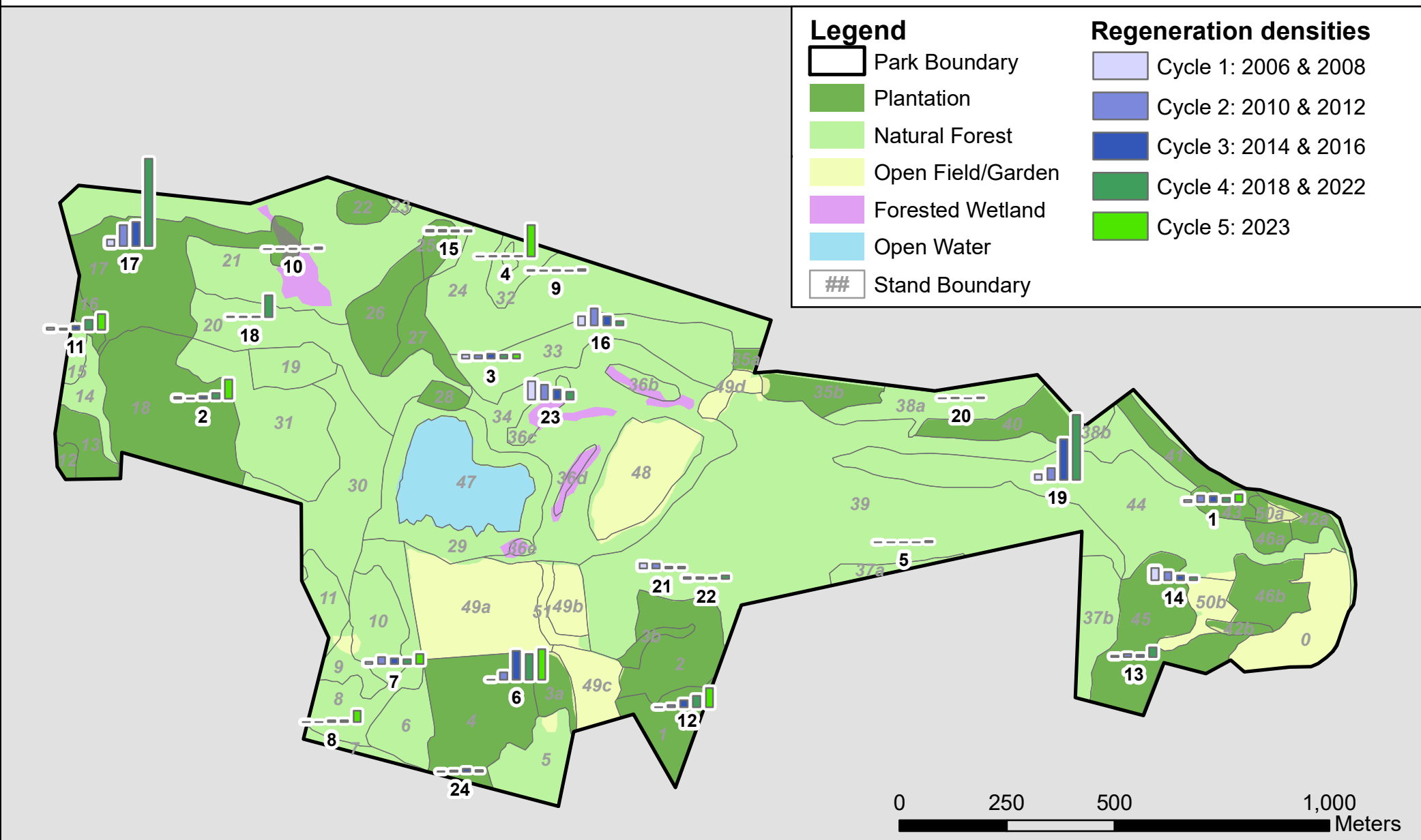




Map 1. Tree Regeneration by Cycle

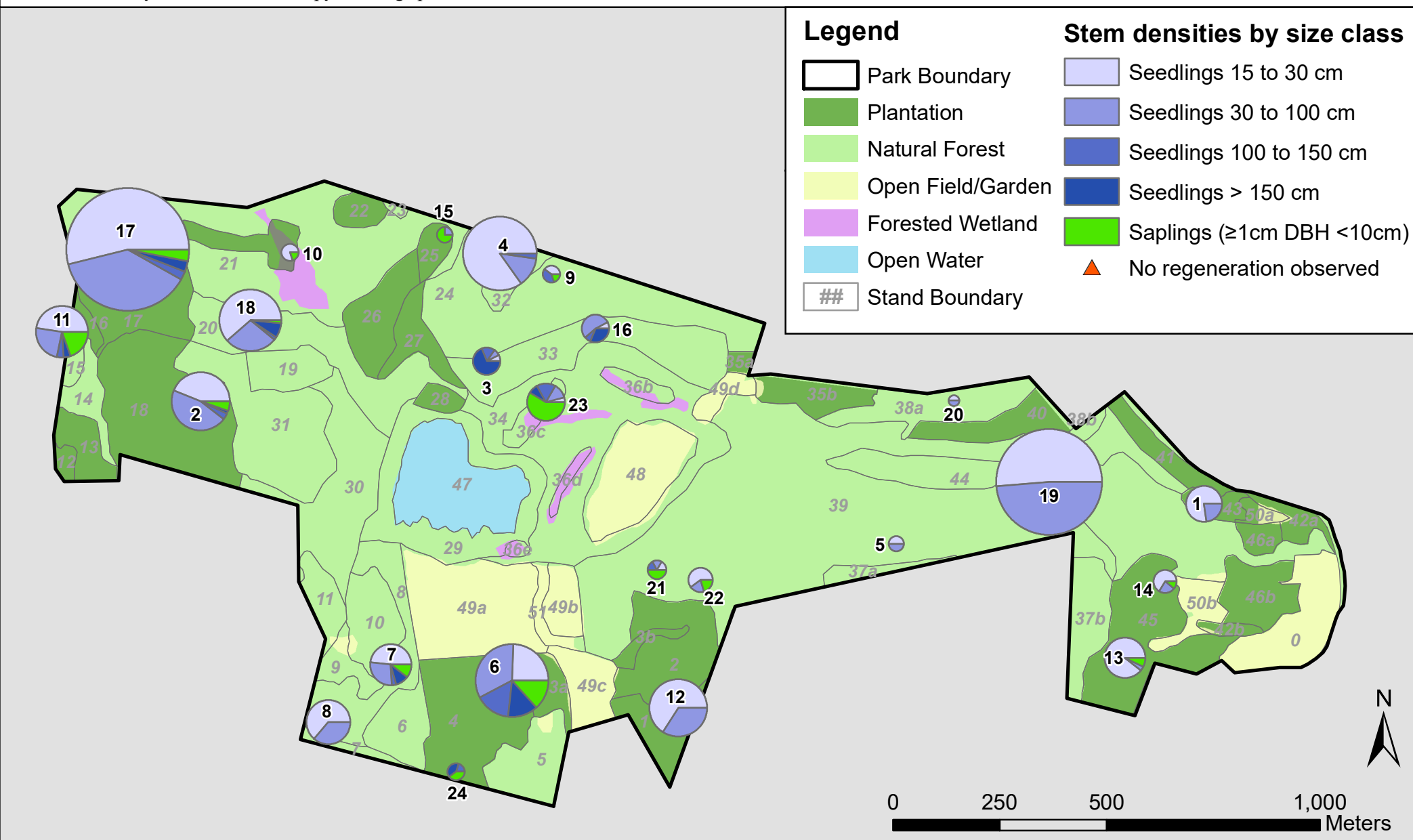
Trends in tree regeneration, including seedlings and saplings, observed in forest plots sampled from 2006-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2006, 2010, 2014, 2018, and 2023, and plots 13-24 sampled in 2008, 2012, 2016, and 2022. Densities range from 0 to 6.7 stems/m², and only include native canopy-forming species. See Table 1 for more details. Date: 7/10/2023.





Map 2. Tree Regeneration by Size Class

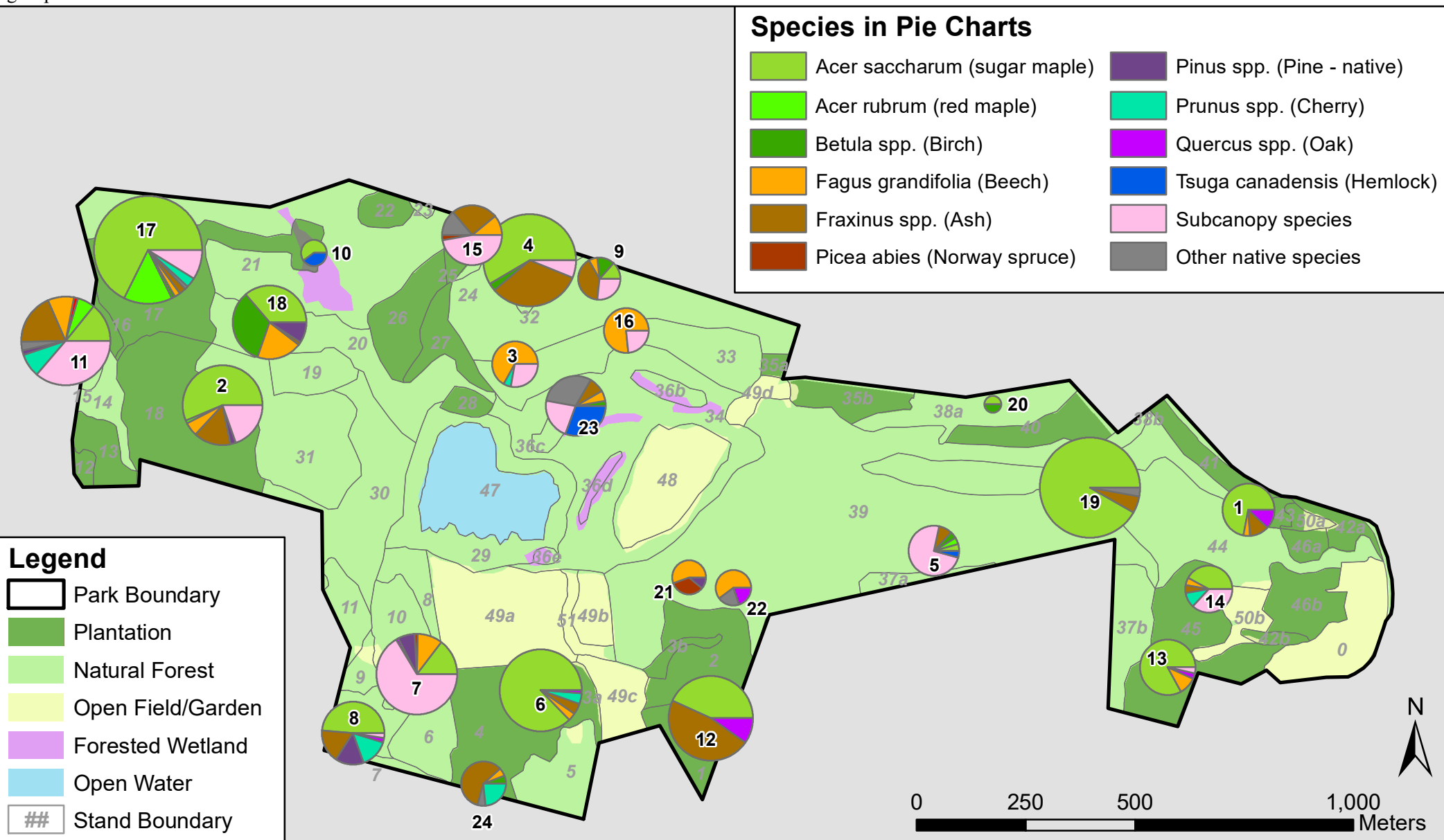
Trends in tree regeneration by size class in forest plots from the most recent 4-year census (2022 and 2023). Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023, and plots 13-24 sampled in 2022. Pie size is proportional to plot-level regeneration and location may be shifted to prevent overlap. Total densities range from 0 to 6.8 stems/m² and only include native canopy-forming species. See Table 1 for more details. Date: 7/10/2023.





Map 3. Tree Regeneration Composition

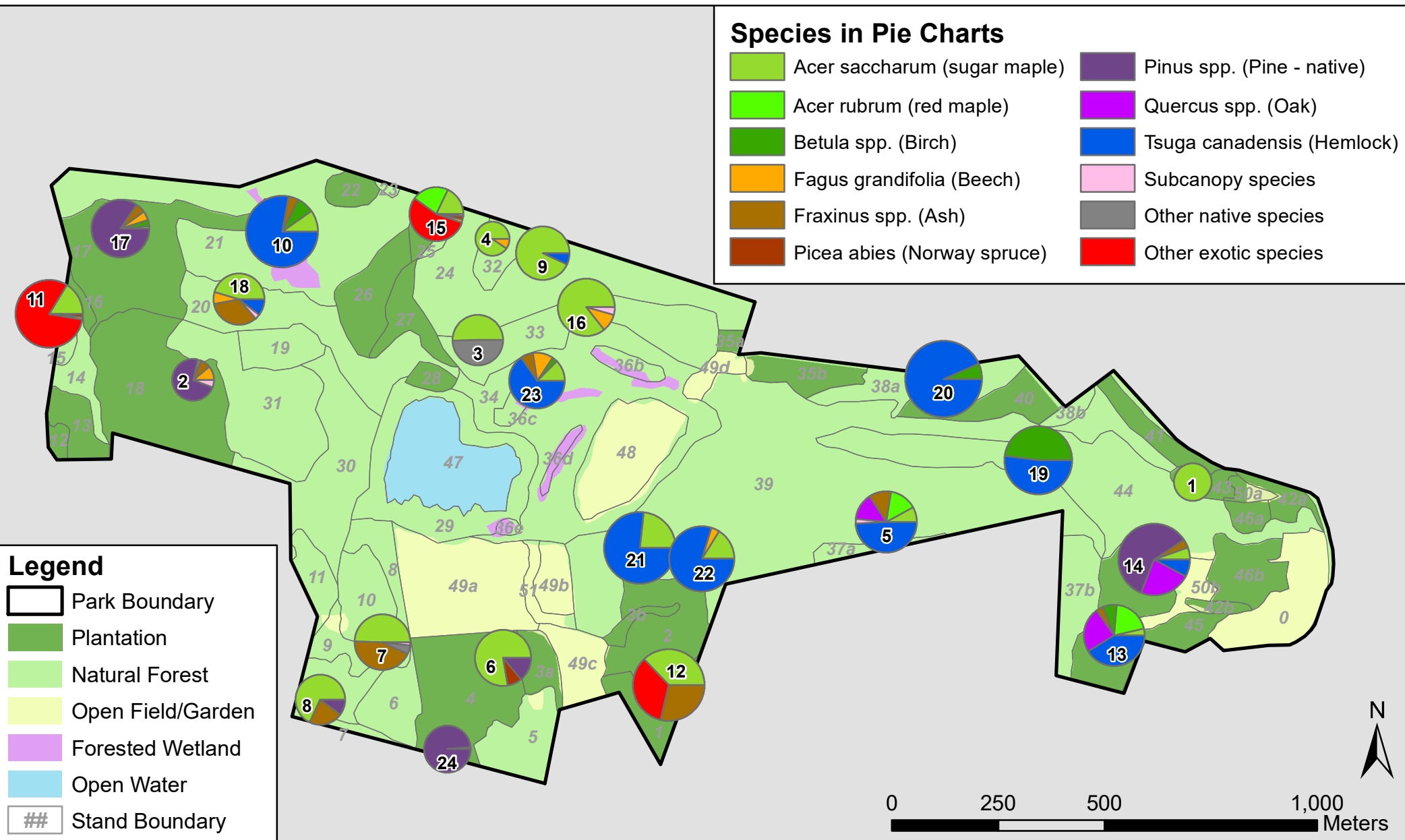
Trends in tree regeneration, including seedlings and saplings, by species group observed in forest plots in the most recent 4-year census (2022 and 2023). Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023, and plots 13-24 sampled in 2022. Pie size is proportional to the total plot-level regeneration (range: 0.05 to 7.8 stems/m²). Pies may be shifted from actual plot location to prevent overlap. Note that striped maple (*A. pensylvanicum*) and mountain maple (*A. spicatum*) are included in the subcanopy species group. Date: 7/10/2023.





Map 4. Tree Canopy Composition

Trends in tree composition, by species group, observed in forest plots in the most recent 4-year census (2022 and 2023). Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023, and plots 13-24 sampled in 2022. Pie size is proportional to the total plot-level basal area (range: 10.5 to 52.8 m²/hectare). Pies may be shifted from actual plot location to prevent overlap. Date: 7/10/2023.



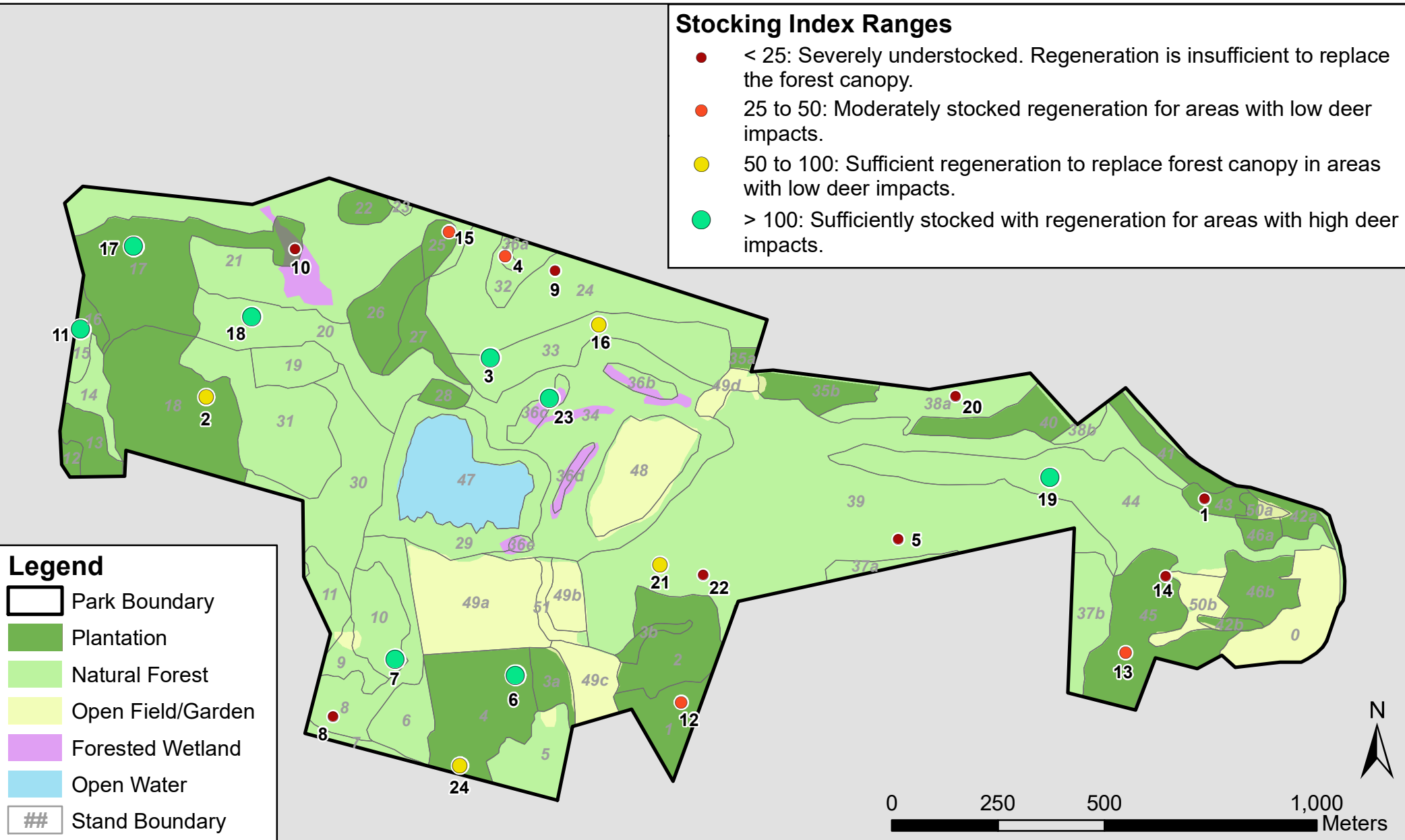


Map 5. Tree Regeneration Stocking Index

Trends in the regeneration stocking index for the most recent 4-year census (2022 and 2023). This index is a weighted sum of seedling and sapling densities where larger seedling size classes get higher weights and quantifies whether current regeneration densities are sufficient to restock a forest canopy. The stocking index is averaged over three 2-m radius microplots per forest plot and only includes native canopy-forming species (range 0-504). See Table 1 for stocking index values. Date: 7/10/2023.

Stocking Index Ranges

- < 25: Severely understocked. Regeneration is insufficient to replace the forest canopy.
- 25 to 50: Moderately stocked regeneration for areas with low deer impacts.
- 50 to 100: Sufficient regeneration to replace forest canopy in areas with low deer impacts.
- > 100: Sufficiently stocked with regeneration for areas with high deer impacts.





Map 6. Index of Deer Browse Impacts

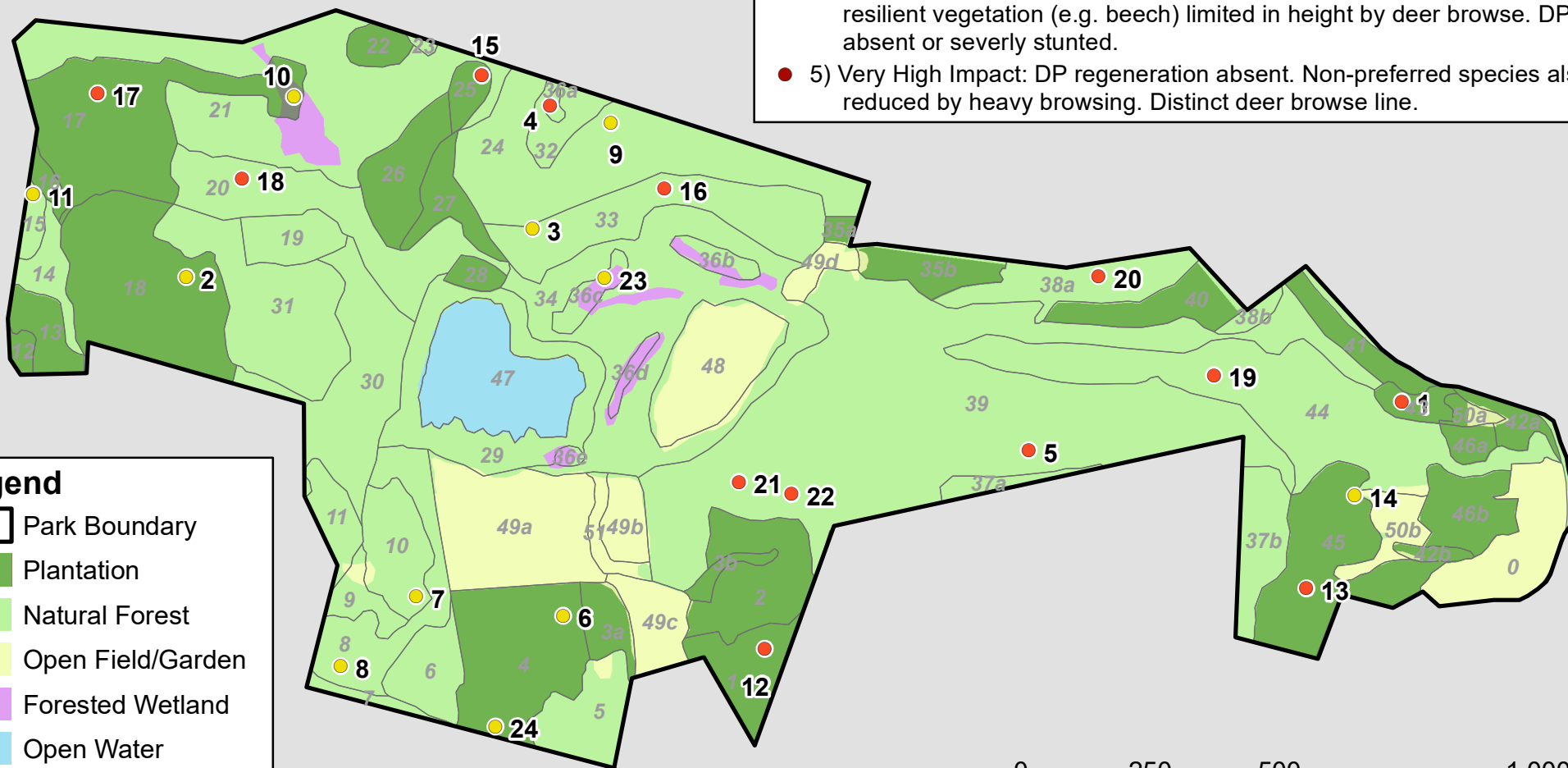
Index of deer browse impacts observed in forest plots in the most recent 4-year census (2022 & 2023). Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023 and plots 13-24 sampled in 2022. Deer browse impacts are assessed on a scale of 1-5, with 1 representing no impact and 5 representing severe impacts. Date: 7/10/2023.

Deer Browse Index

- 1) No Impact: found only in well-maintained deer exclosures.
- 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 (e.g. beech) limited in height by deer browse. DP herbs absent or severely stunted.
- 5) Very High Impact: DP regeneration absent. Non-preferred species also reduced by heavy browsing. Distinct deer browse line.

Legend

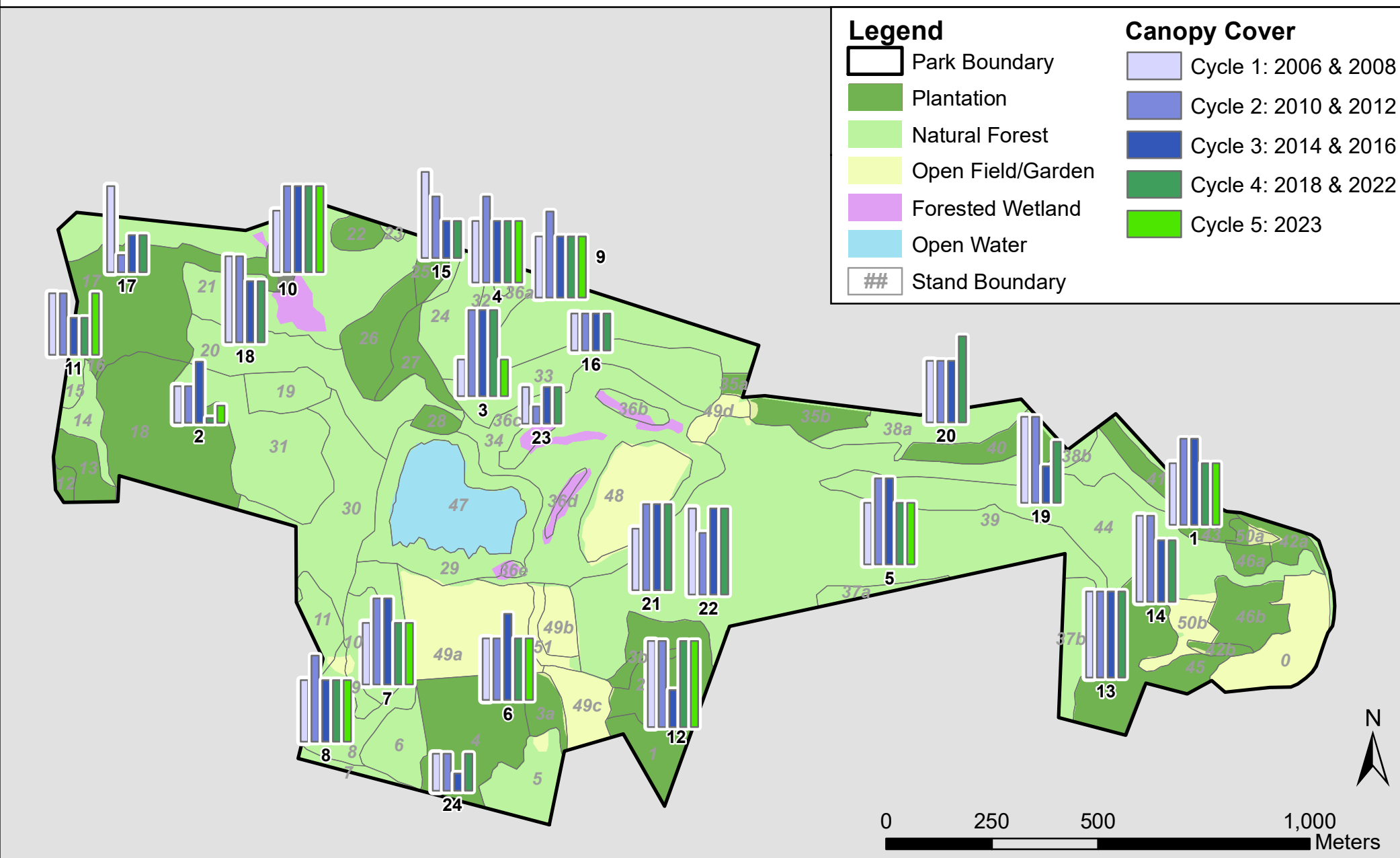
- Park Boundary
- Plantation
- Natural Forest
- Open Field/Garden
- Forested Wetland
- Open Water
- Stand Boundary





Map 7. Canopy Cover by Cycle

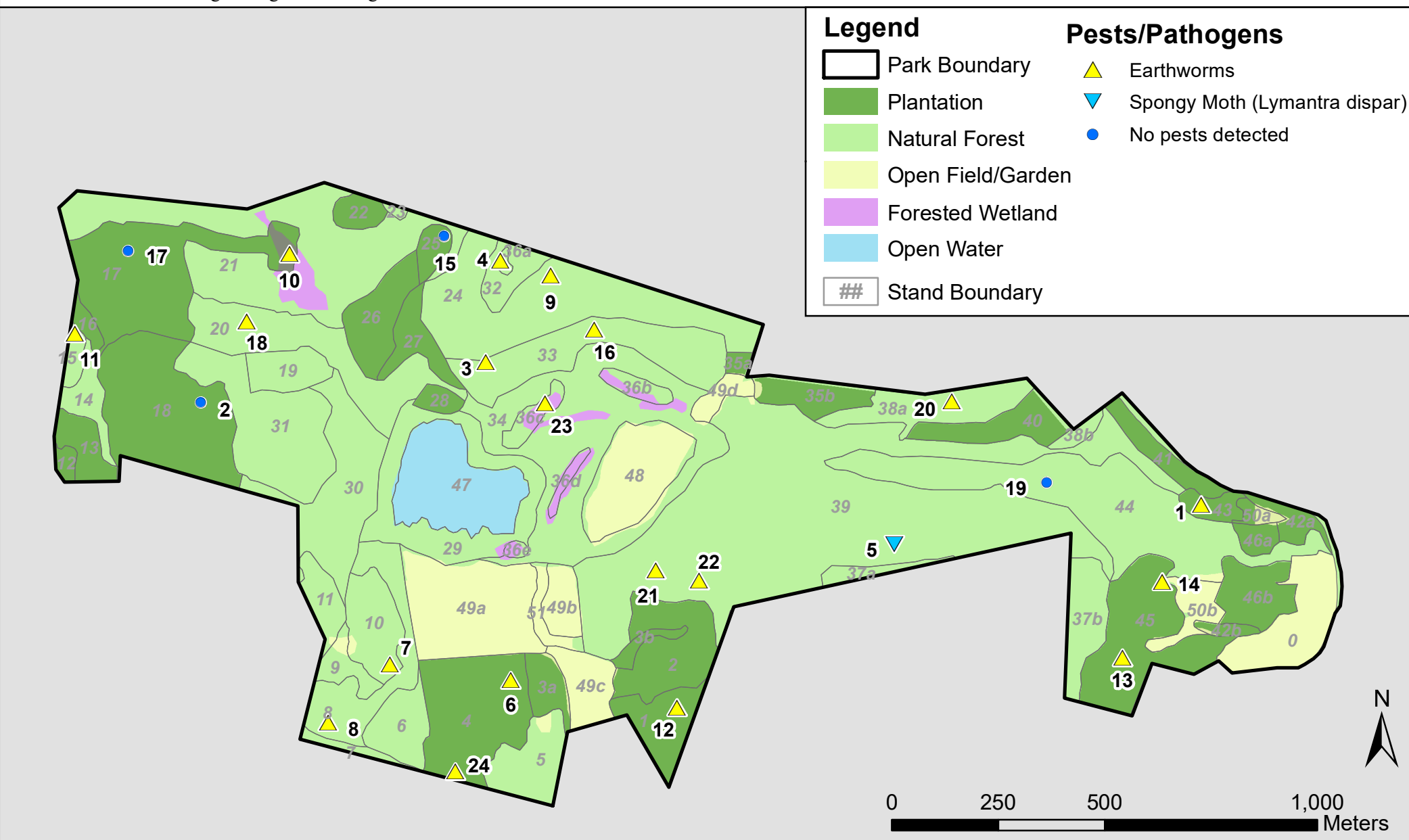
Trends in tree canopy cover in forest plots sampled from 2006-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2006, 2010, 2014, 2018, and 2023 and plots 13-24 sampled in 2008, 2012, 2016, and 2022. Canopy cover ranges from 10 - 25% to >75%. See Table 5 for plot harvest history. Date: 7/10/2023.





Map 8: Forest Pest/Pathogen Detections

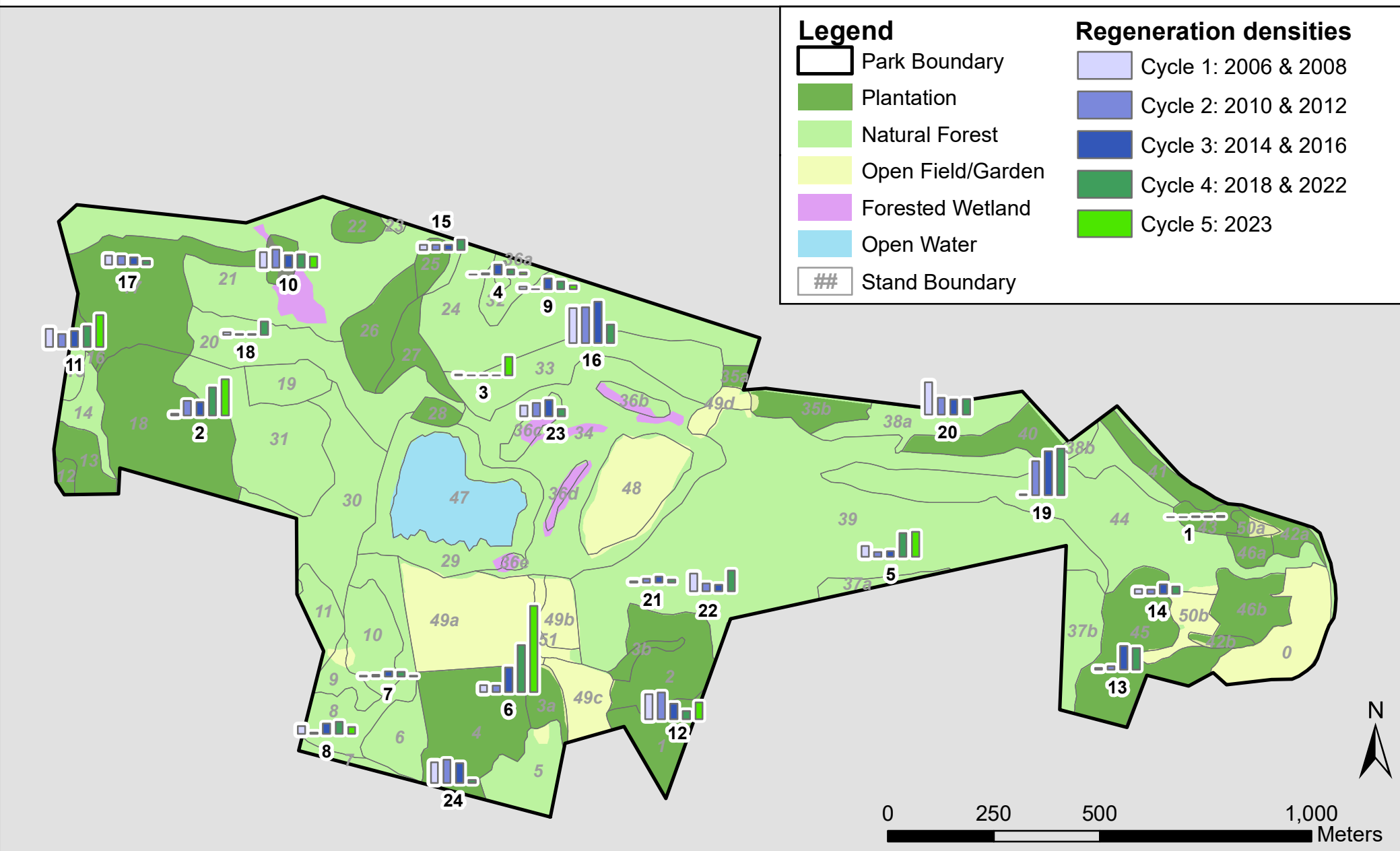
Priority pest and pathogen detections in forest plots sampled from 2022-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023, and plots 13-24 sampled in 2022. Beech Bark Disease is widespread where beech is present and not noted here. Beech Leaf Disease has yet to be detected in MABI, although the late frost on 5/18/2023 made distinguishing frost damage from BLD difficult in 2023. Date: 7/11/2023.





Map 9. Coarse Woody Debris by Cycle

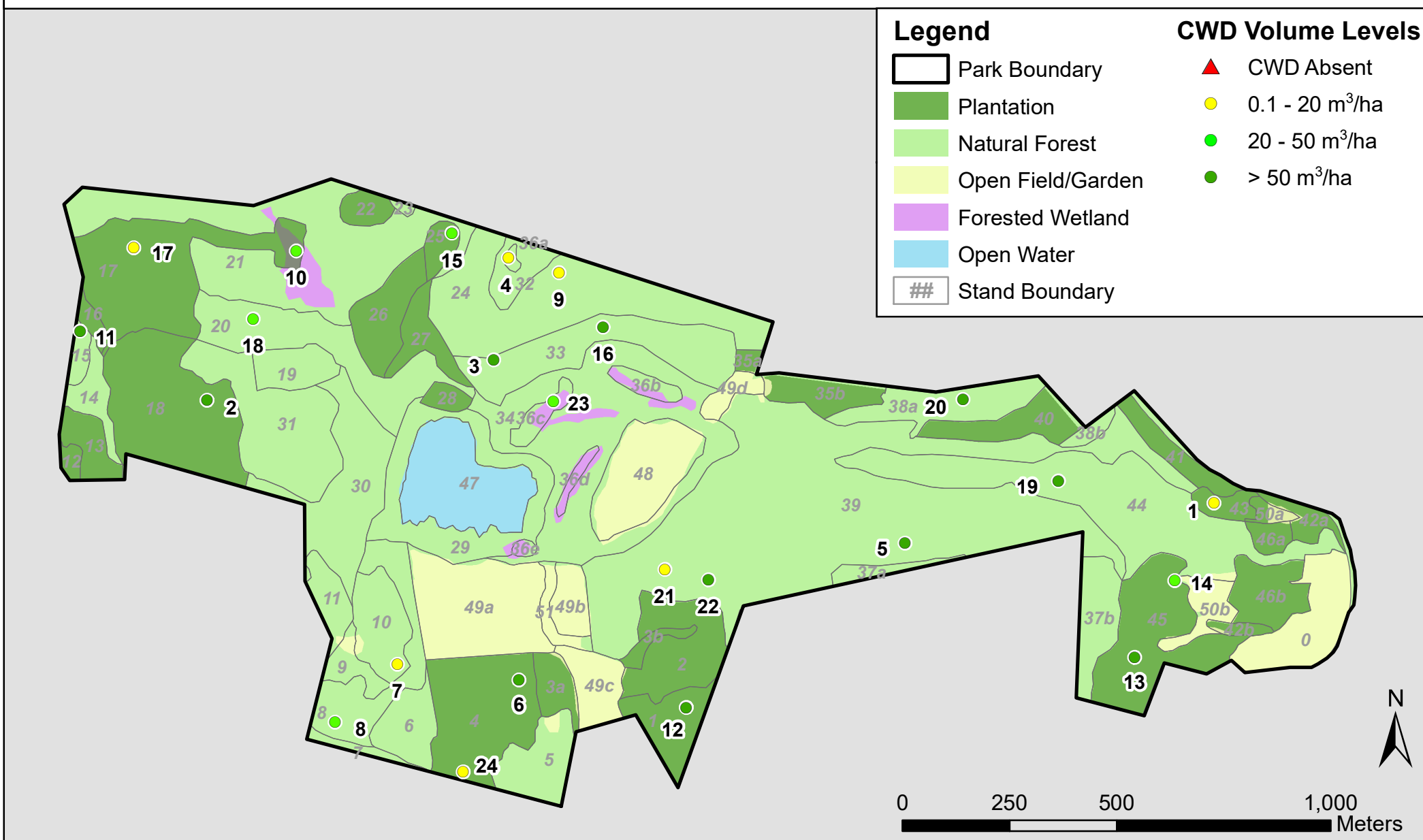
Trends in Coarse Woody Debris (CWD) volume observed in plots sampled from 2006-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2006, 2010, 2014, 2018, and 2023, and plots 13-24 sampled in 2008, 2012, 2016, and 2022. CWD volume ranges from 0 to 301.5 m³/ha (4,308.4 ft³/ac). Date: 7/11/2023.





Map 10. Coarse Woody Debris Ratings

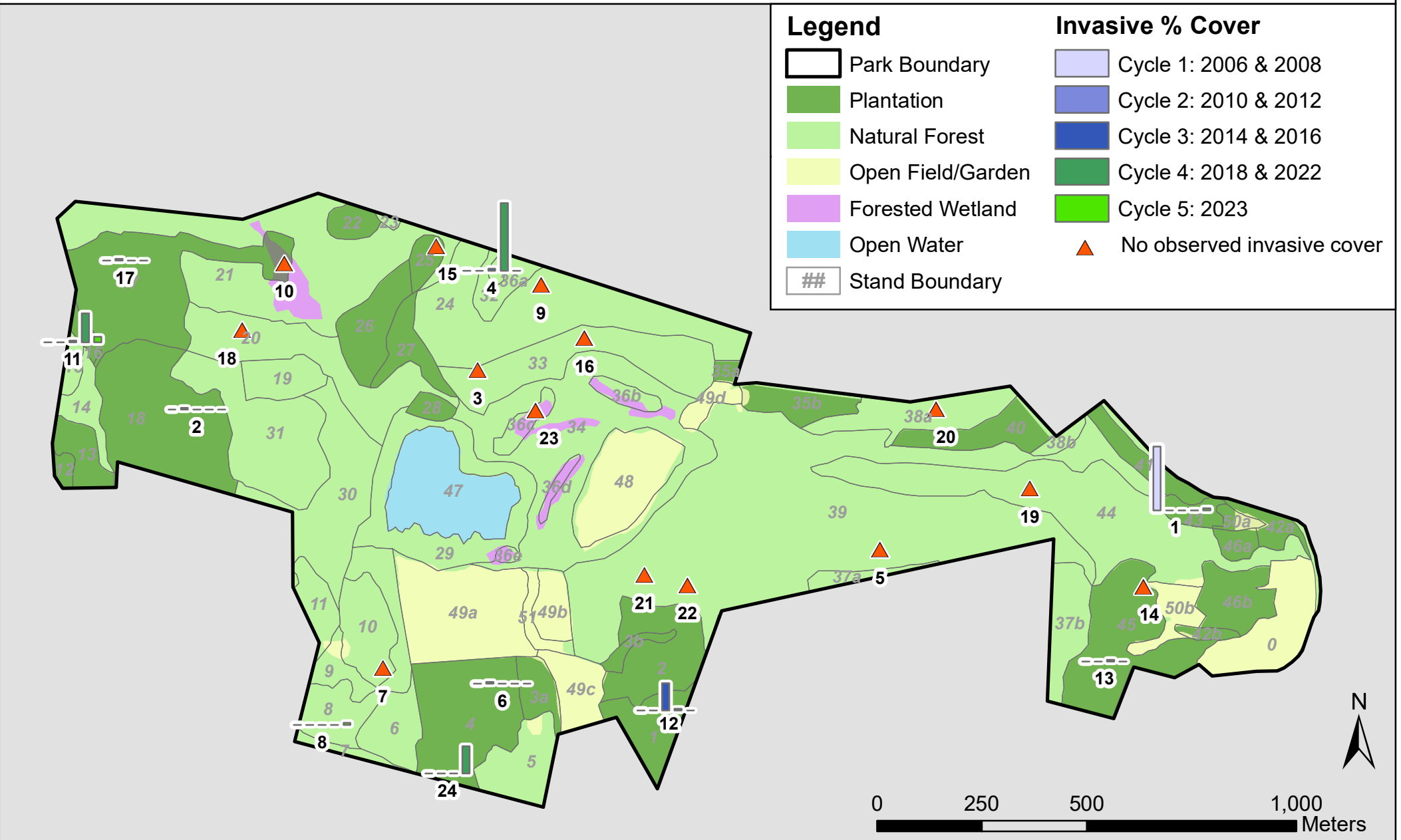
Coarse woody debris volume (m^3/ha) for the most recent survey cycle (2022 and 2023). Plots 1-12 were sampled in 2023, and plots 13-24 were sampled in 2022. Volumes range from 0 to $301.5 \text{ m}^3/\text{hectare}$ ($4,308.4 \text{ ft}^3/\text{ac}$). Plots are color coded by volume to indicate whether they meet the $20\text{-}50 \text{ m}^3/\text{ha}$ ($285.8\text{-}714.6 \text{ ft}^3/\text{ac}$) threshold in Müller and Bütler (2010). Date: 7/11/2023.





Map 11. Invasive % Cover by Cycle

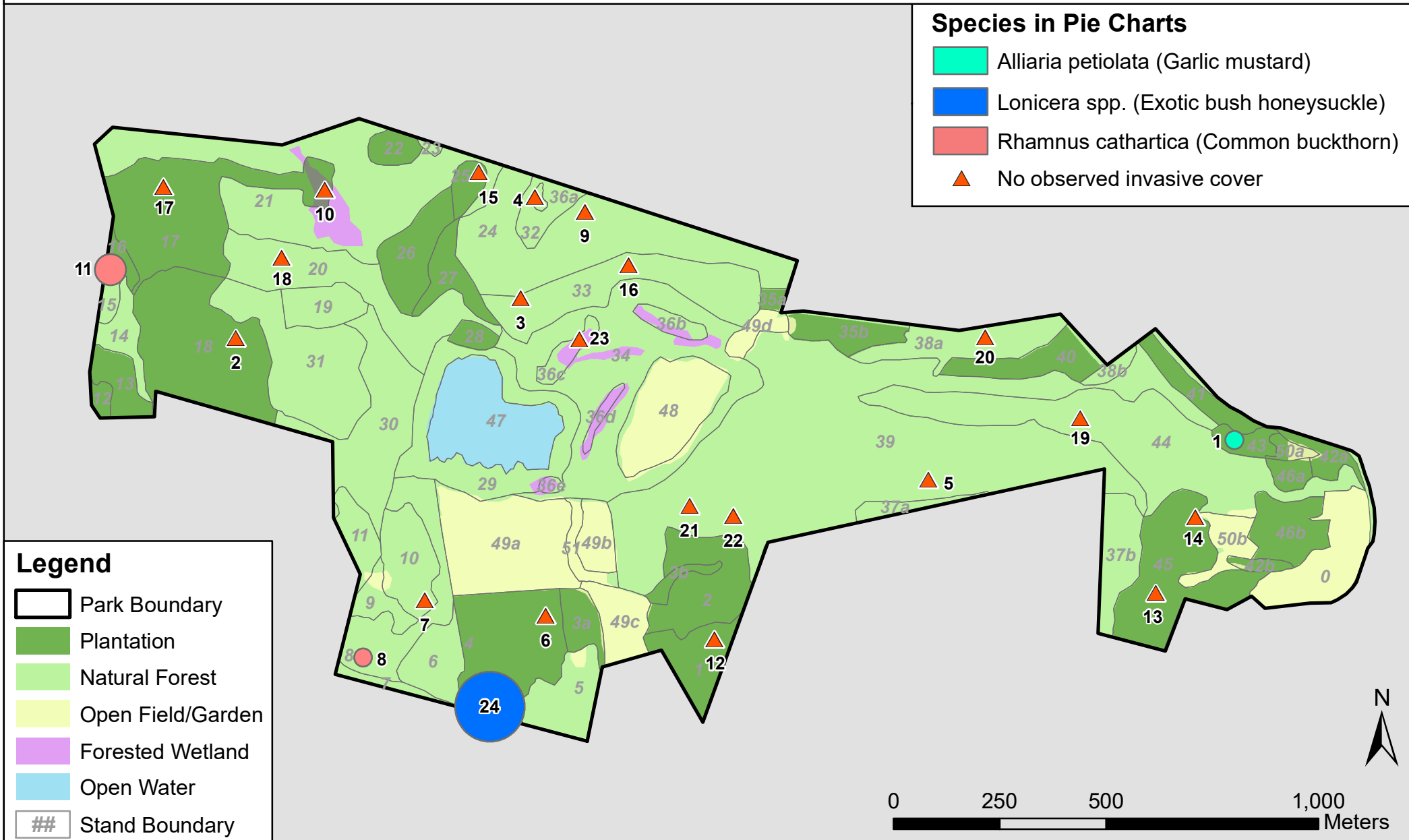
Trends in percent cover of invasive species observed in plots sampled from 2006-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2006, 2010, 2014, 2018, and 2023, and plots 13-24 sampled in 2008, 2012, 2016, and 2022. Average invasive cover ranges from 0 to 0.46%. See Table 2 for % cover values. Date: 7/11/2023.





Map 12. Invasive % Cover by Species

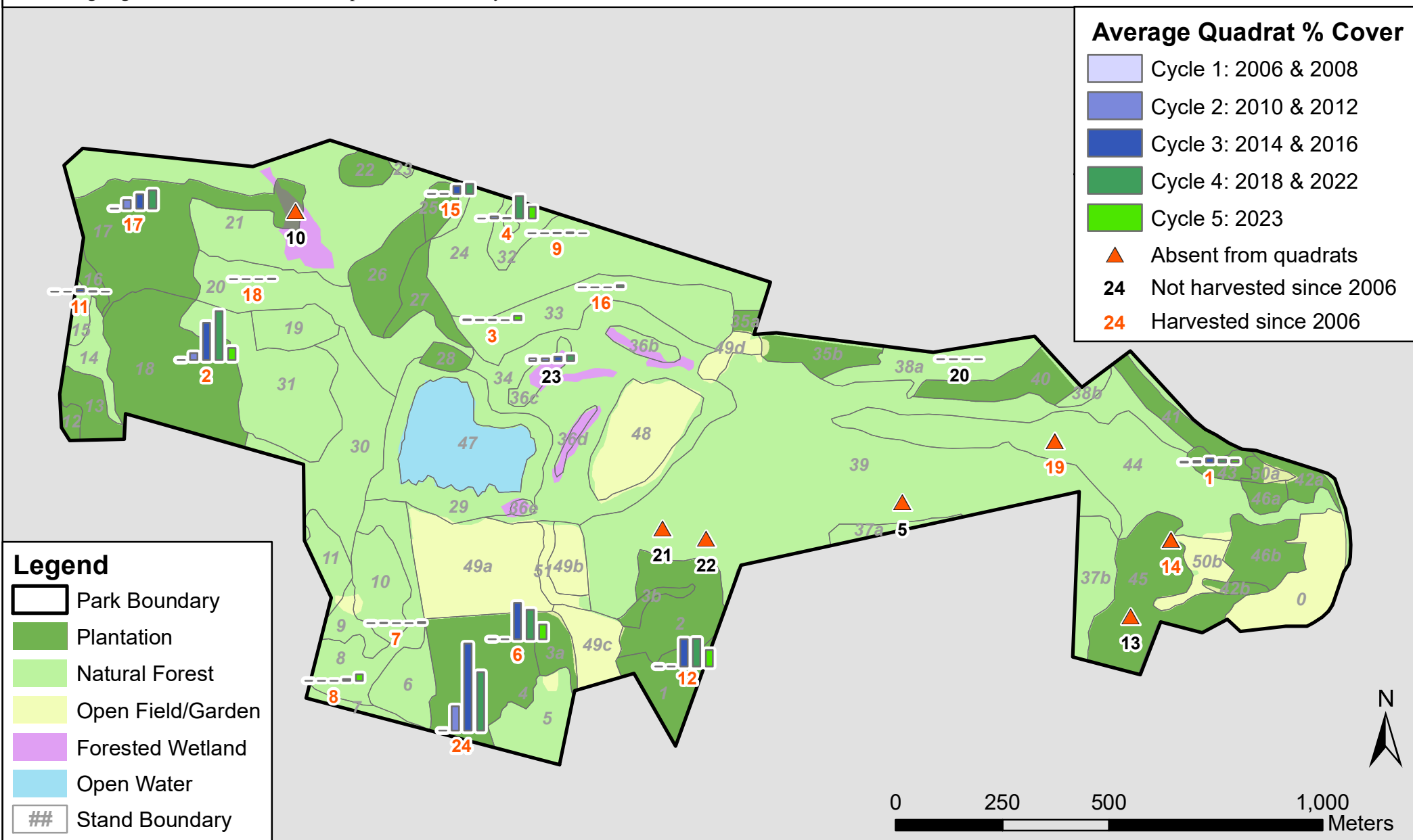
Trends in % invasive cover by species observed in quadrats for plots in the most recent survey cycle (2022 & 2023). Plots are sampled in an alternating panel, with plots 1-12 sampled in 2023 and plots 13-24 sampled in 2022. Pie size is proportional to total invasive cover (range: 0 to 0.4%), and location may be shifted to prevent overlap. See Table 2 for more information. Date 7/11/2023.





Map 13. Rubus spp. Cover by Cycle

Trends in *Rubus* spp. (blackberries and raspberries) observed in forest plots sampled from 2006-2023. Plots are sampled in an alternating panel, with plots 1-12 sampled in 2006, 2010, 2014, 2018, and 2023 and plots 13-24 sampled in 2008, 2012, 2016, and 2022. % cover ranges from 0 to 91%. Plot numbers labeled red have been harvested since monitoring began in 2006. See Table 5 for plot harvest history. Date: 7/14/2023.



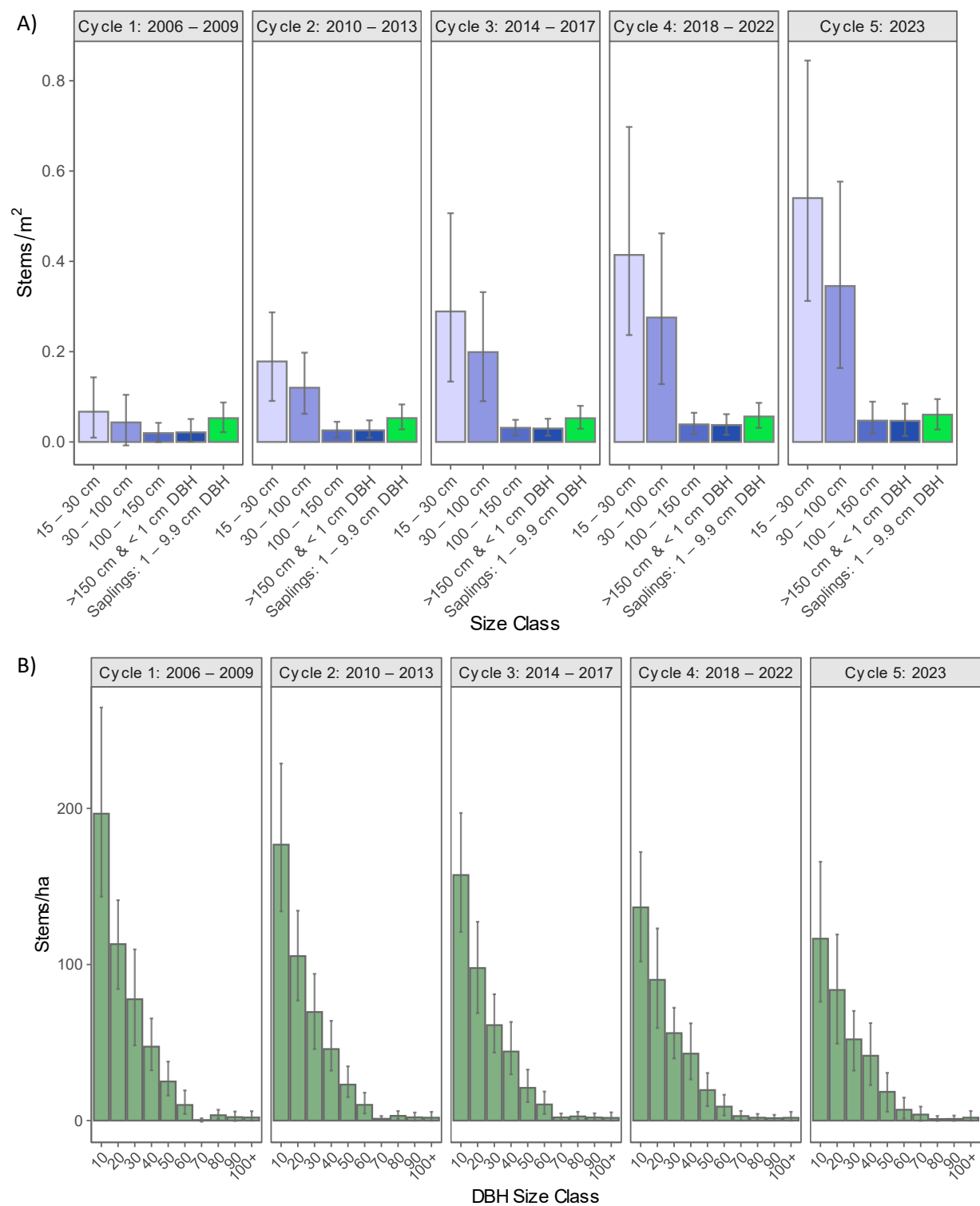


Figure 1. Stem density distributions in 10 cm increments by survey cycle in Marsh-Billings-Rockefeller National Historical Park. Cycle 1 is 2006-2009; Cycle 2 is 2010-2013; Cycle 3 is 2014-2017; Cycle 4 is 2018-2022; Cycle 5 is 2023. Note that Cycle 5 only includes the first panel of 10 plots. Figure A shows regeneration densities by size class. Figure B shows tree density by diameter at breast height (DBH) increments. Error bars are 95% bootstrapped confidence intervals. An asterisk denotes a linear DBH distribution that is indicative of long-term recruitment failure.

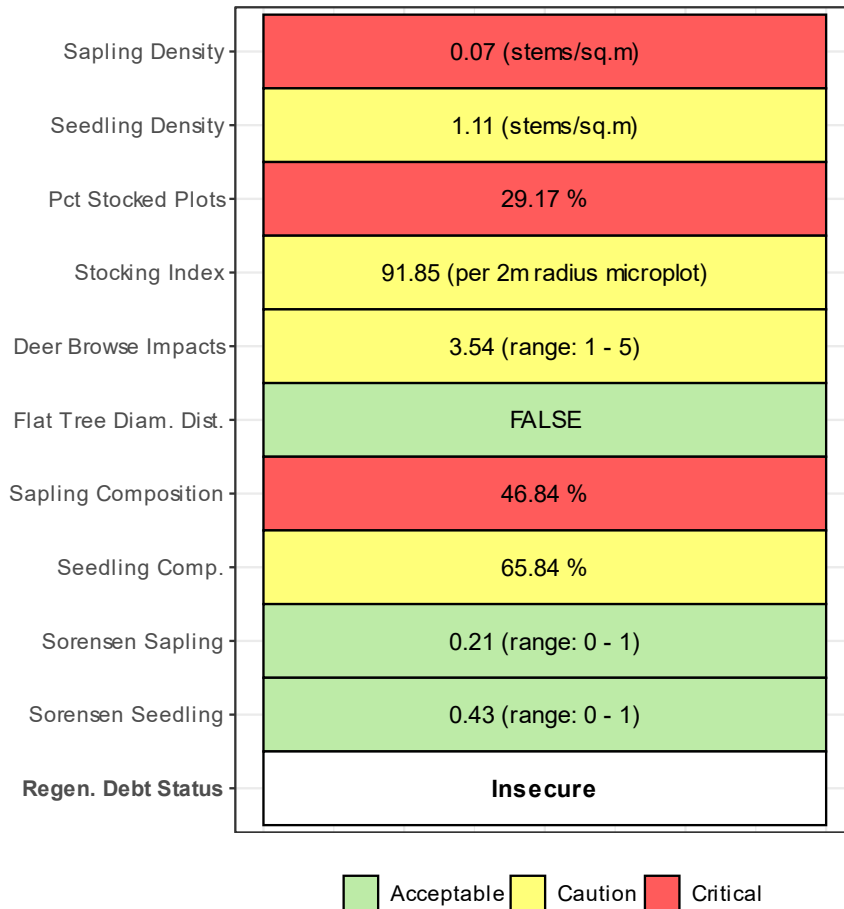
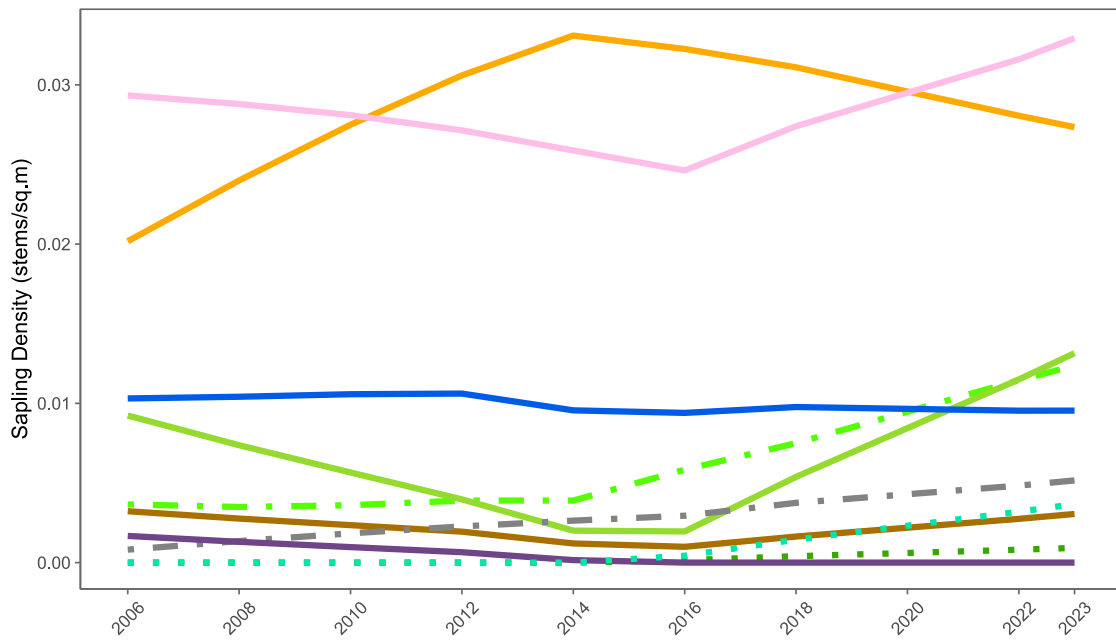


Figure 2. Regeneration Debt metrics and status for the most recent 4-year census (2022 and 2023) in Marsh-Billings-Rockefeller National Historical Park. Flat Tree Diam. Dist. stands for Flat Tree Diameter Distribution. If TRUE, the density of small trees is lower than expected due to chronic regeneration failure. See [Miller et al. 2023](#) for more details on metric calculations, thresholds, and assessment of status.

A)



B)

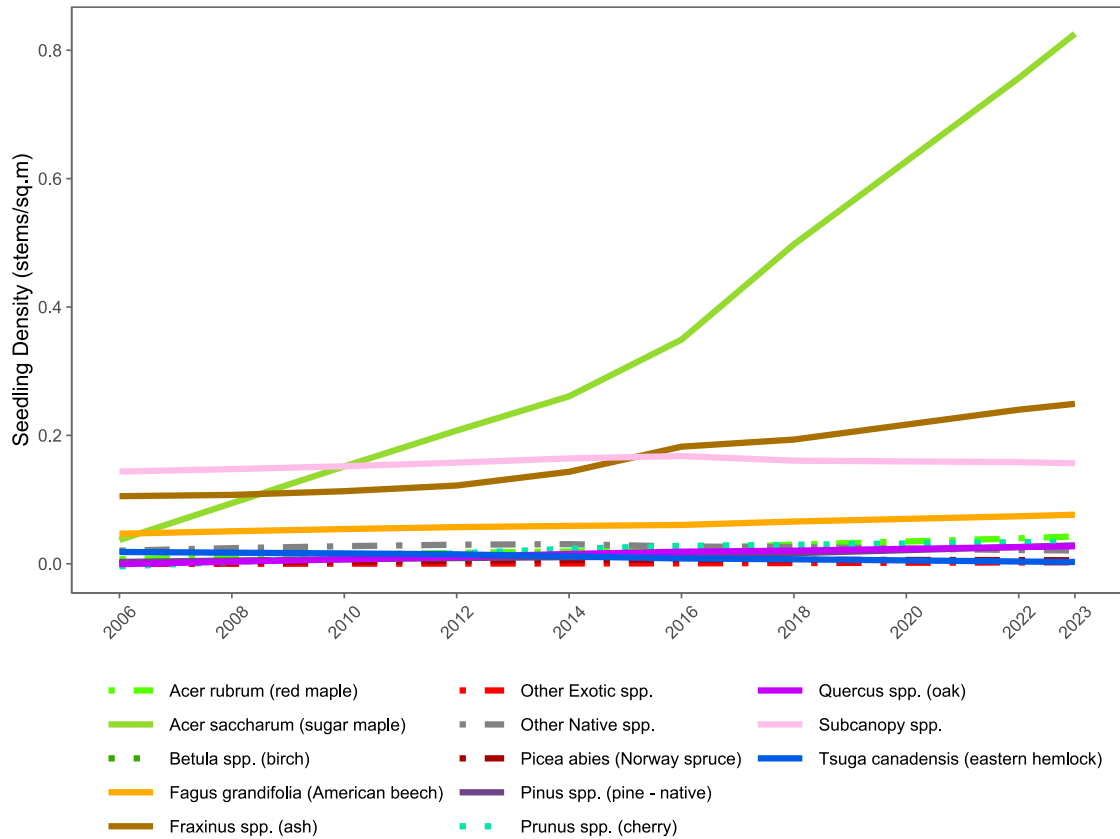


Figure 3. Loess smoothed changes in stem density for saplings (A) and seedlings (B) by species group and sample year in Marsh-Billings-Rockefeller National Historical Park. Specified loess span approximated a linear trend between consecutive sample events per panel.

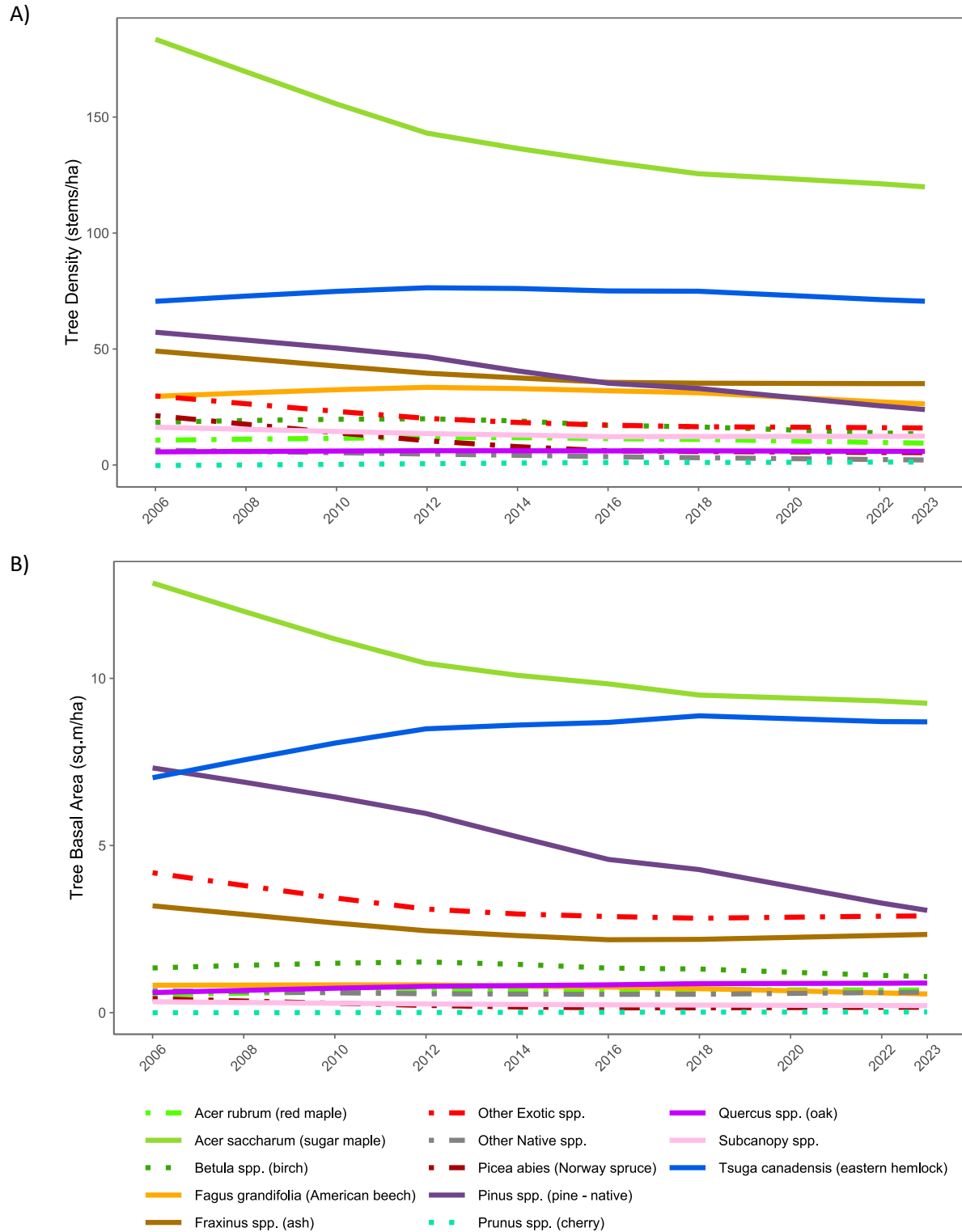


Figure 4. Loess smoothed changes in tree stem density (A) and basal area (B) by species group and sample year in Marsh-Billings-Rockefeller National Historical Park. Specified loess span approximated a linear trend between consecutive sample events per panel.

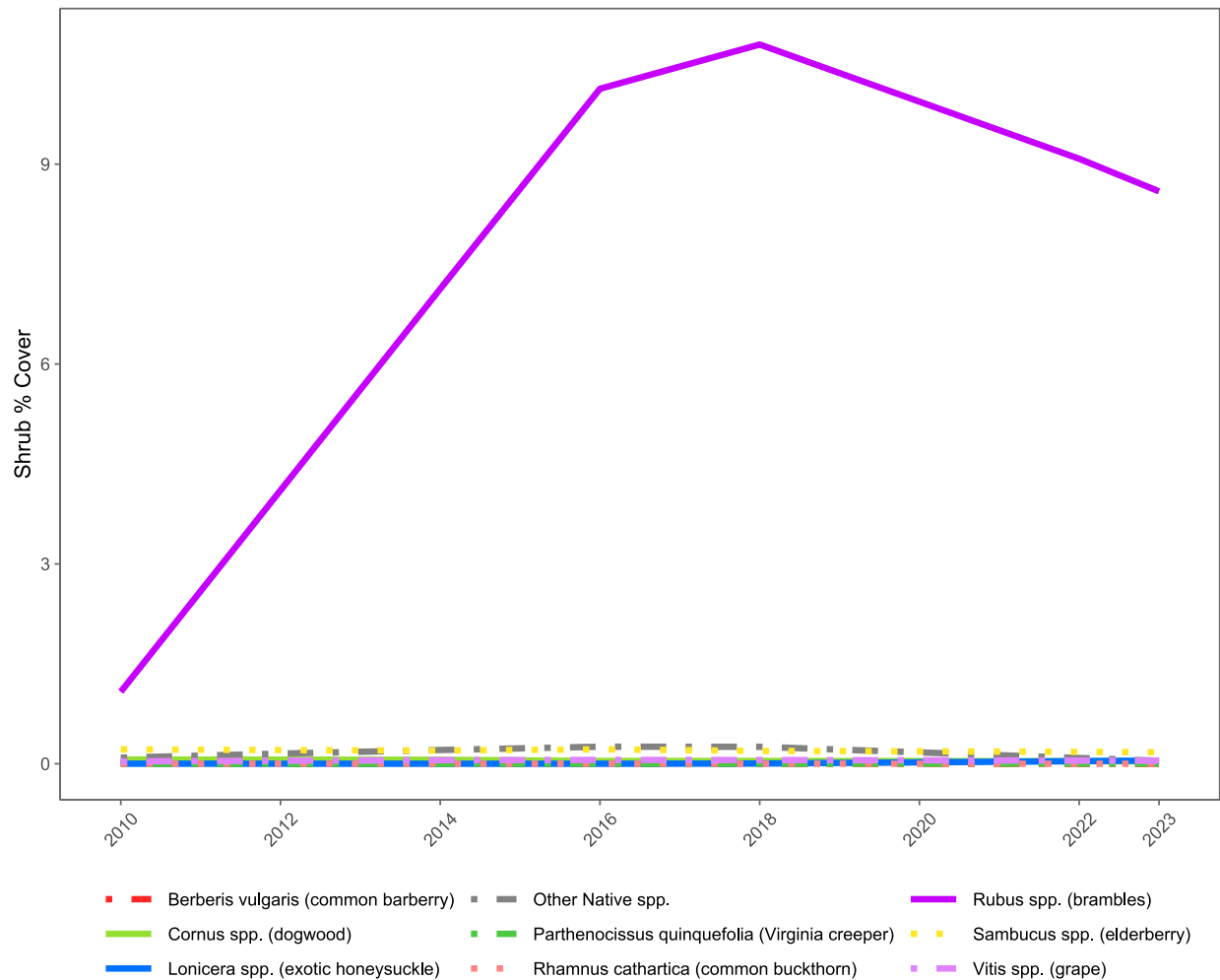


Figure 5. Loess smoothed changes in shrub % cover collected in 2-m radius microplots by species group and sample year in Marsh-Billings-Rockefeller National Historical Park. Specified loess span approximated a linear trend between consecutive sample events per panel. Note that this metric differs from quadrat % cover in that data collection started in 2010, and there's no height limit for shrub cover (vs. quadrats only including cover up to 1.5m).

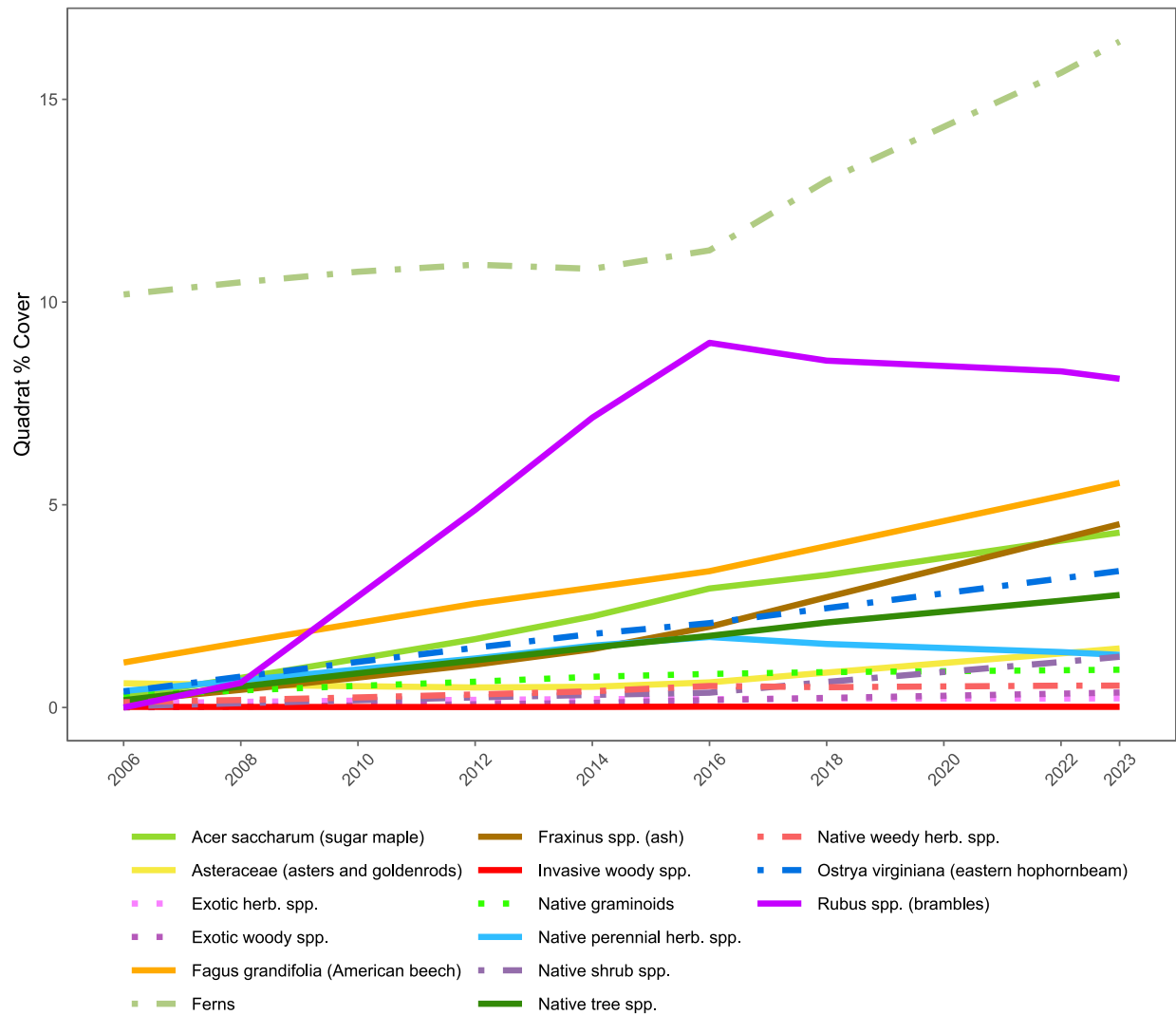


Figure 6. Loess smoothed changes in understory % cover averaged across eight 1m² quadrats by species group and sample year in Marsh-Billings-Rockefeller National Historical Park. Specified loess span approximated a linear trend between consecutive sample events per panel. The understory is defined as 0 to 1.5m.

Table 1. Average plot-level seedling and sapling stem densities, converted to stems per m², and stocking index by cycle. Only native, canopy-forming species are included. Note that *Fraxinus* spp. (ash species) are no longer considered canopy-forming species. Cycle 1= 2006 & 2008; Cycle 2= 2010 & 2012; Cycle 3= 2014 & 2016; Cycle 4= 2018 & 2022; Cycle 5 = 2023. Plots are sampled in alternating years, with Panel 1 sampled the first year, and Panel 2 sampled the second year. The stocking index quantifies whether current regeneration densities are sufficient to restock a forest canopy. The index is a weighted sum of seedling and sapling densities where larger seedling size classes get higher weights. Cells highlighted in green are plots that meet the minimum management target of 0.25 seedlings/m² and 0.14 saplings/m² or have a stocking index >100. Plots 13-24 have not yet been sampled in Cycle 5.

Plot	Panel	Seedlings per m ²					Saplings per m ²					Stocking Index				
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
1	1	0.16	0.50	0.45	0.32	0.58	0.00	0.00	0.00	0.00	0.00	2.00	8.67	8.67	5.33	9
2	1	0.08	0.03	0.21	0.42	1.43	0.08	0.03	0.00	0.03	0.08	51.00	17.00	10.00	30.67	72.33
3	1	0.32	0.16	0.21	0.13	0.34	0.00	0.11	0.16	0.16	0.00	44.00	114.00	160.33	120.67	164.33
4	1	0.00	0.03	0.03	0.03	2.44	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	0.67	47.33
5	1	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2
6	1	0.00	0.58	2.23	1.99	2.07	0.00	0.00	0.00	0.03	0.32	0.00	7.33	57.00	115.00	504
7	1	0.16	0.53	0.42	0.34	0.69	0.00	0.00	0.00	0.03	0.08	3.00	22.33	44.33	68.67	100
8	1	0.00	0.00	0.11	0.13	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	2.33	15
9	1	0.08	0.05	0.05	0.03	0.11	0.00	0.00	0.03	0.03	0.03	1.00	7.33	18.00	17.33	14
10	1	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.00	0.00	1.33
11	1	0.00	0.08	0.24	0.66	0.98	0.16	0.03	0.05	0.13	0.24	50.00	18.33	43.00	149.00	178
12	1	0.00	0.19	0.53	0.90	1.49	0.00	0.00	0.00	0.00	0.00	0.00	2.33	8.33	16.33	25
13	2	0.08	0.19	0.11	0.69	---	0.03	0.05	0.05	0.05	---	33.67	35.33	34.67	42.33	---
14	2	0.88	0.61	0.34	0.21	---	0.05	0.03	0.03	0.03	---	51.67	43.00	35.33	20.00	---
15	2	0.08	0.08	0.05	0.03	---	0.05	0.05	0.05	0.08	---	34.33	40.33	17.00	34.00	---
16	2	0.58	0.93	0.45	0.34	---	0.13	0.40	0.27	0.00	---	140.33	375.67	229.67	78.33	---
17	2	0.11	1.62	1.72	6.58	---	0.40	0.00	0.13	0.21	---	150.67	39.67	293.67	334.00	---
18	2	0.00	0.00	0.05	1.70	---	0.05	0.05	0.00	0.03	---	0.00	0.00	1.33	132.00	---
19	2	0.40	0.90	3.18	5.07	---	0.05	0.03	0.00	0.00	---	38.67	35.67	41.33	117.00	---
20	2	0.00	0.03	0.00	0.05	---	0.00	0.00	0.00	0.00	---	0.00	0.33	0.00	1.00	---
21	2	0.40	0.29	0.05	0.08	---	0.00	0.08	0.08	0.08	---	71.67	60.67	51.00	57.67	---
22	2	0.08	0.08	0.03	0.21	---	0.05	0.05	0.05	0.05	---	1.67	1.33	0.67	3.33	---
23	2	1.09	0.95	0.53	0.27	---	0.34	0.21	0.27	0.37	---	297.00	336.00	222.00	179.00	---
24	2	0.03	0.11	0.21	0.08	---	0.00	0.00	0.00	0.05	---	0.67	2.33	10.67	73.33	---

Table 2. Average % cover and number of invasive species detected in each plot by cycle. Cycle 1= 2006 & 2008; Cycle 2= 2010 & 2012; Cycle 3= 2014 & 2016; Cycle 4= 2018 & 2022; and Cycle 5= 2023. Plots are sampled in alternating years, with Panel 1 sampled the first year, and Panel 2 sampled the second year. Note that plots 13-24 have not yet been sampled in Cycle 5.

Plot	Panel	Average % Cover					Number of Species per Plot				
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
1	1	0.44	0.00	0.00	0.00	0.01	1	3	2	0	3
2	1	0.00	0.01	0.00	0.00	0.00	1	1	1	1	0
3	1	0.00	0.00	0.00	0.00	0.00	0	1	2	1	2
4	1	0.00	0.00	0.01	0.46	0.00	0	1	2	3	3
5	1	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0
6	1	0.00	0.01	0.00	0.00	0.00	1	2	2	1	4
7	1	0.00	0.00	0.00	0.00	0.00	2	1	1	1	2
8	1	0.00	0.00	0.00	0.00	0.01	1	3	2	2	2
9	1	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0
10	1	0.00	0.00	0.00	0.00	0.00	0	0	0	0	0
11	1	0.00	0.00	0.01	0.20	0.04	1	0	2	3	3
12	1	0.00	0.00	0.19	0.01	0.00	0	0	1	1	0
13	2	0.00	0.00	0.01	0.00	---	2	1	5	2	---
14	2	0.00	0.00	0.00	0.00	---	2	2	3	0	---
15	2	0.00	0.00	0.00	0.00	---	0	0	2	0	---
16	2	0.00	0.00	0.00	0.00	---	0	0	0	0	---
17	2	0.00	0.01	0.00	0.00	---	0	1	0	1	---
18	2	0.00	0.00	0.00	0.00	---	0	0	0	2	---
19	2	0.00	0.00	0.00	0.00	---	1	0	1	1	---
20	2	0.00	0.00	0.00	0.00	---	0	1	1	2	---
21	2	0.00	0.00	0.00	0.00	---	0	0	0	0	---
22	2	0.00	0.00	0.00	0.00	---	0	0	0	0	---
23	2	0.00	0.00	0.00	0.00	---	0	0	0	0	---
24	2	0.00	0.00	0.00	0.19	---	1	2	2	2	---

Table 3. Number of plots out of 24 where priority invasive species were detected by cycle. Cycle 1= 2006 & 2008; Cycle 2= 2010 & 2012; Cycle 3= 2014 & 2016; Cycle 4= 2018 & 2022; Cycle 5= 2023. Species on the list include all exotic vascular plant species that are capable of dominating Northeastern US forest habitats, but does not include all exotic species detected in MABI forest plots. Note that only 12 plots have been sampled in Cycle 5.

Latin Name	Common Name	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
<i>Acer platanoides</i>	Norway maple	0	0	1	1	0
<i>Alliaria petiolata</i>	garlic mustard	0	0	2	0	2
<i>Berberis thunbergii</i>	Japanese barberry	1	0	0	2	3
<i>Berberis vulgaris</i>	common barberry	4	6	3	0	1
<i>Celastrus orbiculatus</i>	Asian bittersweet	0	1	1	1	2
<i>Chelidonium majus</i>	celandine	0	0	1	0	0
<i>Cirsium vulgare</i>	bull thistle	0	1	0	2	0
<i>Daphne mezereum</i>	paradise plant	1	0	1	1	1
<i>Elaeagnus</i> spp.	exotic olive	0	0	0	1	0
<i>Euonymus alatus</i>	burningbush	0	1	3	1	0
<i>Hesperis matronalis</i>	dames rocket	2	1	2	2	1
<i>Lonicera</i> spp.	exotic bush honeysuckle	5	6	11	10	6
<i>Rhamnus cathartica</i>	common buckthorn	2	4	8	8	5
<i>Tussilago farfara</i>	coltsfoot	0	0	1	2	1

Table 4. Priority forest pest and invasive plant detections by plot in the most recent 4-year census (2022 & 2023) in Marsh-Billings-Rockefeller National Historical Park. Coordinates are in NAD83 UTM Zone 18N. Average quadrat % cover provided where data exist to indicate abundance. Cover of 0 indicates the species was present on the plot, but did not occur in quadrats.

Plot	X	Y	Latin Name	Common Name	Avg. % Cover	Type
MABI-001	699991	4834089	Alliaria petiolata	garlic mustard	0.0125	herb
MABI-001	699991	4834089	Celastrus orbiculatus	Asian bittersweet	0	vine
MABI-001	699991	4834089	Rhamnus cathartica	common buckthorn	0	shrub
MABI-004	698344	4834661	Rhamnus cathartica	common buckthorn	0	shrub
MABI-005	699270	4833995	Lymantra dispar	spongy moth	NA	pest
MABI-006	698369	4833675	Alliaria petiolata	garlic mustard	0	herb
MABI-006	698369	4833675	Celastrus orbiculatus	Asian bittersweet	0	vine
MABI-006	698369	4833675	Rhamnus cathartica	garlic mustard	0	herb
MABI-007	698085	4833712	Berberis vulgaris	common barberry	0	shrub
MABI-008	697939	4833577	Rhamnus cathartica	common buckthorn	0.0125	shrub
MABI-011	697344	4834490	Rhamnus cathartica	common buckthorn	0.0375	shrub
MABI-013	699806	4833728	Acer platanoides	Norway maple	0	tree
MABI-013	699806	4833728	Elaeagnus	exotic olive	0	shrub
MABI-013	699806	4833728	Euonymus alatus	burningbush	0	shrub
MABI-017	697469	4834685	Rhamnus cathartica	common buckthorn	0	shrub
MABI-018	697748	4834519	Rhamnus cathartica	common buckthorn	0	shrub
MABI-019	699628	4834140	Rhamnus cathartica	common buckthorn	0	shrub
MABI-020	699405	4834331	Celastrus orbiculatus	Asian bittersweet	0	shrub
MABI-024	698238	4833461	Rhamnus cathartica	common buckthorn	0	shrub

Table 5. Harvesting history of plots in MABI. Xs indicate that a plot was harvested in the interval between sampling events. Plots in Panel 1 were sampled in 2006, 2010, 2014, 2018, and 2023. Plots in Panel 2 were sampled in 2008, 2012, 2016, and 2022. Plots 13-24 have not been sampled in cycle 5 yet. The increase in plots harvested from the 2022 report is due to querying trees that were cut, rather than reported stand disturbances.

Plot	Panel	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
		(2006-2009)	(2010-2013)	(2014-2017)	(2018-2022)	(2023)
1	1				X	
2	1		X		X	
3	1					X
4	1			X		
5	1					
6	1			X		
7	1			X	X	
8	1			X	X	
9	1			X		
10	1					
11	1		X			
12	1			X		
13	2					
14	2				X	
15	2			X		
16	2				X	
17	2		X		X	
18	2			X		
19	2			X		
20	2					
21	2					
22	2					
23	2					
24	2	X		X		