosa	Wild Yam	FAC	✓	✓						
Epigaea repens	Trailing Arbutus	UPL		✓						-
Eurybia divaricata	White Wood Aster	FACU/ UPL	✓	✓					X/o	
Galium triflorum	Bedstraws	FACU	✓	✓					X/X	
Galium circaezan	Wild Licorice	UPL		✓						
Gaultheria procumbens	Teaberry	FACU		✓					/X	
Geranium maculatum	Wild Geranium	FACU		✓					-/X	
Goodyera pubescens	Rattlesnake Plantain	FACU	✓	✓						
Hieracium paniculatum	Panicled Hawkwort	UPL	✓							
Hieracium venosum	Hawkwort	UPL	✓	✓						-
Impatiens capensis	Jewelwort	FACW	✓	✓			-/X		X/-	
Isotria verticillata	Whorled Pogonia	FACU	✓							
Lespedeza spp.	Bush Clover (*procumbens*)	UPL		✓						
Lycopus spp.	Bugleworts	OBL	✓	✓			-/X		X/-	
Maianthemum racemosa	Plume Lily	FACU	✓	✓						
Medeola virginiana	Indian Cuc. Root	FAC	✓							
Mitchella repens	Partridgeberry	FACU	✓	✓					X/-	
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)	FACU	✓	✓					-/X	
Oxalis spp.	Wood Sorrel	FACU	✓	✓					X/o	
Packera obovata	Rnd-leaved Ragwort	FACU		✓						
Parthenocissus quinquefolia	Virginia Creeper	FACU	✓	✓						
Persicaria sagittatum/arifolium	Tearthumb	OBL	✓						X/-	
Pilea pumila	Clearwort	FACW	✓	✓					X/-	
Polygonatum biflorum	Solomon's Seal	FACU	✓							
Potentilla spp.	Cinquefoil	FACU	✓	✓					X/X	
Prunella vulgaris	Heal-All	FACU	✓						X/-	
Scuttellaria spp.	Skullcap (*lateriflora*)	FACW		✓			-/X			
Solidago spp.	Goldenrods	na	✓	✓						
Uvularia perfoliata	Perfoliate Bellwort	FACU	✓	✓					-/X	o
Uvularia spp.	Bellworts (*puberula*)	FACU	✓	✓						X
Veronica officinalis	Speedwell	FACU		✓						
Viola spp.	Violets	na	✓	✓					X/X	
Perilla frutescens	Beefsteak Plant	FACU	✓	✓					- /X	X
Microstigeum	Stiltgrass	FAC	✓	✓					X/X	

Table 5.14

Herbaceous taxa with significant indicator values
Herbaceous taxa with significant indicator values (by themselves, not in combination with other taxa) present in plots at turtle points and random points in Virginia and West Virginia during June-August 2011-2013; reported indicator values (A x B) with the p-values beneath (as calculated by R package "indicSpecies"). Site groups: VM male Wood Turtles, WMT = WV male Wood Turtles, VWT = VA Wood Turtles, WWT = WV Wood Turtles, VR random points, WRP = WV random points, WFR = West Virginia female random points. Taxa with an * had a 0.(value ≤ 0.1 for a group.

		Groups					
Taxon	**Common name**	**VMT / WFR**	**WMT**	**VWT (M+F)**	**WWT (M+F)**	**VRP (M+F)**	**WRP (M+F)**
Ageratina altissima	White Snake Root			0.564 0.023			
Agrimonia grypsophela	Agrimony [VMT]	0.349 0.001					
Amphicarpaea bracteata	Hog Peanut			0.639 0.001	0.454 0.027		
Arisaema triphyllum	Jack-in-the-pulpit			0.499 0.001			
Aster					0.474 0.005		
Boehmeria cylindrica	False Nettle			0.540 0.001			
Chimaphila maculata	Spotted Wintergreen					0.624 0.001	0.521 0.021
Cicuta maculata	Water Hemlock			0.345 0.009			
Circaea lutetiana	Enchanter's Nightshade			0.503 0.001	0.470 0.006		
Collinsonia canadensis	Stone Root			0.418 0.003			
Cunila origanoides	Dittany					0.363 0.039	
Desmodium spp.	Tick Trefoil [WFR]	0.306 0.051					
Epigaea repens	Trailing Arbutus						0.373 0.026
Eurybia divaricata	White Wood Aster *			0.631 0.001	0.493 0.058		
Galium triflorum	Bedstraw			0.541 0.003	0.589 0.019		
Gaultheria procumbens	Teaberry				0.398 0.039		
Geranium maculatum	Wild Geranium				0.419 0.051		
Hepatica americana	Round-lobed Hepatica						0.458 0.020
Hieracium venosum	Hawkwort *						0.464 0.10
Impatiens capensis	Jewelwort		0.361 0.004	0.528 0.001			
Lycopus spp.	Bugleworts		0.486 0.001	0.536 0.001			
Mitchella repens	Partridgeberry			0.391 0.010			
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)				0.491 0.020		
Oxalis spp.	Wood Sorrel *			0.412 0.008	0.498 0.081		
Pilea pumila	Clearwort			0.352 0.009			
Polygonum sagittatum/arifolium	Tearthumb			0.343 0.007			
Potentilla spp.	Cinquefoil			0.658 0.002	0.673 0.010		
Prunella vulgaris	Heal-All			0.369 0.009			
Scuttellaria spp.	Skullcap		0.359 0.017				
Uvularia perfoliata	Perfoliate Bellwort *				0.469 0.003	0.279 0.066	
Uvularia spp.	Bellworts					0.492 0.026	
Viola spp.	Violets			0.709 0.001	0.675 0.001		
Perilla frutescens	Beefsteak Plant				0.374 0.010	0.404 0.003	
Microstigeum vimineum	Stiltgrass			0.644 0.001	0.634 0.001		

Table 5.15

Herbaceous taxa used in association analyses – 400m^2 plots
Taxa used in association analyses of herbaceous taxa present in 400m^2 plots at turtle points and random pc Virginia and West Virginia during June-August 2013-2014. Taxa present in a state are marked with an X. Tax significant Pearson's phi coefficients of association (by themselves, not in combination with other taxa) for a site are marked with an X (alpha ≤ 0.05); o = an indicator for that site group (0.05 < alpha ≤ 0.11); - = not an inc denotations are in the order VA/WV. Site groups: FWT = female Wood Turtles, FRP = female random points, M male Wood Turtles, MRP = male random points. Wetland class: FAC = facultative, FACU = facultative upland, = facultative wetland, OBL = obligate wetland, UPL = upland.

			State		Site Groups					
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**FWT**	**FRP**	**MWT**	**MRP**	**FWT+ MWT**	**FRP+ MRP**
Ageratina altissima	White Snake Root	FACU	✓	✓					o/-	
Agrimonia grypsophela	Agrimony	FACU	✓				X/-			
Alium cernum	Nod. Wild Onion	FACU		✓						
Amphicarpaea bracteata	Hog Peanut	FAC	✓	✓					X/o	
Anemone americana	Rnd-lobed Hepatica	UPL		✓				-/X		
Antennaria spp.	Pussytoes	UPL	✓	✓						
Arisaema triphyllum	Jack-in-the-pulpit	FACW	✓						X/-	
Aster spp.	Asters	na	✓	✓					-/X	
Boehmeria cylindrica	False Nettle	FACW	✓						X/-	
Chimaphila maculata	Spot. Wintergreen	UPL	✓	✓						X/o
Cicuta maculata	Water Hemlock	OBL	✓						X/-	
Circaea lutetiana	Ench.'s Nightshade	FACU	✓	✓					X/X	
Collinsonia canadensis	Stone Root	FAC	✓						X/-	
Cunila origanoides	Dittany	UPL	✓	✓		o/o				
Desmodium spp.	Tick Trefoil (*glabellum*)	UPL	✓	✓		-/X				
Dioscorea villosa	Wild Yam	FAC	✓	✓						
Epigaea repens	Trailing Arbutus	UPL		✓						-/X
Eurybia divaricata	White Wood Aster	FACU/ UPL	✓	✓					X/-	
Galium triflorum	Bedstraws	FACU	✓	✓					X/o	
Galium circaezans	Wild Licorice	UPL		✓						
Gaultheria procumbens	Teaberry	FACU		✓	-/X					
Geranium maculatum	Wild Geranium	FACU		✓						
Goodyera pubescens	Rattlesnake Plantain	FACU	✓	✓						
Hieracium paniculatum	Panicled Hawkwort	UPL	✓			X/-				
Hieracium venosum	Hawkwort	UPL	✓	✓						
Impatiens capensis	Jewelwort	FACW	✓	✓			-/X		X/-	
Isotria verticillata	Whorled Pogonia	FACU	✓							
Lespedeza spp.	Bush Clover (*procumbens*)	UPL		✓						
Lycopus spp.	Bugleworts	OBL	✓	✓			-/X		X/-	
Maianthemum racemosa	Plume Lily	FACU	✓	✓						
Medeola virginiana	Ind. Cucumber Root	FAC	✓							
Mitchella repens	Partridgeberry	FACU	✓	✓					X/-	
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)	FACU	✓	✓					-/o	
Oxalis spp.	Wood Sorrel	FACU	✓	✓	-/o				X/-	
Packera obovata	Rnd-leaved Ragwort	FACU		✓						
Parthenocissus quinquefolia	Virginia Creeper	FACU	✓	✓				o/-		
Persicaria sagittatum/arifolium	Tearthumb	OBL	✓						X/-	
Pilea pumila	Clearwort	FACW	✓	✓					X/-	
Polygonatum biflorum	Solomon's Seal	FACU	✓							
Potentilla spp.	Cinquefoil	FACU	✓	✓					X/X	
Prunella vulgaris	Heal-All	FACU	✓		X/-					
Scuttellaria spp.	Skullcap (*lateriflora*)	FACW		✓			-/X			
Solidago spp.	Goldenrods	na	✓	✓				-/X		
Uvularia perfoliata	Perfoliate Bellwort	FACU	✓	✓	-/X					o/-
Uvularia spp.	Bellworts (*puberula*)	FACU	✓	✓						X/-
Veronica officinalis	Speedwell	FACU		✓						
Viola spp.	Violets	na	✓	✓					X/X	

Table 5.16

Herbaceous taxa with significant association values – 400m^2 plots
Herbaceous taxa with significant Pearson's phi coefficients of association (by themselves, not in combination wit taxa) present in 400m^2 plots at turtle points and random points in Virginia and West Virginia during June-August 2013; reported are the coefficient values with the p-values beneath (as calculated by R package "indicSpecies groups: VMT = VA male Wood Turtles, WMT = WV male Wood Turtles, VWT = VA Wood Turtles, WWT = WV Turtles, VRP = VA random points, WRP = WV random points, WFR = West Virginia female random points. Ta an * had a 0.05 < p-value < 0.1 for a group.

		Groups					
Taxon	**Common name**	**VMT / WFR**	**WMT**	**VWT (M+F)**	**WWT (M+F)**	**VRP (M+F)**	**WRP (M+F)**
Ageratina altissima	White Snake Root						
Agrimonia grypsophela	Agrimony [VMT]	0.249 0.002					
Amphicarpaea bracteata	Hog Peanut *			0.340 0.001	0.185 0.072		
Anemone americana	Round-lobed Hepatica MRP						0.225 0.017
Arisaema triphyllum	Jack-in-the-pulpit			0.273 0.001			
Aster spp.					0.266 0.007		
Boehmeria cylindrica	False Nettle			0.336 0.001			
Chimaphila maculata	Spotted Wintergreen *					0.333 0.001	0.185 0.066
Cicuta maculata	Water Hemlock			0.250 0.001			
Circaea lutetiana	Enchanter's Nightshade			0.279 0.002	0.246 0.010		
Collinsonia canadensis	Stone Root			0.217 0.006			
Cunila origanoides	Dittany	0.160 0.055				VFR	
Desmodium spp.	Tick Trefoil [WFR]	0.214 0.025					
Epigaea repens	Trailing Arbutus						0.188 0.049
Eurybia divaricata	White Wood Aster			0.229 0.004			
Galium triflorum	Bedstraw *			0.178 0.032	0.182 0.0.80		
Gaultheria procumbens	Teaberry WFT				0.237 0.013		
Geranium maculatum	Wild Geranium						
Hieracium paniculata	Panicled Hawkwort VFR	0.170 0.038					
Impatiens capensis	Jewelwort		0.320 0.001	0.528 0.001			
Lycopus spp.	Bugleworts		0.320 0.001	0.536 0.001			
Mitchella repens	Partridgeberry			0.165 0.045			
Nabalus spp. (*albus, altissimus*)	Gall-of-the-Earth *				0.171 0.096		
Oxalis spp.	Wood Sorrel *			0.174 0.026			
Parthenocissus cinquefolia	Virginia Creeper *VMR	0.148 0.084					
Persicaria sagittatum/ arifolium	Tearthumb			0.171 0.047			
Pilea pumila	Clearwort			0.198 0.022			
Potentilla spp.	Cinquefoil			0.208 0.013	0.208 0.025		
Prunella vulgaris	Heal-All VFT	0.190 0.023					
Scuttellaria spp.	Skullcap		0.256 0.011				
Solidago spp.	Goldenrods WMR	0.200 0.052					
Uvularia perfoliata	Perfoliate Bellwort WFT				0.237 0.011		
Uvularia spp.	Bellworts					0.492 0.026	
Viola spp.	Violets			0.401 0.001	0.325 0.001		
Perilla frutescens	Beefsteak Plant VFR				0.332 0.021	0.309 0.001	
Microstegium vimineum	Stiltgrass			0.440	0.315		

Table 5.17

Herbaceous taxa used in indicator species analyses – 1m² plots

Taxa used in indicator analyses of herbaceous taxa present in 1m² plots at turtle points and random points in V and West Virginia during June-August 2013-2014. Taxa present in a state are indicated with a ✓. Taxa with sigr indicator values (by themselves, not in combination with other taxa) for a site group are marked with an X (a 0.05); o = an indicator for that site group (0.05 < alpha ≤ 0.084); – = not an indicator; denotations are in the VA/WV. Site groups: FWT = female Wood Turtles, FRP = female random points, MWT = male Wood Turtles, male random points. Wetland class: FAC = facultative, FACU = facultative upland, FACW = facultative wetlan = obligate wetland, UPL = upland.

			State		**Site Groups**				
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**FWT**	**FRP**	**MWT**	**MRP**	**FWT+ MWT**
Ageratina altissima	White Snake Root	FACU	✓	✓			X/-		
Alium cernum	Nodding Wild Onion	FACU		✓					
Amphicarpaea bracteata	Hog Peanut	FAC	✓	✓					X/o
Antennaria spp.	Pussytoes	UPL		✓				-/o	
Arisaema triphyllum	Jack-in-the-pulpit	FACW	✓						
Circaea canadensis	Ench.'s Nightshade	FACU	✓				X/-		
Convolvulus spp.	Bindweed	FACU		✓					
Cunila origanoides	Dittany	UPL		✓					
Dioscorea villosa	Wild Yam	FAC	✓	✓					
Eurybia divaricata	White Wood Aster	FACU/ UPL	✓						X/-
Galium circaezans	Wild Licorice	UPL		✓					
Galium pilosum	Bedstraw	UPL	✓						
Galium triflorum	Bedstraw	FACU	✓	✓			X/-		-/X
Gaultheria procumbens	Teaberry	FACU	✓			X/-			
Hieracium venosum	Hawkwort	UPL		✓			-/o		
Impatiens capensis	Jewelwort	FACW	✓				-/X		X/-
Mitchella repens	Partridgeberry	FACU		✓					
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)	FACU		✓					
Oxalis spp.	Wood Sorrel (*stricta*)	FACU	✓	✓					
Packera obovata	Round-leaved Ragwort	FACU		✓					
Parthenocissus quinquefolia	Virginia Creeper	FACU	✓	✓					X/-
Potentilla spp.	Cinquefoil	FACU	✓	✓					X/-
Prunella vulgaris	Heal-All	FACU		✓			-/o		
Solidago spp.	Goldenrods		✓						
Solidago caesia	Blue-stemmed Goldenrod	FACU	✓						X/-
Uvularia spp.	Bellworts (*puberula*)	FACU	✓	✓					
Viola spp.	Violets	-	✓	✓					X/X
Microstigeum vimineum	Stiltgrass	FAC	✓	✓			X/-		-/X

Table 5.18

Herbaceous taxa used in association analyses – 1m^2 plots

Taxa used in association analyses of herbaceous taxa present in 1m^2 plots at turtle points and random points in V
and West Virginia during June-August 2013-2014. Taxa present in a state are marked with a ✓. Taxa with sigr
Pearson's phi coefficients of association (by themselves, not in combination with other taxa) for a site group are r
with an X (alpha ≤ 0.05); o = an indicator for that site group (0.05 < alpha ≤ 0.10); - = not an indicator; denotat
the site groups are in the order VA/WV. Site groups: FWT = female Wood Turtles, FRP = female random points,
= male Wood Turtles, MRP = male random points. Wetland class: FAC = facultative, FACU = facultative upland,
= facultative wetland, OBL = obligate wetland, UPL = upland.

			State		Site Groups					
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**FWT**	**FRP**	**MWT**	**MRP**	**FWT+ MWT**	**F N**
Ageratina altissima	White Snake Root	FACU	✓	✓			X/-			
Alium cernum	Nodding Wild Onion	FACU		✓						
Amphicarpaea bracteata	Hog Peanut	FAC	✓	✓			-/o		X/-	
Antennaria spp.	Pussytoes	UPL		✓				-/o		
Arisaema triphyllum	Jack-in-the-pulpit	FACW	✓							
Circaea canadensis	Ench.'s Nightshade	FACU	✓				X/-			
Convolvulus spp.	Bindweed	FACU		✓						
Cunila origanoides	Dittany	UPL		✓			-/o			
Dioscorea villosa	Wild Yam	FAC	✓	✓						
Eurybia divaricata	White Wood Aster	FACU/UPL	✓						X/-	
Galium circaezans	Wild Licorice	UPL		✓						
Galium pilosum	Bedstraw	UPL	✓							
Galium triflorum	Bedstraw	FACU	✓	✓			X/-		-/o	
Gaultheria procumbens	Teaberry	FACU	✓			X/-				
Hieracium venosum	Hawkwort	UPL		✓			-/o			
Impatiens capensis	Jewelwort	FACW	✓						X/-	
Mitchella repens	Partridgeberry	FACU		✓						
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)	FACU		✓						
Oxalis spp.	Wood Sorrel (*stricta*)	FACU	✓	✓						
Packera obovata	Round-leaved Ragwort	FACU		✓						
Parthenocissus quinquefolia	Virginia Creeper	FACU	✓	✓					X/-	
Potentilla spp.	Cinquefoil	FACU	✓	✓			X/X			
Prunella vulgaris	Heal-All	FACU		✓			-/o			
Solidago spp.	Goldenrods	na	✓							
Solidago caesia	Blue-stemmed Goldenrod	FACU	✓						o/-	
Uvularia spp.	Bellworts (*puberula*)	FACU	✓	✓						
Viola spp.	Violets	na	✓	✓					X/o	
Microstigeum vimineum	Stiltgrass	FAC	✓	✓			X/-		-/X	

Table 5.19

Woody seedling taxa used in indicator species analyses – $1m^2$ plots
Taxa used in indicator analyses of woody seedling taxa present in $1m^2$ plots at turtle points and random points in V and West Virginia during June-August 2013-2014. Taxa present in a state are marked with a ✓. Taxa with sigr indicator values (by themselves, not in combination with other taxa) for a site group are marked with an X (a 0.05); - = not an indicator; denotations under site groups are in the order VA/WV. Site groups: FWT = female Turtles, FRP = female random points, MWT = male Wood Turtles, MRP = male random points. Wetland class: facultative, FACU = facultative upland, FACW = facultative wetland, OBL = obligate wetland, UPL = upland.

			State		Site Groups					
Taxon	Common name	Wetland class	VA	WV	FWT	FRP	MWT	MRP	FWT+ MWT	FR M
Acer rubra	Red Maple	FAC	✓	✓						X
Amelanchier spp.	Serviceberry	FAC	✓	✓			-/X			
Carya spp. (*glabra, tomentosa*)	Hickories	FACU	✓							
Fraxinus americana	White Ash	FACU	✓							
Hamamelis virginiana	Witch Hazel	FACU	✓	✓						
Hypericum prolificum	Bush St. John's Wort	FACU		✓						
Lindera benzoin	Spicebush	FAC	✓		X/-					
Liriodendron tulipifera	Tulip Tree	FACU	✓							
Ostrya virginiana	Ironwood	FACU	✓	✓			X/-			
Pinus strobus	White Pine	FACU		✓						
Quercus alba	White Oak	FACU	✓	✓						
Quercus montana	Chestnut Oak	UPL	✓	✓						X
Quercus rubra	Northern Red Oak	FACU	✓							X
Rhododendron periclymenoides	Pinkster Azalea	FAC	✓							
Rubus spp.	Blackberries	na	✓	✓			-/X		X/-	
Smilax spp.	Greenbriar	FAC	✓						X/-	
Vaccinium spp.	Blueberries	FACU	✓	✓						X

Table 5.20

Woody seedling taxa used in association analyses – 1m[2] plots
Taxa used in association analyses of woody seedling taxa present in 1m[2] plots at turtle points and random po Virginia and West Virginia during June-August 2013-2014. Taxa present in a state are marked with a ✓. Tax significant Pearson's phi coefficients of association (by themselves, not in combination with other taxa) for a site are marked with an X (alpha ≤ 0.05); o = an indicator for that site group (0.05 < alpha ≤ 0.08); - = not an inc denotations under site groups are in the order VA/WV. Site groups: FWT = female Wood Turtles, FRP = female r points, MWT = male Wood Turtles, MRP = male random points. Wetland class: FAC = facultative, FACU = facu upland, FACW = facultative wetland, OBL = obligate wetland, UPL = upland.

			State		Site Groups					
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**FWT**	**FRP**	**MWT**	**MRP**	**FWT+ MWT**	**F I**
Acer rubra	Red Maple	FAC	✓	✓						
Amelanchier spp.	Serviceberry	FAC	✓	✓			-/X			
Carya spp.	Hickories	FACU	✓							
Fraxinus americana	White Ash	FACU	✓							
Hamamelis virginiana	Witch Hazel	FACU	✓	✓						
Hypericum prolificum	Bush St. John's Wort	FACU		✓						
Lindera benzoin	Spicebush	FAC	✓		X/-					
Liriodendron tulipifera	Tulip Tree	FACU	✓							
Ostrya virginiana	Ironwood	FACU	✓	✓			X/-			
Pinus strobus	White Pine	FACU		✓						
Quercus alba	White Oak	FACU	✓	✓						
Quercus montana	Chestnut Oak	UPL	✓	✓		-/X				
Quercus rubra	Northern Red Oak	FACU	✓							
Rhododendron periclymenoides	Pinkster Azalea	FAC	✓							
Rubus spp.	Blackberries	na	✓	✓			-/X		o/-	
Smilax spp.	Greenbriar	FAC	✓						X/-	
Vaccinium spp.	Blueberries	FACU	✓	✓						

Table 5.21

Herbaceous taxa used in association analyses – 400m^2 plots and forest type groups
Taxa used in association analyses of herbaceous taxa present in 400m^2 plots at random points in Virginia an
Virginia during June-August 2013-2014. Taxa present in a state are marked with a ✓. Taxa with significant Pe
phi coefficients of association (by themselves, not in combination with other taxa) for a site group are marked v
X (alpha ≤ 0.05); o = associated with that site group (0.05 < alpha ≤ 0.1); − = not associated; denotations are
order VA/WV. Site groups: Dm = mesic deciduous, M = dry mixed pine and deciduous, Mm = mesic mixed pi
deciduous, Od = oligotrophic oak, Om = mesic oak, P = pine.

			State		Site Groups				
Taxon	**Common name**	**Wetland class**	**VA**	**WV**	**Dm**	**M**	**Mm**	**Od**	**Om**
Ageratina altissima	White Snake Root	FACU	✓	✓					
Agrimonia grypsophela	Agrimony	FACU	✓				X/-		
Alium cernum	Nod. Wild Onion	FACU		✓					
Amphicarpaea bracteata	Hog Peanut	FAC	✓	✓			o/-		
Anemone americana	Rnd.-lobed Hepatica	UPL		✓	-/X				
Antennaria spp.	Pussytoes	UPL	✓	✓					
Arisaema triphyllum	Jack-in-the-pulpit	FACW	✓				X/-		
Aster spp.	Asters	na	✓	✓					
Boehmeria cylindrica	False Nettle	FACW	✓				o/-		
Chimaphila maculata	Spotted Wintergreen	UPL	✓	✓			o/		
Cicuta maculata	Water Hemlock	OBL	✓						
Circaea lutetiana	Ench.'s Nightshade	FACU	✓	✓					
Collinsonia canadensis	Stone Root	FAC	✓		o/-				
Cunila origanoides	Dittany	UPL	✓	✓					
Desmodium spp.	Tick Trefoil (*glabellum*)	UPL	✓	✓					
Dioscorea villosa	Wild Yam	FAC	✓	✓			-/X		
Epigaea repens	Trailing Arbutus	UPL		✓					
Eurybia divaricata	White Wood Aster	FACU/UPL	✓	✓			o/-		
Galium triflorum	Bedstraws	FACU	✓	✓	-/o				
Galium circaezans	Wild Licorice	UPL		✓					
Gaultheria procumbens	Teaberry	FACU		✓					
Geranium maculatum	Wild Geranium	FACU		✓	-/X				
Goodyera pubescens	Rattlesnake Plantain	FACU	✓	✓					
Hieracium paniculatum	Panicled Hawkwort	UPL	✓			X/-			
Hieracium venosum	Hawkwort	UPL	✓	✓					
Impatiens capensis	Jewelwort	FACW	✓	✓			o/-		
Isotria verticillata	Whorled Pogonia	FACU	✓						
Lespedeza spp.	Bush Clover (*procumbens*)	UPL		✓					
Lycopus spp.	Bugleworts	OBL	✓	✓			o/-		
Maianthemum racemosa	Plume Lily	FACU	✓	✓					
Medeola virginiana	Ind. Cucumber Root	FAC	✓				o/-		
Mitchella repens	Partridgeberry	FACU	✓	✓					
Nabalus spp.	Gall-of-the-Earth (*albus, altissimus*)	FACU	✓	✓					
Oxalis spp.	Wood Sorrel	FACU	✓	✓					
Packera obovata	Rnd.-leaved Ragwort	FACU		✓					
Parthenocissus quinquefolia	Virginia Creeper	FACU	✓	✓					
Persicaria sagittatum/arifolium	Tearthumb	OBL	✓				X/-		
Pilea pumila	Clearwort	FACW	✓	✓			X/-		
Polygonatum biflorum	Solomon's Seal	FACU	✓						
Potentilla spp.	Cinquefoil	FACU	✓	✓			X/-		
Prunella vulgaris	Heal-All	FACU	✓						
Scuttellaria spp.	Skullcap (*lateriflora*)	FACW		✓					
Solidago spp.	Goldenrods	na	✓	✓			o/-		
Uvularia perfoliata	Perfoliate Bellwort	FACU	✓	✓	-/X				
Uvularia spp.	Bellworts (*puberula*)	FACU	✓	✓					
Veronica officinalis	Speedwell	FACU		✓					
Viola spp.	Violets	na	✓	✓	-/o				
Perilla frutescens	Beefsteak Plant	FACU	✓	✓					
Microstigeum vimineum	Stiltgrass	FAC	✓	✓			o/-		
Asplenium platyneuron	Ebony Spleenwort	FACU		✓					
Onoclea sensibilis	Sensitive Fern	FACW	✓		X/				

CHAPTER 6: MULTI-SCALE HABITAT PREFERENCES OF WOOD TURTLES (*GLYPTEMYS INSCULPTA*) IN CENTRAL APPALACHIAN FORESTS

Introduction

What controls who lives where and concomitant issues of scale are of fundamental theoretical and empirical importance for ecologists (Levin 1992, Jackson *et al*. 2001). In a word, the focus is on *habitat*, an area with the resources and conditions that allow a particular species' occupancy, survival, and reproduction (Hall *et al*. 1997, Mitchell and Powell 2003, Kearney 2006, Morrison *et al*. 2006, Beyer *et al*. 2010). All habitats are patchily distributed in geographical space (Aarts *et al*. 2008) and habitat selection emerges because organisms are better adapted to live and reproduce in some places than in others (Morris *et al*. 2008). Knowledge of habitat associations is critical for maintaining the spaces essential to organismal conservation.

Used habitat is any place occupied by the animal (Boyce *et al*. 2002). Prudent choices are necessary to acquire adequate energy, obtain refuge from predators, and avoid environmental extremes. These necessities may increase or decrease the use of *available habitat* (Halstead *et al*. 2009), which is any habitat actually accessible by the animal (Beyer *et al*. 2010). The ease with which an individual can reach a point in geographic space is a complex function of behavioral and environmental factors that might constrain access (Garshelis 2002). The comparison of used and available habitats allows us to identify habitats that are used non-randomly, *i.e.,* disproportionate to their availability to the animal

(Aarts *et al*. 2008). Estimates of this non-random *habitat preference* are contingent upon and sensitive to the samples of used and available habitat (Beyer *et al*. 2010). *"Habitat selection" sensu stricto* refers to the behavioral process of choosing to use habitat if it is encountered (Lele *et al*. 2013), while habitat preference is an attempt to quantify selection by a statistical description of habitat used relative to a particular sample of available habitat (Beyer *et al*. 2010). Such habitat suitability models assess the relationship between a species' presence or abundance and a suite of ecological predictor variables (Bollman *et al*. 2005, McDonald *et al*. 2013). The fundamental assumption of such models is that an organism's distribution reflects its ecological requirements, it being present in suitable habitats and absent from unsuitable ones (Guissan and Zimmerman 2000, Hirzel and Le May 2008).

The objective of this study was to determine a small set of predictor variables that best explain summer habitat use by North American Wood Turtles (*Glyptemys insculpta*) at two neighboring forested montane study sites in Virginia and West Virginia. The pertinent habitat attributes can be related to food availability, security from predation, thermo- and osmo-regulation, reproductive opportunities, or shelter from environmental extremes. Knowledge of the conditions underlying habitat preference can assist in identifying the factors influencing population distribution, abundance, or persistence. A better understanding of Wood Turtle habitat preference, informed by empirical data, model construction, and statistical analyses, will help focus conservation efforts, especially where commercial logging, recreational activities, road construction, vehicular traffic, or other anthropogenic disturbances may occur (Gardner *et al*. 2007). The findings from this study could contribute to an understanding of proximate ecological consequences arising from alterations of Wood Turtle habitat by human activities. Because the resources and conditions that allow survival and reproduction of a particular taxon are often not distributed uniformly, I hypothesized that habitat quality at the study sites was spatially heterogeneous and predicted that a subset of the environmental variables measured in the field at used and available locations would be correlated with Wood Turtle occurrences and thereby indicate habitat preference.

Focal Species

Wood Turtles are amphibious emydid turtles of eastern deciduous, coniferous, and mixed forests (see "Focal Species" in Chapter 1 for more detail). Wood Turtle foraging and ingestion occur in both terrestrial and aquatic settings, including underwater (Carroll 1999, Krichbaum pers. obs.). Wood Turtles forage on herbaceous plant leaves *(e.g., Viola*), fruits (*e.g.*, *Rubus*), mushrooms (*e.g., Boletus* and *Amanita*), earthworms, slugs, crayfish, beetles, and millipedes (see, *e.g.*, Strang 1983, Kaufmann 1992a, Niederberger and Seidel 1999, Ernst 2001a, Compton *et al*. 2002, Walde *et al*. 2003, Ernst and Lovich 2009, Jones 2009, Krichbaum pers. obs.). Turtle habitat use may be in response to fine-scale presence or abundances of litter invertebrates, fungi, or herbs that are distributed non-randomly in the forest (Meier *et al*. 1995, Caldwell 1996, Hanula 1996, Hutchinson *et al.* 1999, Rubino and McCarthy 2003, Van de Poll 2004, Kappes 2006, Gilliam 2007).

Due to their long lives and exhibited philopatry (Kaufmann 1995, Ernst 2001a&b, Arvisais *et al*. 2002, Tuttle and Carroll 2003, Akre and Ernst 2006, Willoughby *et al*. 2008, Parren 2013, Krichbaum this study), an adult Wood Turtle is presumably familiar with its activity area and the location of resources and clumped habitat patches therein, so its location at any time can be reasonably assumed to represent selection (McLellan 1986). A turtle's movement patterns thus implicitly include biotic and abiotic interactions (Kearney 2006).

Methods

Study Area

I studied two adjacent populations of Wood Turtles at their southern range periphery in Virginia and West Virginia. See "Study Area" in Chapter 1, Fig. 1.1, Tables 5.3-5.5, and Appendix 1 for details.

Field Procedures

Radio-telemetry and detailed sampling of turtle and random points at three spatial scales (stands, 400m^2 and 1m^2 plots) were used to evaluate habitat selection by Wood Turtles. See "Field Procedures" at Chapters 1 and 5 for details on turtles, radio-telemetry, and data collection. Detailed habitat variables lists and definitions are provided in Tables 6.1 and 6.2. In addition to the 1m^2 plot centered on the individual's location, in 2011-2012 I positioned four 1m^2 plots at the perimeter of each 400m^2 plot located at the four cardinal directions from the animal's location.

Each turtle and random point was also located within and assigned to a specific "stand" as defined by the US Forest Service. For management and inventory purposes the entire GWNF is divided into tracts that average *ca*. 10-20ha in size. Each of these delineated "stands" is consigned an age in years and specific "forest type" based on canopy composition and when previous stand-replacing logging took place (see Tables 5.4 and 5.5) (USDA Forest Service undated). As grouping of related forest types improves classification accuracy (Baker 2015), I aggregated these thirteen forest types into six forest type groups: Dm = mesic deciduous (composed of FT 56), M = dry mixed pine and deciduous (FTs 10, 42, 45), Mm = mesic mixed pine and deciduous (FT 41), Od = oligotrophic oak (FTs 52, 59, 60), Om = sub-mesic oak (FTs 53, 54), and P = pine (FTs 3, 33, 39). Depending upon their age, stands were aggregated into four different seral stages: esh = early successional habitat (0-35 years old), mid-suc. = mid-successional forest (36-75 years old), mature = forest at least 75 years old, but less than the lower age limit for designation as "old growth", OG = old growth (minimum years of age [90-140] depends upon forest type – see USDA FS 1997). These forest composition (forest type) and structure (seral stage) categories at the stand level provided for a third scalar grain of spatial analysis.

Analytic Procedures

I used conditional logistic regressions to analyze the habitat data at the different plot scales. In this method variables at each individual turtle point are compared with those at the paired random point. Results from these tests were assessed through an information-theoretic approach.

Akaike's information criterion (AIC_c), modified for small sample sizes relative to estimated parameters, was used to rank models, select the most parsimonious models, and for averaging of habitat variable coefficients. AIC_c values were rescaled to Δ_i values for ease of interpretation and ranking, and Akaike weights (w_i) were calculated to give the approximate probability of each model being the best model in the set (Anderson and Burnham 2002). All models with AIC_c values within two of the minimum value were considered well supported (Burnham and Anderson 1998) and of the well-supported models the one with the smallest number of variables can be considered to be the best model (Arnold 2010).

Different analyses were run for each state and gender as well as by gender for both states combined. The acronyms used herein are: VA female Wood Turtles = VFT, VA female random points = VFR, VA male Wood Turtles = VMT, VA male random points = VMR; WV female Wood Turtles = WFT, WV female random points = WFR, WV male Wood Turtles = WMT, WV male random points = WMR; female Wood Turtles = FWT, female random points = FRP, male Wood Turtles = MWT, male random points = MRP.

Analyses were conducted with the R statistical program (R Development Core Team 2015), specifically, the "Survival" and "mclogit" packages were used for the conditional logistic regressions and the "AICcmodavg" package for AIC_c values and model averaged coefficients.

Microhabitat Preference

This was assessed using data from the 1m^2 plots. Variables used in modeling were chosen based on their lack of correlation with each other; only the least correlated variables (Spearman or Pearson correlation coefficients ≤ 0.50) were retained for multivariate candidate models. Except for sand and rock for Virginia male turtles, none of the initial variables were strongly correlated so all were retained. Some variables had to be dropped from various model formulations due to lack of convergence in the regressions.

Fifteen candidate models were formulated with different combinations of inorganic, herbaceous living, non-herbaceous living, and organic non-living cover variables (Table 6.3). Some initial variables were dropped due to their miniscule (<0.5%) mean overall amounts of coverage. In addition, as leaf litter cover was the matrix element for ground cover and co-varied directly with the proportion of cover provided by the other variables, it was not included in any models to avoid the interpretation of a forest dwelling turtle avoiding leaf litter. Inorganic variables for ground cover were sand/gravel and rock; herbaceous living variables included forb and grass; non-herbaceous living cover variables were woody vegetation and moss; organic non-living cover variables included coarse woody debris (cwd) and bare soil. Models were the same for the different analyses except that rock was retained and sand dropped from the model formulations for Virginia males.

Mesohabitat Preference

Variables from the 400m^2 plots were retained for multivariate candidate models based on their lack of correlation (Spearman or Pearson correlation coefficients ≤ 0.50). None of the initial variables were strongly correlated so all were retained. Some variables were dropped from some model formulations due to lack of convergence in the regressions.

Twenty-two candidate models were formulated using different combinations of seventeen structural, compositional, and topographical variables obtained in 2011-2014 (Table 6.4). The ten structural and four compositional variables were each divided into two groups, encompassing attributes found at either overhead or ground levels. The structural overhead variables were number of large trees, number of medium trees, percent of horizontal vegetation obscurity at human-eye level, number of snags, percent of canopy openness, and stand age in years. Structural ground variables included percent of horizontal obscurity at turtle level, area of plot under canopy gaps, and number of pieces of large woody debris (LWD) in two size classes. The four compositional variables were likewise divided. The compositional overhead variables were the number of tree taxa and number of shrub taxa and the compositional ground level variables were the number of seedling taxa and the number of herbaceous taxa. I used the herbaceous taxa metric only in separate modeling and analyses performed with 2011-2013 data. The four topographical variables were distance to the main stream, slope inclination, slope aspect, and elevation. In addition, for analyses using pooled males and females from both VA and WV, I formulated nine additional models using the "importance values" of tree taxa as variables (see models 13-17 and 28-31 in Table 6.4); in these models I dropped number of large trees, number of medium trees, and number of tree taxa as variables. Importance values for individual taxa were calculated from the dbh and counts of every tree ≥ 10cm dbh in the 400m^2 plots (see Chapter 5).

Macrohabitat Preference

Using the stand data obtained from the USFS and the aggregated (Virginia and West Virginia turtles combined) male and female mesohabitat (400m^2 plots) data sets, I ran mixed conditional logistic regressions with stand forest type as the random factor. Using my calculated importance values and US Forest Service descriptions and definitions for forest types (USDA FS undated), I designated a forest type for each 400m^2 plot. Using the two aggregated (Virginia and West Virginia turtles combined) male and female data sets again, I also ran mixed conditional logistic regressions with plot forest type as the random factor. For these mixed conditional logistic regressions involving forest types I used the 2011-2013 datasets that included the number of herbaceous taxa as a variable and used the same model formulations (without importance values) as with the other regressions of meso-habitat data.

In addition, I also ran mixed conditional logistic regressions for males and females using the Virginia 2011-2014 data with stand seral stage as the random factor. I did not do such a seral analysis for the West Virginia data due to the fact that all the points there were either in mature or old growth stands. Forest seral stage is an indirect measure of some age-related environmental attributes (*e.g.,* woody debris, canopy cover, litter depth, and cool, moist, equable microclimatic conditions) that contribute to determining whether a site is suitable for a given species (Welsh 1990, deMaynadier and Hunter 1995).

Study Rationale

In this study, all the random points (*i.e.*, the posited available habitat) were accessible to the individual Wood Turtles for the following reasons. The random points were nearby the known location points of the various individuals; subsequent *post hoc* delineations of activity areas using minimum convex polygons showed the paired random points were within or nearby each individual's estimated summer activity area (Chapter 1). The random points were within or nearby the general zone (*viz*., the area within 300 meters of the main streams) known to be of use by Wood Turtles. Topographic barriers were not apparent, nor were obvious environmental factors that could have served to filter turtles out of forest communities at these lower elevations in the mountains. All the random points were in a proximity (within *ca*. 300m of a turtle point) that could easily be reached by a turtle, *i.e.,* healthy animals were physically capable of reaching them. Wood Turtles are mobile at small spatial scales, with mean daily straight-line distances moved during the summer of *ca*. 28.3m (computed based on the number of days separating the greatest straight-line distances between location points in 59 radio-tracked individuals' activity areas). They can move at a speed of at least

0.32km/hr (Woods 1945) or 1.1km/hr over short distances (Swanson 1940). In 2010 I radio-tracked an adult female in VA who traversed at least 1km in *ca*. 26 hours (Wood Turtles are typically diurnal so it is doubtful she was walking at night). The greatest known distance moved in a day by an individual during this study was *ca*. 520m (straight-line distance between location points) by an adult male in Virginia.

This study is of a "site attribute" design which compares ecological attributes at sites actually used by animals to those at random locations (the proxy for unused sites) (Garshelis 2002). The dependent variable is simply whether a site is used or unused. The fine-scale problem arises, however, when habitat differences might not be detected if the random sites (available habitat) are too similar to the used sites. My study is also a "design III" protocol where availability was sampled for each individual (Manly *et al*. 2002).

The chosen variables were hypothesized to be of biological importance to the animal, with a focus on resources and conditions available at a finer-scale, not coarse-grained land cover. There can be a gross mismatch between the fine-scale habitat patch chosen by an animal and the coarse-scale mapped vegetation cover types within which these smaller sites are embedded (*e.g.*, a patch of mesic deciduous forest within a larger mapped stand of more xeric pine or a canopy gap in an area of forest). Because of the short duration of the overall field study period (3.3 years), the restricted seasonality for the field work (summer only), and the long-term successional nature of these forest ecosystems (Shugart and West 1981), overall habitat quality and conditions were presumed to be somewhat constant at the study sites.

Used-available data do not give probabilities of use, rather, the results are proportional to these; the density of observations is modeled instead of a probability. A typical use-availability design compares number of locations (or time spent) in each habitat type to the relative amount or area of each type (a proportional use study). But frequently used habitats are certainly not selected against even if they are widely available. Likewise, infrequent use is not necessarily indicative of lack of suitability. Therefore, it is unlikely that selection can be accurately assessed "just by comparing relative use to the relative area of different habitats" (Garshelis 2002 at pg. 131). Instead, one must look at differential use, rather than use in terms of sheer availability. Observed actual use, such as is used in a site attribute design, is a stronger indicator of habitat selection than inference based on relative use (Garshelis 2002).

In this study sites classified as "used" were undoubtedly actually used; *i.e.*, the Wood Turtles were definitely found at those points. Of course, the mere occurrence in a habitat, especially of mobile organisms, does not necessarily indicate strong ecological links to that habitat (Lövei *et al*. 2006). Further, there exists the issue of contaminated controls, wherein some random/available points may actually be used points. The relative proportions of such used and unused points are unknown (Beyer *et al*. 2010). Although some sites might eventually be used, a representative sample that does not show presence is still an unbiased sample of use and non-use (Boyce *et al*. 2002). In this study, unless the Turtles were very well hidden, the random points were not being used by Wood Turtles when habitat metrics were obtained in the field; a thread trail revealed that a gravid female had passed through one random plot.

In use-availability and site attribute designs, the exponential logistic model is often used and fitted using logistic regression to evaluate the relative probabilities of use (by using the maximum-likelihood values of the model coefficients) (Beyer *et al*. 2010). Available points are not true zeroes, but numerical tricks to approximate the integral of the likelihood function. It must be remembered that conditional logistic regression coefficients are interpreted as relative differences in the habitat and not as absolute values (Compton *et al*. 2002, Row and Blouin–Demers 2006); *i.e.*, extreme negative values for certain habitat variables does not mean that turtles necessarily avoid such habitats. The conditional logistic regression approach is purely descriptive, it cannot extract causality. In other words, it is correlative; only an experimental approach can test the existence of causal links (Connell 1983). Hence, this method does not examine the fundamental niche, but only the realized niche within a specific geographic area.

If model coefficients indicate non-preference (*i.e.*, their confidence intervals include zero), one should not automatically infer that a habitat is unimportant: at some level of availability, preference is expected to be zero. A habitat attribute may be selected, but because it is widely available at the study site then preference is not reflected. Such an apparent lack of preference may be a phenomenon of scale.

Preference can change with scale because the relative availability of vegetation types or other environmental attributes changes across those scales (Beyer *et al*. 2010). Perhaps a preference for a certain attribute would become manifest if a broader extent of study was used, such as at the scale of Johnson's (1980) first or second order selection. That is to say, one of the reasons a population of organisms is found at a certain finer-scale locale may be because of the widespread availability there of particular habitat attributes. The coefficient in a logistic regression model decreases as availability increases and can even change sign, *i.e.,* changes in the spatial scale of availability can lead to drastic changes in perceived preference (Mysterud and Ims 1998, Beyer *et al*. 2010). The coefficient for a habitat used a lot can even be negative if that habitat is common, and, conversely, low levels of use can have positive coefficients if the used habitat is rare. Despite such anomalous results, even if functional responses exist, resource selection function coefficients for a particular locality can still be modeled (Boyce *et al*. 2002).

Results

Preference for Microhabitat Features

There were salient differences between proportions of ground cover in the $1m^2$ plots at turtle points and random points (Fig. 6.1). Turtles in both states and of both sexes consistently were found in microhabitats with higher amounts of coverage by forbs, grass, and coarse woody debris compared to paired random locations (see Table 6.5 for summary statistics of the metrics in $1m^2$ plots). VA females and WV males also preferred higher woody vegetation coverage, whereas WV females preferred lower amounts of coverage.

For both females and males in Virginia, two regression models were well supported (ΔAICc < 2), and contained similar combinations of cover variables (Tables 6.7 & 6.8, Fig. 6.2). Coefficients of the averaged models suggest that VA male Wood Turtles preferred microhabitats similar to those of females, with the addition of lower amounts of bare soil.

For West Virginia females, only one model, with four variables, was well supported. In addition to the variables stated previously, WV females preferred microhabitats with higher amounts of bare soil cover compared to paired random locations (Table 6.8, Fig. 6.2). West Virginia males' preference was more complex, six competing models had similar support and contained various combinations of six cover variables (Table 6.7).

In both states in 2013-2014, 1m^2 turtle plots had greater herbaceous taxa richness than did random plots, except for WV females (Tables 6.5 and 5.7, Fig. 5.15). In both states in 2011-2014, 1m^2 turtle plots had significantly more herbaceous cover (forbs and grass combined) than did random plots (Tables 6.5 and 5.7, Fig. 5.20): VA paired Wilcoxon signed rank test: $V = 9552$, $p < 0.00001$; WV Wilcoxon signed rank test: $V = 4418$, $p < 0.0001$. Mean herbaceous coverage: VA turtle plots 14.4% ± 1.7, VA RPs 2.5% ± 0.6; WV turtle plots 15.0% ± 1.6, WV RPs 8.1% ± 1.2.

In both states in 2011-2012, the proportional amount of herbaceous cover at $1m^2$ plots at the center of the $400m^2$ plots did not differ from that at the four $1m^2$ plots at the perimeter (using the mean value of the four), for either turtle points or random points (Table 6.5, Fig. 6.3) – VA female turtles paired Wilcoxon signed rank test: $V = 708$, $p = 0.2222$, VA female random points paired Wilcoxon signed rank test: $V = 504$, $p = 0.528$, VA male turtles: $V = 70$, $p = 0.609$, VA male random points: $V = 15$, $p = 0.119$; WV female turtles paired Wilcoxon signed rank test: $V = 125$, $p = 0.974$, WV female random points paired Wilcoxon signed rank test: $V = 88$, $p = 0.948$, WV male turtles: $V = 141$, $p = 0.797$, WV male random points: $V = 135$, $p = 0.509$.

In both states in 2011-2012, the five $1m^2$ plots at $400m^2$ turtle plots had significantly more herbaceous cover (forbs and grass combined) than did the five $1m^2$ plots at $400m^2$ random plots (using the mean of all five for comparisons): VA paired Wilcoxon signed rank test: $V = 2184$, $p < 0.00001$; WV Wilcoxon signed rank test: $V = 860$, $p < 0.0005$. Mean herbaceous coverage of the five plots: VA turtle points 13.7% ± 2.1, VA random points 2.3% ± 0.5; WV turtle points 11.2% ± 1.3, WV RPs 5.5% ± 1.2.

Preference for Mesohabitat Features

Female Wood Turtles in both states consistently preferred mesohabitats with higher levels of turtle-level obscurity, the larger size class of LWD, medium size trees, snags, canopy openness, and shrub taxa, along with gentler slopes and lower elevations, compared to paired random locations (Fig. 6.4). Females in WV also preferred mesohabitats with greater herbaceous richness (see Table 6.6 for summary statistics of the metrics in 400m^2 plots). Whereas VA females preferred warmer aspects, WV females preferred cooler aspects. Habitat preferences by male Wood Turtles were not as obvious and in some cases were contradictory to those for females. Virginia males showed marginal preference for mesohabitats with more canopy openness and fewer herbaceous taxa, compared to random sites. West Virginia males showed some preference for higher amounts of turtle-level obscurity, lower amounts of snags, and gentler slopes compared to paired random locations. See Table 6.17 for a synopsis of important mesohabitat variables for the different turtle groups.

In addition to counts of pieces of LWD, I measured the distance of individual turtles to the closest piece of LWD10 when they were located and did the same for the random points. The mean distance for 320 turtle points was 5.5m (se = 0.29m), while that for the 320 paired random points was 9.7m (se = 0.36m). A paired Wilcoxon signed rank test found turtle points to be significantly closer to LWD than were random points ($p < 0.000001$, $V = 40203$).

Virginia

For Virginia females, only one model, with ten structural, compositional, and topographic variables, was well supported (Table 6.9). Coefficients of the averaged models suggest that female Wood Turtles in Virginia prefer mesohabitats that have higher amounts of turtle-level obscurity, the large size class of LWD, medium size trees, snags, canopy openness, and shrub taxa, along with fewer tree taxa, gentler slopes, warmer aspects, and lower elevations, compared to paired random locations (Table 6.10, Fig. 6.5).

When I ran the same models for Virginia females with data from 2011-2013 that included the number of herbaceous taxa in a plot, the only well supported model was the same model formulation as was the top model for the 2011-2014 data (Table 6.11); moreover, the top five models were the same as resulted from the 2011-2014 data. Important coefficients of the averaged models for 2011-2013 were the same as the results from the 2011-2014 data, except without the larger size class of LWD as a factor (Table 6.12, Fig. 6.6). The number of herbaceous taxa was also not a factor in any of the top models, nor did it show up as an important coefficient from model averaging.

Male Wood Turtles in VA were not as clear as females in their preferences for mesohabitat conditions relative to random sites (Table 6.10, Fig. 6.5). Four competing models had similar support (ΔAICc< 2) and contained combinations of 8-10 habitat variables (Table 6.9).

When I ran models for Virginia males with data from 2011-2013 that included the number of herbaceous taxa in a plot, only one model, with four structural variables, was well supported (Table 6.11). Coefficients of the averaged models suggest that male Wood Turtles in Virginia prefer mesohabitats with more canopy openness and fewer woody seedling and herbaceous taxa, compared to random sites (Table 6.12, Fig. 6.6). The number of herbaceous taxa was not a factor in the top model.

West Virginia

Female Wood Turtles in West Virginia prefer mesohabitats that have higher values for the larger size class of LWD, medium-size trees, snags, turtle-level and eye-level obscurity, and shrub taxa, with cooler aspects, lower elevations, and locations closer to the main stream when compared to paired random locations (Table 6.10, Fig. 6.5). Only one model, with twelve structural, compositional, and topographic variables, was well supported (Table 6.9). Female Wood Turtles in West Virginia preferred mesohabitats that have higher amounts of herbaceous taxa and snags compared to random sites (Table 6.12, Fig. 6.6) when the same models were run with data from 2011-2013 that included the number of herbaceous taxa in a plot (Table 6.11).

Male Wood Turtles in West Virginia prefer mesohabitats with fewer numbers of large trees and snags, and gentler slopes, compared to paired random locations (Table 6.10, Fig. 6.5). Only one model, with eight structural, compositional, and topographic variables, was well supported (Table 6.9). Male Wood Turtles in WV preferred mesohabitats that have higher amounts of turtle-level obscurity and fewer numbers of snags compared to paired random locations (Table 6.12, Fig. 6.6) when the same models were run with data from 2011-2013 that included the number of herbaceous taxa in a plot (Table 6.11).

Pooled VA and WV Turtles

Both female and male Wood Turtles consistently preferred mesohabitats with higher values for canopy openness and turtle-level obscurity, along with gentler slopes, compared to paired random locations. Otherwise, there was not much intersexual overlap in preferred habitat conditions. In addition, females preferred sites with more medium-size trees, while males preferred fewer. There was no intersexual overlap in preference for importance values of overstory tree taxa (Table 5.3). Moreover, females preferred sites with higher values for Red Maple (*Acer rubra*) and Sugar Maple (*Acer saccharum*), while males preferred lower values. The number of herbaceous taxa was a marginally important variable for female turtles, but not males.

Females. Female Wood Turtles prefer mesohabitats that have higher levels of canopy openness, the larger size class of LWD, medium-size trees, snags, turtle-level and eye-level horizontal obscurity, and shrub taxa, along with fewer tree taxa, gentler slopes, and warmer aspects, compared to paired random locations (Table 6.14, Fig. 6.7). The models with importance values indicate that females preferred sites with higher values for White Oak (*Quercus alba*), Red Maple, Sugar Maple, and Tulip Tree (*Liriodendron tulipifera*), than random sites (Fig. 6.8). For Virginia and West Virginia female turtles combined, only one model, with nine structural, compositional, and topographic variables, was well supported (Table 6.13).

Important coefficients of the averaged models for females were similar to the results from the 2011-2014 data (Table 6.16, Fig. 6.7) when the same models for were run with data from 2011-2013 that included the number of herbaceous taxa in a plot. Only one model, with nine structural, compositional, and topographic variables, was well supported (Table 6.15); this was the same model formulation as was the top model for the 2011-2014 data. The number of herbaceous taxa was not a factor in the top model, though it did show up as a marginally important coefficient from model averaging. The models with importance values indicate that females prefer sites with higher values for White Oak, Red Maple, Sugar Maple, and White Ash (*Fraxinus americana*), compared to random sites (Fig. 6.8).

Males. Male Wood Turtles prefer mesohabitats that have higher amounts of turtle-level horizontal obscurity, canopy openness, and large-size trees, with fewer medium-size trees, gentler slopes, and closer to the main streams, compared to paired random locations (Table 6.14, Fig. 6.7). The models with importance values indicate that males prefer sites with lower values for Chestnut Oak (*Quercus montana*), Virginia Pine (*Pinus virginiana*), White Pine (*Pinus strobus*), Sugar Maple, and Tulip Tree, compared to random sites (Fig. 6.8). For combined VA and WV males, only one model, with thirteen structural and topographic variables, was well supported (Table 6.13).

Male Wood Turtles preferred mesohabitats that have higher amounts of turtle-level horizontal obscurity, canopy openness, large-size trees, and tree taxa, with gentler slopes, compared to paired random locations (Table 6.16, Fig. 6.7) when the same models were run with data from 2011-2013 that included the number of herbaceous taxa in a plot. The models with importance values indicate that males prefer sites with higher values for Black Gum (*Nyassa sylvatica*), and lower values for White Pine, Red and Sugar Maple, and Hickories (*Carya* spp.), than random sites (Fig. 6.8). Only one model, with seven structural and topographic variables, was well supported (Table 6.15). The number of herbaceous taxa was not a factor in the top model, nor did it show up as an important coefficient from model averaging.

Preference for Mesohabitat Features Using Random Effect Models

Using data from 2011-2013 that included number of herbaceous taxa, neither forest type of stands, forest type of 400m^2 plots, nor stand seral stage was a significant factor in well-supported regression models wherein it was used as a random effect, except for stand forest type for female turtles. Significant coefficients in the best models were consistent with those obtained from averaging of conditional logistic regression models without random effects; *e.g.*, preference for mesohabitats that have higher amounts of turtle-level horizontal obscurity, the larger size class of LWD, and canopy openness or area under gaps, with gentler slopes and warmer aspects, compared to paired random locations.

Seral stage of stands in VA did not arise as a significant factor in any of the regressions wherein it was used as a random effect. For VA male Wood Turtles, only one model, with seven structural, compositional, and topographic variables, was well supported (Table 6.18). Model coefficients with significant p-values suggest that male turtles preferred mesohabitats with more canopy openness and gentler slopes compared to random locations (Table 6.19). For VA female turtles, two models, each with ten structural, compositional, or topographic variables, were well supported (Table 6.18). Model coefficients with significant p-values suggest that female Wood Turtles preferred mesohabitats with more turtle-level horizontal obscurity, snags, shrub taxa, and medium-sized trees, with gentler slopes, compared to random locations (Table 6.19).

Of the 22 models using stand forest type as the random effect for Virginia and West Virginia female turtles combined, two models had similar support (ΔAICc< 2) (Table 6.18). The top model contained six structural and topographic variables. Model coefficients with significant p-values suggest that female Wood Turtles preferred mesohabitats that had higher amounts of turtle-level horizontal obscurity and area under canopy gaps, with gentler slopes and warmer aspects (with higher amounts of LWD10 being of marginal significance), compared to paired random locations (Table 6.19). Stand forest type was a significant factor in the top model.

For Virginia and West Virginia male turtles combined, of the 22 models using stand forest type as the random effect only one was well-supported (Table 6.18). This model had 8 structural, compositional, and topographic variables variables, including many of those in the top models for the females. Model coefficients with significant p-values suggest that male Wood Turtles prefer mesohabitats that have higher amounts of turtle-level horizontal obscurity (with distance from the main stream being of marginal significance), compared to paired random locations (Table 6.19). Stand forest type did not arise as a significant factor in any of the male turtle regressions.

Forest type of the 400m^2 plots did not arise as a significant factor in any of the regressions wherein it was used as a random effect. Of the 22 models for

Virginia and West Virginia female turtles combined, two models were well supported (Table 6.18). The best model had six structural and topographic variables and was the same formulation as the top model when forest type of stands was used as the random effect. Model coefficients with significant p-values suggest that female Wood Turtles prefer mesohabitats that have higher amounts of turtle-level horizontal obscurity along with gentler slopes and warmer aspects (with higher amounts of LWD10 and area under gaps being of marginal significance), compared to paired random locations (Table 6.19). For pooled Virginia and West Virginia male turtles only one model, with five structural and topographic variables, was well supported (Table 6.18). Model coefficients with significant p-values suggest that male Wood Turtles prefer mesohabitats that have higher amounts of turtle-level horizontal obscurity and warmer aspects, compared to paired random locations (Table 6.19).

Discussion

Tradeoffs in resource allocation to various compartments of their energy budget, result in habitat-mediated choices (manifest as habitat preferences) that ultimately affect reproductive output and fitness (Congdon 1989, Huey 1991, Penick *et al*. 2002). Structural, compositional, and topographical characteristics of forest habitat can impact Wood Turtle fitness either directly or indirectly through foraging success, predator vulnerability or avoidance, and thermo- and osmo-regulatory options. I identify Wood Turtle habitat preference through a subset of multi-scalar environmental variables at the southern periphery of their range.

In the 1m^2 plots female and male Wood Turtles in both VA and WV exhibited the same preferences for microhabitats with greater forb, grass, CWD, and woody ground cover than available at random points. This comports with the well documented Wood Turtle omnivory as well as their apparent preference for more dense ground vegetation in the 400m^2 plots (see “Turtle-level obscurity”, “LWD”, and “Herbaceous richness and cover” subsections below), perhaps using this to avoid predation or high temperatures. Wood Turtles seem more risk averse than syntopic Box Turtles (*Terrapene carolina*): Except for gravid females during the nesting season, I never observed Wood Turtles on roads or roadsides (in the ten years of observing turtles at this study area), whereas I observed Box Turtles sitting on closed roads out in the open many times. Presumably the adaptive advantage of having a closable shell makes Box Turtles less averse to being in open habitats where detection by predators is more likely. Costa (2014) found differences in flight distance between two species of Emydid turtles and Lopez *et al*. (2005) found escape decisions by the Mediterranean Terrapin (*Mauremys leprosa*) to be influenced by habitat-related visibility.

In contrast to the 1m^2 plots, there was limited congruence between turtle groups (VFT, VMT, WFT, and WMT) as to the habitat variables that were preferred or avoided at the 400m^2 plots (Table 6.17, Figs. 6.5 & 6.6). Whereas several variables were consistently significant in various model formulations female turtles, the model results for males were more ambiguous, suggesting that males did not select the sampled meso-habitat conditions as strongly as did the females (Tables

6.10-6.12, 6.14, 6.16, 6.19). All these results may be at least partially explained by the fact that male turtles generally did not disperse into the forest as far as females, *i.e.*, they were located closer to the main streams. The habitats available there may be less variable than the habitats used by the more widely ranging females (*e.g.,* relatively less variation in slope, aspect, soil moisture, or forest types). If this is the case, then perhaps it is not that the males are less selective, it is just that preferred habitats are relatively more available for them, *i.e.*, random points are analytically indistinguishable from the turtle points.

Due to differences in life history characteristics, habitat preferences of animals at the periphery of their geographic ranges can be expected to differ from those at the core (Kapfer *et al*. 2008). For example, though sites that are too open in the region of this study can be potentially problematic with regard to CT_{max} for Wood Turtles in the summer (Chapter 3), such risk changes with the season, geographic location, and behavior. Habitat of limited suitability for use by adults in the summer due to excessive temperatures, such as roadsides or anthropogenic openings, may nevertheless provide valuable nesting sites earlier in the year (Krichbaum pers. obs.). In addition, sites detrimental in the south or summer may be more suitable in the north or spring and vice-versa.

Habitat Variables

Canopy Openness

Amount of canopy cover was a key factor in preferred habitats for these Central Appalachian Wood Turtles; Michigan Wood Turtles also showed such an affinity (Remsberg *et al*. 2006). Broken canopies and gaps provide space for the development of internal habitat patchiness and edges (Noss 1991) and allow enough light and warmth for the ground floor herbaceous layer and associated insect communities (trophic resources) (Jennings *et al*. 1999, Bollman *et al*. 2005). Gaps are important for sustaining herbal growth, richness, and persistence (Goldblum 1997, Anderson and Leopold 2002). Thick herbaceous growth also provides cover from predators (Bollman *et al*. 2005), thus may enhance fitness (survival). Gap formation from a large tree falling also supplies LWD with the below-described benefits.

Wood Turtles, however, did not prefer large canopy openings such as logging cuts, roads, or roadsides. On those few occasions when VA turtles were located in early successional habitat at recent large logging cuts, with one exception (a female eating blackberries) they were at the very edge of the cutting unit (within *ca*. 10-15m of the surrounding uncut forest). Wood Turtles did use small fabricated "wildlife openings" with grassy and herbaceous ground floors and shrubby overstories (*e.g.*, *Rubus* spp.); unlike regenerating logging openings, these did not have high densities of saplings. These types of habitats with small numbers of trees are typically lumped into the early successional category. However, they are structurally and often compositionally different than young sites of regenerating forest with high stem densities of saplings. Managerial mishaps are possible when relevant distinctions of pattern go unrecognized; *i.e.*, fabricating large tracts of esh with dense numbers of saplings, when what would actually be beneficial are small tracts dominated by herbs/grass/shrubs.

For ectotherms, thermoregulatory or energetic requirements may be a primary driver of habitat selection (Lagory *et al*. 2009, Kapfer *et al*. 2010); thus, canopy closure may serve as a coarse surrogate metric of opportunities for thermoregulation (Pringle *et al*. 2003). Utilization of open areas, forest edges, or other habitats could be correlated with thermoregulatory behaviors to maximize physiological states (Row and Blouin-Demers 2006, Halstead *et al*. 2009). Sites with high degree of canopy openness, such as roadsides or recently logged sites, have the highest temperatures and greatest temperature variance (Collins *et al*. 1985, Currylow *et al*. 2012, Chapter 3), while sites with very closed canopies, such as a regenerating clearcut with high stem density, offer the least thermal diversity (Chapter 3). Canopy gaps along with their associated LWD and other ground cover provide basking opportunities for turtles where sunlight reaches the ground (Dodd 2001, Krichbaum pers. obs.), as well as thermal refugia that allow escape from high midday temperatures, thus allowing for thermoregulatory precision via fine-scale shuttling.

In Appalachian forests 2.5-9.6% of the canopy may be in some stage of recovery from natural gap formation (Boerner 2006). Gaps in old-growth Tennessee mesic deciduous forest tended to be larger, more variable in area, and have greater variation in microclimates than the undisturbed forest floor (Clebsch and Busing 1989). Perhaps due to cooler, moister microclimates, the abundance of the largest macroarthropod size class was similar in mature closed-canopy controls and unlogged natural gaps (Greenberg and Forrest 2003); hence, intensive cutting could result in declines of ground-occurring macroarthropods (Greenberg and Forrest 2003) that are preferred food of Wood Turtles.

Turtle- and Eye-level Obscurity

Horizontal obscurity can arise from multiple sources that are not mutually exclusive and can be additive: herbaceous vegetation, as well as woody vegetation, alive and dead (*i.e.*, woody debris). The obscurity board can be conceived as a surrogate metric of exposure to predation; a greater degree of shrub, herbaceous, or grass cover may reduce the risk of predation by taxa that rely on visual cues when hunting. Aside from offering cover, obscurity can be associated with foraging opportunities, either directly (such as consumption of forbs) or indirectly (such as invertebrates associated with herbaceous understories or woody debris). The area beneath low-lying vegetation may provide distinct microclimates with the lower ambient temperatures and increased soil moisture and relative humidity that Wood Turtles prefer (Chapters 3 & 4), conditions that might also favor terrestrial invertebrate populations (Trainor *et al.* 2007).

Eye-level obscurity was not nearly as important a variable as was turtle-level, though it was weakly important for female turtles (Fig. 6.8, Table 6.14). Eye-level and turtle-level horizontal obscurity were only weakly correlated. The potential mismatch between the perception of cover by turtles and humans (Bowne 2008) is important to consider when characterizing a forested site. The term "open habitat" is often employed, but a location that has the appearance of openness to an upright human observer can be densely vegetated at a turtle's level, and *vice-versa*. It is essential to discern and communicate these distinctions when making recommendations for management practices that have the potential to alter site structural conditions.

Slope Inclination

It is important to recognize that the avoidance of steeper slopes was not an absolute result, but relative to the site. In both states slope inclination at random sites was around 50% more that at turtle locations; however, the average slope inclination of turtle locations in WV was around 50% more that at random locations in VA (Table 6.6). Turtles were sometimes located on very steep sites, up to 31° and 33° in VA and WV respectively. Not only could steeper slopes be more metabolically expensive to traverse, there could be a physical limit to a turtle's ability to use steep slopes; Box Turtles (*T. carolina* and *T. ornata*) had trouble maintaining their position on slopes greater than 40° (Muegel and Claussen 1994, Claussen *et al.* 2002). Though Wood Turtles are larger, have stronger limbs (Abdala *et al*. 2008), and are more adept at climbing than Box Turtles (Pope 1939, Krichbaum pers. obs.), there could still be metabolic, physical, and behavioral constraints upon their use of steep slopes.

Aspect

Because Wood Turtles are one of the more northerly distributed chelonians and are considered to be a cold-adapted species (Stephens and Wiens 2009), I expected them to exhibit a clear preference for north aspect sites, which are generally cooler and of higher humidity (Cantlon 1953, Smith and Smith 2002). This was not the case. When the states were examined separately, the logistic regression results suggest that Wood Turtle males did not prefer a specific aspect, as was the case for Box Turtles in WV (Weiss 2009). Males preferred plots with warmer aspects when plot forest type was a factor. And though both males and females used slopes of all aspects, ranging from the warmest (SW orientations with a value of 0) to the coolest (NE orientations with a value of 2), VA females preferred relatively warmer aspects, while WV females preferred relatively cooler aspects (Table 6.6). Thermoregulatory patterns may have differed because temperatures were lower in the higher elevation VA site than in WV (Chapter 3).

Overall diurnal surface temperatures of microhabitats in WV were *ca.* 1.2°C higher than those in VA, a not unexpected result given that elevations in VA were on average 180m higher than those in WV (Chapter 3). Based on temperatures of turtles' carapaces in July and August of 2014, females in VA maintained slightly higher diurnal temperatures than males (22.8°C vs. 21.3°C) (Chapter 3), perhaps due to the differential energetics of reproduction. Due to aspect, height of canopy vegetation, and the degree of slope inclination, some ground-level sites never receive direct solar radiation. So, to bask in direct sunlight a turtle (such as VA females) would have to select certain aspects. In addition, as slopes were generally steeper in WV than VA, warmer aspects in WV can be expected to be warmer than similar aspects in VA (due to greater angle of incidence). Moreover, aspect can influence plant assemblages. In Ohio, herb species richness was higher on south aspect slopes, but density was greater on north aspect slopes (Small and McCarthy 2003) and in a Kentucky deciduous forest, north facing slopes had higher productivity (McEwan and Muller 2011). All these metabolic, ecological, and physiographic differences may contribute to the differences between sexes and states in the use of slope aspects.

Woody Debris

Wood Turtles had a propensity for associating with sites with relatively higher abundance of the larger size-class (diameter ≥ 25cm) of woody debris (LWD10). Turtles also showed a preference at the microhabitat scale (1m^2 plots) for sites with relatively higher amounts of coarse woody debris. Furthermore, turtles were also located closer to LWD than were random points. These three pieces of evidence are strong indication of the Turtles' preference for associating with woody debris.

Many reptile and amphibian and other vertebrate taxa show a close association with woody debris (Whiles and Grubaugh 1996). For instance, Trainor and colleagues (2007) found a positive relationship between woody debris amounts and jumping mouse abundance and survival. Coarse woody debris can be an important substrate for herbaceous plants (Roberts 2004) on which turtles might forage. Woody debris also provides substrate and refuge for macroinvertebrates that are important food items (Harmon *et al*. 1986, Caldwell 1996) and for small vertebrates can provide cover from predation (Everett and Ruiz 1993, Manning and

Edge 2004). Predators can affect the choice of habitat by prey species (Power *et al*. 1985, Ripple and Beschta 2004, Willems and Hill 2009) and such alteration of habitat use can have life history and fitness consequences (Huffaker 1958, Jackson *et al*. 2001). Spaces under large woody debris can also provide thermal and hydric refugia with moister and cooler conditions that can be more favorable than those available on nearby ambient soil and litter (Rittenhouse *et al*. 2008, Krichbaum unpub. data). For instance, at 11:56 on Aug. 8, 2011 the surface temperature where an adult male WV Wood Turtle was sitting in the sun was 35.2°C, while the temperature in the space under an upraised log *ca*. 0.5m away was 27.2°C (Fig. 6.9).

Various mushroom species are important elements of the Turtle's diet (Strang 1983, Kaufmann 1992a, Tuttle 1996, Compton *et al*. 2002, Walde *et al* 2003, Ernst and Lovich 2009, Jones 2009, Krichbaum pers. obs.). Macrofungal and myxomycete fungi richness was positively correlated with log size and amounts of coarse woody debris at old age oak and mixed mesic forest study sites in Ohio (Rubino and McCarthy 2003). Similarly, in New Hampshire all sites with above average CWD cover had above average numbers of species of macro-fungi, with mean mushroom diversity in old growth sites being 2.5 times the amount in non-old growth sites (Van de Poll 2004). Box Turtles (*T. carolina*) can be important dispersal vectors of fungal spores (Jones *et al*. 2007) and Wood Turtles, being facultative mycovores, can be inferred to supply similar ecological function (*viz*., endozoospory and fecal facilitation of fungi reproductive success).

Wood Turtles also relish slugs, snails, and earthworms (Ernst and Lovich 2009, Jones 2009, Krichbaum pers. obs.). Slug densities and land snails are positively correlated with the presence of coarse woody debris (Caldwell 1996, Kappes 2006). After intensive logging (which removes trees that would become large dead trees) it can take many decades for loadings of large woody debris to recover on sites (Hedman *et al*. 1996, McMinn and Hardt 1996, Webster and Jenkins 2005, Keeton *et al*. 2007). Snail assemblages and densities are also positively correlated with litter composition and depth (Martin and Sommer 2004). Other invertebrates, such as beetles, millipedes, and earthworms that Wood Turtles are known to eat (Krichbaum pers. obs.), are associated with forest floor litter or LWD (Caldwell 1996, Hanula 1996, Hendrix 1996, Ulyshen and Hanula 2009).

Snags

Standing dead trees were perhaps affiliated with macro-invertebrates or saprophytic fungi upon which the turtles feed. Of course, snags also can be associated with both LWD on the ground and canopy openness, although statistical tests indicated that these conditions were not strongly correlated at these study sites. Though female turtles in both VA and WV exhibited a preference for sites with relatively greater numbers of snags, male turtles in WV preferred fewer snags relative to random points. Though the situation regarding females has discernible underlying biological explanations, I have no explanation for that involving males, *i.e.*, the results may be a statistical artifact.

Herbaceous Richness and Cover

Turtle $400m^2$ and $1m^2$ plots had greater herbaceous richness than did random plots in both states (Figs. 6.4 & 5.15, Chapter 5); which was also the case at a WV Wood Turtle river site (McCoard *et al*. 2016b). Though I have few direct personal observations of feeding, I assumed that ground floor plant taxa found at a site may be an important driver of turtle use of those sites (see pg. 260 of Ernst and Lovich 2009 for literature citations for foraging observations). I have only observed Wood Turtles feeding, or observed evidence of feeding (such as pieces of foodstuffs on their faces), 39 times from 2006 to 2017 in VA and WV. Almost half of these (18) involved herbaceous leaves, with the only identifiable taxon being *Viola* spp.

In both states $1m^2$ plots positioned at turtle points had significantly more herbaceous cover (combining both forbs and grass) than did those at random points. The lack of difference in amounts of herbaceous cover between $1m^2$ plots at the center of $400m^2$ plots and the four placed at the perimeter of the $400m^2$ plots suggests that the turtles are selecting for higher levels of cover at the meso-scale as well as the micro. Meso-scale preference is also corroborated by the five $1m^2$ plots at turtle points (the central one and four peripheral) having significantly more cover than the five at random points. In addition to providing edible herbaceous flora, high levels of herbaceous ground cover may be correlated to abundance or presence of invertebrate prey as well as facilitate the avoidance of predators.

Shrub Taxa

Sites with more shrub taxa may be preferred because they are more likely to provide foraging opportunities; perhaps Turtles were feeding on the fruits or leaves of seedlings of some species found in the shrub layer, such as Spicebush (*Lindera benzoin*) and Serviceberry (*Amelanchier* spp.). Turtles preferred sites with greater obscurity at the ground- and/or eye-levels; brushier sites with greater eye-level obscurity could have had more taxa, though strong correlations did not exist between these conditions here.

Tree Taxa

Females preferred sites with higher importance values for White Oak, Red Maple, Sugar Maple, and White Ash or Tulip Tree, while males showed an aversion for sites with higher values for Chestnut Oak and Virginia Pine, as well as maples and Tulip Tree. Domination by Chestnut and Scarlet Oaks and Virginia Pine is generally indicative of nutrient poor sites (oligotrophic) (Ashe 1922, Burns and Honkala 1990, Fleming and Coulling 2001, Weakley *et al*. 2012). Greater importance values for Sugar Maple, Red Maple, White Ash, and White Oak at sites may have to do with site productivity (higher soil nutrient availability) and/or moisture regimes (Burns and Honkala 1990). If herbaceous plants are an important foraging resource, Wood Turtles may be differentially using forest tracts dominated by different tree taxa; this study provides some evidence that the number of herbaceous taxa in the 400m^2 plots at these VA and WV sites varied with forest type (Chapter 5). The logistic regressions indicated that female Wood Turtles prefer sites with higher numbers of taxa of both larger trees (≥ 10cm dbh) and shrubs (2.5cm ≤ dbh < 10cm); at a WV river study area McCoard and colleagues (2016a) also reported greater tree species richness at Wood Turtle locations than random locations.

It must be kept in mind that just because a site has high amounts of a certain taxon, such as Chestnut or Scarlet Oaks, does not mean that Wood Turtles cannot or do not use it. Such sites can have habitat attributes that the turtles prefer, such as LWD, abundant mushrooms, particular forbs, or dense understories. In fact, at the plot with the highest importance value for any single tree species, a value of almost 98 for Chestnut Oak, a Wood Turtle was present. Because of this welter of interacting confounding conditions, Wood Turtles overall are labile in their use of sites with different tree taxa and proportions of tree taxa (*i.e.*, different forest types).

Forest Type of Stand and Plot

Except at the stand scale for female turtles, forest type was a significant factor at neither the scale of a stand (generally *ca*. 5-20ha in size) nor the 400m^2 scale when used as a random factor in mixed conditional logistic regressions (Table 6.13). The nonsignificant result may be due to two reasons, one being the size of the stands (generally 10ha or more). Since the summer activity areas of the turtles were generally small (*ca*. 2ha) and the random points were located within 300 meters of the turtle points, many random points would fall within the same stand as the turtle points. Secondly, the resolution of stand categorization is too coarse to reflect actual on-the-ground variation, even if the random point fell within a different stand from the turtle point. For instance, an entire 20ha stand may be validly designated as a Scarlet Oak forest type since overall across the stand that taxon is predominant, but embedded within it there may be tracts that are dominated by White Oaks or maples. Because female turtles disperse farther from the main streams than males, they are more likely to encounter stands of different forest types and seral stages. These differences in overall composition and structure may influence or be in response to the other environmental conditions available on site.

The $400m^2$ plot-scale designations of forest type can be expected to more closely pick up actual on-the-ground variation in forest composition that is meaningful to the spatial scale at which Wood Turtles move about. However, when the forest type of the specific $400m^2$ plots was used as a random effect in the mixed conditional logistic regressions it was not a significant factor for either males or females (Table 6.17). This anomalous result is difficult to reconcile with the often clear differences between the stand- and plot-scale designations of forest types for turtle and random points (Chapter 5).

Both the stand- and plot-scale regression results suggest that forest type composition is of minor importance for Wood Turtles, particularly males. However, as the findings regarding importance values show, these forest type results should not be strictly interpreted as showing sites of a certain species composition are either preferred or avoided relatively more than others. It is just that the environmental variables used in this particular mixed modeling (*e.g.*, number of tree taxa) may vary little with forest type here, or if they do are of little influence on Wood Turtle preference.

Stand Age and Seral Stage

Stand age was of marginal significance (at best) only for male Wood Turtles (VA and WV combined) in the model averaged coefficients for the 2011-2014 data (Table 6.14, Fig. 6.7); the negative sign for the males' age coefficient indicated a preference for stands relatively younger than the random points. This outcome for the males may be due to locations of several Virginia males inside recent "modified shelterwood" logging sites (this type of even-age logging removes around 90% of that of a clearcut). In each case, however, the Turtles were located where a mature "leave tree" was still standing, along with its relatively undisturbed understory, at the very edge of the cutting unit (within *ca*. 10-15m of the surrounding uncut forest) (Fig. 6.10). Overall, Wood Turtles tended to avoid early successional habitat of regenerating sites of recent intensive logging. Seral stage did not arise as a significant factor in any of the regressions wherein it was used as a random effect (Table 6.18). The majority of the turtle points (83.7%) as well as the random points (70.5%) in Virginia were in older forest stands (mature and old growth seral stages). It is possible that if more random points had been in early successional stands that seral stage would have emerged as a significant factor. As an example, in Maine Wood Turtles were considered to not use regeneration sites of the forest-types they inhabit (Bryan 2007 at pg. 62).

General Issues

In general, animals should be trying to leave poor-quality habitats and trying to stay in higher-quality habitats (Garshelis 2002). The consistently observed philopatry and high survival of Wood Turtles at these study sites (this study, T. Akre unpub. data) are indicative of the high habitat quality found there. When a Wood Turtle is located repeatedly at the same site it is not known whether this is due to frequent return to the site or to prolonged stay there. Either way, stay periods within a particular area generally indicate the favorability of that habitat for some performed activity (Owen-Smith *et al*. 2010). Perceived predation risk can alter the use of habitat by prey species (Carrascal *et al*. 1992, Calsbeek and Cox 2010, Costa 2014), though for herbivores the primary influence on home range occupation patterns may be the spatio-temporal availability of resources (Mueller and Fagan 2008).

Summer activity areas of 64 Wood Turtles radio-tracked during this study averaged 2.2ha (se = 0.35, range 0.1-13.3ha) (Chapter 1). Abundant, spatially concentrated, and predictable resources promote small home ranges; though the outcomes of interactions between food availability, habitat structure and complexity, and predator presence are complex and poorly understood (Huffaker 1958, Ritchie and Johnson 2009). Productivity decline or more patchily distributed or spatially unpredictable resources can result in home range expansion (*i.e*., lowering the population density in the landscape); in Ontario, Smith (2002) found Wood Turtle density to be negatively correlated with the size of home ranges.

Resources that are both spatially and temporally unpredictable across years can result in different occupation patterns in different years; hence, there is no single best temporal scale to sample Wood Turtle spatial ecology.

According to “ideal free distribution”, as animal density increases in preferred habitats, less becomes available for each individual, so habitat quality for each diminishes as well (Fretwell and Lucas 1970). Thus, population density can influence habitat selection and in turn reproductive success and potential evolutionary change (Fortin *et al*. 2008). For Wood Turtles at these study sites, however, it is difficult to see how their apparently low population densities (*e.g.*, an estimated 0.7 adults/ha in WV based upon an adult population size of 76 and a site area of 110ha; Chapter 3) could have any appreciable impact on available foraging, cover, or thermoregulatory resources; therefore, activity area size or habitat selection here is probably not influenced by conspecific densities. It is not clear which and to what extent potential interspecific competitors may be affecting Wood Turtle spatial ecology. Perhaps herbivores, omnivores, or insectivores such as White-tailed Deer (*Odocoileus virginianus*), mice, voles, shrews, Wild Turkeys (*Melleagris gallopavo*), or Box Turtles (*T. carolina*) are influencing Wood Turtles’ habitat use.

Wood Turtles are neither herd animals nor territorial (Kaufmann 1992b), though during their winter inactive period they may congregate at underwater stream hibernacula (Harding and Bloomer 1979, Parren 2013). Particularly in spring and fall, they also can be attracted to conspecifics for mating purposes in aquatic habitats, but during the summer they apparently move independently and have overlapping home ranges/activity areas (Fig. 1.2). On several occasions, however, I found the same pairs of females very close to one another (within 1 meter) on different days at successive terrestrial locations separated by hundreds of meters. I also occasionally found males adjacent to females at various distances from the main streams. Those particular occasions aside, differences in habitat use between males and females such as revealed by this study have been observed previously in Wood Turtles as well as other chelonian species (Tingley *et al*. 2010, Millar and Blouin-Demers 2011, Brown *et al*. 2016).

Differences in habitat preferences between Virginia and West Virginia turtles may be due to differences in vegetation, topography, or underlying soil types between the two sites. The West Virginia site is more sharply incised, with generally steeper slopes (see “Slope” at Table 6.6) and more topographic relief than in an area of similar size in Virginia (see Fig. 1.1). The relatively flat benches associated with the main streams are generally far wider in Virginia than in West Virginia. In addition, the forests in West Virginia present a much greater dominance by conifers, indicating somewhat more oligotrophic conditions there than in Virginia. Due to all these differences, there may be subtle though distinct variation in the distributional patterns of beneficial and adverse conditions, resulting in turn in different patterns of Wood Turtle behavior, selective pressures, and spatial ecology. For instance, overall the canopy is more open in West Virginia, so suitable basking sites open to direct sun are more widely available and more easily attained by thermoregulating female turtles.

Conservation Recommendations

Habitat suitability models such as those resulting from my study contribute to conservation by delineating ecological requirements of species, facilitating design of conservation reserves and plans, predicting effects of habitat loss or alteration (including by climate change), providing an understanding of biogeography and dispersal barriers, directing the search for new populations or species, identifying reintroduction sites, and understanding species invasions (Cianfrani *et al*. 2010). The habitat models and metrics described herein are practical, measurable, and understandable (Noss 1990). These allow conservationists and forest managers to 1) identify habitat components of high value to Wood Turtles, 2) assess the abundance, distribution, and quality of suitable habitat, 3) monitor habitat availability and quality over time, and 4) restore or protect suitable habitat and improve carrying capacity for the species (Bollman *et al.* 2005). Using the results from this study and others, a habitat suitability index – a simple scoring system for evaluating the quality of known, potential, or restored habitats – could be developed for Wood Turtles. Also see "Conservation Recommendations" in Chapter 5 and "Conservation Considerations" in Chapter 3 for relevant discussion *in re* Wood Turtles.

Tradeoffs exist between the predictive power and explanatory power of models (Kearney and Porter 2004); its applicability to other areas is one way the robustness of a model can be measured. Some models can be applied to vast areas because habitat is similarly dominant across broad regions; *e.g.*, the old growth Douglas Fir forest constituting Spotted Owl (*Strix occidentalis*) habitat (Boyce *et al*. 2002). My study design does not test for broader-scale landscape effects beyond the extent of the study sites. Extrapolation beyond the region and scale where models were developed is generally to be avoided (Bollman *et al*. 2005, Hirzel and Le May 2008); there is little theoretical support for believing preferences estimated in one region will be good predictors of preference in different regions (Beyer *et al*. 2010). The Wood Turtle models generated by this study, however, may have applicability in the region with similar ecological conditions Omernik and Bailey 1997), *e.g.*, the Ridge and Valley physiographic province and where oak and mixed forests dominate (*sensu* Dyer 2006, McNab *et al*. 2007).

Within natural forests where this study was located, as well as in much of the northeast region where Wood Turtles range, a disturbance regime of small-scale, within-stand gap processes is the norm (Runkle 1985 & 1990, Mladenoff *et al*. 1993, White and White 1996, Seymour *et al*. 2002, Rentch 2006). These intermittent canopy disruptions occur through such mechanisms as windthrow, tree senescence, ice storms, drought, insects, American Beaver (*Castor canadensis*), floods, and pathogens (Braun 1950, Rentch 2006). Large "catastrophic" stand replacing events, such as hurricanes and conflagrations (canopy fires), are naturally a rare occurrence (Runkle 1990, Lorimer and White 2003). The congruence and harmonization, or lack thereof, of human disturbance (*e.g.*, cutting regimes) with the spatial and temporal parameters of the natural disturbance regime are an ongoing conservation concern throughout the Turtle's range and elsewhere (Franklin *et al*. 2002, Seymour *et al*. 2002, Lorimer and White 2003, Roberts 2004). Researchers in northern Maine found individual tree selection and group selection systems to be the most obvious silvicultural analogs to the natural disturbance history (White *et al*. 2005). In research involving Appalachian mixed-hardwood sites in West Virginia, Miller and Kochenderfer (1998) found that that "[c]anopy openings with a minimum diameter of 170 feet (0.5 acre) provide suitable light conditions for virtually all desirable [tree] species to develop and grow to maturity".

Intensive logging, such as even-age harvest methods that cut an entire stand, typically simplify structural diversity at sites, reduce litter and woody debris, and alter soil structure and microclimate regimes (Chen *et al*. 1999, Zheng *et al*. 2000, Webster and Jenkins 2005, Todd and Andrews 2008). Except for severe fires, natural disturbances generally result in greater amounts of coarse woody debris (Spies *et al*. 1988). Diminishment, removal, or absence of woody debris, litter, and humus can have a dramatic impact on organisms that depend on them for food and shelter (McMinn and Crossley 1996). Hence, intensive cutting and removal operations can negatively influence the abundance and species composition of turtle prey/forage such as arthropods, slugs, snails, and fruits (Shure and Phillips 1991, Caldwell 1996, Greenberg and Forrest 2003, Kappes 2006, Reynolds-Hogland *et al*. 2006). This could be due to cooler, moister microclimates in unlogged sites (Greenberg and Forrest 2003). For instance, slugs, especially stenoecious forest species, are highly sensitive to climatic fluctuations originating from canopy gaps or from disturbance of the leaf litter layer (Kappes 2006). A typical rationale used for timber sales is the assertion that after cutting the logged sites will have increased berry or soft mast production. However, this enhancement is only short-term (2-9 years), then the cutover sites have a very long period (30-60 years) of very low soft mast production (Reynolds-Hogland *et al*. 2006).

Burning is another concern for Wood Turtles, not only due to the potential for direct mortality, but also because of the potential for habitat degradation. Decay processes generally tend to mesify microsites while fire tends to xerify them (Van Lear 1996). Burning tends to make sites hotter, drier and more open, thereby exposing organisms such as turtles to more predators and desiccation. The incineration of forest floor material (*viz*., woody debris, litter, humus) may also directly destroy or reduce the site quality for biota that serve as turtle prey/forage. By reducing important components of habitat such as leaf litter, fire can degrade mesic micro-habitats (Ford *et al*. 1999), such as that for snails (Martin and Sommer 2004), and hinder turtle osmo- and thermos-regulation. Moreover, fire may not be necessary for maintaining and regenerating northeastern oak forests and increased frequency of burning could potentially reduce forest herb and shrub diversity (Elliot *et al*. 2004, Matlack 2013).

Forested habitats of different structure and composition may yield differences in foraging success, abundance of refugia from predators, or thermal and hydric properties. Seral stages differ in composition and structure (Meier *et al*. 1995, Hardt and Swank 1997) and it can take many decades for forest composition, structure, or function to recover from human disturbance (Likens *et al*. 1978, Meier *et al*. 1995, Bellemare *et al*. 2002). Wood Turtles at these study sites were disinclined to use large recent even-age logging sites except at their very margins. Where Wood Turtle populations occur in this ecoregion, the results of this study suggest that simply letting forests develop mature and old-growth conditions under a natural disturbance regime (*i.e*., restoration by "purposeful action and inaction", Trombulak 1996) would be the best and probably least expensive course for their conservation. Although passive restoration (purposeful inaction) is often successful (Jones *et al*. 2018), in some site-specific situations this general guideline of just ceasing human disturbances and letting a forest develop on its own may not be sufficient. Unlike my study sites, other Wood Turtle sites may not be relatively intact older forest. Active restoration may be necessary to counteract previous disruptions and degradations; *e.g*., countering inflated populations of herbivores, alien invasives, noxious pests, or harmful roads by reintroduction of larger predators, direct removal of invasives/pests, or closure of roads to public vehicular traffic.

Further, some land holders and managers can take ecologically sensitive actions that at some places could improve Wood Turtle habitat. Beyond such focused actions as, *e.g.,* the fabrication or maintenance of nesting sites (Buhlmann and Osborn 2011), I am here referring to silvicultural techniques that fall under the broad rubric of "structural complexity enhancement" (SCE) (Keeton 2006, Scheff 2014). Typical objectives of SCE include vertically differentiated canopies, elevated large snag and LWD volumes and densities, variable horizontal density (including canopy gaps), and re-allocation of tree basal area to larger diameter classes (Keeton 2006). Intensive logging, such as typical even-age harvest methods, generally simplify structural diversity at sites, reduce litter and woody debris, and alter soil structure and microclimate regimes (Chen *et al*. 1999, Zheng *et al*. 2000, Webster and Jenkins 2005, Todd and Andrews 2008). SCE, however, could accelerate the development of important older forest characteristics while allowing for an economic return (Keeton and Troy 2006). Mimicking gap-scale natural disturbance in a limited and targeted manner can fall within the range of disturbance intensities consistent with developing and maintaining old-growth structure while assisting in the regeneration and recruitment of oaks and other shade intermediate-tolerant species (Scheff 2014).

Of course, it is not just the availability of artificial openings fabricated by logging that determines whether oaks can reestablish and sustain themselves at sites in a forest (Rentch *et al*. 2003a, McEwan and Muller 2006, McEwan *et al*. 2010). Where perpetuation of a substantial oak component is a concern, oak recruitment can be facilitated by locating individual selection or small group selection harvests (during winter months when Wood Turtles are totally aquatic) in forest patches with ample advanced oak regeneration. Oak seedlings can grow and out-compete other species in small gaps or even under canopy (Beckage 2000, Clinton 2003, Iffrig *et al*. 2008); for example, Rentch and colleagues (2003b) found oaks were able to establish and persist in gaps < $200m^2$ in area.

As Wood Turtles are not confined to riparian or wetland habitats, but instead regularly range far afield in dry upland habitats (Table 6.6 and Chapter 5), stream courses occupied by Wood Turtles in this and similar ecoregions should be buffered on both sides by at least a 300 meter minimal disturbance zone in order to mitigate for effects to turtle population viability and allow the natural development of conditions essential to their survival. Even when this measure is implemented, offsite effects of forest anthropogenic disturbance remain of concern. It is critical that deleterious edge effects, which translate to a form of habitat loss, receive much more explicit consideration for conservation to prove to be effective (Harris *et al*. 1996, Zheng and Chen 2000, Fletcher 2005, Harper *et al*. 2005). Because the condition of the matrix within which occupied patches reside may influence turtle abundance and population viability, effective restoration and protection must encompass even larger spatial scales (beyond the 300m zones) (Hansen and Rotella 2002, Ficetola *et al*. 2004, Roe and Georges 2007, Quesnelle *et al.* 2013). The 300m prescription should generally be considered a minimum standard (site specific conditions may obviate or preclude its implementation) as this zone may not include lengthy pre-nesting peregrinations by female Wood Turtles or connectivity to other populations. Improving or protecting the quality of other habitats outside of more strictly protected core areas can be crucial (Angermeier

1995, Harris *et al*. 1996, Browne and Hecnar 2007, Hansen and DeFries 2007, Quesnelle *et al*. 2013).

For instance, stream communities at sites with stringently protected riparian buffers can still be significantly degraded by intensive development elsewhere in the catchment (Wahl *et al*. 2013). The cumulative effects of timber harvest on sedimentation rates last for many years, even after cutting has ceased in an area (Frissell 1997), and erosion from roads used for logging often contributes more sediment than the land logged for timber (Box and Mossa 1999). Increased sedimention, turbidity, and/or nutrient loads from erosion are known to reduce dissolved oxygen levels (Henley *et al*. 2000). Oxygen levels may be a critical variable for Wood Turtle survival during winter dormancy (Graham and Forsberg 1991, Ultsch 2006, Greaves and Litzgus 2007 & 2008). See "Small Streams, Springs, and Seepages" and "Hardwood Forests" modules in Mitchell *et al.* (2006) for general habitat management guidelines apropos to Wood Turtles.

The factors identified by this study can be used for well-informed decisions regarding management practices, protective measures, and habitat enhancement or restoration (*e.g*., fabrication of small canopy gaps), as well as make predictions as to the suitability of sites as potential turtle habitat. In short, we need to develop our understanding of the turtles, not develop their habitat. A multitude of other flora and fauna, including human communities, will benefit when we accord Wood Turtles enhanced on-the-ground protections.

Table 6.1

Ground cover variables measured in 1m^2 plots – microhabitat
Terrestrial habitat variables measured in 1m^2 plots at each Wood Turtle and associated random location in Virginia and West Virginia June-August 2011-2014. **Samples taken**: one centered on each turtle and random point; in 2011-2012, also one at each of the four cardinal directions at the perimeter of the 400-m^2 plot circle centered on turtle/random points. Variables visually estimated as proportion (percent) of ground cover in 1m^2 frame.

Variable	**Description**
Inorganic (In)	
Sand	proportion of sand and/or gravel present
Rock	proportion of rock present
Herbaceous vegetation (H)	
Forb	proportion of herbaceous dicot (non-grassy) vegetation present
Grass	proportion of grassy vegetation (including sedges and rushes) present
Non-herbaceous vegetation (Nh)	
Woody	proportion of woody vegetation present
Moss	proportion of ground covered by bryophytes
Fern	proportion of ground covered by ferns
Organic non-living (O)	
CWD	proportion of woody debris $\geq$ 5 cm diameter present
Soil	proportion of bare soil present
Litter	proportion of ground covered by leaf litter
Water	proportion of water (standing or flowing) present
Other	proportion of mushrooms, lichens, lycopodia, or equisetums present
Herbcov	proportion of ground cover in frame that is forb and grass combined

Table 6.2

Environmental variables measured in 400m^2 plots – mesohabitat
Habitat variables measured in 400m^2 plots at each Wood Turtle and associated random location in Virginia and Virginia June-August 2011-2014.

Variable	Description
Structural overhead (So)	
Large	count of each live woody stem ≥ 25 cm dbh – taxon and dbh also recorded
Medium	count of live stems ≥ 10cm & < 25cm dbh – taxon and dbh also recorded
Obs1	obscurity measured (%) at human eye-level with modified Nudds profile board place perimeter of plot at the four cardinal directions (relative to the Turtle point) – mean o readings
Snags	number of standing dead trees ≥ 10cm dbh in plot
Can	canopy openness (%) over turtle and random points – mean of open percentages take each of the four cardinal directions using a spherical densitometer
Age	age of stand in years as determined by USFS
Shrub	count of woody stems ≥ 2.5cm dbh and <10cm dbh
BA	basal area (m^2/ha) of plot calculated from dbh measurements of trees ≥ 10cm dbh
Structural ground (Sg)	
Obs4	obscurity measured (%) at ground floor with Modified Nudds profile board placed at perimeter of plot at the four Cardinal directions (relative to the Turtle point) – mean c readings; care was taken to not place the board behind trees ≥ 10cm dbh
Gapsize	visual estimate of amount of ground area (m^2) under canopy gaps ≥ 9m^2 in the plot; natural or anthropogenic gaps (*e.g.*, treefall gap or grassy game opening)
LWD25	count of woody debris pieces ≥ 25cm diameter in plot (≥ 4m in length and at least 2 length in plot)
LWD10	count of woody debris pieces ≥ 10cm and < 25cm diameter in plot (≥ 4m in length a least 2m of length in plot)
Compositional overhead (Co)	
Tree spp	count of woody taxa present with stems ≥ 10cm dbh
Shrub spp	count of woody taxa present with stems ≥ 2.5cm dbh and <10cm dbh
Compositional ground (Cg)	
Seed spp	count of woody taxa < 50cm high present on ground floor
Herb spp	count of ground floor forb taxa present in plot
Topographical (T)	
Dist	distance (m) to the closest permanent stream; paced off, measured with tape, or estin in GIS
Slope	site inclination in degrees measured with a clinometer
ASPB	aspect – first estimated with compass in degrees, then converted with Beers transfor

Table 6.3

Conditional logistic regression models used – 1m^2 plots

Models used in conditional logistic regression analyses of proportions of cover present in 1m^2 plots at turtle points and random points in Virginia and West Virginia during June-August 2011-2014. **Variable types**: In = inorganic (sand/gravel and rock), H = herbaceous vegetation (forb and grass), Nh = non-herbaceous vegetation (woody and moss), Or = organic non-living (coarse woody debris and bare soil).

Variable type	model #	model variables
	Virginia females, West Virginia females & males	
In-H	mod1	Sand+Rock+Forb+Grass
In-Nh	mod2	Sand+Rock+Woody+Moss
In-Or	mod3	Sand+Rock+CWD+Soil
H-Nh	mod4	Forb+Grass+Woody+Moss
H-Or	mod5	Forb+Grass+CWD+Soil
Nh-Or	mod6	Woody+Moss+CWD+Soil
In-H-Nh	mod7	Sand+Rock+Forb+Grass+Woody+Moss
In-H-Or	mod8	Sand+Rock+Forb+Grass+CWD+Soil
In-Nh-Or	mod9	Sand+Rock+Woody+Moss+CWD+Soil
H-Nh-Or	mod10	Forb+Grass+Woody+Moss+CWD+Soil
In-H-Nh-Or	mod11	Sand+Forb+Woody+CWD
In-H-Nh-Or	mod12	Rock+Grass+Moss+Soil
In-H-Nh-Or	mod13	Sand+Forb+Moss+Soil
In-H-Nh-Or	mod14	Rock+Grass+Woody+CWD
Global	mod15	Sand+Rock+Forb+Grass+CWD+Woody+Moss+Soil
	Virginia males (Sand removed)	
In-H	mod1	Rock+Forb+Grass
In-Nh	mod2	Rock+Woody+Moss
In-Or	mod3	Rock+CWD+Soil
H-Nh	mod4	Forb+Grass+Woody+Moss
H-Or	mod5	Forb+Grass+CWD+Soil
Nh-Or	mod6	Woody+Moss+CWD+Soil
In-H-Nh	mod7	Rock+Forb+Grass+Woody+Moss
In-H-Or	mod8	Rock+Forb+Grass+CWD+Soil
In-Nh-Or	mod9	Rock+Woody+Moss+CWD+Soil
H-Nh-Or	mod10	Forb+Grass+Woody+Moss+CWD+Soil
In-H-Nh-Or	mod11	Forb+Woody+CWD
In-H-Nh-Or	mod12	Rock+Grass+Moss+Soil
In-H-Nh-Or	mod13	Forb+Moss+Soil
In-H-Nh-Or	mod14	Rock+Grass+Woody+CWD
Global	mod15	Rock+Forb+Grass+CWD+Woody+Moss+Soil

Table 6.4

Conditional logistic regression models used – 400m^2 plots
Models used in conditional logistic regression analyses of environmental attributes present in 400m^2 plots at turtle points and random points in Virginia and West Virginia during June-August 2011-2014. **Variable types**: So = structural overhead (Large, Medium, Obs1, Snags, Can, Age), Sg = structural ground (Obs4, Gapsizem2, LWD10, LWD4), Co = compositional overhead (Treespp, Shrubspp), Cg = compositional ground (Seedspp, Herbspp [for 2011-2013 models]), T = topographical (Dist, Slope, ASPB, Elev), Iv = importance value of tree taxa (a synthetic metric incorporating both structural and compositional attributes – models using Iv did not include Large, Medium, or Treespp). See Table 2 for description of variables.

model type	model #	model variables
Virginia females		
So-Sg	mod1	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can
So	mod2	Large+Medium+Obs1+Snags+Can
Sg	mod3	Obs4+LWD10+LWD4+Gapsizem2
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp
T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Treespp+Shrubspp+Seedspp
So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD10+LWD4+Gapsizem2+Seedspp
So-Sg-T	mod13	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+LWD4+ Snags+Can+Dist+ASPB+Slope+Elev
So-T	mod14	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev
Sg-T	mod15	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod16	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod17	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod18	Seedspp+Dist+ASPB+Slope+Elev
So-Co-T	mod19	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
So-Cg-T	mod20	Large+Medium+Obs1+Snags+Can+Seedspp+ Dist+ASPB+Slope+Elev
Sg-Co-T	mod21	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod22	Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev
Virginia males		
So-Sg	mod1	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can
So	mod2	Large+Medium+Obs1+Snags+Can
Sg	mod3	Obs4+LWD4
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp
T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Treespp+Shrubspp+Seedspp
So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD4+Seedspp
So-Sg-T	mod13	Large+Medium+Obs1+LWD10+LWD4+Can+ Dist+ASPB+Slope+Elev

Table 6.4: continued

So-T	mod14	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev
Sg-T	mod15	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod16	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod17	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod18	Seedspp+Dist+ASPB+Slope+Elev
So-Co-T	mod19	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
So-Cg-T	mod20	Large+Medium+Obs1+Snags+Can+Seedspp+ ASPB+Slope+Elev
Sg-Co-T	mod21	Obs4+LWD10+LWD4+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod22	LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev

<u>West Virginia females</u>

So-Sg	mod1	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Age
So	mod2	Large+Medium+Obs1+Snags+Can+Age
Sg	mod3	Obs4+LWD10+LWD4+Gapsizem2
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp
T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+LWD4+ Snags+Can+Treespp+Shrubspp+Seedspp+Age
So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+Age
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp+Age
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD10+LWD4+Gapsizem2+Seedspp
So-Sg-T	mod13	Large+Medium+Obs4+Gapsizem2+LWD10+LWD4+ Snags+Can+Dist+ASPB+Slope+Elev+Age
So-T	mod14	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev+Age
Sg-T	mod15	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod16	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod17	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod18	Seedspp+Dist+ASPB+Slope+Elev
So-Co-T	mod19	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev+Age
So-Cg-T	mod20	Large+Medium+Obs1+Snags+Can+Seedspp+ Dist+ASPB+Slope+Elev+Age
Sg-Co-T	mod21	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod22	Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev

<u>West Virginia males</u>

So-Sg	mod1	Large+Medium+Obs1+Obs4+Snags+LWD10+LWD4+ Can+Gapsizem2+Age
So	mod2	Large+Medium+Obs1+Snags+Can+Age
Sg	mod3	Obs4+LWD10+LWD4+Gapsizem2
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp
T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs1+Obs4+Gapsizem2+LWD10+LWD4+ Snags+Can+Hebcov+Treespp+Shrubspp+Seedspp+Age
So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+Age
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp+Age
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD10+LWD4+Gapsizem2+Seedspp
So-Sg-T	mod13	Large+Medium+Obs1+Obs4+LWD10+Can+ Gapsizem2+ASPB+Slope
So-T	mod14	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev+Age
Sg-T	mod15	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod16	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod17	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod18	Seedspp+Dist+ASPB+Slope+Elev

Table 6.4: continued

So-Co-T	mod19	Large+Medium+Obs1+Snags+Treespp+Shrubspp+ ASPB+Slope+Elev+Age

So-Cg-T	mod20	Large+Medium+Obs1+Snags+Can+Seedspp+ ASPB+Slope+Age
Sg-Co-T	mod21	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod22	Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev

Female Wood Turtles

So-Sg	mod1	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can
So	mod2	Large+Medium+Obs1+Snags+Can
Sg	mod3	Obs4+LWD10+LWD4+Gapsizem2
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp
T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Treespp+Shrubspp+Seedspp
So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD10+LWD4+Gapsizem2+Seedspp
Iv-So-Sg-Co-Cg	mod13	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Obs4+Snags+ LWD10+LWD4+Gapsizem2+Can+Shrubspp+Seedspp
Iv-Sg-Cg	mod14	CO+SM+RM+WO+BG+WA+TP+SO+NRO +Obs4+LWD10+LWD4+Gapsizem2+Seedspp
Iv-So-Co	mod15	CO+SM+RM+WO+BG+WA+TP+SO+NRO+ Obs1+Snags+Can+ Shrubspp
Iv-Sg-Co	mod16	CO+SM+RM+WO+BG+WA+TP+SO+NRO+ Obs4+LWD10+LWD4+Gapsizem2+Shrubspp
Iv-So-Cg	mod17	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+Can+ Seedspp
So-Sg-T	mod18	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+LWD4 +Snags+Can+Dist+ASPB+Slope+Elev
So-T	mod19	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev
Sg-T	mod20	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod21	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod22	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod23	Seedspp+Dist+ASPB+Slope+Elev
So-Co-T	mod24	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
So-Cg-T	mod25	Large+Medium+Obs1+Snags+Can+Seedspp+ Dist+ASPB+Slope+Elev
Sg-Co-T	mod26	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod27	Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev
Iv-So-Co-T	mod28	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+Can +Shrubspp+Dist+ASPB+Slope+Elev
Iv-So-Cg-T	mod29	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+Can+ Seedspp+Dist+ASPB+Slope+Elev
Iv-Sg-Co-T	mod30	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs4+LWD10+ LWD4+Gapsizem2+Shrubspp+Dist+ASPB+Slope+Elev
Iv-Sg-Cg-T	mod31	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs4+LWD10+ LWD4+Gapsizem2+Seedspp+Dist+ASPB+Slope+Elev

Male Wood Turtles

So-Sg	mod1	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can
So	mod2	Large+Medium+Obs1+Snags+Can
Sg	mod3	Obs4+LWD4
Co-Cg	mod4	Treespp+Shrubspp+Seedspp
Co	mod5	Treespp+Shrubspp
Cg	mod6	Seedspp

Table 6.4: continued

T	mod7	Dist+Slope+ASPB+Elev
So-Sg-Co-Cg	mod8	Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Treespp+Shrubspp+Seedspp

So-Co	mod9	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp
So-Cg	mod10	Large+Medium+Obs1+Snags+Can+Seedspp
Sg-Co	mod11	Obs4+LWD10+LWD4+Gapsizem2+Treespp+Shrubspp
Sg-Cg	mod12	Obs4+LWD4+Seedspp
Iv-So-Sg-Co-Cg	mod13	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+LWD10+Can
Iv-Sg-Cg	mod14	CO+SM+RM+WO+BG+WA+TP+SO+NRO+LWD10+LWD4+ Seedspp
Iv-So-Co	mod15	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+Can+ Shrubspp
Iv-Sg-Co	mod16	CO+SM+RM+WO+BG+WA+TP+SO+NRO+LWD10+LWD4+ Gapsizem2+Shrubspp
Iv-So-Cg	mod17	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+Can
So-Sg-T	mod18	Large+Medium+Obs1+LWD10+LWD4+Can+ Dist+ASPB+Slope+Elev
So-T	mod19	Large+Medium+Obs1+Can+Slope+ASPB+Dist+Elev
Sg-T	mod20	Obs4+LWD10+LWD4+Gapsizem2+Slope+ASPB+Dist+Elev
Co-Cg-T	mod21	Treespp+Shrubspp+Seedspp+Dist+ASPB+Slope+Elev
Co-T	mod22	Treespp+Shrubspp+Dist+ASPB+Slope+Elev
Cg-T	mod23	Seedspp+Dist+ASPB+Slope+Elev
So-Co-T	mod24	Large+Medium+Obs1+Snags+Can+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
So-Cg-T	mod25	Large+Medium+Obs1+Snags+Can+Seedspp+ ASPB+Slope+Elev
Sg-Co-T	mod26	Obs4+LWD10+LWD4+Treespp+Shrubspp+ Dist+ASPB+Slope+Elev
Sg-Cg-T	mod27	LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev
Iv-So-Co-T	mod28	CO+SM+RM+WO+BG+WA+TP+SO+NRO+Obs1+Snags+ Can+Shrubspp+ASPB+Slope
Iv-So-Cg-T	mod29	CO+SM+RM+WO+BG+WA+TP+SO+NRO+ Obs1+Snags+ Can+ASPB+Slope
Iv-Sg-Co-T	mod30	CO+SM+RM+WO+BG+WA+TP+SO+NRO+LWD10+LWD4+ Shrubspp+Dist+ASPB+Slope+Elev
Iv-Sg-Cg-T	mod31	CO+SM+RM+WO+BG+WA+TP+SO+NRO+ LWD10+LWD4+ Seedspp+ASPB+Slope+Elev

Table 6.5a

Values of ground cover variables measured in 1m² plots

Values for coverage proportions (in %) of structural-compositional variables obtained at 1m² plots at turtle points and random points (one plot per point) in Virginia and West Virginia during June-August 2011-2014; reported for each variable in descending order are means, standard errors, and ranges. See Table 6.1 for description of variables. FWT = female Wood Turtles (VA: 35 turtles/143 plots, WV: 25 turtles/82 plots), FRP = female random points (VA: 35/141, WV: 24/74), MWT = male Wood Turtles (VA: 15/52, WV: 21/51), MRP = male random points (VA: 15/52, WV: 20/49).

	Virginia				***West Virginia***			
Variable	**FWT**	**FRP**	**MWT**	**MRP**	**FWT**	**FRP**	**MWT**	**MRP**
Sand/Gravel	0.02	0.65	0.15	0	0.71	1.05	2.04	0.27
	0.02	0.53	0.15	0	0.34	0.70	1.25	0.17
	0-3	0-74	0-8	0	0-9	0-47	0-46	0-7
Rock	0.80	1.77	1.77	1.88	0.61	0.11	0.16	0.41
	0.27	0.45	1.31	0.58	0.34	0.04	0.07	0.17
	0-32	0-45	0-68	0-18	0-27	0-2	0-3	0-6
Forb	6.25	1.51	5.35	0.79	4.01	2.23	4.59	3.22
	1.12	0.29	0.79	0.35	0.52	0.45	0.63	0.67
	0-89	0-26	0-20	0-16	0-25	0-64	0-17	1-44
Grass	8.36	1.52	8.83	0.44	10.34	5.88	12.55	4.76
	1.49	0.61	2.11	0.25	1.88	1.69	2.41	1.17
	0-75	0-79	0-65	0-12	0-74	0-80	0-75	0-50
Woody	4.74	3.30	4.54	3.58	2.38	2.64	2.22	1.51
	0.59	0.23	0.60	0.38	0.38	0.59	0.51	0.29
	0-65	0-15	0-20	0-13	0-19	0-34	0-25	0-7
Moss	2.28	3.00	0.83	1.13	3.78	3.27	0.61	2.63
	0.45	0.67	0.24	0.35	1.35	0.86	0.19	1.26
	0-38	0-50	0-10	0-14	0-70	0-40	0-8	0-61
CWD	4.67	1.79	4.96	1.90	2.56	1.51	2.92	1.12
	0.56	0.33	1.20	0.79	0.55	0.34	0.95	0.35
	0-31	0-20	0-40	0-33	0-25	0-15	0-30	0-11
Soil	2.33	0.96	1.81	1.42	0.65	0.36	1.27	0.59
	0.70	0.35	0.98	1.25	0.20	0.15	1.10	0.25
	0-65	0-33	0-47	0-65	0-9	0-7	0-56	0-8
Fern	0.45	0.01	0	0	0.23	0.37	0.20	0.37
	0.28	0.01	0	0	0.10	0.17	0.09	0.14
	0-39	0-1	0	0	0-6	0-10	0-3	0-4
Other	0.15	0.14	0.06	0.15	0.89	0.25	0.31	0.06
	0.05	0.08	0.03	0.08	0.67	0.17	0.23	0.05
	0-100	0-79	0-73	0-28	0-53	0-12	0-10	0-2
Litter	69.95	85.34	71.71	88.69	72.99	82.34	73.14	85.06
	2.16	1.31	3.04	1.91	2.53	2.45	3.12	2.14
	0-98	0-99	5-95	15-100	2-99	13-99	10-97	16-100
Herbaceous	14.63	3.26	14.09	1.34	14.38	8.23	15.92	7.98
cover (forb	2.05	0.74	2.56	0.65	2.13	1.72	2.35	1.53
+ grass)	0-100	0-79	0-73	0-28	0-75	0-81	0-76	0-53
Herb. cover	14.96	2.54	5.29	1.76	9.82	5.31	12.38	4.58
(peripheral)	2.35	0.62	1.64	0.76	1.49	1.80	2.07	1.04
2011-2012)	0-51	0-21	0-23	0-12	0-26	0-30	1-33	0-20
Forb taxa	2.72	1.28	4.33	0.92	2.67	2.63	4.42	2.50
2013-2014	0.27	0.22	0.46	0.32	0.30	0.35	0.47	0.46
(#)	0-9	0-10	0-9	0-9	0-7	0-9	1-8	0-8

Table 6.5b

Values of ground cover variables measured in four peripheral 1m² plots

Values for coverage proportions (in %) of structural-compositional variables obtained at four 1m² plots at turtle and paired random points (means of four peripheral plots per point) in Virginia and West Virginia during June-2011-2012; reported for each variable in descending order are means, standard errors, and ranges. See Table description of variables. FWT = female Wood Turtles (VA: 13 turtles/228 plots, WV: 10 turtles/116 plots), FRP = random points (VA: 13/228, WV: 9/92), MWT = male Wood Turtles (VA: 5/72, WV: 10/100), MRP = male r points (VA: 5/72, WV: 9/96).

	Virginia				***West Virginia***			
Variable	**FWT**	**FRP**	**MWT**	**MRP**	**FWT**	**FRP**	**MWT**	**MRP**
Sand/Gravel	0.22	0.51	4.10	1.13	2.26	1.08	3.77	0.07
	0.12	0.24	1.95	0.95	0.94	0.77	1.54	0.05
	0-16	0-13	0-25	0-17	0-20	0-16	0-29	0-1
Rock	2.59	1.38	2.08	1.83	2.34	0.27	5.38	1.18
	0.49	0.28	0.70	0.58	0.95	0.19	1.58	0.87
	0-17	0-12	0-9	0-10	0-22	0-4	0-21	0-21
Forb	5.14	1.00	2.37	1.10	3.29	1.01	3.61	1.56
	0.89	0.20	0.67	0.49	0.38	0.31	0.54	0.26
	0-26	0-7	0-9	0-7	0-8	0-6	0-10	0-5
Grass	9.82	1.53	2.93	0.67	5.28	4.09	8.90	3.02
	1.71	0.51	1.07	0.30	1.14	1.53	1.72	0.92
	0-42	0-18	0-14	0-5	0-21	0-24	0-25	0-16
Woody	3.31	2.87	4.40	3.58	1.78	2.04	1.40	1.41
	0.41	0.24	0.58	0.54	0.39	0.41	0.37	0.30
	0-14	1-9	1-10	2-12	0-10	0-8	0-8	0-6
Moss	3.62	2.65	2.31	3.68	2.52	3.96	3.20	4.45
	0.49	0.57	0.76	0.97	0.82	1.14	0.80	1.19
	0-19	0-19	0-13	0-16	0-21	0-18	0-15	0-20
CWD	2.63	3.66	3.38	2.31	3.43	3.28	1.90	2.60
	0.45	0.46	0.99	0.61	0.67	0.88	0.61	0.63
	0-13	0-14	0-16	0-11	0-13	0-19	0-14	0-13
Soil	1.45	3.16	2.24	2.67	1.60	0.62	2.72	0.97
	0.36	0.82	1.82	1.72	0.97	0.25	1.11	0.70
	0-16	0-27	0-33	0-27	0-28	0-5	0-18	0-17
Fern	0.36	0.11	0	0.01	0.34	0.28	0.17	0.43
	0.11	0.06	0	0.01	0.13	0.13	0.05	0.12
	0-4	0-4	0	0-0.3	0-3	0-2	0-0.8	0-2
Other	1.14	0.46	1.28	0.22	2.68	0.11	1.85	0.02
	0.51	0.23	0.88	0.21	1.26	0.07	0.88	0.01
	0-23	0-12	0-15	0-4	0-25	0-2	0-18	0
Litter	69.43	82.65	73.78	82.81	74.50	83.25	67.11	84.29
	2.30	1.58	4.75	3.94	2.88	2.72	3.45	2.42
	25-94	42-97	22-94	36-94	35-93	45-96	35-95	50-99
Herb. cover	21.49	2.65	7.39	1.39	14.08	9.58	12.38	5.83
(forb+grass)	4.26	0.83	2.79	1.11	3.79	4.17	3.32	1.40
1 center plot	0-100	0-38	0-40	0-20	0-75	0-81	0-66	0-22
Herbaceous	14.96	2.54	5.29	1.76	9.82	5.31	12.38	4.58
cover (four	2.35	0.62	1.64	0.76	1.49	1.80	2.07	1.04
peripheral)	0-51	0-21	0-23	0-12	0-26	0-30	1-33	0-20
Forb taxa	2.72	1.28	4.33	0.92	2.67	2.63	4.42	2.50
2013-2014	0.27	0.22	0.46	0.32	0.30	0.35	0.47	0.46
(#)	0-9	0-10	0-9	0-9	0-7	0-9	1-8	0-8

Table 6.6a

Values of environmental variables measured in 400m² plots
Values for structural, compositional, and topographical variables obtained at 400m² plots at turtle points and r
points in Virginia and West Virginia during June-August 2011-2014 (numbers of herbaceous taxa are from 2011-
reported in descending order are means, standard errors, and ranges. See Table 6.2 for description of variables.
female Wood Turtles, FRP = female random points, MWT = male Wood Turtles, MRP = male random points.

	Virginia				***West Virginia***			
Variable	**FWT**	**FRP**	**MWT**	**MRP**	**FWT**	**FRP**	**MWT**	**MRP**
Large trees	6.7	7.6	6.2	6.5	5.7	6.7	5.8	6.5
(#)	0.27	0.31	0.44	0.45	0.33	0.37	0.48	0.43
	0-13	0-20	1-15	0-15	1-14	0-14	0-15	1-16
Medium	10.1	12.4	8.7	13.4	14.5	15.0	13.2	13.6
trees	0.60	0.60	0.80	1.07	0.82	0.88	0.86	1.13
(#)	0-39	0-36	0-32	0-38	2-33	5-48	2-28	2-36
Eye-level	26.0	18.4	32.0	20.6	27.5	19.8	29.5	21.6
obscurity	1.9	1.6	3.26	2.54	1.83	1.54	2.61	1.90
(%)	0-96	0-99	2-100	0-89	0-66	0-64	0-98	1-44
Snags	2.0	1.6	1.6	1.6	2.6	2.5	1.9	2.3
(#)	0.15	0.11	0.20	0.25	0.23	0.24	0.23	0.32
	0-9	0-5	0-7	0-9	0-10	0-13	0-7	0-10
Canopy	20.1	13.6	20.0	11.9	19.8	17.9	19.1	15.0
openness	1.10	0.53	1.73	0.38	1.26	1.51	1.19	0.82
(%)	7-81	4-48	6-64	6-20	7-74	9-88	10-50	9-42
Stand age	98.1	88.6	101.4	92.2	109.9	109.6	106.2	112.2
(years)	2.98	3.34	4.40	5.26	1.33	1.48	2.18	1.55
	3-142	5-162	6-142	6-142	75-141	75-142	74-123	90-131
LWD10	2.3	1.6	2.0	1.6	1.9	1.1	1.7	1.2
(#)	0.15	0.16	0.21	0.28	0.15	0.13	0.22	0.19
	0-11	0-9	0-9	0-11	0-6	0-4	0-8	0-5
LWD4	3.3	4.0	2.7	3.5	3.2	3.1	4.3	4.0
(#)	0.27	0.32	0.30	0.28	0.27	0.22	0.54	0.38
	0-16	0-27	0-9	0-11	0-13	0-9	0-18	0-13
Gap size	41.1	11.9	39.1	10.3	27.7	17.6	40.6	18.4
(m^2)	5.35	2.69	6.70	3.79	3.8	4.2	8.1	4.7
	0-352	0-255	0-200	0-175	0-168	0-192	0-225	0-186
Turtle-level	94.0	77.7	94.5	77.3	78.6	67.8	82.0	61.0
obscurity	0.86	1.51	1.15	2.40	1.77	2.34	1.95	3.28
(%)	46-100	25-100	54-100	31-100	30-100	12-100	51-100	14-100
Tree taxa	5.4	5.7	5.8	5.7	5.6	5.3	5.5	5.1
(#)	0.15	0.14	0.23	0.26	0.14	0.17	0.24	0.32
	1-11	1-10	2-9	2-12	3-9	3-9	3-10	3-8
Shrub taxa	10.4	8.3	10.8	8.6	8.1	7.0	8.6	7.6
(#)	0.31	0.25	0.52	0.48	0.28	0.23	0.35	0.32
	4-19	2-18	4-18	4-19	3-15	2-13	4-16	4-13
Seedling	9.1	9.4	8.3	8.8	6.1	5.0	5.5	5.2
taxa	0.30	0.27	0.36	0.35	0.33	0.31	0.51	0.41
(#)	1-19	3-19	0-14	1-14	0-15	0-12	0-17	0-12
Herbaceous	14.3	10.2	16.1	9.9	16.7	11.4	16.8	15.1
taxa	0.71	0.64	1.33	1.28	0.95	0.98	1.26	1.23
(#)	0-31	0-35	1-30	2-35	5-33	0-29	5-31	1-29
Distance to	117.8	170.5	69.6	123.3	93.3	139.4	54.0	107.3
stream	9.7	9.5	10.12	9.06	14.5	11.8	13.3	8.87
(m)	5-502	1-572	3-289	9-287	5-788	16-523	3-650	16-273
Slope	6.3	9.7	4.8	9.8	12.3	19.6	13.0	20.8
(degrees)	0.42	0.41	0.61	0.77	1.06	0.89	1.34	1.45
	1-31	1-28	1-23	2-26	1-32	2-36	1-33	2-38

Table 6.6b

Values of environmental variables measured in 400m^2 plots – pooled data

Values for structural, compositional, and topographic variables obtained at 400m^2 plots at turtle points and r points at pooled Virginia and West Virginia sites during June-August 2011-2014 (numbers of herbaceous taxa ar 2011-2013); reported in descending order for each variable are means, standard errors, and ranges. See Table description of variables. FWT = female Wood Turtle points (n = 218), FRP = female random points (n = 218), M male Wood Turtle points (n = 102), MRP = male random points (n = 102), WT = Wood Turtle points (n = 320 random points (n = 320).

	Virginia and West Virginia					
Variable	**FWT**	**FRP**	**MWT**	**MRP**	**WT**	**RP**
Large trees	6.4	7.3	6.0	6.5	6.3	7.0
(#)	0.22	0.24	0.34	0.31	0.18	0.19
	0-14	0-20	1-15	0-16	0-15	0-20
Medium	11.5	13.2	10.9	13.3	11.3	13.2
trees	0.52	0.50	0.64	0.77	0.41	0.42
(#)	0-39	0-48	0-32	0-38	0-39	0-48
Eye-level	26.8	18.9	31.0	21.1	28.1	19.6
obscurity	1.46	1.17	2.13	1.59	1.21	0.94
(%)	0-96	0-99	2-100	0-89	0-100	0-99
Snags	2.2	1.9	1.7	1.9	2.1	1.9
(#)	0.13	0.11	0.16	0.20	0.10	0.10
	0-10	0-13	0-7	0-10	0-10	0-13
Canopy	20.0	15.1	19.6	13.4	19.9	14.5
openness	0.88	0.63	1.11	0.46	0.70	0.46
(%)	7-81	4-88	6-64	6-42	6-81	4-88
Stand age	102.1	95.7	103.7	101.8	102.6	97.7
(years)	2.05	2.36	2.51	2.99	1.61	1.87
	3-142	5-162	6-142	6-142	3-142	5-162
LWD10	2.1	1.5	1.8	1.4	2.0	1.4
(#)	0.12	0.12	0.16	0.17	0.09	0.10
	0-11	0-9	0-9	0-11	0-11	0-11
LWD4	3.2	3.7	3.4	3.7	3.3	3.7
(#)	0.20	0.23	0.32	0.31	0.17	0.18
	0-16	0-27	0-18	0-14	0-18	0-27
Gap size	37.7	13.8	39.3	14.2	38.2	13.9
(m^2)	3.89	2.29	5.33	2.96	3.14	1.82
	0-352	0-255	0-225	0-186	0-352	0-255
Turtle-level	88.9	74.3	88.2	69.6	88.7	72.8
obscurity	0.86	1.31	1.30	2.15	0.78	1.13
(%)	30-100	12-100	51-100	14-100	30-100	12-100
Tree taxa	5.5	5.6	5.6	5.6	5.5	5.5
(#)	0.11	0.11	0.17	0.16	0.09	0.09
	1-11	1-10	2-9	2-12	1-11	1-12
Shrub taxa	9.6	7.9	9.8	8.1	9.6	7.9
(#)	0.24	0.19	0.34	0.30	0.20	0.16
	3-19	2-18	4-18	4-19	3-19	2-19
Seedling	8.1	7.9	7.0	7.0	7.8	7.6
taxa	0.25	0.25	0.34	0.32	0.20	0.20
(#)	0-19	3-19	0-17	0-14	0-19	0-19
Herbaceous	15.0	10.6	16.5	12.5	15.4	11.1
taxa	0.58	0.54	0.91	0.94	0.49	0.47
(#)	0-33	0-35	1-31	1-35	0-33	0-35
Distance to	110.0	161.0	57.1	116.4	93.2	146.8
stream	8.15	7.57	6.26	6.41	6.05	5.66
(m)	5-502	1-572	3-289	9-287	3-502	1-572
Slope	8.3	13.1	8.6	15.2	8.4	13.8
(degrees)	0.50	0.51	0.82	0.97	0.43	0.47

Table 6.7

Well-supported conditional logistic regression models – using cover variables in $1m^2$ plots

Best of fifteen conditional logistic regression models of Wood Turtle microhabitat selection at sites in Virginia and West Virginia, USA in 2011-2014, based on proportions of habitat variables in $1m^2$ plots. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; AICc weight denotes a model's level of support among the set of 15 candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights (top models are those with a cumulative weight ≥ 0.95). See Table 6.1 for definitions of variables.

Model	LogLik	K	ΔAICc	AICc wt.	Cum.wt.
Virginia females					
Sand+Rock+Forb+Grass+CWD+Woody+Moss+Soil	-57.58	8	0	0.49	0.49
Forb+Grass+CWD+Woody+Moss+Soil	-59.89	6	0.38	0.41	0.90
1 [Null model]	-97.73	0	63.77	0.00	1.00
Virginia males					
Forb+Grass+CWD+Woody+Moss+Soil	-12.42	6	0	0.42	0.42
Rock+Grass+CWD+Woody	-15.43	4	1.56	0.19	0.61
Rock+Forb+Grass+CWD+Woody+Moss+Soil	-12.42	7	2.29	0.13	0.74
1 [Null model]	-36.04	0	34.38	0.00	1.00
West Virginia females					
Forb+Grass+CWD+Soil	-41.32	4	0	0.55	0.55
Sand+Rock+Forb+Grass+CWD+Soil	-40.66	6	3.00	0.12	0.68
Sand+Forb+Woody+CWD	-42.94	4	3.25	0.11	0.79
1 [Null model]	-50.60	0	10.28	0.00	0.99
West Virginia males					
Sand+Rock+Forb+Grass+Woody+Moss	-24.44	6	0	0.18	0.18
Rock+Grass+CWD+Woody	-26.78	4	0.19	0.17	0.35
Sand+Rock+Forb+Grass	-27.24	4	1.11	0.10	0.45
Sand+Rock+Woody+Moss	-27.31	4	1.25	0.10	0.55
Forb+Grass+Woody+Moss	-27.31	4	1.25	0.10	0.65
Rock+Grass+Moss+Soil	-27.32	4	1.25	0.10	0.75
1 [Null model]	-33.96	0	6.12	0.01	1.00

Table 6.8

Best conditional logistic regression model variables – cover variables in $1m^2$ plots Conditional logistic regression model variables that best explain microhabitat selection by Wood Turtles at sites in Virginia and West Virginia, USA in 2011-2014. Measured values are percentages of coverage in $1m^2$ sampling plots. Model coefficient values were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero. See Table 6.1 for definitions of variables.

Variable	**Measured values** (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
	Turtle Plot	*Random Plot*			
Virginia females					
Forb	6.25 ± 1.12	1.51 ± 0.29	0.12 ± 0.06	1.127	1 %
Grass	8.36 ± 1.49	1.52 ± 0.61	0.09 ± 0.03	1.094	1 %
Woody	4.74 ± 0.59	3.30 ± 0.23	0.26 ± 0.08	1.297	1 %
CWD	4.67 ± 0.56	1.79 ± 0.33	0.16 ± 0.04	1.174	1 %
Virginia males					
Forb	5.35 ± 0.79	0.79 ± 0.35	0.23 ± 0.17	1.259	1 %
Grass	8.83 ± 2.11	0.44 ± 0.25	0.51 ± 0.28	1.665	1 %
Woody	4.54 ± 0.60	3.58 ± 0.38	0.29 ± 0.13	1.336	1 %
CWD	4.96 ± 1.20	1.90 ± 0.79	0.07 ± 0.05	1.073	1 %
Soil	1.81 ± 0.98	1.42 ± 1.25	-0.08 ± 0.05	0.923	1 %
West Virginia females					
Forb	4.01 ± 0.52	2.23 ± 0.45	0.25 ± 0.10	1.284	1 %
Grass	10.34 ± 1.49	5.88 ± 1.69	0.02 ± 0.01	1.020	1 %
CWD	2.56 ± 0.55	1.51 ± 0.34	0.12 ± 0.07	1.127	1 %
Soil	0.65 ± 0.20	0.36 ± 0.15	0.16 ± 0.13	1.174	1 %
West Virginia males					
Forb	4.59 ± 0.63	3.22 ± 0.67	0.09 ± 0.07	1.094	1 %
Grass	12.55 ±2.41	4.76 ± 1.17	0.04 ± 0.03	1.041	1 %
Woody	2.22 ± 0.51	1.51 ± 0.29	0.12 ± 0.10	1.127	1 %
CWD	2.92 ± 0.95	1.12 ± 0.35	0.09 ± 0.06	1.094	1 %
Moss	0.61 ± 0.19	2.63 ± 1.26	-0.18 ± 0.15	0.835	1 %
Rock	0.16 ± 0.07	0.41 ± 0.17	-0.70 ± 0.51	0.497	1 %

Table 6.9

Well-supported conditional logistic regression models – using variables in 400m^2 plots 2011-2014

Best of twenty-two conditional logistic regression models of Wood Turtle meso-scale habitat selection at sites in Virginia and West Virginia, USA in 2011-2014, based on habitat variables in 400m^2 plots. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; AICc weight denotes a model's level of support among the set of 22 candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights (top models herein are those with a cumulative weight ≥ .95). See Table 6.2 for definitions of variables.

Model	LogLik	K	ΔAICc	AICc wt.	Cum.wt.
Virginia females					
Obs4+LWD10+LWD4+Gapsizem2+Treespp+ Shrubspp+Dist+ASPB+Slope+Elev	-35.43	10	0	0.88	0.88
Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Dist+ASPB+Slope+Elev	-35.79	12	5.05	0.07	0.95
1 [Null model]	-99.81	0	108.0	0.00	1.00
Virginia males					
Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Slope+Elev	-5.80	9	0	0.29	0.29
Large+Medium+Obs4+LWD10+LWD4+ Snags+Can+Treespp+Shrubspp+Seedspp	-5.03	10	0.90	0.19	0.48
Obs4+LWD10+LWD4+Gapsizem2+Slope+ ASPB+Dist+Elev	-7.60	8	1.20	0.16	0.64
Large+Medium+Obs1+Obs4+Gapsizem2+ LWD10+LWD4+Snags+Can	-6.43	9	1.26	0.16	0.79
1 [Null model]	-36.74	0	42.00	0.00	1.00
West Virginia females					
Large+Medium+Obs1+Snags+Can+Treespp+ Shrubspp+Age+Dist+ASPB+Slope+Elev	-9.99	12	0	0.93	0.93
Large+Medium+Obs4+LWD10+LWD4+Snags+ Gapsizem2+Age+Slope+Elev+ASPB+Dist	-13.10	12	6.22	0.04	0.97
1 [Null model]	-51.29	0	56.29	0.00	1.00
West Virginia males					
Obs4+LWD10+LWD4+Gapsizem2+Seedspp+ Dist+ASPB+Elev	-6.83	8	0	0.72	0.72
Seedspp+Dist+ASPB+Elev	-13.13	4	3.43	0.13	0.86
1 [Null model]	-33.96	0	36.66	0.00	1.00

Table 6.10

Best conditional logistic regression model variables in 400m^2 plots 2011-2014
Conditional logistic regression model variables that best explain meso-scale habitat selection by Wood Turtles at sites in Virginia and West Virginia, USA in 2011-2014. Measured values were obtained in 400m^2 sampling plots. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero.

Variable	**Measured values** (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
	Turtle Plot	*Random Plot*			
Virginia females					
Medium	10.1 ± 0.60	12.4 ± 0.60	0.06 ± 0.05	1.062	1 tree
***Tree spp*.**	5.4 ± 0.15	5.7 ± 0.14	-0.41 ± 0.15	0.667	1 spp.
Shrub spp.	10.4 ± 0.31	8.3 ± 0.25	0.13 ± 0.09	1.139	1 spp.
Obs4	94.0 ± 0.86	77.7 ± 1.51	0.11 ± 0.03	1.116	1 %
LWD10	2.3 ± 0.15	1.6 ± 0.16	0.31 ± 0.18	1.363	1 piece
Snags	2.0 ± 0.15	1.6 ± 0.11	0.47 ± 0.16	1.600	1 snag
Canopy	20.1 ± 1.10	13.6 ± 0.53	0.06 ± 0.03	1.062	1 %
Slope	6.3 ± 0.42	9.7 ± 0.41	-0.16 ± 0.06	0.852	1 °
Elevation	519.7 ± 3.2	534.1 ± 3.0	-0.05 ± 0.02	0.951	1 meter
Aspect	1.1 ± 0.05	1.0 ± 0.05	-0.62 ± 0.48	0.538	.1 unit
Virginia males					
[no variables had strong support]					
West Virginia females					
Medium	14.5 ± 0.82	15.0 ± 0.88	0.29 ± 0.21	1.336	1 tree
Obs1	27.5 ± 1.49	19.8 ± 1.69	0.51 ± 0.34	1.665	1 %
Obs4	78.6 ± 1.77	67.8 ± 2.34	0.11 ± 0.06	1.116	1 %
Shrub spp.	8.1 ± 0.28	7.0 ± 0.23	4.96 ± 3.31	1.642	.1 spp.
LWD10	1.9 ± 0.15	1.1 ± 0.13	0.84 ± 0.57	2.316	1 piece
Snags	2.6 ± 0.23	2.5 ± 0.24	1.40 ± 1.05	4.055	1 snag
Aspect	0.8 ± 0.08	0.9 ± 0.09	3.73 ± 2.81	1.452	.1 unit
Elevation	333.3 ± 2.02	347.2 ± 2.11	-0.36± 0.24	0.698	1 meter
West Virginia males					
Large	5.8 ± 0.48	6.5 ± 0.43	-0.49 ± 0.41	0.613	1 tree
Snags	1.9 ± 0.23	2.3 ± 0.32	-0.62 ± 0.44	0.538	1 snag
Slope	6.3 ± 0.42	9.7 ± 0.41	-0.12 ± 0.10	0.887	1 °

Table 6.11

Well-supported conditional logistic regression models – using variables in $400m^2$ plots, including number of herbaceous taxa 2011-2013
Best of twenty-two conditional logistic regression models of Wood Turtle meso-scale habitat selection at sites in Virginia and West Virginia, USA in 2011-2013, based on habitat variables in $400m^2$ plots, including number of herbaceous taxa. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; AICc weight denotes a model's level of support among the set of 22 candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights.

Model	LogLik	K	ΔAICc	AICc wt.	Cum.wt.
Virginia females					
Obs4+LWD10+LWD4+Gapsizem2+Treespp+ Shrubspp+Dist+ASPB+Slope+Elev	-29.79	10	0	0.78	0.78
Large+Medium+Obs4+Obs1+Gapsizem2+LWD10+ LWD4+Snags+Can+Dist+ASPB+Slope+Elev	-27.95	13	2.99	0.17	0.95
1 [Null model]	-81.79	0	83.03	0.00	1.00
Virginia males					
Large+Medium+Obs4+LWD10	-2.24	4	0	0.99	0.99
Seedspp+Herb+Dist+ASPB+Elev	-6.56	5	11.0	0.01	1.00
1 [Null model]	-22.87	0	32.60	0.00	1.00
West Virginia females					
Obs4+LWD10+LWD4+Gapsizem2+ASPB+ Dist+Slope	-4.26	7	0	0.95	0.95
Dist+ASPB+Slope+Elev	-11.72	4	8.06	0.02	0.97
1 [Null model]	-32.58	0	41.33	0.00	1.00
West Virginia males					
Obs4+Gapsizem2+Shrubspp+ASPB+Slope	-4.07	5	0	0.77	0.77
Obs4+LWD10+Gapsizem2+Dist+ASPB+Elev	-5.11	6	4.52	0.08	0.85
1 [Null model]	-22.18	0	25.18	0.00	1.00

Table 6.12

Best conditional logistic regression model variables in 400m^2 plots 2011-2013, including number of herbaceous taxa

Conditional logistic regression model variables that best explain meso-scale habitat selection by Wood Turtles at sites in Virginia and West Virginia, USA in 2011-2013. Measured values, including number of herbaceous taxa present, were obtained in 400m^2 sampling plots. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero.

Variable	Measured values (mean ± se)		Model coefficient ± se	Odds ratio	Unit increase
	Turtle Plot	*Random Plot*			
Virginia females					
Medium	10.3 ± 0.66	11.9 ± 0.61	0.06 ± 0.05	1.062	1 tree
Obs4	93.1 ± 1.03	77.3 ± 1.68	0.11 ± 0.04	1.116	1 %
Tree spp.	5.4 ± 0.16	5.9 ± 0.15	-0.46 ± 0.17	0.631	1 spp.
Shrub spp.	10.4 ± 0.35	8.4 ± 0.28	0.16 ± 0.11	1.174	1 spp.
Snags	2.0 ± 0.17	1.7 ± 0.12	0.52 ± 0.20	1.682	1 snag
Canopy	19.8 ± 1.29	13.7 ± 0.50	0.05 ± 0.04	1.051	1 %
Aspect	1.1 ± 0.06	1.0 ± 0.06	-0.82 ± 0.52	0.921	.1 unit
Slope	6.3 ± 0.49	10.1 ± 0.46	-0.16 ± 0.06	0.852	1 º
Elevation	521.0 ± 3.59	534.8 ± 3.24	-0.05 ± 0.02	0.951	1 meter
Virginia males					
Seed spp.	7.4 ± 0.50	8.2 ± 0.45	-0.44 ± 0.26	0.644	1 spp.
Herb. spp.	16.1 ± 1.33	9.9 ± 1.28	-0.13 ± 0.08	0.878	1 spp.
Canopy	20.9 ± 2.46	12.2 ± 0.45	0.30 ± 0.25	1.350	1 %
Dist	51.1 ± 10.9	132.2 ± 13.0	-0.05 ± 0.03	0.951	1 meter
West Virginia females					
Herb spp.	16.7 ± 0.95	11.4 ± 0.98	0.32 ± 0.29	1.377	1 spp.
Snags	2.8 ± 0.34	2.6 ± 0.33	1.29 ± 1.04	3.633	1 snag
West Virginia males					
Snags	2.2 ± 0.30	2.2 ± 0.44	-1.87 ± 1.20	0.154	1 snag
Obs4	81.7 ± 2.61	58.4 ± 3.89	0.56 ± 0.61	1.751	1 %

Table 6.13

Well-supported conditional logistic regression models – using variables in 400m^2 plots and pooled data 2011-2014

Best of thirty-one conditional logistic regression models of Wood Turtle meso-scale habitat selection at combined sites in Virginia and West Virginia, USA in 2011-2014, based on habitat variables in 400m^2 plots, including importance values of trees. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; AICc weight denotes a model's level of support among the set of 31 candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights.

Model	**LogLik**	**K**	**ΔAICc**	**AICc wt.**	**Cum.wt.**
Virginia and West Virginia females					
Obs4+LWD10+LWD4+Gapsizem2+ Treespp+Shrubspp+Dist+ASPB+Slope	-69.31	9	0	0.91	0.91
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-74.24	7	5.72	0.05	0.97
1 [Null model]	-151.11	0	146.4	0.00	1.00
Virginia and West Virginia males					
Large+Medium+Obs4+Obs1+LWD10+LWD4+ Snags+Can+Gapsizem2+Age+Slope+ASPB+Dist	-14.42	13	0	0.93	0.93
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-24.18	7	6.18	0.04	0.97
1 [Null model]	-70.70	0	84.64	0.00	1.00
Virginia and West Virginia Wood Turtles					
Obs4+LWD10+LWD4+Gapsizem2+Treespp+ Shrubspp+Slope+ASPB+Dist	-98.42	9	0	0.59	0.59
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-101.23	7	1.50	0.28	0.87
1 [Null model]	-221.81	0	228.5	0.00	1.00

Table 6.14

Best conditional logistic regression model variables in 400m^2 plots, using pooled data 2011-2014

Conditional logistic regression model variables that best explain meso-scale habitat selection by Wood Turtles at combined sites in Virginia and West Virginia, USA in 2011-2014. Measured values were obtained in 400m^2 sampling plots. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero.

Variable	**Measured values** (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
	Turtle Plot	*Random Plot*			
VA & WV females					
Medium	11.5 ± 0.50	13.2 ± 0.50	0.03 ± 0.03	1.03	1 tree
Obs1	26.8 ± 1.46	18.9 ± 1.17	0.02 ± 0.01	1.020	1 %
Obs4	88.9 ± 0.97	74.3 ± 1.31	0.06 ± 0.01	1.062	1 %
Tree spp.	5.5 ± 0.11	5.6 ± 0.11	-0.26 ± 0.10	0.771	1 spp.
Shrub spp.	9.6 ± 0.24	7.9 ± 0.19	0.10 ± 0.06	1.105	1 spp.
LWD10	2.1 ± 0.12	1.5 ± 0.12	0.27 ± 0.11	1.310	1 piece
Snags	2.2 ± 0.13	1.9 ± 0.11	0.11 ± 0.08	1.116	1 snag
Slope	8.3 ± 0.50	13.1 ± 0.51	-0.13 ± 0.03	0.878	1 º
Aspect	1.0 ± 0.05	1.0 ± 0.05	-0.57 ± 0.28	0.945	0.1 unit
WO	18.8 ± 1.37	14.2 ± 1.17	0.02 ± 0.02	1.020	1 unit
RM	11.8 ± 0.95	10.6 ± 0.90	0.03 ± 0.02	1.030	1 unit
SM	4.1 ± 0.70	1.5 ± 0.37	0.04 ± 0.03	1.041	1 unit
TP	7.3 ± 1.14	6.3 ± 1.26	0.03 ± 0.02	1.030	1 unit
VA & WV males					
Large	6.0 ± 0.34	6.5 ± 0.31	0.38 ± 0.20	1.462	1 tree
Medium	10.9 ± 0.64	13.3 ± 0.77	-0.14 ± 0.10	0.869	1 tree
Obs4	88.2 ± 1.30	69.6 ± 2.15	0.19 ± 0.08	1.209	1 %
Can	19.6 ± 1.11	13.4 ± 0.46	0.25 ± 0.12	1.284	1 %
Dist	57.1 ± 6.26	116.4± 6.41	-0.03 ± 0.01	0.970	1m
Slope	8.6 ± 0.82	15.2 ± 0.97	-0.15 ± 0.07	0.861	1 º
WP	16.8 ± 2.02	18.9 ± 2.33	-0.09 ± 0.07	0.914	1 unit
VP	8.8 ± 1.73	7.6 ± 1.61	-0.12 ± 0.08	0.887	1 unit
SM	4.7 ± 0.96	3.8 ± 0.85	-0.20 ± 0.13	0.819	1 unit
SO	2.5 ± 0.96	6.9 ± 1.46	-0.10 ± 0.08	0.905	1 unit
CO	3.8 ± 0.95	11.1 ± 1.64	-0.23 ± 0.11	0.795	1 unit
TP	3.6 ± 0.95	1.0 ± 0.43	-0.18 ± 0.12	0.835	1 unit
VA & WV Wood Turtles					
Obs4	88.7 ± 0.78	72.8 ± 1.13	0.07 ± 0.01	1.073	1 %
Tree spp.	5.5 ± 0.09	5.5 ± 0.09	-0.15 ± 0.08	0.861	1 spp.
Shrub spp.	9.6 ± 0.20	7.9 ± 0.16	0.08 ± 0.05	1.083	1 spp.
LWD10	2.0 ± 0.09	1.4 ± 0.10	0.14 ± 0.08	1.150	1 piece
Can	19.9 ± 0.70	14.5 ± 0.46	0.03 ± 0.02	1.030	1 snag
Slope	8.4 ± 0.43	13.8 ± 0.47	-0.11 ± 0.02	0.890	1 º
Aspect	1.0 ± 0.04	1.0 ± 0.04	-0.43 ± 0.22	0.958	0.1 unit
SM	4.3 ± 0.57	2.2 ± 0.37	0.04 ± 0.03	1.041	1 unit
TP	6.1 ± 0.84	4.6 ± 0.88	0.02 ± 0.02	1.020	1 unit

Table 6.15

Well-supported conditional logistic regression models – using variables in $400m^2$ plots, including number of herbaceous taxa and IVs, pooled data 2011-2013
Best of thirty-one conditional logistic regression models of Wood Turtle meso-scale habitat selection at combined sites in Virginia and West Virginia, USA in 2011-2013, based on habitat variables in $400m^2$ plots, including number of herbaceous taxa present and importance values of trees. LogLik = model log-likelihood; K = number of parameters; ΔAICc= difference in Akaike Information Criterion corrected for small sample size from the top model; AICc weight denotes a model's level of support among the set of 31 candidate models; cumulative weight (Cum. wt.) is the running sum of the individual model weights.

Model	LogLik	K	ΔAICc	AICc wt.	Cum.wt.
Virginia and West Virginia females					
Obs4+LWD10+LWD4+Gapsizem2+ Treespp+Shrubspp+Dist+ASPB+Slope	-51.05	9	0	0.95	0.95
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-56.78	7	7.24	0.03	0.97
1 [Null model]	-114.37	0	108.1	0.00	1.00
Virginia and West Virginia males					
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-8.10	7	0	0.88	0.88
Obs4+LWD10+LWD4+Gapsizem2+Herb+ Seedspp+Slope+ASPB+Dist	-7.95	9	4.28	0.10	0.98
1 [Null model]	-45.05	0	59.00	0.00	1.00
Virginia and West Virginia Wood Turtles					
Obs4+LWD10+LWD4+Gapsizem2+Treespp+ Shrubspp+Slope+ASPB+Dist	-67.53	9	0	0.35	0.35
Obs4+LWD10+LWD4+Gapsizem2+ Slope+ASPB+Dist	-69.88	7	0.54	0.27	0.62
WO+WP+RM+HICK+VP+CO+NRO+TP+SM+ WA+BG+SO+Obs4+LWD10+LWD4+Gapsizem2+ Shrubspp+Slope+ASPB+Dist	-56.40	20	1.25	0.19	0.80
Obs4+LWD10+LWD4+Gapsizem2+ Herb+Seedspp+Slope+ASPB+Dist	-68.47	9	1.88	0.14	0.94
1 [Null model]	-159.42	0	165.4	0.00	1.00

Table 6.16

Best conditional logistic regression model variables in 400m^2 plots, including number of herbaceous taxa and IVs, using pooled data 2011-2013
Conditional logistic regression model variables that best explain meso-scale habitat selection by Wood Turtles at combined sites in Virginia and West Virginia, USA in 2011-2013. Measured values were obtained in 400m^2 sampling plots and include number of herbaceous taxa present. Model coefficients were obtained through model averaging. Variables with positive values for coefficients are preferred, while negative values indicate avoidance. Variables in **bold** denote those with coefficients that did not overlap zero.

Variable	**Measured values** (mean ± se)		**Model coefficient** ± se	**Odds ratio**	**Unit increase**
	Turtle Plot	*Random Plot*			
VA & WV females					
Obs4	88.2 ±1.16	74.7 ± 1.51	0.05 ± 0.02	1.051	1 %
Tree spp.	5.6 ± 0.13	5.8 ± 0.12	-0.34 ± 0.12	0.712	1 spp.
Shrub spp.	10.0 ± 0.27	8.2 ± 0.22	0.16 ± 0.09	1.174	1 spp.
Herb spp.	15.0 ± 0.58	10.6 ± 0.54	0.04 ± 0.03	1.041	1 spp.
LWD10	2.2 ± 0.14	1.6 ± 0.14	0.23 ± 0.13	1.259	1 piece
Snags	2.3 ± 0.16	1.9 ± 0.13	0.16 ± 0.09	1.174	1 snag
Aspect	1.0 ± 0.06	1.0 ± 0.05	-0.98 ± 0.35	0.907	.1 unit
WO	18.7 ± 1.49	14.4 ± 1.30	0.03 ± 0.03	1.030	1 unit
RM	13.4 ± 1.15	12.0 ± 1.10	0.04 ± 0.03	1.041	1 unit
SM	4.3 ± 0.82	0.9 ± 0.33	0.13 ± 0.07	1.139	1 unit
WA	5.7 ± 0.89	1.1 ± 0.26	0.07 ± 0.06	1.073	1 unit
VA & WV males					
Large	5.9 ± 0.40	6.9 ± 0.41	0.37 ± 0.32	1.448	1 tree
Obs4	88.3 ± 1.71	67.8 ± 2.15	0.20 ± 0.10	1.221	1 %
Tree spp.	5.6 ± 0.21	5.4 ± 0.18	0.44 ± 0.32	1.552	1 spp.
Canopy	20.0 ± 1.45	13.3 ± 0.56	0.23 ± 0.15	1.259	1 %
Slope	8.0 ± 0.96	15.6 ± 1.26	-0.11 ± 0.09	0.896	1 º
WP	14.4 ± 2.06	21.7 ± 2.99	-0.11 ± 0.08	0.896	1 unit
RM	9.1 ± 1.22	10.1 ± 1.56	-0.15 ± 0.12	0.861	1 unit
SM	5.2 ± 1.37	5.1 ± 1.25	-0.23 ± 0.16	0.795	1 unit
BG	3.3 ± 0.81	1.8 ± 0.77	0.20 ± 0.18	1.221	1 unit
NRO	3.8 ± 0.90	5.3 ± 1.05	-0.16 ± 0.13	0.852	1 unit
HICK	7.4 ± 1.51	8.9 ± 1.48	-0.13 ± 0.10	0.878	1 unit
VA & WV Wood Turtles					
Obs4	88.2 ± 0.96	72.8 ± 1.32	0.08 ± 0.02	1.083	1 %
Tree spp.	5.6 ± 0.11	5.7 ± 0.10	-0.19 ± 0.10	0.827	1 spp.
Shrub spp.	10.1 ± 0.23	8.3 ± 0.19	0.09 ± 0.08	1.094	1 spp.
Herb spp.	15.4 ± 0.49	11.1 ± 0.47	0.04 ± 0.03	1.041	1 spp.
Slope	7.5 ± 0.45	13.5 ± 0.53	-0.14 ± 0.04	0.869	1 º
Aspect	0.9 ± 0.05	1.0 ± 0.05	-0.89 ± 0.41	0.915	.1 unit
SM	4.5 ± 0.70	2.1 ± 0.44	0.12 ± 0.05	1.127	1 unit
WA	5.5 ± 0.73	1.3 ± 0.28	0.05 ± 0.04	1.051	1 unit

Table 6.17

Synopsis of best conditional logistic regression model variables in 400m^2 plots for various turtle groups in VA and WV

Synopsis of conditional logistic regression model variables that best explain Wood Turtle meso-scale habitat selection based on habitat variables in 400m^2 sampling plots at sites in Virginia and West Virginia, USA during June-August 2010-2014. Based on model coefficients obtained through model averaging. Variables with exes are those with coefficients that did not overlap zero for that particular site group; an **X** of positive sign indicates variables that are preferred, while **–X** indicates avoidance. Variables with **b**s are those with coefficients that slightly overlapped zero for that particular site group; a **b** of positive sign indicates variables that are preferred, while a **–b** indicates avoidance. FT = female Wood Turtles, MT = male Wood Turtles, V = Virginia, W = West Virginia. See Table 6.2 for definition of variables.

	Type of site						
Variable	**VFT**	**VMT**	**WFT**	**WMT**	**FT**	**MT**	**WT**
Large trees				-b		X	
Medium trees			b	-b			
Obs1			b		X		X
Snags	X				b		
Canopy	b					X	b
Stand age						-b	
LWD10	b		b		X		b
LWD4							
Gap size							
Obs4	X		b		X	X	X
Tree taxa	-X				-X		-b
Shrub taxa					b		b
Seedling taxa							
Herbaceous taxa					b		b
Distance to stream						-X	
Slope	-X				-X	-X	-X
Aspect					-X		-X
Elevation	-X		-b				
CO						-X	
SM					X		X

Table 6.18

Well-supported mixed conditional logistic regression models – using variables in 400m^2 plots, including stand and plot forest type and seral stage, pooled data 2011-2013

Best of twenty-two conditional logistic regression models of Wood Turtle meso-scale habitat selection at sites in Virginia and West Virginia, USA, based on habitat variables in 400m^2 plots in 2011-2013; models included stand seral stage, stand forest type, or plot forest type as a random effect. K = number of parameters; ΔAIC = difference in Akaike Information Criterion size from the top model; only models within 2 units of the top model are listed (or the top two models if only one was well supported). AIC values denote models that are well-supported among the set of 22 candidate models. See Table 6.2 for definitions of variables. Number of plots (for both turtle and random points): for seral stage VA F n = 144, VA M n = 52; for stand forest type F n = 197, M n = 89; for plot forest type F n = 330, M n = 120.

Model	AIC	K	ΔAICc
Virginia females – seral stage			
Large+Medium+Obs4+Obs1+LWD10+LWD4+ Gapsize+Snags+Slope+ASPB	98.07	10	0
Large+Medium+Obs4+LWD10+LWD4+ Gapsize+Snags+Treespp+Shrubspp+Seedspp	99.57	10	1.50
Virginia males – seral stage			
Large+Medium+Snags+Can+Seedspp+ASPB+Slope	44.98	7	0
LWD10+Gapsize+ASPB+Slope	47.88	4	2.90
Virginia &West Virginia females – stand forest type (with Herb)			
Obs4+LWD10+LWD4+Gapsize+Slope+ASPB	109.42	6	0
Large+Medium+Obs4+Obs1+LWD10+LWD4+ Snags+Can+Age+Slope+ASPB	110.19	11	0.77
Virginia & West Virginia males – stand forest type (with Herb)			
Obs4+LWD10+LWD4+Gapsize+ Herb+Seedspp+ASPB+Dist	32.96	8	0
LWD10+Treespp+Shrubspp+ASPB+Dist	40.44	5	7.48
Virginia &West Virginia females – plot forest type (with Herb)			
Obs4+LWD10+LWD4+Gapsize+Slope+ASPB	133.35	6	0
Large+Medium+Obs4+Obs1+LWD10+LWD4+ Snags+Can+Age+Slope+ASPB	135.30	11	1.95
Virginia & West Virginia males – plot forest type (with Herb)			
Obs4+ LWD10+LWD4+Gapsize+ASPB	35.38	5	0
Large+Obs4+LWD10+LWD4+Snags+Can+Age	39.81	7	4.43

Table 6.19

Best mixed conditional logistic regression model variables in 400m^2 plots, using stand and plot forest type and s stage, pooled data 2011-2013
Conditional logistic regression model variables that best explain meso-scale habitat selection by Wood Turtles in Virginia and West Virginia, USA in 2011-2014, based on habitat variables in 400m^2 plots. Coefficient values ar the well-supported models run with stand forest type, plot forest type, or stand seral stage as random effects (see 18). Positive values for coefficients indicate preference, while negative values indicate avoidance. Variable coefficients that overlapped zero are denoted with an asterisk. See Table 6.2 for definitions of variables. Number o (for both turtle and random points): for seral stage VA F n = 144, VA M n = 52; for stand forest type F n = 197, 89; for plot forest type F n = 330, M n = 120.

Variable	value	se	p-value
Virginia females – seral stage			
Mod1 - Large+Medium+Obs4+Obs1+LWD10+ LWD4+Snags+Gapsizem2+Slope+ASPB			
Obs4	0.130	0.03	0.00001
Snags	0.483	0.15	0.0011
Slope	-0.117	0.05	0.0099
Gapsizem2	0.015	0.01	0.0193
Seral	0.042	0.06	0.6100
Mod2 - Large+Medium+Obs4+LWD10+LWD4+ Snags+Gapsizem2+Treespp+Shrubspp+Seedpp			
Obs4	0.127	0.03	0.00001
Snags	0.452	0.14	0.0017
Medium	0.089	0.04	0.0381
Gapsizem2	0.018	0.01	0.0195
Shrub spp.	0.213	0.09	0.0198
Seral	0.014	0.01	0.8921
Virginia males – seral stage			
Large+Medium+Snags+Can+Seedspp+ASPB+Slope			
Can	0.265	0.12	0.0220
Slope	-0.211	0.09	0.0179
Seral	0.400	0.33	0.2872
Virginia &West Virginia females – stand forest type (with Herb)			
Mod1			
Obs4	0.059	0.02	0.00017
LWD10 *	0.218	0.12	0.0705
Gapsizem2 *	0.009	0.005	0.0543
ASPB	-0.857	0.34	0.0113
Slope	-0.183	0.04	0.00001
Stand	2.088	0.99	0.0031
Mod2			
Obs4	0.052	0.02	0.0031
Can	0.045	0.02	0.0420
ASPB	-0.881	0.48	0.0182
Slope	-0.221	0.05	0.00001
Stand	0.589	0.48	0.1216
Virginia & West Virginia males – stand forest type (with Herb)			
Obs4	0.148	0.07	0.0432
Dist *	-0.028	0.02	0.0695
Stand	0.102	0.04	0.9431
Virginia &West Virginia females – plot forest type (with Herb)			
Mod1			
Obs4	0.056	0.01	0.00009
LWD10 *	0.205	0.11	0.0623
Gapsizem2 *	0.007	0.004	0.0745
Slope	-0.160	0.04	0.00001
ASPB	-0.718	0.30	0.01629
Plot	0.061	0.06	0.3241
Mod2			
Obs4	0.054	0.02	0.0005
LWD10 *	0.203	0.12	0.0964
Can *	0.033	0.02	0.0864
Slope	-0.185	0.04	0.00001
Age	0.012	0.004	0.0180

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APPENDIX 1. FLORA AT STUDY AREA

Common overstory canopy tree species include *Quercus (alba, cocinna, prinus, rubra,* and *velutina), Pinus (rigida, strobus,* and *virginiana), Acer rubrum and saccharum, Betula lenta, Carya glabra, Fraxinus americana, Liriodendron tulipifera, Nyssa sylvatica*, and *Prunus serotina*. Common midstory tree taxa include smaller individuals of the above species as well as *Amelanchier* spp., *Cornus florida, Hamamelis virginiana,* and *Ostrya virginiana*.

Common shrub and woody understory taxa include seedlings of the above taxa as well as *Gaylusuchia* spp., *Ilex verticilata, Kalmia latifolia, Lindera benzoin, Lyonia* spp., *Parthenocissus quinquefolia, Rhododendron periclymenoides, Rubus* spp., *Smilax* spp., *Vaccinium* spp., and *Viburnum* spp.

Common herbaceous ground floor taxa include *Ageratina altissima, Amphicarpaea bracteata, Aster* spp., *Boehmeria cylindrica, Chimaphila maculata, Cunila origanoides, Desmodium* spp., *Dioscorea villosa, Epigaea repens, Eurybia divaricata, Gallium* spp., *Gaultheria procumbens, Goodyera pubescens, Hieracium venosum, Impatiens capensis, Lobelia* spp., *Lycopus* spp., *Medeola virginiana, Mitchella repens, Nabalus* spp., *Oxalis stricta, Pedicularis canadensis, Potentilla* spp., *Scutellaria* spp., *Smilacena recemosa, Solidago* spp., *Thalictrum* spp., *Uvularia* spp., *Viola* spp., *Carex* spp. and *Panicum* spp.

Forest types (FT) of stands in Virginia: FT3 = White Pine, 10 = White Pine/Upland Hardwoods, 39 = Table Mountain Pine, 41 = Cove Hardwoods/White Pine, 52 = Chestnut Oak, 53 = White Oak – Northern Red Oak – Hickory, 54 = White Oak, 56 = Tulip Poplar – White Oak – Northern Red Oak, 59 = Scarlet Oak, 60 = Chestnut Oak – Scarlet Oak.

The WV site has a greater proportion of relatively more-xeric pine and mixed pine-deciduous forest types: FT10 = White Pine/Upland Hardwoods, 33 = Virginia Pine, 42 = Upland Hardwoods/White Pine, 45 = Chestnut Oak – Scarlet Oak – Yellow Pine, 52 = Chestnut Oak, 53 = White Oak – Northern Red Oak – Hickory (stand designations, nomenclature, and enumeration as per USFS).

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