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Habitat Suitability Study of Parcel in Gourdneck State Game Area for Downy Woodpeckers

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Geography: Environmental Analysis and Resource Management
Carl and Winifred Lee Honors College, Senior Honors Thesis

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ABSTRACT

This study examines the habitat suitability for Downy woodpecker for a parcel of land in Gourdneck State Game Area, Portage, Michigan. Land within the State Game Area has undergone habitat restoration from forest and shrub to savanna and prairie, intentionally excluding two parcels directly north of the restoration. This study took place on one of the excluded parcels. Using the Habitat Suitability Index Model produced by the Fish and Wildlife Service, basal area and number of snags within the study site were measured to determine suitability of the study site for Downy woodpeckers. Ten-1/10th acre sample plots were randomly chosen over the study site to measure a total of 0.4 hectare, or 1 acre. Results from this study revealed the study site holds moderate value for the food life requisite at 46% suitability, measured through basal area, and a high value for the reproduction life requisite at 100% suitability, measured through the number of snags.

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I. Introduction

For many years, landscape change has occurred throughout the United States. The American Dream and the onset of urban sprawl have deeply affected the landscape and the species that occupy these landscapes. Landscape changes that continue to occur are causing habitats to be depleted, destroyed, and/or eliminated (Lindenmayer and Fischer 2006). Many species have been forced to find other lands suitable for survival. This may require seeking new sources of food, reproduction, and shelter. Some species have the ability to cope more so than others. This determines the survival of a species population. In some cases, urban sprawl and landscape changes have caused the demise of a species, which in turn can cause population increases for other species, wreaking havoc on an ecosystem. For example, the loss of a predator, such as wolf or coyote, has the ability to cause deer and rabbit populations to increase. This increase in population can stress the ecosystem, leaving it unable to carry such capacity, causing other collapses in the system and creating a negative domino effect (National Geographic 2015).

Just as urban sprawl has affected the habitats of many different species, habitat restoration also affects certain species. For example, Gourdneck State Game Area has been undergoing habitat restoration on a very large parcel of the State Game Area. This means there is a planned initiative to change the landscape, in this case from forested land to prairie and savannah, in an effort to create a more suitable habitat for certain species (Department of Natural Resources 2015). While this habitat restoration is beneficial to the species being managed, such as wild turkeys and cottontail rabbits, the improvements could be disadvantageous to species that survive within forests, such as the Downy woodpecker.

This study focuses on the species *Picoides pubescens*, more commonly known as the Downy woodpecker. Downy woodpeckers are generally found in habitats with attributes such as deciduous, riparian, and open areas, with little presence in coniferous forests. The Downy woodpecker is also known to occupy areas that have been influenced by humans such as urban and suburban parks and residential areas (Jackson and Ouellett 2002). However adaptive the Downy woodpecker may be, there is still a need for suitable habitat for the species to continue to hold steady population numbers.

Although this habitat restoration brings opportunity for prairie and savanna type habitat, the restoration also sacrifices habitat for species in need of forested or wooded landscapes, such as the Downy woodpecker. This leads us to the purpose of this study: Is the remaining parcel of forested land within the Gourdneck State Game Area (GSGA) a suitable habitat for the Downy woodpecker? Using the Habitat Suitability Index (HSI) model for the Downy woodpecker produced by the Fish and Wildlife Service, I determined whether or not a remaining parcel of forested land is suitable enough for the Downy woodpecker to remain foraging and reproducing in this particular forested area.

This study examines whether or not a particular parcel of land in the Gourdneck State Game Area is suitable for Downy woodpecker habitat requirements. The hypothesis guiding this

research is that the study site is 100% suitable for the Downy woodpecker consistent with both variables (basal area and number of snags) necessary for suitable habitat.

The remainder of this thesis is organized as follows. The literature review in Section II will discuss how landscape change and human modification has fragmented species habitats, contributing to habitat reduction and loss. The literature review also includes general research regarding the Downy woodpecker, including foraging needs and reproductive needs contributing to the level of suitability necessary for a highly valued Downy woodpecker habitat. A short description of the model used for this study is included at the end of Section II. Section III, Methodology, includes detailed information regarding the study site, data collection methods, and data analysis. Section IV provides the final results of this study and includes a discussion of the results and final findings. The conclusion of this study is presented in Section V.

II. Literature Review

Over the span of many decades, landscape change throughout the United States has thoroughly altered the spatial habitats of many different species. Most species are forced to adapt or flee from these landscape changes. Landscape change, which refers to the human perspective of changing the landscape through clearing of vegetation and human modification, is at the forefront of species habitat modification and change (Lindenmayer and Fischer 2006).

Landscape Change and Human Modification

The term landscape, from a human perspective, is defined as an area of hundreds, even thousands of hectares (Lindenmayer and Fischer 2006). Habitat fragmentation, an ambiguous term alongside the term landscape change, is literally the "breaking apart" of habitats that were once contiguous (Bennett and Saunders 2010). There are three processes that are interrelated with habitat fragmentation: 1) original vegetation decreases resulting in habitat loss; 2) the habitat left intact after initial changes is subject to habitat subdivision resulting in fragmented landscapes and increasing edge effect; and 3) new land uses replace the vegetation once present (Bennett and Saunders 2010). Habitat fragmentation, however, is considered a meaningless concept due to studies being unable to distinguish between the latter two processes, which is why the term landscape change is more widely used to define the processes that result from these changes (Lindenmayer and Fischer 2006).

The three processes have impacts on the physical processes that would normally occur prior to the changing of the landscape, with great impact occurring on the boundaries of these fragmented landscapes (Bennett and Saunders 2010; Lindenmayer and Fischer 2006). Areas that are oddly shaped or areas that are small and compacted will see an increase in edge effect. In ecological terms, edges are areas where different ecosystems come together. The areas where these different and diverse ecosystems meet are identified as ecotones (Clary and Medin 1999) These ecotones, and increasing amounts of them, create this edge effect, which can affect the physical processes present in these areas (Bennett and Saunders 2010; Clary and Medin 1999). For example, "the microclimate at a forest edge adjacent to cleared land differs from that of forest interior in attributes such as incident light, humidity, ground and air temperature, and wind speed" (Bennett and Saunders 2010, pp. 90-91). Consequently, these physical changes can have considerable effects on the biological processes that can determine the physical structure and overall health of the vegetation (Bennett and Saunders 2010; Hufkens et al. 2009; Lindenmayer and Fischer 2006).

When looking at two different classifications of landscape change, one by Forman (1995) and one by McIntyre and Hobbs (1999), similarities emerge in recognition of landscape changes. Forman (1995) described five ways in which humans spatially alter the landscape over time resulting in changes of ecological processes and the way plants and animals distribute themselves (Lindenmayer and Fischer 2006). These five landscape changes are similar to those described by McIntyre and Hobbs (1999), and are: 1) perforation; 2) dissection; 3)

fragmentation; 4) shrinkage; and 5) attrition; all of which result in less connectivity between contiguous land parcels. Rather than looking at different kinds of fragmentation, McIntyre and Hobbs (1999) discuss the impact of increasing human modification. They believed that as modification of landscape by humans increased, there is a decrease in habitat. This decrease in habitat produces an increase in habitat degradation. When looking at both Forman (1995) and McIntyre and Hobbs (1999), the similarities between their studies and models begin to emerge. Both studies determine landscape change results in interrupted, fragmented land cover, which in turn affects the flora and fauna present in the area. Both studies determine that human modification of landscape causes a decrease in the average size of vegetation tracts, with an increase in the distance between these tracts. All of which result in an increase in the amount of tract edges and a decrease the amount of suitable interior forestland for many species (Bennett and Saunders 2010; Lindenmayer and Fischer 2006).

Downy Woodpecker: General Research

With the exception of parts of Texas and the arid southwest (McCommons 2002), Downy woodpeckers inhabit virtually the entirety of North American where trees and forests can be found (Bent 1939). Measuring 14.5 to 17 centimeters long and weighing 20 to 28 grams, the Downy woodpecker is the smallest of all the native woodpecker species in North America (Kirschbaum 2005) (Figure 1).

Beal (1911) describe the Downy woodpecker as "one of our most useful species", which is true in many ways. Many birds, not just woodpeckers, consume harmful invasive species, often in large quantities. However, the rate at which Downy woodpeckers consume destructive larvae is effective in controlling insects considered to be pests (Bruns 1960; Beal 1911). For example, the woodpecker is a known predator to the *Agrilus planipennis* (emerald ash borer, or EAB), an invasive beetle that can cause detrimental damage to ash trees (Lindell et al. 2008). When studied, a positive correlation was found between woodpecker predation levels and density of EAB in a tree, with the Downy woodpecker spending much of its time in ash trees (Lindell et al. 2008). According to Beal (1911), the Downy woodpeckers food selection consisted almost entirely of economically harmful species.

Another benefit of a strong Downy woodpecker population is that Downy woodpeckers usually excavate a new nest cavity each year, leaving their old nest cavities for secondary cavity nesters, or those who do not excavate their own nests. "It is well-know that woodpeckers provide cavities for secondary cavity-nesters" (Virkkala 2008, pp. 82). The Downy woodpecker provides secondary cavities for *Sitta canadensis* (red-breasted nuthatches), which are found to rebound their population in areas following a year of Downy woodpeckers nesting in the area (Norris and Martin 2010).

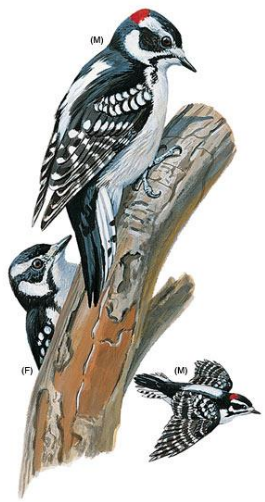


Figure 1: Untitled, Artist depiction of male and female Downy woodpecker. Source: Malick, D.L. (2006)

Foraging needs

Beal (1911) examined the stomachs of 723 of Downy woodpeckers to understand their diets. He concluded 76.05% of their diets consisted of animal foods, such as beetles, caterpillars, ants, while the remaining 23.95% of their diets consisted of vegetable matter, such as seeds and fruit. The foraging behavior of the Downy woodpecker generally varies by efficiency of acquiring food, meaning the bird will use the most efficient method. There are four foraging behaviors used by the Downy woodpecker: percussion, scaling, peering and poking, and flycatching (Jackson 1970). Percussion refers to the "rapid continuous series of blows" the woodpecker produces on a limb, digging out its prey once found. Scaling occurs when the woodpecker moves up and down a tree or trunk, stopping if food presents itself. Peering and poking is self-descriptive, in that the woodpecker utilizes its known senses to find its prey. Flycatching, the most infrequent of all the methods, is usually observed when gatherings of insects occur around sap coming from the tree. Williams (1975) found in a study of the central forests of Illinois that Downy woodpeckers generally forage more in lower areas of trees, as oppose to high in the tree canopies. It was also noted Downy woodpeckers foraged more often through the use of live limbs rather than dead limbs.

It was determined that Downy woodpeckers foraging needs are meet when basal areas measure between 10 and 20 m^2/ha (Schroeder 1982). Although 10 to 20 m^2/ha is ideal for foraging needs of the Downy woodpecker, the species is still capable of finding food in areas where the basal area is greater than 20 m^2/ha.

Reproductive needs

The importance of nesting for a Downy woodpecker is directly related to their ability to reproduce, meaning without a nest/cavity, the Downy woodpecker has no means of reproduction, another life requisite key to survival (Kirschbaum 2005; Schroeder 1982). Because it breeds

yearly, each year the Downy woodpecker must either find a new cavity to nest in or excavate another (Kirschbaum 2005).

Evans and Conner (1979) state the Downy woodpecker is a dominant cavity nester, preferring soft snags for nesting sites, such as those found in deciduous forest, evergreen forest and forested wetlands (Kirschbaum 2005; Schroeder 1982). Generally dead or dying wood is necessary for the woodpecker to be successful in creation of the cavity (Kirschbaum 2005; Schroeder 1982). The male and female excavate a nest together about 15.3 meters above ground (Schroeder 1982), with excavation taking anywhere from seven to ten days (Kirschbaum 2005). The HSI being used in this research states that Downy woodpeckers require nesting trees to have diseases, including sap rot and heart rot, which softens the outside and inside of the tree for more efficient cavity excavation (Schroeder 1982).

Kilham (1974) states Downy woodpeckers have an image of an optimal nest site, which consists of live trees with dead, broken off tops. A photograph of four snags with broken of tops at the study site can be seen in Figure 2. A photograph of a snag with woodpecker evidence from the study site can be seen in Figure 3. Ideal nest sites for Downy woodpeckers are mostly in short supply throughout their North American range, consequently limiting Downy woodpeckers in some regions (Schroeder 1982). Through estimation, Evans and Conner (1979) were able to determine that Downy woodpeckers present in northeastern areas of North America require roughly 9.9 snags with a diameter at breast height (DBH) ranging from 15 to 25 centimeters (6 to 10 inches) per hectare, or about 4 snags per acre. The optimal habitat of the Downy woodpecker is 12.4 snags per hectare, or about 5 snags per acre (Schroeder 1982; Evans and Conner 1979). For the purpose of this study, the Habitat Suitability Index Model's reproduction component of 5 snags per acre is used to determine the suitability of the Downy woodpeckers reproduction resources.

Figure 2: Four snags from study site

Figure 3: Snag with evidence of woodpecker activity from study site

Habitat Suitability Index Model

Currently there is only one habitat suitability model available for the Downy woodpecker, published in 1982. Because this suitability index is the only habitat model currently available for the Downy woodpecker, the model was used to complete this study. To determine whether or not the study site is suitable for the Downy woodpecker, an established Habitat Suitability Index Model was used. The Habitat Suitability Index Model (HSI) for the Downy woodpecker was created by Richard L. Schroeder in 1982 and was funded by the United States Department of the Interior, Fish and Wildlife Service. This model, as well as the many other HSI Models for other species, is composed of measurable variables. The HSI Model used is made up of two (2) measurable variables, basal area and number of snags, which are independent of each other. As seen in Figure 4, basal area is correlated to the food component life requisite of the Downy woodpecker, and the number of snags is correlated to reproduction life requisite.

Variable 1 (V_1) of the HSI model is defined as basal area of one acre of land. V_1 was measured by finding the sum basal area of each sample plot. According to Schroeder (1982, pg. 5), "optimal conditions are assumed to occur in stands with basal areas between 10 and 20 m^2/ha (43.6 and 87.2 ft^2/acre), and suitabilities will decrease to zero as basal area approaches zero". This can be seen in Figure 5. To measure basal area of a sample plot, you must first measure the DBH of each tree in the sample plot, measuring at a height of 1.4 m (4.5 ft) above the ground (Schroeder 1982). Each DBH recorded was then converted to basal area.

Variable 2 (V_2) of the HSI model by definition is the number of snags within one acre. Snags are defined as "trees in which at least 50% of the branches have fallen, or are present but no longer bear foliage" (Schroeder 1982, pg. 7). V_2 is measured by finding, within each sample plot, the trees that are to be considered snags according to the definition above. For the snags to be considered suitable, they must be larger than 15 cm, or 6 inches, DBH. This is seen in Figure 6.

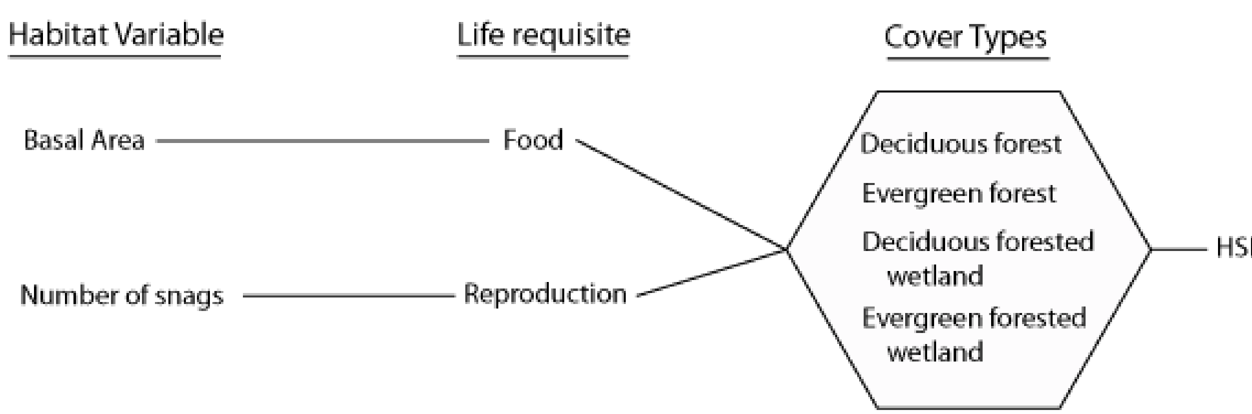


Figure 4: Relationship of habitat variables, life requisites, and cover types in the Downy woodpecker model. Source: Schroeder (1982)

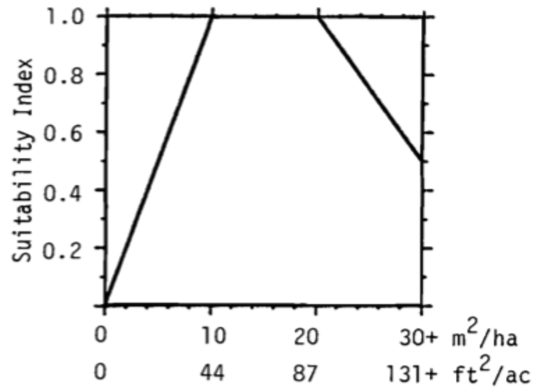
Cover type	Variable		Suitability graph
EF,DF, EFW,DFW	V_1	Basal area.	

Figure 5: Suitability Graph for Variable 1 (V_1), Basal Area. Source: Schroeder (1982)

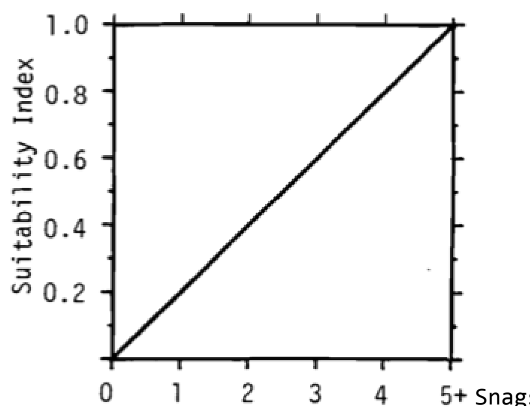
EF,DF, EFW,DFW	V_2	Number of snags > 15 cm dbh/0.4 ha (> 6 inches dbh/ 1.0 acre).	

Figure 6: Suitability Graph of Variable 2 (V_2), Number of snags. Source: Schroeder (1982)

III. Methodology

Study Site

The study site is located in the State of Michigan within Kalamazoo County, in Portage Township. It can be found on a USGS quadrangle map in Section 20 of Township 3 South, Range 11 West. Located within Gourdneck State Game Area (GSGA), the single parcel of land is south of Centre Avenue, east of US-131, west of Oakland Drive, north of Vanderbilt Avenue, and can be seen outlined in red in Figure 7.

The larger parcel of land located within Section 30 and 31 of T3S, R11W, is currently undergoing a habitat restoration project in which the area is being transformed from forested land to prairie and savanna. Prairie and savanna originally covered the land before the introduction of agriculture and farming. Many of the prairie and savanna ecosystems once present in southwest Michigan were lost many years ago to the development of agriculture (Chapman and Brewer 2008). This restoration project, which began in 2005, is in the final stages (Department of Natural Resources 2015).

Because of the larger habitat restoration project coming to its term within GSGA, the study site was chosen to determine whether or not suitable Downy woodpecker habitat is still available in the area. The study site and a similar parcel directly west, which are smaller parcels located directly north of the largest parcel in GSGA, have been intentionally left out of the ongoing restoration project for evaluation as to whether or not they continue to serve the purpose in which they were purchased (Crane Pond Field Office 2005). Even though landscape change, in this case urbanization, has detached the smaller parcels from the larger, it is believed that the smaller parcels (including the study site) are still large enough to support some interior habitat for woodland species (Crane Pond Field Office 2005).

Because of the belief that the remaining smaller parcels within GSGA carry some capacity for interior habitat, it is seemingly necessary to determine whether this area is fit for sustaining some species habitat. To measure the habitat suitability of the study site for the Downy woodpecker, a Habitat Suitability Index (HSI) Model was used.

Data Collection

To use the model properly, 0.4-hectare (one acre) of measurements must be obtained. To gain a clearer picture of the study site, the areas of measurement must be spread out randomly throughout the study site. It would be unreasonable to measure one acre in one small corner of the study site, as most of the flora is diverse and of different ages throughout the area. It was determined that ten, one-tenth acre plots randomly distributed would be sufficient for measuring one acre of the study site (Washington State University Extension).

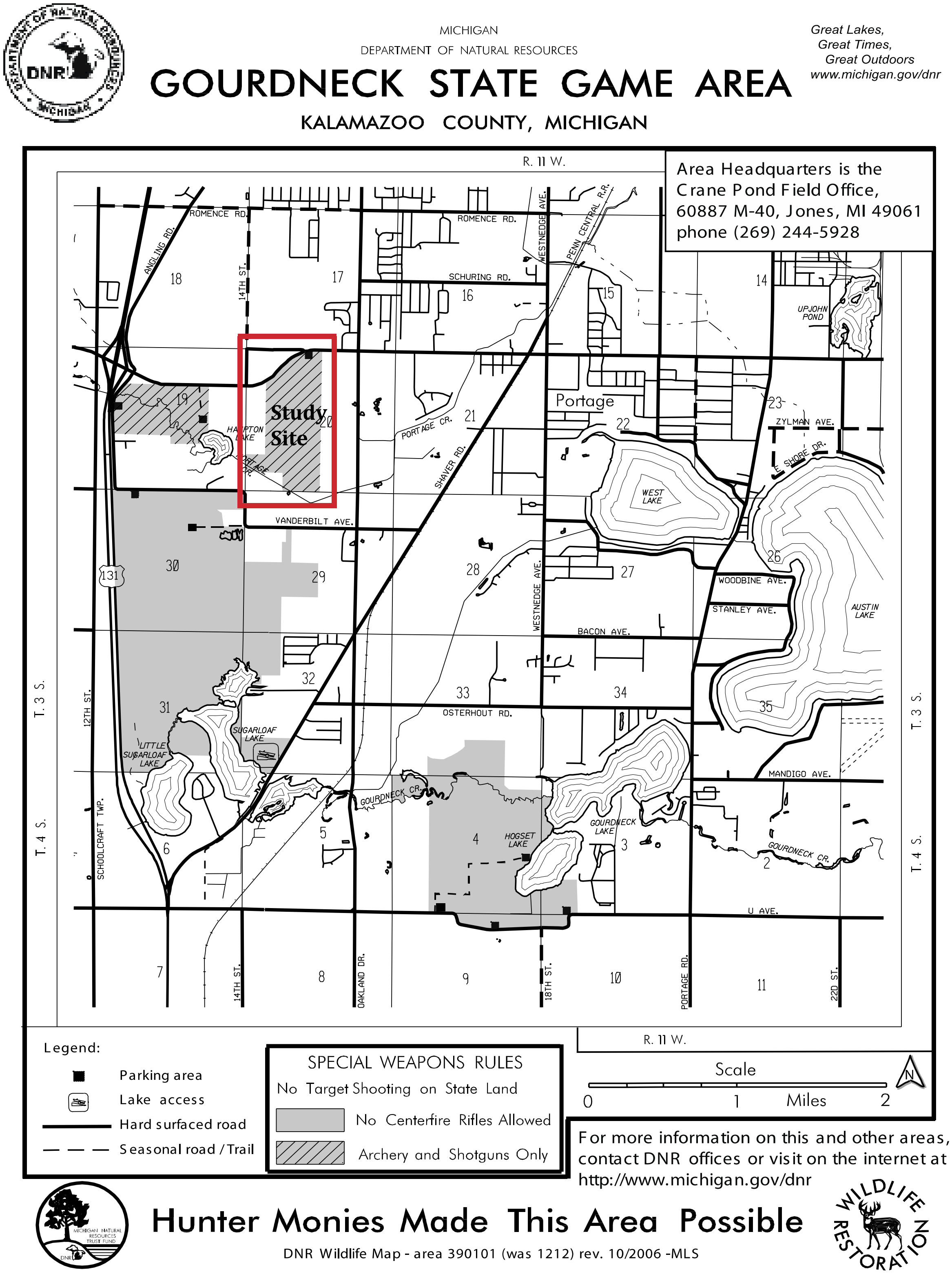


Figure 7: Map of Gourdneck State Game Area with Area of Study Selected. Source: Crane Pond Field Office (2005).

To accomplish this, a map of the study site was created using ArcMap 10.1, a Geographic Information Systems (GIS) program (ESRI 2011) (Figure 8). Next, a random sampling system was created to determine eleven random points within the study site. Ten of these points were used as center points for the one-tenth acre sample plots, with one extra point to be used if one point was unreachable or immeasurable. For each of the ten sample plots to equal one-tenth of one acre a circle of 11.3-meter radius was laid out at each point. Within each plot, the basal area of all trees and the number of snags were recorded.

Each sample plot was visited on foot using a Geographical Positioning System (GPS) unit as guidance to each center point. Once a sample plot was reached, each tree within the plot was measured and recorded within the circle of 11.3-meter radius. Of each tree measured, it was determined and recorded as to whether or not they were snags.

Data Analysis

DBH of each recorded tree within each sample plot was measured using feet and inches. Because values were recorded in standard format, Equation 1 was used to convert DBH to basal

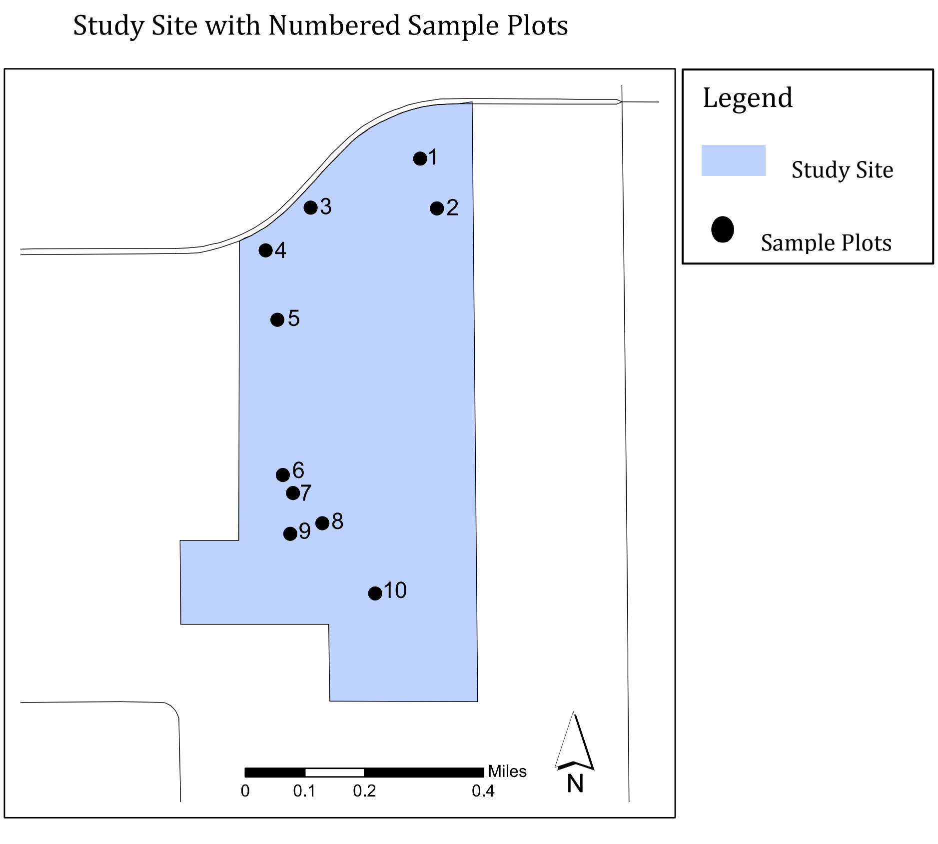


Figure 8: Map of Study Site within Gourdneck State Game Area

area for each individually recorded tree. Equation 1 is the standard formula for converting DBH to basal area and can be seen below.

Once each individual tree's basal area was calculated, the sum of each tree's basal area in one sample plot provided the basal area of that sample plot. The basal area of all ten sample plots was then summed to determine the basal area of 0.4/ha, or one acre, of land within the study site. This total basal area was then compared with the HSI model's graph as seen in Figure 5 to determine whether or not the study site was suitable for the food life requisite.

For snags, the number of snags were simply counted and recorded within each sample plot's radius. Because each sample plot is equal to 1/10th of an acre, the sum of snags in each sample plot provided the number of snags present in one acre of the study site. The total number of snags recorded in the study site was then compared with Figure 6 to determine whether or not the study site was suitable for the Downy woodpeckers reproduction life requisite.

$$0.005454 \times DBH^2 = \text{Basal Area in } ft^2 \qquad \text{Equation 1}$$

IV. Results and Discussion

Individual sample plot data can be viewed in Appendix A. For basal area, the final result from the study site was 31.03-m^2/ha (135.48-ft^2/acre). The suitability of the Downy woodpeckers food life requisite, or Variable 1, was measured to be 46% when plotting the final result of 31.03-m2/ha basal area on the HSI model's graph, seen in Figure 9. Schroeder (1982, pg. 5) does state that, "optimal conditions are assumed to occur in stands with basal areas between 10 and 20 m^2/ha (43.6 and 87.2 ft^2/acre)". Although the percentage of suitability seems low, the HSI model states "stands with basal areas greater than 30 m^2/ha (130 ft^2/acre), or about 50% suitability, are assumed to have moderate value for Downy woodpeckers" (Schroeder 1982). So, although the study site is not 100% suitable for the food life requisite, the study site does appear to have moderate value.

For number of snags, the final result from the study site was 15 snags/0.4 ha, or 15 snags/acre. The optimal habitat of the Downy woodpecker is stated to be 12.4 snags per hectare, or about 5 snags per acre (Schroeder 1982; Evans and Conner 1979). The suitability of the Downy woodpeckers reproduction life requisite, or Variable 2, was measured to be 100% using the HSI model's graph in Figure 6. This result indicates the study site was very valuable to Downy woodpeckers with respect to their reproductive needs.

The original hypothesis stated that both basal area and number of snags would be100% suitable for the habitat necessities of the Downy woodpecker. The study results indicate that this hypothesis cannot be accepted. Although the number of snags yielded a final result of 100%, as the hypothesis predicted, basal area was only 46%. Even though the hypothesis for this thesis cannot be accepted, it does not mean that the study site does not hold any value.

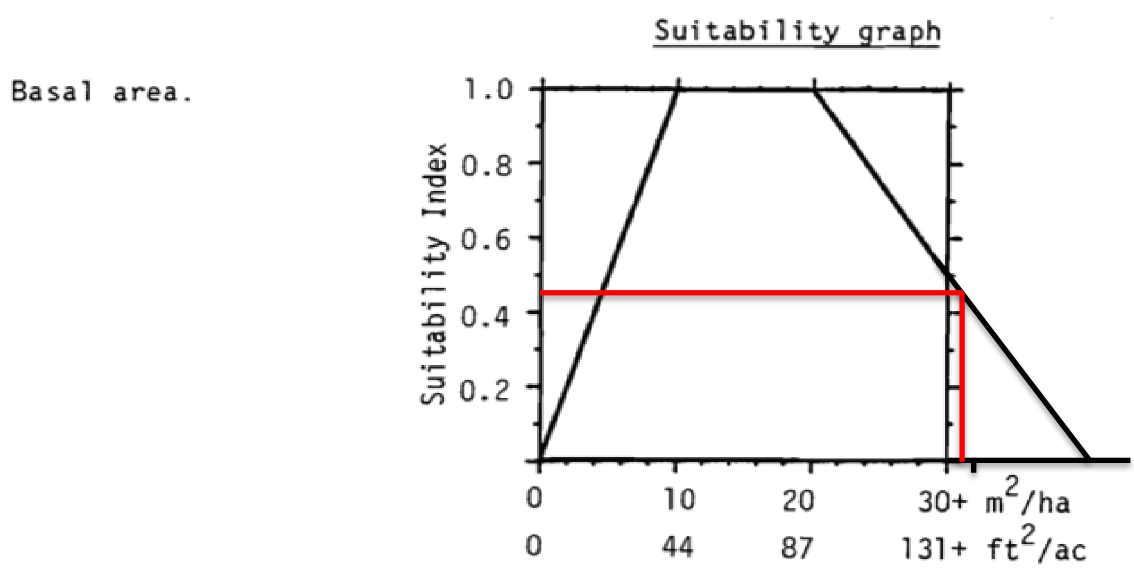


Figure 9: Final Results - Basal Area of one acre at Study Site. Source: Schroeder, R.L. 1982

If the management at GSGA would like to create optimal habitat for the Downy woodpecker, the amount of basal area within the study site would need to be decreased. Schroeder (1982) states that optimal basal area densities for Downy woodpeckers are between 10 and 20 m^2/ha (43.6 and 87.2 ft^2/acre). With a current basal area of 31.038 m^2/ha, the study site's basal area would need to be reduced by about 11 m^2/ha to reach 100% suitability for the Downy woodpecker, which equals a reduction in basal area of about 35%. To accomplish this, certain forest management methods of reducing basal area would need to be reviewed.

Specific to basal area, northern hardwood forests such as those in Michigan have been studied and were found grow at their best when basal area was between 70 and 90 ft^2/acre (Neumann 2001). This ideal range of basal area for northern hardwood forests is consistent with habitat suitability needs of the Downy woodpecker for Variable 1. When basal area of a forest or stand becomes too dense, tree growth and health begin to slow and decline, respectively. It is suggested that forests with basal areas reaching 100 ft^2/acre or more should be subject to thinning using forest management practices (Neumann 2001). Thinning of a forest or stand would normally require mostly dead, diseased, or injured trees to be removed from the stand. However, if thinning were to occur on the study site for this purpose, it would be important to remember that Downy woodpeckers do require some dead or diseased trees for cavity excavation (Kirschbaum 2005; Neumann 2001; Schroeder 1982).

The removal of dead or diseased trees could affect the number of snags in the study site if too many of those trees were removed or destroyed. An optimal habitat requires at least 5 snags per acre for 100% habitat suitability of the Downy woodpecker. If forest thinning were to occur to increase the suitability of basal area, too much thinning could cause a decrease in suitability. To reach 100% suitability at the study site for Downy woodpecker habitat for both basal area and number of snags, a thinning initiative would require both proper planning and understanding of the relationship between both variables. In this particular case, management could visit the sample plots measured in this study and cut down some of the bigger trees with larger basal areas. It was found that if five of the fifteen largest recorded snags were cut down, along with ten more of the largest non-snags recorded, the basal area would be reduced to 18.3966 m^2/ha, This can be seen in Figure 10, which shows both the measured suitability of the study site and the potential suitability if this action were taken, with dashed and solid lines respectively. Not only would the basal area suitability become 100% in this case, the suitability of the number of snags would be unaffected because ten snags of fifteen would still be standing. This would be a temporary solution to produce 100% suitability for both basal area and number of snags, however, if this method were repeated over the course of many years, the suitability may become consistent at 100%.

Although the habitat restoration being implemented within Gourdneck State Game Area has caused a loss of habitat for forest dwelling species, the results of this study show the study site still holds moderate to high value for the variables associated with suitable Downy woodpecker habitat.

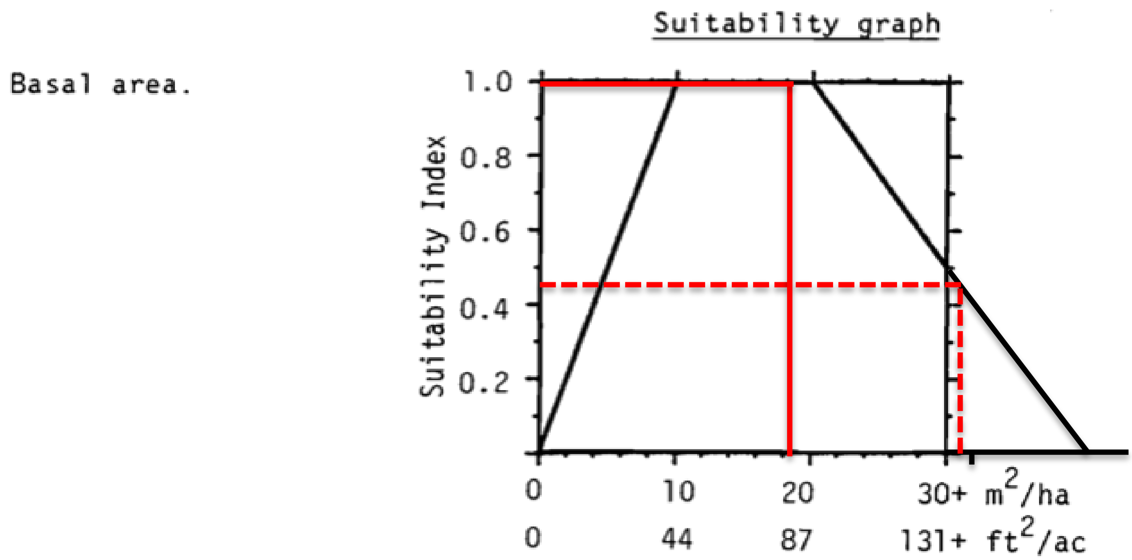


Figure 10: Basal Area suitability before and after management suggestion. The dashed line represents the final result for basal area of the study. The solid line represents the potential suitability if suggestion to remove certain trees from study site were taken into consideration.

V. Conclusion

Due to extensive urban sprawl and urbanization, many species' habitats become victim to the ever-changing landscape. Many species have the ability to adapt to major habitat changes; however, some species are unable to adapt to the fast paced changes humans have produced. Fortunately for the Downy woodpecker, their adaptive capabilities allow the species to occupy areas that have been influenced by humans, such as urban, suburban, and residential parks and areas (Jackson and Ouellett 2002).

Despite the larger restoration project underway within GSGA, these results show that the remaining parcel within GSGA, intentionally left out of the greater ongoing restoration project, is considered suitable habitat for Downy woodpeckers. As you recall, the study site holds moderate value for food necessities (basal area, 46%) and a very high value for reproductive necessities (number of snags, 100%) for the Downy woodpecker. Although this study did not accept the hypothesis, the Downy woodpecker still has potential habitat available to their species within other areas of GSGA.

If this study were to be expanded or repeated, it would be suggested to measure other parcels within GSGA to determine whether or not the entire State Game Area contains suitable habitat for the Downy woodpecker. Referring back to Figure 4 and the relationship between life requisites, it shows that habitats capable of supporting Downy woodpeckers include deciduous and evergreen wetland areas. Of the two parcels intentionally left out of the greater ongoing restoration project within the State Game Area, one parcel consisted mostly of deciduous wetland land cover and the other of mostly deciduous forest land cover. Because of the inaccessibility of wetlands and the fragility of their ecosystems, the parcel with less wetland land cover was chosen as the study site. However, because deciduous wetlands are capable of supporting suitable Downy woodpecker habitat, it would be reasonable to expand this study to the neighboring parcel to determine its suitability.

When viewing both parcels using aerial photography, the wetland parcel appeared to have less basal area than the deciduous forest within the study site. This could mean that the wetland parcel located west of the study site could hold greater habitat suitability for the Downy woodpecker than the study site measured for this thesis. This study could be repeated on the wetland parcel and others within GSGA to gain a greater understanding of the suitability of Downy woodpecker habitat within the entire State Game Area.

Limitations of this study included time, area of study, lack of geographical distribution with sampling system, and lack of up to date suitability index models relating to the Downy woodpecker. A limited amount of time to perform this study constrained the amount of data collected. If more time was allotted for this study, the amount of data collected could have been greater and allowed for more accuracy for the final results. Time also limited the size of the study site, restricting the study site to one parcel within GSGA. More time would have allowed for more area of the State Game Area to be studied, determining the suitability of the entire State Game Area. Lack of multiple models for habitat suitability limited this study to one habitat

suitability model. Future studies may find that more variables contribute to habitat suitability of the Downy woodpecker. The deciduous wetland parcel located west of the study site, and other areas of the State Game Area, could have been measured for suitability if proper equipment had been available.

All of the limitations mentioned deny this study from determining the overall suitability of Downy woodpeckers in the area. If more time and equipment had been available, and more land had been studied, this study would be more robust and complete. An expansion of this study could overcome these limitations.

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Appendix A

Final Results

Plot #	Feet	inches	DBH (inches)	DBH^2 (inches)	Basal Area (ft^2)	Basal Area (m^2)	V1 Sum Basal Area (per plot)	V2 Snag?
1	2	9	33	1089	5.939406	0.55179		N
	2	9	33	1089	5.939406	0.55179		N
	5	1	61	3721	20.294334	1.8854		N
	2	10	34	1156	6.304824	0.58574		N
	2	7	31	961	5.241294	0.48693		N
	2	9	33	1089	5.939406	0.55179		N
	3	2	38	1444	7.875576	0.73166		N
	2	8	34	1156	6.304824	0.58574		N
							5.93084	
2	3	11	47	2209	12.047886	1.1193		N
	2	9	33	1089	5.939406	1.55179		Y
	3	8	44	1936	10.558944	0.98096		N
	3	1	37	1369	7.466526	0.69646		Y
	7	9	93	8649	47.171646	4.3796		N
	3	0	36	1296	7.068384	0.65667		N
	13	1	157	24649	134.435646	12.489		N
							21.87378	
3	3	3	39	1521	8.295534	0.77068		N
	4	7	55	3025	16.49835	1.5327		N
	4	7	55	3025	16.49835	1.5327		N
	2	5	29	841	4.586814	0.42613		N
	3	8	44	1936	10.558944	0.98096		N
	3	2	38	1444	7.875576	0.73166		Y
	2	3	27	729	3.975966	0.36938		N
	4	2	50	2500	13.635	1.2667		Y
	4	7	55	3025	16.49835	1.5327		Y
	3	9	45	2025	11.04435	1.0261		N
	5	10	70	4900	26.7246	2.4828		N
	3	4	40	1600	8.7264	0.81071		N
	5	1	61	3721	20.294334	1.8854		N
							15.34862	
4	4	1	49	2401	13.095054	1.2166		N
	3	8	44	1936	10.558944	0.98096		N
	3	5	41	1681	9.168174	0.85175		N
	3	2	38	1444	7.875576	0.73166		N
	2	1	25	625	3.40875	0.31668		N
	1	9	21	441	2.405214	0.22345		N
	2	0	24	576	3.141504	0.29186		N
	2	2	26	676	3.686904	0.34252		N
	1	10	22	484	2.639736	0.24524		N
	3	4	40	1600	8.7264	0.81071		N
							6.01143	

5	4	2	50	2500	13.635	1.2667		N
	3	2	38	1444	7.875576	0.73166		N
	2	11	35	1225	6.68115	0.6207		N
	4	0	48	2304	12.566016	1.1674		N
	3	5	41	1681	9.168174	0.85175		N
	3	0	36	1296	7.068384	0.65667		N
	3	6	42	1764	9.620856	0.89381		N
	3	0	36	1296	7.068384	0.65667		N
	3	0	36	1296	7.068384	0.65667		N
	4	1	49	2401	13.095054	1.2166		N
	4	0	48	2304	12.566016	1.1674		N
	3	5	41	1681	9.168174	0.85175		N
	2	8	32	1024	5.584896	0.51885		N
	3	11	47	2209	12.047886	1.1193		N
	4	9	57	3249	17.720046	1.6462		N
	3	11	47	2209	12.047886	1.1193		N
	3	7	43	1849	10.084446	0.93688		N
	4	3	51	2601	14.185854	1.3179		N
	2	11	35	1225	6.68115	0.6207		N
	3	9	45	2025	11.04435	1.0261		N
	3	8	44	1936	10.558944	0.98096		N
	4	11	59	3481	18.985374	1.7638		N
	2	6	30	900	4.9086	0.45602		N
	3	5	41	1681	9.168174	0.85175		N
							23.09554	
6	3	7	43	1849	10.084446	0.93688		N
	3	6	42	1764	9.620856	0.89381		N
	3	4	40	1600	8.7264	0.81071		N
	2	8	34	1156	6.304824	0.58574		N
	3	7	43	1849	10.084446	0.93688		N
	2	10	34	1156	6.304824	0.58574		**Y**
	3	4	40	1600	8.7264	0.81071		N
	3	6	42	1764	9.620856	0.89381		N
	3	7	43	1849	10.084446	0.93688		N
	3	6	42	1764	9.620856	0.89381		N
	3	6	42	1764	9.620856	0.89381		N
							9.17878	
7	3	2	38	1444	7.875576	0.73166		**Y**
	3	1	37	1369	7.466526	0.69646		N
	3	7	43	1849	10.084446	0.93688		**Y**
	3	3	39	1521	8.295534	0.77068		**Y**
	2	1	25	625	3.40875	0.31668		N
	2	6	30	900	4.9086	0.45602		**Y**
	2	11	35	1225	6.68115	0.6207		N
	2	1	25	625	3.40875	0.31668		N
	3	1	37	1369	7.466526	0.69646		N
	3	6	42	1764	9.620856	0.89381		N
	6	8	80	6400	34.9056	3.2428		N
	1	10	22	484	2.639736	0.24524		**Y**
	5	8	68	4624	25.219296	2.3429		N
	2	9	33	1089	5.939406	0.55179		N
	3	2	38	1444	7.875576	0.73166		N
							13.55042	

8	2	7	31	961	5.241294	0.48693		N
	1	11	23	529	2.885166	0.26804		N
	8	11	107	11449	62.442846	5.8011		Y
	2	9	33	1089	5.939406	0.55179		N
	4	9	57	3249	17.720046	1.6462		N
	4	2	50	2500	13.635	1.2667		N
	2	7	31	961	5.241294	0.48693		N
	5	5	65	4225	23.04315	2.1408		N
	3	9	45	2025	11.04435	1.0261		Y
							13.67459	
9	3	0	36	1296	7.068384	0.65667		N
	1	10	22	484	2.639736	0.24524		N
	2	8	32	1024	5.584896	0.51885		N
	2	3	27	729	3.975966	0.36938		N
	2	5	29	841	4.586814	0.42613		N
	2	9	33	1089	5.939406	0.55179		N
	2	4	28	784	4.275936	0.39725		N
	2	6	30	900	4.9086	0.45602		N
	2	3	27	729	3.975966	0.36938		N
	2	9	33	1089	5.939406	0.55179		N
	2	7	31	961	5.241294	0.48693		N
	2	2	26	676	3.686904	0.34252		N
	2	7	31	961	5.241294	0.48693		N
	2	6	30	900	4.9086	0.45602		N
	2	11	35	1225	6.68115	0.6207		N
	2	1	25	625	3.40875	0.31668		N
	2	0	24	576	3.141504	0.29186		N
	1	11	22	484	2.639736	0.24524		N
	2	2	26	676	3.686904	0.34252		N
	3	5	41	1681	9.168174	0.85175		Y
	2	10	34	1156	6.304824	0.58574		N
	1	10	22	484	2.639736	0.24524		N
	2	7	31	961	5.241294	0.48693		N
							10.30156	
*10	5	10	70	4900	26.7246	2.4828		N
	1	11	22	484	2.639736	0.24524		N
	6	11	83	6889	37.572606	3.4906		Y
	4	11	59	3481	18.985374	1.7638		N
	6	11	83	6889	37.572606	3.4906		N
	7	9	93	8649	47.171646	4.3824		Y
	2	1	25	625	3.40875	0.31668		N
	2	2	26	676	3.686904	0.34252		N
							16.51464	
							135.4802	15

V1(=(135.4802(ft^2/acre
V2(=(15(snags