

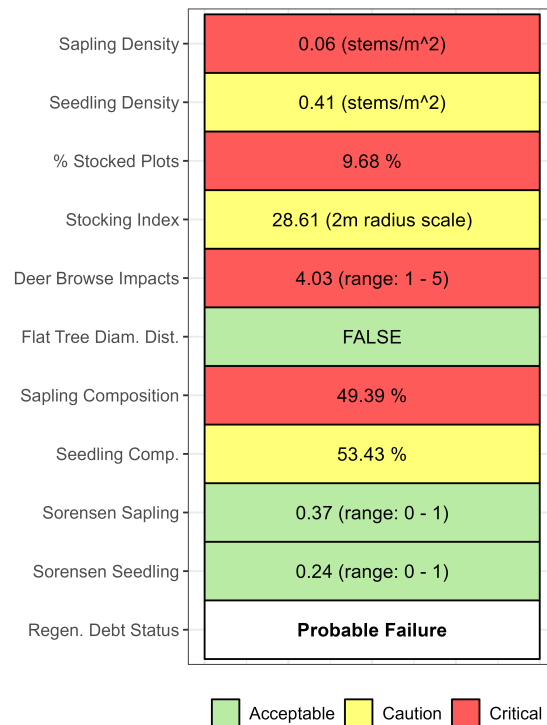


Figure 1. Regeneration Debt status for the most recent 4-year census (2021 – 2024) in Richmond National Battlefield Park (RICH). Flat Tree Diam. Dist. stands for Flat Tree Diameter Distribution. If TRUE, the density of small trees is lower than expected due to chronic regeneration failure. Sapling/Seedling Composition is the % of total stems composed of native canopy-forming species. Sorensen is a measure of how closely the regen. layer matches canopy composition. For more details on metric calculations, thresholds and assessment of status, see Miller et al. 2023 (<https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/eap.2837>).

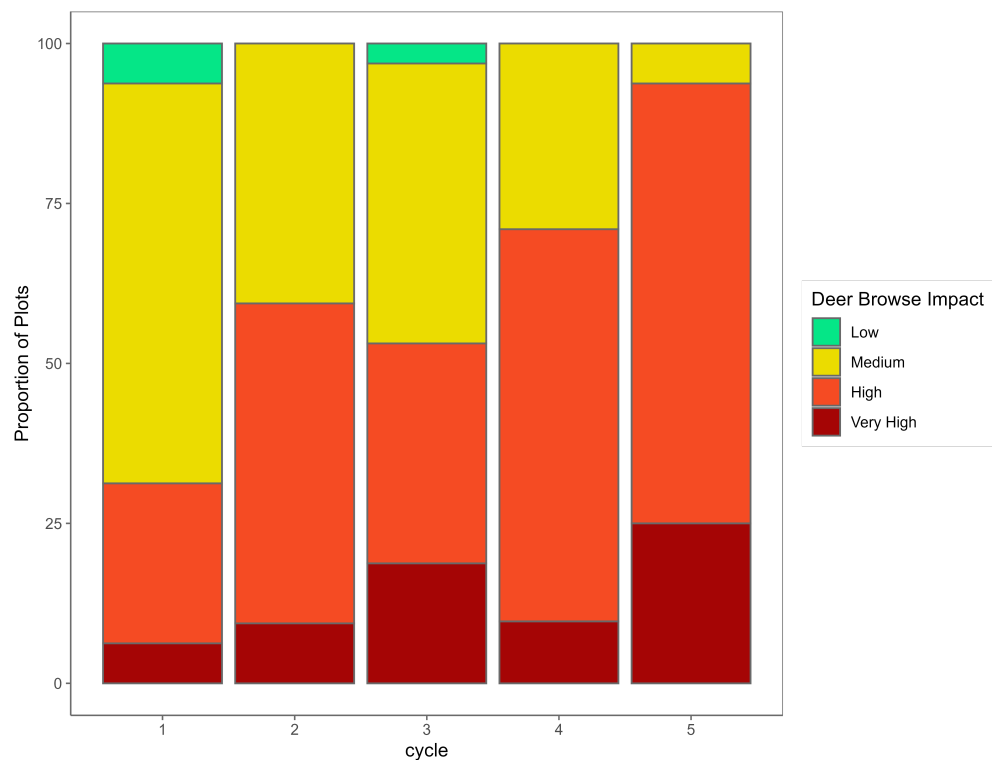
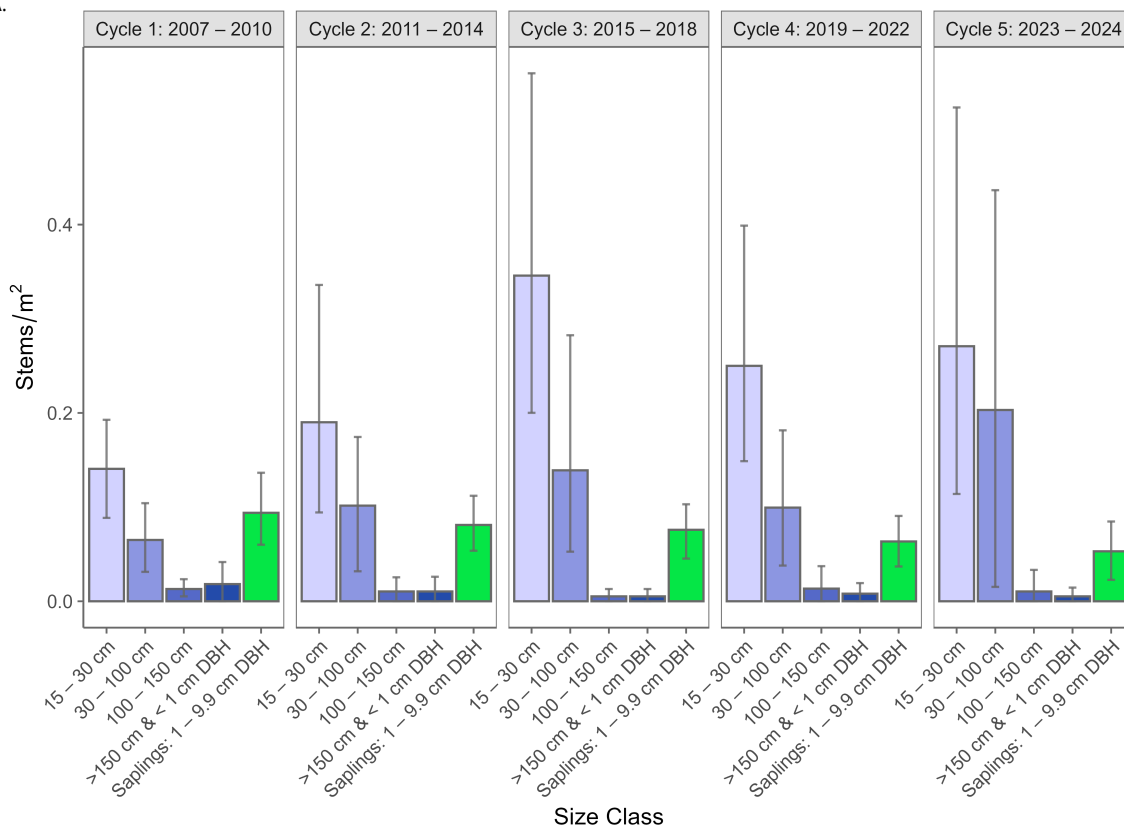


Figure 2. Deer browse impacts by cycle in Richmond National Battlefield Park (RICH). Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. **Note that Cycle 5 is only partially complete.**



A.



B.

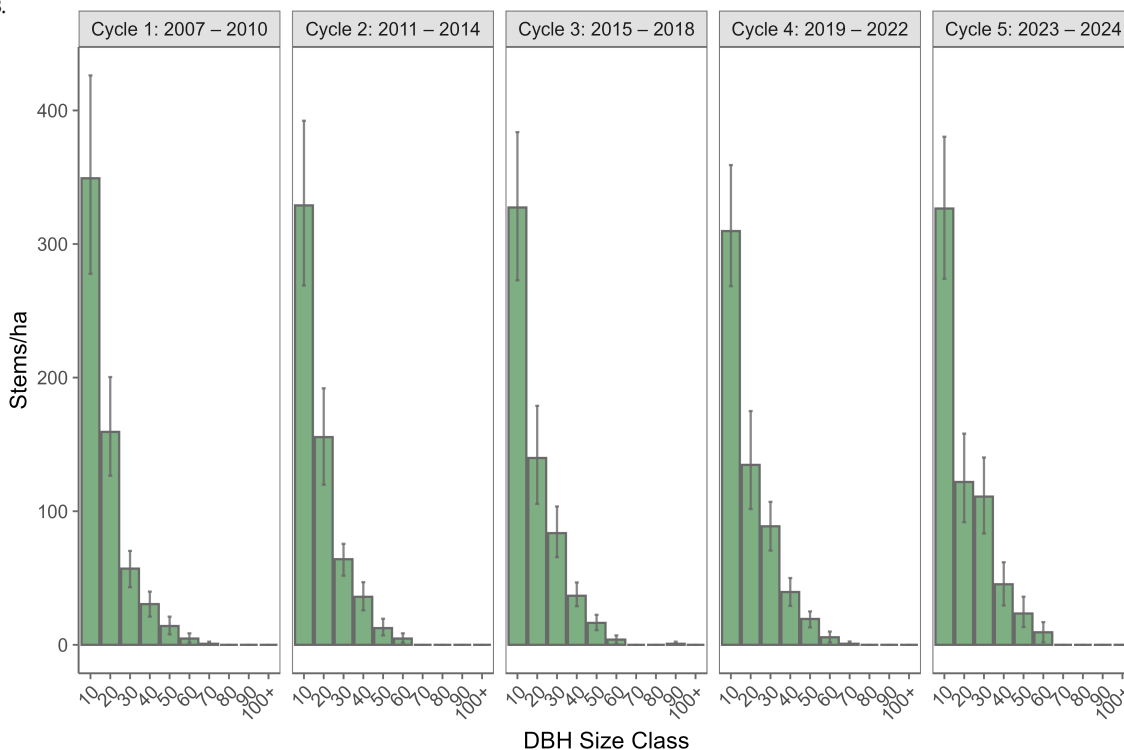


Figure 3. Stem density distributions by cycle in Richmond National Battlefield Park (RICH). Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. **Note that Cycle 5 is only partially complete.** Figure A shows regeneration densities by size class. Figure B shows tree density by diameter at breast height (DBH) increments. Error bars are 95% bootstrapped confidence intervals to account for non-normal error. An asterisk denotes a linear DBH distribution that is indicative of long-term recruitment failure.

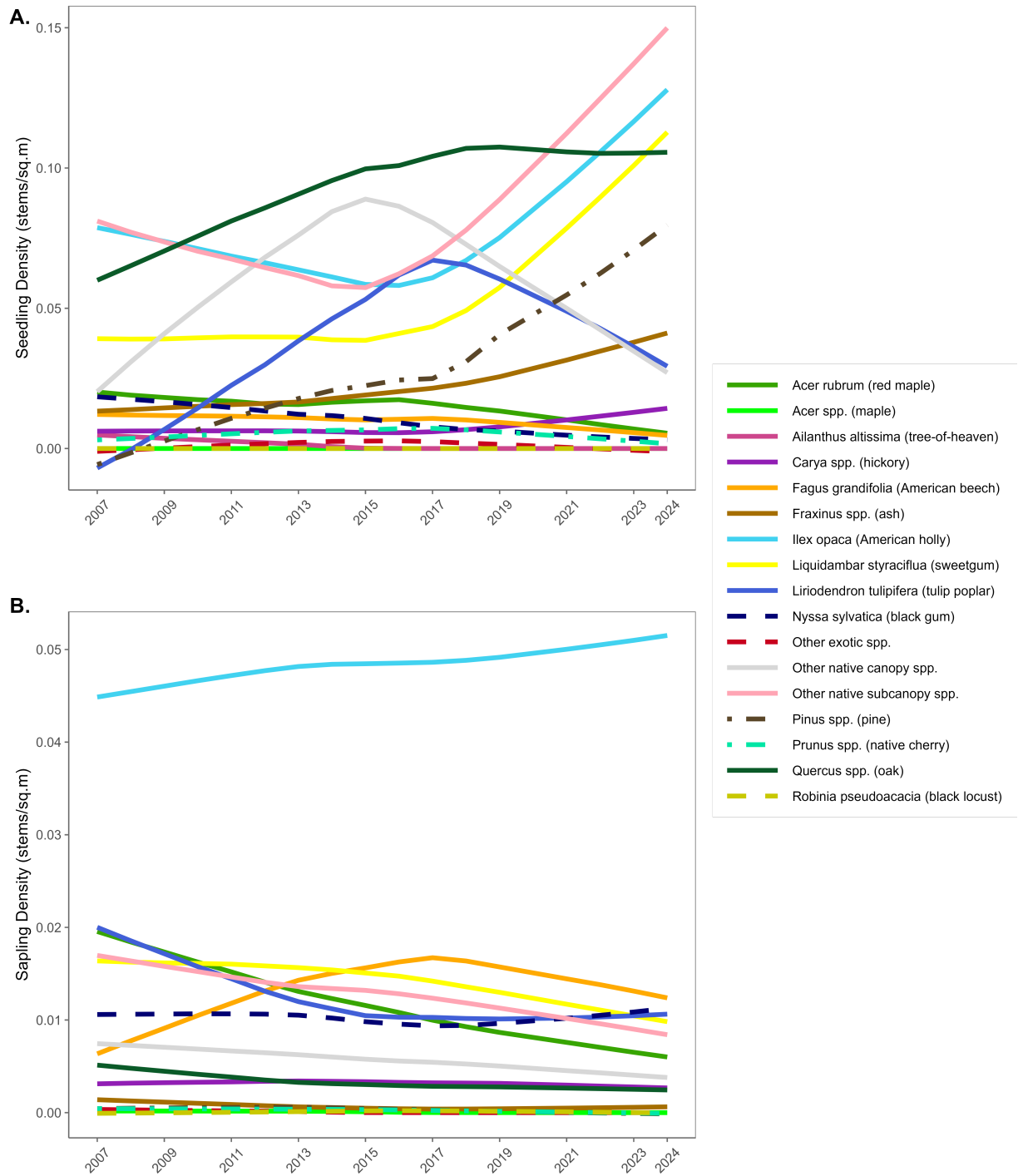


Figure 4. Loess smoothed changes in stem density for seedlings (A) and saplings (B) by species group and sample year in Richmond National Battlefield Park. Specified loess span approximated a linear trend between consecutive sample events per panel.

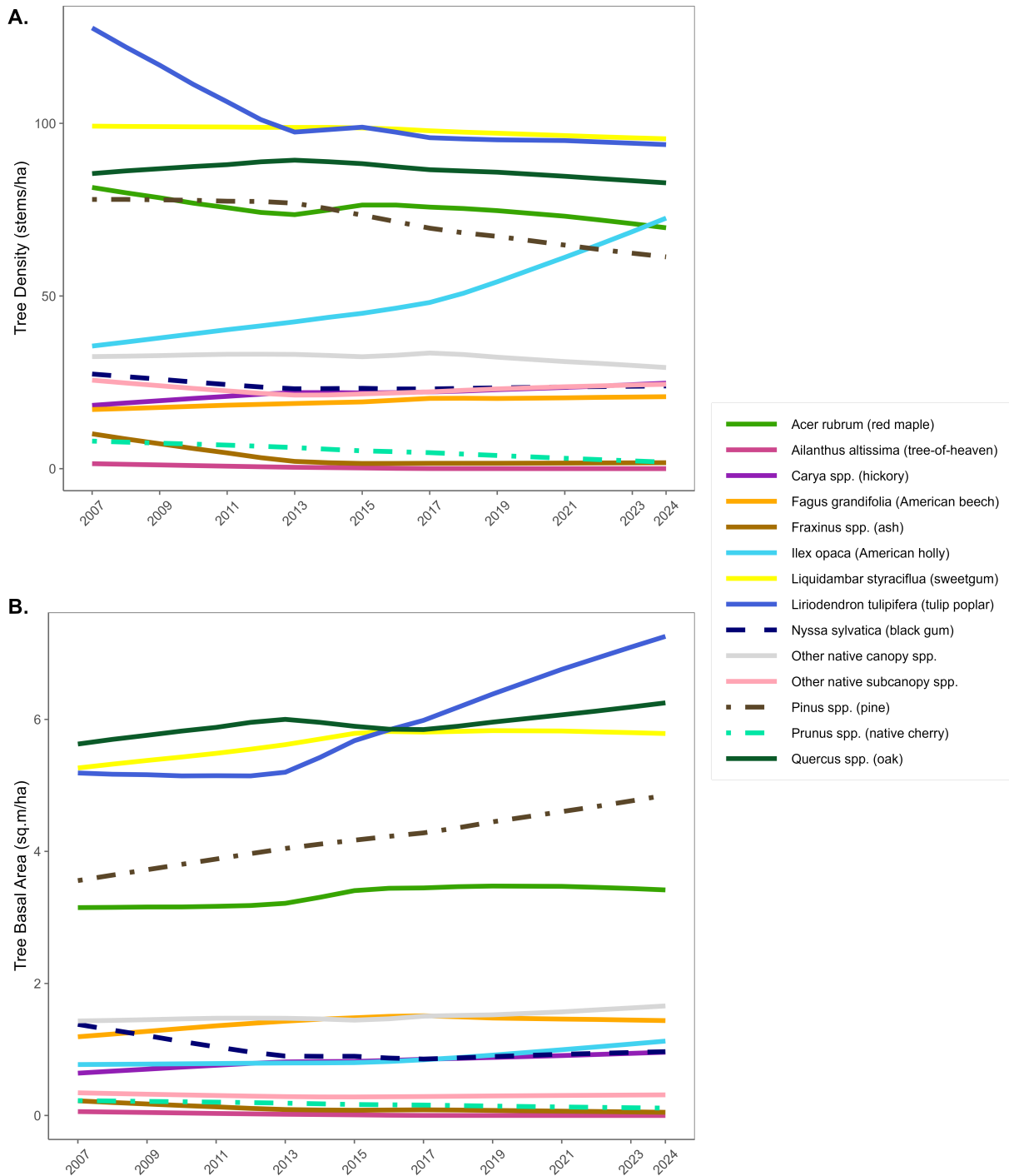


Figure 5. Loess smoothed changes in tree stem density (A) and basal area (B) by species group and sample year in Richmond National Battlefield Park. Specified loess span approximated a linear trend between consecutive sample events per panel.

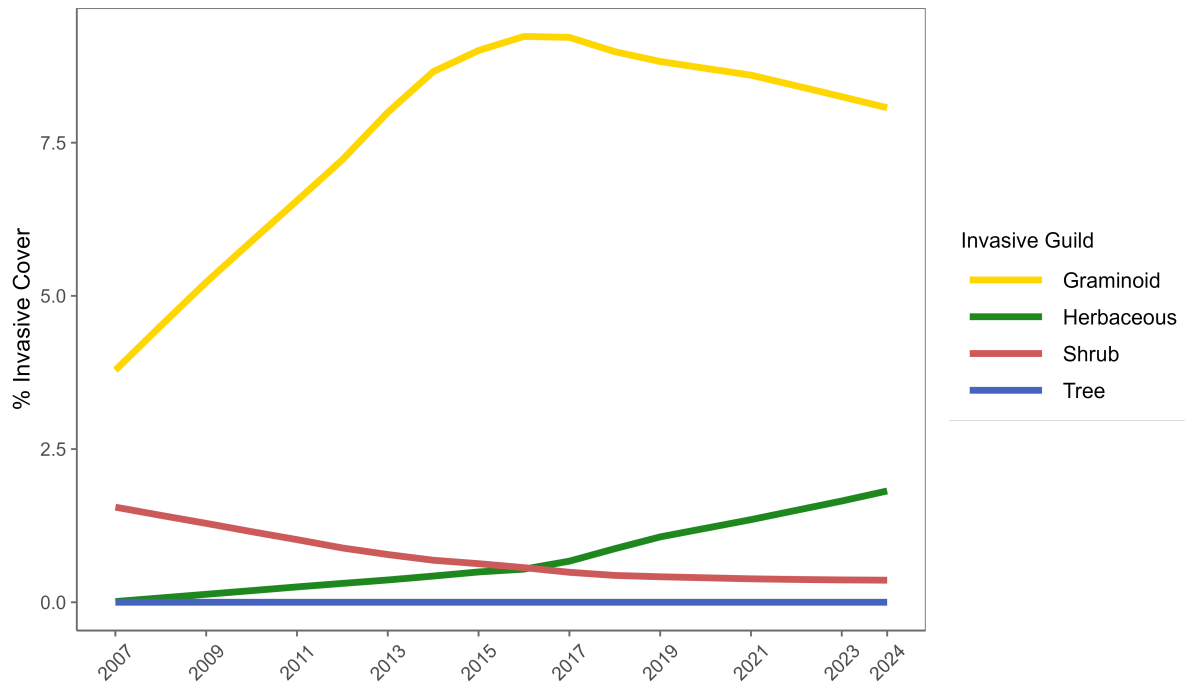


Figure 6. Loess smoothed changes in invasive plant percent cover by guild and sample year in Richmond National Battlefield Park. Specified loess span approximated a linear trend between consecutive sample events per panel.



Table 1. Average plot-level seedling and sapling stem densities (stems per m²) and stocking index (at the 2m radius scale) by cycle. Only native, canopy-forming species are included. Note that *Fraxinus* spp. (ash species) are no longer considered canopy-forming species. Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. Plots are sampled in 4-year rotations, with a quarter of the plots sampled each year (i.e. a panel). 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. These are the same thresholds used in Figure 2 and are described in Miller et al. 2023. **Note that Cycle 5 is only partially complete.**

Plot	Panel	Seedlings per sq.m					Saplings per sq.m					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
15	1	0.00	0.42	0.25	0.08	0.08	0.07	0.06	0.02	0.02	0.02	14.83	21.11	10.56	8.42	8.42
16	1	0.00	0.00	1.33	0.25	2.25	0.02	0.00	0.01	0.02	0.07	0.00	0.00	17.84	10.56	67.23
19	1	0.08	0.17	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.01	2.14	2.14	0.00	0.00	8.42
20	1	0.58	0.25	0.25	0.25	0.08	0.04	0.01	0.02	0.02	0.02	22.12	3.14	10.56	11.56	9.55
63	1	0.50	0.00	0.17	0.00	0.08	0.01	0.01	0.01	0.01	0.00	10.43	0.00	2.14	0.00	1.01
64	1	0.08	0.00	0.00	0.00	0.08	0.01	0.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	1.01
72	1	0.33	0.00	0.00	0.17	0.25	0.33	0.07	0.06	0.01	0.00	192.89	7.41	7.41	2.14	3.14
73	1	0.42	0.00	2.10	0.75	0.50	0.21	0.17	0.12	0.07	0.06	27.52	29.66	36.32	11.56	7.29
129	2	0.25	0.33	0.17	0.33	0.42	0.09	0.13	0.08	0.08	0.07	34.81	35.94	17.97	20.11	12.69
131	2	0.17	0.08	0.25	0.67	0.50	0.00	0.00	0.00	0.00	0.00	2.14	1.01	3.14	8.42	6.28
133	2	0.33	0.25	0.25	0.17	0.08	0.32	0.25	0.26	0.14	0.12	81.43	69.62	62.20	11.56	9.55
134	2	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.00	0.00	7.41	0.00	7.41
148	2	0.25	0.25	0.00	0.08	0.08	0.13	0.07	0.05	0.02	0.02	85.07	17.97	7.41	1.01	1.01
153	2	0.25	0.08	3.42	2.00	0.17	0.04	0.04	0.18	0.27	0.22	23.00	8.42	148.53	306.75	120.13
154	2	0.33	0.58	0.58	1.92	3.17	0.25	0.22	0.21	0.19	0.20	86.71	76.15	61.32	76.91	145.02
155	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	3	0.33	0.33	0.17	0.08	-	0.18	0.25	0.27	0.28	-	254.47	298.83	143.88	193.15	-
207	3	0.50	0.17	0.08	0.08	-	0.02	0.05	0.04	0.02	-	8.42	16.96	9.55	9.55	-
215	3	0.08	3.17	2.08	0.58	-	0.15	0.19	0.20	0.15	-	24.38	96.76	145.27	60.19	-
219	3	0.67	0.67	1.17	-	-	0.11	0.14	0.14	-	-	57.93	51.65	43.23	-	-
226	3	0.08	0.17	0.33	0.17	-	0.01	0.01	0.04	0.04	-	8.42	11.56	28.53	25.38	-
230	3	0.50	0.75	0.58	0.42	-	0.05	0.06	0.05	0.06	-	29.28	42.98	18.98	25.26	-
233	3	0.75	0.33	1.00	0.58	-	0.06	0.07	0.06	0.05	-	46.24	77.79	79.80	22.12	-
238	3	0.00	0.00	0.00	0.00	-	0.05	0.05	0.01	0.01	-	22.24	22.24	0.00	0.00	-
303	4	0.25	0.42	0.42	0.58	-	0.06	0.06	0.06	0.06	-	17.97	20.11	13.70	14.70	-
304	4	0.42	0.92	0.92	2.00	-	0.14	0.13	0.11	0.09	-	15.83	55.54	35.56	49.26	-
306	4	0.00	0.00	0.00	0.00	-	0.07	0.07	0.06	0.01	-	14.83	7.41	7.41	0.00	-
307	4	0.25	0.42	0.17	0.17	-	0.02	0.01	0.05	0.06	-	5.28	6.28	25.38	32.80	-
309	4	0.00	0.08	0.00	0.00	-	0.02	0.01	0.00	0.00	-	14.83	2.14	0.00	0.00	-
311	4	0.17	0.17	0.17	0.17	-	0.02	0.02	0.01	0.01	-	2.14	2.14	2.14	2.14	-



Table 1 (cont.). Average plot-level seedling and sapling stem densities (stems per m²) and stocking index (at the 2m radius scale) by cycle. Only native, canopy-forming species are included. Note that *Fraxinus* spp. (ash species) are no longer considered canopy-forming species. Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. Plots are sampled in 4-year rotations, with a quarter of the plots sampled each year (i.e. a panel). 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. These are the same thresholds used in Figure 2 and are described in Miller et al. 2023. **Note that Cycle 5 is only partially complete.**

Plot	Panel	Seedlings per sq.m					Saplings per sq.m					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
314	4	0	0	0	0	-	0.48	0.41	0.28	0.22	-	111.09	81.43	51.9	44.48	-
317	4	0	0	0	0	-	0.02	0.02	0.02	0.01	-	0.00	0.00	0.0	0.00	-



Table 2. Average % cover and number of invasive species detected in each plot by cycle. Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. Plots are sampled in 4-year rotations, with a quarter of the plots sampled each year (i.e. a panel). **Note that Cycle 5 is only partially complete.** Plots with at least 10% average cover or 4 or more invasive species present are in yellow. Protocol evolution over time has impacted invasive species % cover and counts. The estimated change in invasive species % cover and count in Richmond National Battlefield Park (RICH) that can be attributed to protocol change is 0.73% and 0.13 species per plot for the most recent census. More details can be found in the MIDN Summary of Major Protocol Changes. (<https://irma.nps.gov/DataStore/Reference/Profile/2189101>)

PlotCode	PanelCode	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
15	1	9.96	8.77	11.79	27.46	21.13	2	3	3	3	2
16	1	14.72	44.09	24.53	12.47	15.57	2	3	2	2	2
19	1	0.00	0.00	0.17	4.40	17.09	0	1	4	4	5
20	1	0.00	0.00	0.00	0.00	0.13	0	0	1	1	1
63	1	8.08	4.95	23.62	8.02	5.63	2	2	2	4	4
64	1	2.25	1.34	18.18	5.35	5.54	2	2	2	4	4
72	1	6.29	0.99	15.72	44.37	20.24	3	4	4	4	4
73	1	0.00	0.01	0.00	0.02	0.01	0	1	0	1	1
129	2	0.97	33.67	9.20	12.44	4.28	2	2	4	4	6
131	2	10.76	25.21	22.73	12.43	22.60	3	3	3	3	3
133	2	0.00	0.01	0.00	0.63	5.47	0	1	1	3	2
134	2	0.00	0.00	0.00	0.00	0.00	0	1	0	0	0
148	2	2.59	12.14	6.52	19.33	18.17	5	5	6	5	5
153	2	0.00	0.00	0.17	0.03	0.00	0	1	2	1	1
154	2	0.00	0.00	0.00	0.00	0.00	0	0	1	0	0
155	2	0.19	0.04	0.05	0.01	0.01	2	4	3	3	5
203	3	0.00	0.00	0.00	0.00	-	0	0	0	0	-
207	3	0.15	0.90	3.82	0.46	-	1	2	2	1	-
215	3	3.81	10.11	4.42	0.03	-	8	5	5	2	-
219	3	0.14	0.02	0.02	-	-	2	1	1	-	-
226	3	0.00	0.31	0.01	0.01	-	0	1	1	1	-
230	3	0.16	0.32	0.27	0.04	-	2	2	2	2	-
233	3	0.00	0.02	0.12	0.29	-	1	1	1	2	-
238	3	0.30	1.40	13.70	5.30	-	5	3	5	3	-
303	4	0.00	0.00	0.00	0.00	-	0	0	0	0	-
304	4	0.00	0.00	0.00	0.00	-	0	0	0	0	-
306	4	3.41	4.03	1.62	0.29	-	3	4	4	2	-
307	4	0.03	0.04	0.01	17.07	-	1	2	2	6	-
309	4	33.48	60.19	71.45	63.33	-	4	4	4	7	-
311	4	0.00	0.00	0.00	0.00	-	0	0	0	0	-



Table 2 (cont.). Average % cover and number of invasive species detected in each plot by cycle. Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. Plots are sampled in 4-year rotations, with a quarter of the plots sampled each year (i.e. a panel). **Note that Cycle 5 is only partially complete.** Plots with at least 10% average cover or 4 or more invasive species present are in yellow. Protocol evolution over time has impacted invasive species % cover and counts. The estimated change in invasive species % cover and count in Richmond National Battlefield Park (RICH) that can be attributed to protocol change is 0.73% and 0.13 species per plot for the most recent census. More details can be found in the MIDN Summary of Major Protocol Changes. (<https://irma.nps.gov/DataStore/Reference/Profile/2189101>)

PlotCode	PanelCode	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
314	4	0.01	0.02	0	0.00	-	1	1	1	1	-
317	4	0.00	0.00	0	0.01	-	0	1	1	1	-



Table 3. Number of plots out of 31 where exotic species were detected. Cycle 1: 2007 – 2010; Cycle 2: 2011 – 2014; Cycle 3: 2015 – 2018; Cycle 4: 2019 – 2022; Cycle 5: 2023 – 2024. Priority invasive species capable of dominating Eastern US forest habitats are highlighted in yellow. **Note that Cycle 5 is only partially complete.** Protocol evolution has impacted the number of invasive species monitored through time. Species were not consistently monitored before the year specified in the Year Added column. More details can be found in the MIDN Summary of Major Protocol Changes. (<https://irma.nps.gov/DataStore/Reference/Profile/2189101>)

Latin Name	Common Name	Invasive	Year Added	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
<i>Ailanthus altissima</i>	tree-of-heaven	Yes	2019	3	1	0	2	0
<i>Celastrus orbiculatus</i>	Asiatic bittersweet	Yes	2007	1	1	1	3	1
<i>Dioscorea oppositifolia</i>	Chinese yam	Yes	2013	0	0	2	0	0
<i>Duchesnea indica</i>	mock strawberry	No	2007	3	1	1	1	1
<i>Euonymus</i>	burningbush	Yes	2019	0	0	0	0	2
<i>Glechoma hederacea</i>	ground ivy	Yes	2007	0	1	1	1	0
<i>Hedera helix</i>	English ivy	Yes	2007	1	1	2	3	4
<i>Ligustrum</i>	privet	Yes	2009	1	4	7	13	8
<i>Lonicera - Exotic</i>	honeysuckle - exotic	Yes	2007	3	1	0	0	0
<i>Lonicera japonica</i>	Japanese honeysuckle	Yes	2007	17	21	20	20	11
<i>Microstegium vimineum</i>	Japanese stiltgrass	Yes	2007	13	19	21	18	11
<i>Murdannia keisak</i>	Asian spiderwort	Yes	2022	0	0	0	1	1
<i>Paulownia tomentosa</i>	princess tree	Yes	2019	1	0	0	0	0
<i>Persicaria longiseta</i>	Asiatic lady's thumb	Yes	2009	6	8	9	7	5
<i>Persicaria perfoliata</i>	mile-a-minute weed	Yes	2007	0	1	1	0	0
<i>Prunus avium</i>	sweet cherry	No	2019	0	0	1	0	0
<i>Pyrus</i>	pear	No	2019	0	0	0	0	1
<i>Rosa multiflora</i>	multiflora rose	Yes	2007	3	2	3	2	2
<i>Vinca minor</i>	periwinkle	Yes	2007	1	0	0	0	0



Table 4. Invasive plant and pest/pathogen early detections in Richmond National Battlefield Park observed in the most recent census of each plot. Coordinates are in UTM NAD83 Zone 18N.

Plot	Year	X	Y	Latin Name	Common Name	Type
RICH-230	2021	300349	4143063	<i>Agrilus planipennis</i>	emerald ash borer	pest



Table 5. List of tree species included in Maps 3 and 4 and how each was displayed.

Latin Name	Group: Map 3. Regeneration	Group: Map 4. Tree Canopy
<i>Acer rubrum</i>	Acer rubrum (red maple)	Acer rubrum (red maple)
<i>Amelanchier</i>	Other native subcanopy spp.	-
<i>Betula nigra</i>	-	Other native canopy spp.
<i>Carpinus caroliniana</i>	Other native subcanopy spp.	Other native subcanopy spp.
<i>Carya</i>	Carya spp. (hickory)	-
<i>Carya glabra</i>	Carya spp. (hickory)	Carya spp. (hickory)
<i>Carya tomentosa</i>	Carya spp. (hickory)	Carya spp. (hickory)
<i>Celtis occidentalis</i>	Other native canopy spp.	Other native canopy spp.
<i>Cornus florida</i>	-	Other native subcanopy spp.
<i>Diospyros virginiana</i>	Other native canopy spp.	-
<i>Fagus grandifolia</i>	Fagus grandifolia (American beech)	Fagus grandifolia (American beech)
<i>Fraxinus</i>	Fraxinus spp. (ash)	-
<i>Fraxinus americana</i>	Fraxinus spp. (ash)	Fraxinus spp. (ash)
<i>Ilex opaca</i>	Ilex opaca (American holly)	Ilex opaca (American holly)
<i>Juglans nigra</i>	-	Other native canopy spp.
<i>Juniperus virginiana</i>	Other native canopy spp.	Other native canopy spp.
<i>Liquidambar styraciflua</i>	Liquidambar styraciflua (sweetgum)	Liquidambar styraciflua (sweetgum)
<i>Liriodendron tulipifera</i>	Liriodendron tulipifera (tulip poplar)	Liriodendron tulipifera (tulip poplar)
<i>Magnolia virginiana</i>	Other native canopy spp.	Other native canopy spp.
<i>Morus rubra</i>	Other native canopy spp.	-
<i>Nyssa sylvatica</i>	Nyssa sylvatica (black gum)	Nyssa sylvatica (black gum)
<i>Pinus taeda</i>	Pinus spp. (pine)	Pinus spp. (pine)
<i>Pinus virginiana</i>	-	Pinus spp. (pine)
<i>Platanus occidentalis</i>	-	Other native canopy spp.
<i>Prunus serotina</i>	Prunus spp. (native cherry)	Prunus spp. (native cherry)
<i>Quercus</i>	Quercus spp. (oak)	-
<i>Quercus (Red group)</i>	Quercus spp. (oak)	-
<i>Quercus (White group)</i>	Quercus spp. (oak)	-
<i>Quercus alba</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Quercus bicolor</i>	-	Quercus spp. (oak)
<i>Quercus coccinea</i>	-	Quercus spp. (oak)
<i>Quercus falcata</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Quercus michauxii</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Quercus pagoda</i>	-	Quercus spp. (oak)
<i>Quercus phellos</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Quercus rubra</i>	-	Quercus spp. (oak)
<i>Quercus stellata</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Quercus velutina</i>	Quercus spp. (oak)	Quercus spp. (oak)
<i>Salix</i>	-	Other native canopy spp.
<i>Sassafras albidum</i>	Other native subcanopy spp.	Other native subcanopy spp.
<i>Ulmus</i>	Other native canopy spp.	-
<i>Ulmus alata</i>	Other native canopy spp.	Other native canopy spp.
<i>Ulmus americana</i>	Other native canopy spp.	Other native canopy spp.
<i>Ulmus rubra</i>	-	Other native canopy spp.
<i>Unknown Tree - 02</i>	Other native canopy spp.	-