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Appendix A1

Detailed SEM methods

Coding of variables

In structural equation modelling, levels of exogenous categorical variables are coded and interpreted as dummy variables given a numerical descriptor for the purpose of analysis (Grace 2006). To be consistent among variables and ease interpretation, in our experiment the dummy variable value of ‘0’ refers to ambient or control conditions, while ‘1’ refers to the application of the summer or winter defoliation, added nitrogen, or added water treatment. Summer defoliation and winter defoliation were coded as separate variables, as there is no obvious increase in disturbance from one type of defoliation to another on which to base the order of the dummy variable categories, and thus we included a covariance arrow between these two variables.

Assumptions

We evaluated our data for the SEM assumptions of multivariate normality and absence of nonlinear bivariate correlations (see Table A2 for summary statistics). Our data violated the SEM assumption of multivariate normality, which can lead to overestimation of path significance; thus, we calculated bootstrapped path coefficient standard errors to determine path significance (Blunch 2008).

Model fit

The model was fit using AMOS 18.0 (SPSS Inc. 2009). As suggested by the AMOS modification indices (Grace 2006), we modified the initial model by adding a covariance arrow from Richness 2006 to Richness 2008. Non-significant paths were retained in the final model because we believed that all

paths were potentially biologically relevant and their deletion would result in over-fitting of the model. Model fit was judged using the chi-square test comparing the covariance matrix implied by the model to that of the actual data chi-square test; a p-value over 0.05 suggests adequate model fit (Grace 2006).

Table A1. Full table of bootstrapped unstandardized path coefficients, 95% confidence intervals and p-values, and bootstrapped standardized path coefficients from the SEM of abiotic change/disturbance effects on *P. pratensis* cover, native species cover, and species richness. Significant paths ($p < 0.05$) are italicized. The paths described in each section of the table are from the variables in lower case to the variable at the top in bold.

Dependent variable Independent variable	Unstandardized coefficients	Lower 95% CI	Upper 95% CI	p-value	Standardized coefficients
Cover 2006					
<i>Summer Def</i>	<i>-56.531</i>	<i>-69.97</i>	<i>-44.483</i>	<i>0.011</i>	<i>-0.661</i>
Winter Def	8.172	-12.64	22.332	0.307	0.096
<i>Nitrogen</i>	<i>15.698</i>	<i>4.716</i>	<i>25.751</i>	<i>0.012</i>	<i>0.195</i>
Water	1.885	-8.888	13.790	0.803	0.023
Richness 2006					
<i>Summer Def</i>	<i>-1.156</i>	<i>-2.248</i>	<i>-0.080</i>	<i>0.032</i>	<i>-0.221</i>
<i>Winter Def</i>	<i>1.406</i>	<i>0.259</i>	<i>2.580</i>	<i>0.016</i>	<i>0.269</i>
Nitrogen	0.458	-0.370	1.518	0.247	0.093
Water	-0.250	-1.141	0.824	0.775	-0.051
Poa 2006					
Summer Def	-0.750	-8.034	6.805	0.757	-0.025
Winter Def	-0.047	-6.736	8.073	1.000	-0.002
Nitrogen	-3.146	-8.579	2.787	0.271	-0.111
Water	-1.604	-7.216	4.447	0.563	-0.057
Cover 2007					
<i>Cover 2006</i>	<i>0.364</i>	<i>0.184</i>	<i>0.564</i>	<i>0.008</i>	<i>0.497</i>
Richness 2006	1.088	-0.797	3.084	0.231	0.091
<i>Poa 2006</i>	<i>-0.949</i>	<i>-1.283</i>	<i>-0.348</i>	<i>0.044</i>	<i>-0.457</i>
<i>Summer Def</i>	<i>33.362</i>	<i>16.139</i>	<i>49.627</i>	<i>0.009</i>	<i>0.543</i>
Winter Def	3.047	-10.526	11.930	0.655	0.049

Nitrogen	-0.518	-8.163	9.761	0.971	-0.009
Water	-9.093	-18.994	0.172	0.058	-0.154
Richness 2007					
Richness 2006	0.218	-0.016	0.416	0.086	0.211
Cover 2006	0.009	-0.010	0.031	0.238	0.137
Poa 2006	-0.025	-0.066	0.020	0.261	-0.059
<i>Summer Def</i>	2.597	1.037	4.022	0.009	0.482
Winter Def	0.685	-0.609	2.010	0.319	0.127
Nitrogen	0.500	-0.339	1.548	0.324	0.098
Water	-0.022	-1.123	1.022	0.930	-0.004
Poa 2007					
<i>Poa 2006</i>	0.993	0.719	1.246	0.032	0.801
Cover 2006	-0.113	-0.196	-0.048	0.005	-0.259
Richness 2006	-0.421	-1.154	0.229	0.197	-0.057
Summer Def	-06.95	-6.432	3.798	0.639	-0.019
Winter Def	1.656	-2.724	5.875	0.499	0.044
<i>Nitrogen</i>	4.218	0.891	8.752	0.013	0.120
Water	1.535	-1.304	5.565	0.264	0.044
Cover 2008					
Cover 2007	0.252	0.000	0.420	0.050	0.245
Richness 2007	1.647	-0.285	3.238	0.155	0.138
Poa 2007	-0.886	-1.191	-0.686	0.005	-0.210
Summer Def	6.865	-4.282	18.146	0.264	0.107
Winter Def	1.391	-10.480	12.789	0.890	0.022
Nitrogen	-4.140	-12.232	5.255	0.365	-0.068
Water	7.752	-2.340	16.078	0.124	0.125
Richness 2008					
<i>Richness 2007</i>	0.230	0.064	0.388	0.012	0.266
Cover 2007	0.013	-0.001	0.032	0.069	0.181
Poa 2007	-0.026	-0.050	0.001	0.059	-0.210
Summer Def	0.108	-0.736	1.303	0.722	0.023
Winter Def	-0.751	-1.665	0.362	0.203	-0.161
Nitrogen	-0.660	-1.298	0.348	0.169	-0.150
Water	-0.112	-0.924	0.717	0.816	-0.025
Poa 2008					
<i>Poa 2007</i>	1.242	1.004	1.423	0.009	0.910
Cover 2007	0.007	-0.107	0.125	0.897	0.008
Richness 2007	0.286	-0.472	1.182	0.458	0.030
Summer Def	0.176	-7.160	6.648	0.910	0.003
Winter Def	-0.690	-6.451	5.159	0.840	-0.014
Nitrogen	-0.954	-6.134	3.700	0.713	-0.020
Water	1.053	-2.831	5.399	0.590	0.022

Table A2. Average 2008 biomass ($\text{g m}^{-2} \pm \text{SE}$) for *P. pratensis* and non-*P. pratensis* vascular plants.

	Control	Summer defoliation	Winter defoliation	Nitrogen addition	Water addition
<i>P. pratensis</i>	41.1 \pm 18.3	26.1 \pm 18.1	101.2 \pm 54.8	2.1 \pm 1.0	42.0 \pm 26.7
Non- <i>P. pratensis</i>	232.9 \pm 57.1	287.0 \pm 50.6	261.8 \pm 40.7	295.8 \pm 39.3	226.5 \pm 31.4

Table A3. Means \pm 1SE, data ranges, and Pearson bivariate correlations among variables in our SEM of the effects of resource/disturbance treatments on *P. pratensis* cover, native species cover, and native species richness.

Variable	Cover 2006	Richness 2006	<i>Poa</i> 2006	Cover 2007	Richness 2007	<i>Poa</i> 2007	Cover 2008	Richness 2008	<i>Poa</i> 2008
Means \pm 1SE	113.3 \pm 4.1	10.8 \pm 0.2	8.0 \pm 1.7	142.5 \pm 3.1	11.1 \pm 0.3	6.8 \pm 1.8	128.0 \pm 3.2	10.2 \pm 0.3	12.5 \pm 2.8
Data range	31 – 214%	6 – 16	0 – 45%	62 – 222%	5 – 18	0 – 60%	31.5 – 200.5%	5 – 15	0 – 90%
Cover 2006	1								
Richness 2006	-	1							
<i>Poa</i> 2006	-	-	1						
Cover 2007	0.278**	0.204*	-0.581***	1					
Richness 2007	-0.048	0.177	-0.144	-	1				
<i>Poa</i> 2007	-0.414***	-0.257*	0.848***	-	-	1			
Cover 2008	-	-	-	0.611***	0.399***	-0.683***	1		
Richness 2008	-	-	-	0.474***	0.453***	-0.441***	-	1	
<i>Poa</i> 2008	-	-	-	-0.547***	-0.214*	0.904***	-	-	1

*0.01 < p < 0.05; **0.001 < p < 0.01; ***p < 0.001

Table A4. Means \pm 1SE by treatment for response variables in our SEM of the effects of resource/disturbance treatments on *P. pratensis* cover, native species cover, and native species richness. For each treatment indicated, the mean response to this treatment was calculated, with all other treatments at control levels.

	Control	Summer defoliation	Winter defoliation	Nitrogen addition	Water addition
<i>Poa</i> 2006 cover)	(% 12.0 \pm 5.8	0.6 \pm 0.4	9.5 \pm 7.3	10.6 \pm 4.9	6.3 \pm 4.9
<i>Poa</i> 2007 cover)	(% 6.9 \pm 4.3	5.6 \pm 2.4	7.8 \pm 3.9	10.4 \pm 7.3	9.3 \pm 7.3
<i>Poa</i> 2008 cover)	(% 11.6 \pm 5.9	5.6 \pm 2.3	13.6 \pm 6.3	16.8 \pm 11.3	16.3 \pm 7.8
Cover 2006 cover)	(% 126.2 \pm 10.7	65.7 \pm 7.6	117.4 \pm 9.7	135.0 \pm 15.1	120.7 \pm 4.2
Cover 2007 (% cover)	134.4 \pm 11.0	150.1 \pm 7.0	140.4 \pm 9.2	147.7 \pm 15.5	129.1 \pm 9.3
Cover 2008 (% cover)	114.4 \pm 9.3	148.4 \pm 6.5	132.6 \pm 10.8	121.8 \pm 14.1	119.3 \pm 10.9
Richness 2006 (no. species / 0.25 m ²)	9.1 \pm 0.9	9.0 \pm 0.9	11.8 \pm 0.9	11.1 \pm 0.9	9.6 \pm 0.9
Richness 2007 (no. species / 0.25 m ²)	9.6 \pm 0.9	11.6 \pm 1.3	10.5 \pm 0.7	12.3 \pm 1.1	8.8 \pm 0.6
Richness 2008 (no. species / 0.25 m ²)	9.8 \pm 0.6	12.6 \pm 0.8	10.3 \pm 1.0	11.1 \pm 1.0	11.0 \pm 0.7

References

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