Appendix S1 ***Supporting tables and figures***

Table S1 Geographic locations, habitat types, and disturbance treatments for 22 experiments conducted across Europe and North America. Complete citations for each study are provided in the references section of the Supporting Information.

Study	Location	Habitat type	Disturbance treatment
Bakker et al. (2003)	Canada - Saskatchewan	prairie grassland - tableland	herbicide
Bakker et al. (2003)	Canada - Saskatchewan	prairie grassland - valley	herbicide
Brudvig et al. (2011)	USA - Iowa	woodland	clipping
Dickson & Foster (2011)	USA - Kansas	old-field grassland	clipping
Eskelinen & Virtanen (2005)	Finland - Lapland	montane snowbed	clipping
Foster & Dickson (2004)	USA - Kansas	old-field grassland	soil disturbance & litter removal
Foster et al. (2004)	USA - Kansas	old-field grassland	soil disturbance, litter removal & clipping
Fraser & Madson (2008)	USA - Ohio	wet meadow	herbivory & granivory
Long et al. (2014)	USA - Kansas	grassland	fire
Maccherini & Santi (2012)	Italy - Tuscany	calcareous grassland	grazing
Maron et al. (2014)	USA - California	coastal-influenced grassland	soil disturbance & biomass removal
Maron et al. (2014)	Germany - Central	semi-dry grassland	soil disturbance & biomass removal
Mayers & Erschbamer (2011)	Austria - Tyrol	Rotmoose fen - ephemeral	horse trampling (simulated)
Mayers & Erschbamer (2011)	Austria - Tyrol	Rotmoose fen - wet	horse trampling (simulated)
Mayers & Erschbamer (2011)	Austria - Tyrol	subalpine grassland	horse trampling (simulated)
Myers & Harms (2009)	USA - Louisiana	longleaf pine savanna	herbicide applied to dominant bunchgrass
Myers & Harms (2009)	USA - Louisiana	longleaf pine savanna	clipping applied to dominant shrub
Myers & Harms (2011)	USA - Louisiana	longleaf pine savanna	fire intensity
Questad & Foster (2008)	USA - Kansas	prairie-forest ecotone	herbicide & soil disturbance
Reynolds et al. (2007)	USA - Michigan	grassland	mowing & herbicide
Suding & Gross (2006)	USA - Michigan	remnant prairie-savanna	fire
Zobel et al. (2000)	Estonia - Hanila	calcareous alvars grassland	biomass removal (36 % of plot area)

Table S2 Mean (unweighted) deviations of observed β-diversity (Jaccard dissimilarity) from two null models. Negative Raup-Crick values indicate treatments where observed β-diversity was lower than would be expected if differences in species richness among local communities (α-diversity) were random with respect to species identities. Positive β-deviation values indicate treatments where observed β-diversity was higher than would be expected if individuals are assigned at random to local communities while preserving the total numbers of individuals in local communities (community size) and the species pool (total species richness and species relative abundance) in each treatment.

β-diversity variable	Number of experiments	Treatment			
		Control	Disturbance	Dispersal	Disturbance & Dispersal
Raup-Crick	22	-0.63	-0.55	-0.51	-0.50
β-deviation	10	6.22	6.79	5.81	5.34

Table S3 Heterogeneity in effect sizes of disturbance, dispersal, disturbance with dispersal on observed β-diversity (Jaccard dissimilarity) and Raup-Crick β-diversity across studies (n = 22 experiments). Raup-Crick β-diversity accounts for differences in observed β-diversity that would be expected if differences in species richness among local communities (α-diversity) were random with respect to species identities. Q (d.f. = 21) is the test statistic for effect size heterogeneity ($P < 0.05$ if significant). Tau^2 is the total amount of variation in effect sizes attributed to both within treatment sampling error and among-study variation. I^2 is the proportion of this variation not due to within treatment sampling variance.

β-diversity variable	Treatment	Q	P-value	Tau^2	I^2
Observed	Disturbance	28.40	0.129	0.06	26.06
	Dispersal	72.31	<0.0001	0.46	70.96
	Disturbance & dispersal	112.92	<0.0001	0.89	81.40
Raup-Crick	Disturbance	64.24	<0.0001	0.39	67.31
	Dispersal	77.17	<0.0001	0.50	72.79
	Disturbance & dispersal	154.32	<0.0001	1.32	86.39

Table S4 Influence of covariates on effect sizes of disturbance, dispersal, disturbance with dispersal on observed β-diversity and Raup-Crick β-diversity across studies (n = 22 experiments). Raup-Crick β-diversity accounts for differences in observed β-diversity that would be expected if differences in species richness among local communities (α-diversity) were random with respect to species identities. The effect sizes and statistical significance of each covariate were estimated from mixed-effects models. Dashes indicate covariates that were not evaluated for particular models, either because heterogeneity in effects were insignificant (-) or the covariate was not relevant to the treatment (N/A). The median plot size was 0.5 m^2 (range = 0.016 – 6.25 m^2), median study length was 32 months (range = 12 – 108 months), the median richness of unmanipulated (control) treatments was 9 species (range = 1 – 32 species), and median richness of seeds added in dispersal treatments was 21 species (range = 4 – 45 species).

β-diversity variable	Covariates	Disturbance		Dispersal		Disturbance & Dispersal	
		Effect size	*P*-value	Effect size	*P*-value	Effect size	*P*-value
Observed	plot size	-	-	0.11	0.403	0.18	0.272
	study length	-	-	-0.02	0.030**	-0.03	0.018**
	latitude	-	-	-0.01	0.910	-0.01	0.620
	disturbance freq.	-	-	N/A	N/A	0.11	0.826
	dispersal freq.	-	-	-0.40	0.279	-0.35	0.460
	seed addition richness	-	-	-0.03	0.042**	-0.02	0.260
Raup-Crick	plot size	0.78	0.376	-0.60	0.669	0.02	0.915
	study length	-0.01	0.992	-0.03	<0.001***	-0.04	0.006**
	latitude	-0.01	0.813	-0.01	0.691	-0.02	0.518
	disturbance freq.	-0.61	0.065*	N/A	N/A	-0.23	0.689
	dispersal freq.	N/A	N/A	-0.58	0.114	-0.63	0.273
	seed addition richness	N/A	N/A	-0.03	0.046**	-0.03	0.213

Signfic. codes: < 0.001 *** < 0.05 ** < 0.10 *.

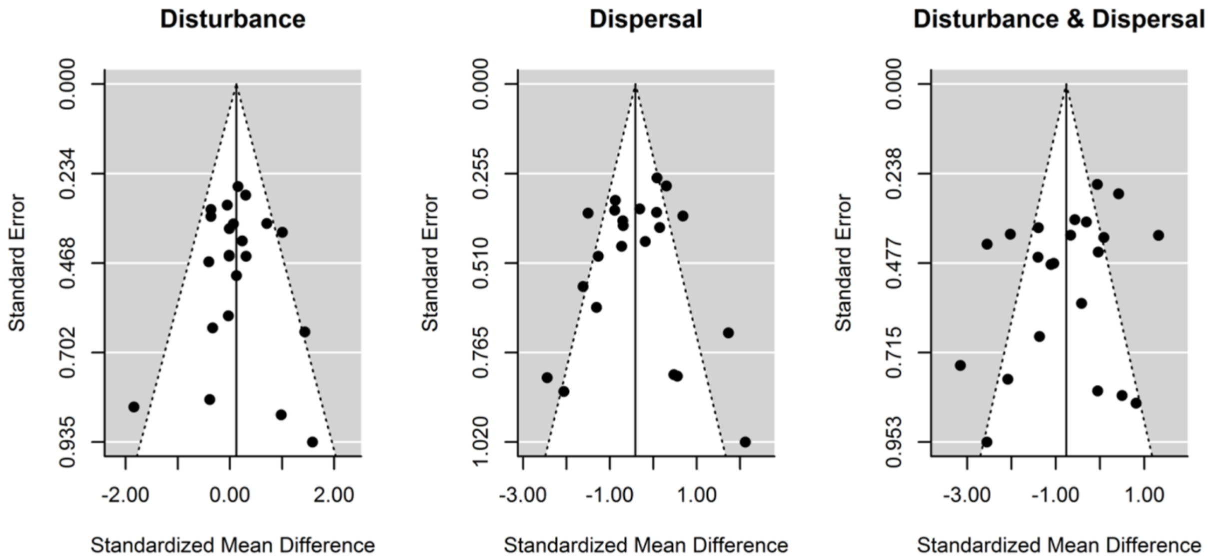

Figure S1 To test for bias in study selection, funnel plots of effect sizes on standard errors for each treatment were constructed using the trim-and-fill method. Funnel plots show no skewness or missing expected effects (which would appear as empty circles). Rank correlation tests for asymmetry were not significant: Disturbance (Kendall's $\tau = 0.03$, $P = 0.87$), Dispersal (Kendall's $\tau = -0.07$, $P = 0.66$), Disturbance & Dispersal (Kendall's $\tau = -0.15$, $P = 0.34$).

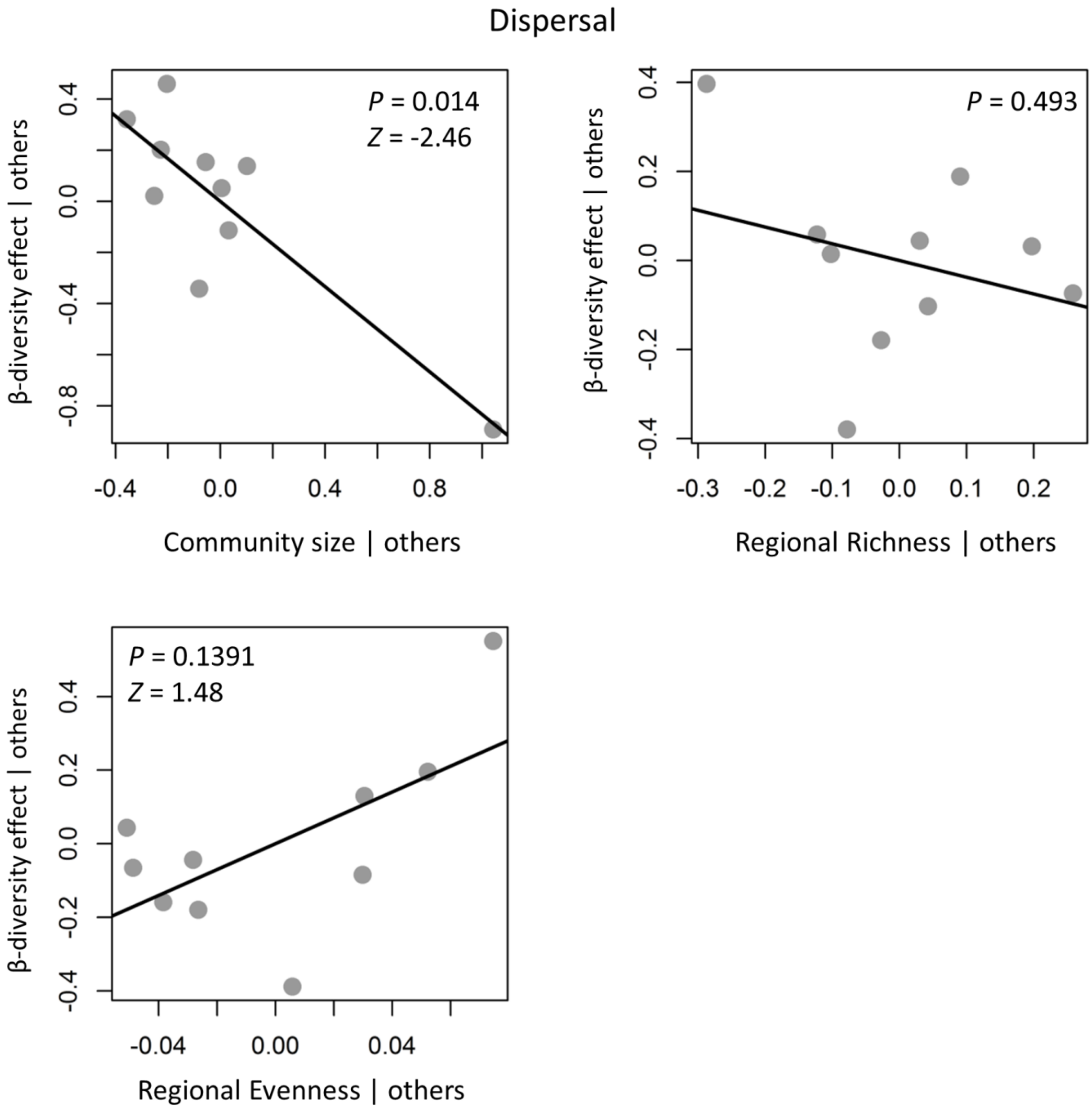

Figure S2 Contributions of change in mean community size, regional evenness, and regional richness to change in β-diversity (Bray-Curtis) following dispersal. *Z* and *P* values were estimated from random-effects models (n = 10) where the β-diversity effect is the standardized mean differences between dispersal treatments and unmanipulated controls, weighted by the inverse of the sampling variance. Community size, regional richness, and regional evenness effects were calculated as the log ratio between treatments and unmanipulated controls.

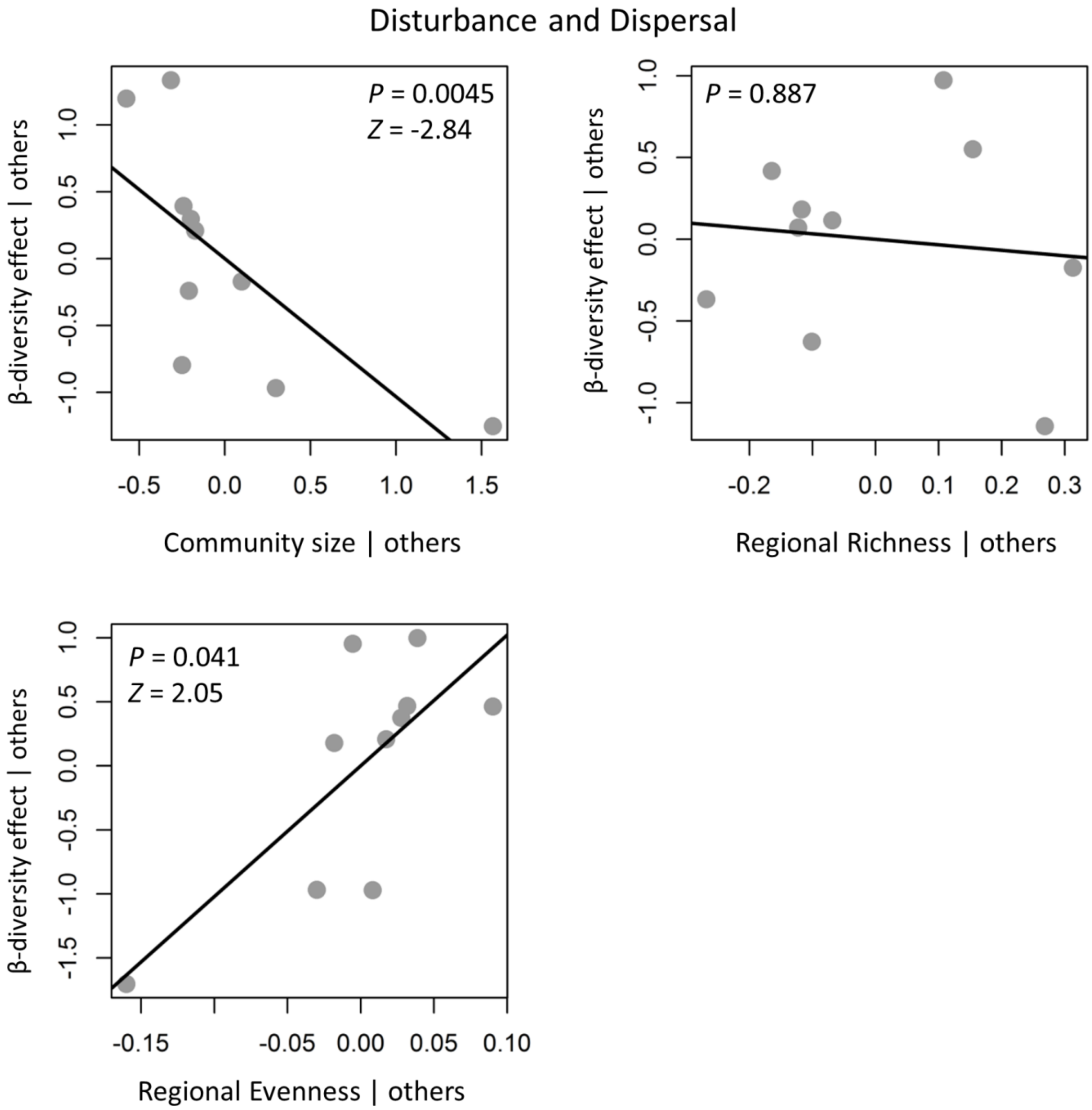

Figure S3 Contributions of change in mean community size, regional evenness, and regional richness to change in β-diversity (Bray-Curtis) following disturbance and dispersal. *Z* and *P* values were estimated from random-effects models (n = 10) where the β-diversity effect is the standardized mean differences between dispersal treatments and unmanipulated controls, weighted by the inverse of the sampling variance. Community size, regional richness, and regional evenness effects were calculated as the log ratio between treatments and unmanipulated controls.

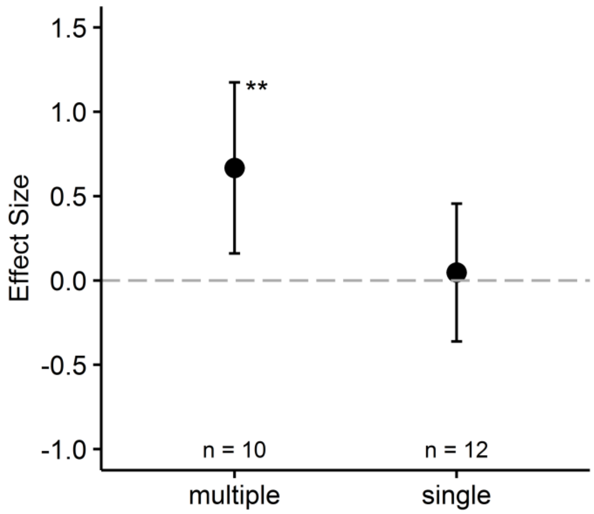

Figure S4 Mean effect size (95% confidence interval) of disturbance on Raup-Crick β-diversity in experiments where a disturbance treatment was applied multiple times (*n* = 10 experiments) or a single time (*n* = 12). Mean effect sizes were calculated as the grand mean of the standardized mean differences between disturbance treatments and unmanipulated controls using mixed-effects models. Overlap with dashed lines at zero indicates no difference between treatments. Stars indicate mean effect sizes significantly different from zero (** $P < 0.01$).

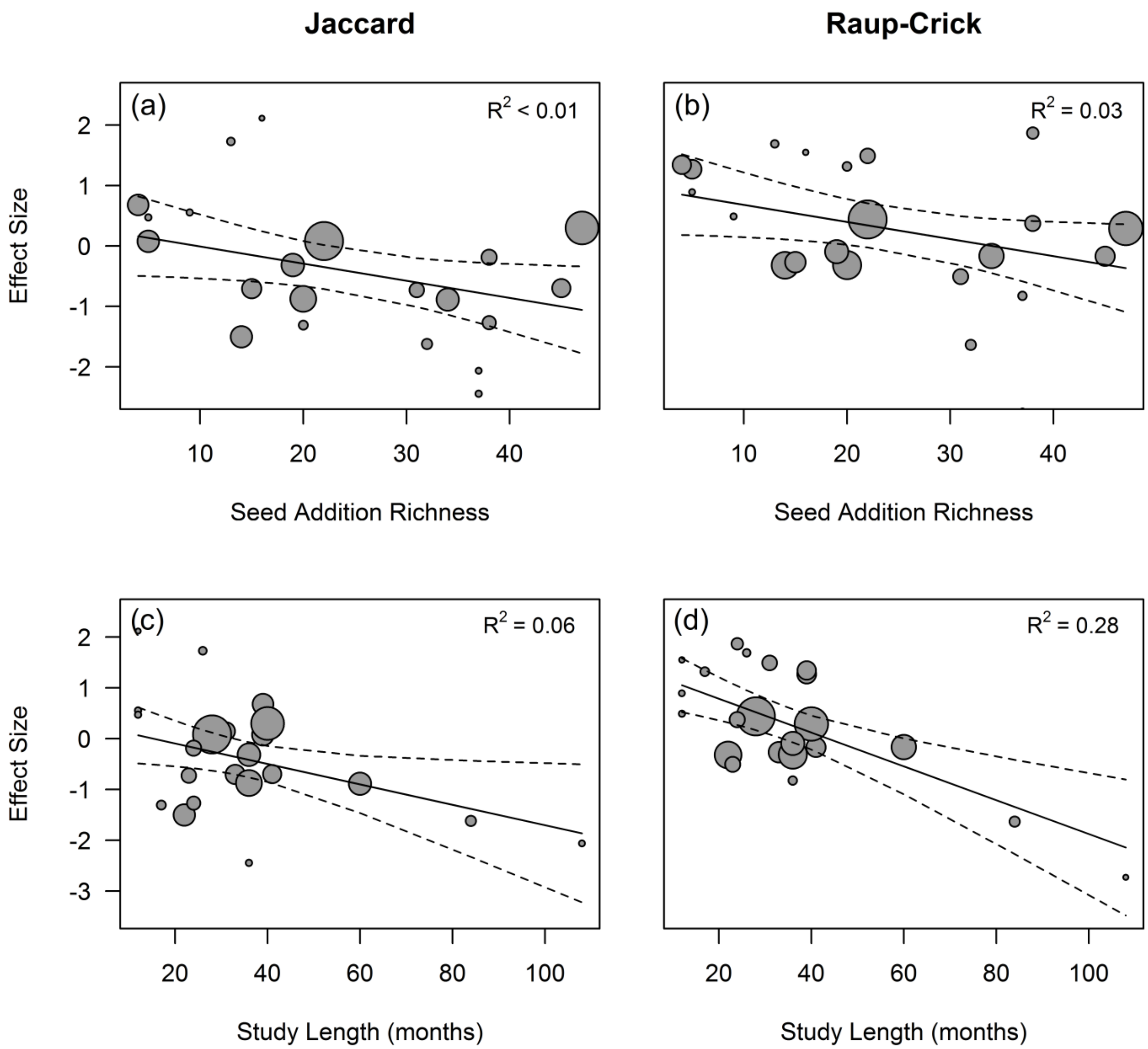

Figure S5 Influence of species richness of seeds added in dispersal treatments (seed-addition richness) and study length on mean effect sizes of dispersal on observed β-diversity (Jaccard dissimilarity) and Raup-Crick β-diversity. Mean effect sizes were calculated as the mean of the standardized mean differences between dispersal treatments and unmanipulated controls using random-effects models. **a**) Observed β-diversity plotted against seed-addition richness (slope = -0.03, P = 0.042). **b**) Raup-Crick β-diversity plotted against seed-addition richness (slope = -0.03, P = 0.046). **c**) Observed β-diversity plotted against study length (slope = -0.02, P = 0.030). **d**)

Raup-Crick β-diversity plotted against study length (slope = -0.03, $P < 0.001$). Points are sized according to their weight in the model, calculated as the inverse of the within-treatment sampling variance.

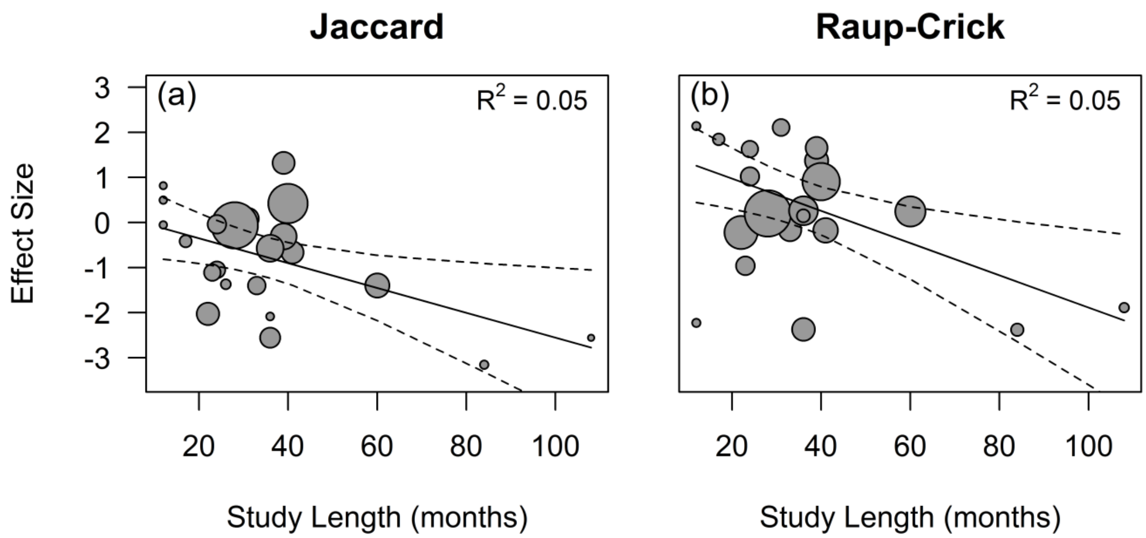

Figure S6 Influence of study length on mean effect sizes of disturbance with dispersal on **a**) observed β-diversity (Jaccard dissimilarity; slope = -0.03, P = 0.018) and **b**) Raup-Crick β-diversity (slope = -0.04, P = 0.012). Mean effect sizes were calculated as the mean of the standardized mean differences between the combined disturbance and dispersal treatment and unmanipulated controls using random-effects models. Points are sized according to their weight in the model, calculated as the inverse of the within-treatment sampling variance.

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Appendix S2 ***Supplemental Methods***

Heterogeneity & Covariate Analysis: We calculated mean effects of disturbance, dispersal, and disturbance with dispersal across experiments with random-effects models. Random-effects models allow for conservative inferences more suitable for broad generalization (Borenstein *et al.* 2009; Koricheva *et al.* 2013). Mean effects are typical of meta-analyses, but can mask important variation in treatment effects across studies that are caused by differences in experimental or environmental conditions (Koricheva *et al.* 2013). Therefore, we estimated the total variation in effect sizes among studies (T^2) using the DerSimonian and Laird method (Borenstein *et al.* 2009), which we evaluated statistically using the Q metric (Borenstein *et al.* 2009) (Supplemental Information SA1, Table S3). Next, we determined the proportion of this variation that could be caused by differences in experimental or environmental conditions across studies (I^2), as opposed to variation simply due to sampling variance within studies.

We then performed a covariate analysis to evaluate the extent to which differences in experimental design or environmental conditions explained variation in effect sizes among experiments (I^2). The following covariates were included as a moderator in the random effects models: (1) plot size (which could influence observed α-diversity and community size); (2) study length (to account for differences in temporal extent which could influence variability); (3) latitude; (4) single versus multiple applications of disturbance treatments; (5) single versus multiple applications of dispersal treatments; and (6) species richness in the seed-addition treatments (Supplemental Information SA1, Table S4, Figs S4-S6.). Only latitude and seed addition richness had a correlation strength greater than 0.3 (-0.42). Because the ratio of covariates to sample size was large, we evaluated each individually rather than together in a single model. We evaluated these factors for the full set of experiments based on species incidence data (Jaccard and Raup-Crick β-diversity) to maximize statistical power. We did not have the power to adequately test the effects of disturbance type because classification of disturbance can be subjective and most were represented by only a few experiments. All heterogeneity and covariate analyses were performed with the R package ‘metafor’, version 1.9-5 (Viechtbauer 2010).

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