Assessment of Forest Regeneration in Mill Creek Park, Huntington Woods, and Hitchcock Woods

June 2023

Introduction:

By definition, forest regeneration is the process that allows a forest to replace and sustain itself in the long-term through the establishment and survival of seedlings and saplings that replace mature canopy trees as they die, either by natural causes or by large disturbance events such as windstorms, wildfire, or disease.

Healthy forest regeneration is a crucial component to forest management to ensure the long-term sustainability of our forest ecosystems for future generations.

Forest regeneration can be influenced by a number of variables such as habitat disturbance, invasive species introduction, disease, and herbivory by ungulates such as white-tailed deer.

While white-tailed deer are known as generalist herbivores, feeding on a wide range of woody and herbaceous plant growth, they are also preferential in their feeding habits which can negatively influence forest regeneration when populations exceed ecological carrying capacity.

In the case of Mill Creek MetroParks, the ecological effects of white-tailed deer overabundance such as distinct browse lines, stunted forest regeneration, and low species diversity have been anecdotally noted in some areas for over two decades, however, the effects of overbrowning have not previously been quantified.

Objectives:

To evaluate current conditions related to forest regeneration based upon seedling and sapling abundance/height and track changes through time in response to management changes such as deer management, invasive species treatment, and/or habitat manipulation.

Methods:

Plot Description

Survey plots (1-acre in size) were distributed throughout Mill Creek Park, Huntington Woods, and Hitchcock Woods where space allowed. Within each survey plot, five (5) microplots were established (6' radius circle). The placement of microplots was standardized, with one microplot placed at the center of each 1-acre survey plot, additional plots were established at a distance of 60' from the center point in four directions.

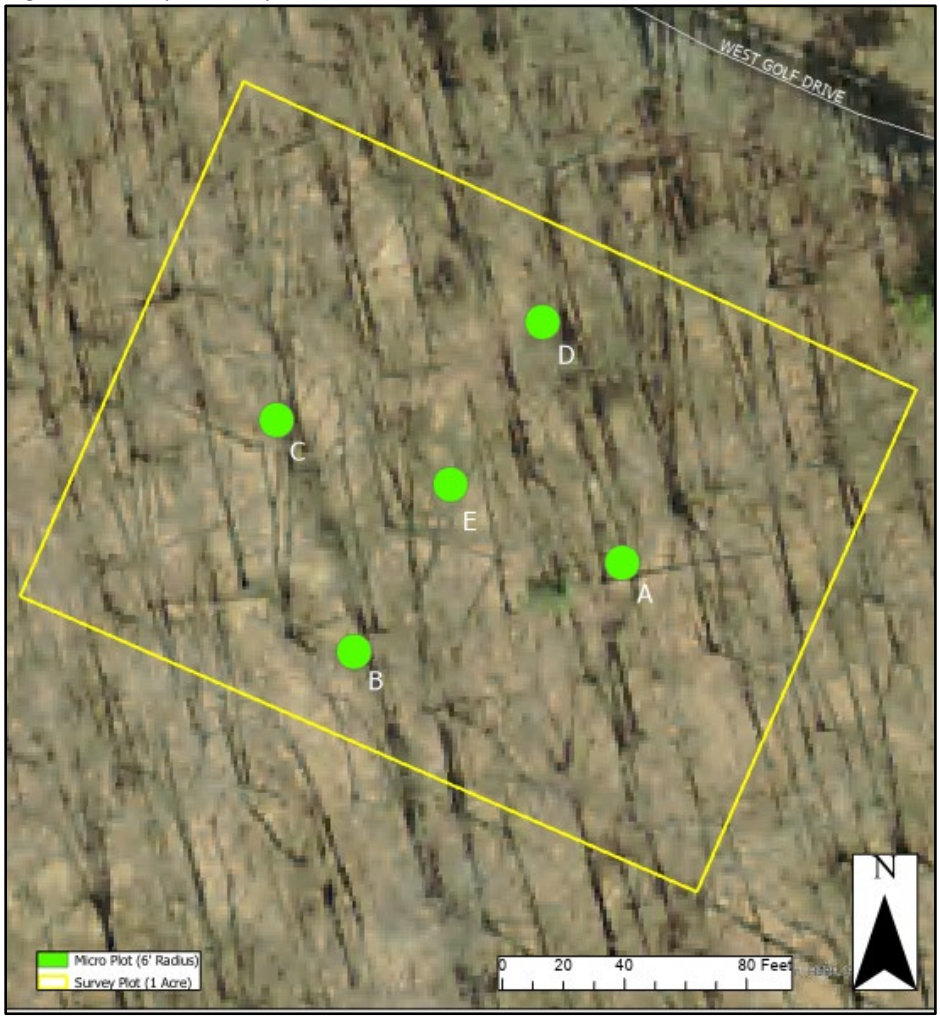
Plot Selection

Survey plots were established in upland hardwood sites with varying degrees of canopy closure (0%-95%). Sites with a lower prevalence of invasive species and desirable light availability were preferred when available to assess forest regeneration under the best possible circumstances given current site conditions. All plot locations were free of human caused disturbance such as logging, prescribed fire, or other active management.

If any of the following conditions are present at the predetermined 60' spacing, the microplot center point will be adjusted to the nearest suitable location:

- Obstructions such as rocks, downed trees, mature trees, roadways, or open water hinder the establishment of the microplot and/or subplot.
- The proposed plot location is located on a slope greater than 70%.
- The proposed plot location is dominated by large invasive shrubs (<75% coverage).

Figure 1. Plot Layout Example



Once microplots are established they are affixed with a permanent stake. These plots will be used to gauge changes in forest regeneration on an annual basis, but may also be used to examine other metrics such as winter browse damage and/or spring ephemeral wildflower abundance.

Data Collection

For the purposes of assessing forest regeneration, all woody vegetation less than 4.5" DBH located within each microplot was identified and categorized based upon size class. Woody vegetation was separated into five (5) size classes: <6", 6-12", 1-3', 3-5', and 5'+ with each size class being assigned a weighted score which reflects the survivability of each size class and it's value in terms of forest regeneration.

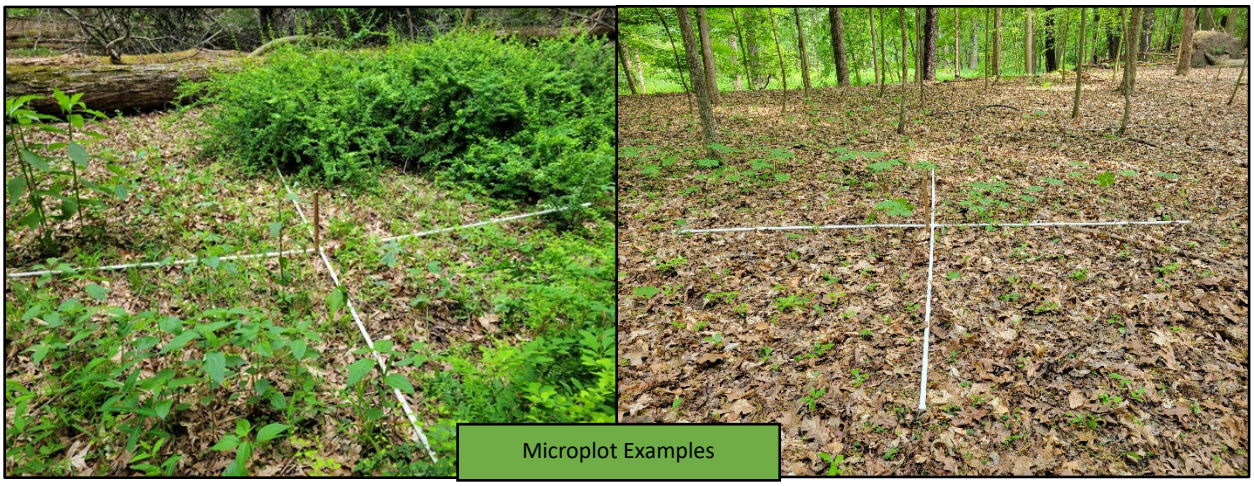
Additionally, percent canopy closure was assessed at the center point of each microplot, and photographs were gathered depicting both current plot conditions and canopy closure.

To provide a control, data was also collected from the deer exclosure located in Hitchcock Woods, which was first constructed in the year 2000 but was not refurbished and fully functional until 2018. The exclosure is 18x18' (324 sq ft) and has ~80% canopy closure directly above but is adjacent to a sizeable light gap to the south.

Figure 3. MCMP Forest Regeneration Scoring Chart

Size Class	Score
0-6"	0
6-12"	1
1-3'	2
3-5' Native Sub-Canopy or Shrub Species	7.5
3-5' Native Canopy Species	15
5'+ Native Sub-Canopy or Shrub Species (<4.5" DBH	15
5'+ Native Canopy Species (<4.5" DBH)	30

- Invasive species are noted but not assigned a positive score.
- Trees showing outward signs of disease or severe damage are scored at half value.
- Ash spp. will not be assigned a positive score due to their lack of long-term viability, caused by the emerald ash borer.
- Each microplot is assessed individually, a score of 150 points or greater signifies that plot as sufficiently stocked for forest regeneration.



Microplot Examples

Results:

22 survey plots (110 microplots) were established throughout Mill Creek Park, Huntington Woods, and Hitchcock Woods the results are as follows:

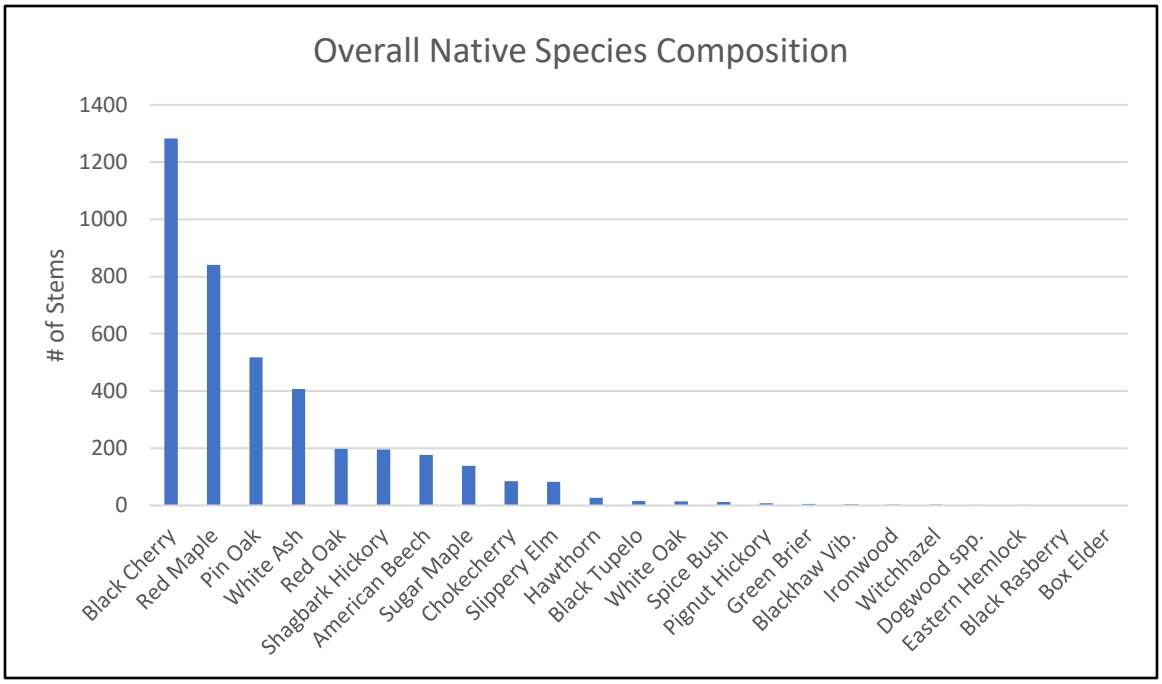
Species Composition and Diversity

In total, 4,446 woody stems were surveyed of those, a total of 22 native species and 8 invasive species were documented – native species accounted for 90% of the total stems surveyed (plots with <75% invasive shrub cover were excluded).

Of the 22 native species identified black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) occurred with the most frequency and in combination account for 53% of all native woody stems. This is not surprising as these species typically have dense seeding rates, fast growth, and are tolerant to a wide range of soil conditions, often times making them the first canopy species to repopulate disturbed areas.

Other prominent species include pin oak (*Quercus palustris*), white ash (*Fraxinus americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), American beech (*Fagus grandifolia*) , sugar maple (Acer saccharum), and slippery elm (*Ulmus rubra*). Other species such as box elder (*Acer negundo*), eastern hemlock (*Tsuga canadensis*), and dogwood (*Cornus spp.)* occurred very infrequently in only 1 or 2 microplots. Of the 22 native species documented, only 11 (50%) were present in the 3-5’ and 5’ size class.

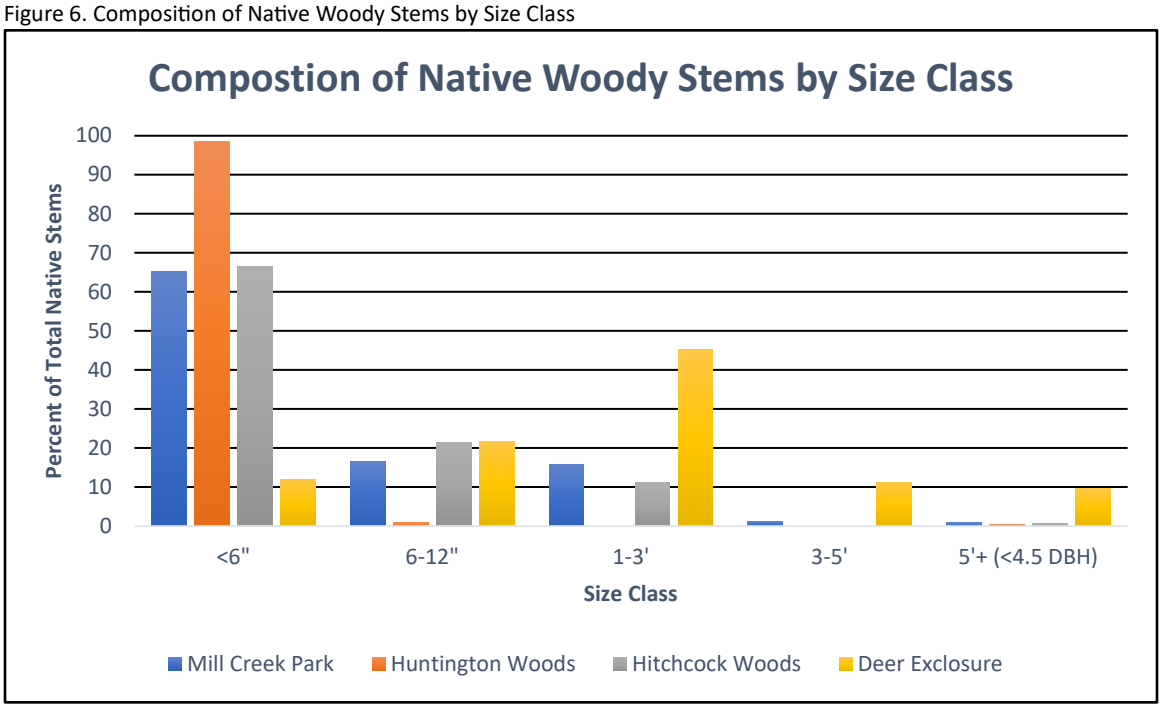
Figure 5. Overall Native Species Composition



Native Woody Stems by Size Class

As stated above, woody stems were separated into five (5) size classes the following data depicts the size class breakdown of woody stems found in all three (3) survey areas and the Huntington Woods deer exclosure.

Figure 6. Composition of Native Woody Stems by Size Class



The results show that overwhelmingly the <6” size class as the most abundant in areas unprotected from deer browsing, overall 75% of all native woody stems surveyed were less than 6” in height. In general, the larger size classes (3-5’ and 5’+) were absent from the unprotected survey areas and accounted for only 1.4% of the total stems surveyed.

On the contrary, in the Hitchcock Woods deer exclosure all size classes were well represented with 45% of stems being found in the 1-3’ size class.

Size Class: <6” (Germinant)

Woody stems less than 6” are considered “germinants” and were by far the most common size class documented– this size class represented 75% of all native woody stems surveyed with black cherry and red maple occurring most frequently. This size class is comprised of newly germinated trees – this is considered a very vulnerable size class with survivability being influenced by many variables such as sunlight availability, soil condition, weather, and herbivory.

Size Class: 6-12” (Small Seedling)

Woody stems from 6-12” are considered “small seedlings” and are typically 0-1 years old, however, this can vary widely based upon species and growing conditions. This size class accounted for 13% of all native woody stems surveyed – white ash and pin oak were the most common species in this size class. Small seedlings are still vulnerable to changes in growing condition and herbivory; however, this size class does have a higher rate of survival as compared to germinants.

Size Class: 1-3’ (Seedling)

Woody stems from 1-3’ are considered “seedlings” and are typically 1-2 years old depending upon species and growing condition. This size class accounted for 10% of all native woody stems surveyed – white ash and shagbark hickory were the most common species in this size class. This size class is less susceptible to environmental conditions such as changes in weather; however, we found this size class to be the most impacted by herbivory. Species (native and invasive) in this size class such as white ash, American beech, hawthorn, spicebush, multiflora rose, common privet, and glossy buckthorn all show signs heavy browse pressure from white-tailed deer.

Size Class: 3-5’ (Large Seedling)

Woody stems from 3-5’ are considered “large seedlings” and are typically 2-3 years old depending upon species and growing conditions. This size class accounted for only 0.5% of all native woody stems surveyed – chokecherry, American beech, and white ash were the only native species represented in this size class. Seedlings are robust by this stage and can tolerate a number of environmental pressures, however, heavy browsing can still negatively impact this size class.

The stark drop in both seedling abundance and species diversity in the 3-5’ size class can likely be attributed to heavy browse pressure at the lower size classes where preferred browse species are selected against – species such as chokecherry and American beech are low browse preference species, with chokecherry foliage being toxic to white-tailed deer.

Size Class: 5'+ <4.5" DBH (Sapling)

Woody stems taller than 5' in height but less than 4.5" DBH (diameter at breast height) are considered "saplings" and are typically a minimum of 3-5 years in age depending upon species and growing conditions. This size class represented 0.8% of all native woody stems surveyed – chokecherry and American beech were the most common species found in this size class. This size class is very robust and is generally unaffected by environmental pressures or herbivory – the greatest risk to saplings would be pests, disease, or heavy site disturbance.

Plot Scoring

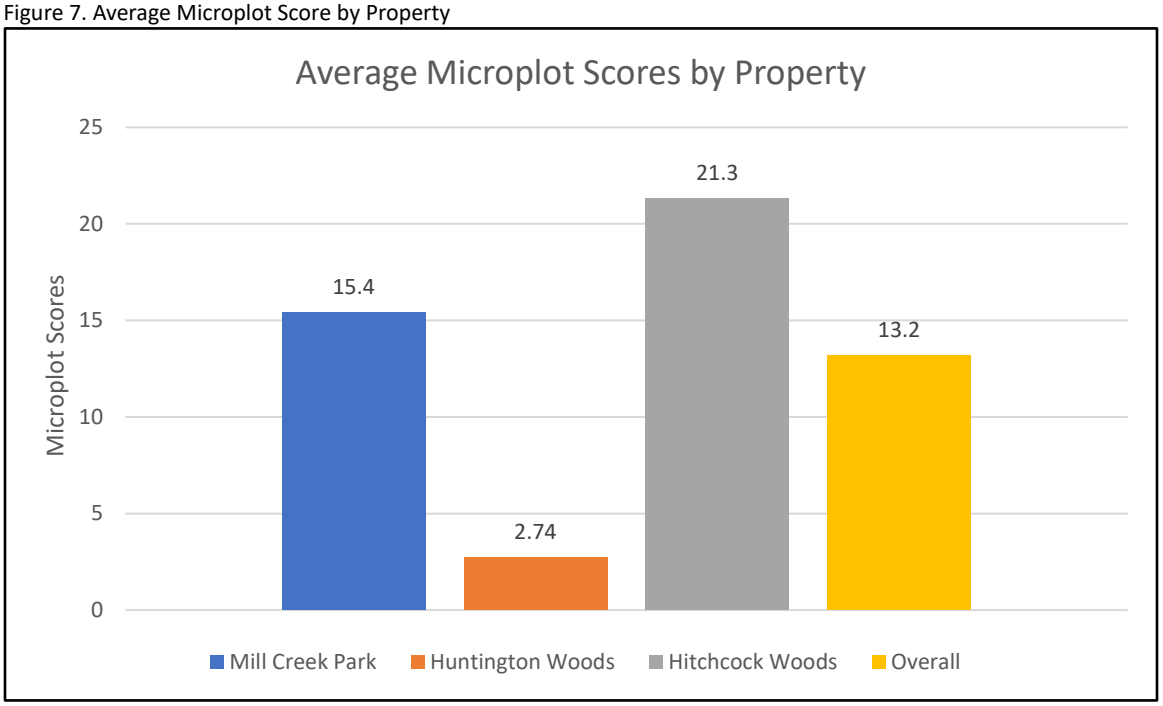
Using the scoring system described above, all microplots were assigned a score which reflects the stage of forest regeneration for each plot based upon native species abundance and height. Overall, the average microplot score for all surveyed areas was 13.2, with zero (0) of the 110 surveyed plots surpassing a forest regeneration score of 150 points.

Again, white ash was not assigned a positive score due to their lack of long-term viability. It is important to note that white ash is heavily susceptible to the emerald ash borer (EAB), a non-native boring insect that is responsible for the destruction of millions of ash trees across much of the eastern United States. It is estimated that only 1% of ash trees on the landscape have a higher-than-average resistance to this pest, with that being said ash regeneration is still taking place on the landscape, typically in the smaller size classes. Impacts from EAB will likely continue once saplings reach a suitable size rendering them largely incapable of reaching full maturity and becoming the dominant canopy species they once were.

Also, woody stems showing severe damage or outward sign of disease were scored at half-value this primarily impacted American beech which oftentimes showed both heavy browse pressure and advanced signs of beech leaf disease (BLD).

As a control, the Hitchcock Woods deer exclosure was scored using the same metrics in total the 324 sq ft area produced a forest regeneration score of 571 – scaled down to match the size of the microplots (113.1 sq ft) the deer exclosure scores 199.65 (15x better than the overall average microplot score).

Figure 7. Average Microplot Score by Property

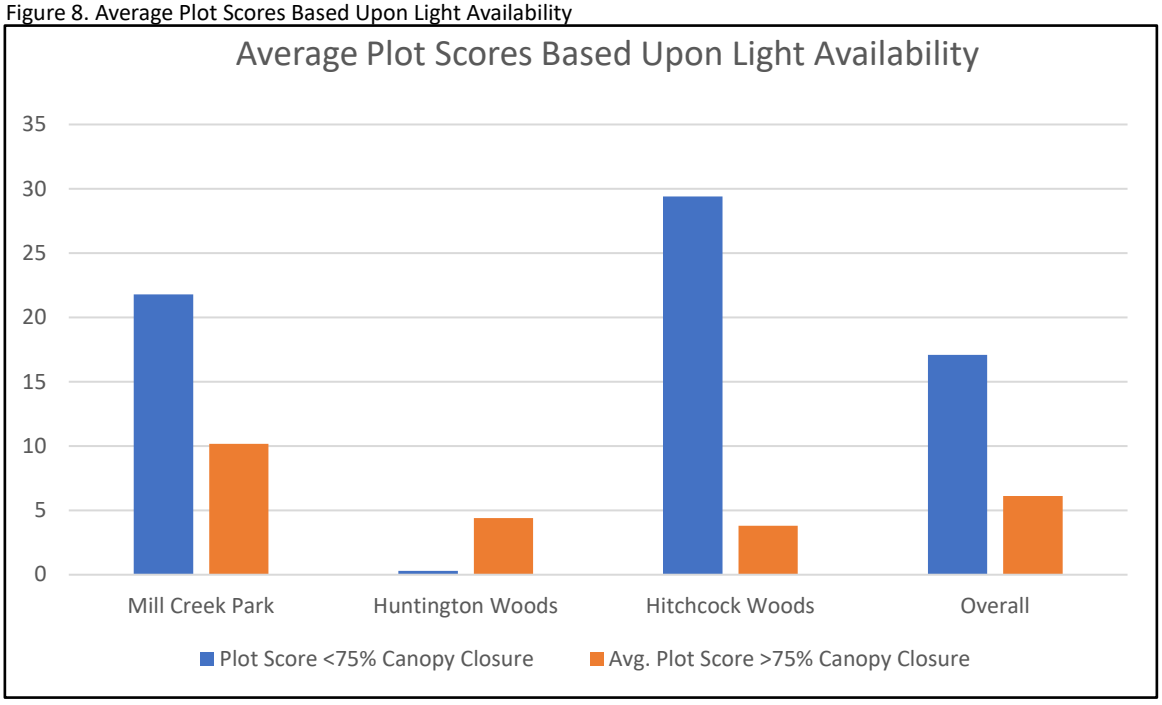


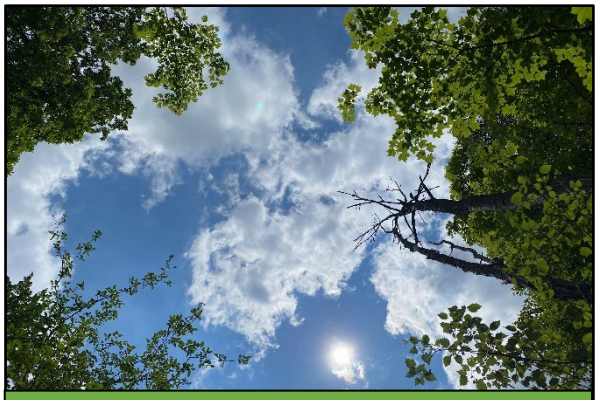
Canopy Closure

Receiving adequate amounts of sunlight is a necessary component for all plant growth. In forested settings, canopy closure affects the amount of light that reaches the forest floor, therefore, can impact a forest's ability to regenerate by affecting both growth rates and species composition. During this study, microplots displayed a wide range of % canopy closure (0-95%) with 48% of microplots with above average light availability (<75% canopy closure) due to prior disturbance from EAB and/or storm damage.

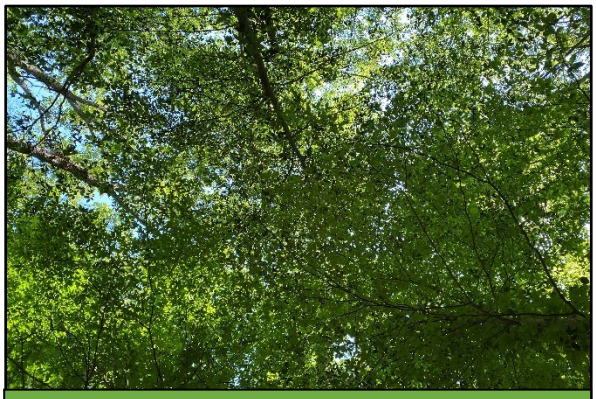
As expected, light availability had a large influence on plot scoring – microplots with less than 75% canopy closure scored 2.79x higher than microplots with greater than 75% canopy closure. Huntington Woods proved to be an exception to this rule, where available light gaps were dominated by ferns and sedges.

Figure 8. Average Plot Scores Based Upon Light Availability





Example of Microplot with <75% Canopy Closure



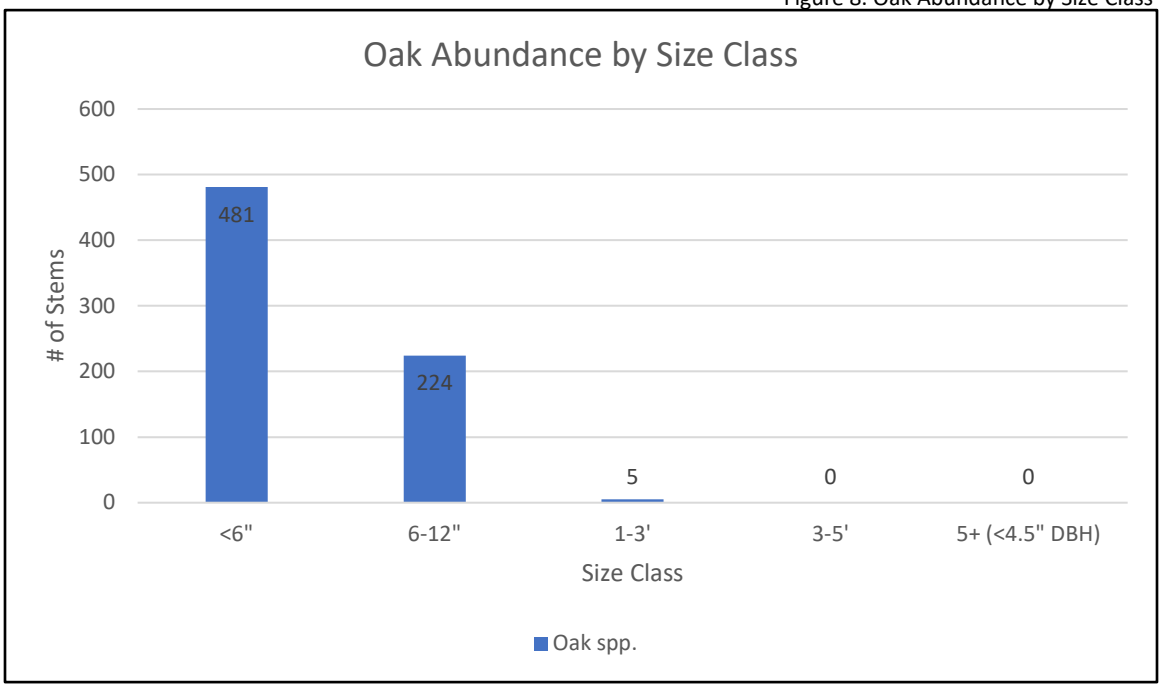
Example of Microplot with >75% Canopy Closure

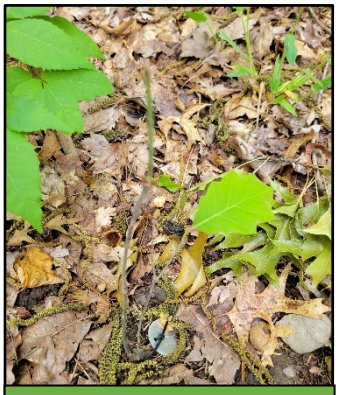
Oak Regeneration:

Across their range, oaks (*Quercus spp*.) exist as common canopy trees, however, they are largely absent in the understory seedling and sapling layers. This has led to increased concern in recent decades regarding the overall lack of oak regeneration in Eastern hardwood forests – likely caused by intensive browsing by white-tailed deer (oaks are a highly preferred browse species), increased competition with other plants, land use changes, and fire suppression. Oaks provide mast crops in the form of acorns which are an essential part of the forest ecosystem providing valuable fall and winter forage for wildlife. If the current trajectory is not corrected, we may face losing this valuable forest resource in the coming decades as mature trees die with nothing in the understory to replace them.

This same principles apply here as the northern red oak (*Quercus rubra*), pin oak (*Quercus palustris*), white oak (*Quercus alba*), and swamp white oak (*Quercus bicolor*) are all species commonly found on MetroParks properties as mature canopy species and many were also found in the smaller (<6” and 6-12”) size classes, however, oaks of all species were completely absent from 3-5’ and 5+ size classes, with only five (5) being found in the 1-3’ size class.

Figure 8. Oak Abundance by Size Class





Unprotected Red Oak Seedling

Protected Red Oak Seedling

Discussion, Management Objectives, and Recommendations:

Discussion

The results of this study reinforce the anecdotal evidence regarding a lack of forest regeneration that has been observed by MetroParks staff beginning in the 1990's by documenting the severe lack of native seedlings and/or saplings in the understory, most notably those in the larger size classes.

White-tailed deer herbivory appears to be the primary driver of forest regeneration in Mill Creek Park, Huntington Woods, and Hitchcock Woods. This is evidenced by the intensive browse pressure and overall lack of preferred browse species evidenced by this study and other anecdotal references. Other factors such as light availability, lack of disturbance, exotic pests, disease, and competition from invasive species are also contributing factors that are impacting forest health.

Management Objectives

The following set of objectives have been established regarding forest regeneration within Mill Creek MetroParks:

- 75% of Microplots Scoring 150 Points or More.
- 25% of All Surveyed Oak Stems Measuring Greater than 12" in Height with at Least 10% Reaching the 5'+ Size Class.
- Increase in Native Species Diversity with 75% of Surveyed Species Present as Germinants (<6") Also Being Present in the Large Seedling (3-5') or Sapling (5'+) Size Class.
- Maintain 80% or Greater Coverage of Native Species in Surveyed Areas.

Recommendations:

To achieve the abovementioned objectives, it is recommended that the MetroParks consider implementing the following management techniques until goals are met:

- White-tailed Deer Population Reduction and Management
- Native Species Planting
- Invasive Species Management
- Habitat Manipulation Where Appropriate
- Deer Exclusion via Fencing and/or Tree Tubes/Caging Where Appropriate

Hitchcock Woods Deer Exclosure

Collier Preserve Tree Planting

References:

Carter, David & Barrett, Scott & Barkman, Rebecca & Madigan, Olivia & Olinger, Zachary. (2022). Tree Seedling and Understory Plant Presence in Deer Exclosures on the Matthews State Forest.

Mcwilliams, W.H., Stout, S.L., Bowersox, T.W., & McCormick, L. (1995). Adequacy of Advance Tree-Seedling Regeneration in Pennsylvania's Forests. Northern Journal of Applied Forestry, 12, 187-191.

Shirer, R., & Zimmerman, C. (2010). Forest Regeneration in New York State. https://forestadaptation.org/sites/default/files/NYS_Regen_091410_0.pdf

The National Parks Service: Forest Regeneration 2022 https://www.nps.gov/articles/000/forest-regeneration-2022.htm

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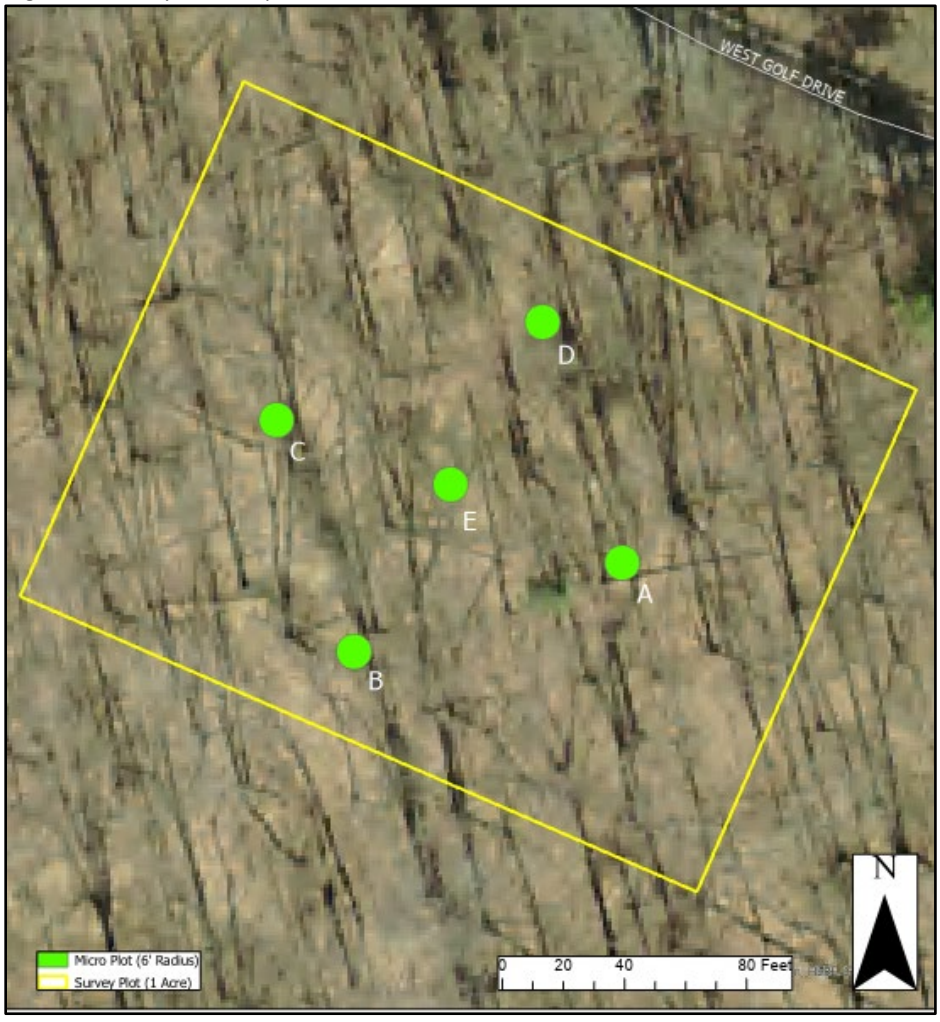

Once microplots are established they are affixed with a permanent stake. These plots will be used to gauge changes in forest regeneration on an annual basis, but may also be used to examine other metrics such as winter browse damage and/or spring ephemeral wildflower abundance.

*In 2024, some microplots had to be reestablished due to suspected vandalism. This potentially caused some minor changes in microplot location.

Data Collection

For the purposes of assessing forest regeneration, all woody vegetation less than 4.5" DBH located within each microplot was identified and categorized based upon size class. Woody vegetation was separated into five (5) size classes: <6", 6-12", 1-3', 3-5', and 5'+ with each size class being assigned a weighted score which reflects the survivability of each size class and its value in terms of forest regeneration.

Additionally, percent canopy closure was assessed at the center point of each microplot, and photographs were gathered depicting both current plot conditions and canopy closure.

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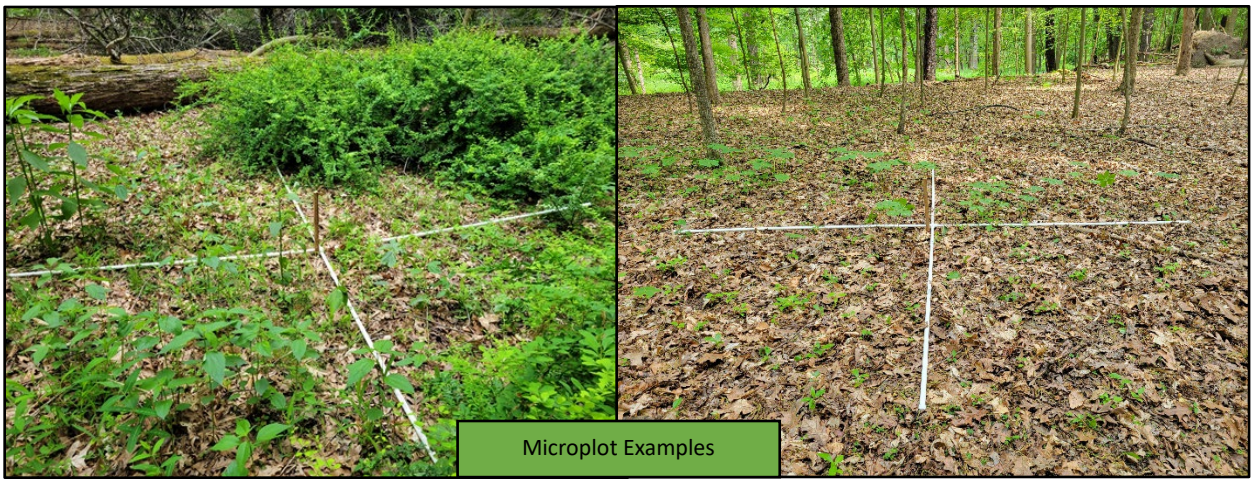


Microplot Examples

Results:

22 survey plots (110 microplots) were evaluated throughout Mill Creek Park, Huntington Woods, and Hitchcock Woods the results are as follows:

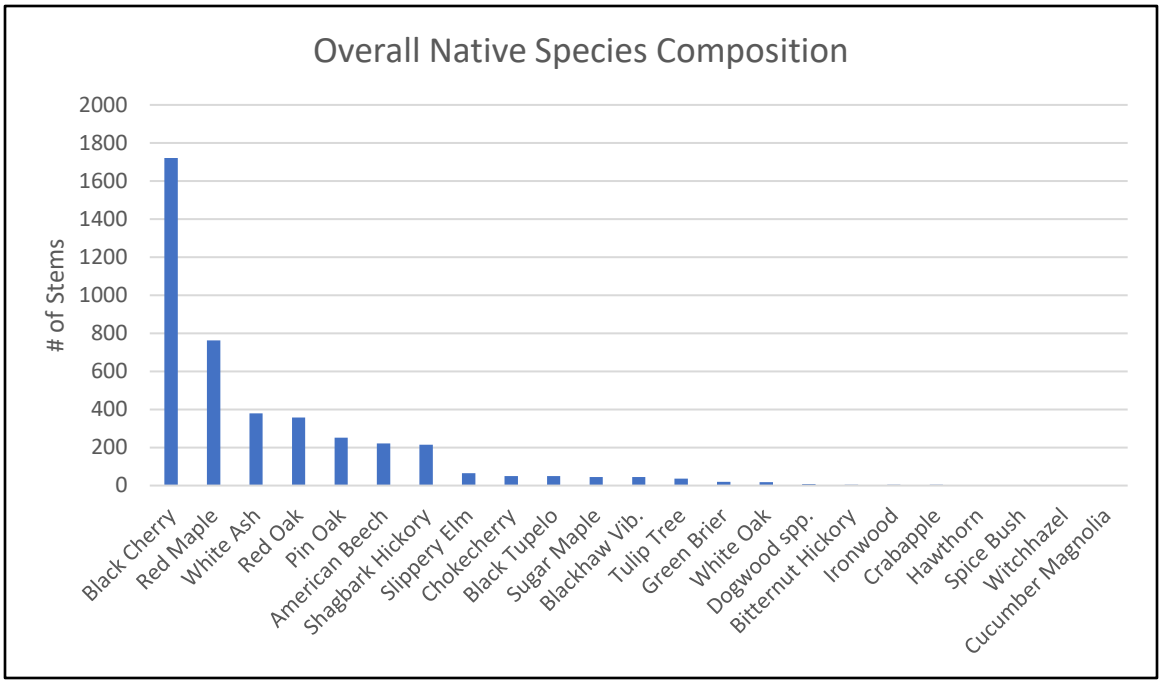
Species Composition and Diversity

In total, 4,589 woody stems were surveyed of those, a total of 24 native species and 9 invasive species were documented – native species accounted for 91.5% of the total stems surveyed (plots with <75% invasive shrub cover were excluded).

Of the 24 native species identified black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) occurred with the most frequency and in combination account for 57.4% of all native woody stems. This is not surprising as these species typically have dense seeding rates, fast growth, and are tolerant to a wide range of soil conditions, often times making them the first canopy species to repopulate disturbed areas.

Other prominent species include pin oak (*Quercus palustris*), white ash (*Fraxinus americana*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), American beech (*Fagus grandifolia*) , sugar maple (Acer saccharum), and slippery elm (*Ulmus rubra*). Of the 24 native species documented, only 8 (33%) were present in the 3-5’ and 5’ size class.

Figure 5. Overall Native Species Composition



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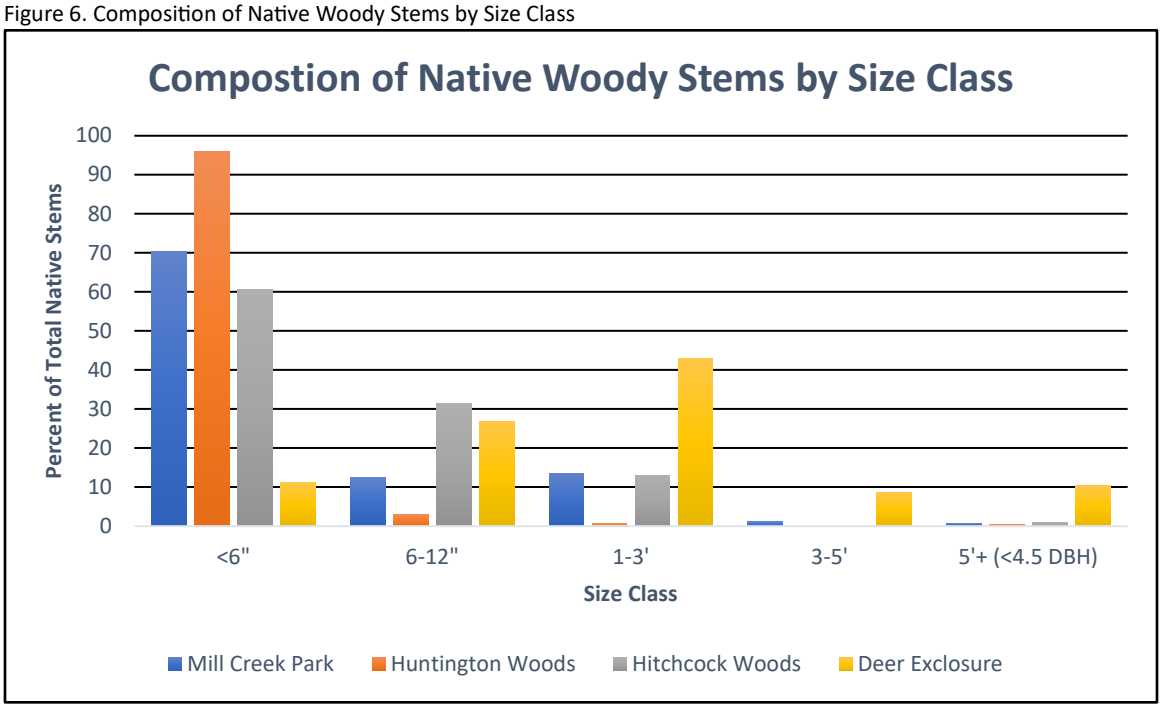


The results show that overwhelmingly the <6” size class as the most abundant in areas unprotected from deer browsing, overall 75.5% of all native woody stems surveyed were less than 6” in height. In general, the larger size classes (3-5’ and 5’+) were largely absent from the unprotected survey areas and accounted for only 1.4% of the total stems surveyed.

On the contrary, in the Hitchcock Woods deer exclosure all size classes were well represented with the 1-3’ size class being most abundant (42.9%).

Size Class: <6” (Germinant)

Woody stems less than 6” are considered “germinants” and were by far the most common size class documented– this size class represented 75.6% of all native woody stems surveyed with black cherry and red maple occurring most frequently. This size class is comprised of newly germinated trees – this is considered a very vulnerable size class with survivability being influenced by many variables such as sunlight availability, soil condition, weather, and herbivory.

Size Class: 6-12” (Small Seedling)

Woody stems from 6-12” are considered “small seedlings” and are typically 0-1 years old, however, this can vary widely based upon species and growing conditions. This size class accounted for 13% of all native woody stems surveyed – white ash, pin oak, and red oak were the most common species in this size class. Small seedlings are still vulnerable to changes in growing condition and herbivory; however, this size class does have a higher rate of survival as compared to germinants.

Size Class: 1-3’ (Seedling)

Woody stems from 1-3’ are considered “seedlings” and are typically 1-2 years old depending upon species and growing condition. This size class accounted for 10% of all native woody stems surveyed – white ash, American beech, and shagbark hickory were the most common species in this size class. This size class is less susceptible to environmental conditions such as changes in weather; however, we found this size class to be the most impacted by herbivory. Species (native and invasive) in this size class such as white ash, American beech, hawthorn, spicebush, multiflora rose, common privet, and glossy buckthorn all show signs heavy browse pressure from white-tailed deer.

Size Class: 3-5’ (Large Seedling)

Woody stems from 3-5’ are considered “large seedlings” and are typically 2-3 years old depending upon species and growing conditions. This size class accounted for only 0.6% of all native woody stems surveyed – chokecherry, American beech, and white ash were the only native species represented in this size class. Seedlings are robust by this stage and can tolerate a number of environmental pressures, however, heavy browsing can still negatively impact this size class.

The stark drop in both seedling abundance and species diversity in the 3-5’ size class can likely be attributed to heavy browse pressure at the lower size classes where preferred browse species are selected against – species such as chokecherry and American beech are low browse preference species, with chokecherry foliage being toxic to white-tailed deer.

Size Class: 5'+ <4.5" DBH (Sapling)

Woody stems taller than 5' in height but less than 4.5" DBH (diameter at breast height) are considered "saplings" and are typically a minimum of 3-5 years in age depending upon species and growing conditions. This size class represented 0.7% of all native woody stems surveyed – sugar maple, chokecherry, slippery elm, and American beech were the most common species found in this size class. This size class is very robust and is generally unaffected by environmental pressures or herbivory – the greatest risk to saplings would be pests, disease, or heavy site disturbance.

Plot Scoring

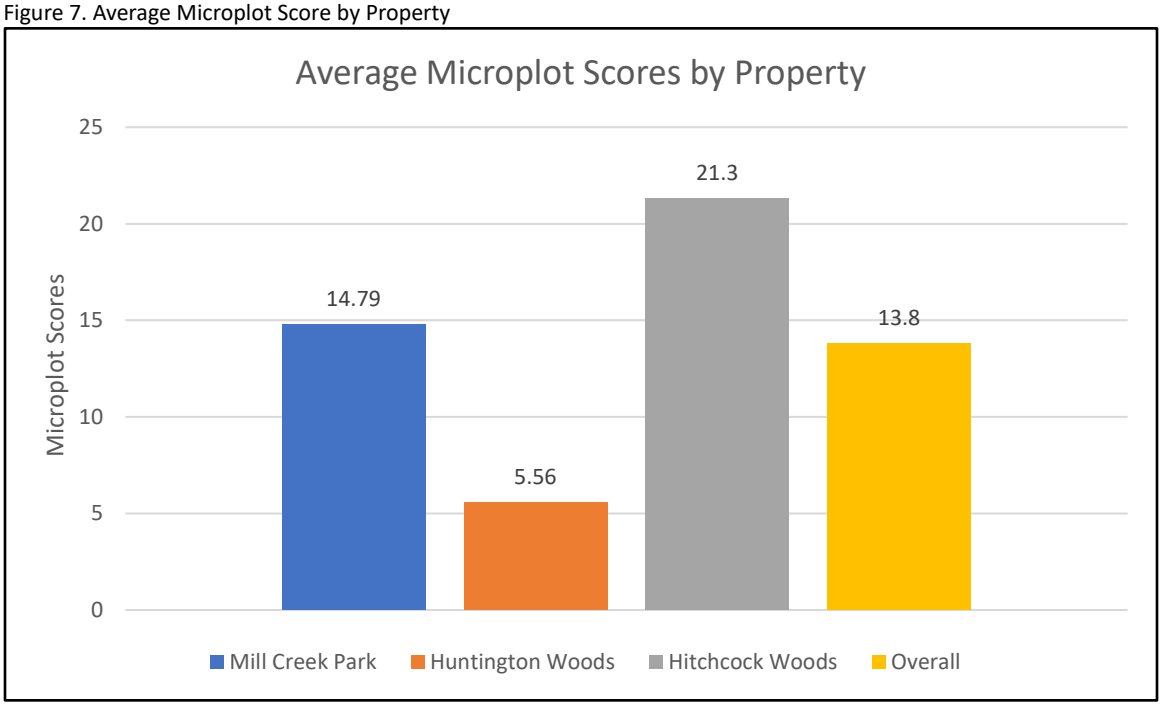
Using the scoring system described above, all microplots were assigned a score which reflects the stage of forest regeneration for each plot based upon native species abundance and height. Overall, the average microplot score for all surveyed areas was 13.8, with one (1) of the 110 surveyed plots surpassing a forest regeneration score of 150 points. In this instance, the score of 177.5 was produced due to high stem count of chokecherry in the 3-5' size class. In this case it is important to note that chokecherry is considered highly deer-resistant and even toxic to deer and other animals if eaten in large quantities, therefore, its presence could be a symptom of selective browsing pressure.

Again, white ash was not assigned a positive score due to their lack of long-term viability. It is important to note that white ash is heavily susceptible to the emerald ash borer (EAB), a non-native boring insect that is responsible for the destruction of millions of ash trees across much of the eastern United States. It is estimated that only 1% of ash trees on the landscape have a higher-than-average resistance to this pest, with that being said ash regeneration is still taking place on the landscape, typically in the smaller size classes. Impacts from EAB will likely continue once saplings reach a suitable size rendering them largely incapable of reaching full maturity and becoming the dominant canopy species they once were.

Also, woody stems showing severe damage or outward sign of disease were scored at half-value this primarily impacted American beech which oftentimes showed both heavy browse pressure and advanced signs of beech leaf disease (BLD).

As a control, the Hitchcock Woods deer exclosure was scored using the same metrics in total the 324 sq ft area produced a forest regeneration score of 571 – scaled down to match the size of the microplots (113.1 sq ft) the deer exclosure scores 195.45 (~14x better than the overall average microplot score).

Figure 7. Average Microplot Score by Property

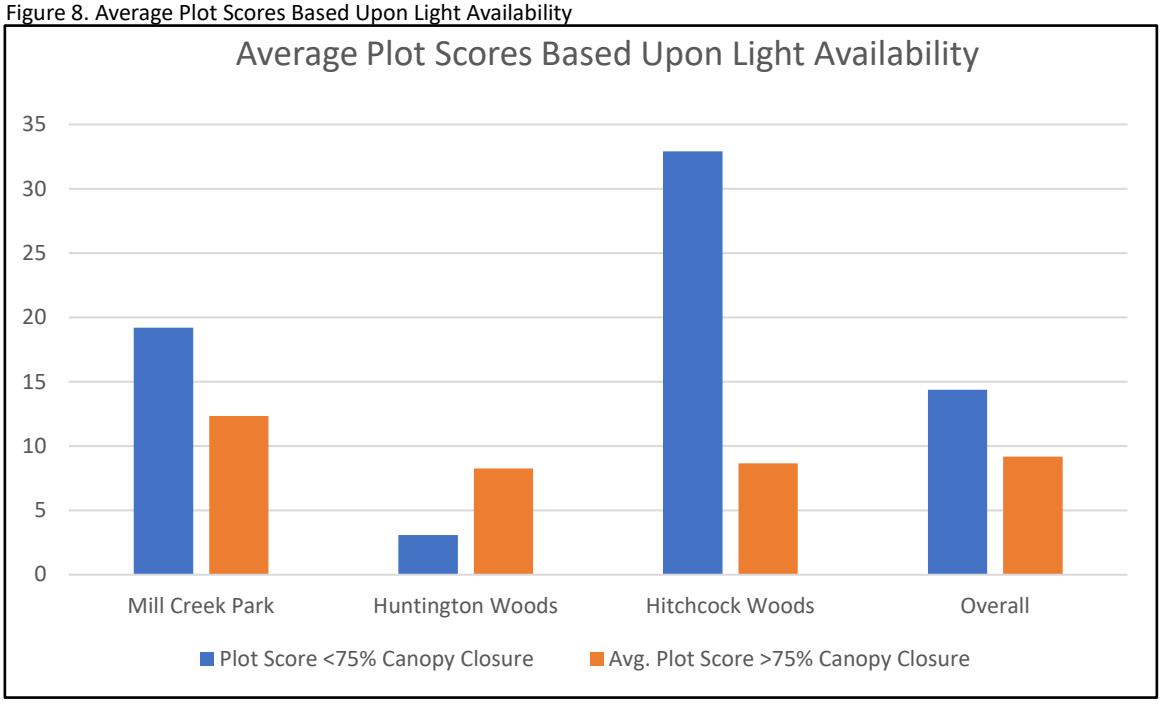


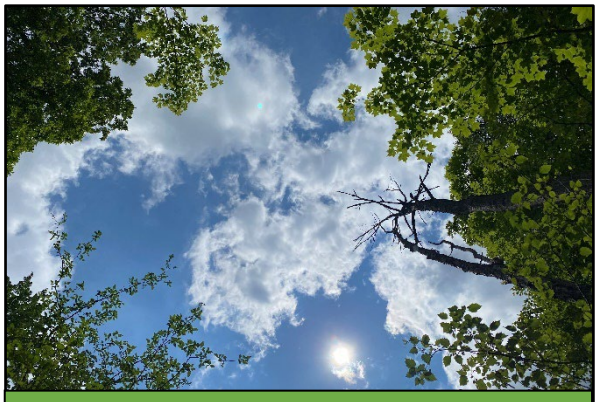
Canopy Closure

Receiving adequate amounts of sunlight is a necessary component for all plant growth. In forested settings, canopy closure affects the amount of light that reaches the forest floor, therefore, can impact a forest's ability to regenerate by affecting both growth rates and species composition. During this study, microplots displayed a wide range of % canopy closure (0-95%) with 50% of microplots with above average light availability (≤75% canopy closure) due to prior disturbance from EAB and/or storm damage.

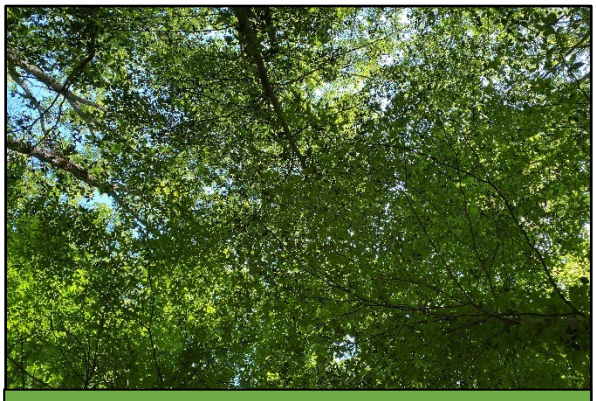
As expected, light availability had a large influence on plot scoring – microplots with less than 75% canopy closure scored higher than microplots with greater than 75% canopy closure. Huntington Woods proved to be an exception to this rule, where available light gaps tend to be dominated by ferns, sedges, and invasive shrubs.

Figure 8. Average Plot Scores Based Upon Light Availability





Example of Microplot with <75% Canopy Closure



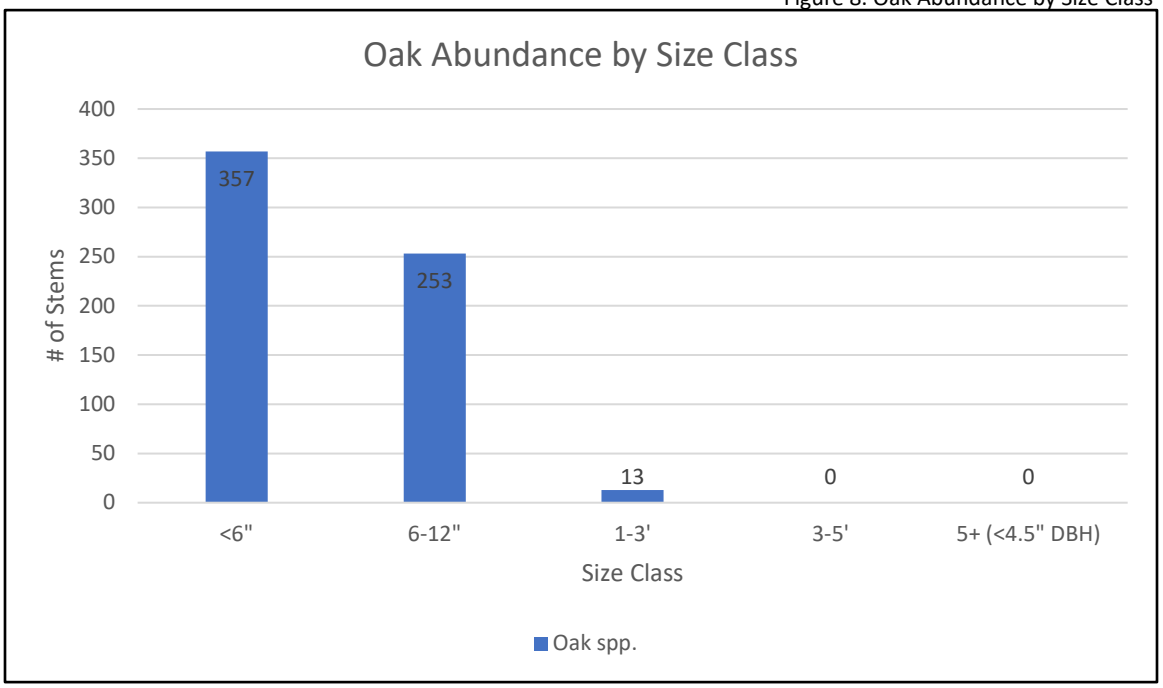
Example of Microplot with >75% Canopy Closure

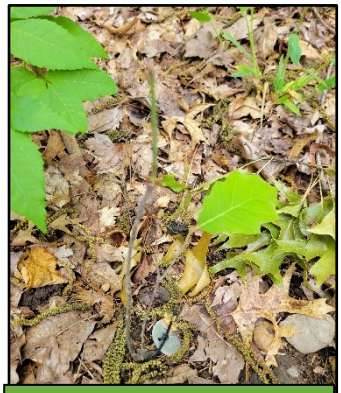
Oak Regeneration:

Across their range, oaks (*Quercus spp*.) exist as common canopy trees, however, they are largely absent in the understory seedling and sapling layers. This has led to increased concern in recent decades regarding the overall lack of oak regeneration in Eastern hardwood forests – likely caused by intensive browsing by white-tailed deer (oaks are a highly preferred browse species), increased competition with other plants, land use changes, disease, and fire suppression. Oaks provide mast crops in the form of acorns which are an essential part of the forest ecosystem providing valuable fall and winter forage for wildlife. If the current trajectory is not corrected, we may face losing this valuable forest resource in the coming decades as mature trees die with nothing in the understory to replace them.

This same principles apply here as the northern red oak (*Quercus rubra*), pin oak (*Quercus palustris*), white oak (*Quercus alba*), and swamp white oak (*Quercus bicolor*) are all species commonly found on MetroParks properties as mature canopy species and many were also found in the smaller (<6” and 6-12”) size classes, however, oaks of all species were completely absent from 3-5’ and 5+ size classes, with only thirteen (13) being found in the 1-3’ size class.

Figure 8. Oak Abundance by Size Class



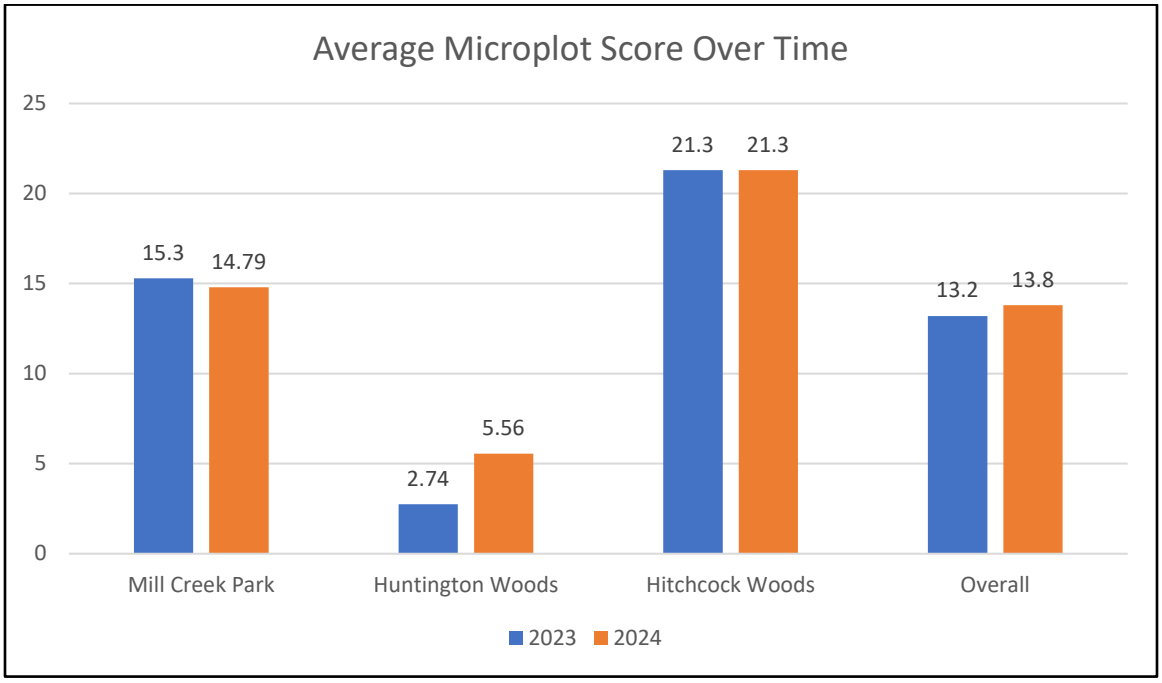


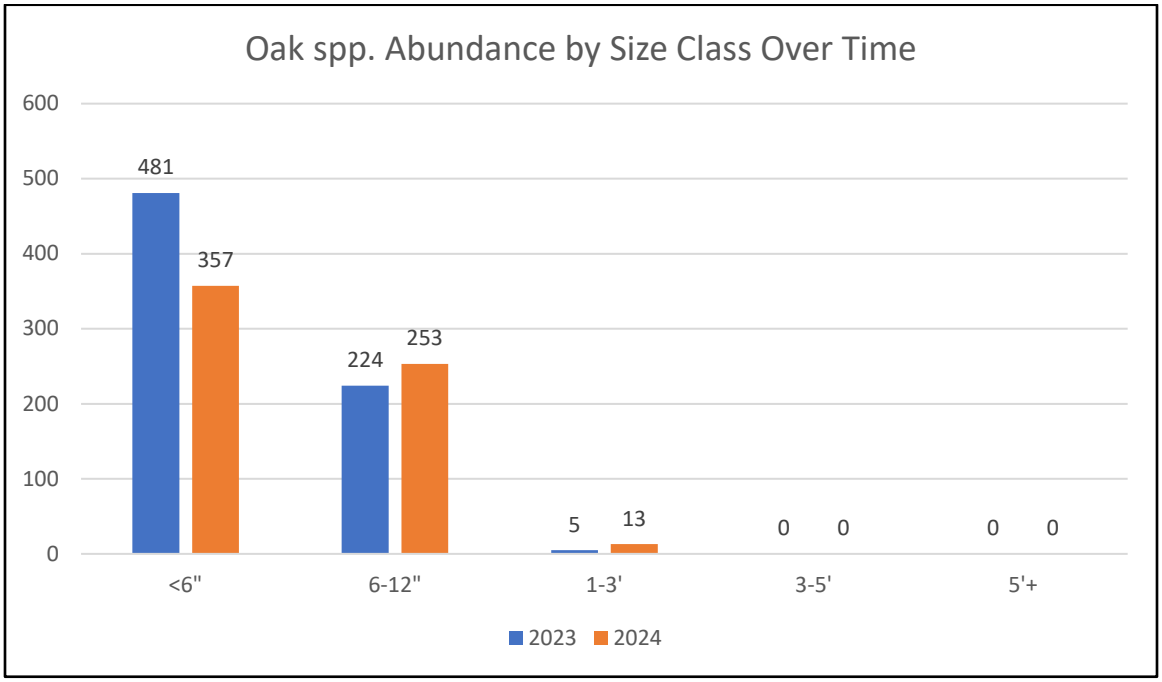
Unprotected Red Oak Seedling

Protected Red Oak Seedling

Ongoing Changes:

While it will take years to fully evaluate changes on a landscape level, this scoring assessment will continue to be conducted on an annual basis to identify noticeable trends over time.





Discussion, Management Objectives, and Recommendations:

Discussion

White-tailed deer herbivory continues to be the primary driver of forest regeneration in Mill Creek Park, Huntington Woods, and Hitchcock Woods. This is evidenced by the intensive browse pressure and overall lack of preferred browse species evidenced by this study and other anecdotal references. Other factors such as light availability, lack of disturbance, exotic pests, disease, and competition from invasive species are also contributing factors that are impacting forest health.

Management Objectives

The following set of objectives have been established regarding forest regeneration within Mill Creek MetroParks:

- 75% of Microplots Scoring 150 Points or More.
- 25% of All Surveyed Oak Stems Measuring Greater than 12” in Height with at Least 10% Reaching the 5’+ Size Class.
- Increase in Native Species Diversity with 75% of Surveyed Species Present as Germinants (<6”) Also Being Present in the Large Seedling (3-5’) or Sapling (5’+) Size Class.
- Maintain 80% or Greater Coverage of Native Species in Surveyed Areas.

Recommendations:

To achieve the abovementioned objectives, it is recommended that the MetroParks consider implementing the following management techniques until goals are met:

- White-tailed Deer Population Reduction and Management
- Native Species Planting
- Invasive Species Management
- Habitat Manipulation Where Appropriate
- Deer Exclusion via Fencing and/or Tree Tubes/Caging Where Appropriate

Hitchcock Woods Deer Exclosure

Collier Preserve Tree Planting

References:

Carter, David & Barrett, Scott & Barkman, Rebecca & Madigan, Olivia & Olinger, Zachary. (2022). Tree Seedling and Understory Plant Presence in Deer Exclosures on the Matthews State Forest.

Mcwilliams, W.H., Stout, S.L., Bowersox, T.W., & McCormick, L. (1995). Adequacy of Advance Tree-Seedling Regeneration in Pennsylvania's Forests. Northern Journal of Applied Forestry, 12, 187-191.

Shirer, R., & Zimmerman, C. (2010). Forest Regeneration in New York State. https://forestadaptation.org/sites/default/files/NYS_Regen_091410_0.pdf

The National Parks Service: Forest Regeneration 2022 https://www.nps.gov/articles/000/forest-regeneration-2022.htm

Assessment of Forest Regeneration in Mill Creek Park, Huntington Woods, and Hitchcock Woods

June 2025

Introduction:

By definition, forest regeneration is the process that allows a forest to replace and sustain itself in the long-term through the establishment and survival of seedlings and saplings that replace mature canopy trees as they die, either by natural causes or by large disturbance events such as windstorms, wildfire, or disease.

Healthy forest regeneration is a crucial component to forest management to ensure the long-term sustainability of our forest ecosystems for future generations.

Forest regeneration can be influenced by a number of variables such as habitat disturbance, invasive species introduction, disease, and herbivory by ungulates such as white-tailed deer.

While white-tailed deer are known as generalist herbivores, feeding on a wide range of woody and herbaceous plant growth, they are also preferential in their feeding habits which can negatively influence forest regeneration when populations exceed ecological carrying capacity.

In the case of Mill Creek MetroParks, the ecological effects of white-tailed deer overabundance such as distinct browse lines, stunted forest regeneration, and low species diversity have been anecdotally noted in some areas for over two decades, however, the effects of overbrowning had not previously been quantified prior to 2023.

Objectives:

To evaluate current conditions related to forest regeneration based upon seedling and sapling abundance/height and track changes through time in response to management changes such as deer management, invasive species treatment, and/or habitat manipulation.

Methods:

Plot Description

Survey plots (1-acre in size) are distributed throughout Mill Creek Park, Huntington Woods, and Hitchcock Woods where space allowed. Within each survey plot, five (5) microplots were established (6’ radius circle). The placement of microplots was standardized, with one microplot placed at the center of each 1-acre survey plot, additional plots were established at a distance of 60’ from the center point in four directions.

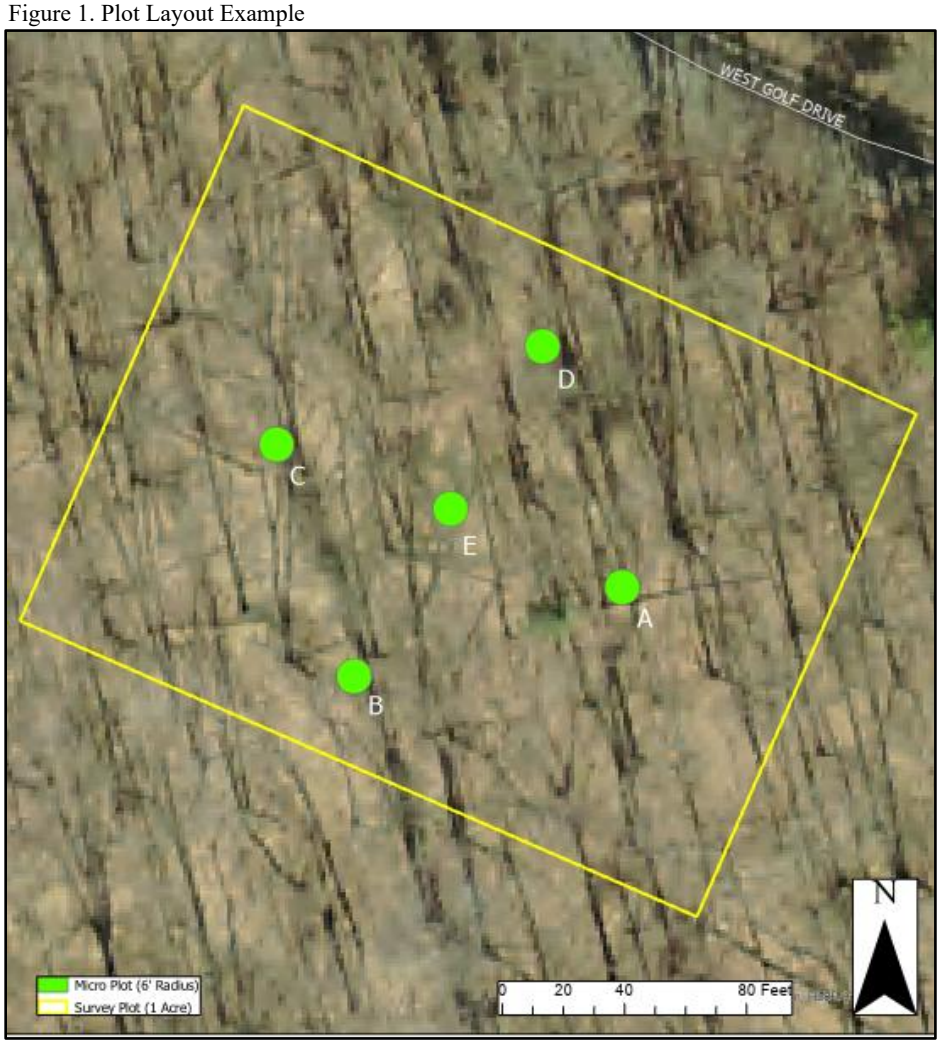
Plot Selection

Survey plots were established in upland hardwood sites with varying degrees of canopy closure (0%-95%). Sites with a lower prevalence of invasive species and desirable light availability were preferred when available to assess forest regeneration under the best possible circumstances given current site conditions. All plot locations were free of human caused disturbance such as logging, prescribed fire, or other active management.

If any of the following conditions are present at the predetermined 60' spacing, the microplot center point will be adjusted to the nearest suitable location:

- Obstructions such as rocks, downed trees, mature trees, roadways, or open water which hinder the establishment of the microplot and/or subplot.
- The proposed plot location is located on a slope greater than 70%.
- The proposed plot location is dominated by large invasive shrubs (<75% coverage).

Figure 1. Plot Layout Example



Once microplots are established they are affixed with a permanent stake. These plots will be used to gauge changes in forest regeneration on an annual basis but may also be used to examine other metrics such as winter browse damage and/or spring ephemeral wildflower abundance.

*In 2024 and 2025, some microplots had to be reestablished due to suspected vandalism. This potentially caused some minor changes in microplot location.

Data Collection

For the purposes of assessing forest regeneration, all woody vegetation less than 4.5" DBH located within each microplot was identified and categorized based upon size class. Woody vegetation was separated into five (5) size classes: <6", 6-12", 1-3', 3-5', and 5'+ with each size class being assigned a weighted score which reflects the survivability of each size class and its value in terms of forest regeneration.

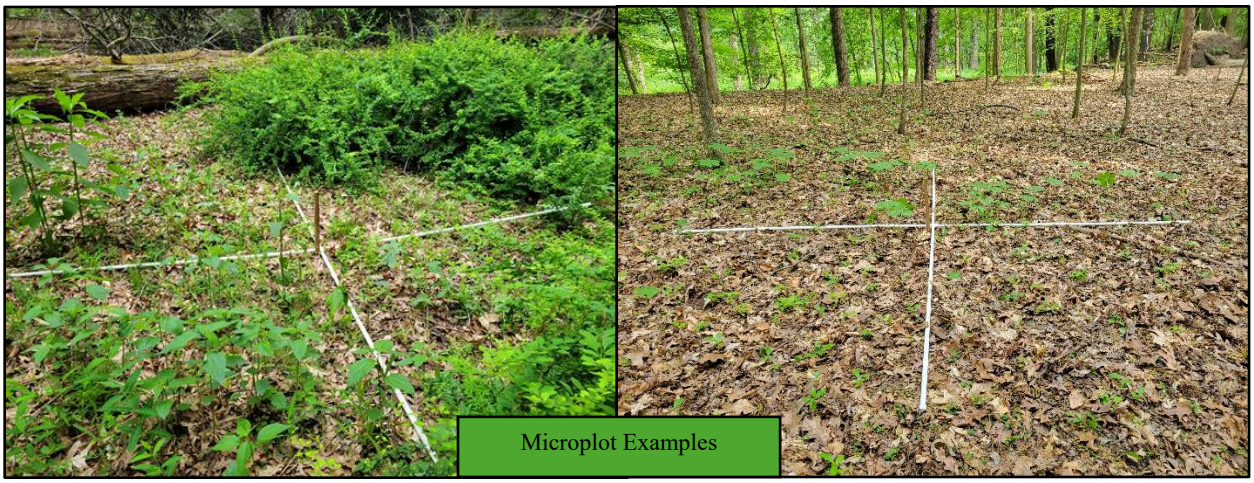
Additionally, percent canopy closure was assessed at the center point of each microplot, and photographs were gathered depicting both current plot conditions and canopy closure.

To provide a control, data was also collected from the deer exclosure located in Hitchcock Woods, which was first constructed in the year 2000 but was not refurbished and fully functional until 2018. The exclosure is 18x18' (324 sq ft) and has ~80% canopy closure directly above but is adjacent to a sizeable light gap to the south.

Figure 3. MCMP Forest Regeneration Scoring Chart

Size Class	Score
0-6"	0
6-12"	1
1-3'	2
3-5' Native Sub-Canopy or Shrub Species	7.5
3-5' Native Canopy Species	15
5'+ Native Sub-Canopy or Shrub Species (<4.5" DBH	15
5'+ Native Canopy Species (<4.5" DBH)	30

- Invasive species are noted but not assigned a positive or negative score.
- Trees showing outward signs of disease or severe damage are scored at half value.
- Ash spp. will not be assigned a positive score due to their lack of long-term viability, caused by the emerald ash borer.
- Each microplot is assessed individually, a score of 150 points or greater signifies that plot as sufficiently stocked for forest regeneration.



Microplot Examples

Results:

22 survey plots (110 microplots) were evaluated throughout Mill Creek Park, Huntington Woods, and Hitchcock Woods. The results are as follows:

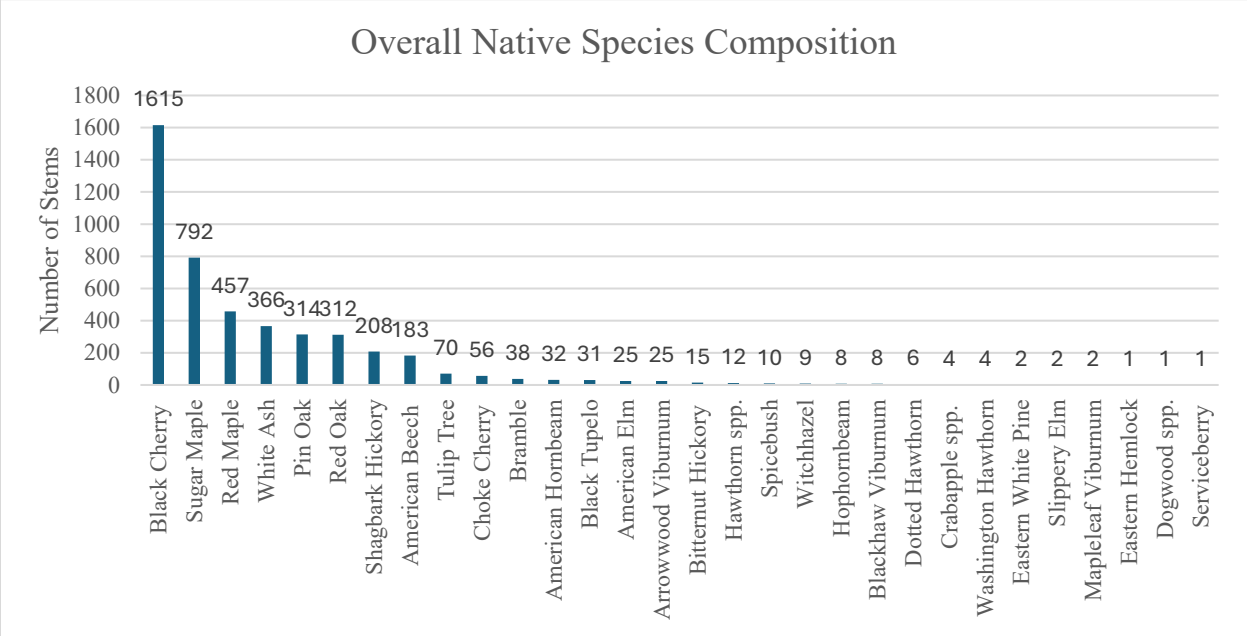
Species Composition and Diversity

In total, 4975 woody stems were recorded. Of those, a total of 30 native species and 8 invasive or non-native species were documented – native species accounted for 92.6% of the total stems surveyed.

Of the 30 native species identified, black cherry (*Prunus serotina*) and sugar maple (*Acer saccharum*) occurred with the most frequency and in combination account for 52.2% of all native woody stems. This is not surprising because both species produce abundant seed crops, tolerate shade, and are less preferred by deer than highly palatable species like oaks. These traits allow them to persist and dominate regeneration layers in forests with heavy browsing pressure and limited disturbance.

Other prominent species include red maple (*Acer rubrum*), white ash (*Fraxinus americana*), pin oak (*Quercus palustris*), red oak (*Quercus rubra*), shagbark hickory (*Carya ovata*), and American beech (*Fagus grandifolia*). Of the 30 native species documented, only 6 were present in the 3-5’ and 5’+ size classes.

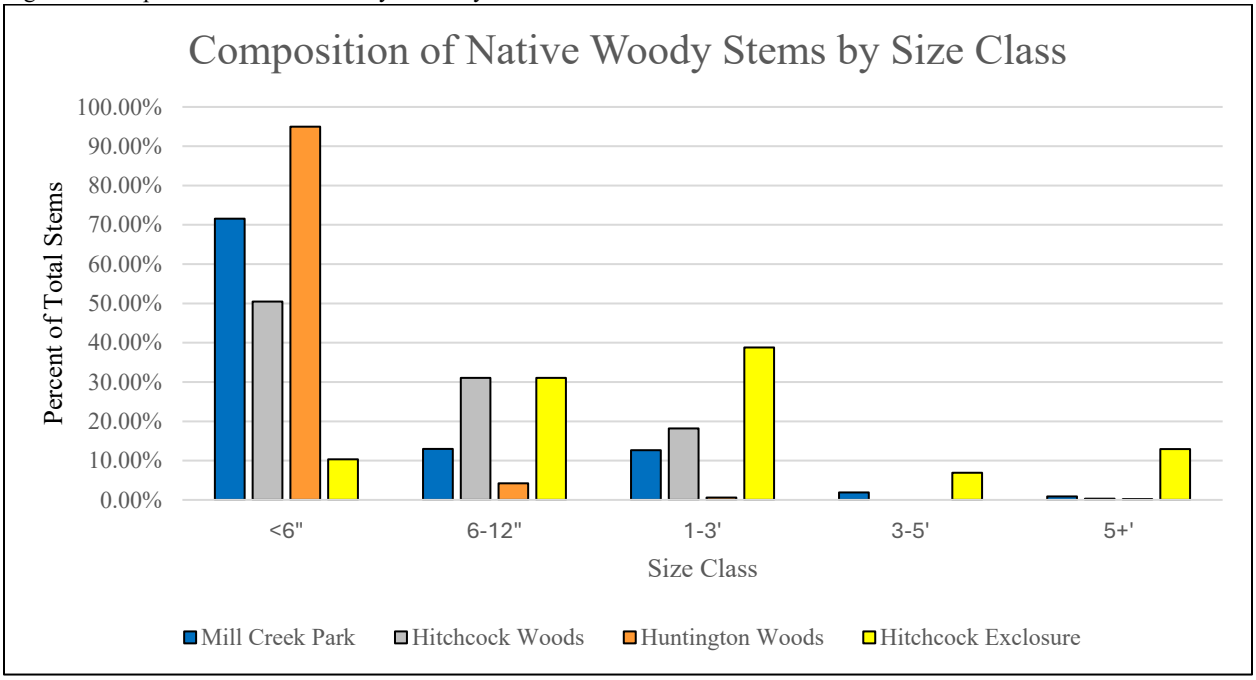
Figure 4. Overall Native Species Compositions



Native Woody Stems by Size Class

As stated above, woody stems were separated into five (5) size classes the following data depicts the size class breakdown of woody stems found in all three (3) survey areas and the Huntington Woods deer exclosure.

Figure 5. Composition of Native Woody Stems by Size Class



The results show that overwhelmingly the <6” size class is the most abundant in areas unprotected from deer browsing. Overall, 69.3% of all native woody stems surveyed were less than 6” in height. In general, the larger size classes (3-5’ and 5’+) were largely absent from the unprotected survey areas and accounted for only 1.3% of the total stems surveyed.

On the contrary, in the Hitchcock Woods deer exclosure, all size classes were well represented, with the 1-3’ size class being most abundant (38.8%).

Size Class: <6” (Germinant)

Woody stems less than 6” are considered “germinants” and were by far the most common size class documented– this size class represented 69.3% of all native woody stems surveyed with black cherry and sugar maple occurring most frequently. This size class is comprised of newly germinated trees – this is considered a very vulnerable size class with survivability being influenced by many variables such as sunlight availability, soil condition, weather, and herbivory.

Size Class: 6-12” (Small Seedling)

Woody stems from 6-12” are considered “small seedlings” and are typically 0-1 years old; however, this can vary widely based upon species and growing conditions. This size class accounted for 12.9% of all native woody stems surveyed – pin oak, red oak, and white ash were the most common species in this size class. Small seedlings are still vulnerable to changes in growing condition and herbivory; however, this size class does have a higher rate of survival compared to the germinants.

Size Class: 1-3’ (Seedling)

Woody stems from 1-3’ are considered “seedlings” and are typically 1-2 years old depending upon species and growing condition. This size class accounted for 9.2% of all native woody stems surveyed – white ash, American beech, and shagbark hickory were the most common species in this size class. This size class is less susceptible to environmental conditions such as changes in weather; however, we found this size class to be the most impacted by herbivory. Species (native and invasive) in this size class such as white ash, American beech, hawthorn, spicebush, multiflora rose, common privet, and glossy buckthorn all show signs heavy browse pressure from white-tailed deer.

Size Class: 3-5’ (Large Seedling)

Woody stems from 3-5’ are considered “large seedlings” and are typically 2-3 years old depending upon species and growing conditions. This size class accounted for only 0.8% of all native woody stems surveyed – chokecherry, American beech, and white ash were the only native species represented in this size class. Seedlings are robust by this stage and can tolerate a number of environmental pressures; however, heavy browsing can still negatively impact this size class.

The stark drop in both seedling abundance and species diversity in the 3-5’ size class can likely be attributed to heavy browse pressure at the lower size classes where preferred browse species are selected against – species such as chokecherry and American beech are low browse preference species, with chokecherry foliage being toxic to white-tailed deer.

Size Class: 5'+ <4.5" DBH (Sapling)

Woody stems taller than 5' in height but less than 4.5" DBH (diameter at breast height) are considered "saplings" and are typically a minimum of 3-5 years in age depending upon species and growing conditions. This size class represented 0.5% of all native woody stems surveyed – sugar maple, chokecherry, slippery elm, American beech, and blackhaw viburnum were the only species found in this size class. This size class is very robust and is generally unaffected by environmental pressures or herbivory – the greatest risk to saplings would be pests, disease, or heavy site disturbance.

Examples of Deer Browse

Plot Scoring

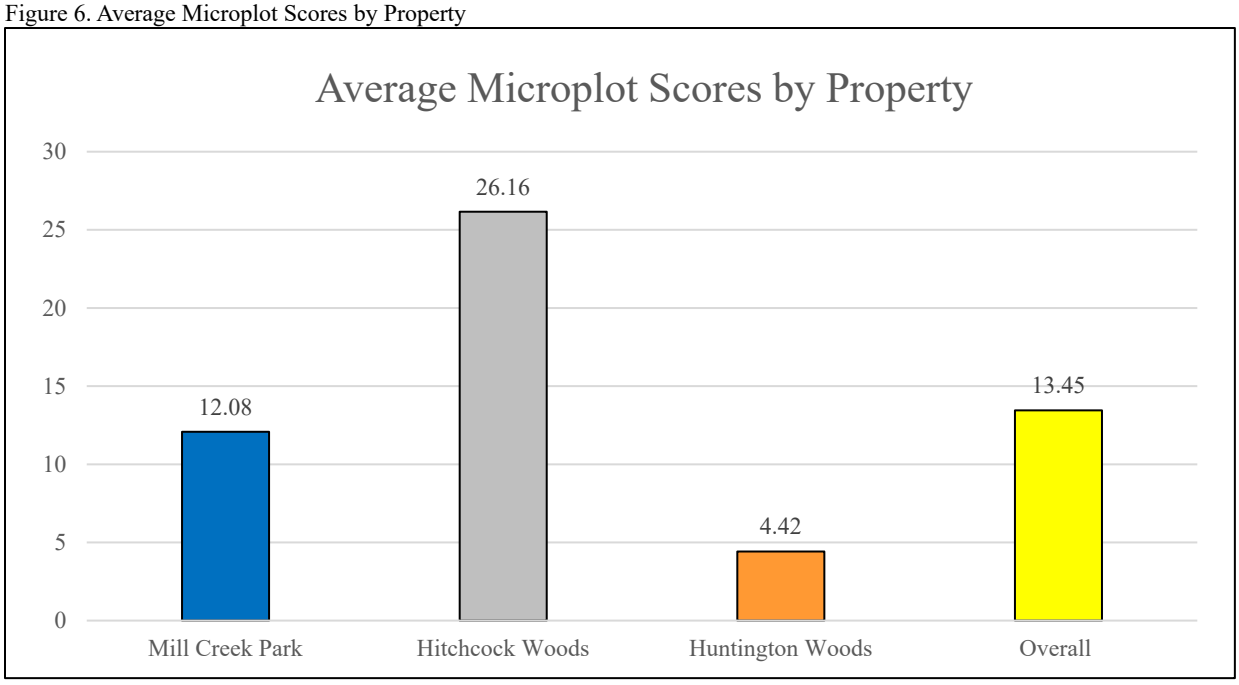
Using the scoring system described above, all microplots were assigned a score which reflects the stage of forest regeneration for each plot based upon native species abundance and height. Overall, the average microplot score for all surveyed areas was 13.5, with one (1) of the 110 surveyed plots surpassing a forest regeneration score of 150 points. In this instance, the score of 177.5 was produced due to high stem count of chokecherry in the 3-5' size class. In this case it is important to note that chokecherry is considered highly deer-resistant and even toxic to deer and other animals if eaten in large quantities; therefore, its presence could be a symptom of selective browsing pressure.

Again, white ash was not assigned a positive score due to their lack of long-term viability. It is important to note that white ash is heavily susceptible to the emerald ash borer (EAB), a non-native boring insect that is responsible for the destruction of millions of ash trees across much of the eastern United States. It is estimated that only 1% of ash trees on the landscape have a higher-than-average resistance to this pest. With that being said, ash regeneration is still taking place on the landscape, typically in the smaller size classes. Impacts from EAB will likely continue once saplings reach a suitable size, rendering them largely incapable of reaching full maturity and becoming the dominant canopy species they once were.

Also, woody stems showing severe damage or outward sign of disease were scored at half-value. This primarily impacted American beech which oftentimes showed both heavy browse pressure and advanced signs of beech leaf disease (BLD).

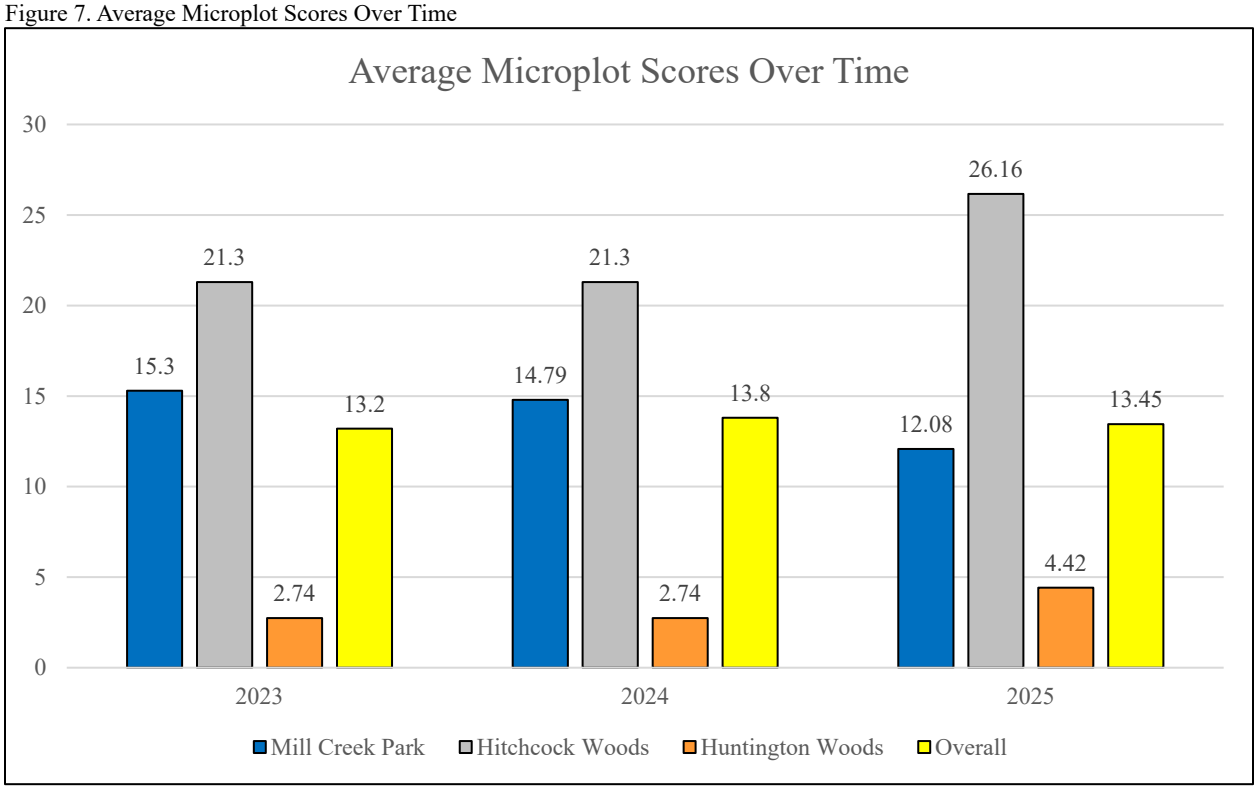
As a control, the Hitchcock Woods deer exclosure was scored using the same metrics. In total, the 324 sq ft area produced a forest regeneration score of 696. Scaled down to match the size of the microplots (113.1 sq ft), the deer exclosure scores 243.2 points (~18x better than the overall average microplot score).

Figure 6. Average Microplot Scores by Property



The overall average microplot scores for those same properties were also graphed to show changes over the last three years. Although this is not a long enough period to determine whether or not that change is statistically significant, this metric will be continually assessed each year in the future to help analyze whether manipulating factors such as mammalian herbivore population may have an effect on forest regeneration.

Figure 7. Average Microplot Scores Over Time



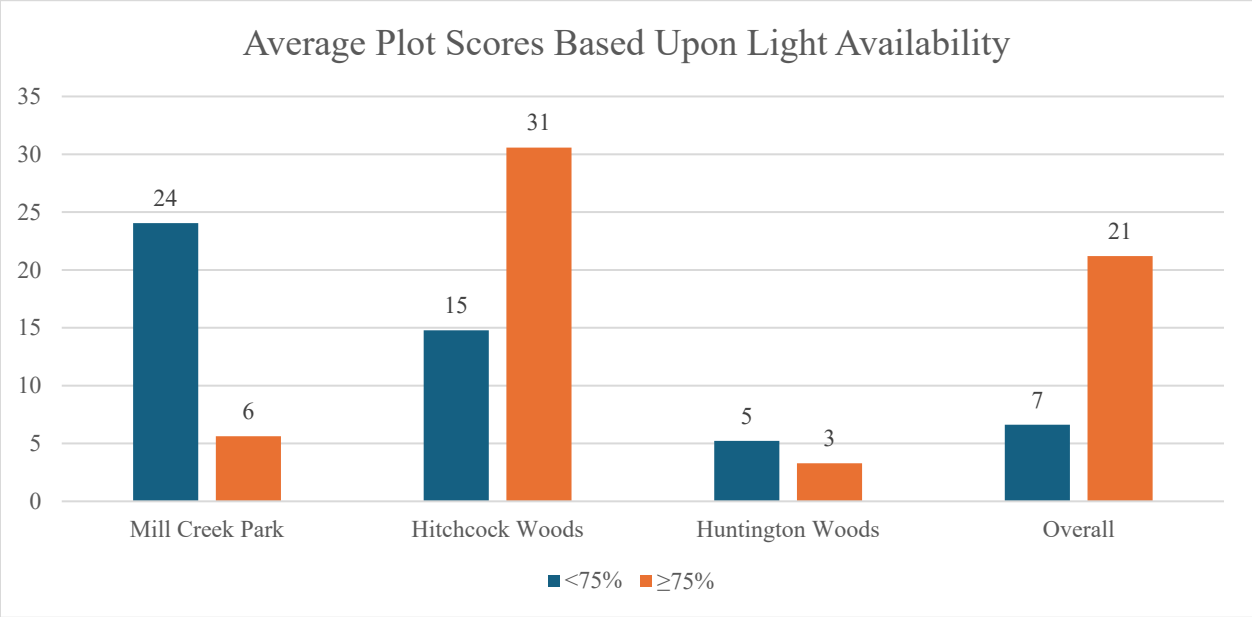
The average microplot scores across the three surveyed properties offer insight into forest regeneration trends and the potential impact of deer browsing over time. Hitchcock Woods, despite not being fully protected from deer, consistently showed the highest average scores among the three sites, increasing notably from 21.3 in 2023 and 2024 to 26.16 in 2025. This may suggest site-specific advantages such as better light availability, fewer invasive species, or localized browse pressure. Mill Creek Park showed a steady decline over time (from 15.3 to 12.08), while Huntington Woods remained low, despite a slight improvement from 2.74 to 4.42. These results suggest that deer herbivory continues to constrain regeneration, particularly in sites lacking protection or favorable growing conditions. The overall average microplot score has remained relatively stable (13.2–13.8), underscoring the need for continued monitoring and targeted management to assess long-term regeneration success.

Canopy Closure

Receiving adequate amounts of sunlight is a necessary component for all plant growth. In forested settings, canopy closure affects the amount of light that reaches the forest floor, and therefore, can impact a forest's ability to regenerate by affecting both growth rates and species composition. During this study, microplots displayed a wide range of canopy closure percentage (0-95%) with 50% of microplots having above average light availability (≤75% canopy closure) due to prior disturbance from EAB and/or storm damage.

As expected, light availability had a large influence on plot scoring – microplots with less than 75% canopy closure scored higher than microplots with greater than 75% canopy closure. Huntington Woods proved to be an exception to this rule, where available light gaps tend to be dominated by ferns, sedges, and invasive shrubs.

Figure 8. Average Plot Scores Based Upon Light Availability



Example of Microplot with <75% Canopy Closure

Example of Microplot with >75% Canopy Closure

Oak Regeneration:

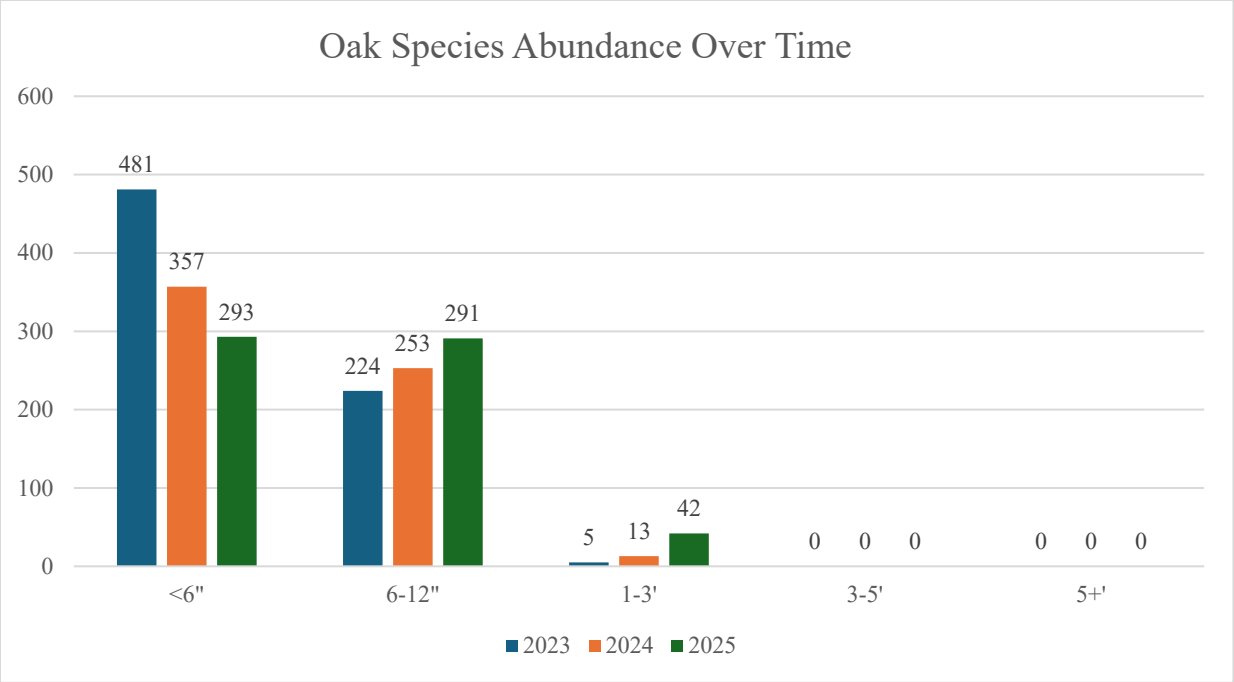
Across their range, oaks (*Quercus spp*.) exist as common canopy trees; however, they are largely absent in the understory seedling and sapling layers. Oak species are highly preferred browse for deer, often experiencing significant herbivory pressure in areas with high deer populations. Due to this preference, oaks are typically used as an indicator species. (Indicator species are organisms whose presence, absence, or abundance reflects the health or condition of an ecosystem, serving as a sign of environmental changes or disturbances.)

The absence of oak regeneration has led to increased concern in recent decades regarding the overall lack of oak regeneration in Eastern hardwood forests – likely caused by intensive browsing by white-tailed deer, increased competition with other plants, land use changes, disease, and fire suppression. Oaks provide mast crops in the form of acorns which are an essential part of the forest ecosystem, providing valuable fall and winter forage for wildlife. If the current trajectory is not corrected, we may face losing this valuable forest resource in the coming decades as mature trees die with nothing in the understory to replace them.

This same principle applies here as the northern red oak (*Quercus rubra*), pin oak (*Quercus palustris*), white oak (*Quercus alba*), and swamp white oak (*Quercus bicolor*) are all species commonly found on MetroParks properties as mature canopy species and many were also found in the smaller (<6” and 6-12”) size classes; however, oaks of all species were completely absent from 3-5’ and 5+ size classes, with only 42 individuals being found in the 1-3’ size class.

It should also be noted that no species within the white oak family were found in any size class within the microplots, although there are certainly many mature white oaks (*Quercus alba*) and swamp white oaks (*Quercus bicolor*) found in the canopies of all surveyed MetroParks properties. On a more positive note, it can be observed that there has been a steady shift in the size classes of oaks in the last three years, with the number of <6’ individuals decreasing and the number of 6-12” and 1-3’ individuals increasing.

Figure 9. Oak Species Abundance Over Time



Invasive Species:

To better understand how invasive plant presence may be influencing forest regeneration, the percentage of invasive woody stems was calculated for each property across the 2023–2025 survey years (Figure 10). Mill Creek Park consistently had the highest proportion of invasive stems, averaging between 12–14% annually. Hitchcock Woods followed with fluctuating levels, while Huntington Woods maintained very low invasive presence (<1%).

To explore the potential relationship between invasive species presence and overall regeneration outcomes, a scatter plot was created comparing the percent of invasive stems to the average microplot score for each property (Figure 11). The trend suggests an **inverse relationship** — properties with **higher percentages of invasives generally exhibited lower regeneration scores**. For example, Mill Creek Park had the highest invasive stem percentage and the lowest average score (~12), while Hitchcock Woods, with lower invasive presence, had the highest average score (~26). Huntington Woods showed both low invasive presence and a moderately low average score, possibly due to factors other than invasives (e.g., low stem density or canopy closure).

These results support the idea that **invasive species may suppress native regeneration**, either through direct competition or by altering habitat conditions. Continued monitoring of invasive stem abundance and distribution will be important for interpreting long-term regeneration trends.

Figure 10. Percent of Invasive Species

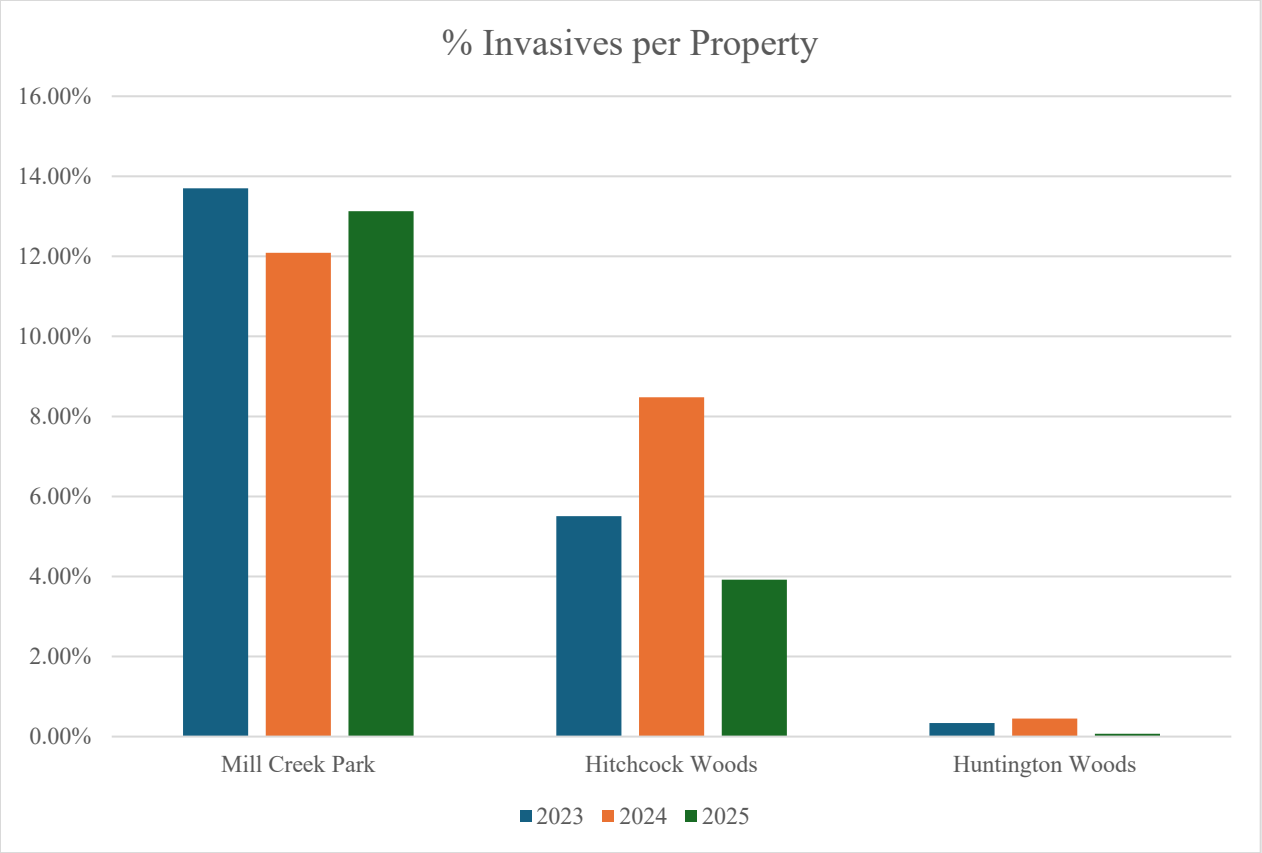
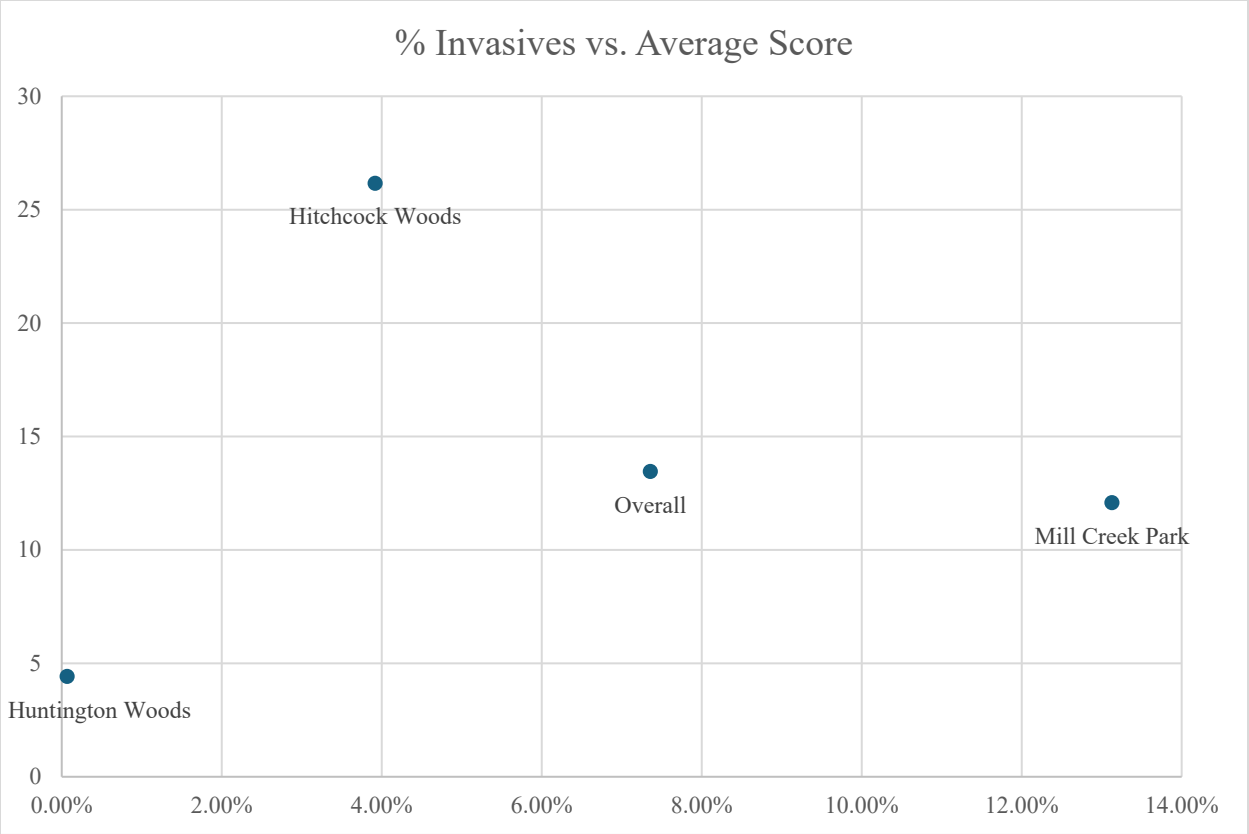


Figure 11. Percent of Invasives vs. Average Scores



Shannon Diversity Index

To evaluate changes in species diversity across properties and over time, the **Shannon Diversity Index (H′)** was calculated annual from 2023 to 2025 **using only native woody species**. Focusing exclusively on native species provides a clearer picture of ecological regeneration and avoids skewing results due to the presence of invasive species, which can inflate diversity metrics despite offering little value to forest health.

The Shannon Index is a widely used ecological metric that captures both **species richness** (number of species) and **evenness** (how evenly individuals are distributed among those species). Higher values of H′ indicate more diverse and balanced plant communities, which are generally more resilient and better able to recover from stressors such as deer browsing.

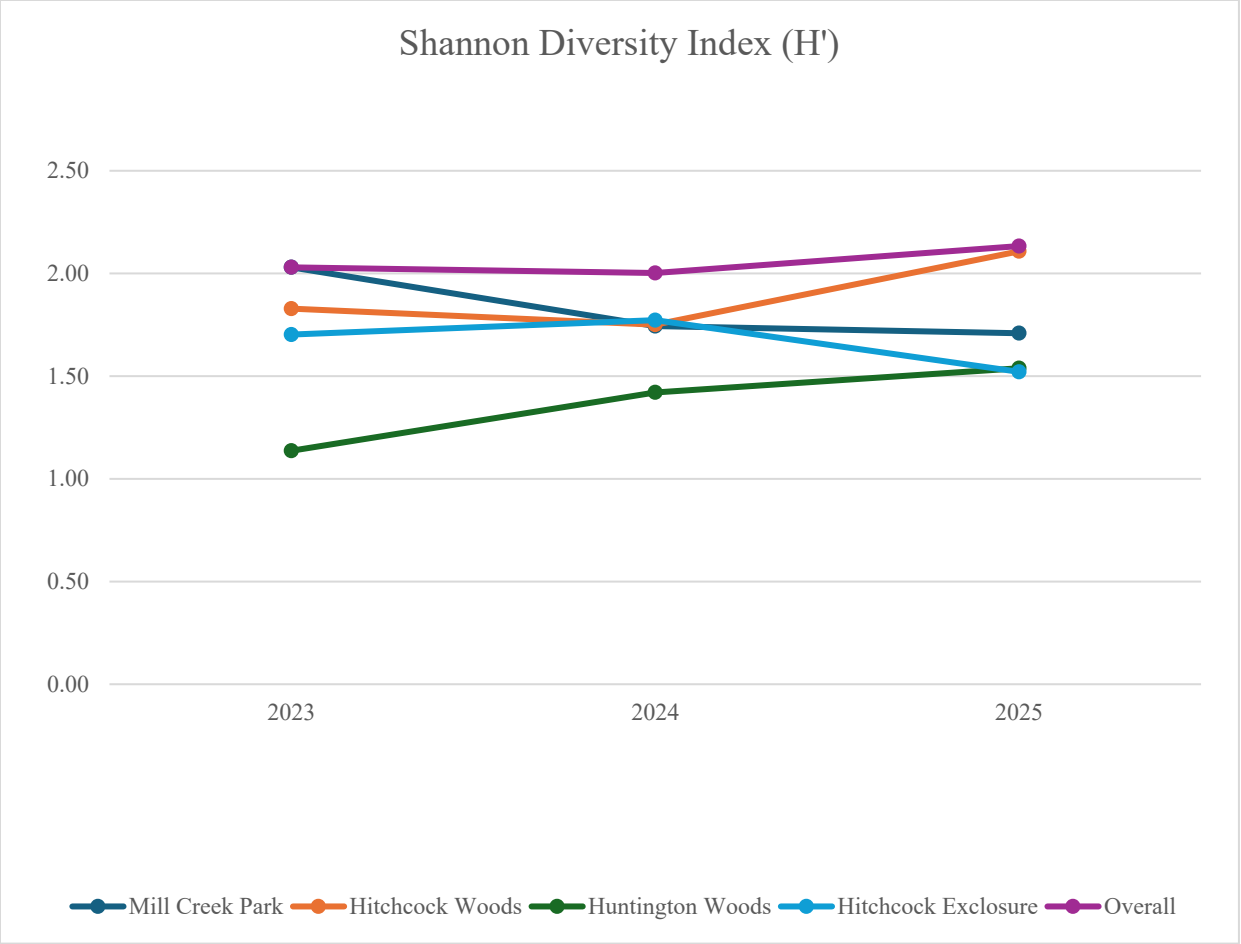
In the context of forest regeneration, high species diversity suggests that a broader range of native woody species is successfully establishing. Conversely, **lower diversity may indicate overbrowsing**, which can lead to regeneration dominated by a few unpalatable or browse-tolerant species — often reducing overall forest structure and ecological function.

As shown in **Figure 12**, overall diversity remained relatively stable but increased slightly from 2023 to 2025. Notably:

- **Huntington Woods** showed a steady **increase in diversity**, reflecting improved regeneration conditions or a gradual shift in species establishment.
- **Mill Creek Park** and **Hitchcock Woods** both showed slight **declines** or fluctuations in diversity, which may be linked to persistent deer pressure or competition from invasive species.
- The **Hitchcock Exclosure** maintained relatively high and stable diversity, highlighting the positive effects of **protection from deer browsing**.
- The **Overall** trend suggests that, while diversity has not drastically declined, **active deer management and invasive control remain important** to support long-term forest health.

These trends reinforce the value of the Shannon Index as a tool to detect subtle changes in regeneration quality that may not be captured by stem counts alone.

Figure 12. Shannon Diversity Index


Shannon Diversity Index (H')
2.50
2.00
1.50
1.00
0.50
0.00
2023
2024
2025
Mill Creek Park
Hitchcock Woods
Huntington Woods
Hitchcock Exclosure
Overall

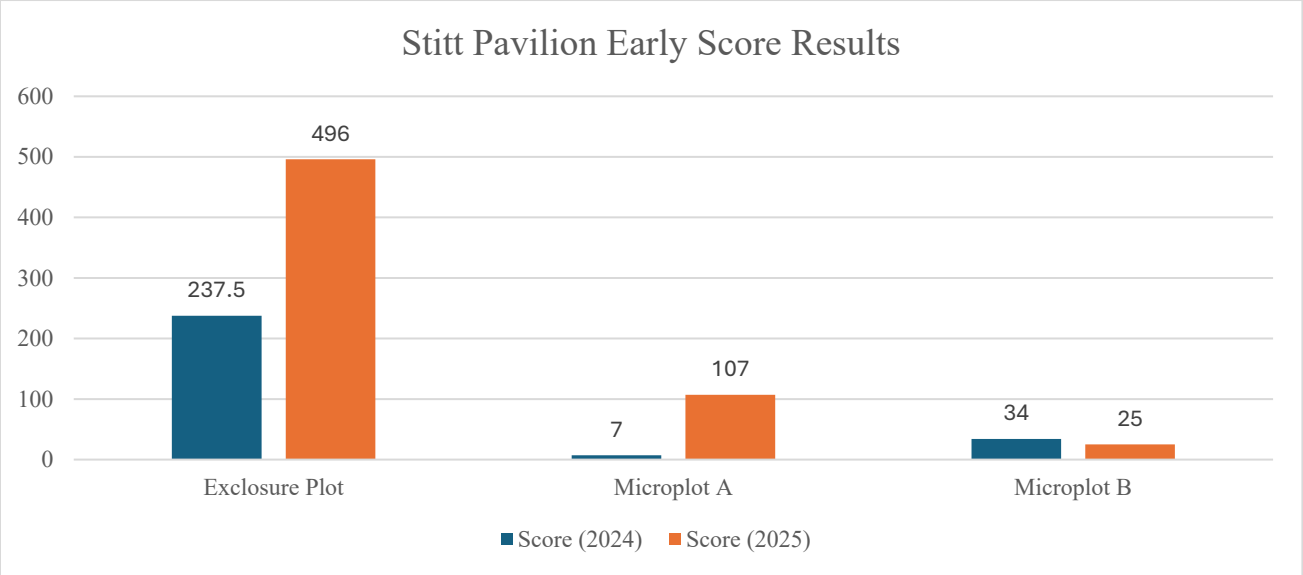
Stitt Pavillion Exclosure

In 2024, a deer exclosure plot was established near **Stitt Pavilion** to serve as an additional control site for assessing the impacts of deer herbivory on forest regeneration. The fenced area is **25 by 25 feet** (625 sq ft), and it was constructed following baseline data collection in 2024. As with the existing exclosure in Hitchcock Woods, this site allows for direct comparison of regeneration **inside vs. outside deer protection** under otherwise similar environmental conditions.

To strengthen this comparison, **two new microplots** were added in 2024 — one on each side of the fence — to represent adjacent **unfenced** conditions. This paired design isolates the effects of browse pressure while holding other variables (light availability, slope, soil) relatively constant. Data collection began in 2024 prior to fencing and continued in 2025.

Although the Stitt Pavilion exclosure is not included in site-wide averages or broader cross-property charts this year, it will be tracked as a **long-term reference point** and may be integrated into larger analyses in future reports.

Figure 13. Stitt Pavillion Scores 2024 vs. 2025



The **doubling in score** within the fenced plot between 2024 and 2025 highlights a strong early regeneration response following protection from deer. Microplot A showed a notable increase in regeneration, while Microplot B declined slightly — illustrating the variability of unfenced conditions even within the same site.

To enable direct comparison with microplots from the broader survey (each 113.1 sq ft), the Hitchcock Woods exclosure plot score (696 in 2025 over 324 sq ft) was scaled down using the following formula:

Scaled Score = (696 × 113.1) ÷ 324 ≈ 242.3

This adjusted score can be compared to the average microplot score across all properties, which was 13.45 in 2025. That means the scaled exclosure score is approximately 18 times greater than the overall

average, clearly demonstrating the positive effect of browse exclusion on forest regeneration under comparable light and site conditions.

Interestingly, the scaled 2024 score from the new Stitt Pavilion exclosure (496 over 625 sq ft) yields an almost identical value when adjusted — approximately 243.2 – to the scaled score from the Hitchcock Woods exclosure. This similarity is noteworthy, considering that the Hitchcock exclosure was first erected around 2000, but fell into disrepair over the years and was only refurbished and fully functional again in 2018. The comparable outcomes at both sites provide strong support for the effectiveness of long-term deer exclusion in promoting native woody regeneration.

Discussion, Management Objectives, and Recommendations:

Discussion

White-tailed deer herbivory continues to be the primary opponent of forest regeneration in Mill Creek Park, Huntington Woods, and Hitchcock Woods. This is evidenced by the intensive browse pressure and overall lack of preferred browse species evidenced by this study and other anecdotal references. Other factors such as light availability, lack of disturbance, exotic pests, disease, and competition from invasive species are also contributing factors that are impacting forest health.

Management Objectives

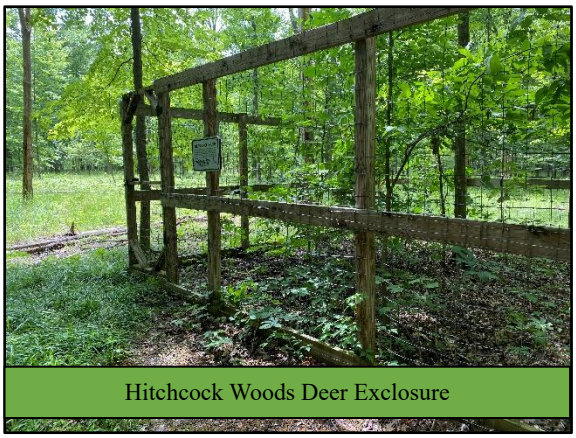
The following set of objectives have been established regarding forest regeneration within Mill Creek MetroParks:

- 75% of Microplots Scoring 150 Points or More.
- 25% of All Surveyed Oak Stems Measuring Greater than 12" in Height with at Least 10% Reaching the 5'+ Size Class.
- Increase in Native Species Diversity with 75% of Surveyed Species Present as Germinants (<6") Also Being Present in the Large Seedling (3-5') or Sapling (5'+) Size Class.
- Maintain 80% or Greater Coverage of Native Species in Surveyed Areas.

Recommendations:

To achieve the abovementioned objectives, it is recommended that the MetroParks consider implementing the following management techniques until goals are met:

- White-tailed Deer Population Reduction and Management
- Native Species Planting
- Invasive Species Management
- Habitat Manipulation Where Appropriate
- Deer Exclusion via Fencing and/or Tree Tubes/Caging Where Appropriate



Hitchcock Woods Deer Exclosure

Collier Preserve Tree Planting

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