RELATING FIA DATA TO HABITAT CLASSIFICATIONS VIA TREE-BASED MODELS OF CANOPY COVER

Mark D. Nelson, Brian G. Tavernia, Chris Toney, and Brian F. Walters[1]

Abstract.—Wildlife species-habitat matrices are used to relate lists of species with abundance of their habitats. The Forest Inventory and Analysis Program provides data on forest composition and structure, but these attributes may not correspond directly with definitions of wildlife habitats. We used FIA tree data and tree crown diameter models to estimate canopy cover, from which we assigned FIA conditions to NatureServe forest and woodland habitat domains and National Land Cover Dataset (NLCD) forest classes within the 20-state northern FIA region. Hardwood and softwood types were most abundant for FIA, least abundant for NLCD, and intermediate for NatureServe classes. NatureServe hardwood types were evenly distributed between forest and woodland, but softwood types were more abundant in NatureServe woodland than forest. Mixed types were substantially more abundant for NLCD, intermediate for NatureServe (equally distributed between forest and woodland), and least abundant for FIA. Area of woody wetlands, which were defined only for NLCD, exceeded area of NLCD softwoods. These habitat assignments are useful for estimating current and potential future abundance of habitats for forest-associated terrestrial vertebrate wildlife species in the region.

INTRODUCTION

Strategic estimates of wildlife habitat abundance can be obtained from forest composition and structure data provided by the Forest Inventory and Analysis (FIA) Program (Woudenberg et al. 2010). FIA data spanning several decades are easily queried to estimate status and trends of coarse-scale habitat characteristics, like area of young hardwood forest or old softwood forest. However, FIA attributes are not directly relatable to wildlife species-habitat matrices, such as those developed by NatureServe (2011). Furthermore, spatially explicit landscape metrics are required for assessing habitat quality for many wildlife species but are not available directly from FIA plot data. Landscape metrics typically are obtained from ancillary geospatial datasets such as the National Land Cover Database of 2006 (NLCD) (Fry et al. 2011), but NLCD forest classes are defined differently from FIA forest types. There is an opportunity for increasing the utility of FIA data by relating it to species-habitat relationships and to ancillary datasets used for assessing habitats.

Tree canopy cover thresholds are used to characterize NatureServe forest and woodland habitat domains and NLCD forest land cover classes, but historical and current FIA data do not include estimates of tree canopy cover. Therefore, we adapted a procedure described by Toney et al. (2009) to estimate tree canopy cover from FIA tree data, which we used to assign NatureServe and NLCD classes to conditions in the FIA Database (FIADB; Woudenberg et al. 2010). The NatureServe system defines canopy cover thresholds that separate forest from woodland, with subcategories of hardwood, conifer, and mixed

[1] Research Forester (MDN) and Forester (BFW), U.S. Forest Service, Northern Research Station, 1992 Folwell Ave., St. Paul, MN 55108; Science Coordinator (BGT), Integrated Waterbird Management and Monitoring Program, USGS Patuxent Wildlife Research Center; Biologist (CT), U.S. Forest Service, Rocky Mountain Research Station. MDN is corresponding author: to contact, call 651-649-5104 or email at mdnelson@fs.fed.us.

classes, resulting in six habitat types (Table 1). Similarly, NLCD forest land cover is separated into deciduous, evergreen, and mixed forest classes based on canopy cover thresholds. Canopy cover thresholds for NatureServe and NLCD differ from one another. NLCD's woody wetland class was included in this study as an additional forest class, but is not based upon a canopy cover threshold (Table 2).

Table 1.—NatureServe habitat domains (adapted from NatureServe 2011)

Code	Habitat Domain	Description
0	No data	
	Forest	Woody vegetation at least 6 m tall (usually much taller) with a fairly continuous and complete (two-thirds or greater) canopy closure.
1	Forest-Hardwood	Angiosperms comprise over two-thirds of the canopy.
2	Forest-Conifer	Gymnosperms comprise over two-thirds of the canopy.
3	Forest-Mixed	Composed of both hardwood and conifer trees, neither dominating as much as two-thirds of the canopy.
	Woodland	Crowns often not interlocking; tree canopy discontinuous (often clumped), averaging between 40 and 66 percent overall cover [Modified to include tree canopy between 10 and 40 percent (Savanna), per recommendations from NatureServe.]
4	Woodland-Hardwood	Angiosperms comprise over two-thirds of the canopy.
5	Woodland-Conifer	Gymnosperms comprise over two-thirds of the canopy.
6	Woodland-Mixed	Stand composed of both hardwood and conifer trees, neither dominating as much as two-thirds of the canopy.
--	Savanna	Mosaic of trees or shrubs and grassland; between 10 and 40 percent cover by trees and shrubs.

Table 2.—National Land Cover Dataset (2006) forest cover classes (adapted from NatureServe 2011)

Code	Land Cover Class	Description
0	No data	
41	Deciduous Forest	Areas dominated by trees generally greater than 5 m tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
42	Evergreen Forest	Areas dominated by trees generally greater than 5 m tall, and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
43	Mixed Forest	Areas dominated by trees generally greater than 5 m tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.
90	Woody Wetlands	Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

DATA AND METHODS

A canopy cover modeling approach (Toney et al. 2009) was used to estimate canopy cover for trees (≥ 5 inches d.b.h., on subplots), if present, or saplings (1 to 4.9 inches d.b.h., on microplots) on forested FIA conditions within 20 states of the Upper Midwest and Northeast, during the inventory period 2004-2008. These states include Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Wisconsin, and West Virginia. FIA forest land is defined as having "…at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated" (Woudenberg et al. 2010).

Canopy cover estimation was based on tree species-specific predicted crown dimensions, and tree stem location coordinates recorded by field crews within FIA subplots and microplots. Tree and sapling crown width predictions are based on Bechtold (2003) and Bragg (2001). An optional spatial statistic (Ripley's K) included as a predictor in Toney et al. (2009) was not used for canopy cover modeling in the present study. Because FIA plots may contain multiple conditions, tree and sapling canopy cover estimates were weighted based on condition proportion and appended to the CONDITION table in a Microsoft Access database.

All forested conditions with more than 0 percent estimated canopy cover were assigned a NatureServe forest or woodland habitat type and an NLCD forest land cover class using tree or sapling canopy cover thresholds defined in Tables 1 and 2, respectively, with minor modifications. NatureServe wildlife habitat categories are distinct from those developed by NatureServe and others for the U.S. National Vegetation Classification (FGDC 2008). That classification defines a "Forest to Open Woodland" class that includes all forest stands with tree canopy cover >10 percent, including stands where the sapling layer is the dominant layer (e.g., regenerating stands) (Faber-Langendoen et al. 2012). Conditions with canopy cover below the minimum thresholds in Tables 1 and 2 were assigned to NatureServe woodland or NLCD forest class, respectively. Canopy cover between 10 and 40 percent is defined as "Savanna" in NatureServe's habitat domains (Table 1), but was grouped with woodland in this study because sparse canopy cover in this region is predominately associated with young/regenerating woodland or forest (NatureServe, personal communication).

A small number of forested FIA conditions contained no trees or saplings. Thus, no canopy cover estimates were available for these conditions, and canopy cover could not be used to assign habitat or land cover classes to those conditions. During a plot visit, a field crew can look beyond subplot boundaries to determine some condition attributes via visual interpretation, including those conditions containing no trees at the time of field data collection. For conditions with no trees or saplings (i.e., estimated canopy cover = 0), habitat and land cover classes were recoded to valid classes using other FIA condition attributes, including ALSTKCD–"a code indicating the stocking of the condition by live trees, including seedlings"; FORTYPCD–"the forest type used for reported purposes, primarily derived using a computer algorithm, except when less than 25 percent of the plot samples a particular forest condition"; and PHYSCLCD–"the general effect of landform, topographical position, and soil on moisture available to trees" (Woudenberg et al. 2010).

NatureServe:
If ALSTKCD = 5 (nonstocked), then assign condition to "0".
Else, if ALSTKCD = 4 (poorly stocked, 10-34 percent), assign to "Woodland".
if FORTYPCD is between 500 and 998, assign to code "Woodland Hardwood". (4)
if FORTYPCD <400, assign to code "Woodland Conifer". (5)
if FORTYPCD is between 400 and 499, assign to code "Woodland Mixed". (6)

Else, if ALSTKCD is between 1 and 3 (overstocked, fully stocked, medium stocked; 35-100+ percent), assign to "Forest".
if FORTYPCD is between 500 and 998, assign to code "Forest Hardwood". (1)
if FORTYPCD <400, assign to code "Forest Conifer". (2)
if FORTYPCD is between 400 and 499, assign to code "Forest Mixed". (3)

NLCD2006:
If PHYSCLCD is between 30 and 39 (hydric site), assign to code "90" (Woody Wetlands).
Else, if ALSTKCD = 5 (nonstocked), then assign condition to "0".
Else, if FORTYPCD is between 500 and 998, assign to code "41" (Deciduous Forest).
if FORTYPCD <400, assign to code "42" (Evergreen Forest).
if FORTYPCD is between 400 and 499, assign to code "43" (Mixed Forest).

An attribute was added to the Access database CONDITION table to record which method was used to determine the NatureServe and NLCD condition assignment: 1 = tree canopy cover, 2 = sapling canopy cover, 0 = other FIA condition attributes. FIA's PC-EVALIDator tool was revised to include NatureServe and NLCD categories as row and column variables. PC-EVALIDator was used to estimate forest land area for NatureServe forest and woodland classes, NLCD forest and woody wetland land cover classes, and FIA forest type group aggregations-softwoods (100-390), mixed (400), and hardwoods (500-990) (Fig. 1). Different class names have similar, but not identical, meaning among FIA, NatureServe, and NLCD (i.e., softwood/conifer/evergreen, hardwood/hardwood/deciduous, respectively); we used FIA's terminology for labeling comparisons.

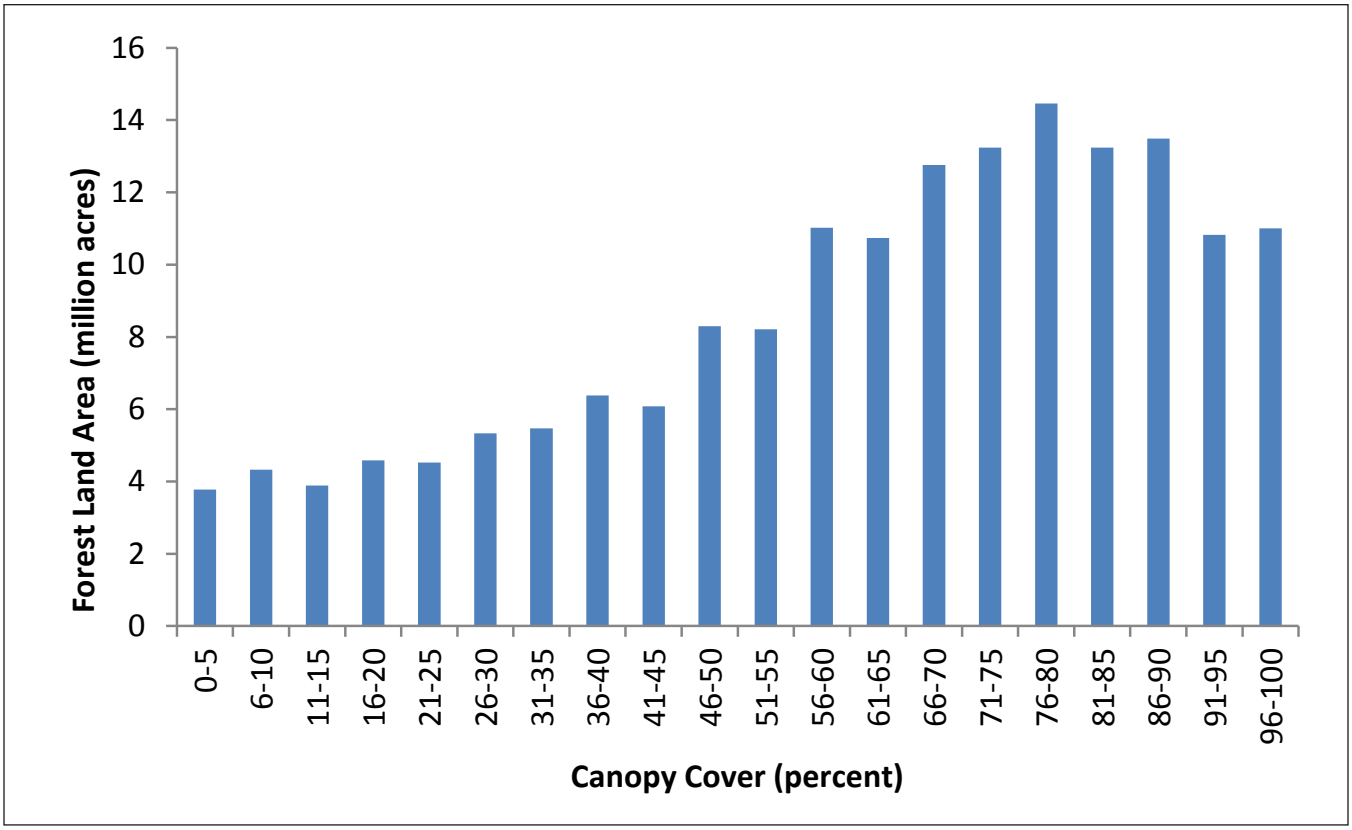

Figure 1.—Canopy cover distribution on FIA forested conditions, 2004-2008, Midwest and Northeast.

RESULTS

Figure 1 portrays the distribution of predicted canopy cover across the region. Because all FIA forested conditions were assigned labels, total area was essentially equivalent across all three classification systems (Fig. 2). Canopy cover of 0 to 10 percent was estimated for 4.7 percent of all forest land, most of which was defined as nonstocked. Hardwood and softwood types were most abundant for FIA, least abundant for NLCD, and intermediate for NatureServe. NatureServe hardwood types were evenly distributed between forest and woodland, but softwood types were more abundant in NatureServe woodland than forest. Mixed types were substantially more abundant for NLCD, intermediate for NatureServe (equally distributed between forest and woodland), and least abundant for FIA. Woody wetlands were defined only for NLCD; total area of NLCD woody wetlands exceeded NLCD softwoods (Fig. 2). No statistical validations were performed for this study.

DISCUSSION AND CONCLUSION

The method presented here provides an operational approach to predicting per condition tree canopy cover from FIA tree data. The resulting classifications were used to assign FIA conditions to NatureServe forest and woodland habitat domains and NLCD forest land cover classes, for which population estimates were produced. Although FIA's forest land definition requires a minimum of 10 percent canopy cover, a small area of FIA forest land was characterized by canopy cover below this threshold. Such conditions likely occur shortly after full canopy removal (e.g., harvest, wildfire), but before regenerating seedlings

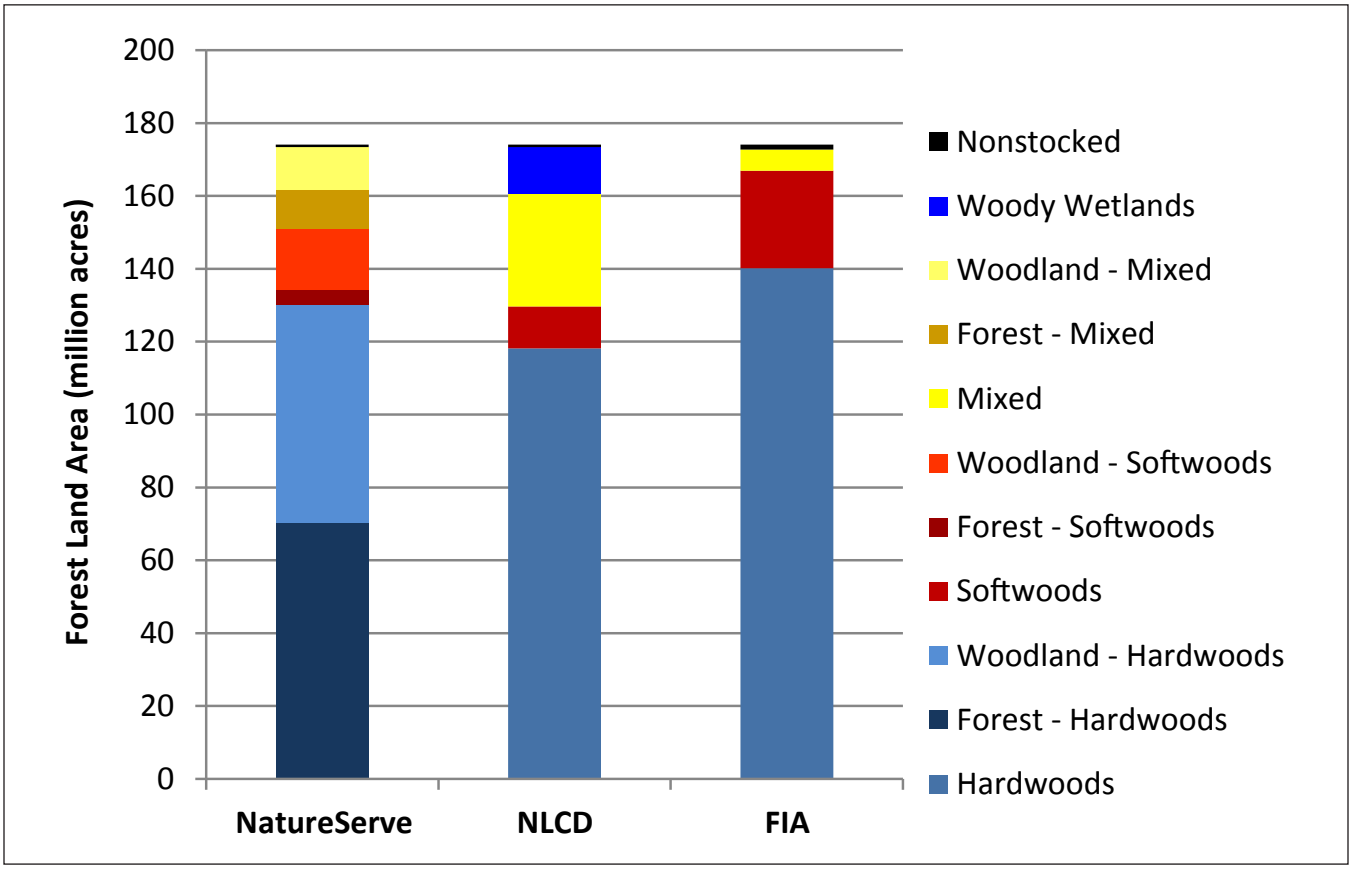

Figure 2.—Forest land area estimates for NatureServe forest and woodland habitat types, NLCD forest and woody wetland land cover types, and FIA aggregations of forest-type groups, 2004-2008, Midwest and Northeast.

have established significant canopy. Tree canopy cover predictions allowed FIA data to be used with wildlife species-habitat matrices and ancillary habitat datasets that are based on canopy cover thresholds. Choice of habitat classification systems can affect resulting estimates of habitat abundance. Resulting assignments of FIA data to NatureServe habitats were used to estimate habitat abundance.

ACKNOWLEDGMENTS

The authors thank NatureServe for producing a terrestrial vertebrate species-habitat matrix for forest-associated species. The authors also thank Don Faber-Langendoen, Randall Morin, and James Westfall for reviewing this manuscript.

LITERATURE CITED

Bechtold, W.A. 2003. **Crown-diameter prediction models for 87 species of stand-grown trees in the Eastern United States.** Southern Journal of Applied Forestry. 27(4): 269-278.

Bragg, D.C. 2001. **A local basal area adjustment for crown width prediction.** Northern Journal of Applied Forestry. 18(1): 22-28.

Faber-Langendoen et al. 2012. **Classification and description of world formation types. Part I (Introduction) and Part II (Description of formation types).** Hierarchy Revisions Working Group, Federal Geographic Data Committee, FGDC Secretariat. U.S. Geological Survey, Reston, VA; and NatureServe, Arlington, VA. Available at http://www.natureserve.org/explorer/classeco.htm.

FGDC. 2008. **National Vegetation Classification Standard.** Vegetation Subcommittee, Federal Geographic Data Committee, FGDC Secretariat. Reston, VA: U.S. Geological Survey. 55 p.

Fry, J.A.; Xian, G.; Jin, S.; Dewitz, J.A.; Homer, C.G.; Yang, L.; Barnes, C.A.; Herold, N.D.; Wickham, J.D. 2011. **Completion of the 2006 National Land Cover Database for the conterminous United States.** Photogrammetric Engineering & Remote Sensing. 77(9): 858-864.

NatureServe. 2011. **Lists of vertebrate species in the contiguous U.S.** Microsoft Access database. Available at http://www.natureserve.org.

Toney, C.; Shaw, J.D.; Nelson, M.D. 2009. **A stem-map model for predicting tree canopy cover of Forest Inventory and Analysis plots.** 2008 Forest Inventory and Analysis Symposium, 2008 October 21-23; Park City, UT. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: CD-ROM. 1-19.

Woudenberg, S.W.; Conkling, B.L.; O'Connell, B.M.; LaPoint, E.B.; Turner, J.A.; Waddell, K.L. 2010. **The Forest Inventory and Analysis Database: database description and users manual version 4.0 for Phase 2.** Gen. Tech. Rep. RMRS-GTR-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 336 p.