The worldwide importance of honey bees as pollinators in natural habitats

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Electronic Supplementary Material S2

Supplementary Information Table S2-1: The best-fit multiple linear regression model relating environmental variables to the proportion of floral visits contributed by western honey bees (*Apis mellifera*) in plant-pollinator interaction networks (n = 54 networks where *A. mellifera* was present). Temperature PC1 increases with overall temperature and isothermality, and decreases with temperature seasonality and annual range. The dependent variable (proportion of visits by *A. mellifera*) was logit-transformed to improve normality. Models examining the influence of *A. mellifera* native status and last year of study on proportion of visits by *A. mellifera* were constructed by adding these two variables to the best-fit model of environmental variables. Best-fit models were selected based on corrected AIC scores from the same candidate models as those used in our main analysis (see Methods and table 1).

Model (Δ AICc) / Variable	**Estimate**	**Test statistic**	***P* value**
Best-fit environmental model ("BFEM") (Δ AICc = 0)	Adj. R^2 = 0.28	$F_{2,51}$ = 11.17	< 0.001
Temperature PC1	β = 0.70	*t* = 4.68	< 0.001
Land category (mainland = 1, island = 0)	β = 1.40	*t* = 2.12	0.04
BFEM + *Apis* native status (Δ AICc = 1.11)	Adj. R^2 = 0.28	$F_{3,50}$ = 7.90	< 0.001
Temperature PC1	β = 0.71	*t* = 4.77	< 0.001
Land category (mainland = 1, island = 0)	β = 1.22	*t* = 1.79	0.08
Apis native status (native = 1, introduced = 0)	β = 0.65	*t* = 1.11	0.27
BFEM + last study year (Δ AICc = 2.02)	Adj. R^2 = 0.27	$F_{3,50}$ = 7.49	0.003
Temperature PC1	β = 0.68	*t* = 4.44	< 0.001
Land category (mainland = 1, island = 0)	β = 1.37	*t* = 2.04	0.05
Last study year (years CE)	β = 0.02	*t* = 0.62	0.54
BFEM + *Apis* native status + last study year (Δ AICc = 3.42)	Adj. R^2 = 0.27	$F_{4,49}$ = 5.88	< 0.001
Temperature PC1	β = 0.70	*t* = 4.53	< 0.001
Land category (mainland = 1, island = 0)	β = 1.20	*t* = 1.75	0.09
Apis native status (native = 1, introduced = 0)	β = 0.60	*t* = 1.02	0.31
Last study year (years CE)	β = 0.02	*t* = 0.45	0.65

Supplementary Information Table S2-2: The μ, σ, and ν coefficient intercepts of the zero-inflated, multiple beta regression models reported in table 1.

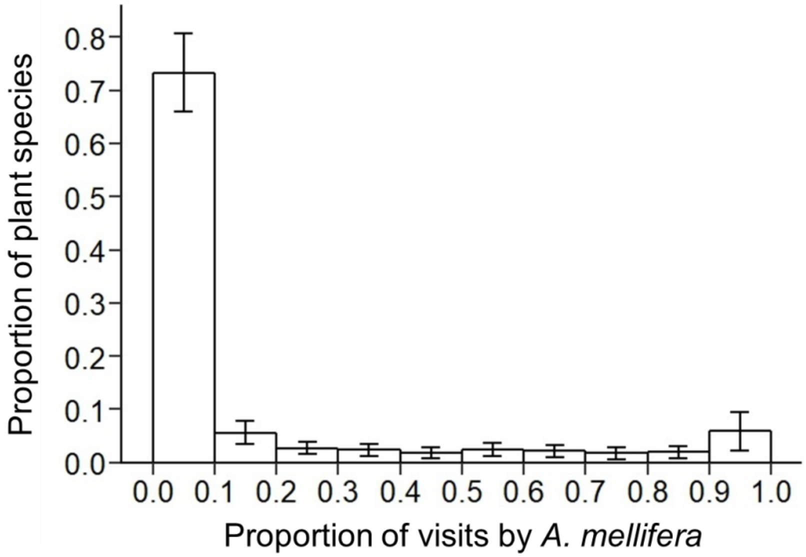
Model (Δ AICc) / Variable	Estimate	*t* value	*P* value
Bes-fit environmental model ("BFEM") (Δ AICc = 0)	Cox-Snell R^2 = 0.19		
μ coefficient intercept (link = logit)	μ = -2.26	6.53	< 0.001
σ coefficient intercept (link = log)	σ = 1.23	6.04	< 0.001
ν coefficient intercept (link = logit)	ν = -0.77	3.18	0.002
BFEM + *Apis* native status (Δ AICc = 1.39)	Cox-Snell R^2 = 0.20		
μ coefficient intercept (link = logit)	μ = -2.32	6.61	< 0.001
σ coefficient intercept (link = log)	σ = 1.25	6.12	< 0.001
ν coefficient intercept (link = logit)	ν = -0.77	3.18	0.002
BFEM + last study year (Δ AICc = 2.25)	Cox-Snell R^2 = 0.19		
μ coefficient intercept (link = logit)	μ = -13.38	0.37	0.71
σ coefficient intercept (link = log)	σ = 1.22	7.67	< 0.001
ν coefficient intercept (link = logit)	ν = -0.77	3.18	0.002
BFEM + *Apis* native status + last study year (Δ AICc = 3.75)	Cox-Snell R^2 = 0.20		
μ coefficient intercept (link = logit)	μ = -10.52	0.29	0.77
σ coefficient intercept (link = log)	σ = 1.25	7.82	< 0.001
ν coefficient intercept (link = logit)	ν = -0.77	3.18	0.002

Electronic Supplementary Material S3

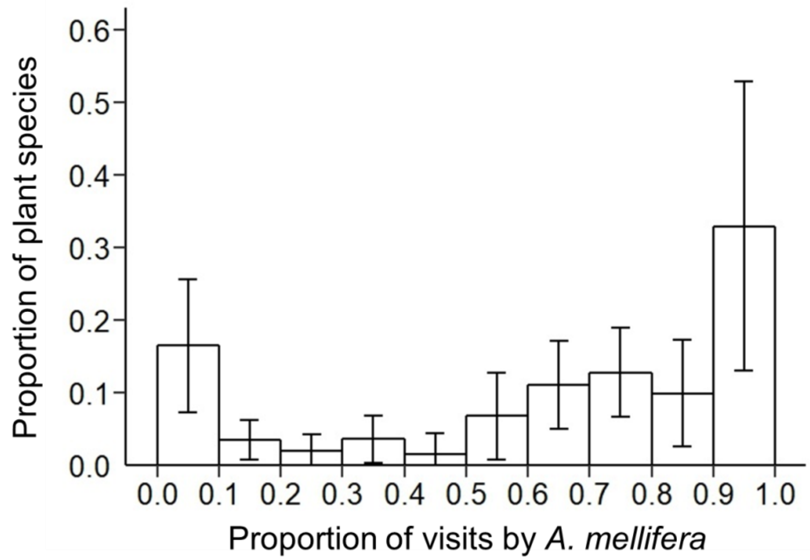
Supplementary Information Table S3: Results of principal components analysis (PCA) of 11 bioclimatic variables describing patterns in temperature, and a separate PCA of eight bioclimatic variables describing patterns of precipitation. The first two axes of each PCA were used as independent variables in constructing the environmental model explaining variation in the proportion of visits contributed by western honey bees (*Apis mellifera*) in plant-pollinator interaction networks worldwide.

	PC1	PC2	PC3	PC4	PC5	PC6
Temperature variables						
% of variance explained	66.97%	19.28%	9.35%	3.54%	0.06%	0.02%
Cumulative variance explained	66.97%	86.25%	95.60%	99.14%	99.70%	99.91%
Standard deviation	2.714	1.456	1.014	0.624	0.248	0.152
Axis loadings						
Mean annual temp.	0.362	-0.108	-0.077	0.073	-0.039	-0.219
Mean temp. warmest quarter	0.302	-0.337	-0.255	0.183	-0.263	-0.115
Mean temp. coldest quarter	0.367	0.044	0.023	0.037	0.103	-0.215
Mean temp. wettest quarter	0.248	-0.312	-0.393	-0.668	0.339	0.350
Mean temp. driest quarter	0.342	0.083	0.148	0.469	0.107	0.784
Mean diurnal temp. range	-0.056	-0.496	0.655	-0.010	0.462	-0.081
Max. temp. of warmest month	0.256	-0.476	-0.066	0.262	-0.115	-0.175
Min. temp. of coldest month	0.362	0.117	-0.047	0.065	0.072	-0.155
Temp. annual range	-0.286	-0.429	0.017	0.079	-0.157	0.083
Temp. isothermality	0.290	0.014	0.516	-0.455	-0.648	0.137
Temp. seasonality	-0.315	-0.313	-0.221	0.086	-0.341	0.260
Precipitation variables						
% of variance explained	73.14%	15.63%	8.34%	2.08%	0.06%	0.01%
Cumulative variance explained	73.14%	88.77%	97.11%	99.19%	99.80%	99.91%
Standard deviation	2.419	1.118	0.817	0.408	0.221	0.093
Axis loadings						
Annual precip.	-0.409	0.104	-0.027	0.060	-0.125	-0.788
Precip. of wettest month	-0.372	0.358	-0.083	0.295	-0.440	0.335
Precip. of driest month	-0.381	-0.286	0.035	-0.493	-0.221	0.425
Precip. of wettest quarter	-0.377	0.337	-0.093	0.314	-0.049	0.138
Precip. of driest quarter	-0.388	-0.261	0.067	-0.415	-0.197	-0.219
Precip. of warmest quarter	-0.351	-0.022	-0.619	-0.069	0.666	0.089
Precip. of coldest quarter	-0.305	0.211	0.763	-0.017	0.506	0.090
Precip. seasonality	0.201	0.744	-0.112	-0.625	-0.027	-0.050

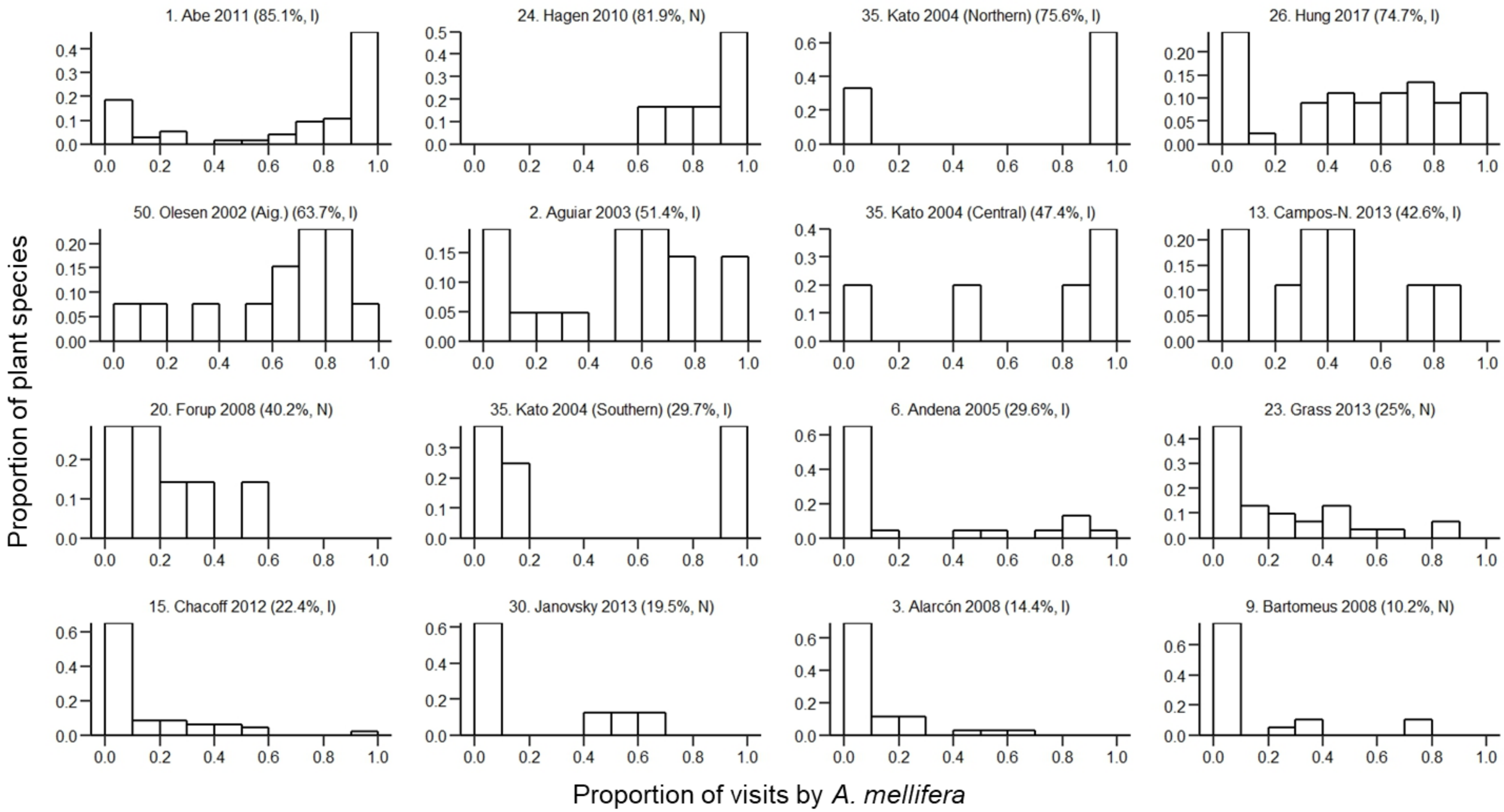
Electronic Supplementary Material S4



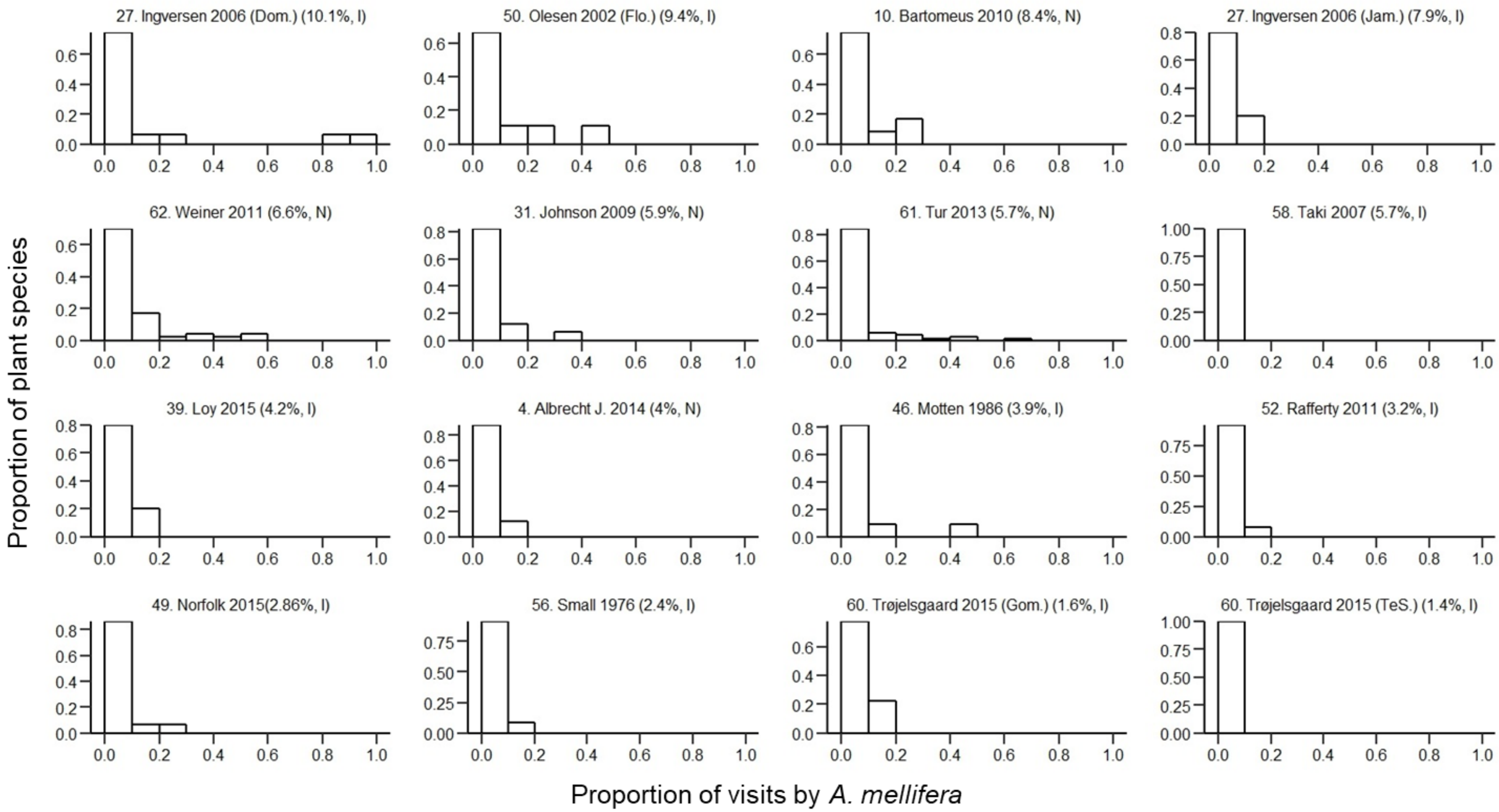
Supplementary Information Figure S4-1. The distribution of the proportion of visits contributed by the western honey bee (*Apis mellifera*) across 1,676 plant species (including those with < 10 visits recorded) in 47 networks where *A. mellifera* was documented and where the proportions of visits to each plant species by *A. mellifera* were available. Bars show the mean value of each bin across networks; whiskers show 95% confidence intervals.



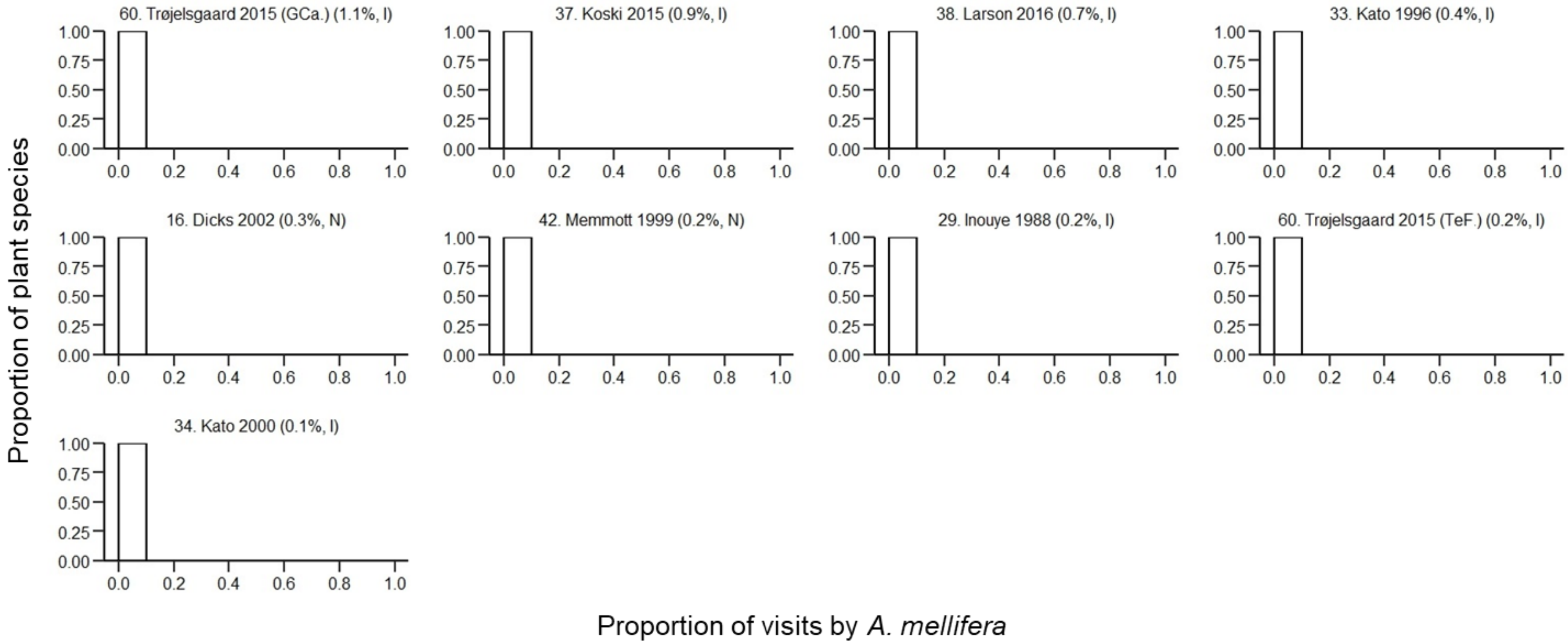
Supplementary Information Figure S4-2. The distribution of the proportion of visits contributed by the western honey bee (*Apis mellifera*) across 164 plant species in six networks where *A. mellifera* contributed > 50% of all visits documented in each network. Bars show the mean value of each bin across networks; whiskers show 95% confidence intervals.



Supplementary Information Figure S4-3. Individual histograms depicting the distribution of the proportion of visits contributed by the western honey bee (*Apis mellifera*) across plant species in 41 networks where *A. mellifera* was documented and where the numbers of visits to each plant species by *A. mellifera* and other visitors were available. Histograms are arranged in descending order of network-level *A. mellifera* numerical importance. The heading of each histogram denotes the identity of each network (using the same labeling scheme as that used in table S1-1 of electronic supplementary material, S1), the percentage of all visits in each network contributed by *A. mellifera*, and the native status of *A. mellifera* (N = native, I = introduced). Figure continues onto next two pages.



Supplementary Information Figure S4-3 (Continued).



Supplementary Information Figure S4-3 (Continued).

Electronic Supplementary Material S5

Comparison of *Apis mellifera* and *Bombus* spp. in pollination networks

Because studies vary in the taxonomic resolution with which floral visitors other than the western honey bee (*Apis mellifera*) are reported, we cannot reasonably compare frequencies of *A. mellifera* visitation with those of other single species across all of our networks. However, data are sufficiently detailed in 68 of the 80 networks (see table S1-1 in electronic supplementary material, S1) to enable comparison between *A. mellifera* and bumble bees (Apidae: *Bombus*); the latter are the only other pollinator genus with a similar pattern of local numerical abundance and current cosmopolitan distribution (in part owing to human-mediated introductions) compared to *A. mellifera* [7,9,54]. We used a Wilcoxon signed rank test to compare the network-level proportion of visits contributed by *A. mellifera* versus that contributed by all bumble bee species combined (bumble bee species were combined because species-level resolution for *Bombus* was not available in all datasets). Since our goal was to compare global patterns of numerical importance, this analysis did not exclude networks in which *A. mellifera*, bumble bees, or both taxa were absent.

Across the 68 networks examined, the average proportion of floral visits contributed by *A. mellifera* was more than double that contributed by bumble bees (*A. mellifera* mean = 13.79%, *Bombus* mean = 6.26%); although this comparison achieved only marginal statistical significance due to high variation among networks (Wilcoxon signed rank test v = 1000, P = 0.055). This finding supports our position that *A. mellifera* is currently the single most frequent floral visitor to plant species in natural ecosystems worldwide.

We caution that many of the 12 networks excluded from this analysis (i.e., those that lacked available data on bumble bee visitation; see table S1-1 in electronic supplementary material, S1) are situated in localities where bumble bees are likely to be abundant, or where *A. mellifera* is absent. Our results therefore may slightly underestimate the relative numerical importance of bumble bees in pollination networks worldwide. Nevertheless, the contribution of bumble bees, as a guild, to floral visitation worldwide is unlikely to exceed that of *A. mellifera*.