

Supplemental Material

Abella SR, Chiquoine LP. The good with the bad: when ecological restoration facilitates native and non-native species. Restoration Ecology.

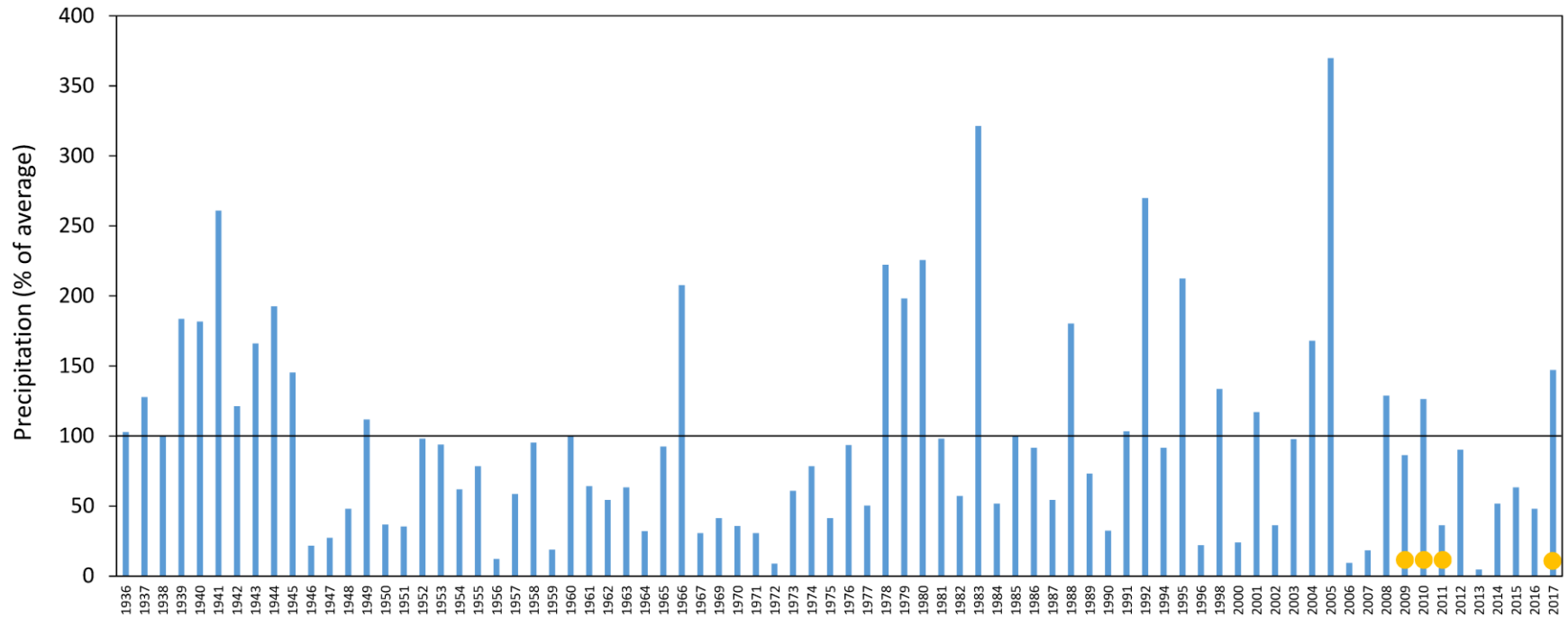


Figure S1. Growing season precipitation (November through April) for winter annual plants, shown according to hydrological year expressed as the percent of the long-term average of 5.38 cm/year for November through April. Years represent January through April of that calendar year plus November-December precipitation of the previous calendar year. Dots symbolize sampling years after the completion of restoration activities in 2008. Precipitation records are from the Twentynine Palms, California weather station at an elevation of 604 meters (Western Regional Climate Center, Reno, Nevada, U.S.A.). This is lower than elevations of 1,300-1,500 m at our study sites 20 km southwest of Twentynine Palms along Keys View Road in Joshua Tree National Park, California, U.S.A.

Table S1. Native perennial species outplanted on plots during a roadside restoration project in Joshua Tree National Park, California, U.S.A.

Scientific name	Common name	Lifeform	Family
<i>Achnatherum speciosum</i>	desert needlegrass	grass	Poaceae
<i>Atriplex canescens</i>	fourwing saltbush	shrub	Chenopodiaceae
<i>Ephedra nevadensis</i>	Nevada jointfir	shrub	Ephedraceae
<i>Eriogonum fasciculatum</i>	Eastern Mojave buckwheat	shrub	Polygonaceae
<i>Hymenoclea salsola</i>	cheesebush	shrub	Asteraceae
<i>Lycium andersonii</i>	Anderson thornbush	shrub	Solanaceae
<i>Lycium cooperi</i>	peach thorn	shrub	Solanaceae
<i>Pleuraphis rigida</i>	big galleta	grass	Poaceae
<i>Salazaria mexicana</i>	Mexican bladdersage	shrub	Lamiaceae

Table S2. Statistical results for effects of restoration treatments on annual plants at the 40-m², whole-plot scale in Joshua Tree National Park, California, U.S.A. Results are for repeated measures analysis of variance including year (2009, 2010, 2011, or 2017) and treatment (vertical mulching, outplanting, vertical mulching + outplanting, disturbed and unrestored, or undisturbed reference). *P*-values that are < 0.1 are noted in bold at the appropriate level of statistical resolution for interactions or main effects. These statistical results correspond with comparisons of means in Fig. 3 of the paper. Degrees of freedom (numerator, denominator) are as follows: year (Y; 3, 59), treatment (T; 4, 25), and year × treatment (Y × T; 12, 59).

	Year (Y)	Treatment (T)	Y × T	Y	T	Y × T
	<i>F</i> -statistic			<i>P</i> -value		
Figure 3a						
Non-native species/40 m ²	24.05	0.72	0.76	<0.001	0.585	0.690
Figure 3b						
Native species/40 m ²	6.96	9.84	1.08	<0.001	<0.001	0.394
Figure 3c						
Non-native species cover	13.35	12.89	3.19	<0.001	<0.001	0.002
Figure 3d						
Native species cover	1.97	1.07	1.20	0.128	0.394	0.303

Table S3. Statistical results for effects of restoration treatments on annual plants at the microsite scale in Joshua Tree National Park, California, U.S.A. Results are for repeated measures analysis of variance including year (2009, 2010, 2011, or 2017) and microsite (vertical mulch, outplant, or interspace) for the whole-plot restoration treatments of vertical mulch (comparing vertical mulch versus interspace microsites), outplant (comparing outplant versus interspace microsites), and vertical mulch + outplant (comparing vertical mulch, outplant, and interspace microsites). *P*-values that are < 0.1 are noted in bold at the appropriate level of statistical resolution for interactions or main effects. These statistical results correspond with comparisons of means in Fig. 4 of the paper. Degrees of freedom (numerator, denominator) are as follows: Fig. 4a,d within vertical mulch whole-plot treatment: year (3, 192), microsite (1, 10), $Y \times M$ (3, 192); Fig. 4b,e within outplant whole-plot treatment: year (3, 197), microsite (1, 10), $Y \times M$ (3, 197), and Fig. 4c,f within vertical mulch + outplant whole-plot treatment: year (3, 267), microsite (2, 15), $Y \times M$ (6, 267).

	Year (Y)	Microsite (M)	$Y \times M$	Y	M	$Y \times M$
	<i>F</i> -statistic			<i>P</i> -value		
Figure 4a,d vertical mulch treatment						
Non-native species/0.25 m ²	13.39	0.25	2.59	<0.001	0.629	0.054
Native species/0.25 m ²	24.31	0.51	4.07	<0.001	0.490	0.008
Non-native species cover	6.46	3.86	0.32	<0.001	0.078	0.812
Native species cover	5.28	0.00	1.43	0.002	0.992	0.235
Figure 4b,e outplant treatment						
Non-native species/0.25 m ²	18.05	0.04	2.54	<0.001	0.852	0.058
Native species/0.25 m ²	3.04	2.65	9.51	0.030	0.135	<0.001
Non-native species cover	3.63	35.57	2.68	0.014	<0.001	0.048
Native species cover	1.64	0.79	4.24	0.183	0.394	0.006
Figure 4c,f vertical mulch + outplant						
Non-native species/0.25 m ²	19.66	0.08	2.07	<0.001	0.920	0.057
Native species/0.25 m ²	4.05	0.90	7.66	0.008	0.428	<0.001
Non-native species cover	14.76	3.56	1.54	<0.001	0.054	0.165
Native species cover	2.78	0.31	1.32	0.042	0.740	0.245

Table S4. Ratio of percent cover of annual species below outplants (OP), vertical mulch (VM), and natural perennial plants (in undisturbed reference sites [UND]) relative to in interspaces (INT). Data are average ratios by species among years during a restoration project in Joshua Tree National Park, California, U.S.A. The symbol (–) signifies that a species was absent from interspaces and hence no ratio was calculated. The symbol (<) indicates that a species occurred only in interspaces.

	2009	2009	2010	2010	2011	2011	2017	2017	2017
	OP:INT	VM:INT	OP:INT	VM:INT	OP:INT	VM:INT	OP:INT	VM:INT	UND:INT
Non-native									
<i>Bromus</i> spp.	2.6	1.0	4.6	1.7	2.6	1.6	4.1	2.5	3.6
<i>Erodium cicutarium</i>	0.8	1.1	0.3	0.6	0.8	3.8	2.0	0.8	0.4
<i>Schismus arabicus</i>	0.7	0.5	–	–	–	–	2.2	0.5	0.8
<i>Schismus barbatus</i>	–	–	0.8	0.8	<	5.6	–	–	–
<i>Sisymbrium altissimum</i>	–	–	<	0.7	<	0.5	0.7	0.9	<
<i>Sisymbrium irio</i>	–	–	–	–	–	–	5.0	2.4	0.5
<i>Sisymbrium orientale</i>	<	<	–	–	–	–	–	–	–
Native									
<i>Ambrosia acanthicarpa</i>	0.3	1.0	0.7	1.3	0.3	1.0	5.4	2.1	<
<i>Amsinckia tessellata</i>	2.6	0.7	9.0	1.2	2.6	0.2	5.0	1.3	1.7
<i>Anisocoma acaulis</i>	<	0.5	–	–	–	–	–	–	–
<i>Antheropeas wallacei</i>	<	<	<	<	<	<	1.4	0.5	<
<i>Centrostegia thurberi</i>	–	–	–	–	<	<	–	–	–
<i>Chaenactis carphoclinia</i>	–	–	0.1	0.3	–	–	2.8	2.3	3.7
<i>Chaenactis fremontii</i>	<	1.5	0.8	0.3	–	–	1.7	0.5	<
<i>Chaenactis</i> spp.	0.5	0.9	–	–	<	<	–	–	–
<i>Chaenactis stevioides</i>	–	–	–	–	<	0.2	0.7	0.2	<
<i>Chorizanthe brevicornu</i>	–	–	–	–	<	<	–	–	–
<i>Cryptantha circumscissa</i>	<	<	–	–	–	–	0.6	0.6	<
<i>Cryptantha pterocarya</i>	3.3	<	<	0.8	<	<	–	–	–
<i>Cryptantha</i> spp.	<	<	–	–	<	<	<	<	<
<i>Draba cuneifolia</i>	–	–	<	<	–	–	–	–	–

<i>Eriastrum diffusum</i>	—	—	<	2.5	<	0.2	2.0	0.6	0.5
<i>Eriogonum deflexum</i>	<	<	—	—	—	—	1.2	0.5	<
<i>Gilia sinuata</i>	—	—	—	—	—	—	1.5	0.6	<
<i>Gilia</i> spp.	0.8	0.7	0.4	0.3	0.5	0.3	2.1	<	<
<i>Layia glandulosa</i>	1.2	0.5	1.1	0.5	<	<	—	—	—
<i>Lepidium lasiocarpum</i>	—	—	<	<	<	<	0.8	0.3	8.9
<i>Leptosiphon aureus</i>	<	<	<	<	0.1	0.5	0.1	0.1	0.4
<i>Malacothrix glabrata</i>	1.5	2.0	2.0	1.5	<	<	1.6	0.6	9.9
<i>Mentzelia albicaulis</i>	<	<	0.1	0.4	<	<	4.8	2.1	15.7
<i>Oxytheca trilobata</i>	—	—	<	<	—	—	—	—	—
<i>Pectocarya heterocarpa</i>	—	—	<	<	—	—	0.1	<	<
<i>Pectocarya setosa</i>	5.0	<	—	—	<	<	—	—	—
<i>Phacelia fremontii</i>	<	<	<	<	—	—	—	—	—
<i>Phacelia vallis-mortae</i>	<	<	—	—	—	—	—	—	—
<i>Plantago patagonica</i>	—	—	<	<	—	—	<	<	<
<i>Salvia columbariae</i>	—	—	—	—	<	<	—	—	—