Bisht, A., K.L. Fracica, A.M. Gutierrez, J.R. Hinson, A.A. Hopkins, J.M. Josimovich, M.N. Matthews, A.L. Myers, J.E. Myers, R.A. Ratsch, A.J. Rudolph, A.J. Silowsky, C.E. Smith, K. Tolliver, A.M. Yaney-Keller, and J.M. Marshall. 2017. Survey of Haskamp Woods, Allen County, Indiana, and floristic comparison with neighboring forest properties. Phytoneuron 2017-69: 1–13. Published 27 September 2017. ISSN 2153 733X

SURVEY OF HASKAMP WOODS, ALLEN COUNTY, INDIANA, AND FLORISTIC COMPARISON WITH NEIGHBORING FOREST PROPERTIES

ABHIJEET BISHT, KASEY L. FRACICA, ARELI M. GUTIERREZ, JESSICA R. HINSON, ALYSA A. HOPKINS, JILLIAN M. JOSIMOVICH, MONICA N. MATTHEWS, ANDREA L. MYERS, JOHN E. MYERS, RIKKI A. RATSCH, AARON J. RUDOLPH, ALEXANDER J. SILOWSKY, CECELIA E. SMITH, KELCY TOLLIVER, ADAM M. YANEY-KELLER, and **JORDAN M. MARSHALL**

Department of Biology
Indiana University-Purdue University Fort Wayne
Fort Wayne, Indiana 46805
marshalj@ipfw.edu

ABSTRACT

The vascular plant community was surveyed at Haskamp Woods, Allen County, Indiana, which we compared to six neighboring forests. We encountered 54 unique species across the understory, midstory, and overstory strata. Species richness and diversity at Haskamp Woods were greatest in the understory. Coefficient of conservatism at Haskamp Woods was only greater than one of the neighboring forests, while floristic quality index was the median value. Additionally, using nonmetric multi-dimensional scaling to visualize dissimilarity between the seven forests, Haskamp Woods was more dissimilar to the two properties with the longest protection history and the two privately owned properties. Overstory and midstory at Haskamp Woods were dominated by *Acer saccharum*. The overstory composition was relatively similar to five of the neighboring forests, with the sixth differing because it is an uncommon forest type in the region. Overall, Haskamp Woods had similarities and differences in species composition compared to the six neighboring forests. Variability in protection and disturbance histories, as well as edaphic conditions, result in variable forest communities.

In the Midwest United States, agriculture, including cultivated crops, pastureland, or other open-field agricultural practices, dominates the land cover types (Fry et al. 2011). Across the entire region, agriculture accounts for 60% of land use types. However, focusing on the southern half of the Midwest, cultivated and pastoral agriculture accounts for 80-90% of land use, with fragmentation of forests further driven by urban and suburban development (Radeloff et al. 2005). The majority of forests in the region are relatively small woodlots, most of which are privately owned (Fuelling 2014).

Forest fragments serve as important, suitable habitat for a wide range of organisms due to the often-unsuitable nature of surrounding matrix (Bouma et al. 2013). Influence by the surrounding matrix is variable depending on fragment isolation, quality of the matrix, and other underlying factors (Davies et al. 2000; Vandermeer & Carvajal 2001). This surrounding matrix is important as seed sources for plant community development through colonization and extinction processes (Fröborg & Eriksson 1997). Additionally, interactions between soil types and disturbance histories can lead to the development of uncommon forest types, which may differ from surrounding forests (Adkins et al. 2016).

Haskamp Woods is a 31.8 ha property that was privately owned until 2002, when it was purchased by the New Haven Parks and Recreation Department (pers. comm., A. Gurney). Over two-thirds of the property is currently cultivated row crop agriculture with 10.1 ha forested (pers. observ.). The forest canopy was patchy with large gaps visible in aerial images from 1938 and 1964, with canopy closure happing at some point after 1972 (IHAPI 2017a-c). Haskamp Woods is surrounded by privately owned land, which is a mixture of agriculture, forests, and suburban development. Close proximity to agriculture and suburban development is typical for forest fragments within Indiana and the surrounding region (e.g. Brothers & Spingarn 1992; Fuelling 2014; Arvola et al. 2014; Adkins et al. 2016).

Understanding the baseline community composition and structure is important for development of sound management strategies. The objectives of this study were to conduct an ecological plant survey of understory, midstory, and overstory species in Haskamp Woods, Allen County, Indiana, and compare the plant community with neighboring forest properties. Results from this study regarding plant community composition, environmental variables, and forest structure will assist New Haven Parks and Recreation in making management decisions about Haskamp Woods.

MATERIALS AND METHODS

Study Design

Five transects were established at Haskamp perpendicular to the eastern edge of the property, with five plot centers along each transect 30 m apart (Figure 1). The eastern most plots were 33 m from the eastern edge of the property. At each plot center, two 1 m^2 understory quadrats were located

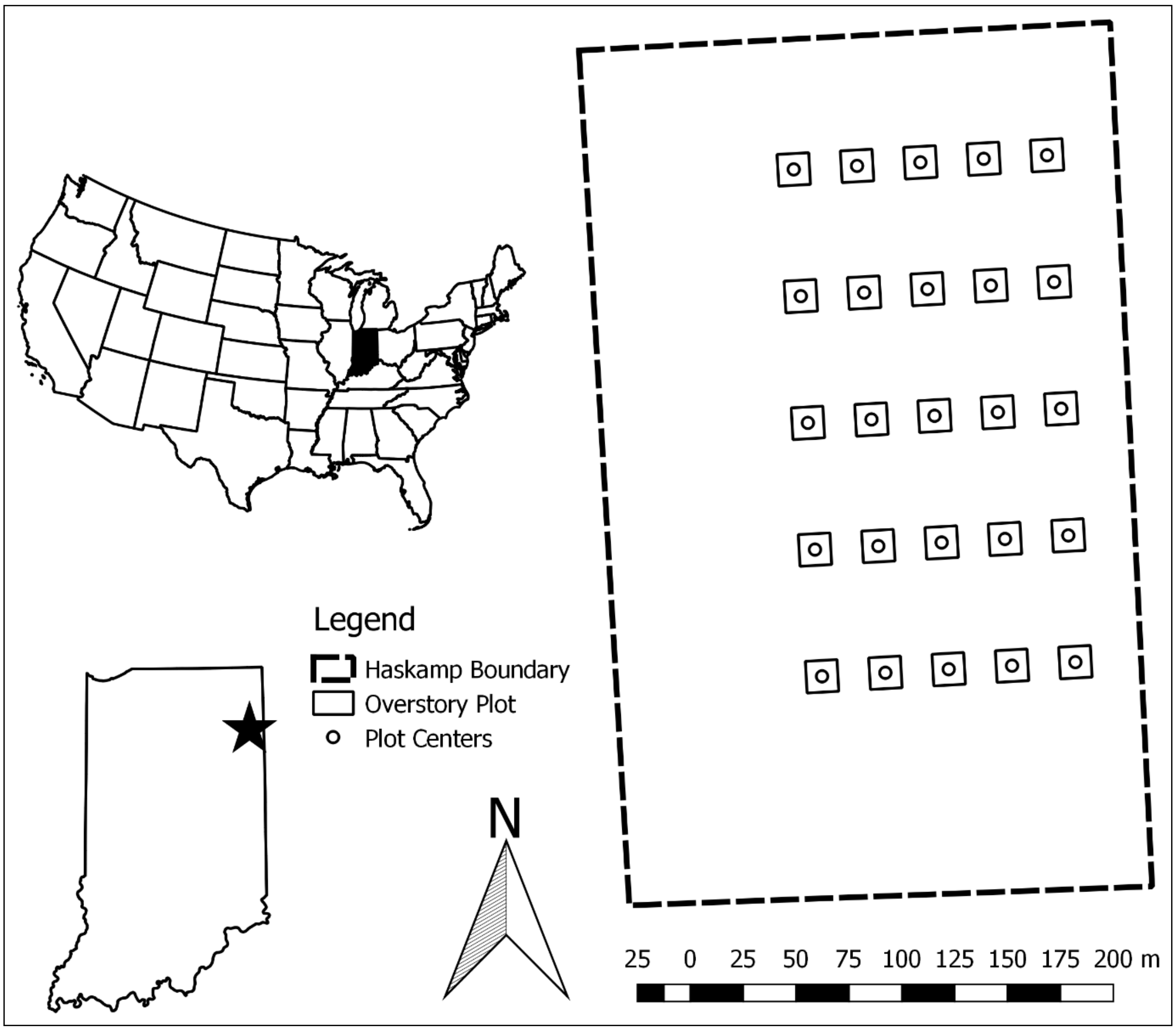

Figure 1. Study design in the forested portion of Haskamp Woods (location marked with star), Indiana, USA.

randomly within a 5 x 5 m area. A 10 x 10 m midstory plot and a 15 x 15 m overstory plot were established at each plot center. Mapping and spatial analyses were conducted in QGIS (version 2.18.3). Field data collection occurred 17-30 September 2016.

Plant Surveys

Within each 1 m^2 understory quadrat, all plants ≤ 2 m tall were counted and identified to species. Understory data was pooled at each plot center. Voucher specimens of understory plants were deposited in the Indiana University-Purdue University herbarium. Within each 100 m^2 midstory plot, all plants > 2 tall and ≤ 8 cm in diameter at breast height (dbh, 1.3 m above the soil surface) were counted and identified to species. Within each 225 m^2 overstory plot, all plants > 8 cm in dbh were counted, identified to species, and dbh was recorded. The largest diameter overstory individual in each plot was selected and two cores were collected at breast height, perpendicular to each other, with a 4.3 mm diameter increment borer (Haglöf Sweden AB, Långsele, Sweden). Cores were air dried, mounted on wood rails for support, progressively sanded with 220 to 500 grit sandpaper, and rings were counted.

Environmental Data

We measured percent volumetric soil moisture content, percent canopy cover, soil pH, litter depth, soil compaction, and percent available light at the corner of each 5 x 5 m, 10 x 10 m, and 15 x 15 m plot. Percent volumetric soil moisture content (VMC) was measured with a 12 cm long probe attached to a FieldScout TDR moisture meter (Spectrum Technologies Inc., Aurora, IL, USA). Percent canopy cover was measured with a concave spherical densiometer (Forestry Suppliers, Jackson, MS, USA). Soil pH was measured with a Fieldscout SoilStik meter (Spectrum Technologies Inc., Aurora, IL, USA). Litter depth was measured with a meter stick to the nearest 0.1 cm. Soil compaction was measured with a Lang penetrometer (Forestry Suppliers, Jackson, MS, USA) as insertion force (kgf). Percent available light was calculated from a six-sensor bar at each plot corner and an unattended single sensor (Spectrum Technologies Inc., Aurora, IL, USA) set outside of the forest in full sun. Light data was collected as $\mu mol/m^2/sec$ of photons and converted to percent available light. Soil types and drainage information were defined by the USDA NRCS Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/) as the dominant values at the site.

Data Analysis

Species richness (S = number of species), Shannon's diversity index ($H' = -\Sigma p_i \ln p_i$, where p_i is the proportion of *i*th species in plot), and Pielou's evenness index ($J' = H'/\ln S$) were calculated for understory, midstory, and overstory plants at each plot. Floristic Quality Index (FQI) was calculated for the property for understory species (FQI = C_{mean} x square root of the number of species, where C_{mean} is the mean coefficient of conservatism value for the entire property). Coefficient of conservatism values were attained from Rothrock (2004). Sørensen similarity index was calculated between midstory and overstory species (2 * number of shared species / sum of mistory and overstory richness). Overstory species relative importance values (RIV) were calculated as sum of relative frequency, relative dominance, and relative density. Relative frequency was calculated as frequency of $species_i$ / sum of all frequencies, where frequency of $species_i$ is the number of plots $species_i$ occurred / number of plots surveyed. Relative dominance was calculated as basal area of $species_i$ / sum of all basal areas, where basal area was the cross-sectional area of each species per ha calculated from dbh data. Relative density was calculated as density of $species_i$ / sum of all densities. We used RIV to determine the forest type of Haskamp Woods.

Haskamp Woods understory, midstory, and overstory compositions were compared to those of six neighboring forests in Allen County, Indiana (Figure 2). Detailed property descriptions can be found in their respective citations but are presented here briefly. **Fogwell Forest Nature Preserve** is a 12.3 ha state designated nature preserve owned and managed by ACRES Land Trust, which has

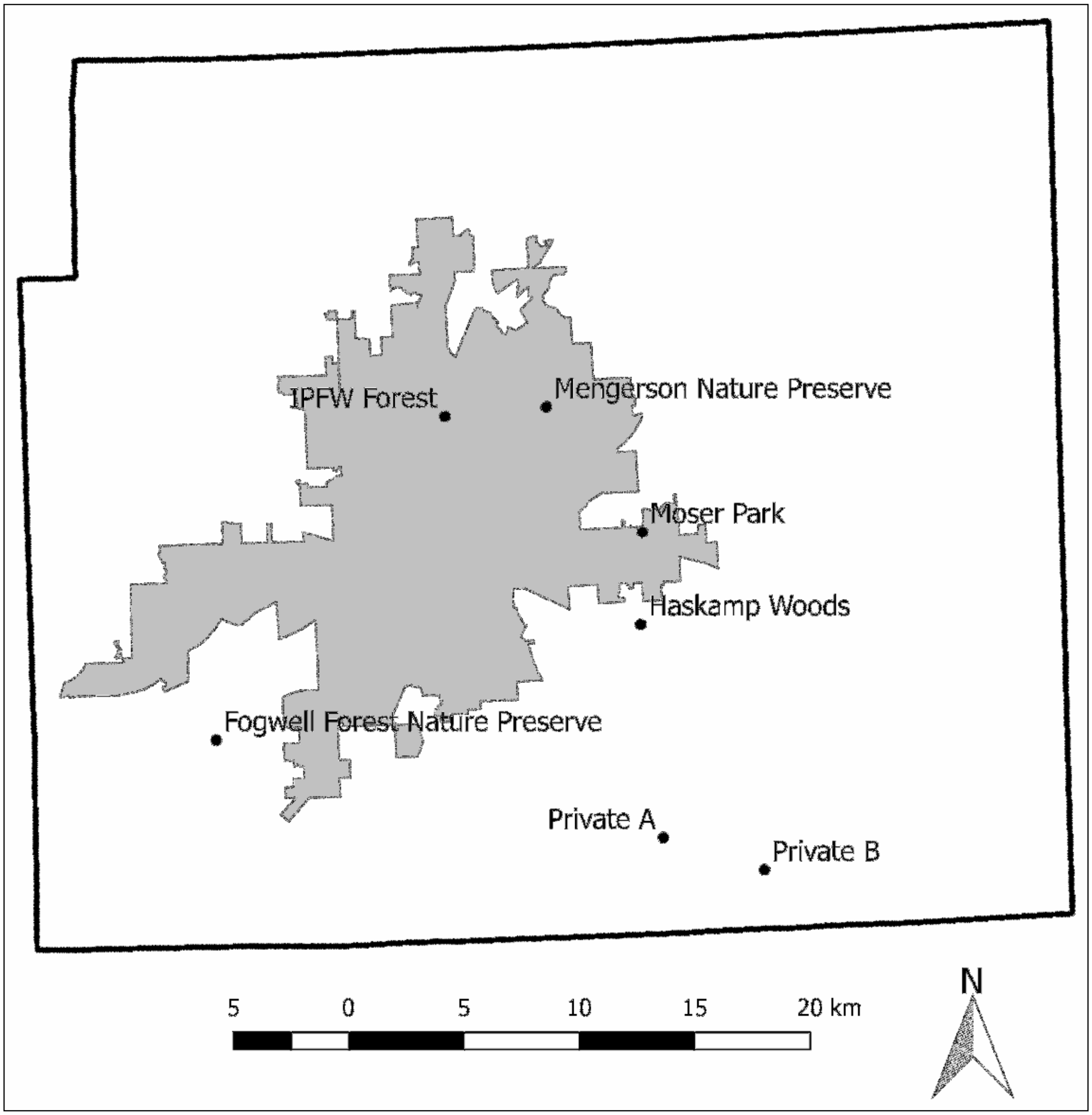

Figure 2. Geographic relationship between Haskamp Woods and six neighboring forests in Allen County, Indiana. Grey polygon represents City of Fort Wayne boundary.

been protected since the 1930s (Arvola et al. 2014). **Indiana University-Purdue University Fort Wayne (IPFW) forest** is a 13.8 ha forest adjacent to the university, which has been owned by IPFW since 2004 and does not have a formal protection status (Arvola et al. 2014). **Mengerson Nature Preserve** is a 14.4 ha state designated nature preserve owned and managed by ACRES Land Trust, which has been protected since 1973 (Arvola et al. 2016). **Moser Park** is a 5.6 ha forest managed by New Haven Parks and Recreation since 1962, which had previously been used for railroad storage and landings (Adkins et al. 2016). The two privately owned properties (**Private A** and **Private B**) were 10.4 ha and 6.7 ha, respectively (Fuelling 2014).

Plot means for each environmental data were calculated. Pearson correlation was used to identify relationships between environmental variables. We used non-metric multidimensional scaling (NMDS) ordination to visualize relationships between understory communities in Haskamp and six neighboring forests, and environmental data (percent canopy cover and overstory richness), displayed as joint vectors. Understory species presence/absence values were used for the six properties from Adkins et al. (2016), Arvola et al. (2014), and Fuelling (2014). For NMDS, alternative Gower distances were calculated between communities. The alternative Gower distance excludes double-zeros between communities (Anderson et al. 2006). We used simple linear regression to relate understory and midstory species richness and diversity to the environmental variable mean values. Data analysis was conducted using base and Vegan packages in R (version 3.4.0, R Core Team 2017).

RESULTS

Three plots on the southern transect were omitted from the survey due to accessibility issues related to flooding. However, we were able to complete plant surveys at 22 plot center locations. We encountered 44 species in the understory, 18 in the midstory, and 20 in the overstory at Haskamp Woods (Appendix).

Mean percent canopy cover was high and relatively consistent throughout Haskamp (95.1% [SD = 3.5]), which resulted in low mean percent available light (7.2% [SD = 8.4]). Canopy cover and available light were negatively correlated (r = -0.59, P = 0.004). Mean percent volumetric soil moisture (18.5% [SD = 6.3]), pH (6.4 [SD = 0.3]), litter depth (2.9 cm [SD = 0.8]), and soil compaction (5.1 kgf [SD = 0.7]) were relatively more variable than canopy cover. Compaction and pH were positively correlated (r = 0.51, P = 0.038). Similarly, compaction and available light were positively correlated (r = 0.48, P = 0.023).

Understory richness was greater than the other two strata (Table 1). The most common understory plants were *Geum canadense* (Rosaceae) and *Fraxinus pennsylvanica* (Oleaceae), occurring in 20 and 16 of the plots, respectively. Additionally, these two species accounted for 51.6% of all individuals encountered in the understory. Fourteen species occurred only in one plot each. Additionally, six more species occurred in only two plots each. While mean coefficient of conservatism for Haskamp Woods was on the low end of the range of values at neighboring properties, FQI was the median for the values pooled (Table 2).

Distance between points in the NMDS plot represents dissimilarity in community compositions (i.e. points farther apart from each other are more dissimilar). It is important to note that in the NMDS plot, distance is in species-space and not in geographic space. Haskamp Woods was less dissimilar to IPFW Forest and Moser Park compared to the other properties. Direction of the joint vectors plotted over the NMDS ordination indicates the direction of influence on the understory communities (Figure 3). Similar to distance, direction in the NMDS plot is not related to geographic-space but is associated with the regression analysis between the plant community and the vector variable. The understory plant species presence and absence in Haskamp Woods was negatively influenced by percent canopy cover, although overstory species richness had minimal influence on the understory (Figure 3). Moser Park, which had a lower mean coefficient of conservatism and FQI compared to Haskamp Woods, was also influenced negatively by percent canopy cover (Figure 3).

Richness and diversity were lowest in the midstory (Table 1), which was skewed towards *Acer saccharum* (Sapindaceae) occurring in all plots and accounting for 65.8% of midstory individuals. The second most common midstory species, *Ostrya virginiana* (Betulaceae), accounted for only 10.5% of individuals. Seven midstory species occurred in only one plot and two additional species occurred in only two plots. Midstory diversity was positively related to percent light available (r = 0.60, P = 0.003) but was not related to soil moisture or compaction. Haskamp Woods shared relatively few species with the six neighboring forests (Table 3). The other forests had fewer total species compared to Haskamp Woods (range = 5-12, mean = 8.2, SD = 3.1).

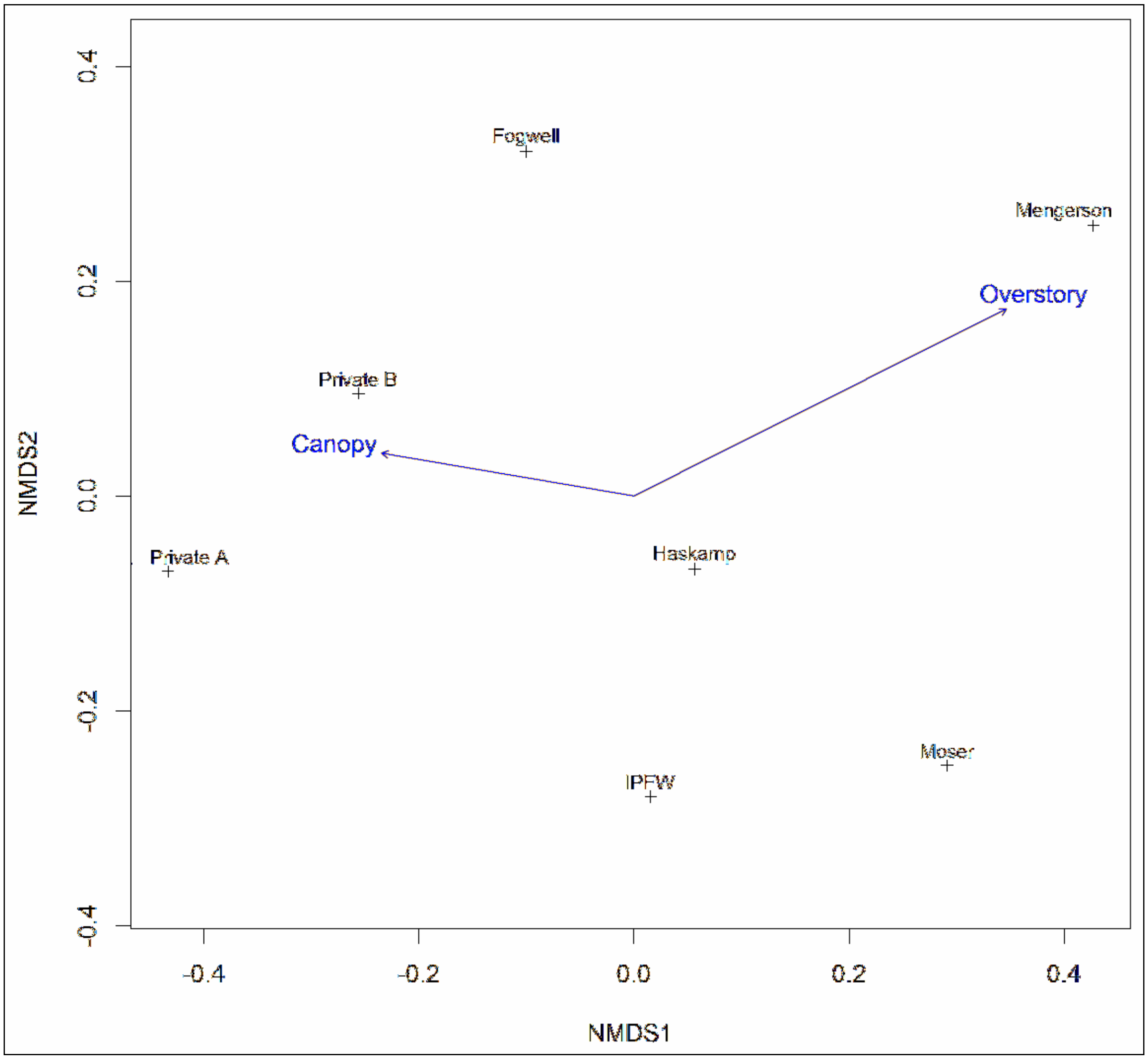

Figure 3. Nonmetric multi-dimensional scaling (NMDS) ordination of understory species presence and absence in Haskamp Woods and six neighboring forests. Joint vectors represent mean percent canopy cover (Canopy) and overstory species richness (Overstory) in each forest.

In the overstory, *Acer saccharum* was also the most common species accounting for 34.8% of individuals. Additionally, similar to the midstory, *Ostrya virginiana* was the second most common accounting for 21.8% of individuals. Because of the high frequency, dominance, and density, *A. saccharum* was the highest ranked species in relative importance value in the overstory, which aligned with a Sugar Maple forest type (Table 4). Seven overstory species occurred only in one plot and two species occurred in only two plots. Overstory and midstory strata were relatively similar (Sørensen similarity index = 0.74). Haskamp Woods overstory composition was more similar to the six neighboring forests than the midstory (Table 3). Additionally, there was a relatively similar number of species in those six forests compared to Haskamp Woods (range = 14-25, mean = 17.8, SD = 4.2). Overstory at 4 of the neighboring forests (Fogwell, IPFW, Mengerson, Private B) was also dominated by *A. saccharum*. While the other private property aligned more with a Beech-Maple forest type, it was still relatively similar to Haskamp Woods (Table 3). Moser was the least similar because of the different forest type, which was dominated by *Celtis occidentalis*, *Ulmus americana*, and *Fraxinus pennsylvanica* (Table 3). The median age of the largest diameter overstory individual in each plot was 43.5 years, with a range of 25 to 125 years.

Table 1. Mean richness, Shannon's diversity index, and Pielou's evenness index (standard error) for understory, midstory, and overstory plant community strata in Haskamp Woods calculated from plot level values.

Stratum	Richness	Diversity	Evenness
Understory	8.41 (0.59)	1.37 (0.10)	0.66 (0.05)
Midstory	3.95 (0.62)	0.77 (0.14)	0.65 (0.05)
Overstory	4.41 (0.31)	1.14 (0.09)	0.79 (0.03)

Table 2. Understory mean coefficient of conservatism (C_{mean}), floristic quality index (FQI), dominant soil type, and drainage description for Haskamp Woods and six neighboring properties in Allen County, Indiana. Values for Fogwell Forest Nature Preserve, IPFW Forest, and Mengerson Nature Preserve from Arvola et al. (2014). Values from Moser Park from Adkins et al. (2016). Private property values from Fuelling (2014).

Property	C_{mean}	FQI	Soil Type	Drainage
Fogwell Forest Nature Preserve	4.1	23.4	Blount Silt Loam	Somewhat Poor
Haskamp Woods	3.1	20.2	Glynwood Silt Loam	Moderately Well
IPFW Forest	3.4	18.6	Glynwood Silt Loam	Moderately Well
Mengerson Nature Preserve	3.6	18.9	Blount Silt Loam	Somewhat Poor
Moser Park	2.7	15.9	Eel Silt Loam	Moderately Well
Private Property A	4.4	26.3	Pewamo Silt Loam	Very Poor
Private Property B	4.2	25.3	Pewamo Silt Loam	Very Poor

Table 3. Sørensen similarity index values for midstory and overstory species between Haskamp and six neighboring forest properties in Allen County, IN, with forest types. Values for Fogwell Forest Nature Preserve, IPFW Forest, and Mengerson Nature Preserve from Arvola et al. (2014). Values from Moser Park from Adkins et al. (2016). Private property values from Fuelling (2014).

	Fogwell	IPFW	Mengerson	Moser	Private A	Private B
Midstory	0.33	0.54	0.47	0.33	0.33	0.26
Overstory	0.65	0.52	0.57	0.33	0.53	0.59

DISCUSSION

Haskamp Woods is a 10.1 ha forested property owned and managed by New Haven Parks and Recreation that is centrally located in Allen County, Indiana. Like many small forests in the region, it is surrounded by cultivated row-crop agriculture and suburban development. The dominant soil type at Haskamp Woods is derived from glacial moraines, which is common for the region, and the subsequent forest type that has developed at this site is an *A. saccharum* dominated forest type, common in the region (Gray 2000; Homoya et al. 1985). While the forest type may be common, the importance of Haskamp Woods is in the limited forest cover in the region.

Over the last four decades, canopy closure has occurred from large patchy gaps in 1972 to 95% canopy cover in 2016 (IHAPI 2017c). In the historic aerial photos from 1938-1972, these gaps remained visible and likely are the result of selective harvesting by previous land owners (IHAPI 2017a-c). The median age of 43.5 years calculated for the forest aligned with potential canopy closure beginning in the early to mid-1970s. New Haven Parks and Recreation has owned the property since only 2002, so the owner prior to this most recent sale removed few trees allowing the canopy to close. As would be expected — as canopy cover increased light availability decreased. The positive relationship between compaction and available light is likely due to old two-track and single-track paths in Haskamp Woods, some of which were apparent.

The two most common understory species (*Geum canadense* and *Fraxinus pennsylvanica*) both had a coefficient of conservatism value of 1 (Rothrock 2004). Coefficient of conservatism values 0 to 3 are assigned to species that are highly tolerant of disturbance and provide little to no indication of undisturbed habitat (Rothrock 2004). Only one species in the community, *Circaea alpina*, fit the coefficient of conservatism value range of 9 to 10 (indicating species restricted to remnant habitat with very little post-settlement disturbance; Rothrock 2004), in three plots in the southwest corner. Even though Haskamp Woods has reached closed canopy status, the understory is dominated by species that tolerate disturbance. This dominance of the understory by disturbance tolerant species is why Haskamp Woods was the least dissimilar from IPFW and Moser in the NMDS ordination. Moser also had high frequency of low coefficient of conservatism value species due to intense disturbance history (Adkins et al. 2016). Additionally, IPFW was also dominated by low coefficient of conservatism value species and has a relatively recent protection history (Arvola et al. 2014).

Domination of the midstory stratum by *Acer saccharum* is not unusual for the site or the region. Considering the overstory domination by this species and time since major disturbances, Haskamp Woods likely is progressing through the understory reinitiation stage of stand development (Oliver and Larson 1996). The relatively few *A. saccharum* individuals in the understory (10% of understory individuals) and relatively large number of *A. saccharum* in the midstory (>65% of midstory individuals) suggest that many of the early individuals to establish during the reinitiation stage have progressed into subsequently larger size classes (i.e. grown from understory to midstory). Progression from understory reinitiation to later stages of stand development is variable and difficult to predict (Oliver & Larson 1996). Shade-tolerant species like *A. saccharum* have the ability to "wait for release" and respond to gap formation following long-term suppression (Canham 1985). Since Haskamp Wood canopy has closed (95% canopy cover), *A. saccharum* will continue to dominate the midstory as the stand ages. This will likely lead to continued dominance of *A. saccharum* in the overstory as gaps form and those midstory individuals are released into the canopy.

Based on the high RIV ranking of *Acer saccharum* in the overstory, Haskamp Woods fits the Sugar Maple forest type (Eyre 1980). While Black Cherry-Maple is a defined forest type and *Prunus serotina* was third ranked in RIV, Haskamp Woods did not align with this type; second ranking of *Ostrya virginiana* and lower relative dominance of *P. serotina* align better with the Sugar Maple type. This forest type, along with other types co-dominated by *A. saccharum*, are common throughout this region (Gray 2000; Homoya et al. 1985). The similarity in overstory species composition between Haskamp Woods and five of the neighboring forests is expected due to the prevalence of *A. saccharum* forest types in the region.

Evidence of past disturbance is still present in Haskamp Woods (i.e. relatively low C_{mean}, visible remnants of two-track paths). However, the forest has progressed through developmental stages (i.e. canopy closure since 1970s, well established midstory tree community). There are clear similarities and differences in species composition when comparing Haskamp Woods to neighboring forests. If Haskamp Woods is allowed to progress naturally through succession, it will likely continue to be dominated by *A. saccharum*. Active management by New Haven Parks and Recreation could increase the speed that certain species are lost from the overstory stratum and are replaced by midstory *A. saccharum*. This would add to the unique disturbance history experienced by Haskamp Woods.

Table 4. Frequency (number of plots), basal area (m^2/ha), density (individuals/ha), and rank order of relative importance values (RIV) for overstory species encountered in Haskamp Woods.

Species	Frequency	Dominance	Density	RIV Rank
Acer rubrum	3	0.82	22.22	8
Acer saccharum	20	5.00	238.38	1
Aesculus glabra	1	0.01	2.02	20
Carya cordiformis	1	0.04	2.02	16
Carya ovata	1	0.65	2.02	13
Carya tomentosa	2	0.18	12.12	12
Celtis occidentalis	4	0.46	16.16	9
Fagus grandifolia	5	1.20	12.12	7
Fraxinus pennsylvanica	1	0.03	2.02	18
Gleditsia triacanthos	1	0.01	2.02	19
Juglans nigra	2	0.17	4.04	14
Ostrya virginiana	16	1.66	149.49	2
Populus grandidentata	2	0.74	10.10	10
Prunus serotina	11	2.05	123.23	3
Quercus alba	3	2.91	6.06	6
Quercus rubra	7	2.09	40.40	4
Quercus velutina	1	0.03	2.02	17
Ulmus americana	11	0.92	28.28	5
Ulmus rubra	4	0.16	8.08	11
Ulmus thomasii	1	0.05	2.02	15

ACKNOWLEDGEMENTS

The authors would like to thank New Haven Parks and Recreation, especially Anna Gurney, for their permission and assistance in this study. This research was conducted as part of a field botany course at Indiana University-Purdue University Fort Wayne, with enrolled students participating equally as authors. Authors are listed alphabetically with the course instructor listed last, as the author of correspondence.

LITERATURE CITED

Adkins, K.D., J.A. Chang, L.A. Danels, L.M. DeBruhl, M.M. Ellison, J.L. Hammond, D.C. Klepper, T.M. Lehman, S.D. Rupert, M. Shustova, R.R. Smith, D.L. Thomas, J.A. Thompson, L.W. Vorndran, and J.M. Marshall. 2016. An analysis of a hackberry-American elm-green ash forest type at Moser Park, Allen County, Indiana. Rhodora 118: 189–205.

Arvola, K.D., P.F. Booth, C.C. Ellinwood, A.J. Fry, J.L. Furge, K.A. Haehnle, L.E. Hall, M.A. Jablonski, D.K. Jones, J.T. Martin, K.M. McLane, K.C. Mensch, V.A. Mumaw, R.N. Quirindongo, M.J. Ravesi, J.J. Rinard, P.R. Selig, A.N. Turley, M.T. Voors, A.R. Warrix, T.C. Wood, and J.M. Marshall. 2014. Comparative analysis of urban and rural forest fragment structure and diversity in northeastern Indiana. Mich. Bot. 53: 39–59.

Anderson, M.J., K.E. Ellingsen, and B.H. McArdle. 2006. Multivariate dispersion as a measure of beta diversity. Ecol. Lett. 9: 683–693.

Bouma, C., E. Huizenga, and D. Warners. 2013. Assessing a reconciliation ecology approach to suburban landscaping: Biodiversity on a college campus. Mich. Bot. 52: 93–104.

Brothers, T.S., and A. Spingarn. 1992. Forest fragmentation and alien plant invasion of Central Indiana old-growth forests. Conserv. Biol. 6: 91–100.

Canham, C.D. 1985. Suppression and release during canopy recruitment in *Acer saccharum*. Bull. Torrey Bot. Club 112: 134–145.

Davies, K.F., C.R. Margules, and J.F. Lawrence. 2000. Which traits of species predict population declines in experimental forest fragments? Ecology 81: 1450–1461.

Eyre, F.H. 1980. Forest Cover Types of the United States and Canada. Society of American Foresters, Washington, D.C.

Fröborg, H., and O. Eriksson. 1997. Local colonization and extinction of field layer plants in a deciduous forest and their dependence upon life history features. J. Veg. Sci. 8: 395–400.

Fry, J.A., G. Xian, S. Jin, J.A. Dewitz, C.G. Homer, L. Yang, C.A. Barnes, N.D. Herold, and J.D. Wickham. 2011. Completion of the 2006 National Land Cover Database for the conterminous United States. Photogramm. Eng. Remote Sens. 77: 858–864.

Fuelling, R.R. 2014. Diversity and Distribution of Plant Communities Related to Forest Fragment Size, Shape, Age, and Structure. MS thesis. Purdue University Fort Wayne, Fort Wayne, Indiana.

Gray, H.H. 2000. Physiographic Divisions of Indiana. Special Report 61. Indiana University, Indiana Geological Survey, Bloomington.

Homoya, M.A., D.B. Abrell, J.R. Aldrich, and T.W. Post. 1985. The natural regions of Indiana. Proc. Ind. Acad. Sci. 94: 245–268.

IHAPI. 2017a. Indiana Historic Aerial Photo Index. Image BEU-4-34, 28 September 1938. Indiana Geological Survey, Bloomington.

IHAPI. 2017b. Indiana Historic Aerial Photo Index. Image BEU-2EE-131, 5 July 1964. Indiana Geological Survey, Bloomington.

IHAPI. 2017c. Indiana Historic Aerial Photo Index. Image 18003-272-116, 1972. Indiana Geological Survey, Bloomington.

ITIS. 2017. Integrated Taxonomic Information System. <http://www.itis.gov/>

Oliver, C.D. and B.C. Larson. 1996. Forest Stand Dynamics. John Wiley & Sons, Inc. New York.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>

Radeloff, V.C., R.B. Hammer, and S.I. Stewart. 2005. Rural and surburban sprawl in the U.S. Midwest from 1940 to 2000 and its relation to forest fragmentation. Conserv. Biol. 19: 793–805.

Rothrock, P.E. 2004. Floristic Quality Assessment in Indiana: The Concept, Use, and Development of the Coefficient of Conservatism. Final Report for ARN A305-4-53, EPA Wetland Program Development Grant CD97558601. <http://www.lrl.usace.army.mil/Portals/64/docs/regulatory/ FloristicAssessment_IND.pdf>

Vandermeer, J., and R. Carvajal. 2001. Metapopulation dynamics and the quality of the matrix. Amer. Nat. 158: 211–220.

Appendix. Annotated list of vascular plants encountered in Haskamp Woods, Allen County, Indiana.

Nomenclature follows ITIS (2017). Taxa are arranged alphabetically by family, genus, and specific epithet. Species followed by an asterisk (*) after authority name are considered non-native based on USDA NRCS (2017). Herbarium collection numbers [in brackets] listed for those understory species with voucher specimens deposited in Indiana University-Purdue University Fort Wayne, Department of Biology herbarium. Relative abundance is listed for each species as Rare (one or two occurrences), Occasional (sporadic occurrence), Frequent (widespread throughout plant community), or Common (dominants in the plant community). Understory were individuals ≤ 2 m tall, midstory were > 2 m tall and ≤ 8 cm in diameter at breast height (dbh, 1.3 m above the soil surface), and overstory were > 8 cm dbh.

Adoxaceae
Viburnum prunifolium L. [*HW15*] - Understory (Occasional)

Anacardiaceae
Toxicodendron radicans (L.) Kuntze - Understory (Occasional)

Aristolochiaceae
Asarum canadense L. [*HW31*] - Understory (Rare)

Asparagaceae
Maianthemum racemosum (L.) Link [*HW19*] - Understory (Occasional)

Asteraceae
Ambrosia trifida L. [*HW05*] - Understory (Rare)
Symphyotrichum sp. [*HW34*] - Understory (Rare)

Betulaceae
Carpinus caroliniana Walter - Midstory (Rare)
Ostrya virginiana (Mill.) K. Koch [*HW12*] - Understory (Frequent), Midstory (Frequent), Overstory (Common)

Brassicaceae
Alliaria petiolata (M. Bieb.) Cavara & Grande* [*HW30*] - Understory (Rare)

Cannabaceae
Celtis occidentalis L. [*HW41*] - Understory (Rare), Midstory (Rare), Overstory (Occasional)

Caprifoliaceae
Lonicera maackii (Rupr.) Herder* [*HW37*] - Understory (Occasional), Midstory (Rare)

Celastraceae
Euonymus americanus L. [*HW40*] - Understory (Rare)

Cyperaceae
Carex sp. L. - Understory (Rare)

Fabaceae
Gleditsia triacanthos L. - Overstory (Rare)

Fagaceae
Fagus grandifolia Ehrh. [*HW28*] - Understory (Rare), Midstory (Occasional), Overstory (Occasional)
Quercus alba L. [*HW11*] - Understory (Rare), Overstory (Occasional)
Quercus rubra L. [*HW26*] - Understory (Occasional), Midstory (Rare), Overstory (Occasional)
Quercus velutina Lam. - Overstory (Rare)

Grossulariaceae
Ribes cynosbati L. [*HW38*] - Understory (Rare)

Juglandaceae
Carya cordiformis (Wangenh.) K. Koch [*HW06*] - Understory (Occasional), Midstory (Occasional), Overstory (Rare)
Carya ovata (Mill.) K. Koch [*HW18*] - Understory (Occasional), Midstory (Rare), Overstory (Rare)
Carya tomentosa (Lam. ex Poir.) Nutt. - Midstory (Rare), Overstory (Rare)
Juglans nigra L. - Overstory (Rare)

Menispermaceae
Menispermum canadense L. [*HW35*] - Understory (Rare)

Oleaceae
Fraxinus americana L. [*HW21*] - Understory (Rare), Midstory (Occasional)
Fraxinus pennsylvanica Marsh. [*HW07*] - Understory (Common), Midstory (Occasional), Overstory (Rare)

Onagraceae
Circaea alpina L. [*HW39*] - Understory (Occasional)

Oxalidaceae
Oxalis stricta L. [*HW33*] - Understory (Rare)

Poaceae
Unidentified species - Understory (Occasional)

Polygonaceae
Persicaria virginiana (L.) Gaertn. [*HW13*] - Understory (Occasional)

Primulaceae
Lysimachia nummularia L. [*HW44*] - Understory (Rare)

Ranunculaceae
Thalictrum thalictroides (L.) Eames & B. Boivin [*HW42*] - Understory (Rare)

Rosaceae
Crataegus mollis Scheele [*HW25*] - Understory (Rare)
Fragaria virginiana Duchesne [*HW29*] - Understory (Rare)

Geum aleppicum Jacq. [*HW24*] - Understory (Occasional)
Geum canadense Jacq. [*HW02*] - Understory (Common)
Geum laciniatum Murray [*HW20*] - Understory (Rare)
Malus coronaria (L.) Mill. - Midstory (Rare)
Prunus serotina Ehrh. [*HW14*] - Understory (Occasional), Midstory (Occasional), Overstory (Frequent)
Rosa multiflora Thunb.* [*HW10*] - Understory (Occasional), Midstory (Rare)
Rubus allegheniensis Porter [*HW17*] - Understory (Occasional)

Rubiaceae
Galium aparine L. [*HW22*] - Understory (Rare)

Salicaceae
Populus grandidentata Michx. - Overstory (Rare)

Sapindaceae
Acer rubrum L. [*HW27*] - Understory (Occasional), Overstory (Occasional)
Acer saccharum Marsh. [*HW03*] - Understory (Frequent), Midstory (Common), Overstory (Common)
Aesculus glabra Willd. - Midstory (Rare), Overstory (Rare)

Smilacaceae
Smilax tamnoides L. [*HW16*] - Understory (Occasional)

Ulmaceae
Ulmus americana L. [*HW08*] - Understory (Occasional), Midstory (Occasional), Overstory (Frequent)
Ulmus rubra Muhl. - Overstory (Occasional)
Ulmus thomasii Sarg. - Overstory (Rare)

Urticaceae
Boehmeria cylindrica (L.) Sw. [*HW32*] - Understory (Rare)

Violaceae
Viola sororia Willd. [*HW09*] - Understory (Occasional)

Vitaceae
Parthenocissus quinquefolia (L.) Planch [*HW04*] - Understory (Occasional)
Vitis riparia Michx. [*HW23*] - Understory (Frequent)