

Forest Health Data Summaries for **Friendship Hill National Historic Site (2007 – 2024)**

Background

Forests are crucial resources in Friendship Hill National Historic Site (FRHI), providing an important backdrop for interpreting the Gallatin estate, recreation opportunities for park visitors, habitat for countless animal and plant species, as well as protecting soil stability and stream health. The following forest health summaries are based on data collected in Eastern Rivers and Mountains Inventory and Monitoring Network (ERMN) long-term forest health monitoring plots between 2007 - 2024. There are 20 ERMN forest health monitoring plots in FRHI, with each plot sampled on a 4-year cycle. Most plots were visited four times during this reporting period.

Within each forest plot, tree and stand measurements, including an assessment of deer browse impact, are made within fixed-area, circular plots, 15-m in radius. Tree regeneration data are collected in four 2-m radius circular microplots embedded within each plot. Plots are permanently marked and measured at the same location every cycle. For a more detailed description of our methods, refer to the [ERMN forest monitoring protocol](#).

This document provides data summaries and interpretations of trends in tree regeneration, deer browse impacts, forest structure, tree canopy composition, and invasive plants to help inform National Park Service (NPS) staff of forest health condition and trends.

Tree Regeneration and Deer Impacts

An abundant regeneration layer that is composed of tree seedlings and saplings of varying sizes is an important component of a healthy forest. Regeneration debt occurs when forests lack sufficient regeneration, or the species composition in the regeneration layer does not match the canopy. FRHI has a forest regeneration status of Imminent Failure ([Miller et al. 2023](#)), meaning that the park is experiencing severe regeneration failure and has an elevated risk of forest loss.

The vast majority of seedlings in FRHI are <15 cm in height (Map 2), likely due to deer browse pressure that prevents seedlings from maturing. Park-wide, seedling abundance is increasing (Map 1), with increases observed in taller height classes (Figure 1). This is a positive trend, however, increases in native canopy-forming tree seedlings are outpaced by increases in short-statured native understory tree seedlings that cannot replace the current canopy ([Miller et al. 2023](#)).

Forests in FRHI have a mismatch between the forest canopy and the seedling and sapling layers (compare Maps 3 and 4). Although tuliptree (*Liriodendron tulipifera*) is strongly dominant in the canopy, that species is uncommon as seedlings and saplings. Maples (*Acer* spp.) are dominant in the regeneration layers, along with ash (*Fraxinus* spp.), American beech (*Fagus grandifolia*), cherries (*Prunus* spp.), and paw paw (*Asimina triloba*, Map 3). Sugar maple (*Acer saccharum*) and box elder (*Acer negundo*) seedlings have increased, with concurrent losses in red maple (*Acer rubrum*, Figure 2). Ash seedlings peaked during the middle of the monitoring period as ash trees dying from emerald ash borer (*Agrilus planipennis*) infestation produced an abundance of seeds. Saplings are declining in

abundance, most notably in the two most common species, paw paw and sugar maple (Figure 3). American beech is one of the few species that are increasing as both seedlings and saplings.

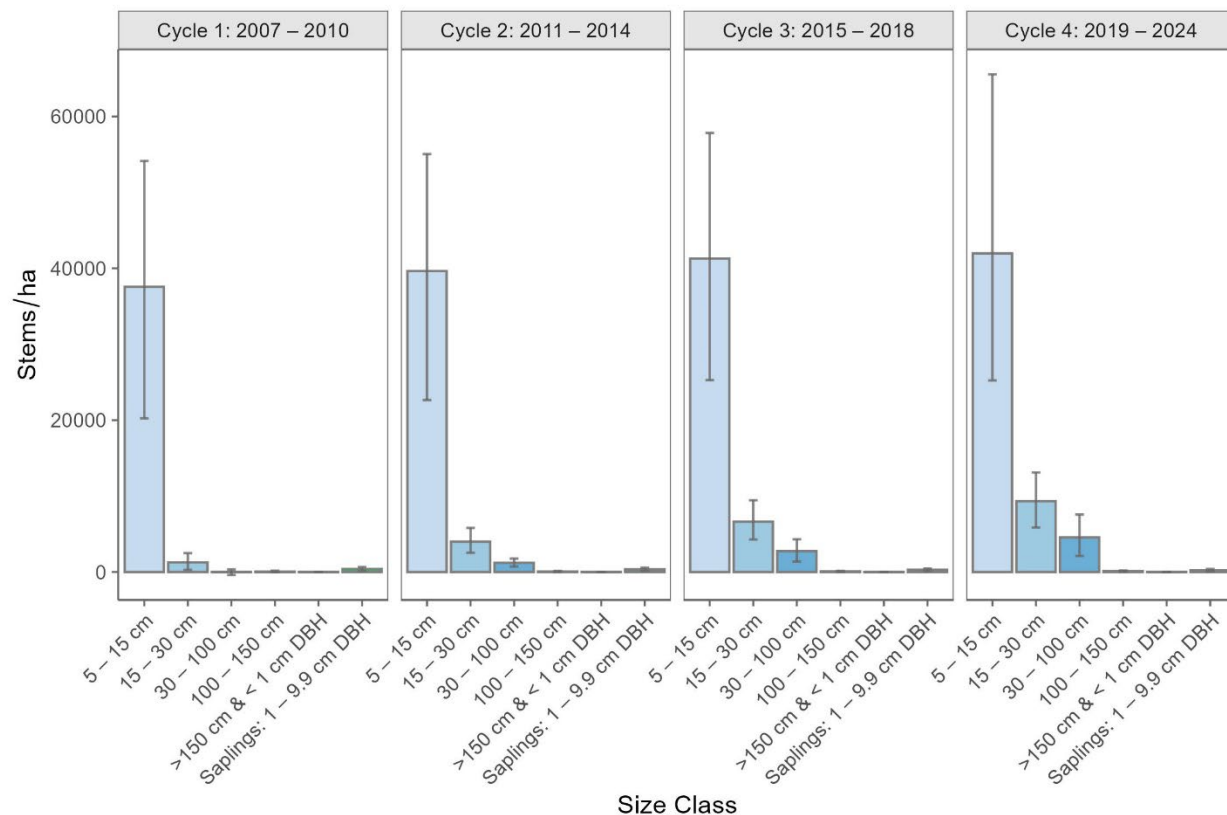


Figure 1. Trends in tree regeneration densities by height class in Friendship Hill National Historic Site, 2007 – 2024. Error bars are 95% bootstrapped confidence intervals to account for non-normal error.

The regeneration stocking index, which quantifies whether native seedling and sapling densities are sufficient to restock a forest canopy, shows that forests in FRHI are severely understocked in 14 out of 20 plots (Map 5). Since FRHI forests don't contain enough seedlings and saplings of the native canopy-forming trees species, canopy gaps caused by storms or insect pests are likely to convert to impenetrable thickets of invasive shrubs, leading to forest loss.

Deer browse impacts are assessed on a scale of 1 – 5, with 1 representing unnaturally low impacts from deer exclusion and 5 representing severe impacts evidenced by a distinct browse line. Impacts of 3 or higher typically require management intervention to maintain adequate forest regeneration. In the most recent 4-year survey, all plots in FRHI were rated 3 or 4 (Map 6) indicating that deer browse is significantly impacting forest regeneration and forest understory diversity.

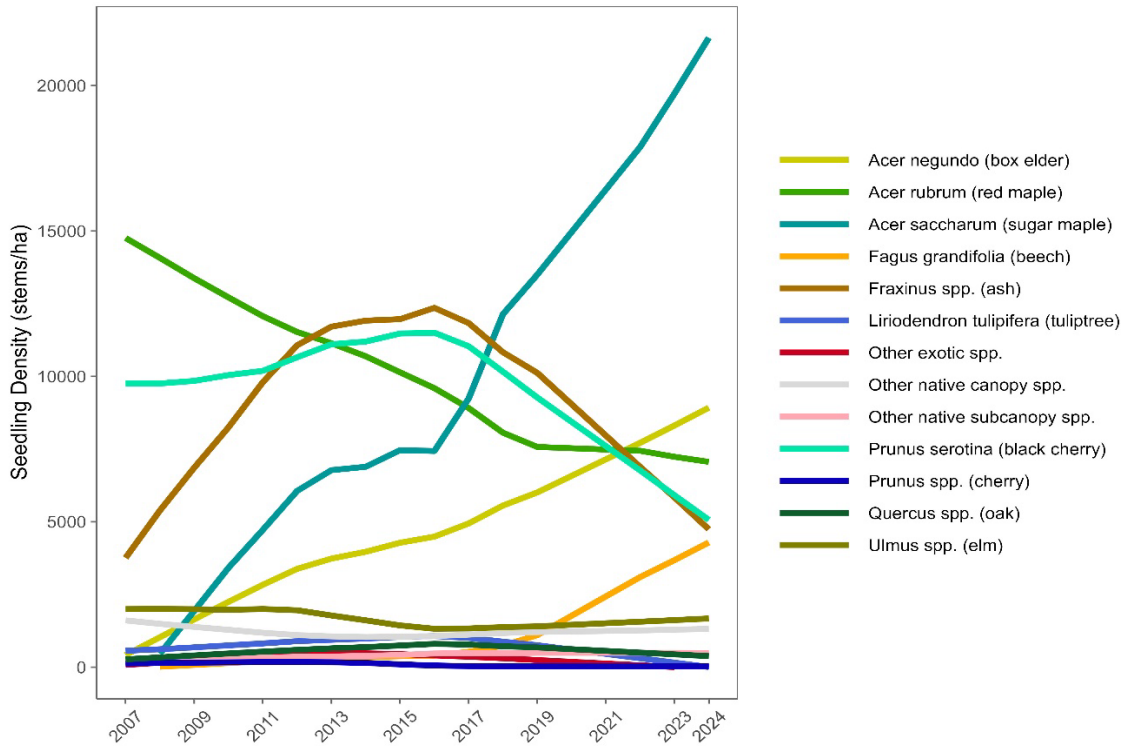


Figure 2. Trends in seedling density by species group and sample year in Friendship Hill National Historic Site. Local regression smoothing approximated a linear trend between consecutive sample events per panel.

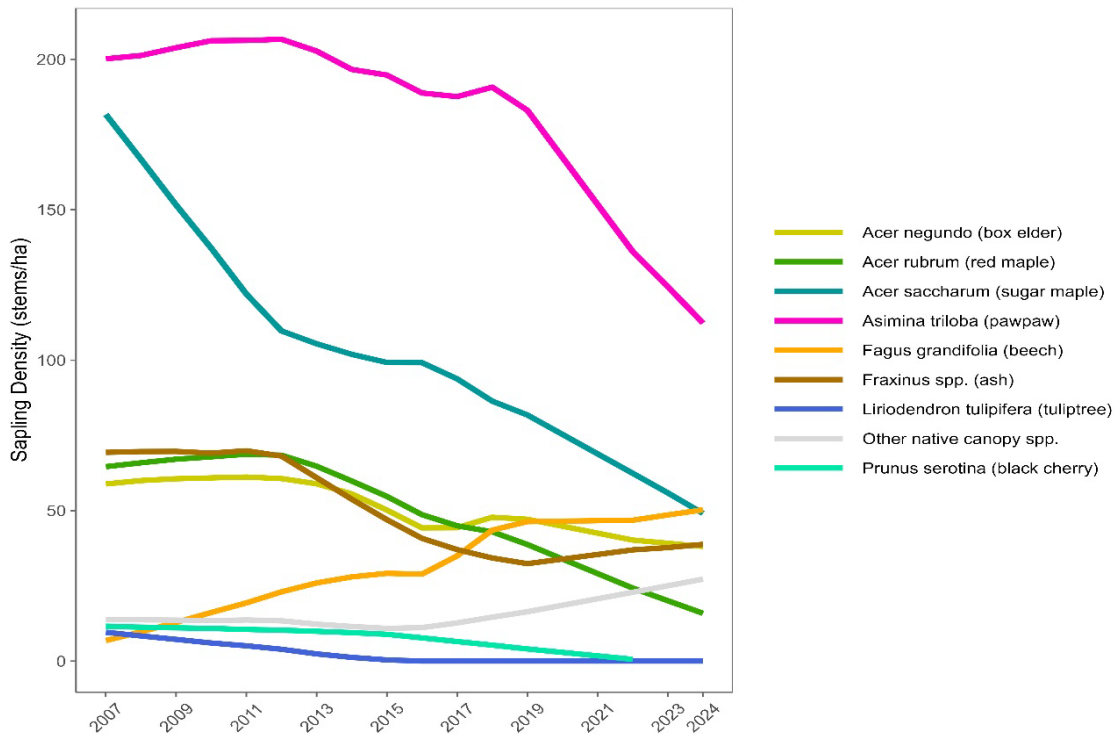


Figure 3. Trends in sapling density by species group and sample year in Friendship Hill National Historic Site. Local regression smoothing approximated a linear trend between consecutive sample events per panel.

Forest Structure and Canopy Composition

Based on tree cores collected near our plots, trees in FRHI are primarily 40 to 90 years old, with the oldest cored tree, a tuliptree, originating over 125 years ago. Despite being young to middle-aged, the forests in FRHI have more complex older forest structure, such as large live standing trees and downed coarse woody debris (Map 10), than surrounding forests sampled by the US Forest Service (Miller et al. 2016). Therefore, the protection and management of park forests has importance beyond the boundaries of the park. Canopy cover within monitoring plots is stable in middle-aged forests or increasing in younger successional forests that have established in abandoned fields (Map 7).

Forest canopies in FRHI are dominated by tuliptree and maples (*A. rubrum*, *A. saccharum*, *A. negundo*), with lesser amounts of oak (*Quercus* spp.), American beech (*Fagus grandifolia*), pines (*Pinus* spp.), and cherries (*Prunus* spp., Figures 4 and 5, Map 4). Tuliptrees and maples are gaining in basal area as trees mature (Figure 4), accompanied by expected declines in tree density as smaller trees lose out to competition (Figure 5). Notably, mature ash trees (*Fraxinus* spp.) have been nearly eliminated by emerald ash borer during this period. Black cherry (*Prunus serotina*) shows concerning declines in both basal area and density. Aside from emerald ash borer's elimination of mature ash trees, no other significant tree pest or pathogen outbreaks were observed during the monitoring period.

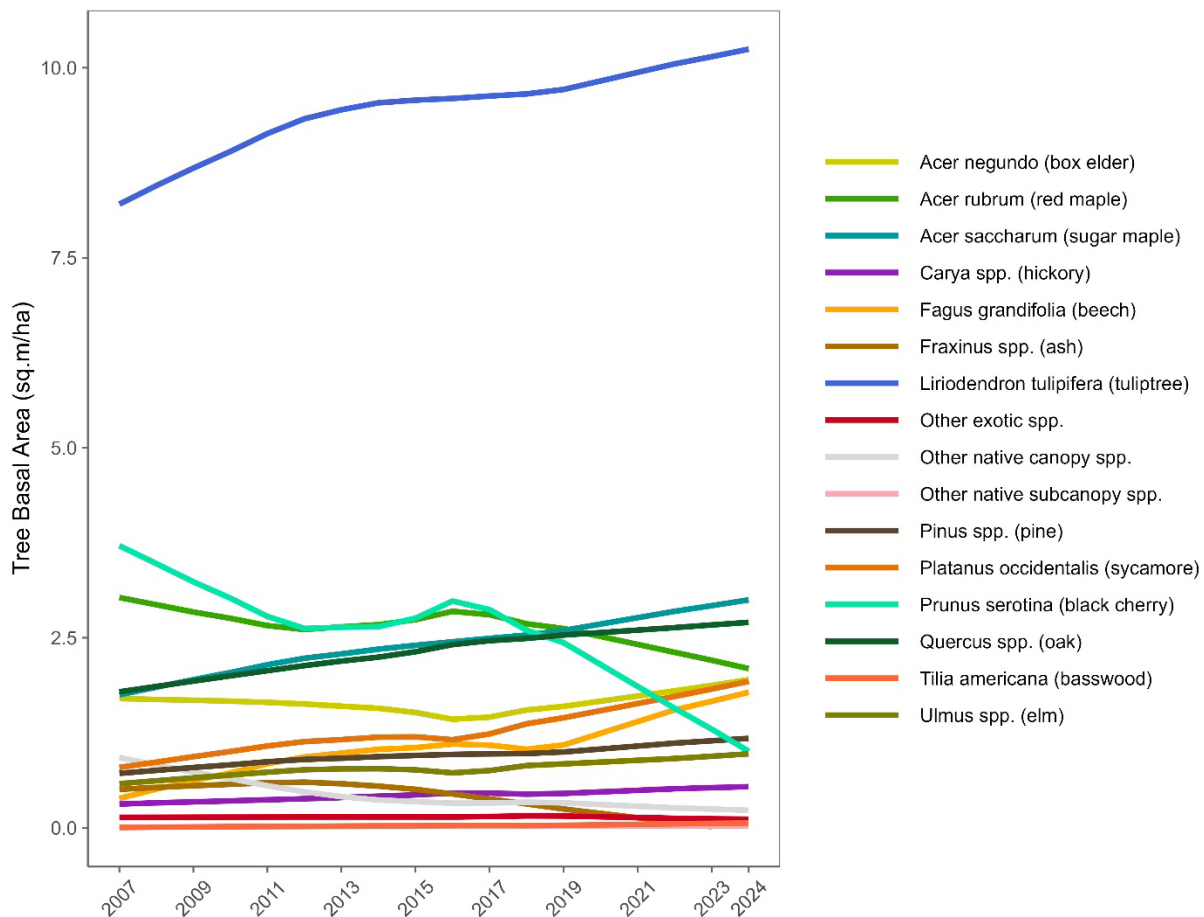


Figure 4. Trends in tree basal area by species group and sample year in Friendship Hill National Historic Site. Local regression smoothing approximated a linear trend between consecutive sample events per panel.

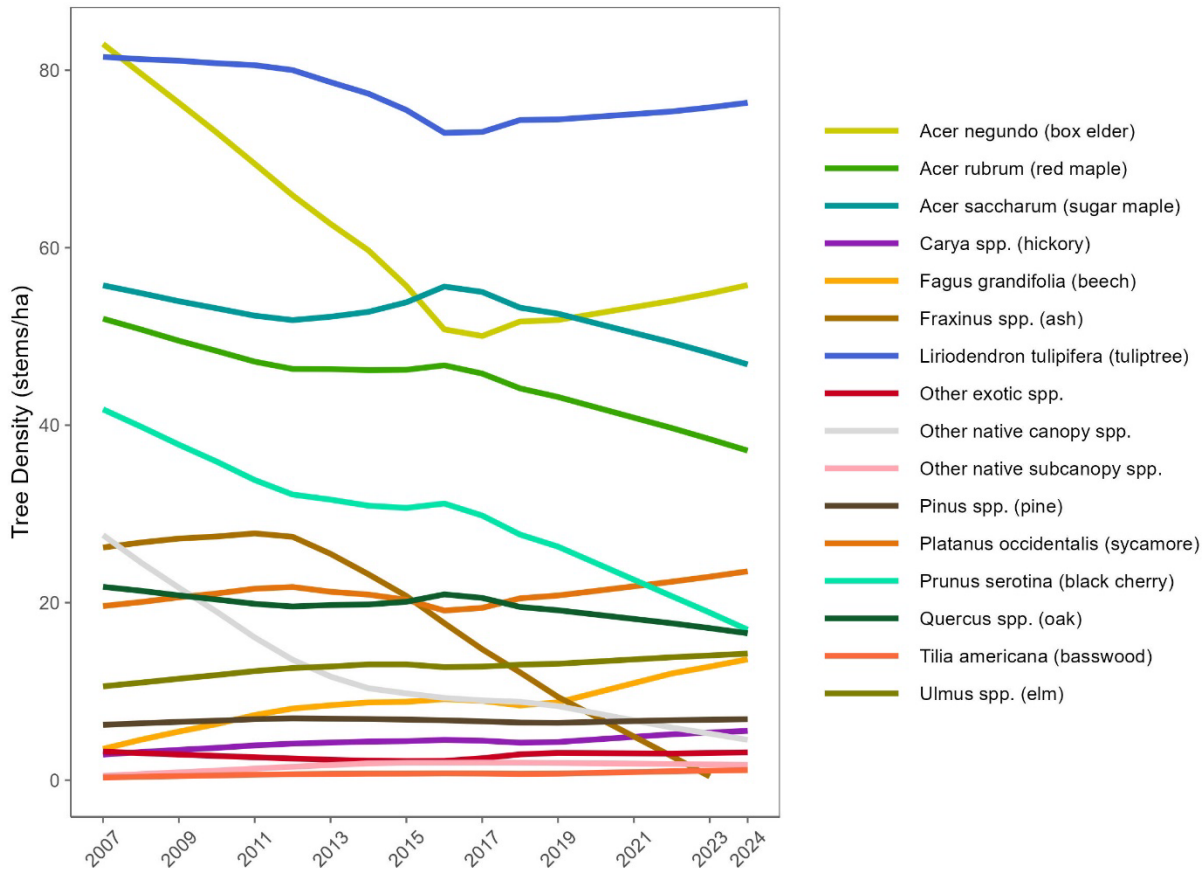


Figure 5. Trends in tree density by species group and sample year in Friendship Hill National Historic Site. Local regression smoothing approximated a linear trend between consecutive sample events per panel.

Invasive Species

Invasive plants can have dramatic impacts on forest health by altering forest structure and diversity, suppressing tree regeneration, altering nutrient cycling and disturbance regimes, and reducing native species diversity. In FRHI, invasive plants were detected in every monitoring plot (Map 8), with Japanese stiltgrass (*Microstegium vimineum*) as the most abundant invasive species (Map 9). Invasive shrubs such as multiflora rose (*Rosa multiflora*) and autumn olive (*Elaeagnus umbellata*) are common, along with Japanese honeysuckle (*Lonicera japonica*), creeping Charlie (*Glechoma hederacea*), and non-native smartweeds (*Persicaria* spp.). Invasive abundance is increasing in FRHI ([Miller et al. 2021](#)), highlighting the importance of implementing strategic invasive plant management at FRHI.

Conclusions

Forests are an important ecological and cultural resource in FRHI that provide under-represented and regionally significant forest habitat. That said, several forest health trends warrant concern. The consistently high deer browse impacts and low levels of tree regeneration are most concerning. If these trends persist or worsen, reversing the trajectory will only get harder and more costly over time,

and can ultimately lead to loss of forest habitat in the most severe cases. Implementing deer management and continuing strategic investment in invasive plant management would bolster forest resilience and address these forest health concerns.

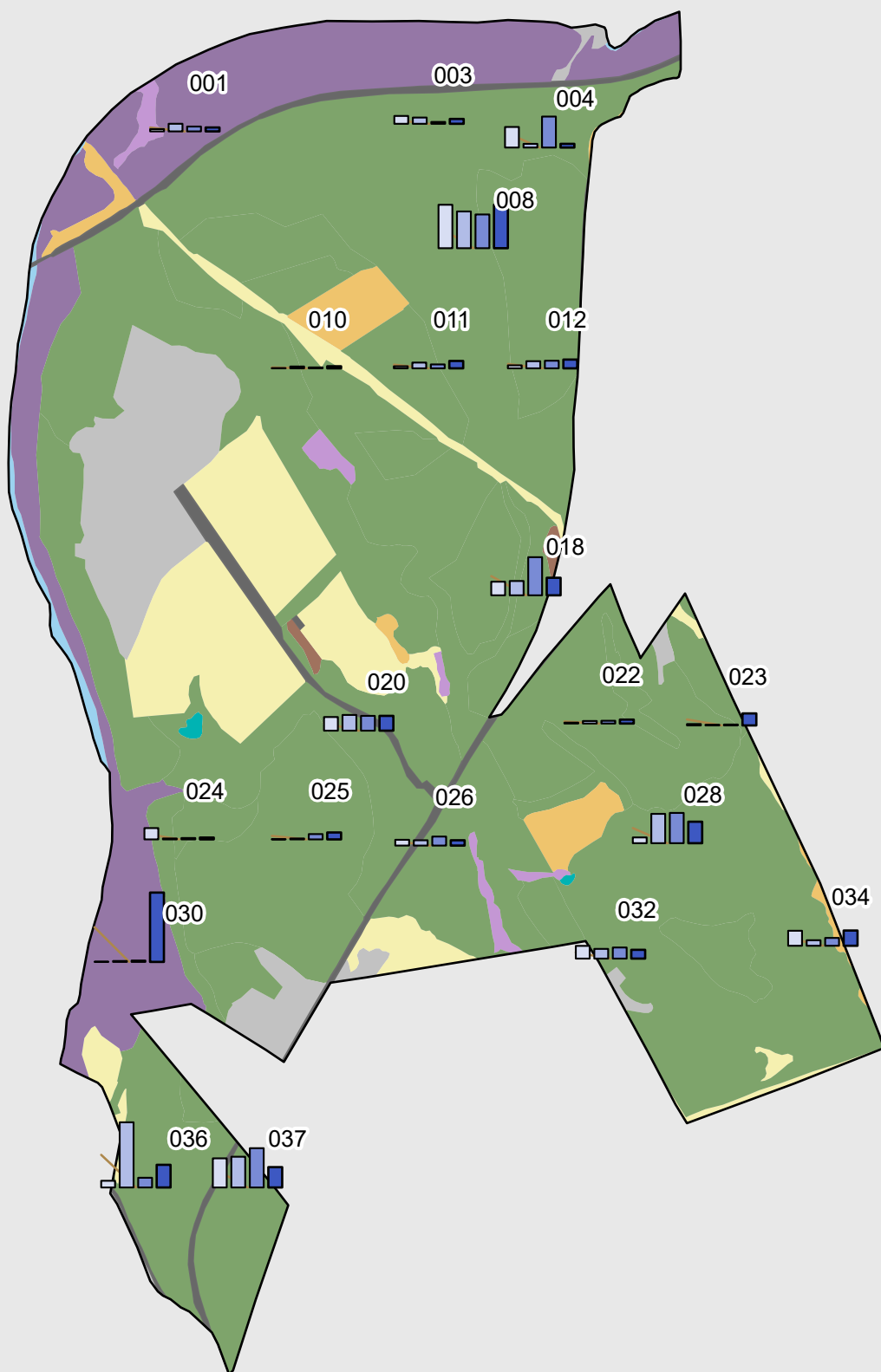
Author Contributions

This summary document, completed in December 2025, was written by Stephanie Perles, ERMN Plant Ecologist. Maps and figures were created by Norman Bourg (Regional Biologist), Hannah Cabell (ERMN Forest Crew Member), and Stephanie Perles. This document was adapted from materials developed by staff from the NPS Northeast Temperate and Mid-Atlantic Inventory and Monitoring Networks, including Kate Miller (NETN/MIDN Quantitative Ecologist), Camilla Seirup (former NETN/MIDN Forest Crew Leader), and Jamie Attanasio (NETN/MIDN Forest Crew Member).



Map 1. Native Canopy-Forming Tree Regeneration by Cycle

Trends in tree regeneration, including seedlings and saplings of native canopy-forming species, observed in forest plots during four monitoring cycles spanning 2007 - 2024. Regeneration stem densities range from 796 to 266,783 per hectare. Reporting Date: 12/12/2024.



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Regeneration densities

- Cycle 1: 2007 to 2010
- Cycle 2: 2011 to 2014
- Cycle 3: 2015 to 2018
- Cycle 4: 2019 to 2024

Plot number

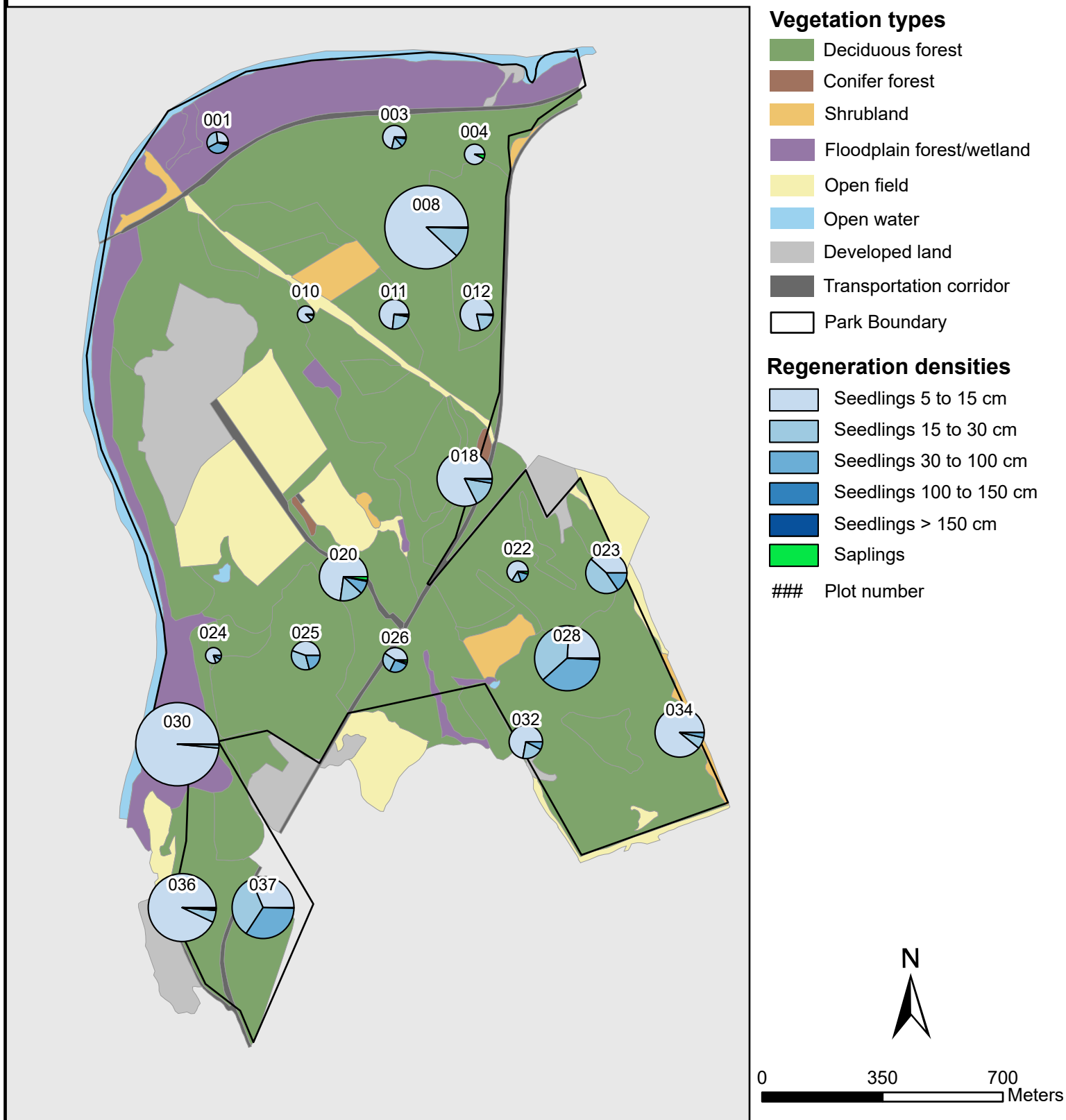


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Map 2. Native Canopy-Forming Tree Regeneration by Size Class

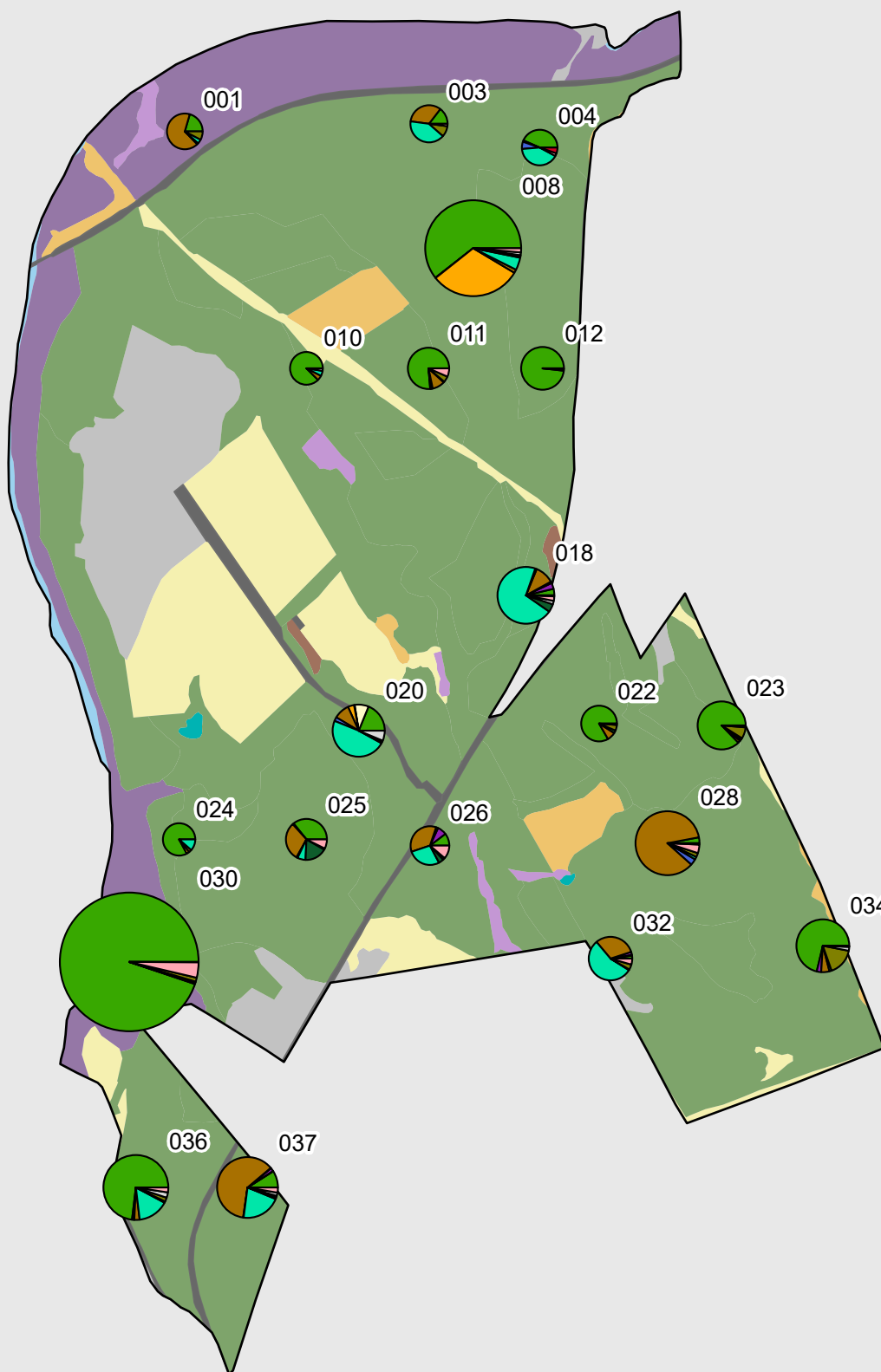
Tree regeneration, including seedlings and saplings of native canopy-forming species, by size class observed in forest plots during the last census (2019 - 2024). Plot-level regeneration stem densities range from 6,963 to 266,783 per hectare. Reporting Date: 12/15/2025.





Map 3. Tree Regeneration Composition

Tree regeneration, including seedlings and saplings, by species group observed in forest plots during the last census (2019 - 2024). Pie size is proportional to plot-level regeneration density. Regeneration stem densities range from 6,963 to 266,783 per hectare. Reporting Date: 12/12/2024.



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Tree regeneration composition

- Acer spp. (Maple)
- Betula spp. (Birch)
- Carya spp. (Hickory)
- Fagus grandifolia (Beech)
- Fraxinus spp. (Ash)
- Liriodendron tulipifera (Tulip poplar)
- Prunus spp. (Cherry)
- Quercus spp. (Oak)
- Ulmus spp. (Elm)
- Other native canopy species
- Other native subcanopy species
- Exotic species

Plot number

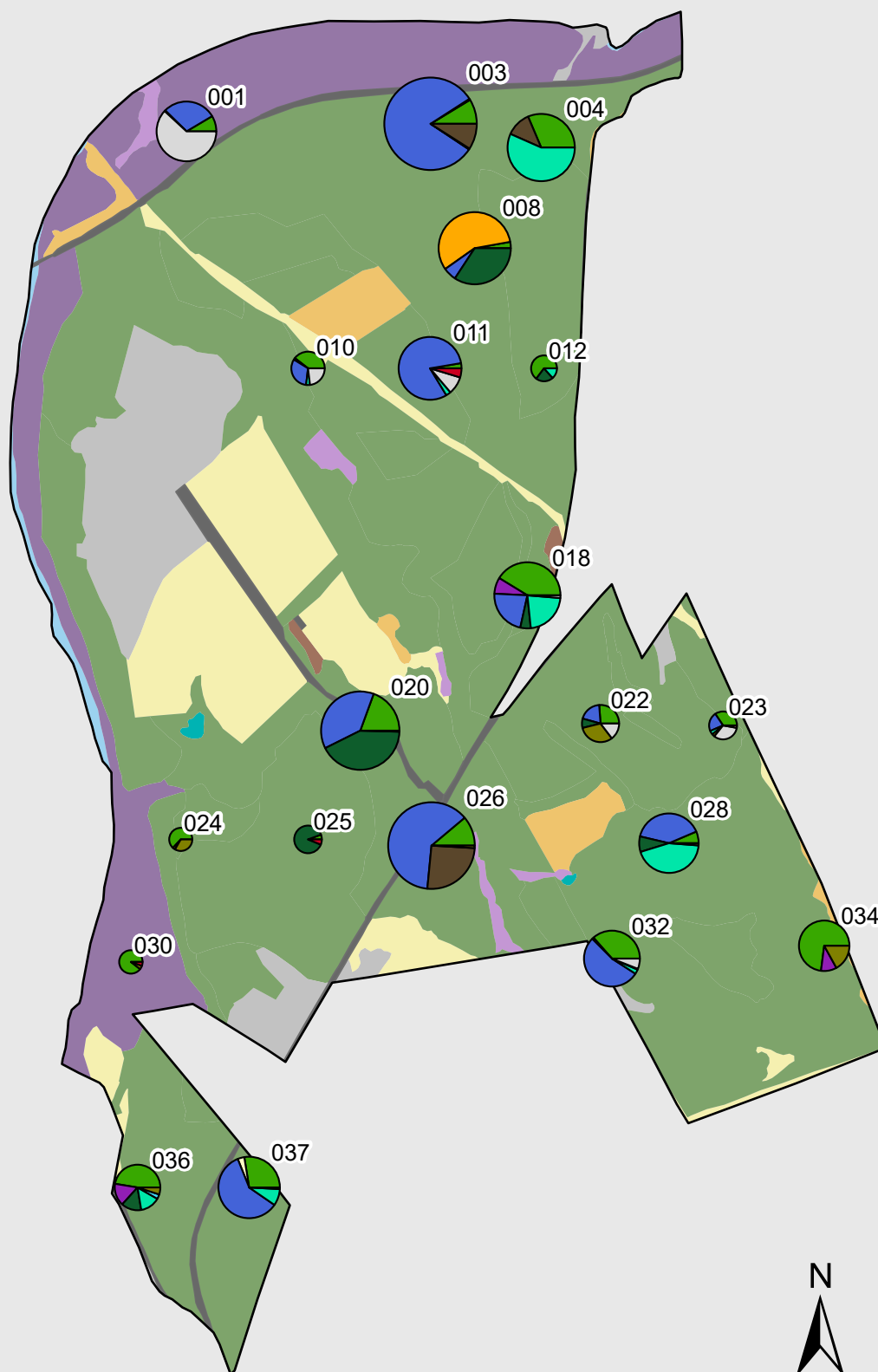


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Map 4. Tree Canopy Composition

Tree composition, by species group, observed in forest plots sampled in the most recent census (2019-2024). Pie size is proportional to plot-level tree basal area. Total basal area ranges from 10.4 to 50.6 m²/ha. Reporting Date: 12/12/2024.



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Tree Canopy Composition

- Acer spp. (Maple)
- Betula spp. (Birch)
- Carya spp. (Hickory)
- Fagus grandifolia (Beech)
- Fraxinus spp. (Ash)
- Liriodendron tulipera (Tulip poplar)
- Quercus spp. (Oak)
- Pinus spp. (Pine)
- Prunus spp. (Cherry)
- Tilia americana (Basswood)
- Ulmus spp. (Elm)
- Other native canopy species
- Other native subcanopy species
- Exotic species

Plot number

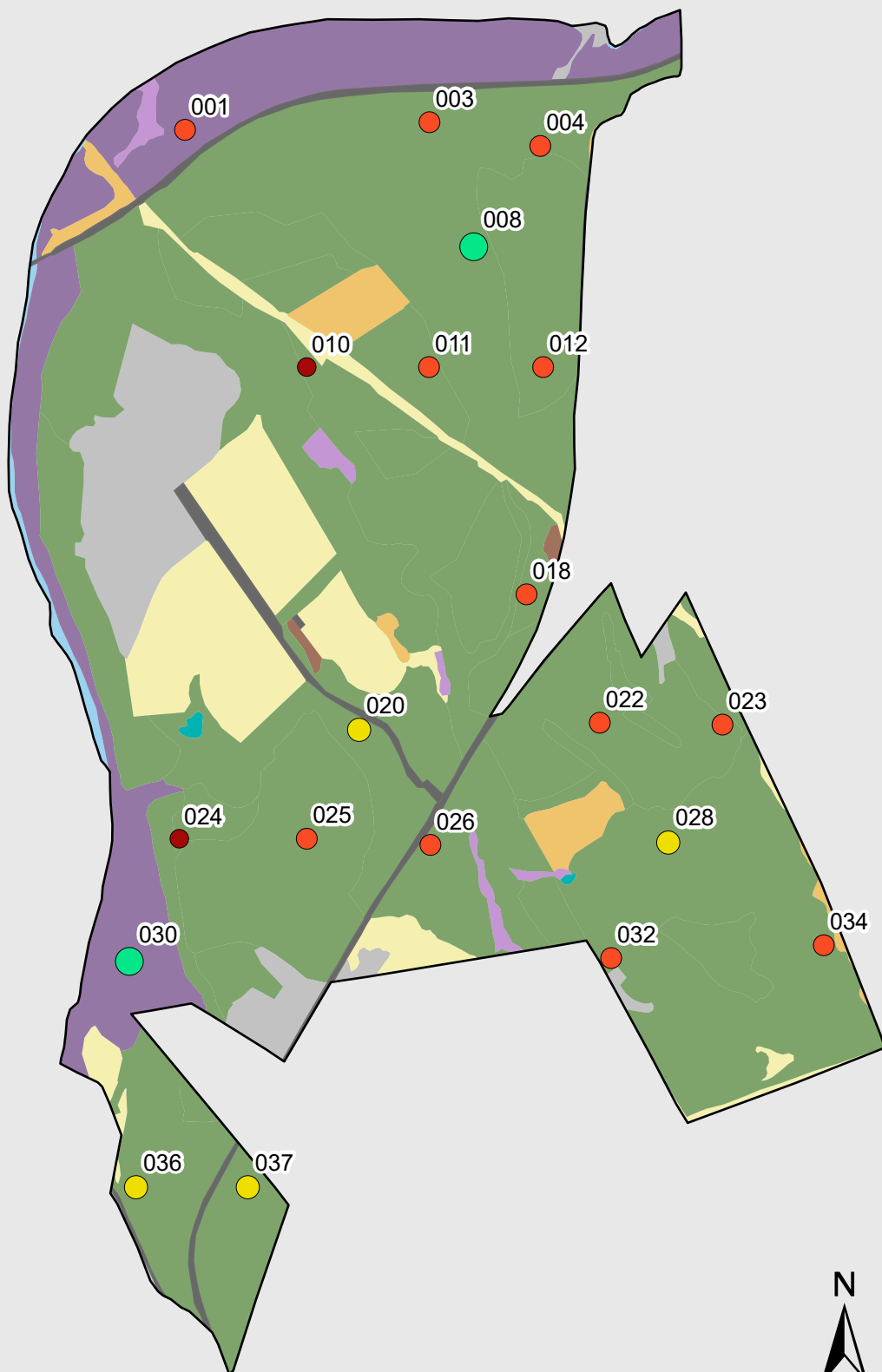


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Map 5. Tree Regeneration Stocking Index

Regeneration stocking index for the most recent census (2019-2024) quantifies whether regeneration is sufficient to restock a forest canopy given deer browse impacts. This index is a weighted sum of native canopy-forming tree seedling and sapling and is reported as a plot-wide average from four microplots. Index values range from 9.5 to 336. Reporting Date: 12/12/2024



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Regeneration Stocking Index

- < 30: Severely understocked. Regeneration is insufficient to replace the forest canopy.
- 30 to 100: Moderately stocked regeneration, sufficient for areas with low deer impacts.
- 100 to 200: Sufficient regeneration to replace forest canopy in areas with moderate (or fewer) deer impacts.
- > 200: Sufficient regeneration to replace forest canopy in areas with high (or fewer) deer impacts.

Plot number

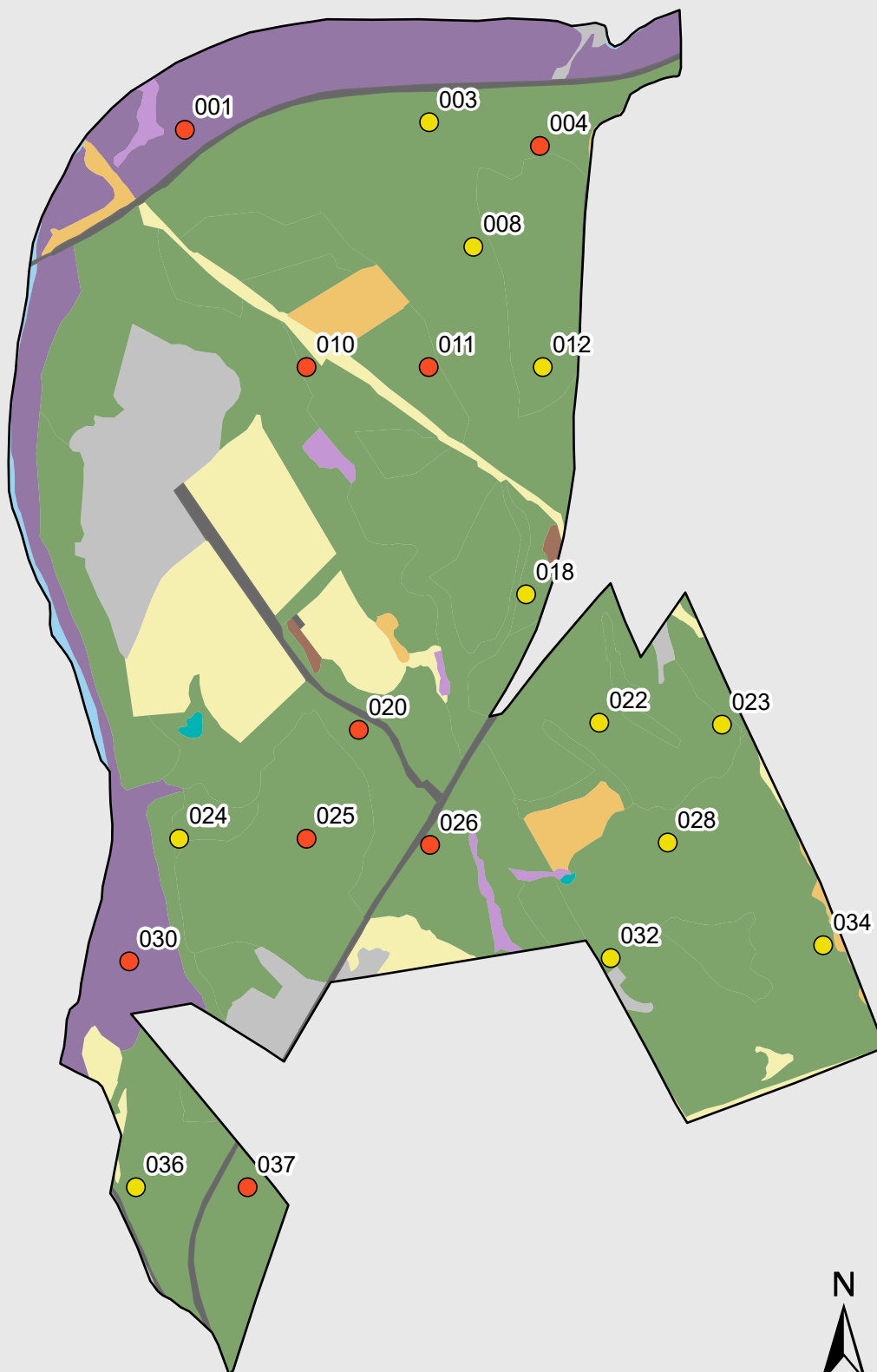


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Map 6. Index of Deer Browse Impacts

Index of deer browse impacts observed in forest plots in the most recent census (2019-2024). Deer browse impacts are assessed on a scale of 1-5, with 1 representing no impact and 5 representing severe impacts. Reporting Date: 12/12/2024



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Deer Browse Impact

- 2: Low impact: deer-preferred (DP) species abundant and of varying heights.
- 3: Medium impact: DP species present, but mostly under 30 cm tall. DP herbs present but stunted and flowering is uncommon.
- 4: High impact: DP species are rare to absent. Non-preferred and browse-resilient vegetation limited in height by deer browse. DP herbs absent or severely stunted.
- Very low impact and Very high impact not observed

Plot number

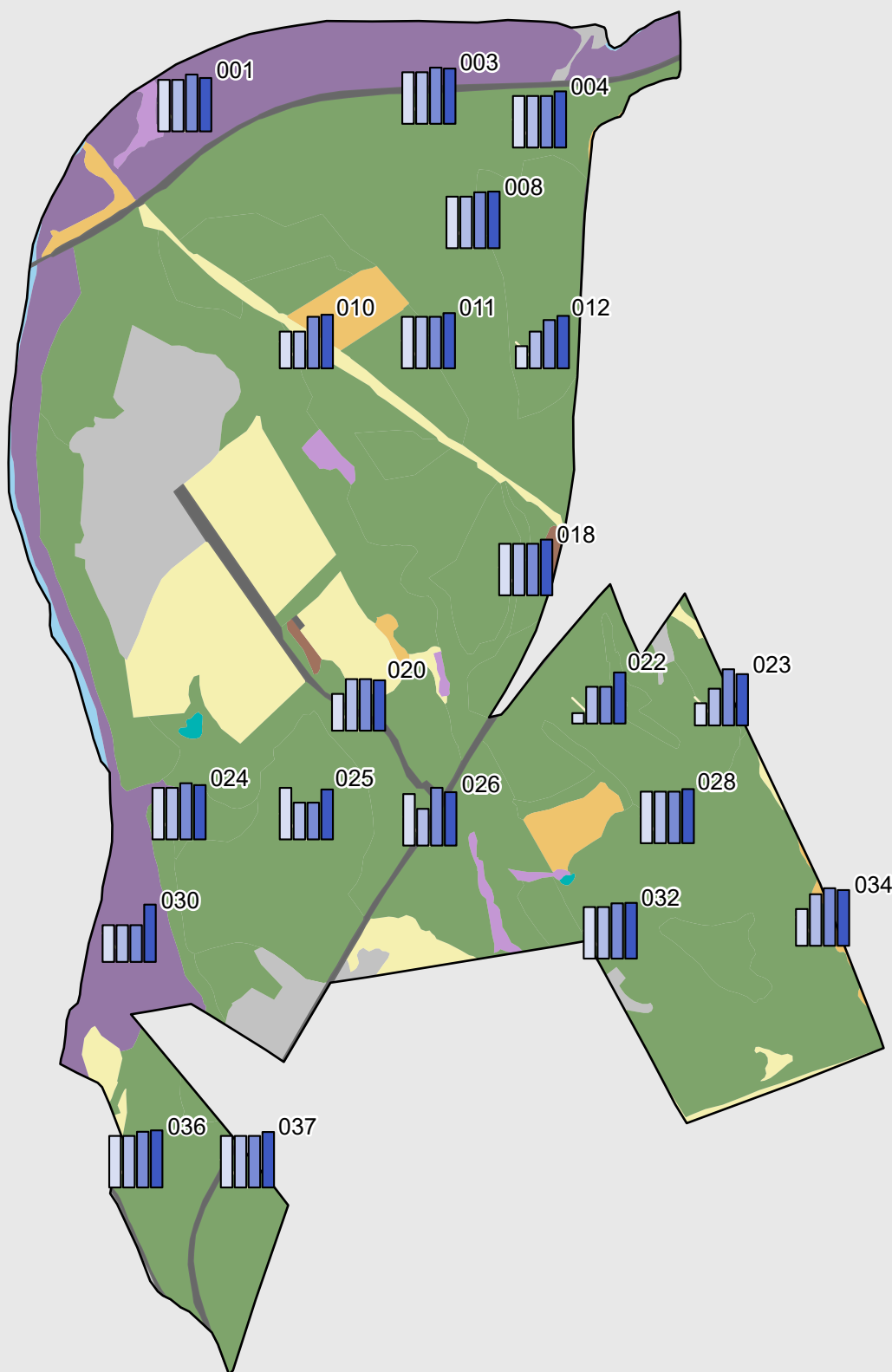


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Map 7. Tree Canopy Cover by Cycle

Trends in tree canopy cover in forest plots from 2007-2024. Canopy cover ranges from 17 - 98%. Reporting Date: 12/12/2024.



Vegetation types

- Deciduous Forest
- Conifer Plantation
- Successional Old Field
- Open field
- Floodplain forest
- Open wetland
- Pond
- River
- Developed land
- Transportation corridor
- Park Boundary

Tree Canopy Cover

- Cycle 1: 2007 to 2010
- Cycle 2: 2011 to 2014
- Cycle 3: 2015 to 2018
- Cycle 4: 2019 to 2024

Plot number

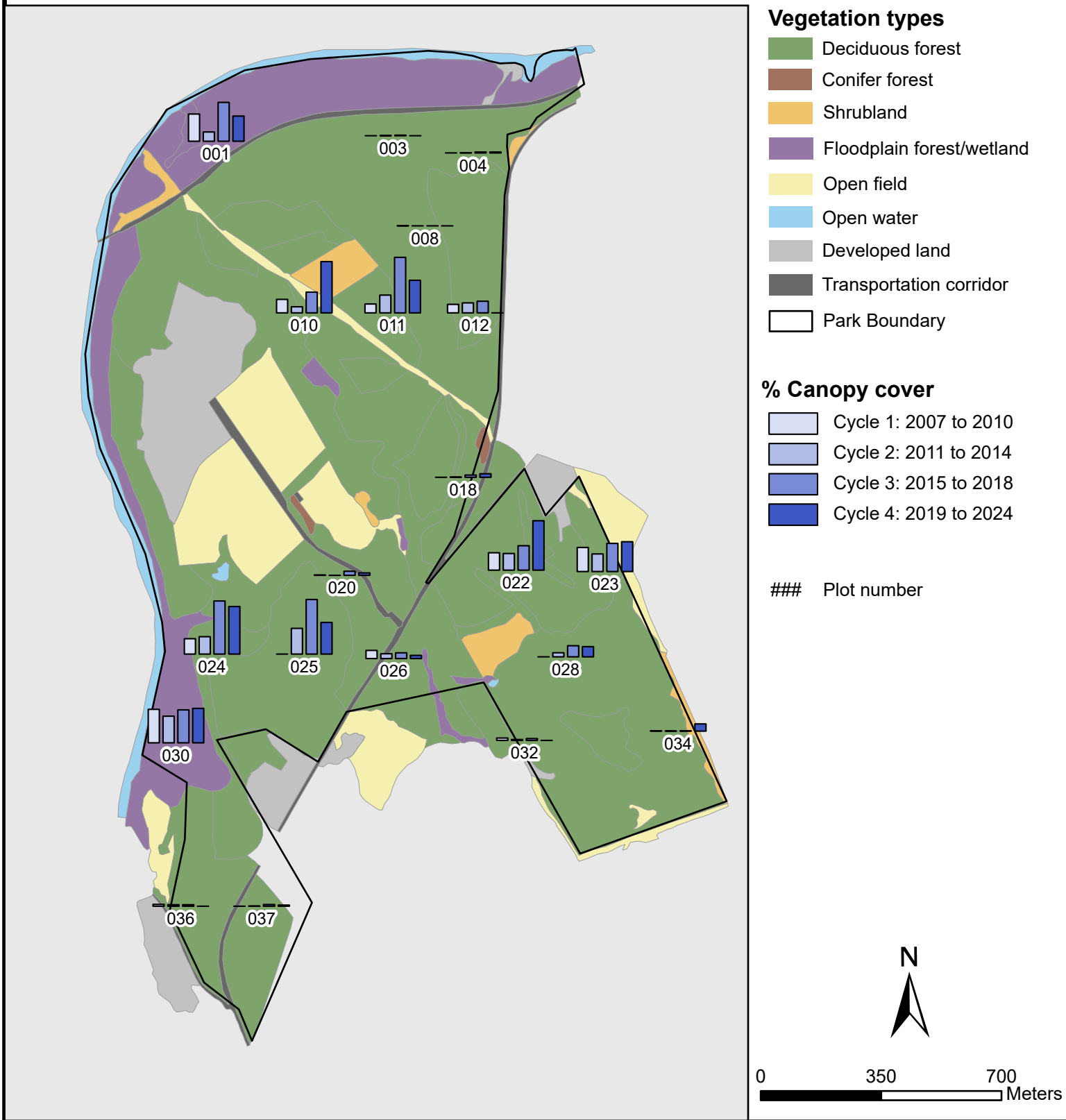


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Map 8. Invasive % Cover by Cycle

Trends in percent cover of invasive species observed in quadrats in forest plots sampled from 2007-2024. Each plot is sampled on a 4-year cycle in a rotating panel, with one quarter of the plots sampled every year. Average invasive cover per plot ranges from 0.008 to 108.3% exceeding 100% indicates multiple invasive species were overlapping within the quadrats. Reporting Date: 12/15/2025.





Map 9. Invasive % Cover by Species

Percent cover of invasive plant species observed in quadrats in forest plots sampled in the most recent census (2019-2024). The top 10 species or genera are displayed individually; less common species are grouped as 'Other invasive spp.'. Each plot is sampled on a 4-year cycle in a rotating panel, with one quarter of the plots sampled every year. Pie size is proportional to total invasive cover (range: 0.7 to 104.5%). Reporting Date: 12/15/2025.

Vegetation types

- Deciduous forest
- Conifer forest
- Shrubland
- Floodplain forest/wetland
- Open field
- Open water
- Developed land
- Transportation corridor
- Park Boundary

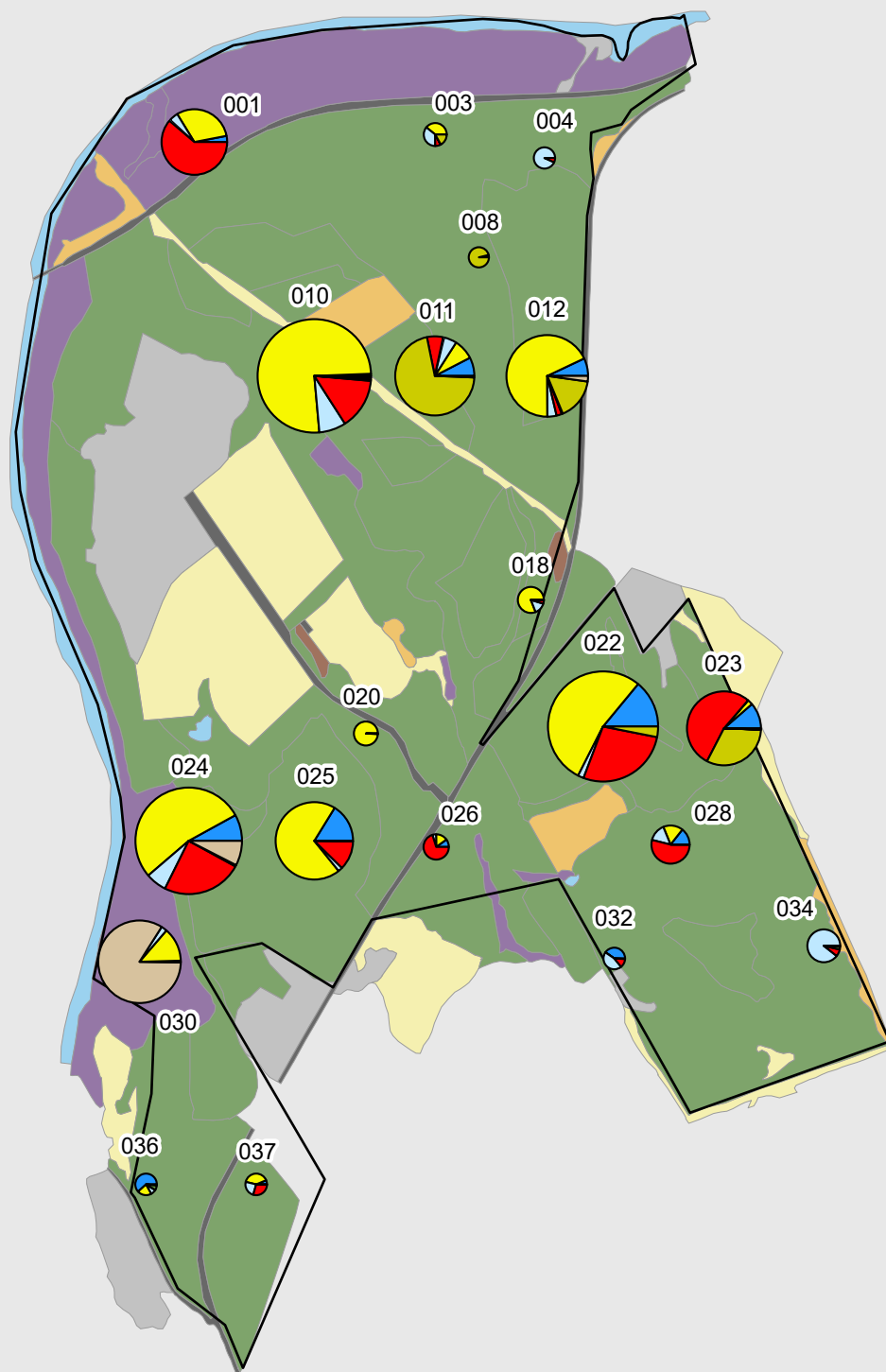
Invasive species

- Alliaria petiolata* (Garlic Mustard)
- Berberis thunbergii* (Japanese Barberry)
- Celastrus orbiculatus* (Asiatic Bittersweet)
- Glechoma hederacea* (Creeping Charlie)
- Elaeagnus umbellata* (Autumn Olive)
- Lonicera exotic* (Exotic Honeysuckle)
- Lonicera japonica* (Japanese Honeysuckle)
- Microstegium vimineum* (Japanese Stiltgrass)
- Persicaria* spp. (Smartweeds)
- Rosa multiflora* (Multiflora Rose)
- Other invasive spp.

Plot number



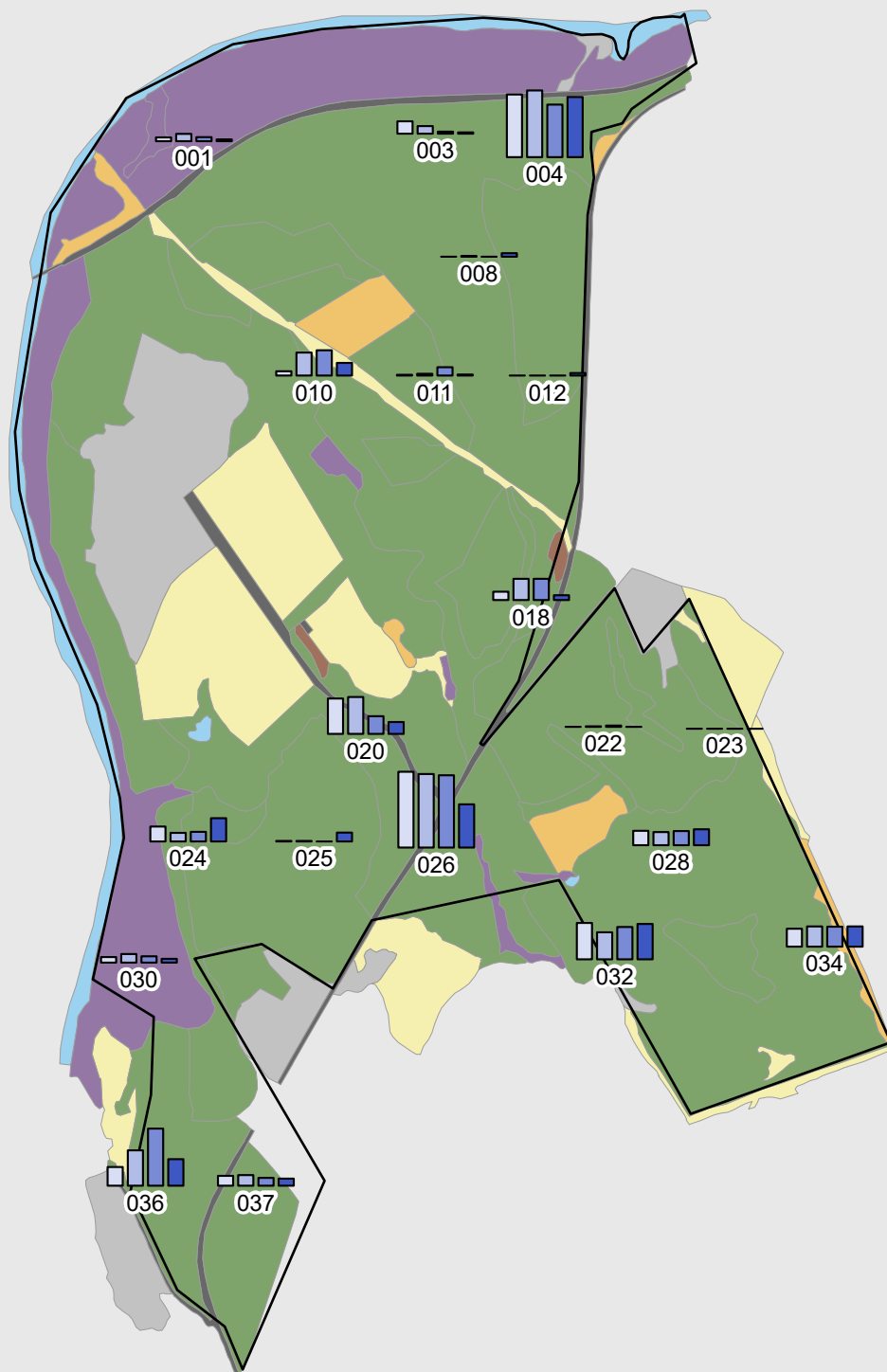
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Map 10. Coarse Woody Debris by Cycle

Trends in coarse woody debris (CWD) volume observed in plots sampled from 2007-2024. Each plot is sampled on a 4-year cycle in a rotating panel, with one quarter of the plots sampled every year. CWD volume ranges from 0.9 to 125.3 m³/ha. Reporting Date: 12/15/2025.



Vegetation types

- Deciduous forest
- Conifer forest
- Shrubland
- Floodplain forest/wetland
- Open field
- Open water
- Developed land
- Transportation corridor
- Park Boundary

Coarse woody debris volume

- Cycle 1: 2007 to 2010
- Cycle 2: 2011 to 2014
- Cycle 3: 2015 to 2018
- Cycle 4: 2019 to 2024

Plot number



0 350 700
Meters