Supplementary material:

Supplementary material text S1: site, treatments, plot, and climate description

Fire frequency:

This study focuses on annual and three to four-year fire frequencies, which is similar to estimated fire frequencies shortly before the arrival of Europeans, although few areas probably burned every year (*1*). Annual to biennial burning is now one of the most common fire frequencies in the region (*2*). Comparable data were available for four catchments in each grazing treatment (Table S1). The ungrazed and bison treatments were split evenly into catchments with an average fire frequency of 3.3 to 3.8 years. The cattle treatments have oscillated between an approximate fire frequency of annual burning and burning every three years until 2008, and then had fixed fire return intervals of annual and triennial burning for the next thirteen years. Our results did not change qualitatively when we directly compared cattle vs. bison treatments in watersheds burned annually: richness increased linearly in the bison treatment, with a dip during the 2011/2012 climate extreme, and in the cattle treatment, species richness showed no net increases from 2008 to 2020 (Fig S6). Comparing only watersheds burned every three (cattle) or four years (bison) yielded similar results (Fig S6). Therefore, all watersheds, regardless of fire frequency, were included in the analyses presented in the main text.

Observational data design:

We used data from permanent 10 m^2 plots arrayed equidistantly along four 50 m long transects. Only transects from uplands were used, because data from other positions were not available in the cattle treatment. Each experimental catchment houses four transects, for a total of 20 plots in each catchment and 80 plots per treatment. Each plot is surveyed in the early and late growing season (to encounter all species present throughout the growing season), with the maximum cover of each species assigned to a Daubenmire cover class (e.g. 0 to 1% cover, 1 to 5% cover, etc., see ref. *3* for details and for data download, see refs. *4*, *5*). We used the mid-point of these classes as the measure of abundance for dominant grass cover, Shannon's index, and forb cover.

Climate data:

Climate data were obtained from climate engine (accessed at https://app.climateengine.com/climateEngine; *6*), which uses gridmet as a data source at a spatial scale of 1/24th degrees latitude/longitude. SPEI is calculated as precipitation minus estimated evapotranspiration based on the Penman-Monteith method (*7*). These data were used to calculate the untransformed 5th and 95th percentiles of SPEI as measures of annual climate extremity during the growing season.

References:

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Supplementary material text S2: GAM model details

For each GAM model we used a Gaussian distribution and identity as the link function. The number of knots (*k*) was set to half the length of each sub dataset (*k* = 15 for bison and ungrazed and *k* = 6 for the cattle treatment), which allowed the model to identify shorter term changes in the response variables. R-squared values did not increase meaningfully (more than 0.02) by increasing *k* above this value (see Table S2 for model performance). The lambda value, which determines whether the model conforms more to a linear model or a complex polynomial spline, was set to the value that produces the lowest restricted maximum likelihood value for each model. This procedure was performed using the *mgcv* package in R (*1*).

References:

1. S. N. Wood, *Generalized Additive Models: An Introduction with R (2nd edition)* (2017). Chapman and Hall/CRC

Supplementary text S3: Changes in community composition

Community composition methods:

Some species rich communities have high unevenness. Therefore, as another measure of biodiversity, we calculated the analog ($e^{H'}$) of the Shannon diversity. Changes in community composition, not just species richness, are also an important aspect of herbivore impacts on plant communities. To quantify changes in composition we performed two sets of analysis: (1) changes in cover and richness of key functional groups, and (2) differences in the frequency of all species present at the end of the experiment.

Changes in Shannon's index and key species/functional groups over time:

Shannon's index was calculated as ($H' = \Sigma(p_i * \ln[p_i])$), using only native species, where p_i is the relative abundance (cover) of each species *i*. $e^{H'}$ estimates the number of species with equivalent abundance (Fig S1, S5). We explored changes over time for three key groups of species: species of conservation concern, forbs, and non-native species. Species of conservation concern are important because over 95% of tallgrass prairie has been converted to other land uses (*1*). Forbs are typically sub-dominant in ungrazed tallgrass prairie (*2*), but provide important ecosystem services, such as support for pollinators (*3*). Finally, we calculated non-native species richness, with the goal of quantifying whether megagrazers also promote non-native species (Fig S4, S5).

To identify species of greater conservation concern we used coefficients of conservatism (CoC), which are assigned by local experts (*4*). We used CoC scores as a proxy for a species conservation status, with higher scores indicating greater conservation value. In general, species with a CoC score of approximately six or higher rarely exist in undegraded ecosystems and therefore, we report the number of species with a CoC score of six or higher (based on CoC derived for our study region; ref. *4*; Fig S2). We represented changes in forbs using total forb cover, which is as the summed cover of all forb species (Fig S3). Finally we calculated non-native species richness each year to compare changes in native and non-native species. Note that all species richnesses reported in the main text are for native species only and we report non-native species richness here in the appendix. For each of these response variables, we derived GAM time series models and performed a mixed effects ANOVA using the final year of data. Both model types used the same procedures that we applied to dominant grass cover and species richness (described in main text).

Changes in species frequency

To understand how our grazing treatments affected plant community composition, we focused on species frequency—the proportion of plots in which a species is found—because the presense or absense of a species determines its contribution to species richness. Out of the 174 species present at the end of the experiment, 94 species were completely absent from at least one of the treatments (Table S7). This resulted in a data-set with high zero inflation, which violates the assumptions of most statistical tests of frequency differences between treatment groups. Considering these statistical limitations, we performed a simple analysis that compares the frequency of species in each treatment, using the following three metrics:

$$\Delta_i \text{ b-ug} = f_{i,b} - f_{i,u}$$

$$\Delta_{i,} \text{ b-c} = f_{i,b} - f_{i,c}$$

$$\Delta_{i,} \text{ c-ug} = f_{i,c} - f_{i,ug}$$

Where $f_{i,b}$ is the frequency of species *i* in the bison treatment, $f_{i,u}$ is the frequency of species *i* in the ungrazed treatment, and $f_{i,c}$ is the frequency of species *i* in the cattle treatment. Δ_i b-ug describes if and how much more frequent each species is in the bison treatment, compared to the ungrazed treatment. Δ_i b-c describes if and how much more frequent a species is in the bison treatment, compared to the cattle treatment. Δ_i c-ug describes if and how much more frequent a species is in the cattle treatment, compared to the ungrazed treatment. Frequencies were calculated using the last three years of data, where frequency is the number of plot by year combinations a species was present, divided by the number of plot by year combinations (three years * 80 plots per treatment = 240).

We developed *a priori* cut-offs to identify which species we would consider to be "increasers" or "decreases" in response to bison grazing: we treated values of Δ_i b-ug between -0.05 and -0.05 as only marginal differences. We treated Δ_i b-ug values less than -0.05 or more than 0.05 as more substantial frequency differences. We identified "increasers" as species that had a Δ_i b-ug value of 0.33 or higher, with the rationale that the increase in frequency would apply to one in three plots, which is a considerable portion of the watersheds. We used the same approach to identify "decreasers" as species with a Δ_i b-ug value of -0.33 or lower. The same approach was extended to contrasts of bison versus the cattle treatment, and cattle versus the ungrazed treatment.

Results and discussion:

Response of key functional groups and species:

e^H initially increased in the ungrazed treatment (Fig S1) and then began a slow decline through 2020. In the bison treatment, e^H increased sharply for the first five years and then declined, reversing half of these gains. After a five-year pause, e^H underwent a long-term linear increase, albeit with greater year-to-year variability than species richness. The 2011/2012 climate extreme was not associated with a decrease in e^H within the bison treatment. In the cattle treatment, e^H has seen a small net increase from 2008 to 2020 and there was no decline during the climate extreme. As of the final year, e^H in the bison treatment was 133% and 200% higher (respectively) at the plot and catchment scales than in the ungrazed treatment. In contrast to the bison treatment, e^H in the cattle treatment was only 33% higher than the ungrazed treatment at the plot scale and 48% higher at the catchment scale (Fig S5).

In the ungrazed treatment, the number of species with high CoC scores increased slightly at both spatial scales (Fig S2, S5). In the bison treatment, this measure has increased approximately linearly over time, and as of the final year, is 45% higher than the ungrazed treatment at the plot scale and 60% higher at the catchment scale. At the plot scale, the number of species with high CoC scores in the cattle treatment saw no net-change at the plot scale and a slight increase at the catchment scale. As of 2020, the confidence interval of this measure overlaps between cattle and bison at plot scale and is lower in cattle treatment at the catchment scale.

At the onset of the experiment, forb cover was similar in the ungrazed and bison treatment (Fig S3). In the ungrazed treatment, forb cover was variable, but as of the end of time series, has fallen from an average of 33% to 25% (Fig S3, S5). In the bison treatment, forb cover tracked patterns in the ungrazed treatment until 2002 and then started to diverge with a sharp increase followed by a series of oscillations and a long-term decline. As of 2020, forb cover in the bison treatment now averages 50% aerial coverage—twice that of the ungrazed treatment. In the cattle treatment, forb cover closely followed the ungrazed treatment and is only marginally higher.

Non-native species were not present in high numbers. As of 2020, the ungrazed treatment has seen almost no increases in non-native species richness, with an average of 0 to 1 species per plot and catchment scales. The bison grazed treatment has seen the largest increase in non-native species with a roughly linear increase at the plot and catchment scales over time. As of 2020, there are an average of three non-native species per plot and five non-native species per catchment. Like native plant species richness, non-native species richness in the cattle treatment fell between the ungrazed and bison treatment.

Community changes in species frequency:

Specific species differences between bison and ungrazed treatments: The final three years of data accounted for 174 species across our 240 plots (Fig S6, Table S7). Comparing species specific frequencies in the bison and ungrazed treatment, 16 species were substantially more common in the ungrazed treatment (△b-ug ≤ -0.05), 8 species were marginally more frequent in ungrazed treatment (-0.05 <△b-ug <0), 28 species had equal abundances in both treatments (△b-ug = 0), 37 species were marginally more frequent in the bison grazed treatment (0 < △b-ug <0.05), and the remaining 77 species were substantially more frequent in the bison treatment (△b-ug ≥ 0.05). Comparing the cattle treatment to the ungrazed treatment, 17 species were substantially more abundant in the ungrazed treatment (△c-ug ≤ -0.05), 18 species were marginally more abundant in the ungrazed treatment (-0.05 <△c-ug <0), 15 species had equivalent abundances in both treatments (△c-ug = 0), 35 species were marginally more abundant in the cattle treatment (0 < △c-ug <0.05), and 44 species were substantially more abundant in the cattle treatment (△c-ug ≥ 0.05). Therefore, the number of substantially more frequent species (relative to ungrazed) was nearly twice as high in bison treatment, compared to the cattle treatment.

Comparing bison and cattle treatments, 29 species were substantially more common in the cattle treatment (△b-c ≤ -0.05), 6 species were marginally more frequent in the cattle treatment (-0.05 <△b-c <0), 26 species had equivalent frequencies in each treatment (△b-c=0), 30 species had marginally higher frequency in the bison treatment (0 < △b-c <0.05), and 70 species were substantially more abundant in the bison treatment (△b-c>0.05). Therefore, more than twice as many species are substantially more frequent in the bison treatment, compared to the cattle treatment.

Key increasers and decreasers:

Specific species differences between bison and ungrazed treatment: After twenty years of bison grazing, only two species were considered decreasers, relative to the ungrazed treatment: a perennial Asteraceae (*Symphyotrichum oblongifolium*) and a perennial grass species (*Sporobolus heterolepis*)(see Table S7 for all frequency comparisons). In contrast, 27 species were increasers. We identified a set of tall increaser species that have become nearly ubiquitous in the bison treatment (△b-ug >0.33 but >0.66 for most species) but rare in ungrazed areas (frequency <0.25 in the ungrazed treatment, but close zero for most species). These include: *Achillea millefolium* (an Asteraceae), *Solidago rigida* (an Asteraceae), *Erigeron strigosus* (an Asteraceae), *Verbena stricta* (a Verbenaceae), *Ratibida columnifera* (an Asteraceae), and *Vernonia baldwinii* (an Asteraceae). These are all taller forb species, which represent new co-dominants alongside typical tallgrass prairie grasses and they all grow tall stiff stems, which makes them strong competitors for light.

Below this new canopy of higher forb cover, an array of annual species are now common (△b-ug >0.33 and frequency in ungrazed <0.20), which span many botanical families, such as Apiaceae, Borginaceae, Brasicaceae, Caryophyllaceae, Cyperaceae, Euphorbiaceae, Linaceae, Oxalidaceae, and Plantaginaceae. Also, four annual grass species are now common. The addition of so many annual species is notable because they can flower early, which is a strategy that allows species to avoid peak growing season temperatures and competition by reproducing primarily in the early spring or late fall. Another set of perennial and biennial species are also common, which includes several Asteraceae species (*Circisum undulatum, Hymenopappus scabiosaeus*), a Cyperaceae species (*Carex austrina*), and the grass species *Bouteloua dactyloides* and *B. gracilis.* The addition of these two grass species is notable because both have fine dispersed foliage, which should make grazing them less efficient (*5*). Also, these two species are co-dominants in many drier Great Plains grasslands (*6*). Together, these increases in annual and *Bouteleau* species suggests that bison grazing can shift the community to more drought-adapted species.

Specific species differences between bison and cattle treatments: Compared to the cattle treatment, bison had many more increaser species, with some strong similarities between the bison versus cattle comparison. Four species were decreasers when comparing bison to cattle, and all were relatively tall perennials: *Sisyrinchium campestre*, *Carex meadii*, *S. oblongifolium,* and *Dalea candida.* However, all four of these species were quite common in the bison treatment (frequency >0.20), but much more common in the cattle treatment (frequency>0.58). Nineteen species were increasers and all of these species were also increasers from the comparison of the bison treatment to the ungrazed treatment. This includes tall forbs from the bison versus ungrazed contrast (*S. rigida*, *V. Baldwini*), seven of the annual species from the bison versus ungrazed contrast, and the two *Boutelou* grass species. Therefore, as before we see that bison cause an increase in tall forbs with limited palatability, annual species, and grasses that are more difficult to graze and more drought tolerant.

Specific species differences between cattle and ungrazed treatments: Compared to the ungrazed treatment, zero species were decreasers in the cattle treatment. Ten species were increasers, and all but one was a perennial forb. Similar to the effect of bison, these tended to be tall forbs mostly from the Asteraceae family, including some of the same increasers from the bison treatment (*V. baldwinii, S. rigida, E. strigosus*, *R. columnifera*) and some species that are common only in the cattle treatment (*Brickellia eupatorioides* and *Dalea candida*). This is in line with observations that most of cattle diet is graminoids, allowing some forbs to become co-dominant species. *Koeleria macrantha*, a common perennial grass, was also an increaser and particularly abundant in the cattle treatment, occurring in all plots. Notably, two sedge species came close to meeting our *a priori* cut-off of a △c-ug value greater than 0.33, with a value of 0.32 for *Carex brevior* and 0.31 for *C. austrina* (also an increaser in the bison treatment, compared to ungrazed). Similar to the *Boutelou* species discussed before, these *Carex* species have fine foliage, which should be inefficient to graze.

References:

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Table S1. A summary of watersheds in each treatment and when data were available.

Catchment ID*	Grazing treatment	Year grazer introduced	Years with plant composition data	Years used for GAMs	Years used for linear model
001d	Ungrazed	NA	1986-2020	1990-2020	1994-2010
00spb	Ungrazed	NA	1994-2020	1994-2020	1994-2010
004b	Ungrazed	NA	1986-2020	1990-2020	1994-2010
004a	Ungrazed	NA	1986-1990, 1992-2020	1990, 1991-2020	1994-2010
n01b	Bison	1992	1986-1990, 1992-2020	1990, 1992-2020	1994-2010
n01a	Bison	1987 (at low density)	1993-2020	1993-2020	1994-2010
n04d	Bison	1992	1986-2020	1990-2020	1994-2010
n04a	Bison	1987 (at low density)	1991-2020	1990-2020	1994-2010
c01a	Cattle 1	1992	2008-2020	2009-2020	NA
c03a	Cattle 1	1992	2008-2020	2009-2020	NA
c03b	Cattle 1	1992	2008-2020	2009-2020	NA
c03c	Cattle 1	1992	2009-2020	2009-2020	NA

*These catchment IDs directly correspond to IDs in the underlying data of this study acknowledged in the data availability statement

Table S2. Summary of GAM model performance

Response variable	Spatial scale	Grazing treatment	Model r^2
Dom. grass cover (%)	Catchment	Cattle	0.34
Dom. grass cover (%)	Catchment	Bison	0.75
Dom. grass cover (%)	Catchment	Ungrazed	0.18
Dom. grass cover (%)	Plot	Cattle	0.18
Dom. grass cover (%)	Plot	Bison	0.43
Dom. grass cover (%)	Plot	Ungrazed	0.13
Species richness	Catchment	Cattle	0.07
Species richness	Catchment	Bison	0.70
Species richness	Catchment	Ungrazed	0.00
Species richness	Plot	Cattle	0.08
Species richness	Plot	Bison	0.57
Species richness	Plot	Ungrazed	0.06
Shannon index (e^H)	Catchment	Cattle	0.13
Shannon index (e^H)	Catchment	Bison	0.74
Shannon index (e^H)	Catchment	Ungrazed	0.21
Shannon index (e^H)	Plot	Cattle	0.11
Shannon index (e^H)	Plot	Bison	0.27
Shannon index (e^H)	Plot	Ungrazed	0.22
Total species w. C-score >5	Catchment	Cattle	0.02
Total species w. C-score >5	Catchment	Bison	0.64
Total species w. C-score >5	Catchment	Ungrazed	0.04
Total species w. C-score >5	Plot	Cattle	0.05
Total species w. C-score >5	Plot	Bison	0.18
Total species w. C-score >5	Plot	Ungrazed	0.08
Forb cover (%)	Catchment	Cattle	0.00
Forb cover (%)	Catchment	Bison	0.54
Forb cover (%)	Catchment	Ungrazed	0.14
Forb cover (%)	Plot	Cattle	0.07
Forb cover (%)	Plot	Bison	0.32
Forb cover (%)	Plot	Ungrazed	0.12
Non-native species richness	Catchment	Cattle	0.26
Non-native species richness	Catchment	Bison	0.58
Non-native species richness	Catchment	Ungrazed	0.14
Non-native species richness	Plot	Cattle	0.09
Non-native species richness	Plot	Bison	0.33
Non-native species richness	Plot	Ungrazed	0.02

Table S3. Summary statistics of the linear regressions from 1994 to 2010 for every applicable combination of scale and grazing treatment

Response variable	**Spatial scale**	**Grazing treatment**	**Model r^2**	**Model slope**	**Model p-value**
Dom. Grass cover	Catchment	Ungrazed	0.138	1.024	**<0.001**
Dom. Grass cover	Catchment	Bison	0.552	-1.582	**<0.001**
Dom. Grass cover	Plot	Ungrazed	0.080	1.024	**<0.001**
Dom. Grass cover	Plot	Bison	0.285	-1.582	**<0.001**
Species richness	Catchment	Ungrazed	0.000	0.009	0.920
Species richness	Catchment	Bison	0.630	1.131	**<0.001**
Species richness	Plot	Ungrazed	0.001	-0.016	0.110
Species richness	Plot	Bison	0.454	0.616	**<0.001**
Shannon index (e^H)	Catchment	Ungrazed	0.137	-0.151	**<0.001**
Shannon index (e^H)	Catchment	Bison	0.578	0.584	**<0.001**
Shannon index (e^H)	Plot	Ungrazed	0.086	-0.092	**<0.001**
Shannon index (e^H)	Plot	Bison	0.167	0.207	**<0.001**

Table S3. Summary statistics of ANOVA performed on data from year 29 (2020)

Response variable	Grazing treatment F-Value	P-value
Dominant grass cover (%)	15.8	**0.001**
Species richness	78.9	**<0.001**
Shannon index (e^H)	26.5	**<0.001**
Number of spp. w/ C-score >5	12.8	**0.002**
Forb cover (%)	4.5	**0.044**
Non-native species richness	24.4	**<0.001**

Table S4. Summary statistics of ANCOVA at the plot scale for the year 2020

Factor	Deg. freedom	Sum sq.	Mean sq.	F-value	P-value
Grazing	2	21278	10639	476.0	**<0.001**
Dominant grass cover	1	883	884	39.5	**<0.001**
Grazing * Dominant grass cover	2	118	59	2.6	**0.074**
Residuals	234	5230	22		

Table S5. ANOVA performed for 2019 to 2020

Factor	Response variable	DF	F-value	p-value
Intercept	Dominant grass cover (%)	1	256	**<0.001**
Grazing	Dominant grass cover (%)	2	29	**<0.001**
Year	Dominant grass cover (%)	1	126	**<0.001**
Grazing*Year	Dominant grass cover (%)	2	3	0.066
Intercept	Species richness	1	2092	**<0.001**
Grazing	Species richness	2	85	**<0.001**
Year	Species richness	1	2	0.194
Grazing*Year	Species richness	2	0	0.856
Intercept	Shannon index (e^H)	1	507	**<0.001**
Grazing	Shannon index (e^H)	2	30	**<0.001**
Year	Shannon index (e^H)	1	1	0.229
Grazing*Year	Shannon index (e^H)	2	1	0.532
Intercept	Number of spp. w/ C-score >5	1	11097	**<0.001**
Grazing	Number of spp. w/ C-score >5	2	36	**<0.001**
Year	Number of spp. w/ C-score >5	1	0	0.893
Grazing*Year	Number of spp. w/ C-score >5	2	0	0.816
Intercept	Forb cover (%)	1	2389	**<0.001**
Grazing	Forb cover (%)	2	4	**0.049**
Year	Forb cover (%)	1	11	**0.001**
Grazing*Year	Forb cover (%)	2	1	0.603
Intercept	Non-native species richness	1	110	**<0.001**
Grazing	Non-native species richness	2	25	**<0.001**
Year	Non-native species richness	1	3	0.09
Grazing*Year	Non-native species richness	2	1	0.34

Table S6. Summary statistics of ANCOVA at the plot scale for the year 2019 to 2020

Factor	**Df**	**Sum Sq**	**Mean Sq**	**F value**	**p-value**
Grazing	2	89206	44603	2543	**<0.001**
Dominant grass cover	1	15603	15603	890	**<0.001**
Year	1	10990	10990	627	**<0.001**
Grazing*dominant grass cover	2	1010	505	29	**<0.001**
Grazing*Year	2	14475	7238	413	**<0.001**
Dominant grass cover *Year	1	50	50	3	0.091
Grazing*Dominant grass cover *Year	2	808	404	23	**<0.001**
Residuals	5048	88542	18		

Table S7. Individual species frequencies and between treatment contrasts. Note that the table is sorted by △b-ug values, with N.A. values at the bottom (species which were absent in both the ungrazed and bison treatments).

$f_{i,b}$	$f_{i,ug}$	$f_{i,c}$	△b-ug	△b-c	△c-ug	Family	Genus	Species	Life cycle*	Functional group**
0.30	0.69	0.71	-0.39	-0.41	0.03	Asteraceae	Symphyotrichum	oblongifolium	p	f
0.01	0.35	0.20	-0.34	-0.19	-0.15	Poaceae	Sporobolus	heterolepis	p	g
0.11	0.36	0.08	-0.25	0.03	-0.28	Asclepiadaceae	Asclepias	verticillata	p	f
0.11	0.34	0.16	-0.23	-0.05	-0.18	Asteraceae	Symphyotrichum	sericeum	p	f
0.10	0.30	0.32	-0.20	-0.22	0.02	Solanaceae	Physalis	virginiana	p	f
0.10	0.26	0.07	-0.16	0.03	-0.20	Asclepiadaceae	Asclepias	viridiflora	p	f
0.56	0.71	0.98	-0.15	-0.42	0.27	Cyperaceae	Carex	meadii	p	s
0.08	0.21	0.03	-0.13	0.05	-0.19	Euphorbiaceae	Tragia	betonicifolia	p	f
0.06	0.18	0.17	-0.12	-0.11	-0.01	Asclepiadaceae	Asclepias	stenophylla	p	f
0.06	0.17	0.26	-0.11	-0.20	0.09	Fabaceae	Baptisia	bracteata	p	f
0.00	0.09	0.00	-0.08	0.00	-0.09	Asteraceae	Eupatorium	altissimum	p	f
0.39	0.45	0.44	-0.07	-0.05	-0.02	Poaceae	Panicum	virgatum	p	g
0.23	0.29	0.40	-0.06	-0.16	0.10	Fabaceae	Lespedeza	capitata	p	f
0.00	0.06	0.15	-0.06	-0.15	0.10	Fabaceae	Lespedeza	violacea	p	f
0.93	0.99	0.97	-0.06	-0.05	-0.02	Poaceae	Schizachyrium	scoparium	p	g
0.01	0.05	0.00	-0.05	0.01	-0.05	Onagraceae	Oenothera	glaucifolia	b	f
0.21	0.25	0.58	-0.04	-0.38	0.33	Fabaceae	Dalea	candida	p	f
0.00	0.02	0.01	-0.02	-0.01	-0.01	Asclepiadaceae	Asclepias	tuberosa	p	f
0.00	0.02	0.00	-0.02	0.00	-0.01	Fabaceae	Desmodium	sessilifolium	p	f
0.00	0.03	0.00	-0.02	NA	-0.02	Asclepiadaceae	Asclepias	sullivantii	p	f
0.00	0.01	0.03	-0.01	-0.02	0.02	Fabaceae	Desmodium	illinoense	p	f
0.00	0.02	0.00	-0.01	0.00	-0.02	Asteraceae	Cirsium	altissimum	b	f
0.30	0.31	0.18	-0.01	0.12	-0.13	Rhamnaceae	Ceanothus	herbaceus	p	w
0.00	0.01	0.00	-0.01	NA	-0.01	Lamiaceae	Monarda	fistulosa	a	f
0.03	0.03	0.13	0.00	-0.10	0.10	Violaceae	Viola	pedatifida	p	f
0.01	0.01	0.05	0.00	-0.04	0.03	Asteraceae	Hieracium	longipilum	p	f
0.02	0.01	0.05	0.00	-0.03	0.03	Poaceae	Muhlenbergia	cuspidata	p	g
0.01	0.02	0.04	0.00	-0.02	0.02	Poaceae	Sphenopholis	obtusata	p	g
0.00	0.01	0.03	0.00	-0.02	0.02	Malvaceae	Callirhoe	alcaeoides	p	f
0.00	0.00	0.03	0.00	-0.02	0.02	Poaceae	Agrostis	hyemalis	p	g
0.01	0.01	0.02	0.00	-0.01	0.01	Onagraceae	Oenothera	serrulata	p	f
1.00	1.00	1.00	0.00	0.00	0.00	Poaceae	Andropogon	gerardii	p	g
1.00	1.00	1.00	0.00	0.00	0.00	Poaceae	Sorghastrum	nutans	p	g
0.00	0.00	0.01	0.00	0.00	0.01	Orchidaceae	Spiranthes	vernalis	p	o
0.00	0.00	0.00	0.00	0.00	NA	Brassicaceae	Descurainia	pinnata	a	f
0.00	0.00	0.00	0.00	0.00	NA	Cactaceae	Coryphantha	missouriensis	p	f

0.00	0.00	0.00	0.00	0.00	NA	Euphorbiaceae	Euphorbia	dentata	a	f
0.00	0.00	0.00	0.00	0.00	NA	Polygonaceae	Eolygonum	ramosissimum	a	f
0.00	0.00	0.00	0.00	0.00	NA	Euphorbiaceae	Euphorbia	stictospora	a	f
0.00	0.00	0.00	0.00	0.00	NA	Amaranthaceae	Chenopodium	berlandieri	a	f
0.00	0.00	0.00	0.00	0.00	NA	Lamiaceae	Trichostema	brachiatum	a	f
0.00	0.00	0.00	0.00	0.00	NA	Asteraceae	Dyssodia	papposa	a	f
0.00	0.00	0.00	0.00	0.00	NA	Fabaceae	Desmanthus	illinoensis	p	f
0.00	0.00	0.00	0.00	0.00	NA	Polygonaceae	Polygonum	tenue	a	f
0.00	0.00	0.00	0.00	0.00	NA	Convolvulaceae	Evolvulus	nuttallianus	p	f
0.00	0.00	0.00	0.00	0.00	NA	Orobanchaceae	Agalinis	densiflora	a	f
0.00	0.00	0.00	0.00	0.00	NA	Liliaceae	Allium	stellatum	p	o
0.01	0.01	0.00	0.00	0.01	-0.01	Plantaginaceae	Penstemon	cobaea	p	f
0.01	0.01	0.00	0.00	0.01	-0.01	Solanaceae	Solanum	carolinense	p	f
0.01	0.00	0.00	0.00	0.01	0.00	Onagraceae	Oenothera	villosa	b	f
1.00	1.00	0.98	0.00	0.02	-0.02	Poaceae	Bouteloua	curtipendula	p	g
0.96	0.96	0.88	0.00	0.08	-0.08	Asteraceae	Ambrosia	psilostachya	p	f
0.01	0.00	0.03	0.01	-0.01	0.02	Fabaceae	Vicia	americana	p	f
0.01	0.00	0.00	0.01	0.00	0.00	Plantaginaceae	Plantago	aristata	a	f
0.01	0.00	0.01	0.01	0.00	0.01	Onagraceae	Oenothera	speciosa	p	f
0.01	0.00	0.00	0.01	0.01	0.00	Rubiaceae	Stenaria	nigricans	p	f
0.02	0.01	0.00	0.01	0.01	0.00	Nyctaginaceae	Mirabilis	albida	p	f
0.01	0.00	0.00	0.01	0.01	0.00	Asteraceae	Helianthus	pauciflorus	p	f
0.01	0.00	0.00	0.01	0.01	NA	Orobanchaceae	Agalinis	aspera	a	f
0.01	0.00	0.00	0.01	0.01	NA	Fabaceae	Senna	marilandica	p	f
0.01	0.00	0.00	0.01	0.01	NA	Apiaceae	Sanicula	canadensis	b	f
0.02	0.00	0.16	0.02	-0.14	0.16	Asteraceae	Solidago	speciosa	p	f
0.12	0.10	0.24	0.02	-0.12	0.14	Anacardiaceae	Rhus	glabra	p	w
0.02	0.00	0.01	0.02	0.01	0.01	Asteraceae	Erigeron	annuus	a	f
0.02	0.00	0.00	0.02	0.02	NA	Poaceae	Elymus	virginicus	p	g
0.03	0.00	0.00	0.02	0.02	NA	Apocynaceae	Apocynum	cannabinum	p	f
0.03	0.00	0.00	0.02	0.02	NA	Verbenaceae	Glandularia	bipinnatifida	p	f
0.02	0.00	0.00	0.02	0.02	NA	Onagraceae	Oenothera	curtiflora	a	f
0.03	0.00	0.00	0.02	0.02	NA	Lamiaceae	Teucrium	canadense	p	f
0.02	0.00	0.00	0.02	0.02	NA	Asteraceae	Helianthus	annuus	a	f
0.02	0.00	0.00	0.02	0.02	NA	Asteraceae	Symphyotrichum	laeve	p	f
0.02	0.00	0.00	0.02	0.02	NA	Apiaceae	Chaerophyllum	tainturieri	a	f
0.03	0.00	0.00	0.02	0.02	NA	Asteraceae	Helianthus	maximilianii	p	f
0.03	0.01	0.00	0.02	0.03	-0.01	Cactaceae	Opuntia	macrorhiza	p	f
0.03	0.01	0.00	0.02	0.03	-0.01	Fabaceae	Gleditsia	triacanthos	p	w
0.03	0.00	0.00	0.02	0.03	0.00	Cannabaceae	Ulmus	americana	p	w

0.85	0.83	0.76	0.02	0.09	-0.07	Fabaceae	Amorpha	canescens	p	w
0.03	0.00	0.04	0.03	-0.01	0.04	Oxalidaceae	Oxalis	violacea	p	f
1.00	0.96	1.00	0.03	0.00	0.04	Poaceae	Dichanthelium	oligosanthes	p	g
0.81	0.78	0.82	0.03	0.00	0.04	Lamiaceae	Salvia	azurea	p	f
0.03	0.00	0.00	0.03	0.03	NA	Euphorbiaceae	Euphorbia	marginata	a	f
0.03	0.00	0.00	0.03	0.03	NA	Violaceae	Viola	bicolor	a	f
0.03	0.00	0.00	0.03	0.03	NA	Rosaceae	Geum	canadense	p	f
0.32	0.29	0.03	0.03	0.29	-0.25	Fabaceae	Mimosa	quadrivalvis	p	f
0.98	0.94	1.00	0.04	-0.03	0.06	Asteraceae	Symphyotrichum	ericoides	p	f
1.00	0.96	1.00	0.04	0.00	0.04	Cyperaceae	Carex	inops	p	s
0.09	0.05	0.07	0.04	0.02	0.02	Campanulaceae	Triodanis	perfoliata	a	f
0.06	0.03	0.00	0.04	0.06	-0.02	Violaceae	Hybanthus	verticillatus	p	f
0.08	0.03	0.28	0.05	-0.20	0.26	Poaceae	Dichanthelium	ovale	p	g
0.05	0.00	0.00	0.05	0.05	NA	Fabaceae	Astragalus	plattensis	p	f
0.05	0.00	0.00	0.05	0.05	NA	Fabaceae	Dalea	multiflora	p	f
0.05	0.00	0.00	0.05	0.05	NA	Brassicaceae	Draba	cuneifolia	a	f
0.06	0.00	0.00	0.05	0.06	0.00	Ranunculaceae	Delphinium	carolinianum	p	f
0.15	0.10	0.01	0.05	0.13	-0.09	Fabaceae	Pediomelum	esculentum	p	f
0.06	0.00	0.00	0.06	0.06	NA	Primulaceae	Androsace	occidentalis	a	f
0.12	0.05	0.18	0.07	-0.06	0.13	Santalaceae	Comandra	umbellata	p	f
0.07	0.00	0.00	0.07	0.07	NA	Brassicaceae	Draba	brachycarpa	a	f
0.16	0.10	0.05	0.07	0.11	-0.05	Fabaceae	Baptisia	australis	p	f
0.17	0.10	0.03	0.07	0.14	-0.08	Euphorbiaceae	Euphorbia	glyptosperma	a	f
0.58	0.50	0.73	0.08	-0.15	0.23	Poaceae	Eragrostis	spectabilis	p	g
0.90	0.83	0.99	0.08	-0.09	0.16	Poaceae	Sporobolus	compositus	p	g
0.08	0.00	0.01	0.08	0.07	0.01	Asteraceae	Liatris	punctata	p	f
0.08	0.00	0.00	0.08	0.08	0.00	Malvaceae	Callirhoe	involucrata	p	f
0.20	0.12	0.67	0.09	-0.47	0.55	Iridaceae	Sisyrinchium	campestre	p	o
0.15	0.06	0.25	0.09	-0.09	0.18	Rosaceae	Rosa	arkansana	p	w
0.09	0.00	0.00	0.09	0.09	NA	Onagraceae	Oenothera	macrocarpa	p	f
0.15	0.05	0.10	0.10	0.05	0.05	Fabaceae	pediomelum	tenuiflorum	p	f
0.10	0.00	0.00	0.10	0.10	NA	Poaceae	Paspalum	setaceum	p	g
0.45	0.34	0.67	0.11	-0.22	0.33	Asteraceae	Brickellia	eupatorioides	p	f
0.12	0.00	0.03	0.11	0.08	0.03	Cyperaceae	Carex	gravida	p	s
0.12	0.01	0.00	0.11	0.12	-0.01	Euphorbiaceae	Euphorbia	nutans	a	f
0.13	0.00	0.03	0.13	0.11	0.02	Poaceae	Tridens	flavus	p	g
0.16	0.03	0.08	0.14	0.09	0.05	Caprifoliaceae	Symphoricarpos	orbiculatus	p	w
0.14	0.00	0.03	0.14	0.12	0.02	Euphorbiaceae	Tragia	ramosa	p	f
0.15	0.01	0.01	0.14	0.14	0.00	Campanulaceae	Triodanis	leptocarpa	a	f
0.40	0.26	0.12	0.14	0.28	-0.14	Solanaceae	Physalis	pumila	p	f

0.39	0.24	0.29	0.15	0.10	0.05	Asclepiadaceae	Asclepias	viridis	p	f
0.19	0.03	0.34	0.16	-0.15	0.31	Asteraceae	Packera	plattensis	b	f
0.16	0.00	0.00	0.16	0.16	NA	Euphorbiaceae	Croton	monanthogynus	a	f
0.83	0.66	0.78	0.18	0.05	0.12	Acanthaceae	Ruellia	humilis	p	f
0.18	0.00	0.01	0.18	0.17	0.01	Euphorbiaceae	Euphorbia	maculata	a	f
0.18	0.00	0.00	0.18	0.18	NA	Poaceae	Bouteloua	hirsuta	p	g
0.20	0.01	0.01	0.19	0.19	0.00	Poaceae	Elymus	canadensis	p	g
0.22	0.02	0.41	0.20	-0.19	0.39	Asteraceae	Antennaria	neglecta	p	f
0.55	0.35	0.67	0.20	-0.12	0.31	Fabaceae	Dalea	purpurea	p	f
0.24	0.05	0.00	0.20	0.24	-0.04	Apiaceae	Lomatium	foeniculaceum	p	f
0.23	0.01	0.00	0.21	0.22	-0.01	Asteraceae	Echinacea	angustifolia	p	f
0.22	0.00	0.00	0.22	0.22	NA	Asteraceae	Grindelia	squarrosa	b	f
0.24	0.01	0.11	0.23	0.13	0.10	Asteraceae	Solidago	altissima	p	f
0.23	0.00	0.01	0.23	0.22	0.01	Fabaceae	Astragalus	crassicarpus	p	f
0.23	0.00	0.01	0.23	0.22	0.01	Poaceae	Digitaria	cognata	p	g
0.32	0.08	0.40	0.24	-0.08	0.32	Cyperaceae	Carex	brevior	p	s
0.67	0.42	0.94	0.25	-0.27	0.52	Asteraceae	Solidago	missouriensis	p	f
0.48	0.22	0.35	0.25	0.12	0.13	Cyperaceae	Cyperus	lupulinus	p	s
0.25	0.00	0.05	0.25	0.20	0.05	Asteraceae	Conyza	canadensis	a	f
0.25	0.00	0.00	0.25	0.25	NA	Plantaginaceae	Plantago	rhodosperma	a	f
0.27	0.00	0.00	0.27	0.27	NA	Asteraceae	Ambrosia	artemisiifolia	a	f
0.82	0.53	1.00	0.29	-0.18	0.47	Poaceae	Koeleria	macrantha	p	g
0.33	0.00	0.00	0.32	0.32	NA	Poaceae	Sporobolus	cryptandrus	p	g
0.41	0.07	0.17	0.34	0.24	0.10	Caryophyllaceae	Silene	antirrhina	a	f
0.37	0.02	0.21	0.35	0.16	0.19	Boraginaceae	Lithospermum	incisum	p	f
0.41	0.03	0.01	0.39	0.40	-0.01	Euphorbiaceae	Euphorbia	spathulata	a	f
0.80	0.41	0.75	0.40	0.06	0.34	Asteraceae	Vernonia	baldwinii	p	f
0.41	0.00	0.03	0.41	0.38	0.02	Poaceae	Bouteloua	dactyloides	p	g
0.95	0.54	0.39	0.42	0.57	-0.15	Asteraceae	Artemisia	ludoviciana	p	f
0.43	0.00	0.00	0.43	0.42	0.00	Brassicaceae	Draba	reptans	a	f
0.45	0.00	0.00	0.45	0.45	NA	Poaceae	Chloris	verticillata	p	g
0.61	0.16	0.03	0.45	0.57	-0.13	Poaceae	Bouteloua	gracilis	p	g
0.61	0.15	0.38	0.46	0.22	0.24	Asteraceae	Achillea	millefolium	p	f
0.52	0.00	0.03	0.52	0.50	0.02	Asteraceae	Hymenopappus	scabiosaeus	b	f
0.55	0.02	0.07	0.54	0.49	0.05	Apiaceae	Spermolepis	inermis	a	f
0.61	0.05	0.53	0.56	0.09	0.48	Asteraceae	Ratibida	columnifera	p	f
0.71	0.15	0.46	0.56	0.25	0.31	Linaceae	Linum	sulcatum	a	f
0.69	0.13	0.28	0.56	0.40	0.15	Asteraceae	Cirsium	undulatum	p	f
0.58	0.00	0.05	0.58	0.53	0.05	Verbenaceae	Verbena	stricta	p	f
0.63	0.00	0.00	0.63	0.63	NA	Poaceae	Schedonnardus	paniculatus	p	g

0.69	0.00	0.02	0.69	0.68	0.02	Lamiaceae	Hedeoma	hispida	a	f
0.75	0.06	0.36	0.70	0.40	0.30	Oxalidaceae	Oxalis	dillenii	p	f
0.82	0.11	0.65	0.71	0.17	0.54	Asteraceae	Erigeron	strigosus	a	f
0.74	0.02	0.13	0.72	0.60	0.11	Poaceae	Vulpia	octoflora	a	g
0.77	0.00	0.00	0.77	0.77	NA	Poaceae	Sporobolus	vaginiflorus	a	g
0.80	0.01	0.32	0.79	0.47	0.31	Cyperaceae	Carex	austrina	p	s
0.79	0.00	0.03	0.79	0.75	0.03	Poaceae	Hordeum	pusillum	a	g
0.82	0.00	0.02	0.82	0.80	0.02	Plantaginaceae	Plantago	patagonica	a	f
0.93	0.02	0.38	0.92	0.55	0.36	Asteraceae	Solidago	rigida	p	f
0.00	0.00	0.09	NA	-0.09	0.09	Cornaceae	Cornus	drummondii	p	w
0.00	0.00	0.03	NA	-0.02	0.02	Asclepiadaceae	Asclepias	lanuginosa	p	f
0.00	0.00	0.01	NA	-0.01	0.01	Cyperaceae	Cyperus	x mesochorus	p	s
0.00	0.00	0.01	NA	-0.01	0.01	Ranunculaceae	Anemone	caroliniana	p	f
0.00	0.00	0.01	NA	-0.01	0.01	Asteraceae	Amphiachyris	dracunculoides	a	f
0.00	0.00	0.01	NA	-0.01	0.01	Fabaceae	Lespedeza	X manniana	p	f
0.00	0.00	0.00	NA	0.00	0.00	Asteraceae	Arnoglossum	plantagineum	p	f
0.00	0.00	0.00	NA	0.00	0.00	Juncaceae	Juncus	interior	p	o

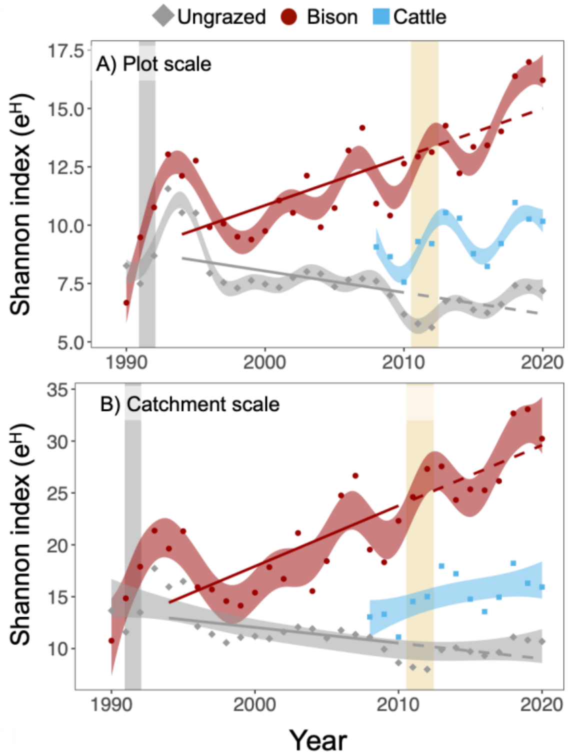

Fig S1. Changes in the exponent of Shannon's index as a function of time (x-axis), scale (different panels), and treatment (different coloring and plot markers). In this graph. All figure conventions follow Fig 2 and 3 in the main text.

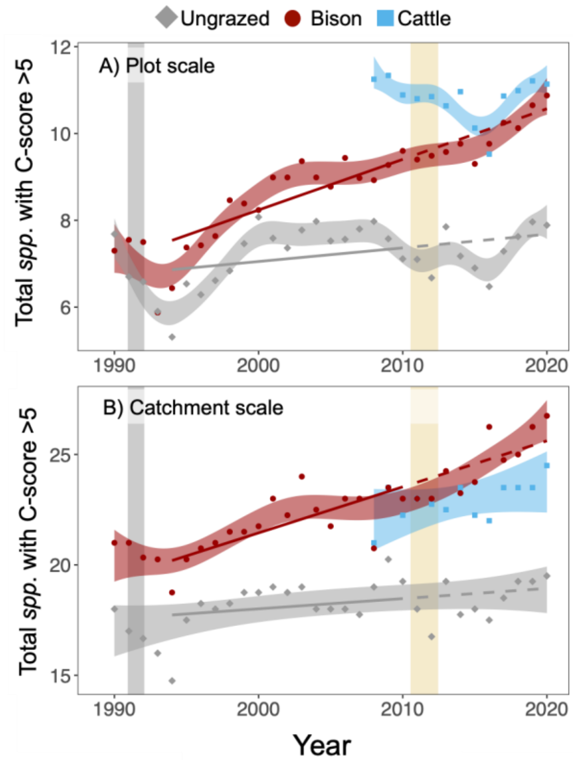

Fig S2. Changes in the total number of species with a coefficient of conservatism greater than five, as a function of time (x-axis), scale (different panels), and treatment (different coloring and plot markers).

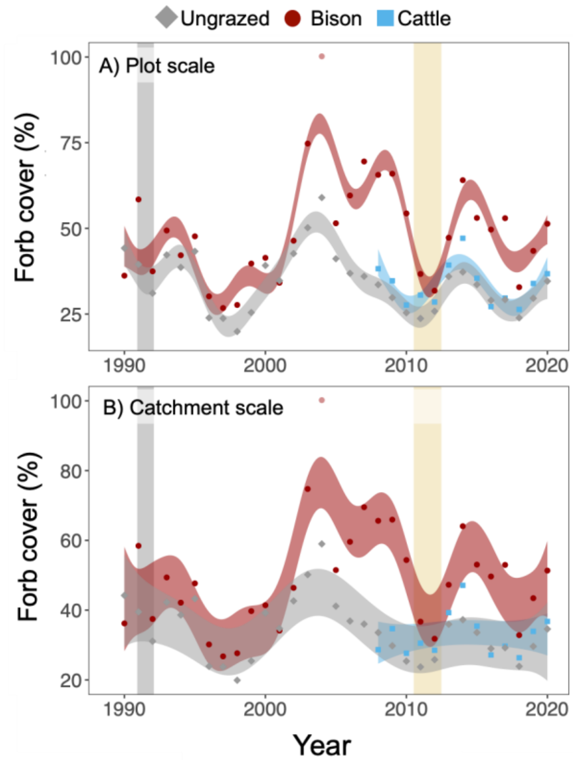

Fig S3. Changes forb cover, as a function of time (x-axis), scale (different panels), and treatment (different coloring and plot markers).

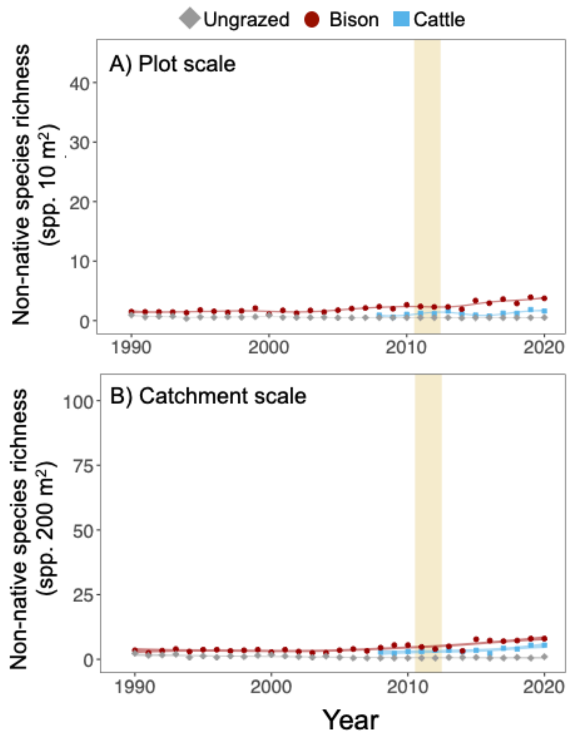

Fig S4. Changes in non-native species richness, as a function of time (x-axis), scale (different panels), and treatment (different coloring and plot markers). Note that the upper limit of the y-axis has been adjusted to be equal to the upper limit of the y-axis for graphs of native species richness (Fig 2).

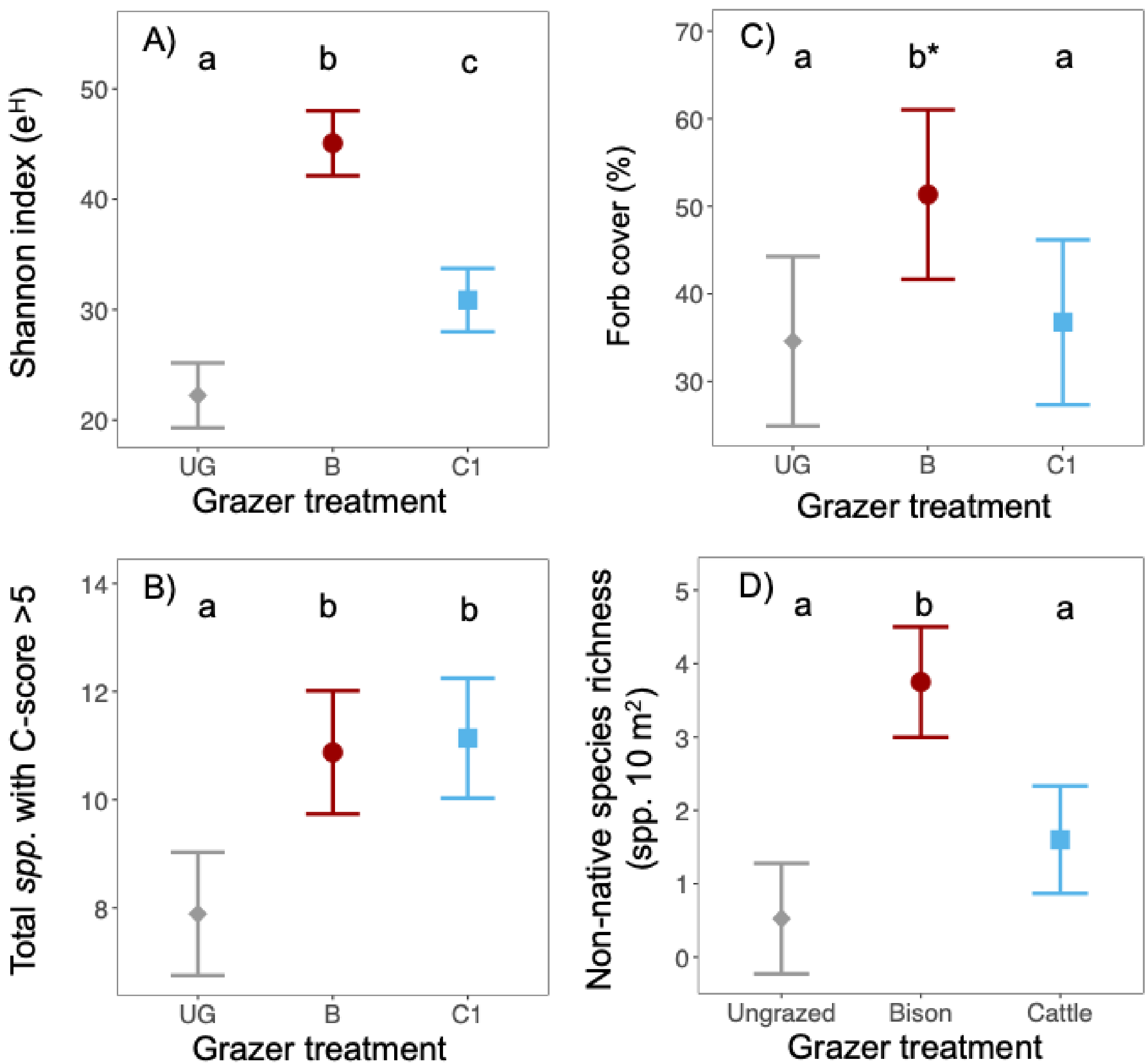

Fig S5. Long-term effects (29 years) of grazing treatments (marker colors) on (A) Shannon index, (B) total species with coefficients of conservatism over 5, (C) forb cover, and (D) non-native species cover. *For forb cover, the difference between the bison treatment and cattle treatment is significant at a p-value of 0.09; the difference between the bison and ungrazed treatment is significant at a p-value of 0.05.

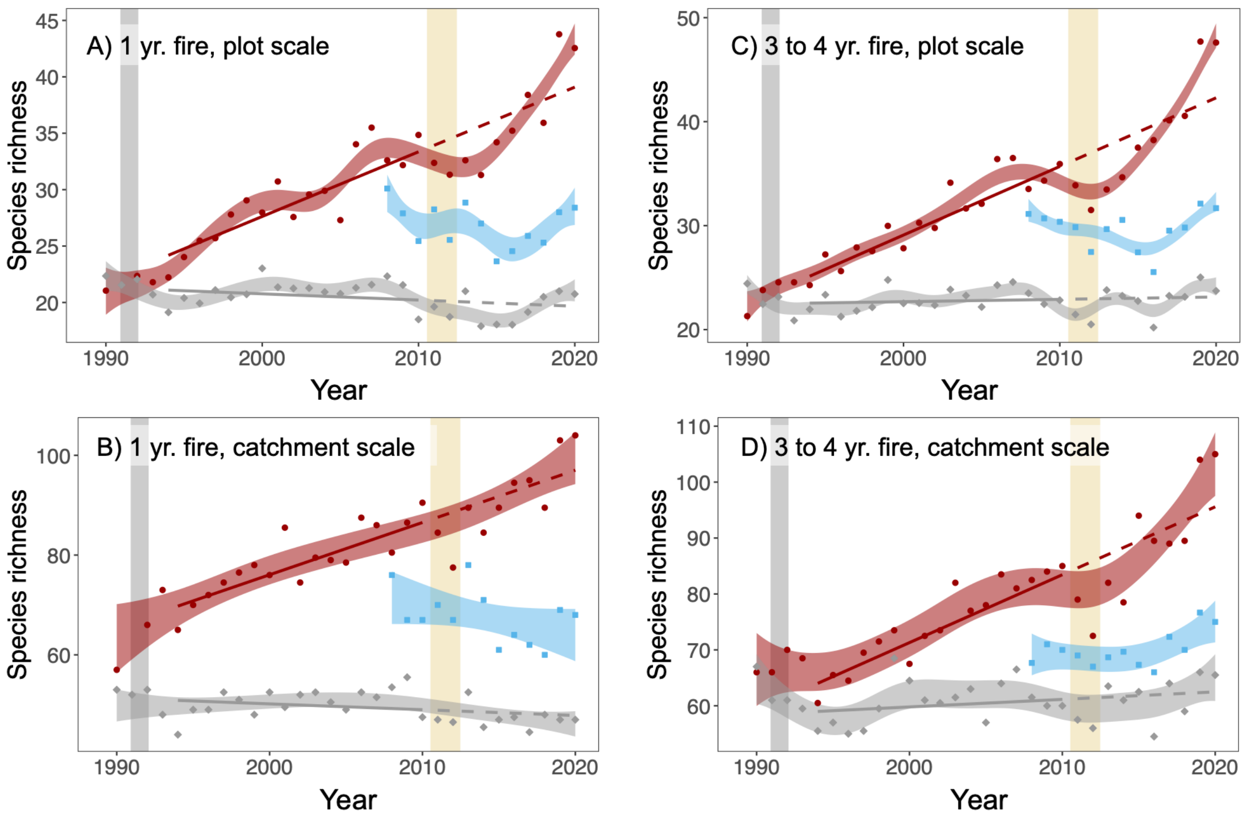

Fig S6. Long-term effects (29 years) of grazing treatments (marker colors) on species richness in watersheds burned annual (A,B) and every three to four years (C,D).

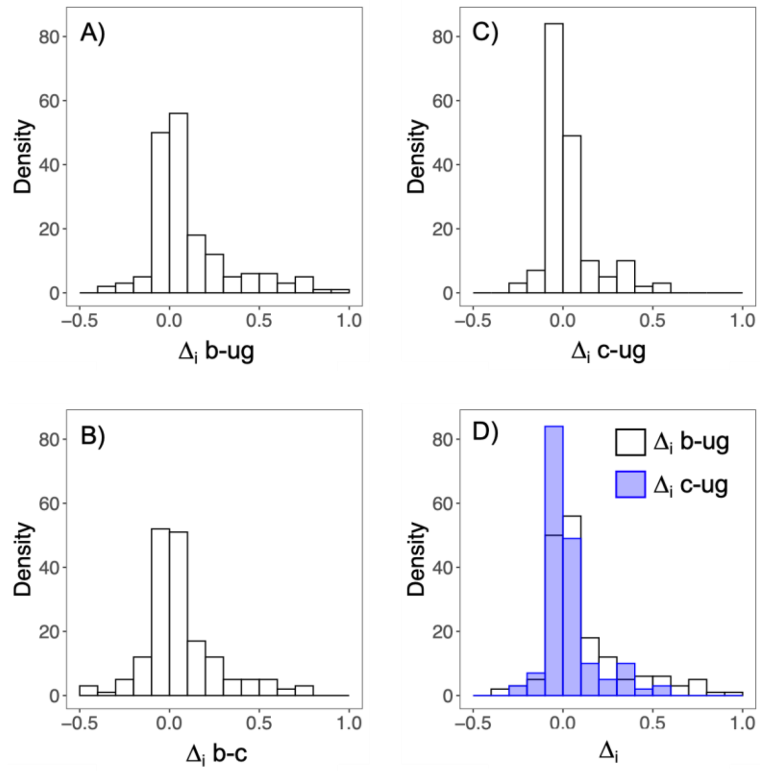

Fig S7. Panels are histograms of species frequency differences between (A) bison and ungrazed, (B) bison and cattle, and (C) cattle and ungrazed. (D) shows differences between bison and ungrazed (white fill) and cattle and ungrazed (blue fill), to facilitate a direct contrast of reintroducing bison versus introducing cattle.