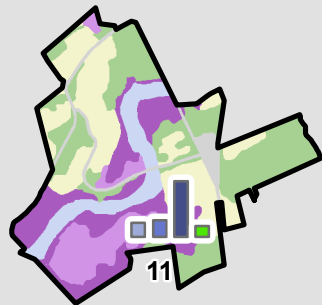




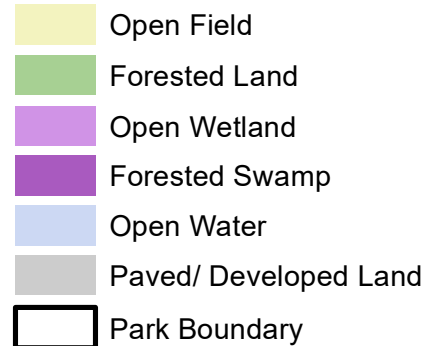
North Bridge



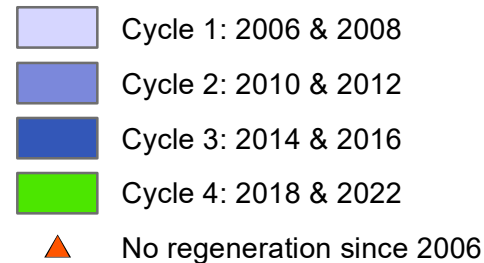
Map 1. Tree Regeneration by Cycle

Trends in tree regeneration, including seedlings and saplings, observed in forest plots sampled from 2006-2022. Plots are sampled in an alternating panel, with plots 1-10 sampled in 2006, 2010, 2014, and 2018, and plots 11-20 sampled in 2008, 2012, 2016, and 2022. Densities range from 0 to 1.0 stems/m² and only include native canopy-forming species. Note the unit change from the 2018 report to match manuscript in review. Date: 8/22/2022.

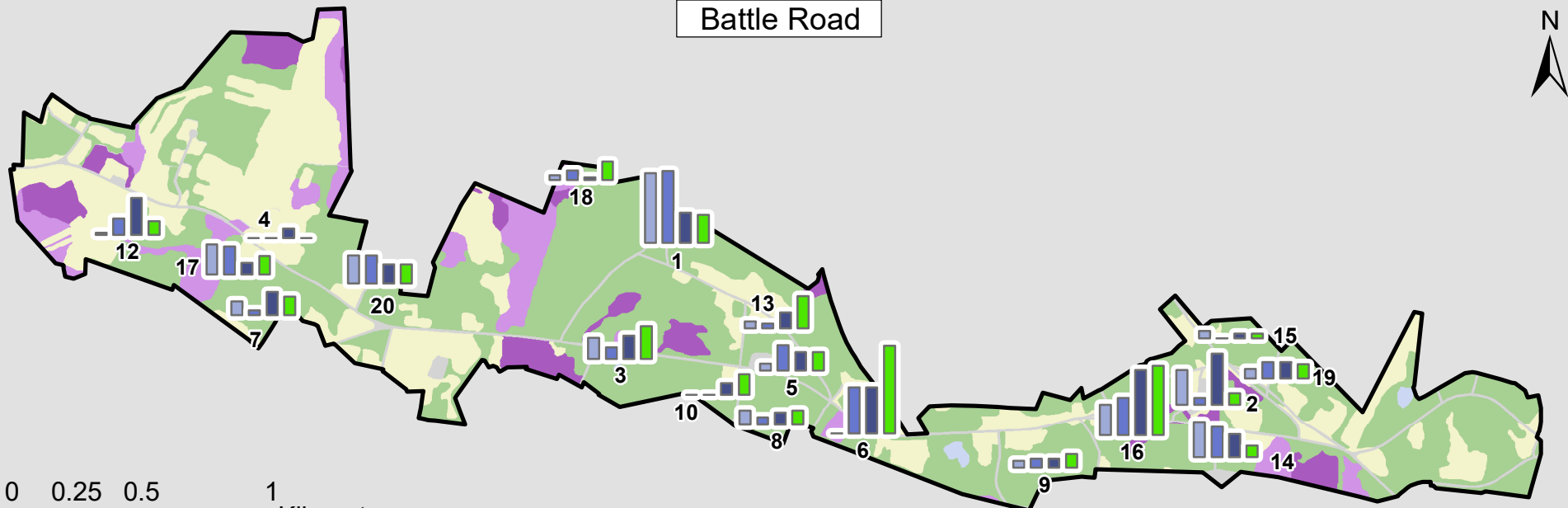
Legend



Regeneration densities



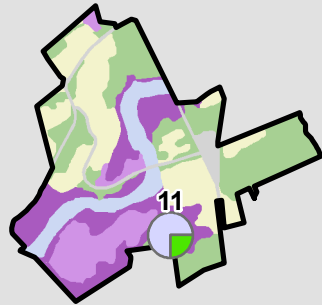
Battle Road



0 0.25 0.5 1
Kilometers



North Bridge



Map 2. Tree Regeneration by Size Class

Trends in tree regeneration by size class observed in forest plots in the most recent survey cycle (2018 and 2022). Plots are sampled in an alternating panel, with plots 1-10 sampled in 2018, and plots 11-20 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 1.0 stems/m² and only include native canopy-forming species. Note the unit change from the 2018 report to match manuscript in review.

Date: 8/22/2022.

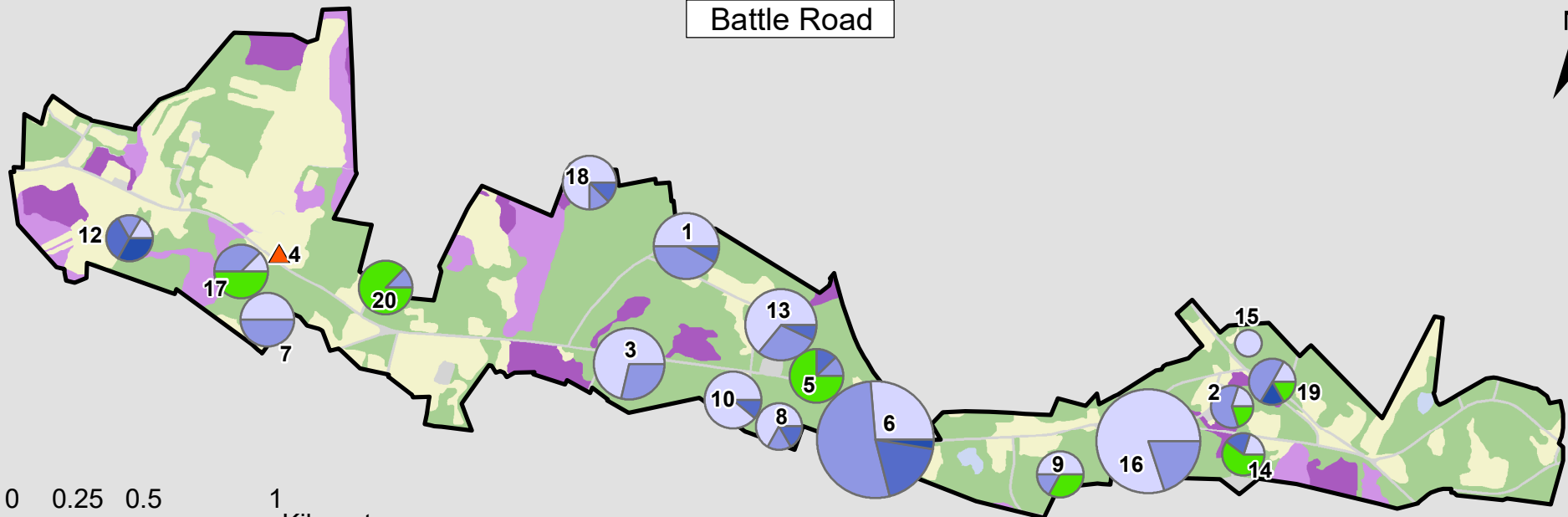
Legend

- Open Field
- Forested Land
- Open Wetland
- Forested Swamp
- Open Water
- Paved/ Developed Land
- Park Boundary

Stem densities by size class

- No regeneration observed
- Seedlings 15 to 30 cm
- Seedlings 30 to 100 cm
- Seedlings 100 to 150 cm
- Seedlings >150 cm
- Saplings (≥ 1 cm & <10 cm DBH)

Battle Road



0 0.25 0.5 1
Kilometers

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, which differs from the 2018 summary. Cycle 1= 2006 & 2008; Cycle 2= 2010 & 2012; Cycle 3= 2014 & 2016, Cycle 4= 2018 & 2022. 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.

Plot	Panel	Seedlings per m ²				Saplings per m ²				Stocking Index			
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 1	Cycle 2	Cycle 3	Cycle 4
1	1	0.80	0.82	0.34	0.32	0.00	0.00	0.00	0.00	10.00	44.67	27.33	12.00
2	1	0.08	0.08	0.58	0.11	0.32	0.00	0.00	0.03	51.00	2.00	77.00	19.00
3	1	0.24	0.13	0.27	0.37	0.00	0.00	0.00	0.00	3.00	1.67	6.00	6.00
4	1	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00
5	1	0.00	0.13	0.05	0.05	0.08	0.16	0.16	0.16	0.00	19.67	24.00	7.33
6	1	0.00	0.53	0.53	1.01	0.00	0.00	0.00	0.00	0.00	35.00	26.67	80.00
7	1	0.16	0.05	0.21	0.21	0.00	0.00	0.05	0.00	3.00	0.67	37.67	4.00
8	1	0.16	0.08	0.13	0.16	0.00	0.00	0.00	0.00	3.00	1.33	2.00	8.67
9	1	0.00	0.03	0.03	0.11	0.08	0.08	0.08	0.05	50.00	17.33	0.67	1.67
10	1	0.00	0.00	0.13	0.24	0.00	0.00	0.00	0.00	0.00	0.00	1.67	9.33
11	2	0.11	0.13	0.53	0.08	0.03	0.03	0.00	0.03	31.00	2.00	7.00	1.00
12	2	0.03	0.19	0.42	0.16	0.00	0.00	0.00	0.00	0.67	3.67	15.33	47.67
13	2	0.08	0.05	0.19	0.37	0.00	0.00	0.00	0.00	1.33	7.33	9.33	12.33
14	2	0.21	0.13	0.08	0.05	0.19	0.21	0.19	0.08	75.67	32.00	40.67	7.00
15	2	0.03	0.00	0.05	0.05	0.05	0.00	0.00	0.00	6.67	0.00	1.00	0.67
16	2	0.32	0.40	0.74	0.80	0.03	0.03	0.00	0.00	21.33	19.33	19.33	12.00
17	2	0.27	0.24	0.03	0.11	0.08	0.08	0.11	0.11	11.33	20.67	17.33	19.00
18	2	0.05	0.11	0.00	0.21	0.00	0.00	0.03	0.00	0.67	2.33	16.67	9.33
19	2	0.05	0.16	0.16	0.13	0.05	0.03	0.03	0.03	7.00	9.00	2.67	19.00
20	2	0.03	0.05	0.00	0.03	0.29	0.27	0.21	0.19	150.00	67.67	50.00	50.67

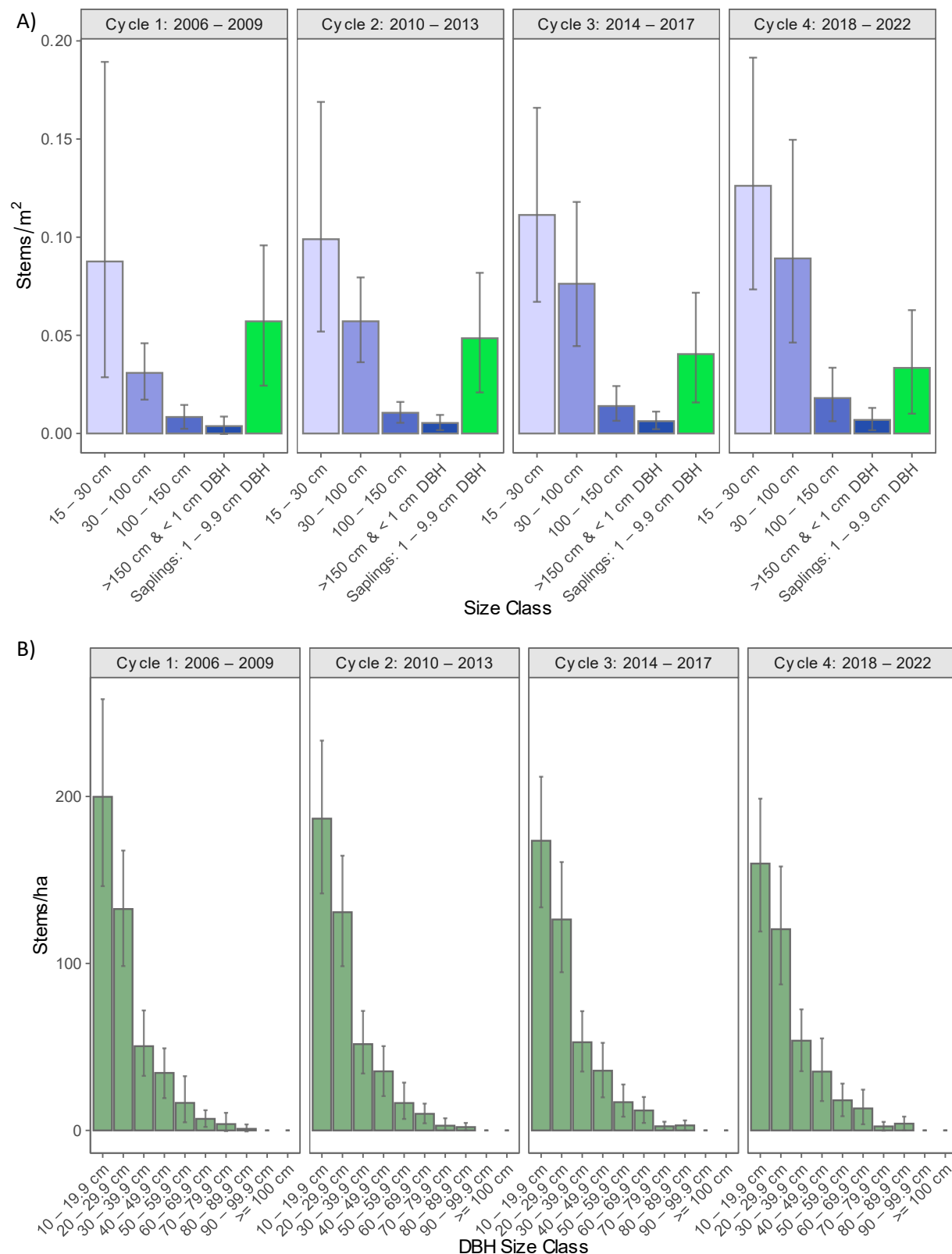
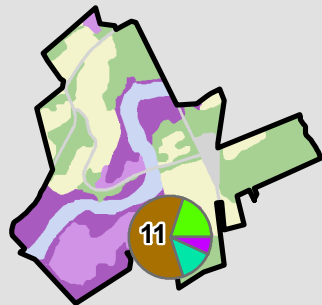


Figure 1. Stem density distributions by survey cycle in Minute Man National Historical Park. Cycle 1 is 2006–2009; Cycle 2 is 2010–2013; Cycle 3 is 2014–2017; Cycle 4 is 2018–2022. Figure A shows regeneration densities by size class. Figure B shows tree density by diameter at breast height (DBH) increments. Error bars are 95% bootstrapped confidence intervals. An asterisk denotes a linear DBH distribution that is indicative of long-term recruitment failure.



North Bridge



Map 3. Tree Regeneration Composition

Trends in tree regeneration, including seedlings and saplings, by species group observed in forest plots in the most recent survey cycle (2018 and 2022). Plots are sampled in an alternating panel, with plots 1-10 sampled in 2018, and plots 11-20 sampled in 2022. Pie size is proportional to the total plot-level regeneration (range: 0 to 1.2 stem/m²). Pies may be shifted from actual plot location to prevent overlap. Date: 8/22/2022.

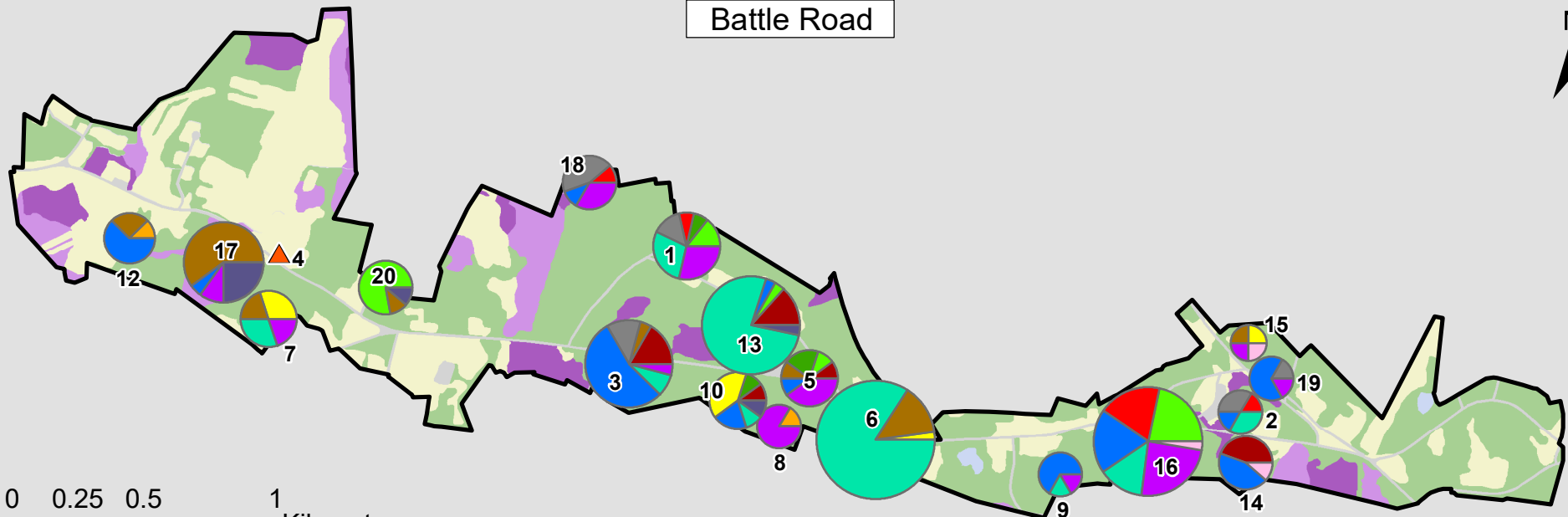
Legend

- Open Field
- Forested Land
- Open Wetland
- Forested Swamp
- Open Water
- Paved/ Developed Land
- Park Boundary
- No regeneration observed

Species in Pie Charts

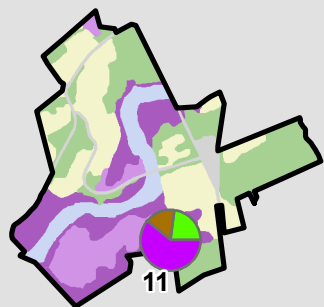
- | | |
|--|---|
| Acer platanoides (Norway maple) | Pinus strobus (White pine) |
| Acer spp. (Maple - Native) | Prunus spp. (Cherry) |
| Betula spp. (Birch) | Quercus spp. (Oak) |
| Carya spp. (Hickory) | Ulmus spp. (Elm) |
| Fagus grandifolia (Beech) | Subcanopy species |
| Fraxinus spp. (Ash) | Other exotic species |
| | Other native species |

Battle Road





North Bridge



Map 4. Tree Canopy Composition

Trends in tree composition, by species group, observed in forest plots in the most recent survey cycle (2018 and 2022). Plots are sampled in an alternating panel, with plots 1-10 sampled in 2018, and plots 11-20 sampled in 2022. Pie size is proportional to the total plot-level basal area (range: 7.6 to 76.0 m²/hectare). Pies may be shifted from actual plot location to prevent overlap. Date: 8/22/2022.

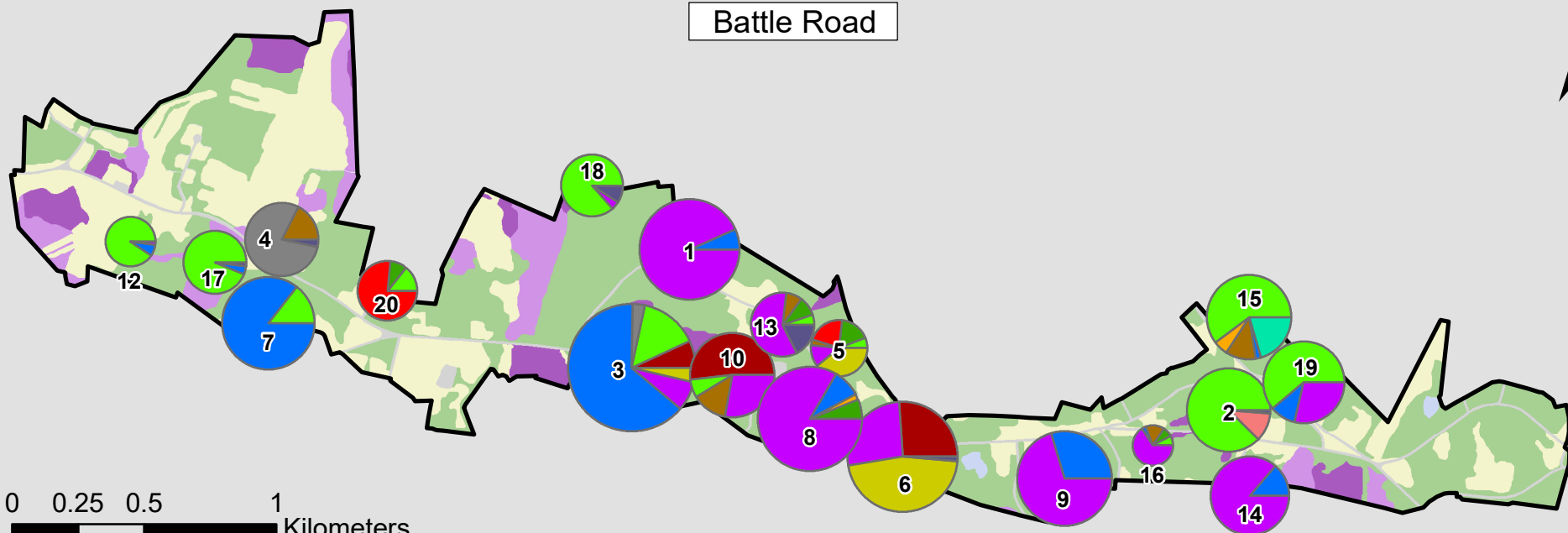
Legend

- Open Field
- Forested Land
- Open Wetland
- Forested Swamp
- Open Water
- Paved/ Dev. Land
- Park Boundary

Species in Pie Charts

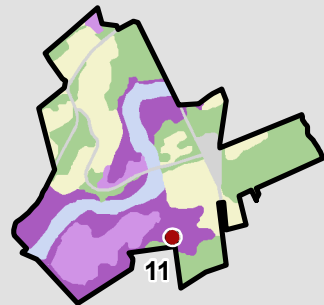
- | | |
|--|--|
| Acer platanoides (Norway maple) | Prunus spp. (Cherry) |
| Acer spp. (Maple - Native) | Quercus spp. (Oak) |
| Betula spp. (Birch) | Robinia pseudoacacia (black locust) |
| Fagus grandifolia (Beech) | Ulmus spp. (Elm) |
| Fraxinus spp. (Ash) | Subcanopy species |
| Pinus strobus (White pine) | Other exotic species |
| Pinus sylvestris (Scots pine) | Other native species |

Battle Road





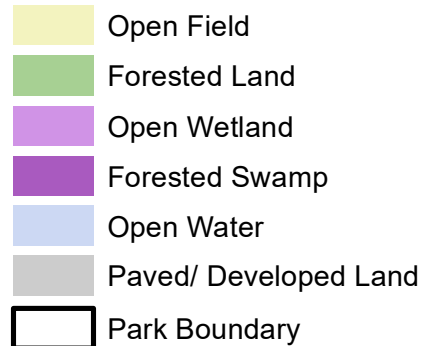
North Bridge



Map 5. Tree Regeneration Stocking Index

Trends in the regeneration stocking index for the most recent survey cycle (2018 and 2022). 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 (range 0-80), and only includes native canopy-forming species. See Table 1 for plot-level stocking index values. Date: 8/22/2022.

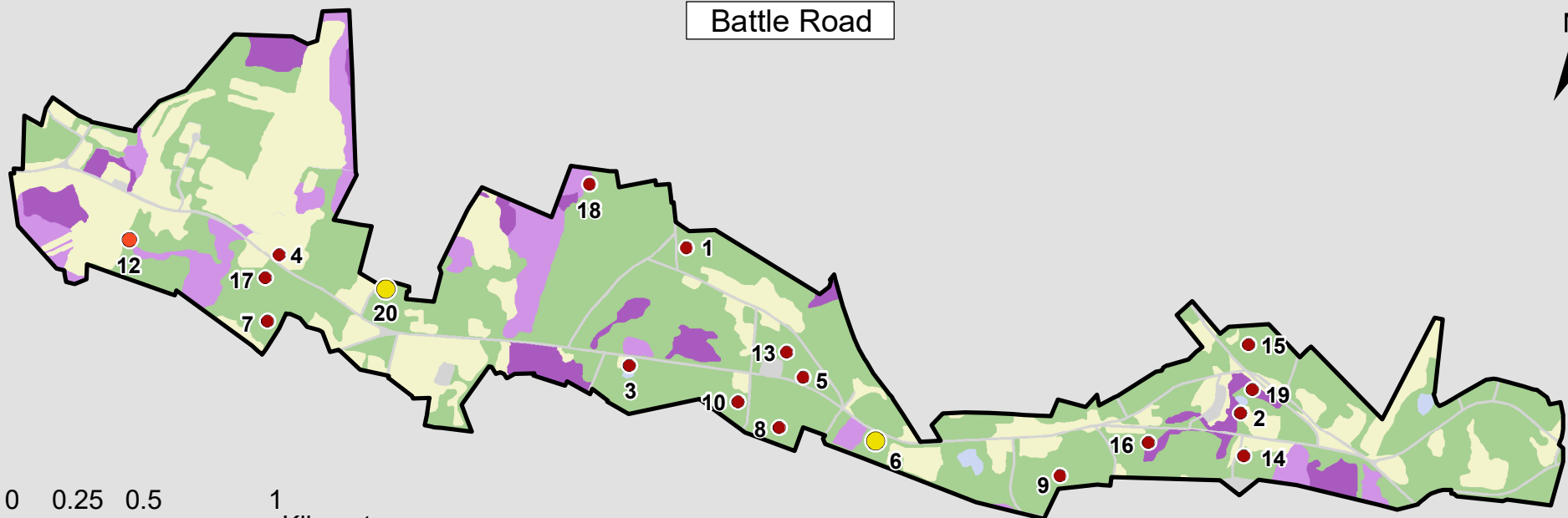
Legend



Stocking Index Ranges

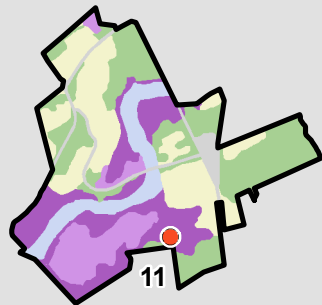
- < 25: Severely understocked. Regeneration is insufficient to replace the forest canopy.
- 25 to 50: Moderately stocked regeneration for areas with low deer impacts.
- 50 to 100: Sufficient regeneration to replace forest canopy in areas with low deer impacts.
- > 100: Sufficiently stocked with regeneration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

Battle Road





North Bridge



Map 6. Index of Deer Browse Impacts

Index of deer browse impacts observed in forest plots in the most recent four years of sampling (2018 & 2022). Plots are sampled in an alternating panel, with plots 1-10 sampled in 2018 and plots 11-20 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: 8/22/2022.

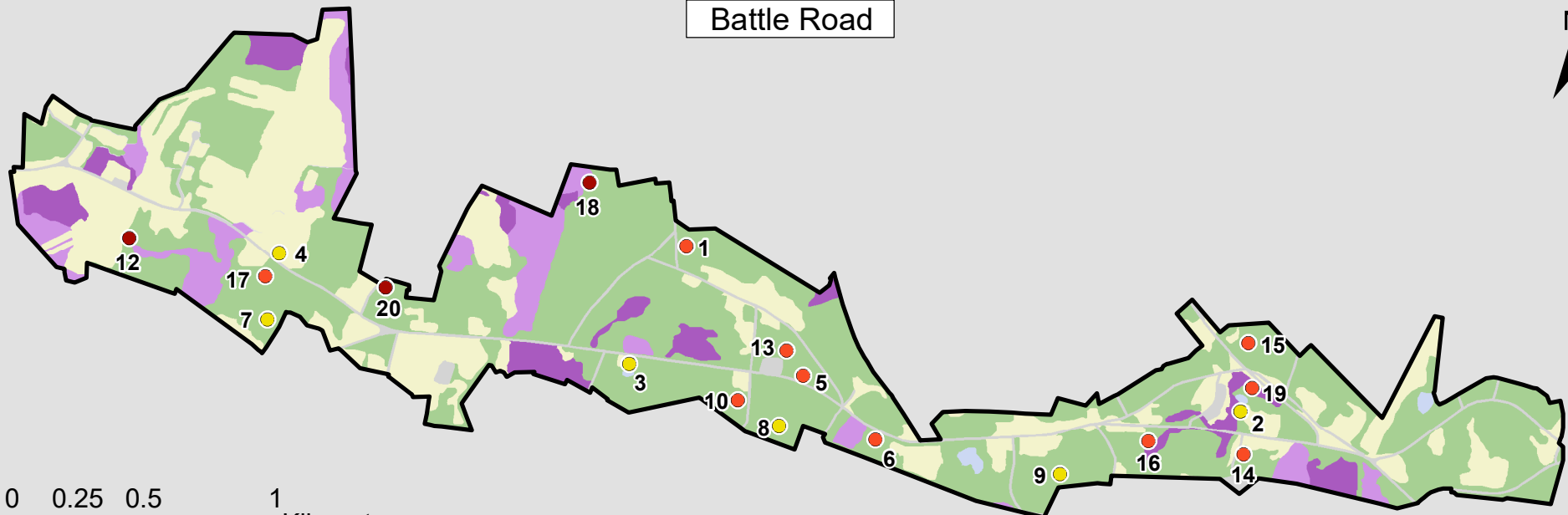
Legend

- Open Field
- Forested Land
- Open Wetland
- Forested Swamp
- Open Water
- Paved/ Developed Land
- Park Boundary

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 < 30 cm tall. DP herbs present but stunted and flowering is uncommon.
- 4) High Impact: DP species are rare to absent. Non-preferred (NP) 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. NP species also reduced by heavy browsing. Distinct deer browse line.

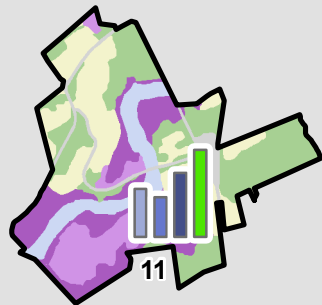
Battle Road



0 0.25 0.5 1
Kilometers



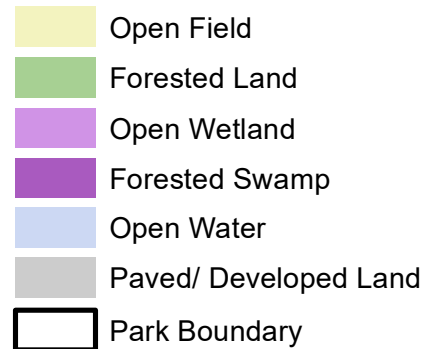
North Bridge



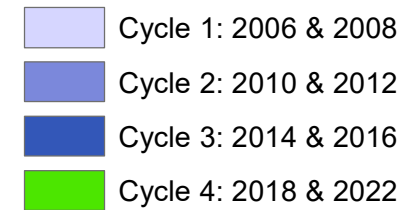
Map 7. Invasive % Cover by Cycle

Trends in percent cover of invasive species observed in plots sampled from 2006-2022. Plots are sampled in an alternating panel, with plots 1-10 sampled in 2006, 2010, 2014, and 2018, and plots 11-20 sampled in 2008, 2012, 2016, and 2022. Average invasive cover ranges from 0 to 53%. See Table 2 for % cover values. Date: 8/22/2022.

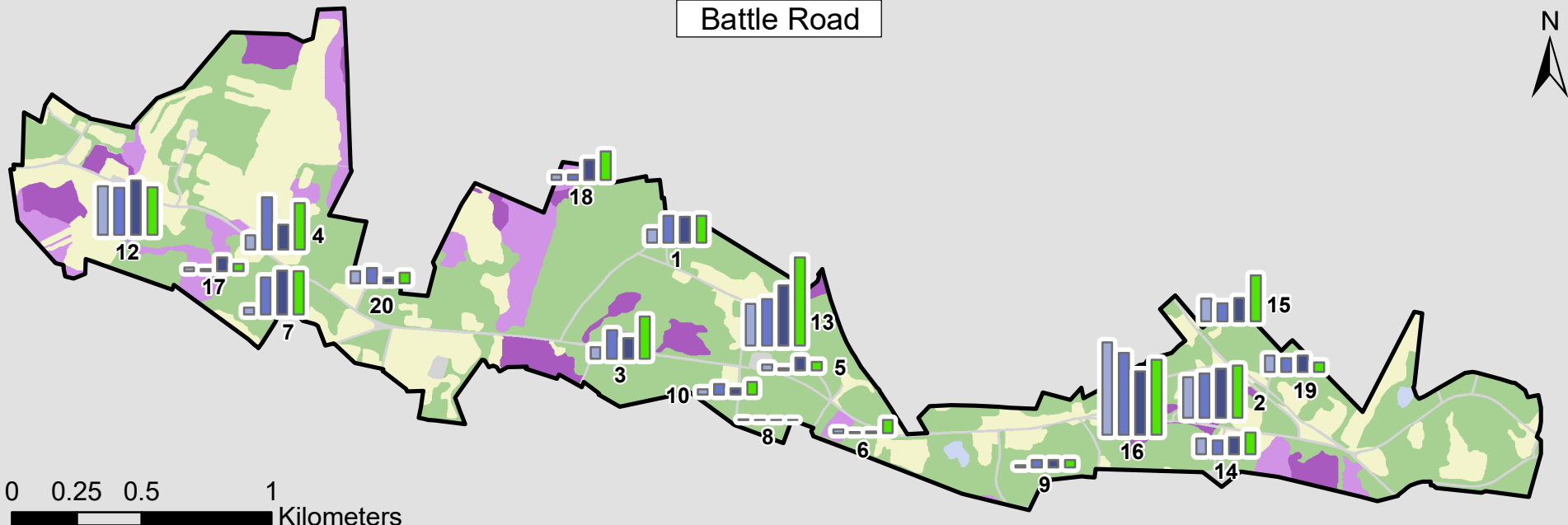
Legend



Invasive % Cover

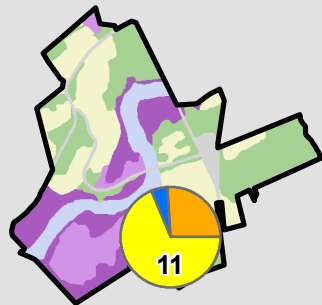


Battle Road





North Bridge



Map 8. Invasive % Cover by Species

Trends in % invasive cover by species observed in quadrats for plots in the most recent survey cycle (2018 & 2022). Plots are sampled in an alternating panel, with plots 1-10 sampled in 2018 and plots 11-20 sampled in 2022. Pie size is proportional to total invasive cover (range: 0 to 51%), and location may be shifted to prevent overlap. See Table 2 for more information.
Date: 8/22/2022.

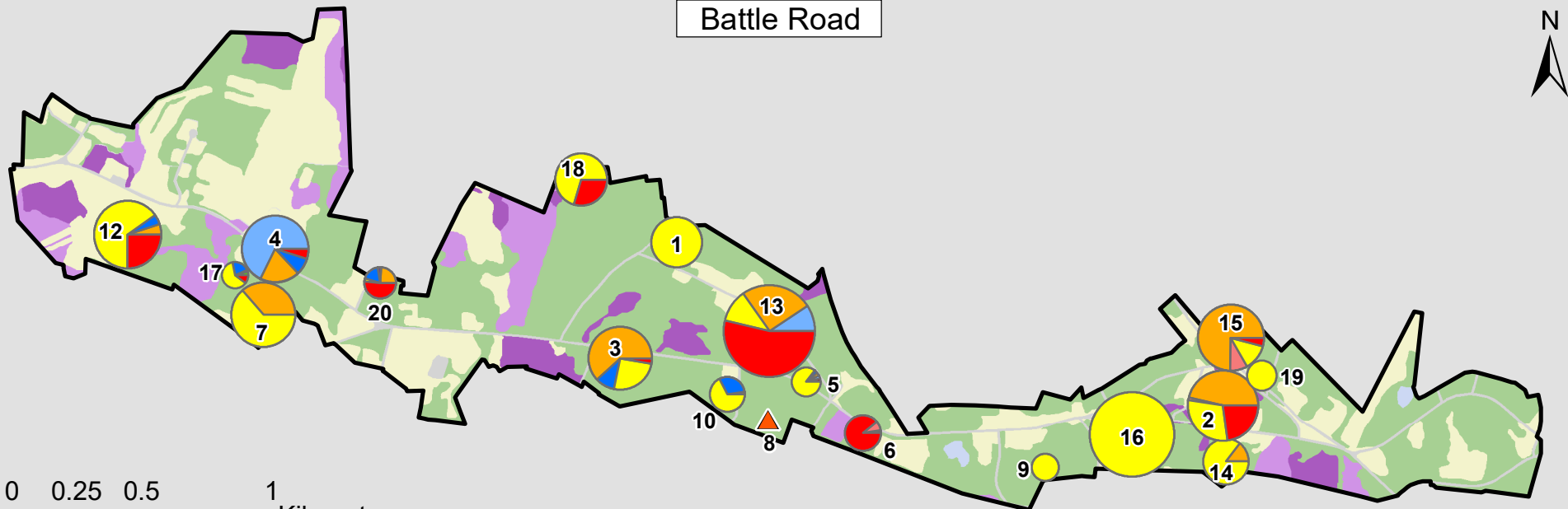
Legend

- Open Field
- Forested Land
- Open Wetland
- Forested Swamp
- Open Water
- Paved/ Dev. Land
- Park Boundary
- No invasive cover

Species in Pie Charts

- | | |
|---|---|
| <i>Acer platanoides</i> (Norway maple) | <i>Rhamnus cathartica</i> (com. buckthorn) |
| <i>Alliaria petiolata</i> (garlic mustard) | <i>Rhamnus frangula</i> (glossy buckthorn) |
| <i>Berberis thunbergii</i> (Jap. barberry) | <i>Rosa multiflora</i> (multiflora rose) |
| <i>Celastrus orbiculatus</i> (Asian bittersweet) | |
| <i>Euonymus alatus</i> (burningbush) | |
| <i>Ligustrum</i> spp. (privet) | |
| <i>Lonicera</i> spp. (exotic bush honeysuckle) | |
| <i>Lonicera japonica</i> (Jap. honeysuckle) | |

Battle Road



0 0.25 0.5 1 Kilometers



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. Plots are sampled in alternating years, with Panel 1 sampled the first year, and Panel 2 sampled the second year.

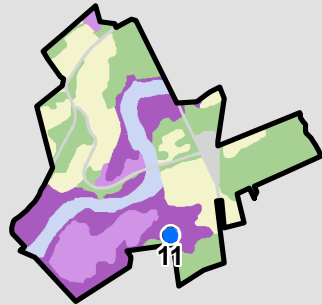
Plot	Panel	Average % Cover				Number of Species per Plot			
		Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 1	Cycle 2	Cycle 3	Cycle 4
1	1	15.25	15.31	14.88	15.50	3	3	3	3
2	1	23.58	25.43	28.29	30.21	3	4	5	6
3	1	6.74	16.05	11.66	24.29	9	8	8	8
4	1	8.31	30.24	14.54	27.04	4	6	6	6
5	1	3.51	1.34	7.40	5.15	8	9	10	10
6	1	2.14	0.66	1.04	7.71	6	4	7	9
7	1	4.08	21.34	25.44	25.09	4	5	4	4
8	1	0.44	0.00	0.00	0.00	2	1	1	1
9	1	1.38	4.41	4.39	4.39	2	2	2	1
10	1	3.23	6.28	3.60	7.33	6	7	8	7
11	2	23.03	19.00	30.55	41.63	4	5	5	6
12	2	27.90	27.16	31.56	27.48	4	4	5	6
13	2	23.99	53.90	34.78	50.96	5	12	9	9
14	2	9.34	8.15	9.84	12.78	6	7	6	7
15	2	13.01	10.46	13.30	26.56	4	5	7	8
16	2	53.49	47.53	36.59	43.44	3	5	5	3
17	2	1.89	1.24	7.80	4.25	3	4	5	5
18	2	2.94	2.88	11.38	16.51	3	5	4	6
19	2	9.38	7.73	9.41	5.44	2	4	2	4
20	2	6.91	8.60	3.36	5.04	5	7	7	7

Table 3. Number of plots out of 21 where priority invasive species were detected by cycle. Cycle 1= 2006 & 2008; Cycle 2= 2010 & 2012; Cycle 3= 2014 & 2016; Cycle 4= 2018 & 2022. This list includes all exotic vascular plant species that are capable of dominating Northeastern US forest habitats, but does not include all exotic species detected in MIMA forest plots.

Latin Name	Common Name	Cycle 1	Cycle 2	Cycle 3	Cycle 4
<i>Acer palmatum</i>	Japanese maple	1	1	1	1
<i>Acer platanoides</i>	Norway maple	10	9	9	10
<i>Aegopodium podagraria</i>	bishop's goutweed	1	0	0	0
<i>Ajuga</i> spp.	bugle	0	0	1	1
<i>Alliaria petiolata</i>	garlic mustard	7	7	7	6
<i>Berberis thunbergii</i>	Japanese barberry	4	5	5	6
<i>Cardamine impatiens</i>	narrowleaf bittercress	0	0	1	0
<i>Celastrus orbiculatus</i>	oriental bittersweet	9	17	18	16
<i>Chelidonium majus</i>	celandine	4	2	3	3
<i>Cirsium vulgare</i>	bull thistle	0	0	1	1
<i>Conium maculatum</i>	poison parsley	0	0	0	1
<i>Elaeagnus</i> spp.	exotic olive	0	0	1	1
<i>Euonymus alatus</i>	burningbush	2	2	7	7
<i>Fallopia japonica</i>	Japanese knotweed	2	0	0	0
<i>Iris pseudacorus</i>	paleyellow iris	0	0	0	1
<i>Ligustrum</i>	privet	0	4	3	4
<i>Lonicera</i> spp.	exotic bush honeysuckle	10	11	11	12
<i>Lonicera japonica</i>	Japanese honeysuckle	0	1	1	2
<i>Lysimachia nummularia</i>	creeping jenny	1	1	1	1
<i>Lythrum salicaria</i>	purple loosestrife	3	5	4	4
<i>Morus alba</i>	mulberry	0	3	1	0
<i>Paulownia tomentosa</i>	princess tree	1	0	0	0
<i>Phalaris arundinacea</i>	reed canary grass	3	1	2	1
<i>Phragmites australis</i>	common reed	1	0	0	0
<i>Rhamnus cathartica</i>	common buckthorn	4	7	5	11
<i>Rhamnus frangula</i>	glossy buckthorn	20	19	19	19
<i>Robinia hispida</i>	bristly locust	0	0	1	0
<i>Robinia pseudoacacia</i>	black locust	4	4	4	4
<i>Rosa multiflora</i>	multiflora rose	14	18	15	16
<i>Viburnum lantana</i>	wayfaringtree	0	0	1	0



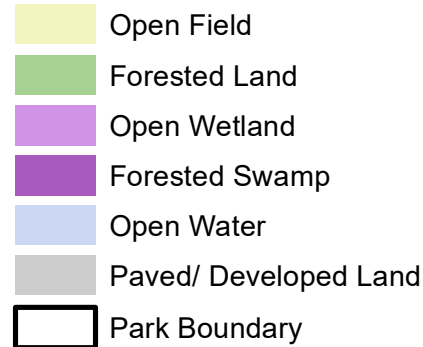
North Bridge



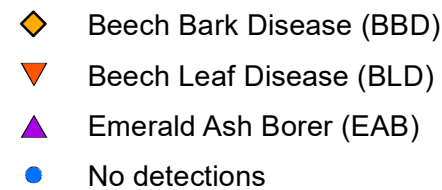
Map 9. Forest Pest/Pathogen Detections

Detections of priority forest pests in forest plots sampled during the most recent survey cycle (2018 and 2022). Plots are sampled in an alternating panel with plots 1-10 sampled in 2018 and plots 11-20 sampled in 2022. Note that BLD may be more widespread than map indicates, as plots 1-10 were sampled prior to the first detection of BLD in 2022. Date 8/22/2022.

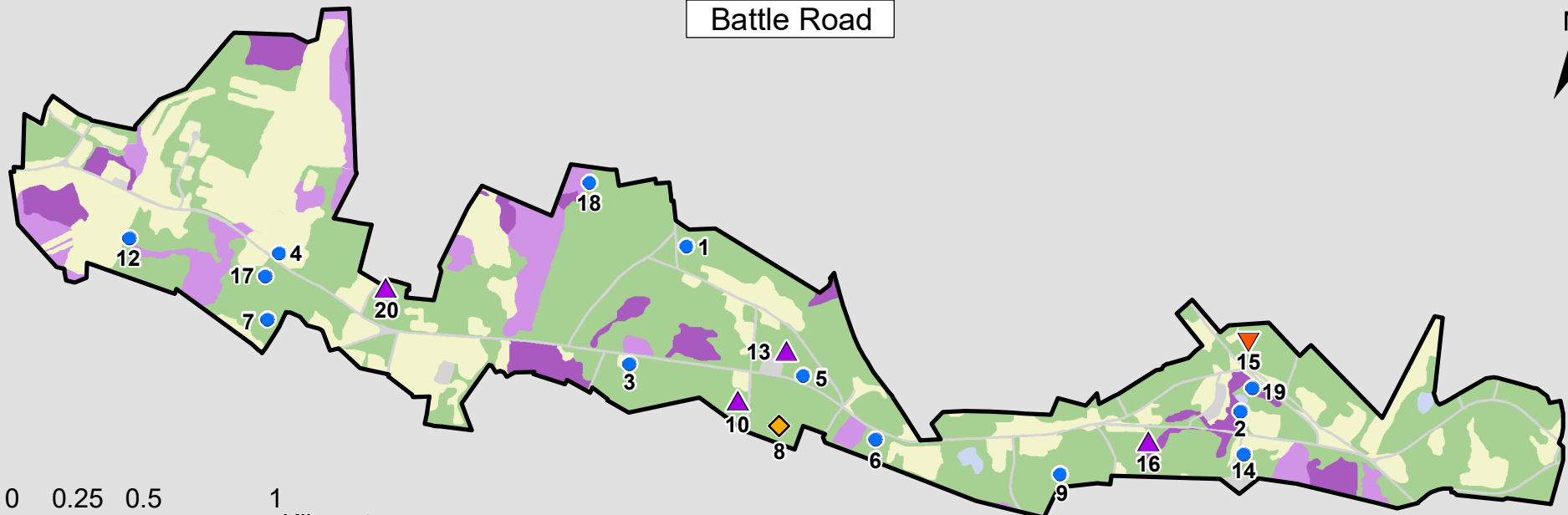
Legend



Pests/Pathogens



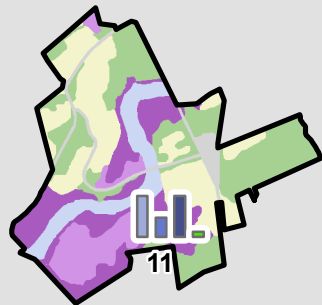
Battle Road



0 0.25 0.5 1
Kilometers



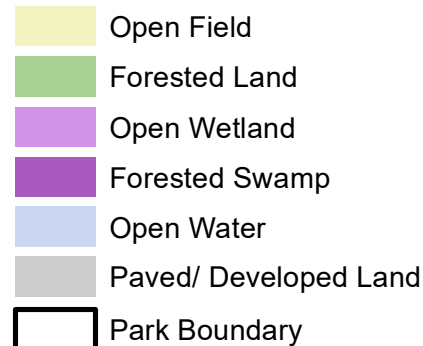
North Bridge



Map 10. Canopy Cover by Cycle

Trends in tree canopy cover in forest plots from 2006-2022. Plots are sampled in an alternating panel, with plots 1-10 sampled in 2006, 2010, 2014, and 2018 and plots 11-20 sampled in 2008, 2012, 2016, 2022. Canopy cover ranges from 0 - 10% to >75%. Date: 8/22/2022.

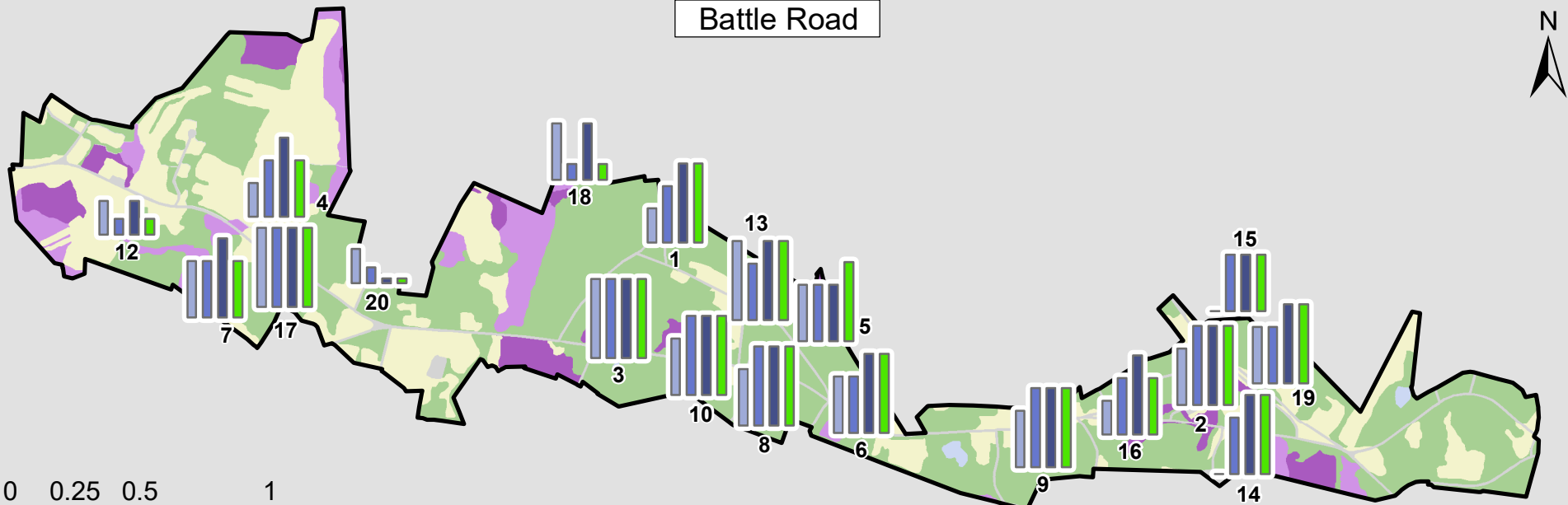
Legend



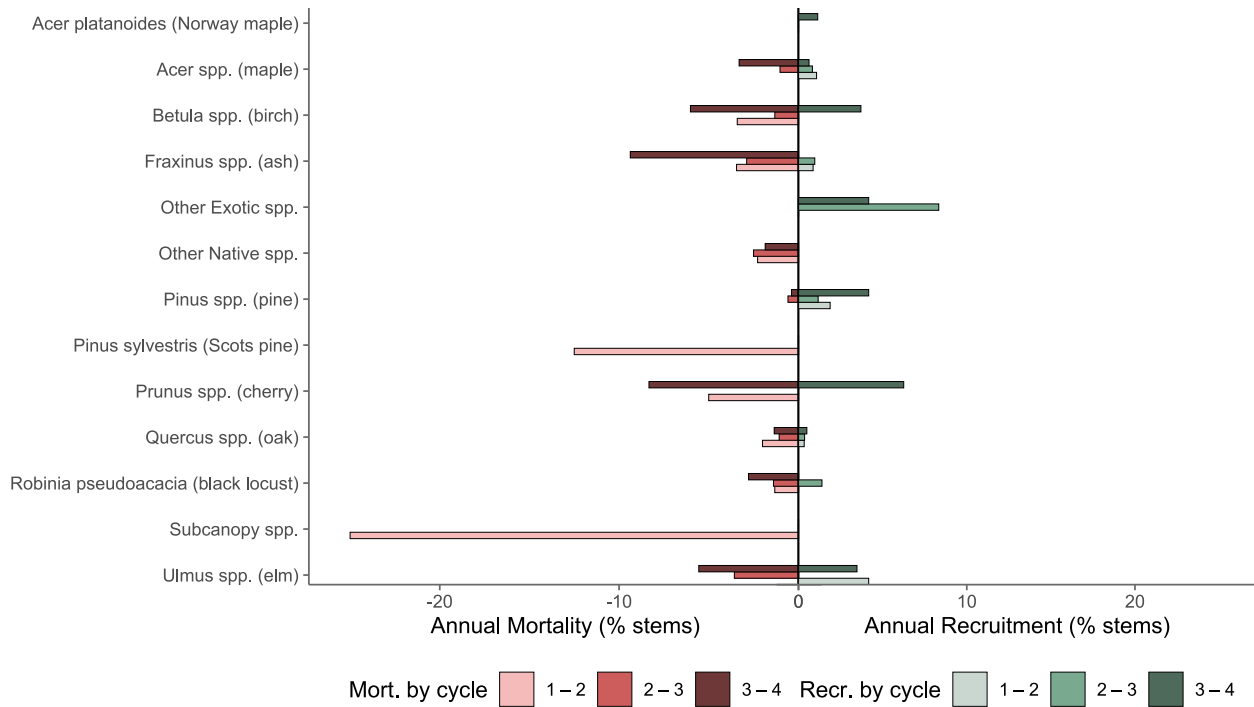
Canopy Cover



Battle Road



A)



B)

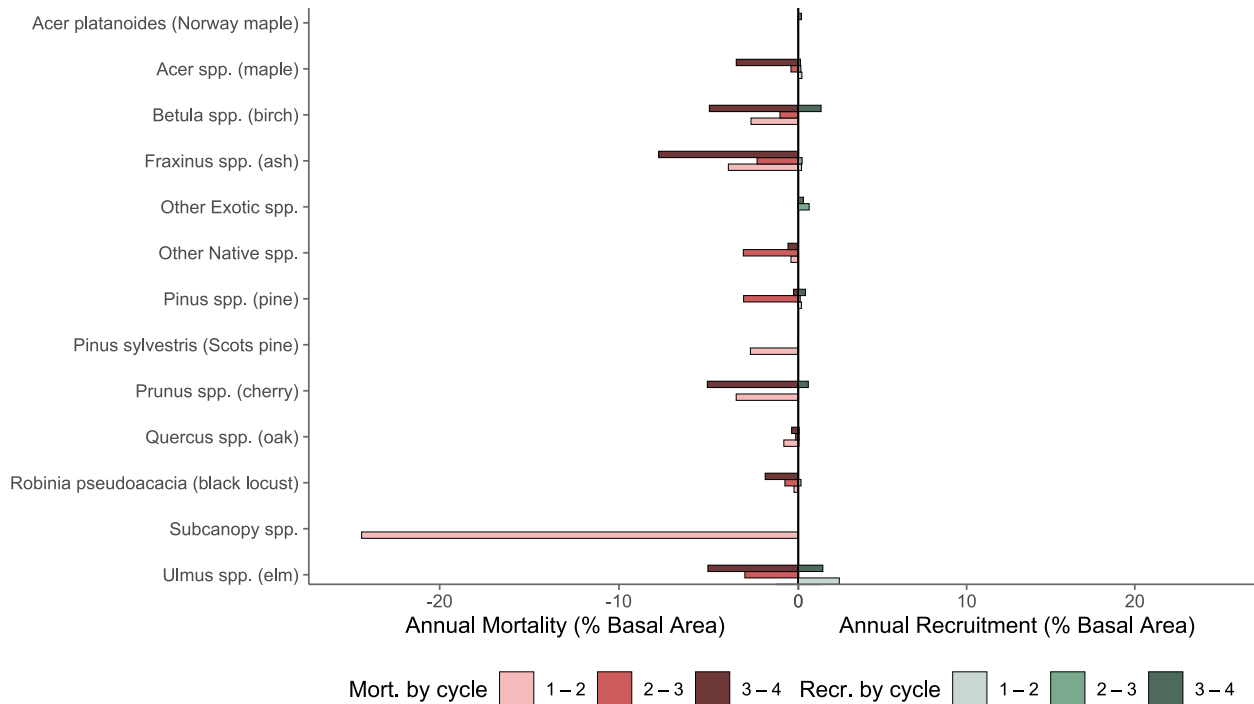


Figure 2. Annual tree mortality and recruitment rates by cycle in Minute Man National Historical Park. Figure A represents % of stems that died (mortality) and the % of stems gained (recruitment) per year from the previous cycle. Figure B is the % of basal area per year that died or was gained from the previous cycle.

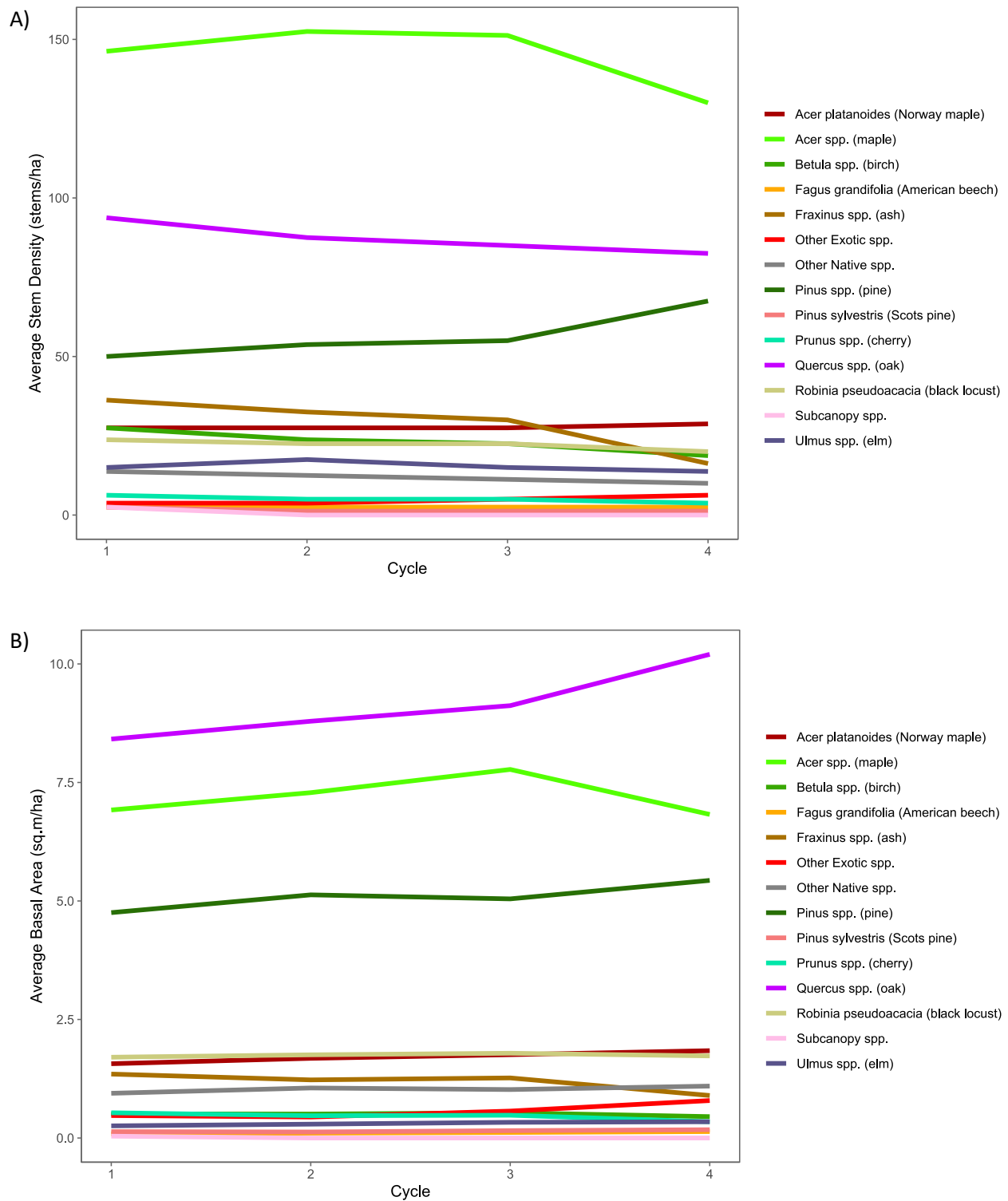
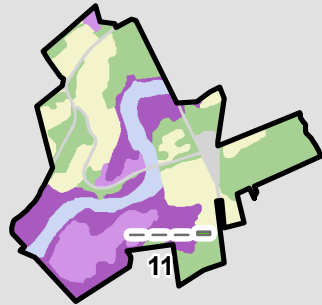


Figure 3. Change in stem density (A) and basal area (B) by species and cycle in Minute Man National Historical Park. Cycle 1 = 2006 – 2009; Cycle 2 = 2010 – 2013; Cycle 3 = 2014 – 2017; Cycle 4 = 2018 – 2022.



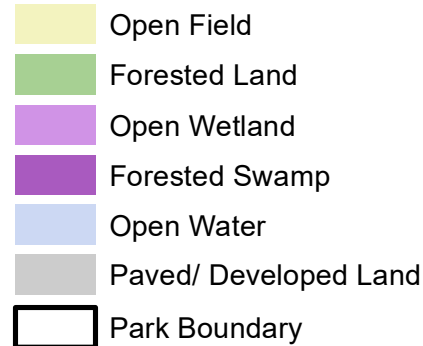
North Bridge



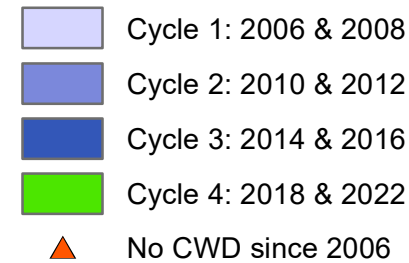
Map 11. Coarse Woody Debris By Cycle

Trends in Coarse Woody Debris (CWD) volume observed in plots sampled from 2006-2022. Plots are sampled in an alternating panel, with plots 1-10 sampled in 2006, 2010, 2014, and 2018 and plots 11-20 sampled in 2008, 2012, 2016, and 2022. CWD volume ranges from 0 - 106.7 m³/ha. Date: 8/22/2022.

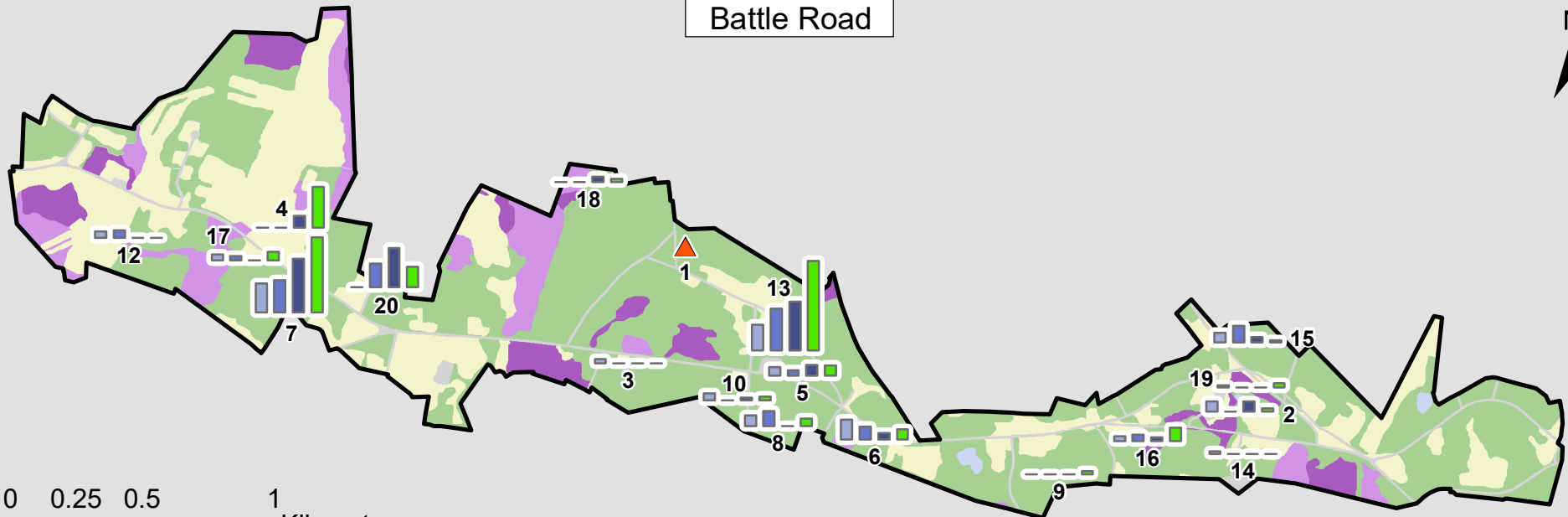
Legend



CWD Volume

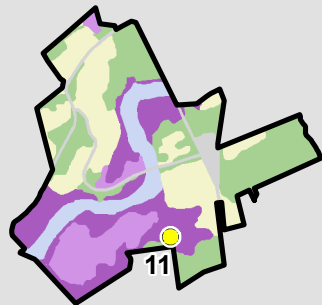


Battle Road





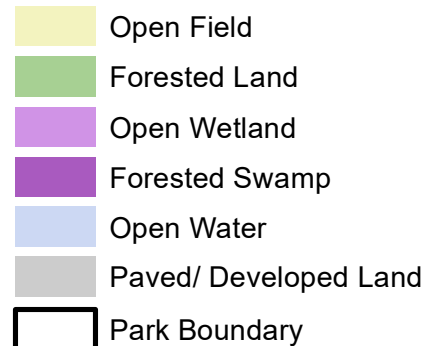
North Bridge



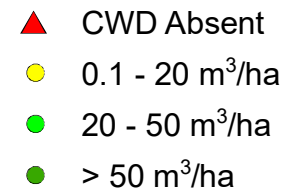
Map 12. Coarse Woody Debris Ratings

Coarse woody debris volume (m^3/ha) for the most recent survey cycle (2018 and 2022). Plots 1-10 were sampled in 2018, and plots 11-20 were sampled in 2022. Volumes range from 0 to $89.3 \text{ m}^3/\text{hectare}$. Plots are color coded by volume to indicate whether they meet the $20\text{-}50 \text{ m}^3/\text{ha}$ threshold in Müller and Büttler (2010). Date: 8/22/2022.

Legend



CWD Volume Levels



Battle Road

