Appendix for: Grassland management intensification weakens the association between the biodiversity of multiple plant and animal taxa (Manning et al.)

Appendix A. Additional methods details.

Regional descriptions

The data in this study were collected in three regions of Germany in each of which there were 50 plots. The 50 sites of each region were selected from a larger random sample to cover the full range of land-use intensity within each region. Within each region plots were selected to maximise the range of land use intensity but to keep variation in other factors (e.g., soils) to a minimum. Regional differences are summarized in Table A1.

TABLE A1. Main geographic and environmental characteristics of the three Biodiversity Exploratories (from Fischer et al. 2010).

	Schorfheide-Chorin	Hainich-Dün	Schwäbische Alb
Location	NE Germany	Central Germany	SW Germany
Size	~1300 km^2	~1300 km^2	~422 km^2
Geology	Young glacial landscape	Calcareous bedrock	Calcareous bedrock with karst phenomena
Altitude a.s.l.	3–140 m	285–550 m	460–860 m
Human population density	23 km^{-1}	116 km^{-1}	258 km^{-1}
Annual mean temperature	8–8.5◦C	6.5–8◦C	6–7◦C
Annual mean precipitation	500–600 mm	500–800 mm	700–1000 mm

Land use intensity (LUI) index

The land-use intensity (LUI) index is an integrated measure of the intensity of grazing (*G*), mowing frequency (*M*), and fertilisation rate (*F*). *G* was calculated from the number and type of grazing animals and the number of days grazed to create a measure of livestock units (LU). Cattle <1 year old = 0.3 LU, 1-2 years = 0.6 LU, cattle >2 years = 1. Sheep and goats <1 year old = 0.05 LU, >1 year =0.1. Horses <3 years old = 0.7, Horses >3 years = 1.1. *M* was the number of cuts per year. *F* included both inorganic and organic forms and was measured as kg nitrogen (N) ha^{-1}. Pesticides were not used in any of the plots of this study and so they are not included in the measure. *G* varied from 0 to 1430, *F* varied from 0 to 163 kg N ha^{-1} and *M* varied from 0 to 3. The intensity of each measure was standardised by its mean in each region and across three years (2006–2008). From these 3 measures the LUI was calculated as:

$$\text{LUI} = \sqrt{\frac{G}{G_{G2006-2008}} + \frac{M}{M_{G\ 2006-2008}} + \frac{F}{F_{G\ 2006-2008}}}$$

Where $G_{G2006-2008}$, $M_{G\ 2006-2008}$ and $F_{G\ 2006-2008}$ are the overall mean values for FG, M and F across all 3 regions and across 3 years. The LUI at which we divided the plots into high and low LUI was 1.53. To place this value in context we examined land use between LUI of 1.4 and 1.6. Within this range mean G was 172 (range 0 to 329), mean M was 0.83 (range 0 to 2) and mean F was 0.98 (range 0 to 10.67). The LUI metric covers the same range within each region and is a generally better predictor of species diversity patterns in these grasslands than its individual components (Allan et al. 2014). For further details on the LUI index see Blüthgen et al. (2012).

Sampling methods

Plants

Between mid-May and mid-June 2009 the vegetation was recorded on a 4 × 4 m area in the centre of each plot by estimating the cover of all lichen, bryophyte, and vascular plant species. From this data we calculated the species richness and the inverse of Simpson's diversity index for lichen, bryophytes, Monocots, Ranunculales, Rosids and Asterids. However, the Ranunculales were dropped from the analysis because of their very low species richness (0–3 species per plot).

Hymenoptera and Diptera

On a transect of 200 × 3 m along the edge of the plot, all individual flower visitors were recorded and identified during three transect walks (total 6 h) on a single day. The total number of individuals of each species of the orders Diptera and Hymenoptera were recorded. In some cases plots were measured several times these were averaged in less than one month apart. If greater than one month the earlier measure was used. See Weiner et al (2014) for details.

Other arthropods

For sampling arthropods of the herb layer (i.e., Hemiptera: Heteroptera, Homoptera; Orthoptera; Coleoptera, Araneae) we use standardised sweep-netting (60 double sweeps per plot) along three plot border transects in June and August 2008. Samples were summed over the two months and number of sampled species per plot and year were used in further analyses.

Lepidoptera

Butterflies were recorded three times from May to August 2008 on each grassland plot. The transects were 300 m in length with approximately 30 min at each site and transects were only conducted when weather conditions were suitable for butterfly recordings. We sampled butterflies by sweep net and either released them after identification or collected them if necessary for further identification by dissection of genitalia in the laboratory. Moths were not recorded. We sampled all 137 study sites three times in a randomized sequence within the regions approximately once a month For further details see Börschig et al. (2013).

Birds

Birds were surveyed by standardized audio-visual point-counts and all birds exhibiting territorial displays (singing and calling) were recorded. All species that were considered to potentially breed on the plot were monitored. We used fixed-radius point counts and recorded all males of each bird species during a five-minute interval per plot. Each plot was visited five times between the 15th of March and the 15th of June (first surveying period15–30 March; 2nd 15–30 April; 3rd 1–15 May; 4th 16–31 May; 5th 1–15 June) each year from 2008–2010. Aerial species (swifts and swallows) were excluded from analysis, since they were surveyed irregularly, were unlikely to breed on the plots and their observation could not be standardised due to difficulties in observation and large habitat area use.

Bats

Bat species were assessed using acoustic monitoring (real time recordings; sampling rate of 384 kHz, 16 bit) along the border of each plot (200m, 24 minutes). Recordings started 30 min after local sunset and plots were visited in a randomized order. Sampling was conducted twice per year on a plot during June/July- and repeated in August/September. Plots that were sampled early in the evening during the first sampling were sampled late in the second sampling. This occurred over 3 years 2008–2010. For our analysis we identified species from their sonotypes.

Sensitivity analysis

We repeated all analyses described in the methods section using inverse Simpson's diversities (the probability that two individuals randomly selected from a sample will belong to the same species) of the 15 taxonomic groups instead of species richness, as well as using nonparametric Spearman's rank correlations instead of parametric Pearson's correlations. Spearman's and Pearson's correlations were generally very closely correlated (r = 0.933 across 91 richness correlations). Thus, when we repeated the analyses with Spearman's correlations data, the results were very similar and our overall conclusions were unchanged, and the same was true for analyses based on Simpson's diversities instead of species richness. We therefore present and discuss only the results of parametric correlations of species richness values.

1 **TABLE A2.** The biodiversity data used in this study.

Taxonomic group	# Plots	Sampling method	Year of measurement and sampling intensity	Trophic group	Group responsible for data collection	Mean correlation with other taxa*	Mean difference in correlation †	Mean richness‡ at low LUI (SD)	Mean richness ‡ at high LUI (SD)	Richness ‡ differen ce (%)†	SD difference (%)†
Bryophytes # per 4 m×4 m subplot	150	% cover on 4 x 4 m subplot	2009, once per plot	Primary producer	Boch, Müller, Prati, Fischer	0.343	0.208	3.43 (3.32)	1.68 (1.26)	-51.0	-62
Lichens # per 4 m×4 m subplot	144	% cover on 4 x 4 m subplot	2009, once per plot	Primary producer	Boch, Prati, Fischer	0.250	0.159	1.79 (5.10)	0.07 (0.37)	-96	-92.8
Monocots # per 4 m×4 m subplot	147	% cover on 4 x 4 m subplot	2009, once per plot	Primary producer	Boch, Müller, Socher, Prati, Fischer, Klaus, Kleinebecker, Hölzel	0.197	0.150	10.0 (3.40)	8.23 (2.30)	-17.7	-32.3
Rosids # per 4 m×4 m subplot	147	% cover on 4 x 4 m subplot	2009, once per plot	Primary producer	Boch, Müller, Socher, Prati, Fischer, Klaus, Kleinebecker, Hölzel	0.349	0.220	7.15 (5.30)	4.5 (2.67)	-37.1	-49.6
Asterids (# species per 4 m×4 m subplot)	147	% cover on 4 x 4 m subplot	2009, once per plot	Primary producer	Boch, Müller, Socher, Prati, Fischer, Klaus, Kleinebecker, Hölzel	0.374	0.194	14.05 (6.62)	10.93 (3.19)	-22.2	-51.8
Heteroptera‡	150	Sweep netting	2008,, twice per plot	Primary consumer	Lange, Pašalić, Türke, Gossner, Weisser	0.268	0.197	9.3 (4.90)	8.68 (4.40)	-7.0	-10.2

Taxonomic group	# Plots	Sampling method	Year of measurement and sampling intensity	Trophic group	Group responsible for data collection	Mean correlation with other taxa*	Mean difference in correlation †	Mean richness‡ at low LUI (SD)	Mean richness ‡ at high LUI (SD)	Richness ‡ difference (%)†	SD difference (%)†
Homoptera‡	144	Sweep netting	2008, twice per plot	Primary consumer	Lange, Pašalić, Türke, Gossner, Weisser	0.207	0.115	11.29 (3.14)	10.21 (3.03)	-9.6	-3.5
Lepidoptera	143	Butterfly netting along a transect	2008, three surveys	Primary consumer	Börschig, Krauss, Klein	0.349	0.127	11.18 (6.98)	7.49 (3.24)	-33.0	53.6
Hymenoptera	138	flower visitor observations	2008, twice per plot	Primary consumer	Werner, Weiner, Blüthgen	0.262	0.156	11.44 (7.18)	10.66 (5.51)	-6.8	-23.3
Orthoptera‡	135	Sweep netting	2008, twice per plot	Primary consumer	Lange, Pašalić, Türke, Gossner, Weisser	0.293	0.190	1.9 (1.34)	1.35 (1.01)	-29.0	-24.6
Diptera	119	Flower visitor observations	2008, one to three times per plot	Primary consumer	Werner, Weiner, Blüthgen	0.104	0.188	21.21 (12.80)	27.50 (17.86)	29.7	39.5
Coleoptera‡	150	Sweep netting	2008-2009, twice per plot per year	Primary consumer	Lange, Pašalić, Türke, Gossner, Weisser	0.222	0.190	13.24 (6.17)	12.73 (7.14)	-3.9	15.7
Araneae‡	141	Sweep netting	2008, twice per plot	Secondary consumer	Lange, Pašalić, Türke, Gossner, Weisser	0.107	0.121	3.56 (1.98)	3.54 (2.41)	-0.06	21.7

Taxonomic group	# Plots	Sampling method	Year of measurement and sampling intensity	Trophic group	Group responsible for data collection	Mean correlation with other taxa*	Mean difference in correlation †	Mean richness‡ at low LUI (SD)	Mean richness ‡ at high LUI (SD)	Richness ‡ difference (%)†	SD difference (%)†
Birds	150	Observation: 5 surveys per year for three years	2008-2010, five times per plot per year	Secondary consumer	Renner, Böhm, Kalko	0.238	0.205	3.72 (3.12)	2.13 (2.05)	-42.7	27.9
Bats	150	Monitoring of echolocation, 3 years data	2008-2010, cumulative species list	Secondary consumer	Jung, Kalko	0.057	0.107	4.68 (2.25)	4.60 (2.45)	-1.7	8.8

* pairwise Pearson's correlation of species richnesses across all land-use intensities (LUIs)

† between high and low LUI

‡ For units of species richness see methods

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