Oikos

OIK-00403

Rebollo, S., Milchunas, D. G., Stapp, P., Augustine, D. J. and Derner, J. D. 2013. Disproportionate effects of non-colonial small herbivores on structure and diversity of grassland dominated by large herbivores. – Oikos 000: 000–000.

Appendix A1

List of plant species, their basal cover (%) in three grazing treatments, and their characteristics used in the grouping of species according to commonness and height. The height of some species (all in the uncommon group) was left unclassified when highly variable due to either treatment or favorable/unfavorable years. Treatment codes: '+L+S' grazed by large and small herbivores (control), '–L+S' ungrazed by large and grazed by small herbivores, and '–L–S' ungrazed by both large and small herbivores.

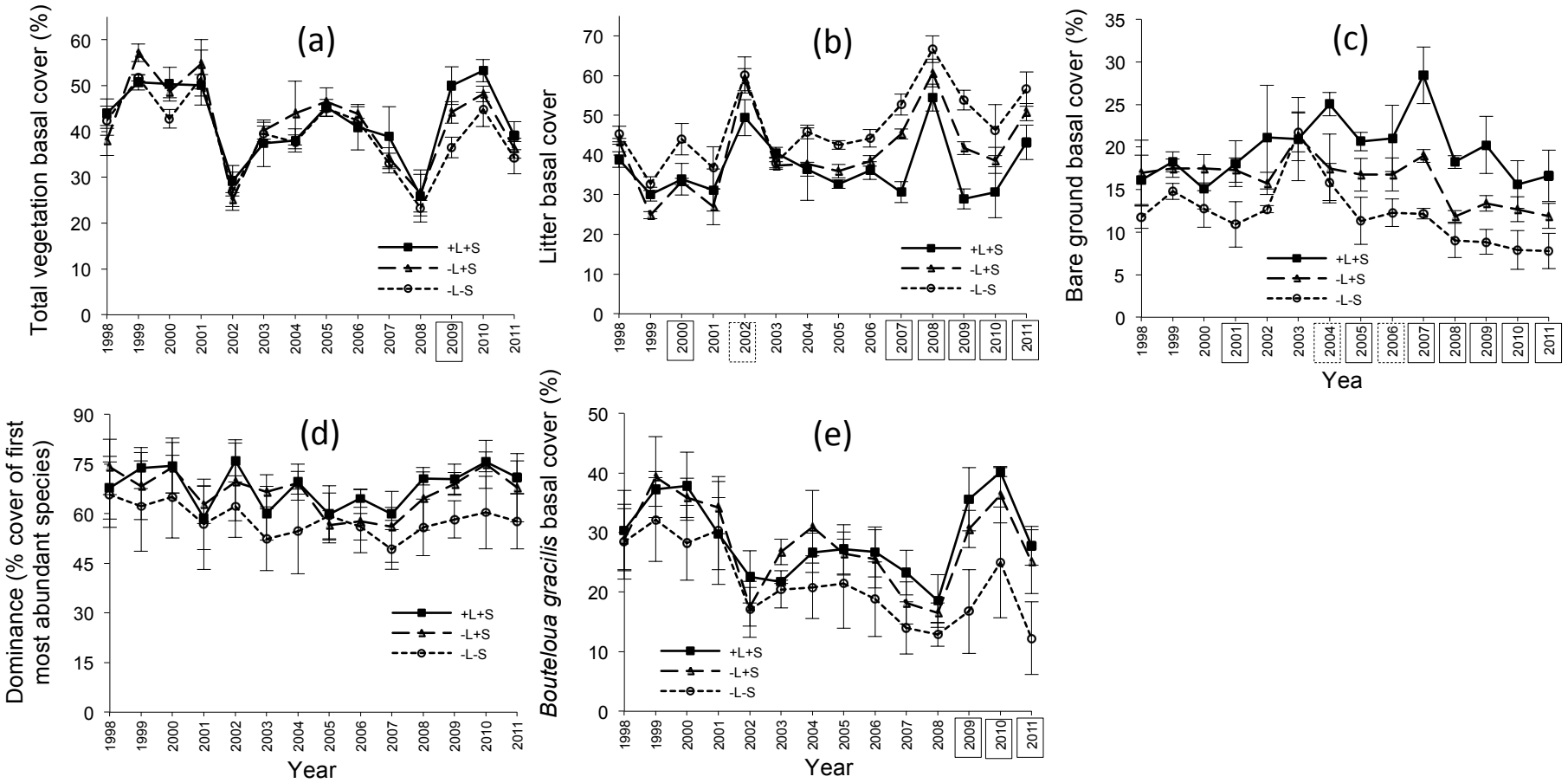
Scientific name	Basal cover in the +L+S treatment	Basal cover in the –L+S treatment	Basal cover in the –L–S treatment	Species commonness (abundant, common and uncommon)	Species height (short, medium, tall and unclassified)
Allium textile A. Nelson & J.F. Macbr.	0.000	0.004	0.003	uncommon	tall
Aristida purpurea Nutt. var. *longiseta* (Steud.) Vasey	1.402	1.300	0.690	abundant	tall
Artemisia dracunculus L.	0.000	0.008	0.000	uncommon	tall
Artemisia frigida Willd.	0.597	1.026	1.072	common	tall
Artemisia ludoviciana Nutt.	0.047	0.009	0.019	uncommon	tall
Astragalus gracilis Nutt.	0.011	0.027	0.035	uncommon	short
Astragalus/Oxytropis sp	0.062	0.143	0.107	uncommon	tall
Atriplex canescens (Pursh) Nutt.	0.060	0.314	0.371	uncommon	tall
Bassia scoparia (L.) A.J. Scott	0.000	0.002	0.000	uncommon	unclassified
Bouteloua dactyloides (Nutt.) J.T. Columbus	2.059	0.398	0.193	abundant	short
Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	29.040	28.227	22.033	abundant	short
Bromus tectorum L.	0.000	0.000	0.001	uncommon	tall

Carex duriuscula C.A. Mey.	2.655	1.470	2.367	abundant	short
Chamaesyce glyptosperma (Engelm.) Small	0.054	0.041	0.023	uncommon	short
Chenopodium album L.	0.329	0.315	0.134	common	short
Chenopodium incanum (S. Watson) A. Heller	0.000	0.004	0.002	uncommon	unclassified
Chenopodium leptophyllum (Moq.) Nutt. ex S. Watson	0.129	0.169	0.279	common	short
Chrysopsis villosa (Pursh) Nutt.	0.000	0.018	0.065	uncommon	short
Chrysothamnus nauseosus (Pall. ex Pursh) Britton var. *nauseosus*	0.025	0.119	0.138	uncommon	tall
Cirsium undulatum (Nutt.) Spreng.	0.000	0.002	0.000	uncommon	tall
Cleome serrulata Pursh	0.000	0.002	0.000	uncommon	unclassified
Conyza canadensis (L.) Cronquist	0.004	0.035	0.095	uncommon	tall
Coryphantha vivipara (Nutt.) Britton & Rose	0.004	0.004	0.001	uncommon	short
Cryptantha jamesii (Torr.) Payson	0.011	0.006	0.004	uncommon	tall
Cryptantha minima Rydb.	0.139	0.034	0.020	common	tall
Descurainia pinnata (Walter) Britton	0.006	0.004	0.003	uncommon	tall
Eriogonum effusum Nutt.	0.111	0.369	0.927	common	tall
Evolvulus nuttallianus Schult.	0.000	0.011	0.000	uncommon	unclassified
Gaura coccinea Nutt. ex Pursh	0.032	0.024	0.017	uncommon	medium
Gutierrezia sarothrae (Pursh) Britton & Rusby	0.066	0.072	0.028	uncommon	tall
Haplopappus spinulosus (Pursh) DC.	0.000	0.000	0.003	uncommon	unclassified
Helianthus annuus L.	0.000	0.004	0.001	uncommon	tall
Helianthus petiolaris Nutt.	0.000	0.034	0.036	uncommon	tall
Ipomopsis laxiflora (J.M. Coult.) V.E. Grant	0.006	0.012	0.012	uncommon	short
Iva axillaris Pursh	0.000	0.002	0.000	uncommon	unclassified
Krascheninnikovia lanata (Pursh) A. Meeuse & Smit	0.061	0.244	0.089	uncommon	tall
Lappula redowskii (Hornem.) Greene	0.035	0.017	0.035	uncommon	tall
Lepidium densiflorum Schrad.	0.282	0.455	0.350	common	tall
Leucocrinum montanum Nutt. ex A. Gray	0.000	0.000	0.006	uncommon	unclassified
Liatris punctata Hook.	0.005	0.004	0.010	uncommon	tall
Lithospermum incisum Lehm.	0.010	0.003	0.025	uncommon	medium
Lygodesmia juncea (Pursh) D. Don ex Hook.	0.002	0.015	0.033	uncommon	tall
Machaeranthera tanacetifolia (Kunth) Nees	0.012	0.023	0.035	uncommon	tall
Mirabilis linearis (Pursh) Heimerl	0.029	0.027	0.013	uncommon	medium
Muhlenbergia torreyi (Kunth) Hitchc. ex Bush	0.072	0.018	0.003	uncommon	short
Oenothera albicaulis Pursh	0.010	0.065	0.037	uncommon	tall
Opuntia polyacantha Haw.	0.672	1.211	1.549	common	tall
Oryzopsis hymenoides (Roem. & Schult.) Ricker ex Piper	0.000	0.000	0.024	uncommon	tall
Pascopyrum smithii (Rydb.) Á. Löve	0.537	1.089	1.074	common	tall
Penstemon angustifolius Nutt. ex Pursh	0.009	0.000	0.003	uncommon	unclassified
Phemeranthus parviflorus (Nutt.) Kiger	0.004	0.000	0.005	uncommon	short
Picradeniopsis oppositifolia (Nutt.) Rydb. ex Britton	0.059	0.075	0.059	uncommon	tall
Plantago patagonica Jacq.	0.178	0.099	0.057	common	short
Portulaca oleracea L.	0.002	0.003	0.000	uncommon	short
Psoralidium tenuiflorum (Pursh) Rydb.	0.013	0.006	0.001	uncommon	tall
Salsola tragus L.	0.025	0.070	0.065	uncommon	medium
Schedonnardus paniculatus (Nutt.) Trel.	0.036	0.019	0.000	uncommon	tall

Scutellaria brittonii Porter	0.002	0.000	0.000	uncommon	unclassified
Sitanion hystrix (Nutt.) J.G. Sm.	0.531	0.646	0.475	cmmon	tall
Solanum triflorum Nutt.	0.002	0.000	0.000	uncommon	unclassified
Sophora nuttalliana B.L. Turner	0.007	0.008	0.005	uncommon	unclassified
Sphaeralcea coccinea (Nutt.) Rydb.	1.986	2.015	2.343	abundant	short
Sporobolus cryptandrus (Torr.) A. Gray	0.424	0.258	0.261	common	tall
Stipa comata Trin. & Rupr.	0.329	1.542	3.973	common	tall
Thelesperma filifolium (Hook.) A. Gray	0.007	0.054	0.017	uncommon	tall
Tragopogon dubius Scop.	0.000	0.002	0.093	uncommon	tall
Unknown forb	0.018	0.016	0.038	uncommon	unclassified
Viola nuttallii Pursh	0.000	0.003	0.000	uncommon	unclassified
Vulpia octoflora (Walter) Rydb.	0.385	0.211	0.451	common	short
Yucca glauca Nutt.	0.030	0.002	0.063	uncommon	tall

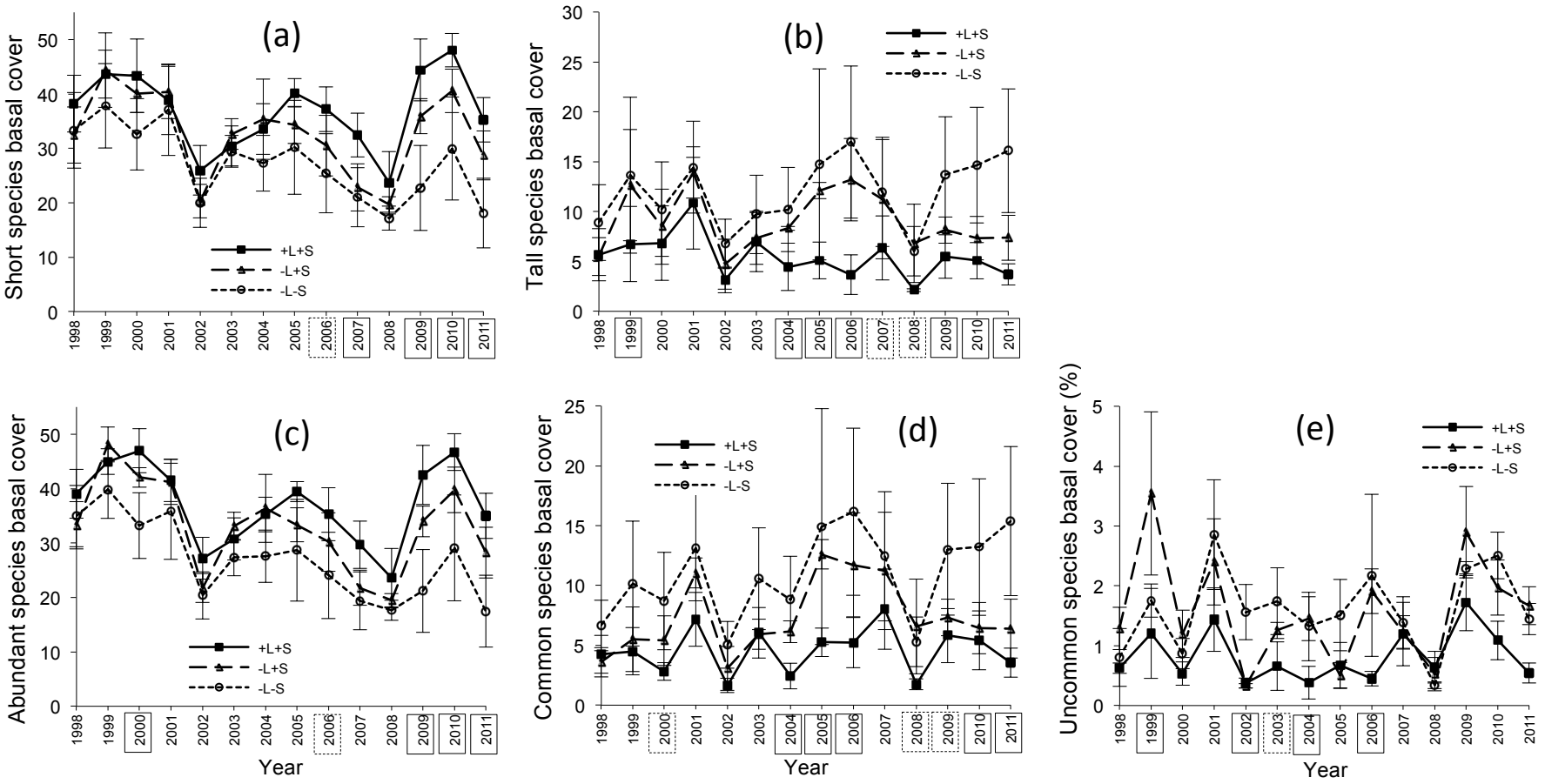
Appendix A2

(a) Total vegetation, (b) litter, (c) bare ground, (d) dominance, and (e) Bouteloua gracilis basal cover (% of total), except dominance (% of total vegetative cover of the first most abundant species) over 14 years and three grazing treatments for the year by grazing interaction: +L+S grazed by large and small herbivores (control), –L+S ungrazed by large and grazed by small herbivores, and –L–S ungrazed by both large and small herbivores. Error bars are ±1 SE. Individual years with a significant effect of grazing are indicated with a box around the year, with solid = ($p < 0.05$) and dashed = ($0.05 < p < 0.1$).



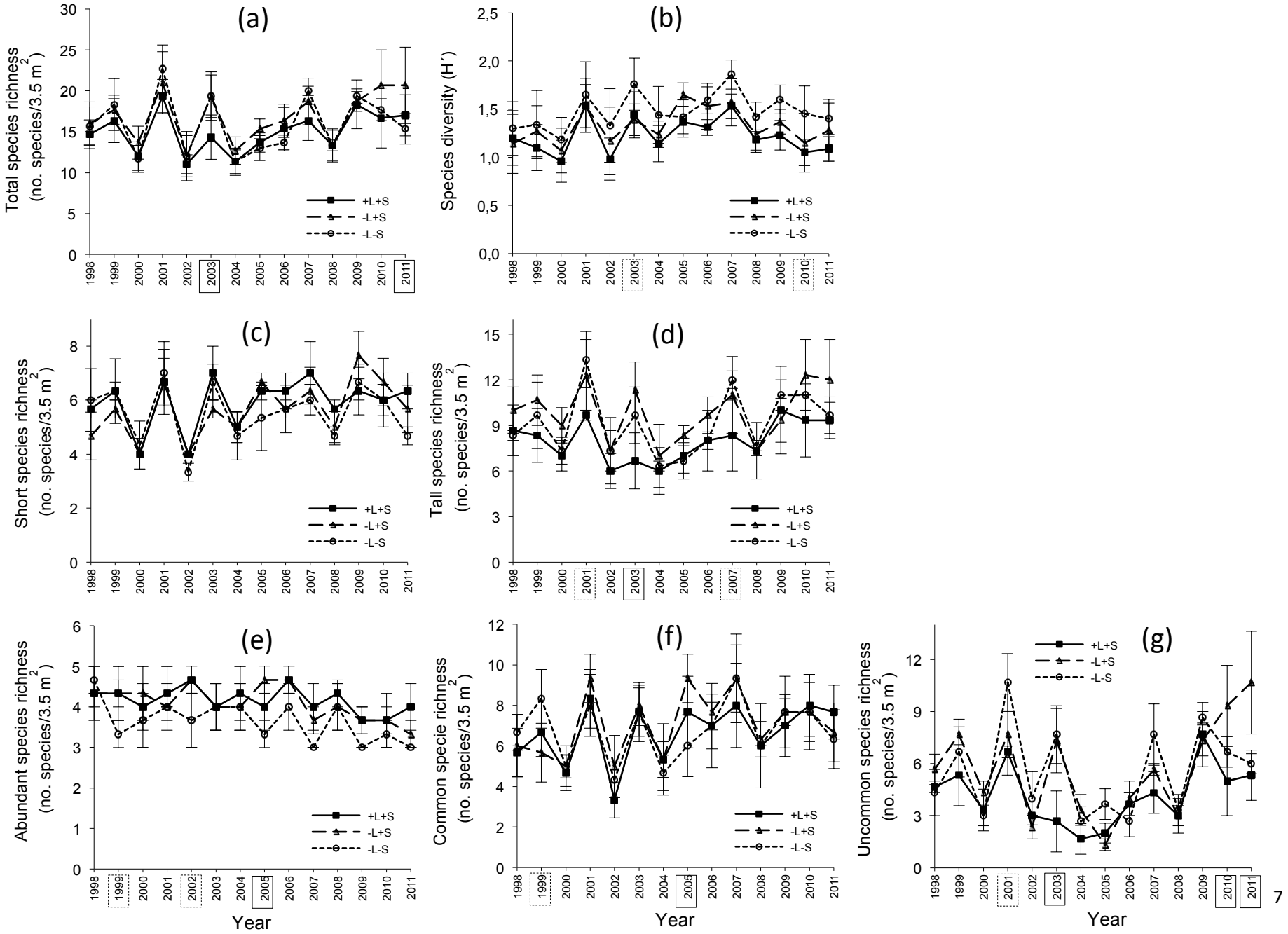
Appendix A3

(a) short (b) tall, (c) abundant, (d) common, and (e) uncommon species basal cover (% of total) over 14 years and three grazing treatments for the year by grazing interaction: +L+S grazed by large and small herbivores (control), –L+S ungrazed by large and grazed by small herbivores, and –L–S ungrazed by both large and small herbivores. Error bars are ±1 SE. Indvidual years with a significant effect of grazing are indicated with a box around the year, with solid = ($p < 0.05$) and dashed = ($0.05 < p < 0.1$).



Appendix A4

(a) total species richness, (b) species diversity, and (c) short, (d) tall, (e) abundant, (f) common, and (g) uncommon species richness (no. species/3.5 m^2 except species diversity –exp. *H'* Shannon and Weaver 1949) over 14 years and three grazing treatments: +L+S grazed by large and small herbivores (control), –L+S ungrazed by large and grazed by small herbivores, and –L–S ungrazed by both large and small herbivores. Error bars are ±1 SE. Individual years with a significant effect of grazing are indicated with a box around the year, with solid = ($p < 0.05$) and dashed = ($0.05 < p < 0.1$).


(a)
Total species richness (no. species/3.5 m2)
(b)
Species diversity (H´)
(c)
Short species richness (no. species/3.5 m2)
(d)
Tall species richness (no. species/3.5 m2)
(e)
Abundant species richness (no. species/3.5 m2)
(f)
Common specie richness (no. species/3.5 m2)
(g)
Uncommon species richness (no. species/3.5 m2)
+L+S
-L+S
-L-S
Year

Appendix A5

Total species richness (no. of species) in the grazed control, large herbivore exclosure, and large-plus-small herbivore exclosure by sampling Daubenmire quadrats (35 quadrats randomly distributed, a total of 3.5 m^2) and contiguous large species–area plots (a total of 28.26 m^2) in a wet (2001) and a dry (2002) year. Values of the Daubenmire quadrats are from the present study (Supplementary material Appendix A4a) and values of the large species-area plots are from Milchunas (2011) (Table 1 of that study). Based on sampling shortly after initiating treatments at the same experimental sites, Bakker et al. (2006, sampling in 2001) and Milchunas (2011, sampling in both years) found significantly greater species richness in the small herbivore exclosures due to richness of less abundant species. However, the Daubenmire sampling used in the present study detected even more species in two out of three grazing treatments than the large species-area plot sampling. This means that sampling a large number of non-contiguous and randomly distributed small quadrats can be a more efficient estimate of species richness than sampling larger contiguous areas in this particular plant community. It is important to note that all studies found a greater total species richness and richness of uncommon species in the large-plus-small herbivore exclosures in 2001 and 2002 compared to the other grazing treatments (Supplementary material Appendix A3a and A3g), but that pattern was not consistent over the 14 years sampled here. Many factors could contribute to this weak long-term effect of small herbivores on richness of uncommon species. Our results show a constant increase of litter cover over time (and a constant decrease of bare soil) in the small herbivore exclosures that could limit germination of less common species. Changes in density of small mammals could also play an important role as rodents and rabbits usually show rapid changes in density and population cycles in these semiarid environments.

Type of sampling	Wet year			Dry year		
	Grazed control	Large herbivore exclosure	Large-plus-small herbivore exclosure	Grazed control	Large herbivore exclosure	Large-plus-small herbivore exclosure
Daubenmire quadrats (3.5 m^2)	19.3	21.0	22.7	11.0	12.0	12.0
Large species-area plot (28.26 m^2)	14.5	16.5	26.0	7.8	9.8	13.2