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Indy Wildlife Watch: Impact of Vegetation Structure on Presence of Wildlife in Urban Environments

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Alexi Zaniker

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Abstract. Increasing rates of urbanization create unique opportunities and challenges to wildlife living within urban and suburban areas. In order to minimize impacts of urbanization on resident wildlife, it is necessary to understand the types of habitats used by wildlife and how these habitats vary in vegetation structure. Based on previous research, it was hypothesized that vegetation structure will indicate preferences of medium-to-large urban mammals toward certain habitat types. Over the past two years, the Center for Urban Ecology at Butler University has been sampling urban wildlife at 53 locations representing a variety of habitat types (parks, remnant forests, cemeteries) spanning downtown Indianapolis northward into suburban areas. Motion-sensitive cameras were deployed seasonally at each location and images from October 2017 (a total of 5,531 photos) were used to determine how wildlife species presence/absence and richness vary with vegetation structure. Vegetation was sampled at a subset of 17 camera locations using a nested sampling design to assess canopy cover, density, and variability of each stratum. Vegetation structural parameters were reduced from twenty-five to nine using principal components analysis and by referencing prior literature. K means cluster analysis and Kruskal-Wallis tests with Dunn's post hoc found that visually determined habitat types did not align with the variability in vegetation structure. The most important structural parameters driving between location variability were canopy cover, tree density, total basal area, shrub cover, honeysuckle cover, leaf litter cover, grass cover, woody debris cover, and number of boles (tree trunks). Wildlife species richness varied among locations and clusters.

INTRODUCTION

Urbanization results in increased human population, energy consumption, and changes to the landscape (McDonnel and Pickett, 1990). Increasing urbanization impacts resident wildlife populations due to resulting environmental modifications, habitat fragmentation, and habitat degradation (Villasenor *et al*., 2004). Urban areas are growing faster than natural green-spaces, like parks or conservation areas (McKinney, 2002), which limits the space wildlife can inhabit. In order to accommodate increasing human populations in urban areas greenspace has been replaced with housing complexes. In the past fifty years (1960-2010) the population of the city of Indianapolis has almost doubled, from 476,258 to 820,445 people (U.S. Census Bureau 2018*a*). Now some urban areas are composed of 80% impervious surfaces, like pavement, and only 20% vegetation (McKinney, 2002)

As urbanization increases, it is important for ecologists and city planners to understand its full impact on wildlife biodiversity so land management and conservation can be applied to improve the area of habitats suitable for wildlife (Alvey, 2006; Angold *et al.*, 2005; Kamba, 2006; McKinney, 2008). The existence of wildlife in urban environments has many benefits for both the environment and the people that reside in that environment. The presence of urban wildlife is a biological indicator for the health of the environment (VanDruff *et al.,* 1995). Wildlife also benefits individuals, as many urban residents enjoy seeing wildlife on a daily basis (Dwyer *et al.,* 1992). Impacts of habitat loss and vegetation changes as the result of urbanization are reviewed throughout the paper.

Habitat loss is a huge threat to biodiversity (McKinney, 2002; Kowarik, 2011; Markovchick *et al*., 2008; Villasenor *et al.*, 2004). Habitat loss resulting from urbanization has a critical impact on wildlife because of the permanent alterations to the environment, for example the replacement of green spaces with buildings and pavement. These alterations force wildlife to adapt, relocate, or utilize novel urban habitat types (Markovchick-Nicholls *et al*., 2008). The effects of urbanization can vary for wildlife species. Certain characteristics, like body size, mobility, and habitat preferences influence the survival of that particular species in response to the changing habitat (Andrade-Núñez and Aide, 2010). Additional consequences of altered habitats include higher predation levels, limited resources, and lack of corridors (connectivity between natural patches), which can lead to local extinctions (Andrade-Núñez and Aide, 2010).

Habitat alterations and landscape characteristics have an impact on the presence of certain wildlife species. The difference in species richness can be explained by landscape characteristics in a variety of habitat types, including: vertical structure index, canopy covering, tree species diversity, and percentage of grasses, forests, and plantations on the landscape level (Andrade-Núñez and Aide, 2010). Plant species diversity has not been shown to impact occupancy of larger mammals, but may have an impact on smaller mammals (Rogers *et. al.,* 2008, Andrade-Núñez and Aide, 2010). In previous studies, areas with greater plant species richness contained 15% more small mammal species (specifically mice, voles, and shrews) than areas lacking in plant species diversity (Carey and Wilson, 2001). The motion-triggered cameras cannot adequately detect the presence of smaller mammals, only medium-to-large sized mammals (i.e., squirrels and larger). Therefore, the plant species diversity (number and type of different plant species) will not be assessed in this study.

There are also certain factors that determine which species can live nearby human settled areas. In order for wildlife to live near humans, they must have certain locomotor abilities and behavioral characteristics that promote survival in urban areas (i.e. fear of humans) (Lopuki *et al.*, 2013). It is also important for these urban areas to have certain characteristics necessary for wildlife, including ideal urban climates, presence of vegetation, decreased habitat fragmentation, and little pollution (Lopuki *et al.,* 2013). Certain species have the ability to adapt to urban lifestyles and are positively impacted by human presence through the availability of subsidized food and water sources, while other species are negatively impacted by urbanization due to habitat fragmentation (FitzGibbon *et al.*, 2007). Several species are impacted by factors like distance to water and density of nearby housing developments (Fidino *et al*., 2016). Some species diversity is dependent on high vegetative complexity and plant species richness (McKinney, 2008); these species will be negatively impacted by urbanization and the structural simplification of vegetation. For non-avian vertebrates, the number of wildlife species has been shown to decrease as the level of urbanization increased from low to high on the urban rural gradient (McKinney, 2008).

To minimize the impact of urbanization, understanding the aspects of vegetation structure that are important for mammal occupancy of a particular location is integral to the effective management of public and private land in urban environments (Andrade-Núñez and Aide, 2010). Current conservation strategies include: preserving native ecosystems, minimizing urban growth, and restoring native species in urban environments (Angold *et al.*, 2005). McKinney states the most important strategy is to preserve as much natural habitat as possible and try to retain pre-development vegetation (McKinney, 2002), a strategy that is often not an option in urban environments. Another important step for wildlife conservation in urban areas is to understand the relationship between landscape and patches and their effect on urban biodiversity (Angold *et al.*, 2005). In order to prevent further habitat alteration, inform the management of existing green spaces, and mitigate the effects of urbanization, it is important to understand the natural habitat characteristics that are most important for wildlife to thrive. A recent study by Gallo *et al*. (2017) determined that certain areas that are more manicured, like parks and cemeteries, have less species diversity compared to natural areas. Therefore, if the differences in vegetation and habitat characteristics between all types of urban greenspaces are understood, then the important variables necessary for wildlife to thrive in urban areas can be determined. This information could potentially give urban ecologists the knowledge to guide urban developers in the creation of an urban environment with minimal impact on nearby wildlife (Adams, 2005).

This study will provide information about how the natural vegetation varies among sampling locations where urban wildlife is being monitored and will improve the understanding of any possible relationships between vegetation structure and animal presence. This study could lead to more focused experimental studies with goals to determine how vegetation structure drives the presence of wildlife species. A greater understanding of the factors necessary for wildlife to thrive in urban areas could change the way urban spaces are designed and could allow urban planners to minimize the impact and improve the overall quality of life for wildlife. As urbanization continues at high rates around the world, understanding how to minimize the impacts on wildlife is becoming increasingly important.

The ultimate goal of this study is to begin to determine key structural parameters of vegetation that may indicate preferences of urban wildlife toward particular habitats in order to incorporate those preferences in urban green space planning and development. The protocol developed through this research will be shared with other cities participating in a national wildlife monitoring study, the Urban Wildlife Information Network (UWIN) spearheaded by the Lincoln Park Zoo in Chicago, so that they can assess vegetation impacts to presence of wildlife. Specific research objectives include: 1) assess whether visual determinations of habitat types are reflected in vegetation structure, 2) understand how locations vary in vegetation structure, and 3) explore how wildlife species richness varies with vegetation structure.

METHODS

Location Selection and Animal Presence Data Collection. This study is part of ongoing urban wildlife monitoring study through Indy Wildlife Watch (IWW) in Indianapolis, Indiana. Indianapolis is ranked the twentieth most populous city in the United States in 1940 and increased to the twelfth most populous city sixty-years later (US Census Bureau 2018*b*). As of July 1, 2016, the greater Indianapolis metropolitan area (counties included: Boone, Hamilton, Hancock, Hendricks, Johnson, Madison, Marion, Morgan, and Shelby) had 1,975,877 people with a 4.2% population increase measured since April 1, 2010 (U.S. Census Bureau 2018*c*). Temperature varies seasonally in Indianapolis, with average temperatures ranging from -7℃ to 5℃ in Winter, 0℃ to 18℃ in Spring, 17℃ to 30℃ in Summer, and 2℃ to 26℃ in Fall (National Weather Service).

The IWW has two 45-km transects (Figure 1) that span from downtown Indianapolis northward into suburban areas with 45 locations along the transects. A maximum of three locations spaced a minimum of 1-km apart were selected within a 2-km buffer every 5-km along each transect (Figure 1). Selected locations were restricted to locations where landowner permission could be obtained and fell into seven main subjectively determined habitat types: remnant forest, riparian forest, cemetery, golf course, park, agriculture, and college campus (Magle *et al*., 2016, Angstmann, pers. comm.) (Figure 2a, Table 1). Eight additional locations are being monitored as part of Butler Wildlife Watch (BWW), located on Butler University's campus, to provide a unique subset of urban habitats within a college campus (Figure 2b, Table 1).

At each location, a single Bushnell motion-triggered camera (Model # 119736C or 119836C) was deployed four months each year (January, April, July, and October, to represent winter, spring, summer, and fall, respectively). Each deployment lasted approximately 4 weeks. So far, the IWW has collected photos from January 2016 to January 2018. Tree-mounted cameras were pointed downward at a 45 degree angle and faced a synthetic fatty acid scent lure on a second tree about 10-m away to bring nearby mammals in view of the camera (Fidino *et al.*, 2016). During the sampling months, cameras were deployed and checked every two weeks (replacing batteries and camera cards) and were removed after the fourth week. Animals found in the photos for each location were manually identified within a Microsoft Access © database by two independent researchers and any conflicting identifications verified by a third independent reviewer.

Vegetation Sampling. Vegetation structure, not species diversity, is likely used by mammals of all sizes to select a habitat (Rogers *et. al.,* 2008, Andrade-Núñez and Aide, 2010), therefore the methodology outlined below does not focus on species-level identification of vegetation. Vegetation was sampled fall 2017 (August-October) at all eight BWW locations and a subset of nine IWW locations. Locations were chosen to represent a variety of different urban habitat types and spatial locations within the metropolitan area (i.e. urban, suburban, and exurban).

The vegetation structure of each location was assessed using a methodology adapted from Rogers *et al.* 2008. At each camera location, a 10.0-m radius circular plot was established 10.0-m in the opposite direction of the camera field of view with plot center either 10.0-m south of the camera or placed nearby in a location that is most indicative of the nearby habitat (Figure 3). In this plot, a nested sampling design was used to assess cover, density, and variability of each stratum: 1.) **overstory:** woody vegetation >5.0-m in height and >7.5-cm DBH (diameter at breast height); 2.) **understory:** woody vegetation >2.0-m in height and <0.75-cm DBH; 3.) **shrub:** woody vegetation >0.4-m and <2.0-m in height and <5.0-cm DBH; 4.) **herbaceous:** vegetation <0.4-m in height; and 5.) **surface components:** e.g. rock, moss, bare soil, litter, dead wood, etc.

Full Plot Measurements: Overstory trees, understory trees, and shrubs were sampled using a modified point-quarter method (Caratti, 2006). All four quarters of the 10.0-m radius circular plot were sampled at each location and several different variables were measured. The height of the nearest overstory tree was also measured with a clinometer. Total tree basal area and density of each 10.0-m plot was assessed by measuring the DBH of all overstory and understory trees >7.5-cm in diameter in the sample plot. The total number of tree stumps, dead trees, and fallen logs was also counted in each 10.0-m radius circular plot.

Line Transects: Transect sampling occurred along each of the four 10.0-m transects (N, S, E, and W directions). The cover of herbaceous and surface component cover stratum was sampled with the point-intercept method (Caratti, 2006). Cover of grass, herb, shrub, tree, and surface component was sampled by recording the vegetation type present every 0.5-m along each transect, for a total of 80 points. Shrub density and cover was sampled using the line-intercept method (Caratti, 2006) along each of the four transects. For each transect, the average height of the herbaceous and shrub stratum was estimated. Height of the small (<0.50-m), medium (0.5-m – 1.5-m), and large (>1.5-m) shrub and herbaceous canopy was measured and average canopy cover height for shrubs and herbaceous plants was estimated. Tree canopy density was measured with a spherical densiometer with measurements at plot center, at 5-m, and at 10-m along each directional transect for a total of nine sample points. Litter depth was also measured every 2-m along each transect by using a meter stick pushed through the litter for a total of 21 sample points.

1x1-m Nested Quadrats: A 1x1-m quadrat was placed along each transect 1.0-m from plot center totaling four plots. Density and percent cover of woody, herbaceous, and surface component strata, such as rocks, leaf litter, and bare soil was measured in each quadrat. For density, each quadrat was subdivided into 25, 20x20cm squares and the number of squares containing each stratum was counted. Percent cover was visually estimated for each cover class (0-100%).

Invasive Species: IWW's partners in Chicago found a negative correlation between the presence of invasive buckthorn on wildlife species present in motion-triggered photos (Lincoln Park Zoo, 2013). The presence of invasive plant species in an area decreases native plant species present (Vilà *et al.*, 2011), which has, in turn, been connected with a decrease in the greater biodiversity of the area (McKinney, 2002). Thus, invasive species may influence wildlife occupancy at a disproportionate rate for a variety of reasons. For example, the presence of certain invasive species (i.e. Amur honeysuckle) prevents native species from growing and also creates physical barriers that prevent larger wildlife from navigating through the thick understory (Lincoln Park Zoo, 2013). To estimate cover of invasive species, but minimize the need for floristic expertise, cover and density of the three most common invasive species for Indianapolis was quantified during sampling (with the line intercept method and the 1x1-m nested quadrats): Amur honeysuckle (*Lonicera maackii*), winter-creeper (*Euonymus fortunei*), and garlic mustard (*Alliaria petiolata*).

Wildlife Species Richness and Detection Sampling. As vegetation was sampled at a subset of 17 locations in this preliminary study, wildlife data presented here is only for those locations. Additionally, wildlife data presented here is from one sample season, October 2017, which aligns with the timing of vegetation sampling. For each location of interest, every image captured during the October 2017 sample period was viewed by two independent researchers and identified to species. Conflicting animal identifications were verified by a third independent researcher. Image data were then exported for a 28 day period starting at 12:00 AM on October 1. Exported data is the presence (1)/absence (0) of a species on any given day at any given location over 28 days. Species richness for each location was calculated by totaling the number of species present in at least one day during the full 28 day period. Percent of days present was calculated by summing the number of days a species was present at a particular location during the sample period and dividing by the total number of days (28).

Habitat Complexity Score (HCS) Index. Given the large number of vegetation structure variables measured in this study, the use of a habitat complexity index may be useful in further understanding the impact of vegetation structure on the presence of certain wildlife species. The index created by Watson *et al*. (2001) is an absolute scale used for structural aspects and results in a Habitat Complexity Score (HCS). Watson HCS is based on six habitat criteria: Canopy Cover (%), Tall (2-4 m) Shrub Cover (%), Low (0.5-2 m) Shrub Cover (%), Ground Herbage Cover (%), Logs/ Rock Cover (%), and Litter Coverage (%). For this study, tall and short shrub were not measured in a similar method, so the two categories were combined to be used as a category for all shrubs, which resulted in a total of five categories. Each category is scored from 0-3 based on cover class: 0 is 0-10%, 1 is 10-20%, 2 is 20-50%, and 3 is >50%. The scores were summed for each location resulting in a value in the range of 0-15, with higher numbers demonstrating more habitat complexity.

Statistical Analysis. All statistical analyses were conducted using JMP software (JMP®, Version 13. SAS Institute Inc., Cary, NC, 1989-2007). Statistical significance was determined at $\alpha = 0.05$. The 25 sampled vegetation variables (Table 2) were reduced to the most important variables driving vegetation differences among sampling locations using correlation-based Principal Components Analysis (PCA) that orthogonally transforms correlated vegetation variables into uncorrelated principal components. The first eight principal components described 81% of the variability in the data (Eigenvalue %: PC1 = 20.02, PC2 = 15.26, PC3 = 11.35, PC4 = 9.84, PC5 = 7.69, PC6 = 6.57, PC7 = 5.65, PC8 = 4.67). All components also had eigenvalues >1. Correlation coefficients between all parameters were examined and a threshold of $r \geq 0.6$ was used to highlight the most important variables and narrow the set to it down to the following 15 variables: honeysuckle % (0.78), shrub % (0.81), wood cover % (0.68), canopy cover (0.71), total basal (0.83), average basal (0.74), leaf litter % (-0.64), number of boles (-0.62), soil cover % (-0.60), moss cover % (0.70), number of stumps (0.70), herbaceous height (0.67), shrub height (0.62), overstory basal total (0.84), understory basal total (0.61), and grass cover % (-0.6). The selection of these 15 variables was also supported by partial contributions of variables. These 15 variables were then considered in the context of existing literature on small, medium, and large mammal habitat preferences

(Andrade-Núñez and Aide, 2010; Newsome & Catling 1979; Cork & Catling 1996; McElhinny et al. 2006; Puttker et al. 2008; Kays et al. 2008; Vernon et al. 2014) and narrowed down to nine key variables (total basal area, canopy cover, shrub cover, honeysuckle cover, leaf litter cover, grass cover, woody debris cover, number of boles, and average basal area), which were also the variables with the highest partial contributions for principal components 1-3. All subsequent analyses were conducted on these nine variables.

All nine vegetation variables were non-normal (Shapiro-Wilk $p<0.0001$) and the majority had unequal variances (Brown-Forsythe $p<0.05$, except total basal area: $p=0.3552$ and leaf litter cover: $p=0.1698$). Because of non-parametric data, comparisons among location, habitat type, and development category were conducted using Kruskal-Wallis tests with Dunn's multiple comparison post hoc tests (Kruskal 1952; Dunn 1964; Corder 2009). The Kruskal-Wallis test is a non-parametric test meaning there is no assumption that the data come from a distribution explained by two parameters (i.e. mean and standard deviation). This test is performed on ranked data, so the measurements are converted into ranks: the smallest values get a rank of one, the next smallest gets a rank of two, and it continues for the remainder of the data set. The Score Mean Rank is the mean rank for each group and the Score Mean Differences are the differences between the mean ranks of each group.

K means clustering was conducted on location means of the nine variables selected via PCA, using a threshold of seven clusters (to represent the seven subjective habitat types) to determine if the seven visual (subjective) designations of habitat "type" could be quantitatively confirmed by vegetation structure. In other words, each location was given a subjective designation such as remnant forest, cemetery, park, etc. and k means methods tested whether locations with the same “type” designation were empirically similar in vegetation structure.

RESULTS

Differences in Vegetation Structure Among Locations. Significant differences among all seventeen locations were quantified for the nine vegetation variables by performing Kruskal-Wallis tests (Table 3, Table 4). Significant differences were found for all nine variables: canopy cover ($p < 0.0001$), total basal area ($p = 0.0244$), average basal area ($p = 0.0251$), shrub % cover ($p < 0.0001$), honeysuckle % cover ($p < 0.0001$), leaf litter % cover ($p < 0.0001$), wood % cover ($p < 0.0001$), grass % cover ($p < 0.0001$), and number of boles ($p = 0.0002$). Dunn’s multiple comparison post hoc tests were used for all nine variables to determine the specific location differences. Table 3 shows the reported differences between locations for five of the nine variables (canopy cover, average basal area, shrub %, honeysuckle %, and leaf litter %). The other four variables (wood cover %, grass cover %, number of boles, and total basal area) were not found to be significant ($p \geq 0.05$).

Empirical assessment of visual habitat type designations. The nine variables determined from PCA were used in K means clustering to determine if locations clustered in the same predicted habitat types from visual assessments (Table 5). Because locations were visually divided into seven habitat “types”, a threshold of seven clusters was used in the K means analysis The first two principal components from K means, reported here, had Eigenvalues >1 (PC1 = 3.59, PC2 = 2.63). PC3 had an Eigenvalue >1 (PC3 = 1.42), but the addition of that axis to the analysis did not further visually separate the clusters.

Integration of vegetation structure via complexity indicator. K means clustering provides a statistical way to combine multiple parameters that are important in determining differences among groups of treatments into a single variable. Biological indices provide an alternative method to collapsing multiple parameters into a single relevant variable. Input parameters can be given weights to give more importance to parameters that are known to influence a particular phenomenon. A Habitat Complexity Score (HCS) was assigned to each location to assess multiple vegetative variables at once (Figure 6a). An average HCS value was calculated for each cluster based on the locations in that cluster (Cluster 1 = 6, Cluster 2 = 9, Cluster 3 = 8.67, Cluster 4 = 7.67, Cluster 5 = 10, Cluster 6 = 6, Cluster 7 = 6). When the locations were grouped together by cluster (Figure 6) and the HCS Watson values were compared, there did not appear to be noticeable differences. On average, the clusters 2, 3, 4, and 5 (clusters that contain many “forested” locations) had higher HCS Watson values than the other clusters.

Presence and absence of wildlife for each cluster. Wildlife species presence/ absence was recorded for all seventeen locations for 28 days in October 2017. The average number of species present at each location varied for each cluster (Cluster 1 = 9, Cluster

2 = 1, Cluster 3 = 8, Cluster 4 = 6.5, Cluster 5 = 4, Cluster 6 = 6, Cluster 7 = 4). Several species were also found at multiple locations (fox squirrel = 13 locations, deer = 6 locations, raccoon = 12 locations, red fox = 8 locations, rabbit = 11 locations, opossum = 10 locations, coyote = 3 locations). Mink and woodchuck were only found at one location (WOG and PKP, respectively). Deer were only found at a few locations (5 out of 17 locations).

Impact of invasive species: Amur honeysuckle. Amur honeysuckle was one of three common invasive species in Indianapolis that was recorded in this study and the only one that varied significantly among locations and clusters (Table 3, Figure 4). Honeysuckle-invaded locations (cover >50%) were all located in the BWW locations on Butler University's campus. Therefore, the percentage of locations with honeysuckle-invaded locations and non-invaded locations was calculated for the eight BWW locations only. Species presence was recorded for all eight BWW locations (honeysuckle invaded and non-invaded (Figure 8). The percentage of locations with wildlife species present was calculated for honeysuckle invaded and non-invaded locations. Of these eight locations, honeysuckle had invaded three of them (invasion meaning cover > 50%). The percentage of locations with opossums and rabbits present was the same with and without honeysuckle invasion (opossum = 67%, rabbit = 67%). For other species (red fox, deer, and raccoon), the percent of locations with species present differed between honeysuckle invaded and non-invaded locations (Figure 8: red fox: invaded = 67%, non-invaded = 100%; deer: invaded = 0%, non-invaded = 33%; raccoon: invaded = 67%, non-invaded = 0%).

DISCUSSION

Differences in Vegetation Structure Among Locations. PCA analysis found that 15 vegetation structure parameters drove 81% of the variability in vegetation structure among locations: honeysuckle %, shrub %, wood cover %, canopy cover %, total basal area, average basal area, leaf litter %, number of boles, soil cover %, moss cover %, number of stumps, herbaceous height, shrub height, overstory basal area total, understory basal area total, and grass cover (Table 2). These variables were likely determined important through PCA because of the distinctly different habitat types that were chosen for this study. This study assessed agriculture, parks, cemeteries, campus, golf courses, and riparian and remnant forests. Of these habitat types, agricultural locations tended to have little to no overstory, wood debris, or grass. At the time of vegetative sampling, NST had 100% cover by soybean plants. WAF is unique because it is an apple farm; at the time of sampling, WAF had several trees present and high grass cover, which made it unique from the homogenous herbaceous layer of NST. Campuses, parks and golf courses often have a few large trees, lots of grass cover, and little shrub density. All of these location types are regularly manicured and maintained to have a short herbaceous layer (grass) and few trees spread out throughout the location. Forests are often complex in their vegetative structure and have high canopy cover, basal area, shrub cover, and leaf litter. In this study, the forested locations clustered together with the cemetery locations. Both cemetery locations (CAC and ROS) had thicker canopy coverings in the forested edges of the location. Previous studies have reported effects of overstory density and canopy type on the forage quality and availability and the vertical structure of the vegetation (the density of understory vegetation at varying heights) may be important for habitat selection by certain wildlife species (Nudds, 1977).

Empirical assessment of visual habitat type designations. The different location clustering patterns of K means clustering from that of the original visually determined habitat types (park, cemetery, campus, golf course, remnant forest, riparian, and agriculture) were attributed primarily to variability among forested (riparian and remnant). Cluster 3 was composed of both remnant and riparian forest locations (PKP, BAF, and BPR) that are all found on the same floodplain and are in a relatively small land area (all three locations were less than 0.75 km apart), which may explain the similarities in vegetative structure. These three locations also have high percentages of canopy cover (>75%), shrub cover (>70%), and honeysuckle (>80%). Cluster 4 was comprised of several remnant forest locations and one riparian location, and two cemetery locations. Examination of the overall vegetative structure of these clustered forested locations, shows them to have less dense vegetation and canopy cover, which could explain why they are grouped together with the cemetery locations. Cemetery locations are often directly next to or contain wooded areas (Fidino *et al.*, 2016) and are maintained regularly (clearing dead wood, watering lawns, clearing understory, etc.) to keep the location looking presentable (Borgström *et al*., 2006). Both ROS and CAC had trees planted around the perimeter of the location and were also less dense in understory vegetation due to regular maintenance. The remaining cluster 4 locations were similar to the cemetery locations in terms of canopy cover percentages (>75%) and honeysuckle shrub density (<10%).

Additional differences were found in the k means cluster analysis through the isolation of the agricultural locations into individual clusters. The formation of separate clusters of the two agricultural locations, WAF and NST, was due to the different types of crops grown at each location. WAF is an apple orchard and NST is located on a soybean field and as a result of the different crops, the locations have completely different vegetative structures. These findings in Figure 5 suggest that WAF, which is positioned closer to cluster 6 (golf course, park, and campus center) than the other agricultural location in cluster 1, may serve as a potential corridor for wildlife (Villasenior *et al.,* 2004).

K means cluster analysis also grouped together the golf course (WOG), park (HCG), and campus (JDH), though they were originally separated into three different subjectively determined habitat types. All three locations are regularly maintained and manicured and generally less dense in vegetation (cleared understory, open canopy, high grass cover, and few large trees). A study done by Gallo *et al.* (2017) compared species richness at urban greenspaces (city parks, golf courses, cemeteries, and natural areas). These different urban greenspaces all differ in size, management, and human activity, yet they are somewhat similar in their vegetative structures. Parks are generally small with well-maintained vegetation and high human presence, while golf courses are generally much larger and have semi-natural vegetation, some form of water (i.e. streams or ponds), and human activity varies based on the season (Gallo *et al.,* 2017). The more natural areas in urban environments are generally remnant forests and have much more complex vegetative structures (Gallo *et al.,* 2017). Species richness analysis determined that city parks had less wildlife diversity than golf courses, cemeteries, and natural areas

(Gallo *et al.,* 2017). In this study, instead of the park having decreased wildlife presence (Figure 7), the campus center had the lowest presence of cluster 6, despite the similarities in vegetative structure. This suggests some inherent difference between these locations that could result in the decreased wildlife presence.

Integration of vegetation structure via complexity indicator. Clusters that contained many forested locations (clusters 2, 3, 4, and 5) had generally higher habitat complexity scores (HCS) than other clusters because of the variables used to quantify HCS values: canopy cover, shrub cover, herbaceous cover, log/rock cover, and leaf litter cover. Typical vegetative structure of forested areas include: the emergent layer, the canopy, the understory, and the forest floor (Enviropol, 2014). Certain measurable attributes of the overstory include: canopy cover, number of canopy layers, and dbh. The herbaceous layer is also a component of forested areas; measurable attributes of the herbaceous layer include: cover of herbaceous layer and richness of plant species (McElhinny, 2002). Forested regions will generally be more dense and more complex (higher percentage of shrub cover, canopy cover, and basal area) than other habitat types, like golf courses or agricultural fields, and will therefore have a higher complexity score.

Although HCS was higher in all forested locations than other subjectively determined habitat types, HCS was highly variable among forested locations. This again showcases the vegetation variability in forested locations an poses critical considerations in habitat mosaics and habitat variability described in the previous paragraph. Non-forested locations were all identical in HCS value to the other locations in their respective habitat type highlighting homogeneity of vegetation in these locations. Habitat heterogeneity has been shown to be an influential factor for populations in urban environments (Kozakiewicz, 1993; Tews *et al*., 2003). Habitats that have a more complex structure provide more niches and thus more species diversity. In these habitats, the vegetative structures determine the physical nature of these locations and as a result have an influence on the animal species that are present (Tews *et al.*, 2003). Habitat heterogeneity and more complicated vegetative structure benefits wildlife species in unequal ways; some benefits of heterogeneity may be deterrents for certain wildlife species (Tews *et al.*, 2003). For example, this heterogeneity may be the result of habitat fragmentation due to human activity (Kozakiewicz, 1993), which can be problematic for mammals if no corridors exist to travel between habitat patches (Fidino *et al*., 2016). Future urban greenspace planning should consider creating heterogeneous greenspaces with effective corridors that allow movement throughout all greenspaces.

Presence and absence of wildlife for each cluster. Even though the different clusters had similar vegetative structures, the presence of wildlife at these locations was not the same. Two notable examples where one location was considerably different in species presence than the others in their respective cluster were JDH and WGP, which had fewer species than the other locations in the cluster. Upon further examination, neither JDH nor WGP differed much in vegetative structure from other locations in their cluster. JDH had the same HCS Watson value as the other two locations in cluster 6 and had similar basal area to the golf course (WOG) but slightly less than a park (HCG). JDH did have 5-10% less shrub cover than the other two locations, which could diminish the habitat quality for some smaller mammal species that might require the cover for protection (Grant & Baird, 1976). WGP had similar vegetation structure to the other cluster 4 locations, including shrub cover, basal area, and canopy cover, but its HCS Watson value was 9 compared to a value of 7 or 8 for the other locations in the cluster.

It is possible that the differences in animal species presence at this location was due to the area and habitats surrounding the camera. WGP is located inside of a 400-acre sports facility with numerous soccer fields and baseball diamonds. This location is mostly open turf grass with a few forested areas throughout the complex. The park also experiences a very large amount of seasonal human traffic, which may dissuade wildlife from inhabiting the few forested areas in this location The main difference between JDH and other cluster 6 locations is the fact that JDH is in the center of the campus of Butler University in an area that receives high human traffic daily (Table 6). The impact of human traffic and activity is species specific (Markovchick-Nicholls *et* al., 2008). Animals will generally try to avoid people and have several options to do so, including: leaving the area, becoming more nocturnal, or avoiding areas where people are often found (Griffiths & Van Schaik, 1993). The differences in species presence for JDH and WGP were likely the result of a combination of factors related to human traffic and activity as well as vegetative structures in the area directly surrounding the camera location.

Comparing species richness at the different locations also revealed several common species were observed at a majority of the locations: rabbits, raccoons, red foxes, and opossums. All of these species are known as urban adapters, or a species that has been able to adapt in some way to benefit from human activity (McKinney, 2002). However, there were several species (i.e. woodchucks, minks, and deer) that are only found in one or a few of the locations, which indicates that some differences exist between locations and these differences may be related to vegetative structure.

The woodchuck was only found at PKP, one of the two riparian locations (Table 6, Figure 7). Woodchucks are urban adapters and primarily inhabit forest edges and occupy open areas nearby forested habitats (Armitage, 2014; Lehrer & Schooley, 2010). Rural locations are generally preferable for woodchucks to urban landscapes, but urban cover is sometimes preferable as some individuals take advantage of the pre-existing shelter that exists in developed areas (Hellgren & Polnaszek, 2011). PKP is one of the urban BWW locations and has a dense canopy cover (70%) and a high overall tree density (600 trees/Ha), both characteristics similar to the other cluster 4 locations. However, PKP has a higher than average shrub, specifically honeysuckle, density than the other locations. This high prevalence of shrub cover and honeysuckle may have an impact on the presence of woodchucks, as it may provide additional protection and cover for their burrows. Figure 8 shows that woodchucks were one of the few animal species that were equally as likely to be found in honeysuckle and non-honeysuckle invaded areas.

Mink is another species that was found at only one location: WOG (golf course) (Table 6, Figure 7). Mink are typically found near a source of water, typically a river or a brook (Sidorovich & Macdonald, 2001). Previous studies have found high density of mink populations near fast flowing rivers or in marshes and swampy meadows during warm periods (Sidorovich & Macdonald, 2001). While several other locations are nearby a source of water (WFD has a pond nearby, the BWW locations are nearby a canal, and ROS has a stream flowing nearby) WOG was one of the only locations used in this study that had a larger flowing stream (Eagle Creek) running directly through it. Mink prefer larger streams (due to increased diversity of aquatic prey) and are positively associated with the water depth of streams (Wolff *et al.*, 2015). Mink also prefer areas that have lower human development (Wolff *et al.*, 2015). These combining factors make WOG a more ideal habitat for mink than some of the other locations with water sources that were involved in this study.

Deer were found in only six of the seventeen locations (Table 6, Figure 7). Deer inhabit areas that provide an abundance of forage, such as old growth forests or mature second growth stands (Pauley *et al*., 1993). As their natural habitats are being diminished, they are being forced to adapt and move from small woodlot to woodlot to maintain protection and cover (Nixon & Hansen, 1992). Deer were found in deer were found in 3 clusters out of 7 clusters (Figure 6). These wide range of habitat types contain several different vegetative structures, for example the canopy cover ranged from 30-90% depending on the location. One thing that all locations had in common was a low percentage (ranging from 0-10%) of honeysuckle present at the location. Previous research done at the Lincoln Park Zoo shows the negative impact of the presence of honeysuckle on native deer populations as it potentially diminishes their food source and makes the forested area too dense to navigate through (Lincoln Park Zoo, 2013).

Impact of invasive species: Amur honeysuckle. The presence of honeysuckle was also compared to the presence of wildlife at the eight BWW locations. Some mammal species were seemingly unaffected by the presence of honeysuckle. However, deer, red foxes, and fox squirrels were found less often in locations that had honeysuckle present although this finding could be compounded by other location differences, such as adjacent habitats and human activity. The presence of honeysuckle did not have a significant impact on a majority of the wildlife species present, but is potentially the result of the small sample size used in the paper.

Limitations and Future Directions. This preliminary study was done to determine potential habitat indicators for urban wildlife. The initial results demonstrate that there are certain habitat characteristics that are important for a few medium-to-large sized mammals, yet in order to fully understand the impact of the vegetative structures on wildlife the remaining locations need to be sampled. Due to time constraints, only 17 of the 53 IWW and BWW locations were sampled. The remaining locations need to be sampled so more robust analyses can be conducted. Vegetation structure is also highly dynamic and many of the selected variables change seasonally, so it would be ideal to sample over multiple seasons. Therefore, it would be beneficial to sample each of the locations during the time of camera deployment every season. This way the changes in vegetative structure over the course of several years could be accurately determined to see how this impacts the presence of wildlife at these locations.

Alternatively, since vegetation sampling is time intensive, the vegetation data should be analyzed in the context of multiple seasons and years of wildlife data to gain a more temporally integrated perspective of how vegetation structure impacts wildlife species richness. Further wildlife analyses should go beyond species richness to assess detection probabilities and occupancy of specific species to further understand the role of various vegetation parameters on the presence of a particular species (Fidino *et al*., 2016).

Vegetative structures and habitat characteristics may not be the only important variable in determining the presence of wildlife. As seen with JDH and WGP, nearby habitat structures and human activity could potentially be influential to the presence of wildlife. To determine additional factors, GIS analysis should be conducted to learn more about the impact of parameters such as distance to nearest buildings, busy roads, nearby housing density, habitat connectivity, human traffic, patch size, socioeconomics (Magle *et al*., 2015), and isolation index (Salsbury, 2008) as they are all potential influential factors for wildlife presence.

Through this study, a vegetation sampling protocol that is accessible to people of varying botanical knowledge was created and refined. This protocol will hopefully be shared with the IWW partners in the Urban Wildlife Information Network (UWIN). The UWIN originated in Chicago and was founded by IWW's partners at the Lincoln Park Zoo after their work studying the urban ecosystems in Chicago began in 2010. The UWIN is now made up of eight major cities around the United States, including Los Angeles, CA, Denver, CO, and Austin, TX (Lincoln Park Zoo). Urban wildlife conservation efforts will not be effective until all of the variables required for these different species to thrive are understood. This study has started to develop the understanding of different vegetative structures present in urban greenspaces. If these differences in vegetation and habitat characteristics between all types of urban greenspaces are understood, more can be learned about the conditions required by wildlife to survive in increasingly urban environments. In order to minimize further habitat alteration and fragmentation, it is important to inform and guide urban developers on how to better create an urban environment that minimizes the impact on nearby wildlife so that the negative impacts of urbanization can be mitigated.

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APPENDIX

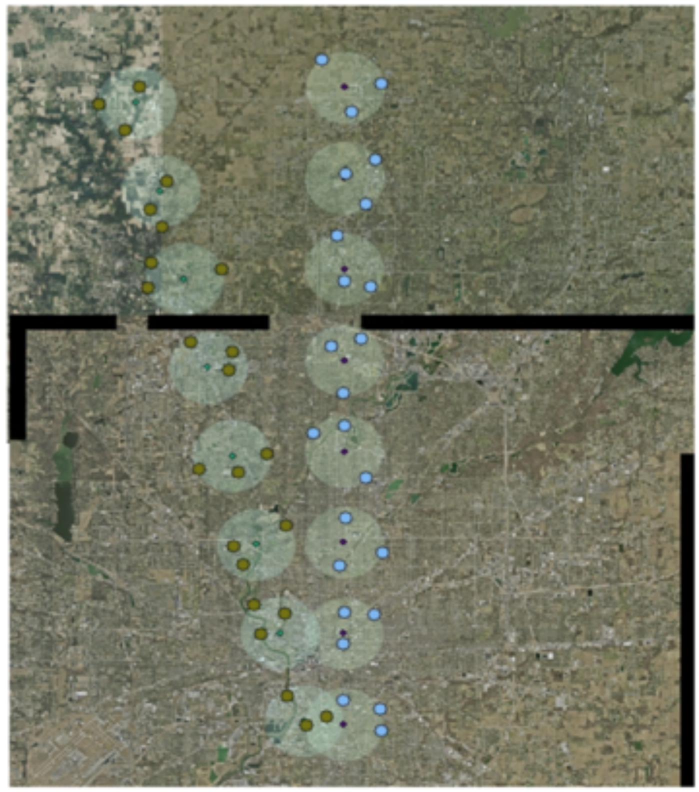
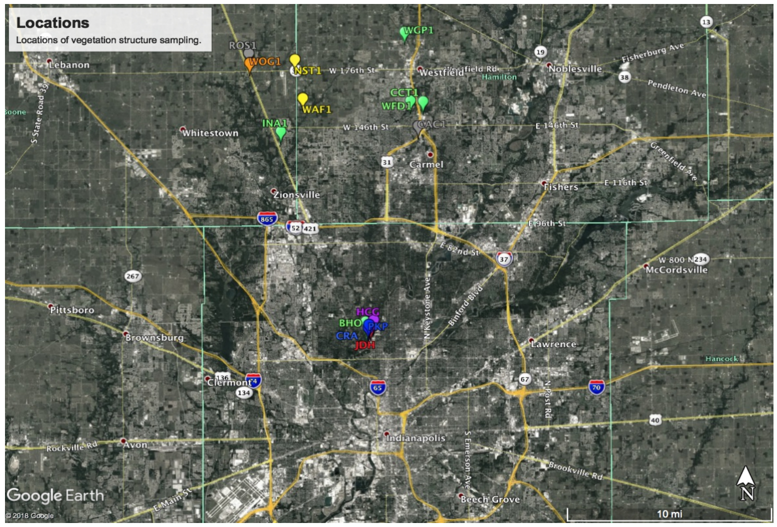


Figure 1: IWW sites spanning northward from downtown Indianapolis. Each transect contains 8, 2-km circular buffers that are spaced 5-km apart along the 45-km transect. Each 2-km circular area buffer contains up to three sites for a total of 45 sites along the two transects.

a



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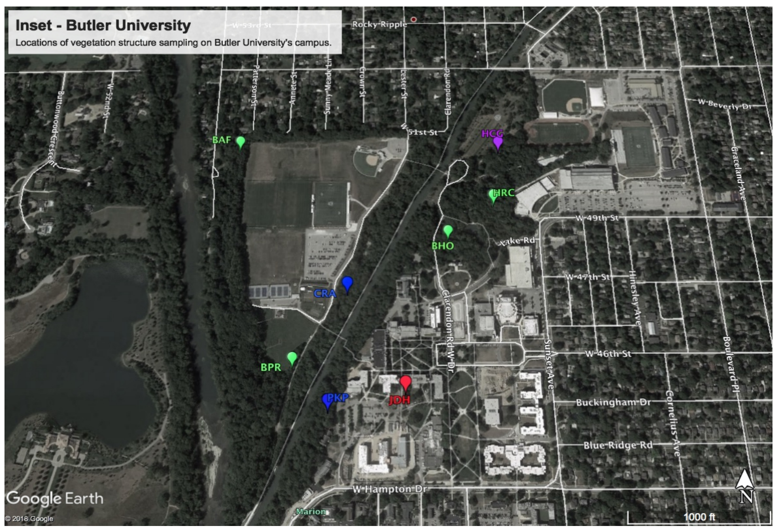


Figure 2: Nine of the IWW locations and all eight of the BWW locations were chosen as representatives of various habitat types and spatial locations around Indianapolis (urban, suburban, and exurban). Figure 2a shows the all locations on a map and Figure 2b shows a closer view of the BWW locations on the campus of Butler University. Locations have been color coordinated to represent subjective habitat type names: yellow = agriculture, orange = golf course, red = campus, green = remnant forest, blue = riparian, purple = park, and gray = cemetery.

Table 1: Location name, code, subjective location type, and color coding.

Location Name	Location Code	Subjective Location Type	Color Code
Coral Court	CCT1	Remnant Forest	Green
Westfield Washington Township Fire Station 82	WFD1	Remnant Forest	Green
Carmel Cemetery	CAC1	Cemetery	Gray
Grand Park	WGP1	Remnant Forest	Green
Interactive Academy	INA1	Remnant Forest	Green
Wild's Apple Farm	WAF1	Agriculture	Yellow
Wolf Run Golf Course	WOG1	Golf Course	Orange
Northside Trailer	NST1	Agriculture	Yellow
Rosston Cemetery	ROS1	Cemetery	Gray
Butler Athletic Fields	BAF	Remnant Forest	Green
Butler Prairie	BPR	Remnant Forest	Green
Phi Kappa Psi	PKP	Riparian	Blue
Canal Riparian Area	CRA	Riparian	Blue
Jordan Hall	JDH	Campus	Red
Butler Holcomb Observatory	BHO	Remnant Forest	Green
Health and Recreation Center	HRC	Remnant Forest	Green
Holcomb Gardens	HCG	Park	Purple

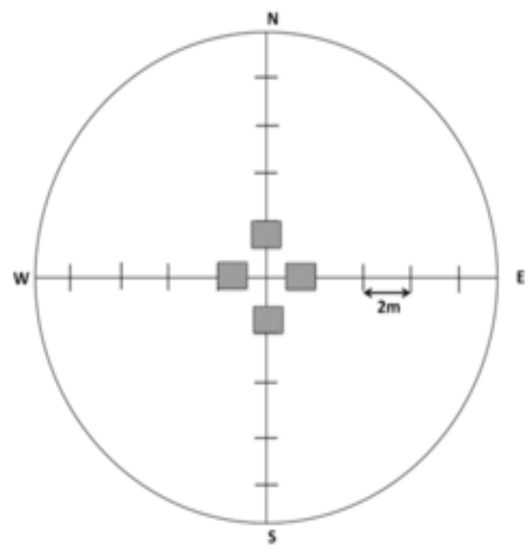


Figure 3: 10.0-m radius circular plot (adapted from Rogers *et al.*, 2008) used to measure habitat characteristics. Vegetation was sampled along the 20-m transects, in the 1x1m plot, and in each quarter.

Table 2: Twenty-five vegetation variables measured in this study. * denotes the fifteen variables highlighted from Principle Component Analysis, ** denotes the nine variables used for subsequent analyses.

Vegetative Variables				
% Canopy Cover	Overstory Basal Total	Overstory Basal Average	Overstory Height	Understory Basal Total
Understory Basal Average	Total Basal Area	Average Basal Area	% Shrub	Shrub Height
Herbaceous Height	% Shrub	% Honeysuckle	% Winter Creeper	% Soil Cover
% Rock Cover	% Wood Cover	% Moss Cover	% Herbaceous Cover	% Grass Cover
Number of Logs	Number of Boles	Number of Stumps	Leaf Litter Depth	% Leaf Litter Cover

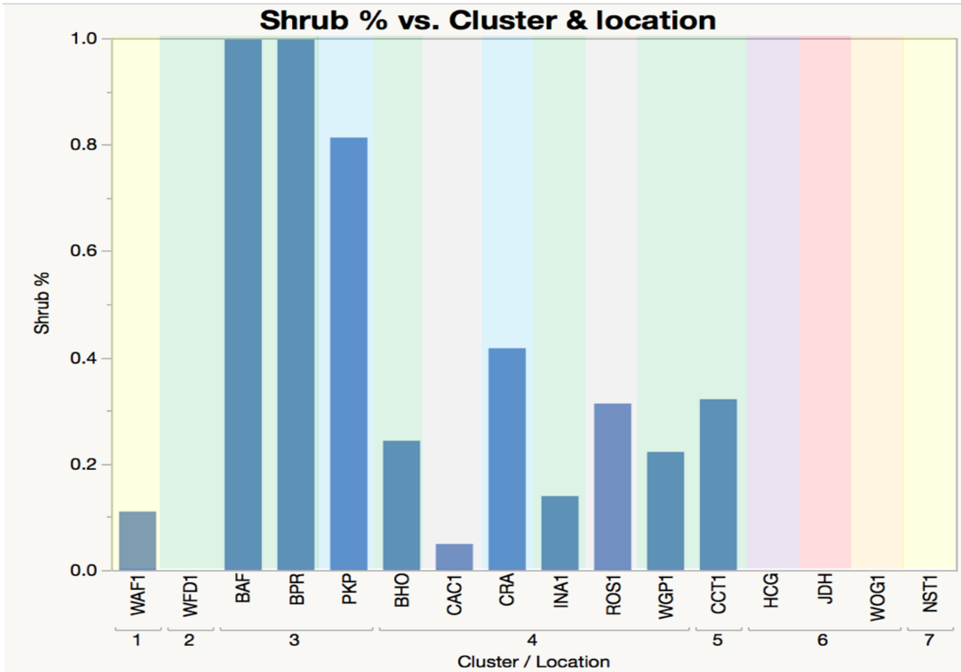
Table 3: Significant location differences for five of nine vegetation parameters using Kruskal-Wallis tests with Dunn's Multiple Comparison post-hoc tests.

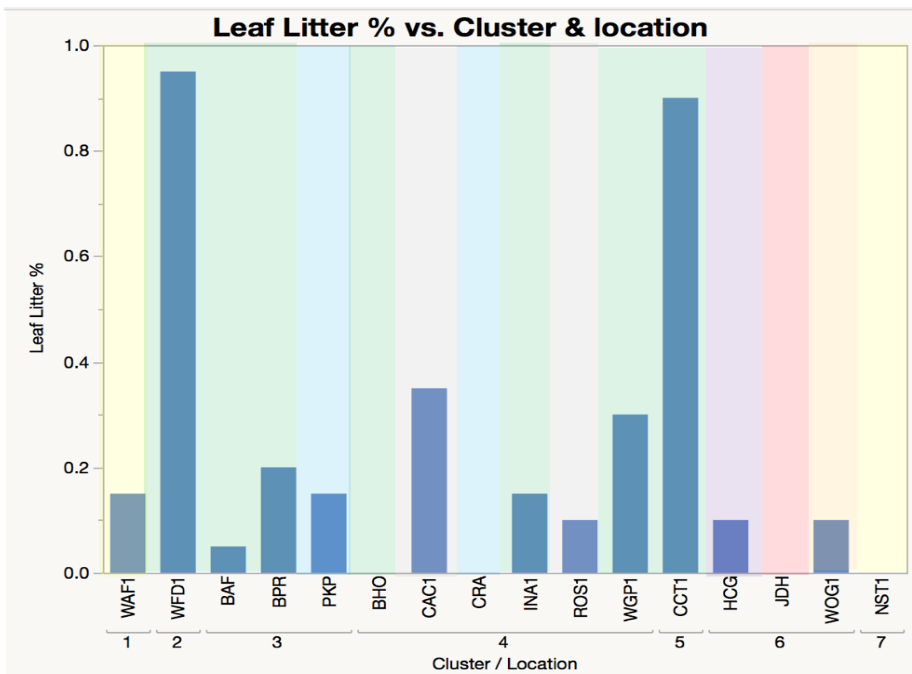
	Level	- Level	Score Mean Difference ± Std Err Diff	Z	p-value
	NST1	JDH	125.722 ± 20.88551	6.01959	< 0.0001
	NST1	HCG	107.111 ± 20.88551	5.12849	< 0.0001
	NST1	INA1	98.333 ± 20.88551	4.70821	0.0003
	WGP1	WAF1	96.111 ± 20.88551	4.60181	0.0006
	NST1	CRA	92.056 ± 20.88551	4.40763	0.0014
	WGP1	JDH	85.722 ± 20.88551	4.10439	0.0055
	HCG	CAC1	-74.444 ± 20.8851	-3.56441	0.0496
	WAF1	HRC	-74.444 ± 20.88551	-3.56441	0.0496
	CRA	BPR	-78.556 ± 20.88551	-3.76125	0.0230
	INA1	BPR	-84.833 ± 20.88551	-4.06183	0.0066
	PKP	NST1	-87.111 ± 20.88551	-4.17089	0.0041

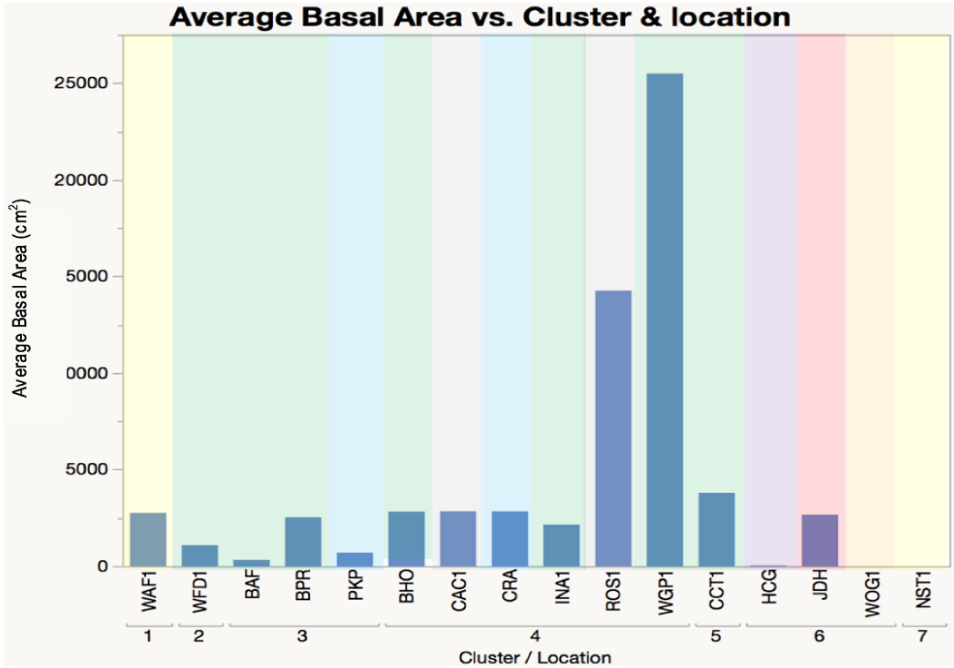
Canopy Cover %	WOG1	WGP1	-92.222 ± 20.88551	-4.41561	0.0014
	JDH	BAF	-92.778 ± 20.8851	-4.4421	0.0012
	JDH	CAC1	-93.056 ± 20.88551	-4.45551	0.0011
	HCG	BPR	-93.611 ± 20.88551	-4.48211	0.0010
	WOG1	BAF	-99.278 ± 20.88551	-4.75343	0.0003
	WOG1	CAC1	-99.556 ± 20.88551	-4.76673	0.0003
	WAF1	BAF	-103.167 ± 20.88551	-4.93963	0.0001
	WAF1	CAC1	-103.444 ± 20.88551	-4.95293	< 0.0001
	JDH	BPR	-112.222 ± 20.88551	-5.37321	< 0.0001
	WOG1	BPR	-118.72 ± 20.88551	-5.68443	< 0.0001
	WAF1	BPR	-122.611 ± 20.88551	-5.87063	< 0.0001
	WOG1	NST1	-132.222 ± 20.88551	-6.33081	< 0.0001
	WAF1	NST1	-136.111 ± 20.88551	-6.51701	<

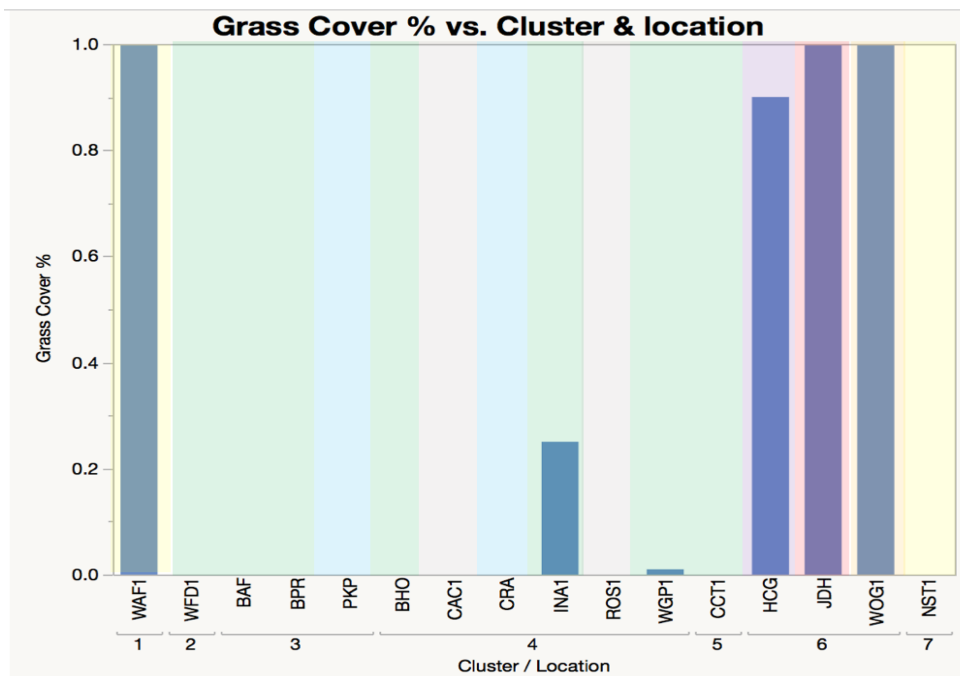
					0.0001
Avg. Basal Area (cm^2)	NST1	CAC1	-48.500 ± 13.16034	-3.68532	0.0274
Shrub % Cover	WOG1	BAF	-51.5000 ± 13.84078	-3.72089	0.0270
	WOG1	BPR	-51.500 ± 13.84078	-3.72089	0.0270
	JDH	BAF	-54.7500 ± 13.84078	-3.95570	0.0104
	JDH	BPR	-54.7500 ± 13.84078	-3.95570	0.0104
	NST1	BAF	-54.7500 ± 13.84078	-3.95570	0.0104
	NST1	BPR	-54.7500 ± 13.84078	-3.95570	0.0104
	BHO	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	CRA	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	HCG	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	HRC	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	INA1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	JDH	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	NST1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	ROS1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266

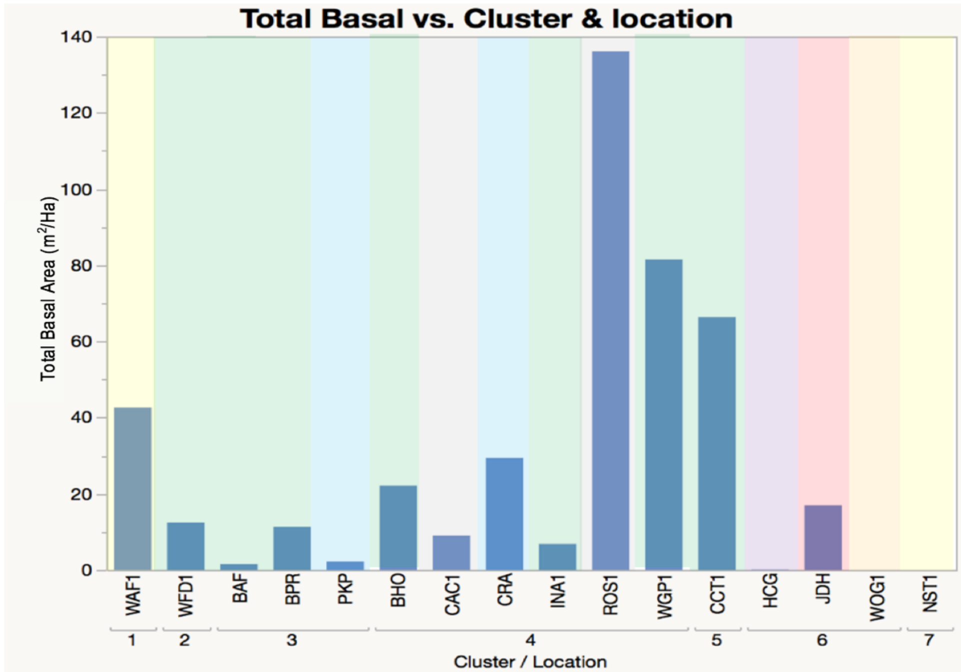
Honeysuckle % Cover	WAF1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	WFD1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	WGP1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
	WOG1	BAF	-37.7500 ± 10.13565	-3.72448	0.0266
Leaf Litter % Cover	WDF1	CRA	57.3750 ± 13.83431	4.14730	0.0046
	WFD1	NST1	57.3750 ± 13.83431	4.14730	0.0046
	WFD1	JDH	49.6250 ± 13.83431	3.58710	0.0455
	JDH	CCT1	-49.3750 ± 13.83431	-3.56903	0.0487
	CRA	CCT1	-57.1250 ± 13.83431	-4.12923	0.0050
	NST1	CCT1	-57.1250 ± 13.83431	-4.12923	0.0050

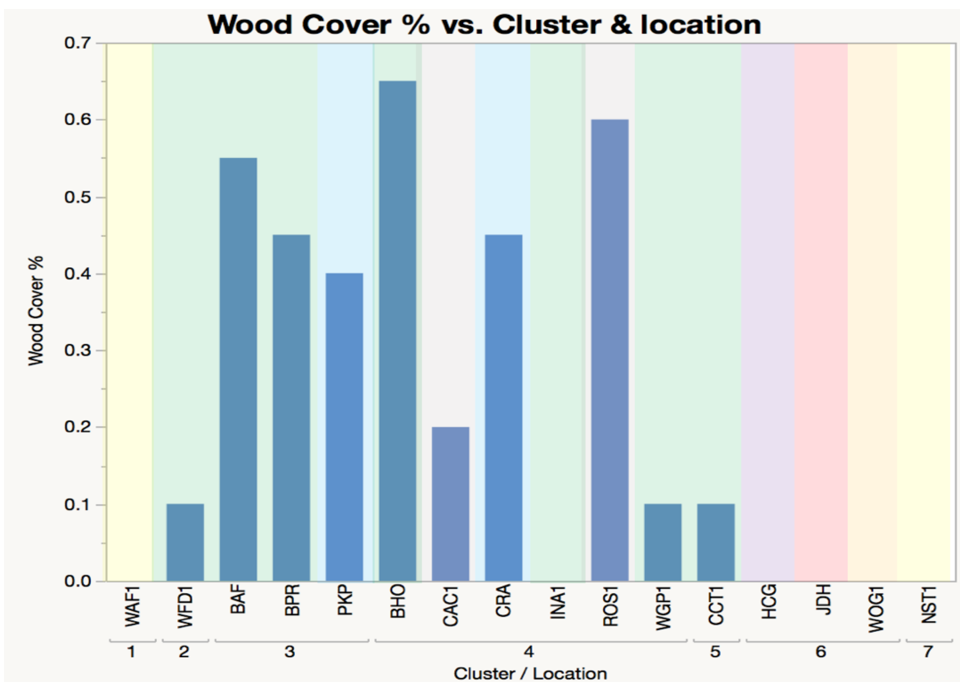

Shrub % vs. Cluster & location
Shrub %
1.0
0.8
0.6
0.4
0.2
0.0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location

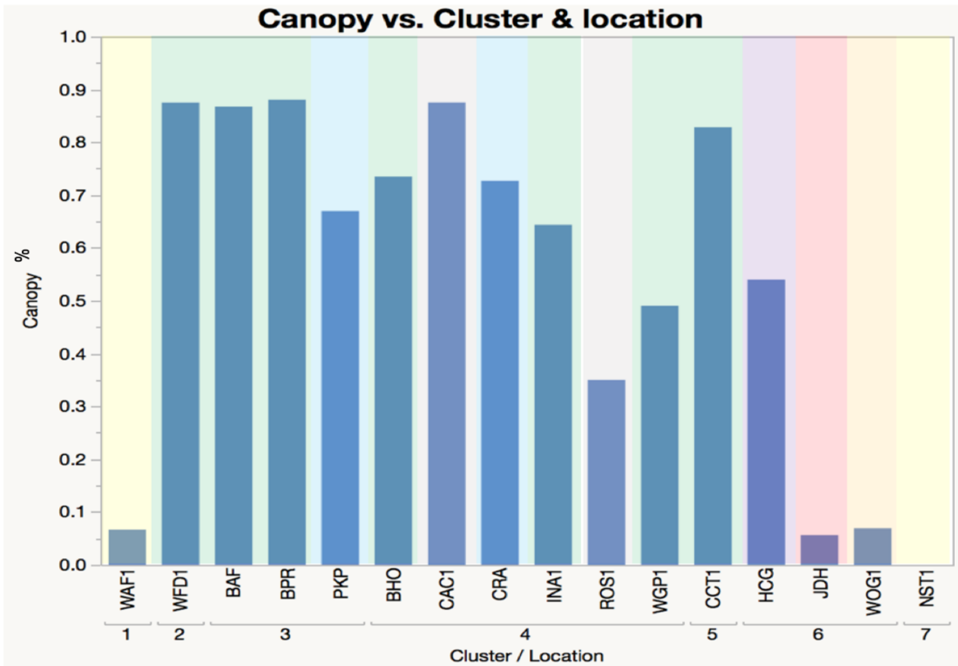

Leaf Litter % vs. Cluster & location
Leaf Litter %
1.0
0.8
0.6
0.4
0.2
0.0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location

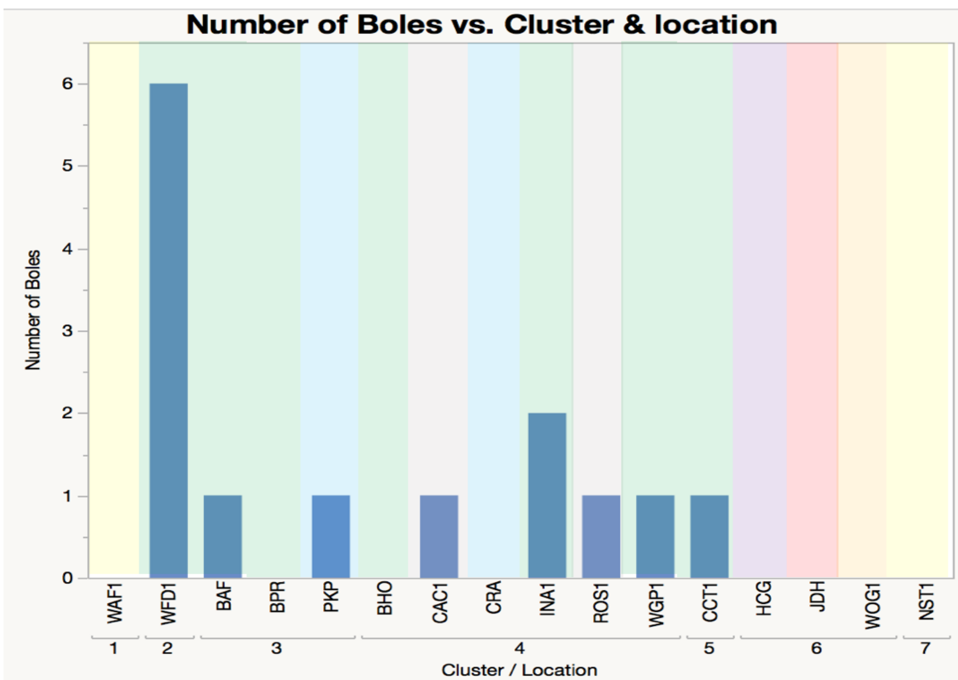

Average Basal Area vs. Cluster & location
Average Basal Area (cm²)
25000
20000
5000
0000
5000
0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location


Grass Cover % vs. Cluster & location
Grass Cover %
1.0
0.8
0.6
0.4
0.2
0.0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location


Total Basal vs. Cluster & location
Total Basal Area (m2/Ha)
0
20
40
60
80
100
120
140
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location


Wood Cover % vs. Cluster & location
Wood Cover %
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location


Canopy vs. Cluster & location
Canopy %
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location


Number of Boles vs. Cluster & location
Number of Boles
6
5
4
3
2
1
0
WAF1
WFD1
BAF
BPR
PKP
BHO
CAC1
CRA
INA1
ROS1
WGP1
CCT1
HCG
JDH
WOG1
NST1
1
2
3
4
5
6
7
Cluster / Location

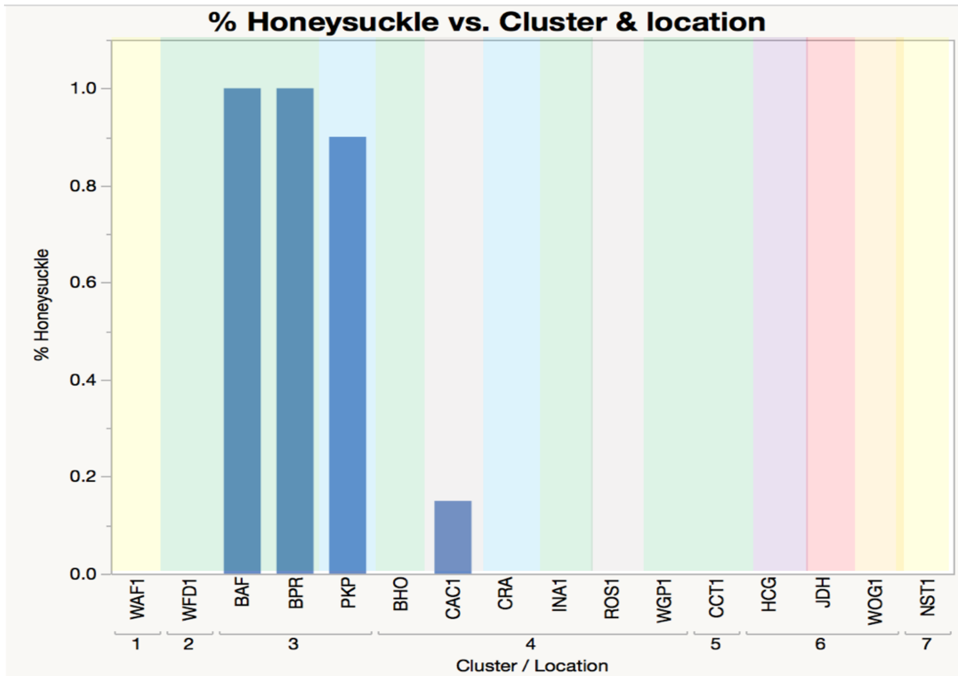


Figure 4: Nine vegetative variables were selected from an original twenty-five variables using Principal Component Analysis (PCA) and research from prior literature (Andrade-Núñez and Aide, 2010; Newsome & Catling 1979; Cork & Catling 1996; McElhinny et al. 2006; Puttker et al. 2008; Kays et al. 2008; Vernon et al. 2014). Kruskal-Wallis with Dunn's Multiple Comparison Post Hoc was performed to determine differences between locations (Table 1) and clusters (letters in Figure 4 subgraphs, cluster analysis, and significant differences among clusters described in the next section).

Table 4: Comparison of the nine vegetative variables used for statistical analyses between locations. Data for Basal Area (Total and Average) not recorded for HRC.

Location	Average % Canopy Cover	Average Total Basal Area (m^2/ha)	Total # of Boles	Average Basal Area (cm^2)	Average % Wood Cover
CCT1	0.792	55.726	21	2841.079	0.25
WFD1	0.808	16.407	26	1391.590	0.14
CAC1	0.883	35.008	3	4340.703	0.163
WGP1	0.854	36.973	7	8148.111	0.143
INA1	0.686	13.488	3	3068.212	0.038
WAF1	0.277	37.022	0	6769.763	0
WOG1	0.331	10.473	0	1810.598	0
NST1	0	0	0	0	0
ROS1	0.775	37.817	3	4690.698	0.35
BAF	0.884	10.529	2	1312.141	0.525
BPR	0.947	18.654	5	2586.217	0.6
PKP	0.741	1.993	2	626.120	0.388
CRA	0.733	13.892	1	1882.211	0.388
JDH	0.446	6.319	0	1318.935	0.1
BHO	0.790	16.425	1	1813.917	0.55
HRC	0.810	-	0	-	0.5
HCG	0.629	19.977	0	3339.293	0

Table 4 (continued):

Location	Average % Leaf Litter	Average % Honey-suckle	Average % Shrub Cover	Average % Grass Cover
CCT1	0.913	0.05	0.552	0
WFD1	0.888	0	0.364	0.003
CAC1	0.325	0.088	0.088	0.038
WGP1	0.138	0	0.320	0.265
INA1	0.2	0	0.127	0.1875
WAF1	0.055	0	0.191	1.0
WOG1	0.113	0	0.016	1.0
NST1	0	0	0	0
ROS1	0.338	0	0.249	0
BAF	0.05	1.0	1.0	0
BPR	0.113	0.913	0.9	0
PKP	0.175	0.863	0.863	0
CRA	0	0	0.425	0
JDH	0.025	0	0	0.713
BHO	0.038	0	0.538	0.063
HRC	0.05	0	0.0875	0.003
HCG	0.075	0	0.088	0.438

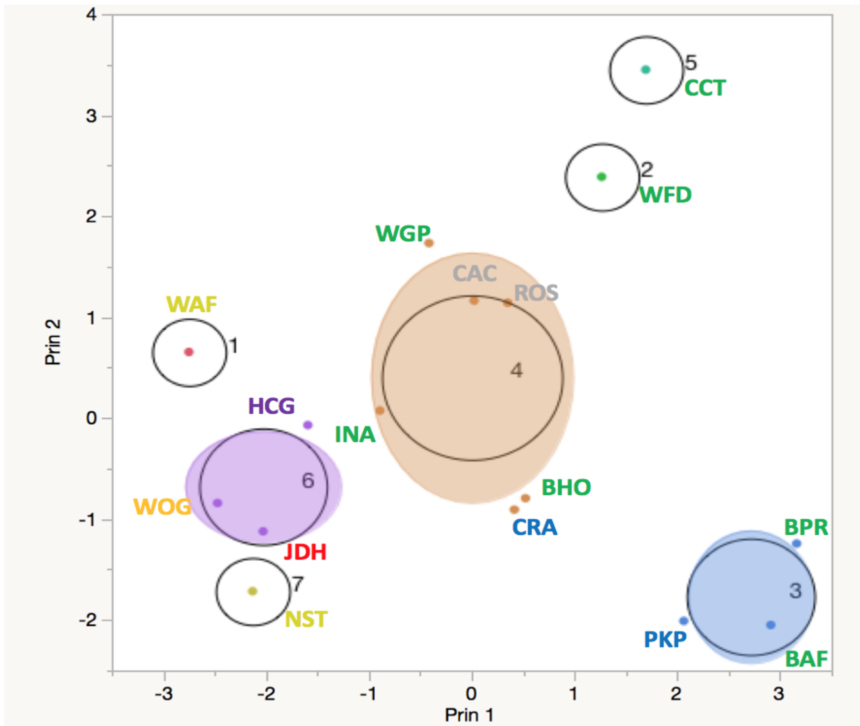


Figure 5: K means clustering of nine vegetation parameters selected via PCA clustered by location into seven clusters. Location names are three letter codes with the colors associated with subjectively determined habitat type as described in Table 1. Location HRC not included in the analysis because of lack of data.

Table 5: K means cluster results. Means +/- 1 SD are presented for clusters with more than one location

Cluster	**Canopy Cover %**	**Total Basal Area (m^2/ha)**	**Avg. Basal Area (cm^2)**	**Shrub %**	**Honey-suckle %**	**Leaf Litter %**	**Wood Cover %**	**Grass Cover %**	**# of Boles**
1	0.2775	37.0225	6769.77	0.191	0	0.055	0	1	0
2	0.8102	16.4072	1391.59	0.36375	0	0.8875	0.14	0.0025	6.5
3	0.8583 ± 0.0869	10.3921 ± 6.803	1508.16 ± 812.12	0.9347 ± 0.0924	0.925 ± 0.0568	0.1125 ± 0.0510	0.5042 ± 0.088	0	0.75
4	0.7869 ± 0.0669	25.600 ± 11.0685	3990.64 ± 2157.6	0.2430 ± 0.1011	0.01458 ± 0.0326	0.1738 ± 0.1292	0.2667 ± 0.1775	0.0921 ± 0.0998	0.75 ±0.5
5	0.792	55.7260	2840.83	0.55225	0.05	0.9125	0.25	0	5.25
6	0.4687 ± 0.1230	12.2273 ± 5.6914	2156.28 ± 860.26	0.0745 ± 0.0658	0	0.0708 ± 0.0358	0.0333 ± 0.04714	0.7167 ± 0.2297	0
7	0	0	0	0	0	0	0	0	0

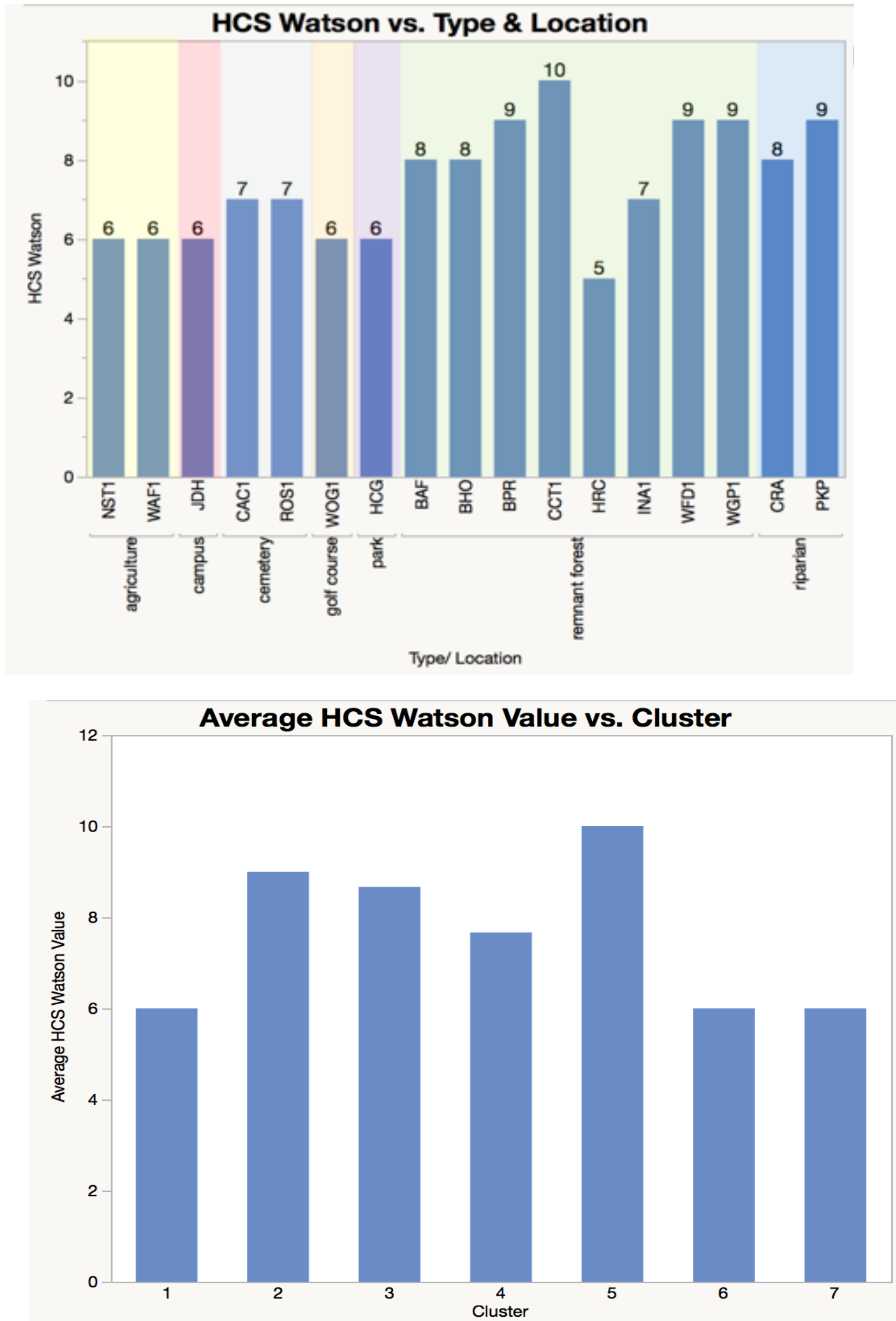


Figure 6: HCS Watson values were calculated for each location. (a) the locations were grouped together in their respective habitat types (numbers above bars represent HCS values and the colors represent the habitat type, Table 1) and (b)the HCS Watson values for all seven clusters were averaged together for comparison between clusters.

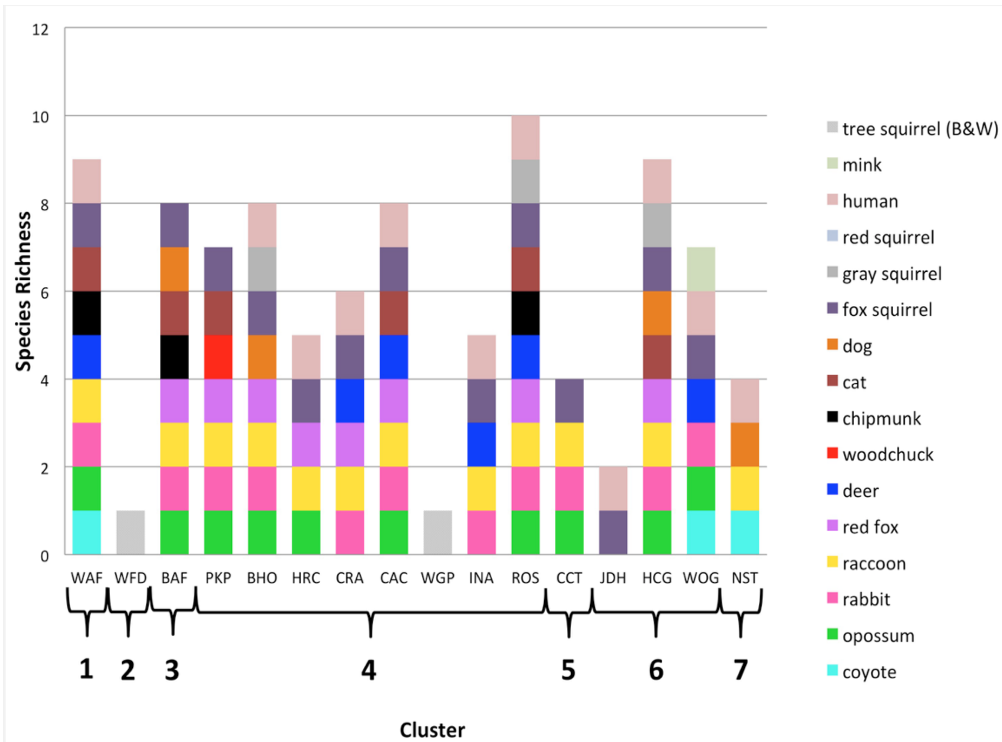


Figure 7: Species richness by location. Locations are grouped by cluster from the k means analysis, meaning grouped locations have similar vegetation structure.

Table 6: List of locations where each wildlife species is present.

Wildlife Species	Locations
Mink	**WOG**
Human	**WAF, BHO, HRC, CRA, CAC, INA, ROS, JDH, HCG, WOG, NST**
Red Squirrel	**-**
Gray Squirrel	**BHO, ROS, HCG**
Fox Squirrel	**WAF, BAF, PKP, BHO, HRC, CRA, CAC, INA, ROS, CCT, JDH, HCG, WOG, NST**
Dog	**BAF, BHO, HCG, NST**
Cat	**WAF, BAF, PKP, CAC, ROS, HCG**
Chipmunk	**WAF, WFD, ROS**
Woodchuck	**PKP**
Deer	**WAF, CRA, CAC, INA, ROS, WOG**
Red Fox	**BAF, PKP, BHO, HRC, CRA, CAC, ROS, HCG**
Raccoon	**WAF, BAF, PKP, BHO, HRC, CRA, CAC, INA, ROS, CCT, HCG, NST**
Rabbit	**WAF, BAF, PKP, BHO, CRA, CAC, INA, ROS, CCT, HCG, WOG**
Opossum	**WAF, BAF, PKP, BHO, HRC, CAC, ROS, CCT, HCG, WOG**
Coyote	**WAF, WOG, NST**

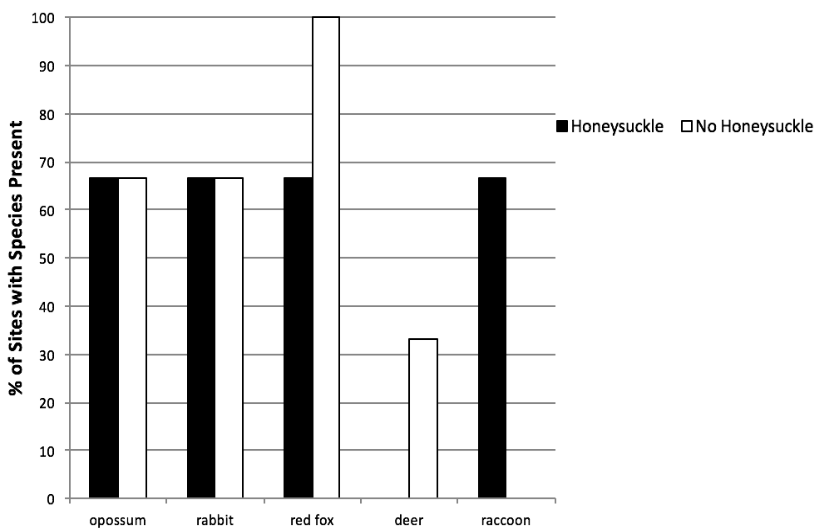


Figure 8: For BWW locations only, percent of sites with species present at honeysuckle invaded sites (n=3) and non-invaded sites (n=3). Invasion was set at a honeysuckle cover of >50%. All three invaded sites had cover >80%. Other sites had honeysuckle cover <10%.