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3 **Native plant community response to alien plant invasion and**
4 **removal**

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6 **Running title:** *Vegetation response to plant invasion and removal*

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22 Exotic plants, impact, management, meta-analysis, plant abundance, reference plots, restoration, species
23 richness

1 **Resumen**

2 Debido a los impactos ecológicos y socioeconómicos causados por las plantas invasoras, su gestión se ha
3 convertido en un desafío importante y una prioridad para los gestores medioambientales. Para considerar
4 exitosa la eliminación de una planta invasora es necesaria tanto la eliminación efectiva de la planta
5 exótica como la restauración de la comunidad vegetal nativa. Se presenta un marco conceptual basado en
6 datos observacionales y experimentales, que compara sitios invadidos, sitios de referencia (no invadidos y
7 no tratados) y sitios donde se ha eliminado una planta invasora. Mediante un meta-análisis se han
8 evaluado cuantitativamente los impactos de las plantas invasoras y las consecuencias de su eliminación en
9 la comunidad de plantas nativas, en una gran variedad de ecosistemas de todo el mundo. Nuestros
10 resultados confirman que la invasión por plantas exóticas es responsable de una disminución local en la
11 riqueza y abundancia de especies nativas. También demuestran que después de la eliminación, la
12 vegetación nativa tiene el potencial para recuperar su composición histórica y sus funciones. Finalmente,
13 esta revisión bibliográfica ha revelado que las tres comparaciones expuestas rara vez se usan
14 simultáneamente, y que los sitios de referencia apenas se utilizan para evaluar la recuperación de las
15 especies nativas después de la eliminación. A pesar de ello, creemos que el uso de estas comparaciones
16 para evaluar los impactos de la planta invasora y monitorizar las consecuencias de su eliminación es
17 extremadamente útil para asegurar el éxito de las medidas de gestión.

1 **Abstract**

2 Given the potential ecological impacts of invasive species, removal of alien plants has become an
3 important management challenge and a high priority for environmental managers. To consider that a
4 removal effort has been successful requires both, the effective elimination of alien plants and the
5 restoration of the native plant community back to its historical composition and function. We present a
6 conceptual framework based on observational and experimental data that compares invaded, non-invaded
7 and removal sites to quantify invaders' impacts and native plant recover after their removal. We also
8 conducted a meta-analysis to quantitatively evaluate the impacts of plant invaders and the consequences
9 of their removal on the native plant community, across a variety of ecosystems around the world. Our
10 results confirm that invasion by alien plants is responsible for a local decline in native species richness
11 and abundance. Our analysis also provides evidence that after removal, the native vegetation has the
12 potential to recover to a pre-invasion target state. Our review revealed that observational and
13 experimental approaches are rarely used in concert, and that reference sites are scarcely employed to
14 assess native species recovery after removal. However, we believe that comparing invaded, non-invaded
15 and removal sites offer the opportunity to obtain scientific information with relevance for management.

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1 **Introduction**

2 In many parts of the world, some alien plant species are threatening biodiversity by altering native
3 community and ecosystem structure, function and dynamics (Vitousek et al. 1997, Parker et al. 1999,
4 Mack et al. 2000, Ehrenfeld 2010, Powell et al. 2011). In addition, considerable socioeconomic and
5 human welfare impacts have also been reported (Pimentel et al. 2005, Kettunen et al. 2009, Vilà et al.
6 2010). Given these ecological and socioeconomic impacts, management of alien plants has become an
7 important challenge and a high priority for the conservation of native species and natural areas (Zavaleta
8 et al. 2001, Smith et al. 2006, Swab et al. 2008).

9 In many natural areas invaded by alien plants, management practices include the removal of alien plants
10 to reduce their population size or, if possible, to eradicate them (Manchester and Bullock 2000,
11 D'Antonio and Meyerson 2002, Price and Weltzin 2003, Holmes et al. 2005). However, to consider that a
12 removal effort has been successful requires both, the effective elimination of alien plants and the
13 restoration of the native plant species community back to its historical composition and function
14 (Zavaleta et al. 2001, SER 2002, Hulme 2006). In order to effectively control invasions, an assessment of
15 the magnitude of their impacts is also required (Stinson et al. 2007). Thus, a comprehensive
16 understanding of the success of alien plant management, would ideally involve observational and
17 experimental comparative studies between invaded, non-invaded and removal sites, that assess the impacts
18 of the alien plant and the resulting native species assemblage, after its removal.

19 Basically, three different types of comparisons can inform us on the magnitude and direction of changes
20 of the native plant community with invasion or the removal of a particular invasive species (Figure 1).
21 Each comparative approach will provide information about the invasion and the removal success and will
22 give answer to different research questions or hypothesis. So far, there are many observational studies
23 comparing invaded communities to their non-invaded reference counterparts (Levine et al. 2003;
24 Comparison A in Figure 1). This approach has been used to infer alien species impact on the native
25 community such as reduced plant richness or diversity, or reduced seedling recruitment (Gaertner et al.
26 2009). However, it does not demonstrate causality as the observed outcome can be confounded with site
27 differences between invaded and non-invaded plots.

1 Other studies have conducted field removal experiments to eliminate the invader and compare the sites
2 where the invasive species have been removed with invaded (unmanaged) sites (e.g. Ogle et al. 2000,
3 Morrison 2002, Hejda and Pysek 2006, Hulme and Bremner 2006; Comparison B in Figure 1). These
4 comparisons present substantial opportunities for demonstrating the impact of plant invasions on the
5 native community (Díaz et al. 2003). If the invasive species is competing with native species, we expect
6 higher richness in removal sites than in invaded ones, given that the native vegetation would be released
7 from the use of resources by the invader. However, the outcomes of these comparisons can be
8 confounded with short-term, local scale disturbance effects after removal. In general, these studies are
9 purely experimental to test impact and do not have a management perspective because they do not
10 measure the success of the removal effort.

11 Many times removal of alien species alone does not always lead to the reestablishment of the desirable
12 native communities because land-use history, seed bank availability and disturbance regime can all
13 strongly influence the outcome of the removal effort, which might not accomplish the preferred level of
14 recovery (Partel et al. 1998, Zavaleta et al. 2001). Thus, an increasingly common goal of ecosystem
15 restoration is to assess whether removal sites may achieve the high levels of plant species, trait and
16 functional group diversity found in remnant intact sites (Mason and French 2007, Stinson et al. 2007,
17 Truscott et al. 2008). In this sense, the identification of non-invaded and non-managed reference sites and
18 their comparison with removal sites may be crucial to assess the success of the removal effort (Chapman
19 and Underwood 2000; Comparison C in Figure 1). A successful removal strategy would be the one in
20 which vegetation recovers similarly to a reference community in species composition and richness
21 (McCoy and Mushinsky 2002). This type of comparisons can be also valuable to evaluate eventual
22 negative side-effects of removal techniques such as the proliferation of other alien species or soil erosion
23 disturbances (Álvarez and Cushman 2002, Truscott et al. 2008).

24 In this study, we conducted a global literature review to quantitatively evaluate the impacts of invaders
25 and the consequences of their removal on the native plant community, across a variety of ecosystems
26 around the world. The response of the native plant community to removal may be an indicator of the
27 success of the management efforts. We evaluate the magnitude and direction of change of two response
28 variables, native plant species richness and abundance, to alien plant invasion and removal, using a meta-
29 analytical approach (Rosenberg et al. 2000). We focused on native species richness and abundance as

1 indicators of community level response because these are the most commonly used response variables
2 across all reviewed papers. Meta-analysis is a technique of quantitative research synthesis that can
3 provide a more robust method than traditional story-telling or vote-counting literature review. It also
4 provides the opportunity to explore heterogeneity among studies and identify large-scale patterns across
5 species and geographic regions (Steward 2010, Harrison 2011).

6 The framework described in Figure 1 is used as a guide to answer the following questions: (1) Does alien
7 plant invasion decrease native species richness and abundance (Comparison A)? (2) Do alien plant
8 removal increase native species richness and abundance (Comparison B)? and finally, (3) Does removed
9 sites resemble to reference non-invaded sites (Comparison C)?

10 **Methods**

11 **Literature search**

12 To compile quantitative evidence of the response of the recipient plant community to alien plant invasion
13 and removal, we searched for papers on the ISI Web of Knowledge (www.isiwebofknowledge.com)
14 database on July 2009, with no restriction on publication year, using the following search term
15 combinations: (Invasive plant OR non-native plant OR exotic plant OR alien plant) AND (restor* OR
16 removal OR clear* OR success OR response OR rehabilitat*) AND (uninvaded OR non-invaded) OR
17 (impact* OR invasion OR effect). Additional literature was obtained screening the reference lists from all
18 retrieved papers. An initial set of 120 studies was evaluated in order to assess their potential for meeting
19 the selection criteria for inclusion in the review. Studies that did not meet these criteria were omitted. The
20 first criterion was that the focus of the study should be a particular terrestrial or a riparian alien plant
21 species, excluding all papers involving strict aquatic species. Second, we decided to include only studies
22 in which native richness or native abundance (i.e. native cover, native density and native biomass) after
23 invasion or removal was assessed. Studies reporting on other community indicators such as diversity,
24 evenness, non-native richness and abundance, were too scarce for some comparisons. We also rejected
25 articles dealing with total species richness, total diversity or total abundance, because our main goal was
26 to focus on the response of the native community. Finally, for those articles involving alien plant removal,
27 we discarded chemical and biological control managements; therefore, we confined our selection of
28 studies to mechanical or manual removal techniques.

1 **Data extraction**

2 A total of 39 published papers involving 34 taxa met our criteria (Appendix I). Some studies investigated
3 several species, at different sites or at different habitats, what left us with 132 cases for the meta-analysis.
4 Eighty-seven of these cases compared native richness or abundance between non-invaded and invaded
5 sites, 33 between removal and invaded sites and 12 between removal and non-invaded sites.

6 Among the alien plant species evaluated, perennial herbs (45 cases), shrubs (33 cases) and annual grasses
7 (24 cases) were more often represented than the other life-forms. Most of the studies (36%) have been
8 conducted in North America (36%), Europe (33%) and Australia (24%), being Mediterranean (34%) and
9 temperate regions (30%) the most investigated.

10 For each response variable (i.e. native plant species richness and abundance) we recorded sample size
11 (N), mean (\bar{X}) and statistical variation (usually SE or SD) in invaded, non-invaded and removal plots for
12 each study. These data were extracted directly from tables or from graphs using the DATATHIEF II
13 software (B. Thumers; <http://www.datathief.org>) or, in some cases, also by measuring mean and statistical
14 variation 'manually' using a ruler. For other studies, we obtained data directly from the corresponding
15 authors.

16 **Meta-analysis**

17 As a unit of analysis (i.e. the unit for calculation of effect sizes and their variances), we used pairs of plots
18 of the following comparisons: non-invaded versus invaded (Comparison A; Figure 1), invaded versus
19 removal (Comparison B; Figure 1), removal versus non-invaded (Comparison C; Figure 1). For each
20 entry of the dataset we calculated the natural log of the response ratio (Ln R) as a measure of the
21 magnitude and direction of the effect size. Ln R is the ratio of a variable in the experimental (e) group to
22 that of the control (c) group (Rosenberg et al. 2000). From each pair of mean values (\bar{X}) the effect size
23 was calculated as:

$$24 \ln R = \ln \left(\frac{\bar{X}^e}{\bar{X}^c} \right)$$

1 where e is the experimental group and c is the control group (see below for selection of experimental and
2 control groups). The variance of Ln R, V_{LnR} was calculated as:

$$3 \quad v_{\text{Ln R}} = \frac{(s^e)^2}{N^e(\bar{X}^e)^2} + \frac{(s^c)^2}{N^c(\bar{X}^c)^2}$$

4 where S is the pooled standard deviation and N is the number of replicates per treatment.

5 Ln R is a unit-free index which ranges from $-\infty$ to $+\infty$ and estimates the effect size as a proportional
6 change. As in classical statistical analysis, the highest effect sizes are from those studies showing large
7 differences between control (i.e non-invaded) and experimental (i.e. invaded or removal) plots and when
8 there is low variability within plots. Zero Ln R values imply no difference in the variable measured
9 between control and experimental plots; positive and negative Ln R values imply a general trend
10 following treatment (invasion or removal) for an increase and decrease, respectively. Ln R calculations
11 and statistical analysis were conducted with the MetaWin v2.1 Software (Rosenberg et al. 2000).

12 The following effect sizes for native species richness and abundance were calculated:

- 13 • Comparison A: Non-invaded (control) vs. invaded (experimental) plots
- 14 • Comparison B: removal (control) vs. invaded (experimental) plots
- 15 • Comparison C: non-invaded (control) vs. removal (experimental) plots.

16 We tested whether effects sizes across studies were homogeneous, using the Q_{total} statistic based on a chi-
17 squared test. A significant Q_{total} indicates that the variance among effect sizes is greater than that expected
18 by sampling error alone (i.e. effect sizes are not equal across studies).

19 For each grouping category, we calculated the cumulative effect size (R+) and the 95% CI across the
20 sample of studies, with information on the response variable. Data were analysed using random-effects
21 models (P_{random}) which are preferable in ecological data synthesis because their assumptions are more
22 likely to be satisfied (Rosenberg et al. 2000). A cumulative effect size (R+) is considered significant (i.e.
23 no change with invasion or removal) when its 95% CI do not overlap zero. Confidence intervals were
24 calculated using bias-corrected bootstrap resampling procedures (Adams et al. 1997, Rosenberg et al.

1 2000). The mean percentage of change in a response variable was estimated as $(e^{R^+} - 1) \times 100$ (Table 1,
2 Appendix I).

3 4 5 **Results and discussion**

6 In general, across all studies, results were quite homogeneous as indicated by p-values associated to Q_{total} ,
7 higher than 0.5 in most cases (Table 1). Therefore, the magnitude and direction of the effect sizes did not
8 vary significantly across studies, making the generality of the results highly consistent.

9 The meta-analysis revealed an overall significant decline of native species richness and abundance after
10 invasion. Invaded plots had lower native species richness and abundance than usually adjacent reference
11 non-invaded plots (Fig. 2, Table 1). The same trend was found when comparing invaded versus removal
12 plots (Fig. 2, Table 1). On average, invaded plots contained 23% fewer native species than non-native
13 plots and 30% less species than removal plots (Table 1). Invaded plots were 41% less abundant in native
14 species than non-native plots and 30% less abundant than in removal plots (Table 1). For none of the
15 response variables evaluated and none of these comparisons, the CI of the mean effect size overlapped
16 zero (Fig.2). Therefore, our review supports that alien plant species has a negative impact on species
17 richness and abundance by replacing native species in the communities they invade (Vilà et al. 2011).
18 Nonetheless, further research should concentrate on the mechanisms underlying alien plant invasions in
19 order to investigate which are the factors that are ultimately responsible for this decline of native species
20 richness and abundance (Levine et al. 2003).

21 Moreover, the CI for each variable overlapped between Comparison A and B suggesting that the
22 magnitude of the impact is not significantly different between observational and removal studies. That is,
23 whether the control plot is a non-invaded community or a community where the invader has been
24 removed does not have an influence on the magnitude of the impact. This result indicates that although
25 observational studies do not demonstrate causality they can be used as surrogates to test for impact. The
26 extended time frame associated with observational studies counterbalances the logistic and man-power
27 requirements for removal experiments, and the usually short-term monitoring afterwards (Sol et al. 2008).

28 When comparing removal and non-invaded sites we found that after removal, native species richness and
29 abundance reached similar values than in reference non-invaded plots as indicated by R^+ values close to

1 zero and the CI of the mean effect size overlapping zero (Fig. 2, Table 1). The magnitude and direction of
2 the native plant community response following removal indicates that restoration of the vegetation to a
3 pre-invasion state is feasible (Truscott et al. 2008). However, one of the consequences of invasive species
4 removal may be to facilitate the proliferation of other invasive species (Álvarez and Cushman 2002,
5 Ogden and Rejmánek 2005, Hulme and Bremner, 2006, Truscott et al. 2008), and to cause soil and
6 vegetation disturbance (D'Antonio et al., 1998; Zavaleta et al., 2001). Thus, although removal increases
7 species richness bringing the native plant community closer to non-invaded sites, an increase in the
8 occurrence and abundance of another non-native undesired species may also occur and should be
9 assessed. None of these side-effects could have been evaluated in this review because in the vast majority
10 of reviewed papers information about soil and vegetation disturbance was not available and only 3 cases
11 (Holmes et al. 2000, Mason and French, 2007, Blanchard and Holmes 2008) specified non-native richness
12 and abundance in removal and non-invaded reference sites, which resulted in the exclusion of these
13 variables from analysis. Nonetheless, the effective re-establishment of native species, suggested in this
14 review, may increase the resistance of the site to re-invasion or to colonization by other non-native
15 species.

16 Despite the complementarity between the three comparisons they have been rarely used in concert (only 6
17 papers). In fact, we found only 12 cases in the literature, meeting our inclusion criteria, which compared
18 removal sites with non-invaded reference sites. This can be explained by the fact that, unfortunately, non-
19 native species are often so widespread by the time they are noticed that a practical limitation of these
20 comparisons is that such comparable non-invaded sites may be extremely rare or in some cases simply
21 impossible to identify.

22 Since removing invasive species requires tremendous time and effort, the potential costs and benefits of
23 managing invaders should be assessed to better inform management and restoration decisions. Thus, it is
24 imperative to determine which invaders have larger effects and to understand the conditions under which
25 restoration projects are likely to succeed. Post-removal monitoring, on both the target invasive species
26 and the invaded community, is extremely helpful because it allows documenting the success of control
27 and provides the opportunity to restrain negative effects before they become severe (Zavaleta et al. 2001,
28 Andreu et al. 2010). Using removal methods without thoroughly testing their effectiveness and non-target
29 effects can lead to routine implementation of inappropriate techniques. Moreover, it is crucial to evaluate

1 if the native vegetation is recovering in order to be able to determine whether further intervention is
2 necessary such as active post-removal revegetation plans. The extent to which post-removal revegetation
3 is required depends on the biology of the invasive species, the magnitude of the invasion and the length of
4 time that the invasive species have been present (D'Antonio & Meyerson 2002).

5 We think that the conceptual framework presented here (Figure 1) may provide guidance for managers
6 and can optimize restoration success. An holistic approach, based on observational and experimental
7 studies, and that evaluate both, the influence of invaders and the consequences of their removal, should be
8 more frequently used in concert. This approach may allow managers to gain a more complete picture of
9 the magnitude and direction of changes after its control measures, giving them an idea of the impact
10 caused by an invasive species as well as the capacity of the native community to achieve the desired
11 target state. The use this comparative monitoring poses challenges to ecologists in deciding how to
12 choose reference sites, how to select response variables, and how to sample in a way that minimizes the
13 influence of confounding factors (Wilkins et al. 2003).

14 **Conclusions**

15 We have presented a conceptual framework based on observational and experimental data that compare
16 invaded, non-invaded and removal sites to quantify invaders' impacts and native plant recover after their
17 removal. We have quantitatively reviewed the impacts of alien plant invasions on native plant community
18 and its response to their removal. Our results have confirmed that the invasion by alien plants is
19 responsible for a marked local decline in native species richness and abundance, posing significant
20 impacts to the native community. On the other hand, our quantitative approach also provides evidence
21 that after removal, native vegetation has the potential to recover to a pre-invasion target state. Moreover,
22 our review revealed that observational and experimental approaches are rarely used in concert, and that
23 reference sites are scarcely employed to assess native species recovery after removal. Since the success of
24 any alien removal operation depends, ultimately, on this recovery we believe that the comparative
25 approach presented here is crucial because it can empirically answer fundamental ecological questions
26 about how invasions affect native communities. Moreover it might simultaneously demonstrate how well
27 a given removal strategy can achieve specific management goals. Therefore, we suggest that this
28 comparative approach can make restoration efforts involving alien plant species more practical and

1 successful, supporting science-based management decisions for the protection and restoration of
2 biological diversity.

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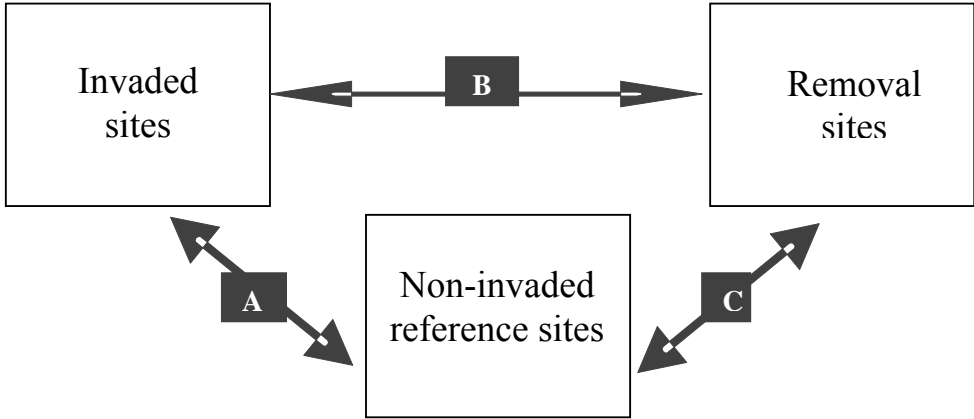
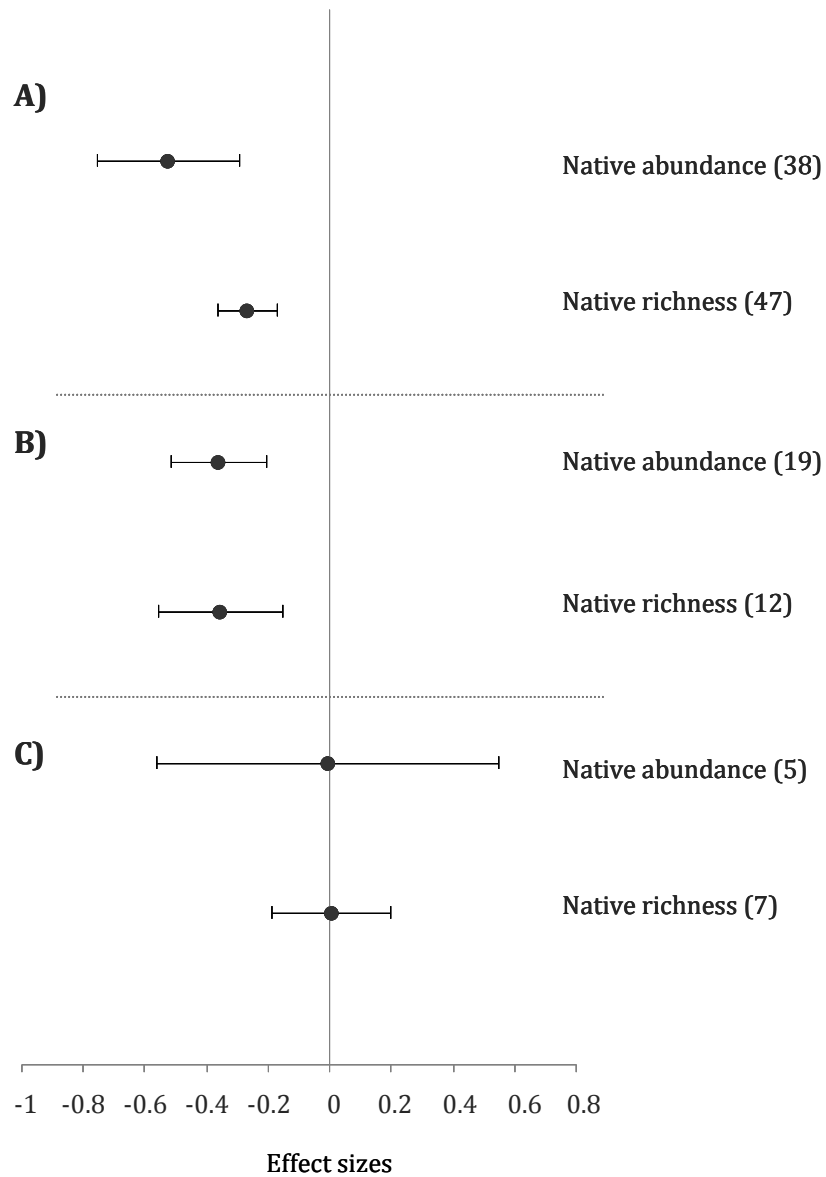


Figure 1: Schematic diagram that summarize the different types of comparison that can be used to assess the impact of an invader and the recovery of the native community after alien plant removal. (A) Observational approach, can provide a potential assessment of impacts (B) Experimental approach, can provide a causal assessment of impact, and (C) Experimental approach, provides an assessment of native community recovery after removal of the invader.

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3 **Figure 2:** Mean effect size (R^+) of differences in native species richness and abundance between A) invaded versus non-invaded, B) invaded versus removal and C) removal versus non-invaded plots. The
4 bars around the means denote bias-corrected 95%-bootstrap confidence intervals. A, B and C correspond
5 to the comparisons indicated in Figure 1. A mean effect size is significantly different from zero when its
6 95% confidence interval do not overlap zero. Positive and negative mean effect sizes indicate,
7 respectively, an increase or decrease of the response variable following treatment (invasion in
8 comparisons A and B, and removal in comparisons C). The sample sizes are given next to each variable.
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1 **Table 1:** Total heterogeneity (Q_t) with indication of P-values, mean effect sizes (R+), degrees of freedom
2 (df) and 95%-CI for each response variable and type of comparison. Significant results of Q_t are in **bold**.
3 The percentage of change of each response variable with invasion or removal is also indicated. See text
4 for a detailed description of statistical analysis.

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Type of comparison	Response variable	Q_t	P-value	R+	df	95%-CI	% of change
Invaded vs. non-invaded	Native richness	73.40	0.008	-0.267	47	-0.363 to -0.171	-23.45
	Native abundance	46.93	0.152	-0.524	38	-0.756 to -0.292	-40.77
Invaded vs. removal	Native richness	9.60	0.651	-0.354	12	-0.557 to -0.152	-29.83
	Native abundance	89.48	0.000	-0.361	19	-0.515 to -0.207	-30.32
Removal vs. non-invaded	Native richness	9.43	0.223	0.005	7	-0.189 to 0.198	0.47
	Native abundance	9.03	0.108	-0.007	5	-0.563 to 0.549	-0.68

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Appendix I

References used to construct the dataset on native plant richness and abundance responses to alien plant invasion and removal.

A) Non-invaded versus invaded comparisons

Species	Life form	Invaded region	Biogeographical region	Invaded habitats	Variable measured	Reference
<i>Agave americana</i>	Shrub	Europe	Mediterranean	Coastal (sand dunes/rocky)	Abundance	Badano and Pugnaire, 2004
<i>Agropyron cristatum</i>	Perennial herb	North America	Temperate	Grassland	Abundance	Henderson and Naeth, 2005
<i>Agrostis stolonifera</i>	Perennial grass	Asia	Temperate	Riparian	Abundance	Gremmen et al., 1998
<i>Ailanthus altissima</i>	Tree	Europe	Mediterranean	Riparian	Richness	Vilà et al., 2006
<i>Asparagus asparagoides</i>	Shrub	Australia	Subtropical	Grassland	Abundance, richness	Turner et al., 2008
<i>Bromus tectorum</i>	Annual grass	North America	Semiarid	Grassland	Abundance	Belnap and Phillips, 2001
<i>Bromus tectorum</i>	Annual grass	North America	Semiarid	Grassland	Abundance	Belnap et al., 2005
<i>Bromus tectorum</i>	Annual grass	North America	Semiarid	Grassland	Abundance	Belnap et al., 2006
<i>Bromus tectorum</i>	Annual grass	North America	Mediterranean	Grassland	Abundance	Blank, 2008
<i>Carpobrotus edulis</i>	Perennial herb	Europe	Mediterranean	Coastal (sand dunes/rocky)	Abundance, richness	Andreu et al., 2009
<i>Carpobrotus spp.</i>	Perennial herb	Europe	Mediterranean	Coastal (sand dunes/rocky)	Richness	Vilà et al., 2006
<i>Chromolaena odorata</i>	Perennial herb	Asia	Subtropical	Forest	Richness	Muralli and Setty, 2001
<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>	Shrub	Australia	Subtropical	Coastal (sand dunes/rocky)	Richness	Mason and French, 2008
<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>	Shrub	Australia	Subtropical	Coastal (sand dunes/rocky)	Richness	Mason et al., 2007.
<i>Cortaderia selloana</i>	Perennial grass	Europe	Mediterranean	Oldfields	Abundance, richness	Domenech and Vilà, 2008
<i>Cytisus scoparius</i>	Shrub	Australia	Temperate	Forest	Richness	Wearne and Morgan, 2004
<i>Delairea odorata</i>	Vine	North America	Mediterranean	Shrubland	Abundance, richness	Alvarez and Cushman, 2002
<i>Heracleum mantegazzianum</i>	Perennial herb	Europe	Temperate	Several habitats	Richness	Pyšek and Pyšek, 1995
<i>Impatiens glandulifera</i>	Annual herb	Europe	Temperate	Riparian	Richness	Hejda and Pyšek, 2006
<i>Lantana camara</i>	Shrub	Asia	Subtropical	Forest	Richness	Muralli and Setty, 2001
<i>Lantana camara</i>	Shrub	Australia	Semi-arid	Forest	Abundance, richness	Gooden et al., 2009
<i>Lonicera tatarica</i>	Shrub	North America	Temperate	Forest	Abundance, richness	Woods, 1993
<i>Lupinus polyphyllus</i>	Perennial herb	Europe	Temperate	Grassland	Abundance, richness	Valtonen et al., 2006
<i>Lythrum salicaria</i>	Perennial herb	North America	Temperate	Grassland	Richness	Treberg and Husband, 1999

<i>Mesembryanthemum crystallinum</i>	Annual herb	Africa	Mediterranean	Coastal (sand dunes/rocky)	Abundance	Vivrette and Muller, 1977
<i>Mimulus guttatus</i>	Perennial herb	Europe	Oceanic	Grassland	Richness	Truscott et al., 2008
<i>Orbea variegata</i>	Perennial herb	Australia	Mediterranean	Shrubland	Abundance, richness	Dunbar and Facelli, 1999
<i>Oxalis pes-caprae</i>	Perennial herb	Europe	Mediterranean	Oldfields	Richness	Vilà et al., 2006
<i>Phragmites australis</i>	Perennial grass	North America	Temperate	Grassland	Abundance, richness	Richburg et al., 2001
<i>Pyracantha angustifolia</i>	Shrub	South America	Subtropical	Shrubland	Richness	Giantomasi et al., 2008
<i>Spartina anglica</i>	Perennial grass	North America	Temperate	Wetland/marshland	Abundance	Hacker and Dethier, 2006
<i>Tradescantia fluminensis</i>	Perennial herb	Pacific islands	Subtropical	Forest	Abundance	Standish et al., 2001

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B) Removal versus invaded comparisons

Species	Life form	Region invaded	Biogeographical region	Invaded habitats	Variable measured	Reference
Annual grasses from the genus <i>Bromus</i>	Annual grass	North America	Subtropical	Desert	Abundance	Brooks, 2000
<i>Bromus tectorum</i>	Annual grass	North America	Temperate	Shrubland	Abundance	Melgoza <i>et al.</i> , 1990
<i>Carpobrotus edulis</i>	Perennial herb	Europe	Mediterranean	Coastal (sand dunes/rocky)	Abundance, richness	Andreu <i>et al.</i> , 2009
<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>	Shrub	Australia	Semi-arid	Coastal (sand dunes/rocky)	Richness	Mason and French, 2008
<i>Delairea odorata</i>	Vine	North America	Mediterranean	Riparian, shrubland	Richness	Alvarez and Cushman, 2002
<i>Impatiens glandulifera</i>	Annual herb	Europe	Temperate	Riparian	Richness	Hejda and Pyšek, 2006
<i>Impatiens glandulifera</i>	Annual herb	Europe	Temperate	Riparian	Richness	Hulme and Bremner, 2006
<i>Lantana camara</i>	Shrub	Australia	Semi-arid	Forest	Abundance, richness	Gooden <i>et al.</i> , 2009
<i>Lespedeza cuneata</i>	Perennial herb	North America	Temperate	Grassland	Abundance	Brandon <i>et al.</i> , 2004
<i>Lupinus arboreus</i>	Shrub	North America	Mediterranean	Shrubland	Abundance	Pickart <i>et al.</i> , 1998
<i>Microstegium vimineum</i>	Annual grass	North America	Temperate	Forest	Abundance, richness	Oswalt <i>et al.</i> , 2007
<i>Microstegium vimineum</i>	Annual grass	North America	Temperate	Forest	Abundance	Flory, 2010
<i>Microstegium vimineum</i>	Annual grass	North America	Temperate	Forest	Abundance, richness	Flory and Clay, 2009
<i>Mimulus guttatus</i>	Perennial herb	Europe	Oceanic	Grassland	Richness	Truscott et al., 2008
<i>Orbea variegata</i>	Perennial herb	Australia	Mediterranean	Shrubland	Abundance, richness	Dunbar and Facelli, 1999
<i>Tamarix</i> spp.	Tree	North America	Temperate	Forest	Abundance, richness	Harms and Hiebert, 2006

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1 C) Non-invaded versus removal comparisons
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Species	Life form	Region invaded	Biogeographical region	Invaded habitats	Variable measured	Reference
<i>Carpobrotus edulis</i>	Perennial herb	Europe	Mediterranean	Coastal (sand dunes/rocky)	Abundance, richness	Andreu <i>et al.</i> , 2009 5
<i>Chrysanthemoides monilifera</i> ssp. <i>rotundata</i>	Shrub	Australia	Semi-arid	Coastal (sand dunes/rocky)	Richness	Mason and French, 2008 6
<i>Lantana camara</i>	Shrub	Australia	Semi-arid	Forest	Abundance, richness	Gooden <i>et al.</i> , 2009
<i>Mimulus guttatus</i>	Perennial herb	Europe	Oceanic	Grassland	Richness	Truscott <i>et al.</i> , 2008 7
<i>Orbea variegata</i>	Perennial herb	Australia	Mediterranean	Shrubland	Richness	Dunbar and Facelli, 1999
<i>Pinus radiata</i> and <i>Hakea sericea</i>	Tree	Africa	Mediterranean	Forest	Abundance, richness	Holmes <i>et al.</i> , 2000 8

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