

Supplementary Data 1

Insect decline in forests depends on species' traits and can be mitigated by management

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Results of linear mixed-effects models testing the relationships between site-level correlations with sampling year (Pearson's r) of species richness, richness accounted for abundance, abundance and biomass and explanatory variables at the site and landscape scale. Significant relationships ($p < 0.05$) are printed in bold. For explanations of variables see Supplementary Table 1. P-values are calculated based on Kenward-Roger-approximated degrees of freedom.

	Estimate $\pm$ SE	t -value	p-value
Total insect community			
<i>Richness correlations</i>			
Harvesting intensity	-0.083 $\pm$ 0.043	-1.939	0.055
Change in harvesting	0.050 $\pm$ 0.041	1.223	0.224
Deadwood volume	-0.008 $\pm$ 0.040	-0.208	0.835
Change in deadwood volume	-0.073 $\pm$ 0.036	-2.032	0.044
Proportion of non-native trees	-0.106 $\pm$ 0.049	-2.172	0.032
Change in proportion of non-native trees	-0.115 $\pm$ 0.042	-2.711	0.008
Tree diversity	-0.002 $\pm$ 0.042	-0.045	0.964
Effective number of layers	-0.043 $\pm$ 0.041	-1.049	0.296
Change in effective number of layers	0.040 $\pm$ 0.043	0.934	0.352
Canopy openness	-0.015 $\pm$ 0.052	-0.285	0.776
Change in canopy openness	-0.130 $\pm$ 0.040	-3.219	0.002
Forest cover	-0.069 $\pm$ 0.048	-1.433	0.154
Disturbance intensity	0.071 $\pm$ 0.039	1.822	0.071
Landscape heterogeneity (PC1)	0.124 $\pm$ 0.052	2.374	0.020
<i>Abundance-accounted richness correlations</i>			
Harvesting intensity	-0.098 $\pm$ 0.054	-1.800	0.074
Change in harvesting	0.026 $\pm$ 0.052	0.510	0.611
Deadwood volume	0.022 $\pm$ 0.050	0.431	0.667
Change in deadwood volume	-0.021 $\pm$ 0.045	-0.453	0.651
Proportion of non-native trees	0.094 $\pm$ 0.062	1.515	0.132

Change in proportion of non-native trees	-0.047 ± 0.053	-0.880	0.381
Tree diversity	-0.059 ± 0.052	-1.127	0.262
Effective number of layers	-0.057 ± 0.052	-1.110	0.269
Change in effective number of layers	-0.070 ± 0.054	-1.302	0.195
Canopy openness	-0.048 ± 0.066	-0.731	0.466
Change in canopy openness	-0.080 ± 0.049	-1.624	0.107
Forest cover	-0.008 ± 0.057	-0.134	0.894
Disturbance intensity	0.050 ± 0.047	1.057	0.292
Landscape heterogeneity (PC1)	0.068 ± 0.055	1.231	0.221
<i>Abundance correlations</i>			
Harvesting intensity	-0.089 ± 0.044	-2.025	0.045
Change in harvesting	0.033 ± 0.042	0.797	0.427
Deadwood volume	-0.030 ± 0.041	-0.735	0.464
Change in deadwood volume	-0.025 ± 0.037	-0.689	0.492
Proportion of non-native trees	-0.177 ± 0.050	-3.539	0.001
Change in proportion of non-native trees	-0.074 ± 0.043	-1.708	0.090
Tree diversity	0.103 ± 0.043	2.411	0.017
Effective number of layers	-0.084 ± 0.042	-2.013	0.046
Change in effective number of layers	0.059 ± 0.043	1.349	0.180
Canopy openness	0.005 ± 0.053	0.087	0.931
Change in canopy openness	-0.104 ± 0.042	-2.487	0.014
Forest cover	-0.066 ± 0.050	-1.326	0.187
Disturbance intensity	0.073 ± 0.040	1.832	0.069
Landscape heterogeneity (PC1)	-0.028 ± 0.055	-0.498	0.620
<i>Biomass correlations</i>			
Harvesting intensity	-0.087 ± 0.043	-1.777	0.078
Change in harvesting	0.048 ± 0.040	1.035	0.303
Deadwood volume	0.004 ± 0.040	0.080	0.937
Change in deadwood volume	-0.005 ± 0.036	-0.118	0.906
Proportion of non-native trees	-0.137 ± 0.050	-2.451	0.016
Change in proportion of non-native trees	-0.107 ± 0.044	-2.207	0.029
Tree diversity	0.071 ± 0.042	1.493	0.138
Effective number of layers	-0.058 ± 0.042	-1.251	0.213
Change in effective number of layers	0.065 ± 0.043	1.340	0.183
Canopy openness	0.021 ± 0.053	0.362	0.718
Change in canopy openness	-0.066 ± 0.042	-1.432	0.155
Forest cover	-0.068 ± 0.077	-1.231	0.221
Disturbance intensity	0.081 ± 0.039	1.805	0.074
Landscape heterogeneity (PC1)	0.075 ± 0.095	1.225	0.223

Herbivores

Richness correlations

Harvesting intensity	-0.079 ± 0.045	-1.748	0.083
Change in harvesting	0.099 ± 0.043	2.329	0.022
Deadwood volume	-0.019 ± 0.042	-0.463	0.644
Change in deadwood volume	-0.065 ± 0.038	-1.738	0.085
Proportion of non-native trees	-0.082 ± 0.051	-1.623	0.107
Change in proportion of non-native trees	-0.049 ± 0.044	-1.103	0.272
Tree diversity	0.034 ± 0.044	0.787	0.433
Effective number of layers	-0.030 ± 0.043	-0.711	0.478
Change in effective number of layers	0.071 ± 0.044	1.605	0.111
Canopy openness	-0.056 ± 0.054	-1.041	0.300
Change in canopy openness	-0.112 ± 0.042	-2.676	0.009
Forest cover	-0.073 ± 0.050	-1.472	0.144
Disturbance intensity	0.069 ± 0.040	1.710	0.090
Landscape heterogeneity (PC1)	0.089 ± 0.053	1.687	0.098

Abundance-accounted richness correlations

Harvesting intensity	-0.035 ± 0.052	-0.673	0.502
Change in harvesting	0.068 ± 0.049	1.371	0.173
Deadwood volume	-0.009 ± 0.048	-0.177	0.859
Change in deadwood volume	-0.006 ± 0.043	-0.129	0.900
Proportion of non-native trees	-0.005 ± 0.059	-0.077	0.939
Change in proportion of non-native trees	0.006 ± 0.051	-0.115	0.908
Tree diversity	-0.032 ± 0.050	-0.627	0.532
Effective number of layers	-0.029 ± 0.049	-0.579	0.564
Change in effective number of layers	0.017 ± 0.051	0.329	0.743
Canopy openness	-0.134 ± 0.062	-2.150	0.034
Change in canopy openness	-0.110 ± 0.049	-2.260	0.026
Forest cover	-0.078 ± 0.058	-1.340	0.183
Disturbance intensity	0.061 ± 0.047	1.304	0.195
Landscape heterogeneity (PC1)	0.009 ± 0.063	0.141	0.888

Abundance correlations

Harvesting intensity	-0.123 ± 0.036	-3.387	0.001
Change in harvesting	0.023 ± 0.034	0.672	0.503
Deadwood volume	0.054 ± 0.024	1.606	0.111
Change in deadwood volume	-0.021 ± 0.030	-0.676	0.500
Proportion of non-native trees	-0.127 ± 0.041	-3.072	0.003
Change in proportion of non-native trees	-0.040 ± 0.036	-1.108	0.270
Tree diversity	0.069 ± 0.035	1.956	0.053
Effective number of layers	-0.045 ± 0.034	-1.307	0.194

Change in effective number of layers	0.055 ± 0.036	1.535	0.127
Canopy openness	0.025 ± 0.043	0.577	0.565
Change in canopy openness	-0.045 ± 0.035	-1.295	0.200
Forest cover	-0.139 ± 0.041	-0.941	0.349
Disturbance intensity	0.083 ± 0.033	2.504	0.014
Landscape heterogeneity (PC1)	0.004 ± 0.046	0.096	0.924
<i>Biomass correlations</i>			
Harvesting intensity	-0.093 ± 0.052	-1.780	0.078
Change in harvesting	0.051 ± 0.050	1.031	0.305
Deadwood volume	-0.006 ± 0.049	-0.118	0.906
Change in deadwood volume	0.026 ± 0.044	0.592	0.555
Proportion of non-native trees	0.020 ± 0.060	0.334	0.739
Change in proportion of non-native trees	-0.058 ± 0.052	-1.128	0.261
Tree diversity	0.098 ± 0.051	1.924	0.057
Effective number of layers	-0.042 ± 0.050	-0.837	0.404
Change in effective number of layers	0.099 ± 0.052	1.922	0.057
Canopy openness	-0.012 ± 0.063	-0.191	0.849
Change in canopy openness	-0.054 ± 0.050	-1.085	0.280
Forest cover	0.012 ± 0.059	0.206	0.837
Disturbance intensity	0.095 ± 0.048	1.994	0.048
Landscape heterogeneity (PC1)	0.066 ± 0.066	1.005	0.317
Myceto-detritivores			
<i>Richness correlations</i>			
Harvesting intensity	-0.074 ± 0.048	-1.556	0.122
Change in harvesting	0.079 ± 0.045	-1.755	0.082
Deadwood volume	-0.011 ± 0.044	-0.243	0.808
Change in deadwood volume	-0.016 ± 0.040	-0.381	0.706
Proportion of non-native trees	-0.070 ± 0.054	-1.293	0.199
Change in proportion of non-native trees	-0.094 ± 0.047	-2.004	0.047
Tree diversity	0.007 ± 0.046	0.146	0.884
Effective number of layers	0.021 ± 0.045	0.463	0.644
Change in effective number of layers	0.062 ± 0.047	1.331	0.186
Canopy openness	-0.049 ± 0.057	-0.858	0.397
Change in canopy openness	-0.111 ± 0.044	-2.528	0.013
Forest cover	-0.073 ± 0.052	-1.395	0.166
Disturbance intensity	0.051 ± 0.043	1.195	0.234
Landscape heterogeneity (PC1)	0.041 ± 0.054	0.744	0.461
<i>Abundance-accounted richness correlations</i>			
Harvesting intensity	-0.023 ± 0.061	-0.384	0.702

Change in harvesting	0.036 ± 0.058	0.619	0.537
Deadwood volume	0.067 ± 0.056	1.192	0.235
Change in deadwood volume	0.039 ± 0.051	0.762	0.447
Proportion of non-native trees	0.077 ± 0.069	1.115	0.267
Change in proportion of non-native trees	-0.025 ± 0.060	-0.419	0.676
Tree diversity	-0.097 ± 0.059	-1.652	0.101
Effective number of layers	0.001 ± 0.058	0.020	0.984
Change in effective number of layers	-0.040 ± 0.060	-0.667	0.506
Canopy openness	-0.099 ± 0.073	-1.351	0.179
Change in canopy openness	-0.058 ± 0.056	-1.044	0.299
Forest cover	-0.050 ± 0.066	-0.770	0.444
Disturbance intensity	0.045 ± 0.054	0.846	0.400
Landscape heterogeneity (PC1)	0.036 ± 0.066	0.538	0.598

Abundance correlations

Harvesting intensity	-0.050 ± 0.047	-1.053	0.294
Change in harvesting	0.047 ± 0.045	1.053	0.295
Deadwood volume	-0.059 ± 0.044	-1.332	0.185
Change in deadwood volume	-0.044 ± 0.040	-1.116	0.266
Proportion of non-native trees	-0.121 ± 0.054	-2.249	0.026
Change in proportion of non-native trees	-0.055 ± 0.047	-1.185	0.239
Tree diversity	0.071 ± 0.046	1.536	0.127
Effective number of layers	-0.036 ± 0.045	-0.801	0.424
Change in effective number of layers	0.038 ± 0.047	0.802	0.424
Canopy openness	-0.014 ± 0.057	-0.238	0.813
Change in canopy openness	-0.076 ± 0.045	-1.710	0.090
Forest cover	-0.075 ± 0.053	-1.406	0.162
Disturbance intensity	0.040 ± 0.043	0.922	0.358
Landscape heterogeneity (PC1)	-0.012 ± 0.057	-0.208	0.836

Biomass correlations

Harvesting intensity	-0.023 ± 0.049	-0.456	0.649
Change in harvesting	0.071 ± 0.047	1.514	0.133
Deadwood volume	-0.048 ± 0.046	-1.059	0.292
Change in deadwood volume	0.015 ± 0.041	-0.376	0.708
Proportion of non-native trees	-0.152 ± 0.056	-2.708	0.008
Change in proportion of non-native trees	-0.098 ± 0.049	-2.012	0.046
Tree diversity	0.118 ± 0.048	2.476	0.015
Effective number of layers	-0.005 ± 0.047	-0.103	0.918
Change in effective number of layers	0.081 ± 0.049	1.669	0.098
Canopy openness	0.033 ± 0.059	0.556	0.579
Change in canopy openness	-0.066 ± 0.046	-1.426	0.157

Forest cover	0.022 ± 0.055	0.397	0.692
Disturbance intensity	0.004 ± 0.045	0.089	0.930
Landscape heterogeneity (PC1)	0.049 ± 0.060	0.812	0.419
Omnivores			
<i>Richness correlations</i>			
Harvesting intensity	-0.117 ± 0.048	-2.463	0.015
Change in harvesting	-0.029 ± 0.045	-0.652	0.515
Deadwood volume	0.004 ± 0.044	0.081	0.935
Change in deadwood volume	-0.087 ± 0.040	-2.190	0.030
Proportion of non-native trees	-0.128 ± 0.054	-2.369	0.019
Change in proportion of non-native trees	-0.092 ± 0.047	-1.965	0.052
Tree diversity	-0.009 ± 0.046	-0.201	0.841
Effective number of layers	-0.035 ± 0.045	-0.764	0.447
Change in effective number of layers	-0.002 ± 0.047	-0.044	0.965
Canopy openness	0.028 ± 0.057	0.481	0.632
Change in canopy openness	-0.119 ± 0.044	2.710	0.008
Forest cover	-0.069 ± 0.052	-1.331	0.187
Disturbance intensity	0.066 ± 0.042	1.564	0.121
Landscape heterogeneity (PC1)	0.068 ± 0.052	1.308	0.201
 <i>Abundance-accounted richness correlations</i>			
Harvesting intensity	-0.072 ± 0.060	-1.196	0.234
Change in harvesting	-0.028 ± 0.057	-0.488	0.626
Deadwood volume	-0.006 ± 0.056	-0.114	0.910
Change in deadwood volume	-0.079 ± 0.050	-1.585	0.116
Proportion of non-native trees	-0.068 ± 0.068	-0.991	0.324
Change in proportion of non-native trees	-0.088 ± 0.059	-1.485	0.140
Tree diversity	-0.056 ± 0.058	-0.956	0.341
Effective number of layers	-0.065 ± 0.057	-1.143	0.255
Change in effective number of layers	-0.140 ± 0.059	-2.370	0.019
Canopy openness	-0.009 ± 0.072	-0.120	0.905
Change in canopy openness	0.034 ± 0.056	0.605	0.546
Forest cover	0.053 ± 0.066	0.795	0.428
Disturbance intensity	0.050 ± 0.054	0.927	0.356
Landscape heterogeneity (PC1)	0.093 ± 0.071	1.311	0.198
 <i>Abundance correlations</i>			
Harvesting intensity	-0.098 ± 0.042	-2.334	0.021
Change in harvesting	-0.031 ± 0.040	-0.775	0.440
Deadwood volume	-0.022 ± 0.039	-0.571	0.569
Change in deadwood volume	-0.042 ± 0.035	-1.199	0.233

Proportion of non-native trees	-0.095 ± 0.048	-1.990	0.049
Change in proportion of non-native trees	-0.084 ± 0.041	-2.028	0.045
Tree diversity	0.039 ± 0.041	0.967	0.336
Effective number of layers	-0.046 ± 0.040	-1.154	0.251
Change in effective number of layers	0.047 ± 0.042	1.132	0.260
Canopy openness	0.015 ± 0.051	0.294	0.769
Change in canopy openness	-0.101 ± 0.039	-2.597	0.011
Forest cover	-0.079 ± 0.046	-1.709	0.091
Disturbance intensity	0.057 ± 0.038	1.512	0.134
Landscape heterogeneity (PC1)	0.040 ± 0.048	0.846	0.404
<i>Biomass correlations</i>			
Harvesting intensity	-0.075 ± 0.049	-1.529	0.129
Change in harvesting	0.019 ± 0.046	0.417	0.678
Deadwood volume	0.039 ± 0.045	0.858	0.393
Change in deadwood volume	-0.006 ± 0.041	-0.151	0.881
Proportion of non-native trees	-0.084 ± 0.056	-1.514	0.133
Change in proportion of non-native trees	-0.096 ± 0.048	-1.986	0.049
Tree diversity	-0.012 ± 0.047	-0.262	0.794
Effective number of layers	-0.016 ± 0.046	-0.352	0.726
Change in effective number of layers	0.071 ± 0.048	1.472	0.143
Canopy openness	-0.012 ± 0.059	-0.203	0.839
Change in canopy openness	-0.114 ± 0.046	-2.470	0.015
Forest cover	-0.189 ± 0.055	-3.451	0.001
Disturbance intensity	0.112 ± 0.044	2.533	0.013
Landscape heterogeneity (PC1)	0.026 ± 0.059	0.438	0.663
Carnivores			
<i>Richness correlations</i>			
Harvesting intensity	-0.061 ± 0.040	-1.530	0.129
Change in harvesting	0.042 ± 0.038	1.105	0.271
Deadwood volume	0.017 ± 0.037	0.470	0.639
Change in deadwood volume	-0.042 ± 0.033	-1.256	0.212
Proportion of non-native trees	-0.052 ± 0.045	-1.142	0.256
Change in proportion of non-native trees	-0.041 ± 0.039	-1.054	0.294
Tree diversity	0.027 ± 0.039	0.698	0.487
Effective number of layers	-0.054 ± 0.038	-1.433	0.154
Change in effective number of layers	0.005 ± 0.039	0.133	0.895
Canopy openness	-0.001 ± 0.048	-0.024	0.981
Change in canopy openness	-0.075 ± 0.038	-2.002	0.048
Forest cover	-0.023 ± 0.045	-0.514	0.608
Disturbance intensity	0.035 ± 0.036	0.973	0.333

Landscape heterogeneity (PC1)	0.076 ± 0.049	1.544	0.126
<i>Abundance-accounted richness correlations</i>			
Harvesting intensity	0.003 ± 0.054	0.062	0.951
Change in harvesting	-0.070 ± 0.052	-1.358	0.177
Deadwood volume	0.003 ± 0.051	0.050	0.961
Change in deadwood volume	-0.022 ± 0.045	-0.492	0.623
Proportion of non-native trees	0.078 ± 0.062	1.264	0.209
Change in proportion of non-native trees	-0.039 ± 0.054	-0.731	0.466
Tree diversity	-0.008 ± 0.053	-0.142	0.887
Effective number of layers	-0.074 ± 0.052	-1.430	0.155
Change in effective number of layers	-0.083 ± 0.054	-1.544	0.125
Canopy openness	-0.022 ± 0.066	-0.329	0.743
Change in canopy openness	-0.021 ± 0.052	-0.409	0.684
Forest cover	-0.030 ± 0.061	-0.481	0.631
Disturbance intensity	0.020 ± 0.050	0.403	0.687
Landscape heterogeneity (PC1)	0.124 ± 0.068	1.831	0.070
<i>Abundance correlations</i>			
Harvesting intensity	-0.075 ± 0.043	-1.762	0.081
Change in harvesting	0.048 ± 0.040	1.176	0.242
Deadwood volume	0.026 ± 0.040	0.655	0.514
Change in deadwood volume	-0.027 ± 0.036	-0.759	0.449
Proportion of non-native trees	-0.106 ± 0.049	-2.189	0.031
Change in proportion of non-native trees	-0.032 ± 0.042	-0.754	0.452
Tree diversity	0.055 ± 0.041	1.334	0.185
Effective number of layers	-0.042 ± 0.041	-1.027	0.306
Change in effective number of layers	0.036 ± 0.042	0.846	0.399
Canopy openness	0.030 ± 0.051	0.575	0.566
Change in canopy openness	-0.074 ± 0.040	-1.834	0.069
Forest cover	-0.002 ± 0.048	-0.033	0.974
Disturbance intensity	0.012 ± 0.039	0.306	0.760
Landscape heterogeneity (PC1)	0.035 ± 0.053	0.668	0.506
<i>Biomass correlations</i>			
Harvesting intensity	0.006 ± 0.051	0.117	0.907
Change in harvesting	0.026 ± 0.048	0.535	0.594
Deadwood volume	-0.016 ± 0.047	-0.344	0.731
Change in deadwood volume	-0.026 ± 0.042	-0.375	0.708
Proportion of non-native trees	-0.100 ± 0.058	-1.730	0.086
Change in proportion of non-native trees	-0.049 ± 0.050	-0.979	0.329
Tree diversity	0.081 ± 0.049	1.643	0.103

Effective number of layers	-0.048 ± 0.048	-0.995	0.322
Change in effective number of layers	0.030 ± 0.050	0.602	0.548
Canopy openness	-0.031 ± 0.061	-0.509	0.611
Change in canopy openness	-0.080 ± 0.048	-1.668	0.098
Forest cover	0.039 ± 0.058	0.677	0.500
Disturbance intensity	0.050 ± 0.046	1.070	0.287
Landscape heterogeneity (PC1)	0.048 ± 0.064	0.749	0.455

Deadwood volume and *Disturbance intensity* were square-root transformed; for *Change in deadwood volume*, *Change in proportion of non-native trees*, *Change in effective number of layers* and *Change in canopy openness* symmetric square-root transformation (separately transforming the absolute values of numbers smaller and larger than zero, subsequently multiplying all transformed values with their original sign) was applied.