Effects of an invasive herbivore at the single plant scale do not extend to population scale seedling dynamics

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Supplementary data Table S.1. Soil nutrient content at the study site in the Ottawa National Forest, Gogebic Co., MI, USA. Samples (0-30 cm depth, n = 20 per year) were analyzed by the University of Wisconsin Soil and Plant Analysis Laboratory, Madison, WI, USA. The accompanying soil fertility level for each nutrient is shown in parentheses as high (H), medium (M), or low (L). Soil fertility levels were based on Kelling et al. (1999).

Nutrient	Year	
	2005	2008
pH	5.0 (L)	5.1 (L)
% Organic Matter	4.2 (H)	3.8 (H)
% N	0.15 (M)	0.12 (L)
P (ppm)	3.7 (L)	5.2 (L)
K (ppm)	44.9 (L)	52.0 (L)
Ca (ppm)	920.1 (M)	450.9 (L)
Mg (ppm)	58.9 (L)	42.8 (L)
NH_4-N (ppm)	12.2 (na*)	11.8 (na*)

* Ammonia is not considered a soil nutrient, and not included in the soil fertility interpretation.

Kelling, K. A., L. G. Bundy, S. M. Combs, and J. B. Peters. 1999. Optimum soil test levels for Wisconsin. University of Wisconsin Cooperative Extension Bulletin A3030. 8 p.

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Supplementary data Table S.2. Mean monthly soil and air temperature and precipitation at the study site in the Ottawa National Forest, Gogebic Co., MI, USA. Mean air and soil temperatures were obtained from five Hobo® data loggers (Onset Corp., Bourne, MA, USA) at the study site. Precipitation data were obtained from a NOAA-operated weather station on the Lac Vieux Desert tribal community center located approximately 15 km from the study site.

		Temperature (°C)				Precipitation (cm)	
			Soil Depth				
Year	Month	Air	Surface	15 cm	30 cm	Rain	Snow
2005	October	8.1	7.8	8.2	9.0	18.1	0.0
2005	November	-0.7	3.6	4.2	5.3	9.0	25.4
2005	December	-9.1	-0.2	0.5	1.4	2.0	40.4
2006	January	-5.5	0.2	0.7	1.2	5.7	47.5
2006	February	-11.9	0.4	0.6	1.2	4.5	70.6
2006	March	-3.0	0.3	0.4	1.2	2.2	33.0
2006	April	7.2	6.3	5.7	5.0	2.2	0.0
2006	May	11.3	10.1	9.6	8.6	8.5	10.9
2006	June	15.7	15.4	14.9	13.6	2.7	0.0
2006	July	18.7	18.4	18.1	16.5	9.9	0.0
2006	August	17.4	17.0	16.7	16.4	10.9	0.0
2006	September	11.2	12.0	12.3	12.5	3.5	0.0
2006	October	3.9	5.4	6.3	6.9	7.3	22.4
2006	November	0.5	1.5	2.4	3.0	3.5	0.1
2006	December	-4.7	-0.5	0.2	0.8	5.2	34.0
2007	January	-8.8	-0.4	0.1	0.5	3.0	32.5
2007	February	-12.8	-0.8	-0.3	0.0	1.7	19.1
2007	March	-0.7	0.1	0.0	0.0	3.6	26.7
2007	April	4.1	4.5	3.9	3.5	5.3	17.5
2007	May	12.6	11.0	10.3	9.5	10.3	0.0
2007	June	17.2	15.0	14.1	13.4	5.5	0.0

2007	July	18.3	16.3	15.3	14.7	4.2	0.0
2007	August	17.9	16.8	16.0	15.5	5.0	0.0
2007	September	13.6	13.2	13.0	13.0	8.2	0.0
2007	October	9.1	9.8	10.0	10.3	12.5	0.1
2007	November	-2.3	1.8	2.7	3.5	4.0	45.0
2007	December	-8.7	0.0	0.4	1.1	6.5	59.6
2008	January	-10.3	0.4	0.6	1.0	2.1	36.1
2008	February	-10.8	-0.1	0.3	0.6	2.1	36.1
2008	March	-5.2	0.2	0.3	0.7	0.9	14.2
2008	April	4.1	2.4	2.0	1.9	7.7	50.8
2008	May	8.2	5.5	5.0	4.4	4.9	0.0
2008	June	15.1	12.6	11.4	10.0	6.2	0.0
2008	July	17.8	15.1	14.5	12.3	7.5	0.0
2008	August	15.3	14.7	14.3	12.9	4.1	0.0
2008	September	12.8	12.6	12.4	11.6	6.0	0.0
2008	October	4.9	6.8	7.1	7.3	6.7	5.1
2008	November	0.9	1.7	1.9	2.5	4.2	34.3
2008	December	-14.2	-0.5	-0.3	1.5	4.8	71.6
2009	January	-16.3	-0.5	-0.3	0.3	3.0	48.5
2009	February	-8.7	-0.5	-0.4	0.0	2.7	48.0
2009	March	-4.6	-0.5	-0.5	0.1	3.7	4.3
2009	April	1.7	1.5	0.1	0.3	8.5	55.4
2009	May	10.6	9.2	8.4	5.5	4.9	0.0
2009	June	14.2	12.1	11.7	8.9	7.4	0.0
2009	July	13.4	13.3	12.9	11.1	7.4	0.0

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Supplementary data Table S.3. Regression equation parameters[a] from individual destructive whole-tree sugar maple seedling harvests conducted at the study site in the Ottawa National Forest, Gogebic Co., MI, USA.

	2005			2006			2008			2009		
Biomass component	*a*	*b*	R^2	*a*	*b*	R^2	*a*	*b*	R^2	*a*	*b*	R^2
Leaf	0.0134	2.5747	0.9167	0.0085	2.6491	0.8364	0.0331	2.0556	0.8519	0.0152	2.5251	0.8042
Branch	0.0001	4.5278	0.7506	2×10^{-5}	5.5275	0.7766	0.0009	3.1670	0.6152	0.0153	0.5414	0.9347
Stem	0.0200	2.8374	0.9589	0.0217	2.8296	0.9477	0.0223	2.7560	0.9614	0.0148	2.9673	0.9029
Shoot[b]	0.0331	2.7925	0.9621	0.0297	2.8553	0.9408	0.0547	2.4882	0.9541	0.0289	2.8487	0.9024
Stump	0.0083	3.0433	0.9225	0.0081	3.0372	0.9283	0.0099	3.1508	0.9133	0.0110	3.2502	0.8692
Coarse root	0.0002	4.1908	0.8110	0.0009	3.3557	0.2276	na[e]	na[e]	na[e]	0.0013	0.8116	0.6588
Fine root (1<5 mm diam.)	0.0155	2.3820	0.8887	0.0013	3.4383	0.8579	0.0009	3.4031	0.7742	na[f]	na[f]	na[f]
Fine root (<1 mm diam.)	0.0021	2.9171	0.7273	0.0132	2.4282	0.9246	0.0222	2.2904	0.9355	0.0139	2.4478	0.8079
Root[c]	0.0232	2.8245	0.9401	0.0203	2.9172	0.9459	0.0304	2.7777	0.9394	0.0221	3.0389	0.8793
Total biomass[d]	0.0574	2.7978	0.9600	0.0514	2.8702	0.9499	0.0855	2.6105	0.9540	0.0496	2.9558	0.9160

[a] Regression equations were of the form $y = ax^b$, where y is the individual tree biomass (g $tree^{-1}$), a and b are the estimated model parameters, and x is basal diameter (mm).
[b] Shoot = leaf + branch + stem.
[c] Root = stump + coarse root + fine roots.
[d] Total biomass = shoot + root.
[e] No coarse roots were obtained during this harvest.
[f] No fine roots 1 < 5 mm were obtained during this harvest.

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Supplementary data Table S.4. Larvae abundance during four years of soil core sampling in a northern hardwood forest in Gogebic Co., MI, USA. During November of each year we sampled 3 soil cores (5.08 cm diam. to a depth of 30 cm) in each of 10 plots per treatment.

Year	Treatment	Larvae ha^{-1} (mean ± SE)	Minimum	Maximum
2005	Natural adult and larvae (control)	4769353 ± 1151223	0	9867626
	Natural adult, killed larvae	5756115 ± 1315683	1644604	13156835
	Enhanced adult, killed larvae	8716403 ± 1809065	3289209	21379857
	Enhanced adult and larvae	7400720 ± 1809065	0	21379857
2006	Natural adult and larvae (control)	3124748 ± 986763	0	8223022
	Natural adult, killed larvae	4604892 ± 1644604	0	13156835
	Enhanced adult, killed larvae	3289209 ± 986763	0	9867626
	Enhanced adult and larvae	4440432 ± 1315683	0	11512231
2007	Natural adult and larvae (control)	3289209 ± 986763	0	8223022
	Natural adult, killed larvae	2631367 ± 986763	0	9867626
	Enhanced adult, killed larvae	4111511 ± 657842	0	6578417
	Enhanced adult and larvae	3618130 ± 822302	0	9867626
2008	Natural adult and larvae (control)	4440432 ± 1151223	0	9867626
	Natural adult, killed larvae	2960288 ± 1315683	0	11512231
	Enhanced adult, killed larvae	3289209 ± 1480144	0	11512231
	Enhanced adult and larvae	4111511 ± 1151223	0	11512231

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Supplementary data Table S.5. Relationships between between sugar maple seedling growth variables and independent variables in the Ottawa National Forest, Gogebic Co., MI, USA. Backwards stepwise regressions were conducted using Proc Reg (SAS Institute, Cary, NC). The lowest *P*-value indicates the vest fitting model using the listed variables for that particular test. Significant relationships are indicated by boldface *P*-values.

Parameter	Independent variables tested	Lowest *P*-value
Total Biomass 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1119
Total Biomass 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**0.0003**
Total Biomass 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1538
Total Biomass 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0429**
Shoot Biomass 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1133
Shoot Biomass 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Shoot Biomass 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1611
Shoot Biomass 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0417**
Root Biomass 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1095
Root Biomass 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Root Biomass 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1537
Root Biomass 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0452**
Basal Area 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.0698
Basal Area 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Basal Area 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1376
Basal Area 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.1327
Stem 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1089
Stem 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Stem 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1527
Stem 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0458**
Root:Shoot 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1493
Root:Shoot 2007	Larvae 2006, Number of seedlings 2007, Defoliation 2007, Emergence 2007	0.3348

Root:Shoot 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.0809
Root:Shoot 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.3783
Fine Root >1 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1266
Fine Root >1 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Fine Root >1 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1874
Fine Root >1 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0345**
Leaf 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1260
Leaf 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Leaf 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1863
Leaf 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, **Emergence 2009**	**0.0347**
Stump 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.1037
Stump 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**<0.0001**
Stump 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.1426
Stump 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.0527
Coarse Root 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.0773
Coarse Root 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**0.0014**
Coarse Root 2008	**Larvae 2007**, Number of seedlings 2008, **Defoliation 2008**, Emergence 2007	**0.0295**
Coarse Root 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.1448
Branch 2006	Larvae 2005, Number of seedlings 2006, Defoliation 2006	0.0814
Branch 2007	Larvae 2006, **Number of seedlings 2007**, Defoliation 2007, Emergence 2007	**0.0007**
Branch 2008	**Larvae 2007**, Number of seedlings 2008, **Defoliation 2008**, Emergence 2007	**0.0357**
Branch 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.1223
Number of Seedlings 2006	**Larvae 2005**, Number of seedlings 2006, Defoliation 2006	**0.0191**
Number of Seedlings 2007	Larvae 2006, Number of seedlings 2007, Defoliation 2007, Emergence 2007	0.5743
Number of Seedlings 2008	Larvae 2007, Number of seedlings 2008, Defoliation 2008, Emergence 2007	0.0916
Number of Seedlings 2009	Larvae 2008, Number of seedlings 2009, Defoliation 2009, Emergence 2009	0.2698

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Supplementary data Table S.6. Relationships between sugar maple seedling growth variables and independent variables in the Ottawa National Forest, Gogebic Co., MI, USA. Backwards stepwise regressions, with specific covariates, were conducted using Proc Reg (SAS Institute, Cary, NC). The lowest *P*-value indicates the vest fitting model using the listed variables for that particular test. Significant relationships are indicated by boldface *P*-values.

Parameter	Covariates	Variables tested	Lowest *P*-value
Total Biomass 2006	Total Biomass 2005	Larvae 2005, Defoliation 2006	0.2127
Total Biomass 2007	Total Biomass 2005	Larvae 2006, Defoliation 2007, Emergence 2007	0.1673
Total Biomass 2008	Total Biomass 2005	Larvae 2007, Defoliation 2008, Emergence 2007	0.0916
Total Biomass 2009	**Total Biomass 2005**	Larvae 2008, Defoliation 2009, **Emergence 2009**	**0.0440**
Total Biomass 2007	Total Biomass 2006	Larvae 2006, Defoliation 2007, Emergence 2007	0.1379
Total Biomass 2008	Total Biomass 2007	Larvae 2007, Defoliation 2008, Emergence 2007	0.2682
Total Biomass 2009	**Total Biomass 2008**	Larvae 2008, **Defoliation 2009**, **Emergence 2009**	**0.0159**
Total Biomass 2006	Basal Area of other species 2006	Larvae 2005, Defoliation 2006	0.2619
Total Biomass 2007	Basal Area of other species 2007	Larvae 2006, Defoliation 2007, Emergence 2007	0.1684
Total Biomass 2008	Basal Area of other species 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.1867
Total Biomass 2009	Basal Area of other species 2009	Larvae 2008, Defoliation 2009, Emergence 2009	0.1125
Total Biomass 2006	Basal Area 2005, Basal Area of other species 2006, Number of seedlings 2006	Larvae 2005, Defoliation 2006	0.2619

Total Biomass 2007	Basal Area 2006, Basal Area of other species 2007, **Number of seedlings 2007**	Larvae 2006, Defoliation 2007, Emergence 2007	**<0.0001**
Total Biomass 2008	Basal Area 2007, Basal Area of other species 2008, Number of seedlings 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.4418
Total Biomass 2009	Basal Area 2008, Basal Area of other species 2009, Number of seedlings 2009	Larvae 2008, Defoliation 2009, Emergence 2009	0.1617
Basal Area 2006	Basal Area 2005	Larvae 2005, Defoliation 2006	0.1955
Basal Area 2007	Basal Area 2005	Larvae 2006, Defoliation 2007, Emergence 2007	0.0606
Basal Area 2008	Basal Area 2005	Larvae 2007, Defoliation 2008, Emergence 2007	0.0872
Basal Area 2009	**Basal Area 2005**	Larvae 2008, Defoliation 2009, Emergence 2009	**0.0494**
Basal Area 2007	Basal Area 2006	Larvae 2006, Defoliation 2007, Emergence 2007	0.0795
Basal Area 2008	Basal Area 2007	Larvae 2007, Defoliation 2008, Emergence 2007	0.2891
Basal Area 2009	**Basal Area 2008**	Larvae 2008, Defoliation 2009, Emergence 2009	**0.0002**
Basal Area 2006	Basal Area of other species 2006	Larvae 2005, Defoliation 2006	0.1975
Basal Area 2007	Basal Area of other species 2007	Larvae 2006, Defoliation 2007, Emergence 2007	0.0898
Basal Area 2008	Basal Area of other species 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.2196
Basal Area 2009	Basal Area of other species 2009	Larvae 2008, Defoliation 2009, Emergence 2009	0.2642
Basal Area 2006	Basal Area 2005, Basal Area of other species 2006, Number of seedlings 2006	Larvae 2005, Defoliation 2006	0.1975
Basal Area 2007	**Basal Area 2006**, Basal Area of other species 2007, **Number of seedlings 2007**	**Larvae 2006**, Defoliation 2007, Emergence 2007	**0.0004**
Basal Area 2008	Basal Area 2007, Basal Area of other species 2008, Number of seedlings 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.1902
Basal Area 2009	Basal Area 2008, Basal Area of other species	Larvae 2008, Defoliation 2009,	0.3203

	2009, Number of seedlings 2009	Emergence 2009	
Number of seedlings 2006	Number of seedlings 2005	Larvae 2005, Defoliation 2006	0.0605
Number of seedlings 2007	Number of seedlings 2005	Larvae 2006, Defoliation 2007, Emergence 2007	**<0.0001**
Number of seedlings 2008	Number of seedlings 2005	Larvae 2007, Defoliation 2008, Emergence 2007	0.2142
Number of seedlings 2009	Number of seedlings 2005	Larvae 2008, Defoliation 2009, **Emergence 2009**	**0.0100**
Number of Seedlings 2007	Number of seedlings 2006	Larvae 2005, Defoliation 2006	0.0538
Number of Seedlings 2008	**Number of seedlings 2007**	Larvae 2006, Defoliation 2007, Emergence 2007	**0.0006**
Number of Seedlings 2009	Number of seedlings 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.0602
Number of seedlings 2006	Basal Area of other species 2006	Larvae 2005, Defoliation 2006	0.0585
Number of seedlings 2007	Basal Area of other species 2007	Larvae 2006, Defoliation 2007, Emergence 2007	0.1733
Number of seedlings 2008	Basal Area of other species 2008	Larvae 2007, Defoliation 2008, Emergence 2007	0.3085
Number of seedlings 2009	**Basal Area of other species 2009**	Larvae 2008, Defoliation 2009, **Emergence 2009**	**0.0158**
Number of seedlings 2006	Basal Area 2005, Basal Area of other species 2006	Larvae 2005, Defoliation 2006	0.1147
Number of seedlings 2007	Basal Area 2006, Basal Area of other species 2007	Larvae 2006, Defoliation 2007, Emergence 2007	0.2027
Number of seedlings 2008	**Basal Area 2007**, **Basal Area of other species 2008**	Larvae 2007, Defoliation 2008, Emergence 2007	**0.0034**
Number of seedlings 2009	**Basal Area 2008**, **Basal Area of other species 2009**	Larvae 2008, Defoliation 2009, **Emergence 2009**	**0.0238**