Supporting Information

for Carvalheiro et al. "Indirect effects between co-flowering plants via shared pollinators depend on resource abundance, accessibility and relatedness"

Appendix S1 - Study selection and field methods description

Sites near blooming mass-flowering crops, or from experimental plots where soil conditions were manipulated were not considered in this study. Information on interaction frequency, plant species' flower abundance and sampling effort (number of floral units observed per plant species) was available for all studies. Each study collected data for a number of plant–pollinator networks for a specific site and time period. For most studies the maximum length of a time period was 15 days, and we hence assume that there is no impossible links within a network due to temporal mismatch. The exception is the Seychelles study, for which data per network was collected over 30 days. However in this study region flower availability was relatively constant over the survey period, and the vast majority of the species that were observed for a given period were overlapping (CKB, personal communication).
Studies used one of two distinct methodological approaches: (1) plant–pollinator interaction data were collected by walking slowly through a pre-defined area, hereafter referred to as 'area-based surveys'; or (2) all flowering plant species present in the study area were observed independently for a fixed time period, hereafter referred to as 'timed surveys'.

Study 1
Country: Kenya
Habitat: Savannah
Responsible: K. Baldock
Flower visitation data were collected in 2004 at Mpala Research Centre, Laikipia Province, Kenya at two 0.5 ha plots approximately 10 km apart with contrasting flowering plant communities. Data were used to construct seven monthly networks in May (one site only), June, July and August. Data for each network were collected over a two-week period, with floral abundance surveys (counts of all floral units in the entire plot) conducted at the start of each sampling week. In each of the two sampling weeks visitation was quantified by observing every flowering species for 20 minutes in each of four daily time intervals (06.00-09.00h, 09.00-12.00h, 1200-1500h and 1500-1800h) spanning the period between dawn and dusk. Full details given in:
Baldock, K. C. R., Memmott, J, Ruiz-Guajardo, J. C., Roze, D. and G. N. Stone. Daily temporal structure in African savanna flower visitation networks, and consequences for sampling. *Ecology* 92: 687- 698.

Study 2
Country: Mauritius
Habitat: Heathlands
Responsible: C. Kaiser-Bunbury

Flower visitors were recorded of all woody flowering plant species in two 6ha-plots in the upload dwarf forest of Le Pétrin, Black River Gorges National Park, Mauritius between September 2003 and March 2004. Each plant species was observed for four 30-min observation sessions every two weeks, totalling 2h of observation per species per two weeks. Here we used data for the main flowering season spanning 24 weeks, i.e., 12 2-week networks per site, 24 networks in total. Data on resource abundance was gathered independently of the observations by counting the number of flowers in cubic metres placed randomly along 23 100m-transects at each site. Detailed methods can be found at:
Kaiser-Bunbury, C. N., Memmott, J. & Müller, C. B. (2009). Community structure of pollination webs of Mauritian heathland habitats. *Perspectives in Plant Ecology, Evolution and Systematics*, 11,241-254.
Kaiser-Bunbury, C. N., Muff, S., Memmott, J. Müller, C. B. & Caflisch, A.. (2010). The robustness of pollination networks to the loss of species and interactions: A quantitative approach incorporating pollinator behaviour. *Ecology Letters*, 13,442-452.

Study 3
Country: Seychelles
Habitat: Granitic inselbergs
Responsible: C. Kaiser-Bunbury
Flower visitors were recorded of all flowering plant species of six inselberg communities (rocky outcrops with dwarf forest vegetation) on the island of Mahé, Seychelles, between September 2007 and April 2008. Each plant species was observed for six 30-min observation sessions every month, totalling 3h of observation per species per month. A total of 48 monthly networks were collected across six sites and eight month. Data on resource abundance was gathered independently of the observations by counting the number of flowers in cubic metres placed randomly along several transects which covered a large proportion of each inselberg habitat. Detailed methods can be found at:
Kaiser-Bunbury, C. N., T. Valentin, J. Mougal, D. Matatiken, and J. Ghazoul. 2011. The tolerance of island plant–pollinator networks to alien plants. *Journal of Ecology* 99, 202-213.

Study 4
Country: South Africa
Habitat: Heathland/Fynbos
Responsible: K. Temitope
Four sites were selected in the Western Cape Province, South Africa between October and December 2010. A 100 m x 50 m plot was demarcated at the centre of each site, and three 50 m transects were placed randomly within the plots. Transect walks were done on days with no rain, minimal wind (Beaufort scale 0-1) and minimal cloud (< 5 %) cover at all sites. Records of insect-flower interactions were taken within a 2 m swathe along each transect. Flower-visiting insect samples were collected to confirm identification to species level in the laboratory. Samples were identified to morphospecies, genus and family level where species identification was not possible especially for groups that are difficult to identify and which are made up of cryptic species (e.g. Braconidae, Tachinidae, Syrphidae). Vegetation sampling was done along the same transects where insect-flower interactions were recorded. Species richness of flowering plants and abundance of floral units were recorded in six 1 m^2 quadrats at 10 m intervals along each 50 m transect.

Further details on methodology and sampling area can be found in: Kehinde, T.O., Samways, M.J. (2014). Management defines species turnover of bees and flowering plants in vineyards *Agricultural and Forest Entomology* 16, 95-101.
Kehinde, T.O., Samways, M.J. (2014). Insect-flower interactions: network structure in organic versus conventional vineyards. *Animal Conservation in press.*

Study 5
Country: England
Habitat: Calcareous gorge
Responsible: R. Boada & J. Memmott
Flower visitation data was collected using timed observations in the bottom region (St. Vincent's rock, Latitude: 51.456, Longitude: -2.627) of Avon Gorge, UK from May to September 2004. For each of 11 surveys, data on flower abundance and flower visitation was collected during 4 to 5 days. For each flowering plant species, an observation point was randomly selected within the areas where the species was present. All floral units present in a semi-circle of 1m radius were observed for a 20 minute period.

Study 6
Country: England
Habitat: Calcareous gorge
Responsible: L.G.Carvalheiro
Flower visitation data was collected using timed observations in the upper region (Gully, Latitude: 51.469, Longitude:-2.630) of Avon Gorge, UK from May to September 2004. For each of 11 surveys, data on flower abundance and flower visitation was collected during 4 to 5 days. For each flowering plant species, an observation point was randomly selected within the areas where the species was present. All floral units present in a semi-circle of 1m radius were observed for a 20 minute period. Further details on methodology can be found in: Carvalheiro, L.G., Barbosa, E.R.M., Memmott, J. (2008). Pollinator networks, alien species and the conservation of rare plants: *Trinia glauca* as a case study. *Journal of Applied Ecology*, 45, 1419–1427.

Study7
Country: England
Habitat: Mesotrophic grassland
Responsible: L. V. Dicks
An area based survey at an ancient hay meadow at Shelfanger, near Diss, Norfolk, UK. Flower visitation data were collected by walking a standard 100 x 1 m belt transect at three time periods on each survey date (09:00-10:30, 12:30-14:00, 16:00-17:30). Data collected in this study were summed across the three transect times and two dates (07 and 13 July 1999). All individual Hymenoptera, Lepidoptera, Diptera and Coleoptera longer than 3 mm seen feeding on a flower within a 1 -m strip to one side of the observer were recorded. The first species of flower each insect was seen visiting was recorded. Abundance of flowering plants was recorded on 09 July 1999, along the same 100 m transect. Five quadrats were randomly positioned in each 10 m section. The number of blossom units of each flowering species, excluding grasses, was recorded.
Further details on the methodology can be found in:
Dicks, L. V., Corbet, S. A. & Pywell, R. F.. (2002). Compartmentalization in plant-insect flower visitor webs. *Journal of Animal Ecology,* 71, 32-43.

Study 8
Country: England
Habitat: Heathland
Responsible: K.S.E. Henson
Data collection between June and September 2005 was undertaken on twelve heathland fragments comprising six pairs of ancient and restored sites, located in the Isle of Purbeck, Dorset, England. Sites were sampled on five occasions, with ten transect routes identified per 100m x 100m plot per site. During each sampling occassion two transects were surveyed per plot for floral abundance, recording the average number of flowers per m^2 for all species present. Foraging bumblebees were sampled from both transects used in the floral surveys including a third transect, with each transect walked twice sampling all bumblebees foraging from flowers within 1m either side of the transect line. Further details on methodology can be found in:
Henson, K.S.E., Craze, P.G., & Memmott, J. (2009). The restoration of parasites, parasitoids and pathogens to heathland communities. *Ecology*, 90, 1840-1851.

Study 9
Country: England
Habitat: Riverine vegetation
Responsible: M. Lopezaraiza-Mikel
Flower visitation data was collected at 8 plots using area based surveys in natural or semi-natural riverine vegetation in Bristol, UK from July to September 2003. For each of 8 surveys, data on flower abundance and flower visitation was collected within a single day. Samples were collected under warm, dry conditions. To collect the visitation data, each transect was slowly walked once, collecting insects observed visiting flowers up to 1 m either side of the transect line and 1 m ahead. The identity and floral abundance of all plant species on the transect was recorded. Further details on methodology can be found in:
Lopezaraiza–Mikel, ME, Hayes, RB, Whalley, MR, Memmott, J. 2007. The impact of an alien plant on a native plant–pollinator network: an experimental approach. *Ecology Letters*, 10, 539-550.

Study 10
Country: Germany
Habitat: Alpine vegetation
Responsible: G. Benadi
Data on flower visitation were collected at six sites along an altitudinal gradient from 950m a.s.l. to 2020m a.s.l. in the National Park Berchtesgaden in the German part of the Alps from May to September 2010. Each network comprises data of at least 6 hours of observation on a single day or two consecutive days. Transect walks were performed to record flower visits of bees, flies and butterflies and moths. Floral abundance was estimated by counting floral units in sampling quadrats of $2m^2$ and converting counts to area by multiplying with the average diameter of a floral unit for each species. Further details on the methodology can be found in:
Benadi, G., Hovestadt, T., Poethke, H. J., & Blüthgen, N. (2014). Specialization and phenological synchrony of plant–pollinator interactions along an altitudinal gradient. Journal of Animal Ecology, *in press*.

Study 11
Country: Germany
Habitat: Meadow

Responsible: J. Frund
Flower visitation data was collected in 32 different meadows in Southern Germany from April to August 2006. Each network comprised one day (different networks at least 3 weeks apart). Flower visitors were recorded in transect walks and observation plots and caught for identification (except honeybees). Floral units were counted in observation plots of 2 m^2.
Further details:
Fründ, J., Linsenmair, K.E., Blüthgen, N. (2010). Pollinator diversity and specialization in relation to flower diversity. *Oikos*, 119, 1581–1590.

Study 12,13,14,15
Country: Germany
Habitat: Fallow, fallow strip, forest edge, intensive grassland
Responsible: A. Holzschuh, C. F. Dormann & T. Tscharntke
For each habitat, flower visitation data was recorded in 12 sites in the vicinity of Göttingen, Germany, in June and July 2006 (unpublished data). Fallows were at least 2 km apart from each other. Fallow strips were 2-3 m wide, located between a cereal field and a farm track, and more than 2 km apart from each other. The forest edge was defined as the usually 2-3 m wide strip of herbal vegetation that borders the outer trees of a forest. Forest edges were at least 2 km apart from each other. Grasslands were at least 2 km apart from each other and were mown several times during spring and summer. All sites were sampled 4 times (sampling rounds at least 7 days apart). Flower visitors (bees, syrphid flies and butterflies) and floral units were recorded on one transect per site, which was 100 m long and 1 m wide. At one of the small ends of each transect, three potted Wild Mustard plants (*Sinapis arvensis;* flowering during sampling rounds 1 and 2) and three potted Coriander plants (*Coriandrum sativu;* flowering during sampling rounds 3 and 4) were placed. Flower visitors were recorded for 15 min on potted plants and for 15 min on wild plants per transect and sampling round. Syrphid flies and bees that could not be identified in the field were caught for identification in the lab.

Study 16
Country: Germany
Habitat: Fallow
Responsible: R. R. Junker
Flower visitation was recorded in six temporally separated quantitative networks between April and June 2010 in Würzburg, Germany. Each time, 32 subplots (area: 9 x 9 m) were individually observed for at least 10 min (up to 72 min depending on flower abundance) and all interactions were recorded. Further details on recording on network data and of measuring of flower/plant traits can be found in:

Junker, R.R., Blüthgen, N., Brehm, T., Binkenstein, J., Paulus, J., Schaefer, H.M., Stang, M. (2013) Specialisation on traits as basis for the niche-breadth of flower visitors and as structuring mechanism of ecological networks. *Functional Ecology*, 27, 329-341.

Study 17
Country: Greece
Habitat: Crop field margins
Responsible: T. Petanidou & T. Tscheulin
Two study sites were selected on Lesvos Island, Greece.

In each site, observation plots (1 m x 1 m) were established randomly on observation days along a 50 m transect so that every plot contained at least one flowering plant. In each of four sampling rounds, in June, July and August 2006, a minimum of six plots per species were observed. Insect visitation to flowers was recorded for 3 min periods per plot and observation took place between 8.30 and 13.00 on sunny and calm days. Flower visitors were collected after the observation for identification.
To assess floral unit abundance we calculated the average number of plant individuals and floral units in each of 30 randomly selected quadrats.
Further details in:
Tscheulin, T., Petanidou, T., Potts, S. G. & Settele, J. (2009). The impact of *Solanum elaeagnifolium*, an invasive plant in the Mediterranean, on the flower visitation and seed set of the native co-flowering species *Glaucium flavum. Plant Ecology*, 205, 77-85.

Study18
Country: Greece
Habitat: disturbed coastal shrubland
Responsible: T. Petanidou & T. Tscheulin
Five study sites were selected on Lesvos Island, Greece.
In each site, observation plots (1 m x 1 m) were established randomly on observation days along a 50 m transect so that every plot contained at least one flowering plant. In each of four sampling rounds, in June, July and August 2006, a minimum of six plots per species were observed. Insect visitation to flowers was recorded for 3 min periods per plot and observation took place between 8.30 and 13.00 on sunny and calm days. Flower visitors were collected after the observation for identification.
To assess floral unit abundance we calculated the average number of plant individuals and floral units in each of 30 randomly selected quadrats.
Further details in Tscheulin, T., Petanidou, T., Potts, S. G. & Settele, J. (2009). The impact of *Solanum elaeagnifolium*, an invasive plant in the Mediterranean, on the flower visitation and seed set of the native co-flowering species *Glaucium flavum. Plant Ecology*, 205, 77-85.

Study 19
Country: Ireland
Habitat: Intensive grassland
Responsible: E. F.Power
Ten conventional dairy farms in lowland permanent grassland (not ploughed or reseeded for at least 8 years) in the Republic of Ireland were surveyed. Two fields from each farm were surveyed three times each between May and July 2009.. Transects 100 × 2 m were walked slowly (10-15 m/min) along the edge and in the centre (30 m from the edge) of every field (12 transects in total per site). All bees, hoverflies and butterflies observed feeding within transects were recorded, together with the flower species visited. Bumblebees (*Bombus spp.*), honeybees *Apis mellifera*, butterflies and solitary bees were identified to species and hoverflies to genus (except for *Bombus terrestris* and *B. lucorum*, which were aggregated due to difficulties in distinguishing between them and other cryptic species. Data on floral abundance were recorded in every transect. For every herbaceous flowering plant (excluding grasses, sedges and rushes), species identity and the number of flowering units was estimated in 10 quadrats per transect (two 1 m^2 quadrats every 20 m along transect). Further details can be found in:: Power, E. F., & Stout, J. C. (2011). Organic dairy farming: impacts on insect–flower interaction networks and pollination. *Journal of Applied Ecology*, 48, 561-569.

Study20

Country: Ireland
Habitat: Low intensity grassland
Responsible: E. F. Power
Ten organic dairy farms in lowland permanent grassland (not ploughed or reseeded for at least 8 years) in the Republic of Ireland were surveyed. Two fields from each farm were surveyed three times each between May and July 2009. Transects 100 × 2 m were walked slowly (10-15 m/min) along the edge and in the centre (30 m from the edge) of every field (12 transects in total per site). All bees, hoverflies and butterflies observed feeding within transects were recorded, together with the flower species visited. Bumblebees (*Bombus spp.*), honeybees *Apis mellifera*, butterflies and solitary bees were identified to species and hoverflies to genus (except for *Bombus terrestris* and *B. lucorum*, which were aggregated due to difficulties in distinguishing between them and other cryptic species). Data on floral abundance were recorded in every transect. For every herbaceous flowering plant (excluding grasses, sedges and rushes), species identity and the number of flowering units was estimated in 10 quadrats per transect (two 1 m^2 quadrats every 20 m along transect).
Further details can be found in:
Power, E. F., & Stout, J. C. (2011). Organic dairy farming: impacts on insect–flower interaction networks and pollination. *Journal of Applied Ecology*, 48, 561-569.

Study 21
Country: Spain
Habitat: Shrublands
Responsible: A. Montero-Castaño
Flower visitation data was collected using timed observations in two sites (20x20 m shrubland plots) in Menorca (Balearic Islands) from March to May 2010. Observation periods of 15 min were conducted for all flowering plant species during which we noted the number of visits achieved by each visitor species and the number of flowers under observation. The number of observation periods varied between plant species depending on the rarefaction curves of richness of their visitor species.

Study 22
Country: Spain
Habitat: Shrublands
Responsible: I. Bartomeus
Flower visitation data was collected in 12 different shrublands in Catalonia from March to July 2005. Each network was sampled 4-6 times (samplings at least 2 weeks apart). Flower visitors were recorded in timed observations to all flowering plants and caught for identification (except honeybees). Floral units were counted in observation plots of 1 m^2.
Further details can be found in:
Bartomeus, I. Vilà, M. A & Santamaria, L. (2008). Contrasting effects of invasive plants in plant–pollinator networks. *Oecologia*, 155, 761–770.

Study 23
Country: Sweden
Habitat: Intensive grasslands
Responsible: R. Bommarco

Flower visitation data was collected in four pastures from South Sweden from May to July 2004 (5 surveys in each pasture, ca. 15 days apart). In each pasture interactions were recorded along one transect (250 x 4m) for a fixed time period of 30 min. Flower abundance data was collected in 10 open plots (2 x 1 m). Any interaction observed in the open plots, which had not been detected with the transect survey, was added to the flower visitation dataset as a rare event (frequency of occurrence = 0.01)

Further information on methods available in:
Westphal, C., Bommarco, R., Carré ,G. Lamborn,E. Morison,N, Petanidou,T *et al.* (2008) Measuring bee diversity in different European habitats and biogeographical regions. *Ecological Monographs*, 78,653–671.

Study 24
Country: Sweden
Habitat: Margins-linear habitat
Responsible: J. Ekroos
Flower visitation data was collected in 2011 using area-based surveys in 1 × 150 m transects. In total, 36 transect were established in 12 non-overlapping study landscapes. The transects were mainly situated in linear non-crop habitats. All flower-visiting bees, butterflies and hoverflies were recorded in each transect, which was divided into 50 m subsections, during 3 × 5 minutes. The identity of the visitor and the flower being visited was recorded. Each transect was visited two times during the season (July and August). Further details on methodology can be found in:
Ekroos, J., Rundlöf, M. & Smith, H.G. (2013). Trait-dependent responses of flower-visiting insects to distance to semi-natural grasslands and landscape heterogeneity. *Landscape Ecology*, 28, 1283–1292.

Study 25
Country: Sweden
Habitat: Semi-natural grassland
Responsible: M. Rundlöf
In 16 semi-natural grasslands, area-based transect walks was used to monitor the species densities of flower-visiting bees, butterflies and hoverflies in 2011 and 2012. The number of flower visitors and the plant species they visited were recorded in 300 m² at each study site for 30 minutes, during two separate survey rounds per year. The cover of flowering forbs were recorded as the number and size of floral units within the transects.

Study 26
Country: Canada
Habitat: Semi-natural grassland
Responsible: R. Cartar
Data were collected throughout June, July and August, 2009 and 2010 at 14 sampling sites, each of which contained a matched heavily- and lightly-grazed study plot (each plot measuring 100 m by 200 m) at least 2.5 km from each other, but no farther than 6 km. Each site was measured within a day during the period 0900 h to 1550 h at least 5 evenly spaced times over the season. Each study plot contained a central transect (of no importance to the current study). Each central transect was flanked by two pairs of 3 parallel transects, the closest of the 3 being 50 m distant from the central transect, and the flanking transects being separated by 25 m. Along these flanking transects, flower-visiting bees were censused and collected in two 30 minute periods each day (one in the AM, one in the PM). Time required

to collect insects was subtracted from the census time. Open flowers of all bee-visited plants were counted along all 7 transects on each day. Transect widths were 2m. So each study plot contained a flower- and insect-censused surface area of 4 (transects) * 100 m (length) * 2 m (width) = 800 m^2.

Study 27
Country: Argentina
Habitat: Desert shrubland
Responsible: N. Chacoff

Flower visitation data was collected in two shrublands in the Monte desert from the west of Argentina along five consecutive years (2006-2010). Each network was sampled during the whole flowering season (between September and December), twice a week. Flower visitors were recorded in timed observations to all flowering plants. Flower abundance was estimated weekly at each site by using quadrats and transects. Further details can be found in:

Chacoff N.P., Vázquez, D.P., Lomáscolo, SB, Stevani, E.L. Dorado, J , Padron, B.. (2012). Evaluating sampling completeness in a desert plant–pollinator network. *Journal of Animal Ecology* 81, 190-200.

Study 28
Country: Australia
Habitat: Coastal heathland
Responsible: I. Nelson & A. Bennet
Flower visitation data was collected in a 100*100m^2 plot in Royal National Park, Sydney, Australia between September and November 2005 (unpublished data). Visitation and flower abundance data was recorded over a period of 6-9 days for each of the 11 surveys undertaken. During each survey, five, 2*1m^2 quadrats were randomly placed along each of 4 transect lines (100m long and randomly placed) in the plot. All the floral units per plant species within each quadrat were quantified and then observed for 30 minutes. Sampling spanned the time period approximately between dawn and dusk, whereby one transect (5 quadrats) was sampled in each of four time intervals: 1) 06:00-09:30h; 2) 09.30-12:30h; 3) 12:30-15:00h; 4) 15:00-18:00h. Insects were captured immediately after flower visitation, either in a glass tube or by a net so they could be identified to morpho-species by taxonomists , Dr Britton, Dr. Batley (Australian Museum) and Dr. Lomov. No *a priori* decisions were made regarding which flower visitors were pollinators. Flower observations always took place in dry conditions with low wind. In total, 20 quadrats were sampled (10 hours of observations) in each survey.
Further details can be found in: Nelson, I. L. (2007) Avian pollination in Australia. Ph.D. Thesis, University of Bristol.

Appendix S2 - Calculating the potential influence via shared pollinators

For each plant–pollinator network, we calculated the potential of each plant species to influence all other co-occurring plant species via shared pollinators (Figure 1b). We quantified how much one resource species (in our study a plant, "acting" plant hereafter) contributes to the diet of each consumer (in our study, a pollinator species) of another resource species ("target" plant hereafter). Or, in other words, we calculated the product of dependencies (sensu Bascompte *et al.* 2006) of the target plant on a pollinator, and of that pollinator on the acting plant, summed across all pollinators. However, this index can also be a measure of apparent facilitation (Davidson 1980). The index will be referred to hereafter as Müller's index and is calculated using function PAC from the R package bipartite 1.17. as:

$$d_{ij} = \sum_{k} \left[\frac{\alpha_{ik}}{\sum_{l} \alpha_{il}} \times \frac{\alpha_{jk}}{\sum_{m} \alpha_{mk}} \right],$$

where α_{ik} represents the number of interactions of pollinator *k* to the target plant species *i* (*l* being the total number of pollinator to that target plant species), and α_{jk} represents the number of interactions of pollinator *k* with the acting plant species *j* (*m* being the total number of plants with which pollinator *k* interacts). The index is a relative measure and varies between zero (if no pollinators are shared) and approximately 1. A higher value of Müller's index indicates a greater potential for the acting plant to influence the target plant via shared pollinators. In the calculations of Müller's index, we accounted for the total number of visits to all plants for a given site and time period (including the contribution of under-sampled plants to the diet of pollinators). Within a plant species pair, two Müller indexes can be calculated (d_{ij} is not equal to 1 minus d_{ji}), as both plant species can be considered acting species. However, Müller's index is not symmetric (d_{ij} is different than d_{ji}) nor complementary (d_{ij} is not equal to 1 minus d_{ji}). However d_{ij} is not completely independent from d_{ji}: in randomly generated networks the average influence of plant *i* on plant *j* will be negatively related with the average influence of plant *j* on plant *i* (Figure S1). When plant *i* contributes to the diet of all pollinators of plant *j* it has a high Müller index, but the contribution of plant *j* to plant *i* depends on how many other pollinators interact with plant *i*. For example, if the influence of plant A on plant B is 0.2, the influence of plant B on plant A will vary between 0 and 0.8. The sum of the two values will therefore never be higher than 1, but the value in one direction cannot be predicted based on the value from the opposite direction. This lack of independence of values of the Müller's index is taken into account in the statistical analyses by including plant identity as a random factor (see methods).

Sampling effort (number of floral units observed) varied between and within studies. In area-based methods sampling effort is proportional to floral unit abundance and in timed observations sampling effort is likely to be related with the distribution of floral units across space. Although we have information on flower abundance for all studies we have no information on the distribution of floral units across space. Therefore, before calculating Müller's index we standardize the number of visits per plant, so that for both timed-observations and transects our visitation unit would be proportional to flower abundance in the study area. To do that, for timed-observation studies, we calculated the number of visits per area unit so that they would be comparable to area-based studies. Thus, if 10 pollinators were observed visiting 20 floral units of a given plant species, with a density of 2 floral units per square meter, that plant species would have 1 flower visit per square meter. Observation time per floral unit also varies from study to study but is equal within studies.

References Appendix S2

Bascompte, J., Jordano, P. & Olesen, J.M. (2006) Asymmetric coevolutionary networks facilitate biodiversity maintenance. *Science*, **312**, 431–433.

Davidson, D.W. (1980) Some consequences of diffuse competition in a desert ant community. *The American Naturalist*, 116, 92–105.

Appendix S3 - Flower traits and phylogenetic distance calculations

The following measures of flower trait similarity were considered in this study: flower shape, floral display, nectar tube depth, nectar splitting within floral units, flower height and colour. Information for these traits was collected directly by the data-holders for as many plant species as possible, or from plant trait databases (e.g. BiolFlor, see Klotz *et al.* 2002, LEDA, see Fitter & Peat 1994; Floran i Skåne, see Tyler *et al.* 2007). Information was obtained for 926 plant species. For flower shape, plants were divided into two categories: "open" and "closed" (see classification details in Table S2). For floral display plants were divided into "clustered" (plants with flowers presented as inflorescences) or "isolated".

Nectar tube length was measured for the 564 plant species either in the field (229 species) or based on detailed flower morphology diagrams available in floras.

For flower height, we defined four levels based on the average distance between the ground and the flowers, described in floras or based on information provided by the data-holders: 1 = up to 5 cm (small herbs); 2 = 5 to 50 cm (tall herbs and small shrubs); 3 = 50 to 150 cm (very tall herbs and shrubs); and 4 = more than 150 cm (tall shrubs and trees). For nectar splitting, we considered three levels: 1= one flower per floral unit ($1cm^2$), 2 = 2 to 5 flowers per floral unit; and 3 = more than 5 flower per floral unit.

There are fundamental differences between colour vision in flower visitors and humans, and hence human vision is considered inappropriate for assessing flower colouration (e.g. Bennett *et al.* 1994). Nevertheless, previous studies have found that flower colour as seen by humans is significantly related to visitation patterns (Gibson *et al.* 2012; Eklöf *et al.* 2013). Therefore, in the absence of more adequate colour classification (e.g. spectral reflectance data) we used colour as seen by humans, using colour classes similar to those used by previous studies (e.g. Gibson *et al.* 2012; Eklöf *et al.* 2013). We divided the plant species in four classes of flower colour as seen by humans: white (includes all white and very pale flowers); yellow; warm colours (includes all orange, red and pink/'salmon' flowers); cold colours (includes all blue and purple flowers, representing short-wave lengths commonly associated with Hymenoptera syndrome colours). Flowers with more than one colour were classified according to the main colour at the centre of the flower. Flower height was considered as continuous variables whereas all other traits were included as categories in the models/statistical analyses.

To calculate phylogenetic distance between pairs of plant species, we used sequence data (*mat*K gene) from GenBank® for all plant species of the 28 studies. Whenever we failed to find a species on GenBank, we chose a phylogenetically closely-related species (from the same genus). We excluded any species for which we did not find an alternative sequence that was phylogenetically closer to the missing species than to other plants present within that network. From the 40794 plant pairs that were not undersampled, we obtained information on phylogenetic distance for 36835 pairs. We then built phylogenetic trees based on maximum likelihood (ML) in GARLI V 2.0 (Zwickl 2006).

DNA data were aligned with the MUSCLE Alignment tool in Geneious Pro v6.0.5 (Biomatters, New Zealand). Alignments were manually checked and ambiguities were adjusted. Then, for each study, we compared 52 models of DNA evolution using model selection based on the Akaike Information Criterion (AIC) and selected the most parsimonious DNA substitution model with MrModeltest 2.3 (Nylander 2004). For all 28 datasets the most parsimonious was the GTR+I+G model (i.e. a model that considered the generalised time reversible model of evolution, the proportion of invariable sites within the gene sequence, and the gamma model of rate heterogeneity). Based on this model we built phylogenetic trees in GARLI V 2.0 (Zwickl 2006). For each dataset the branch lengths of the

highest-likelihood tree were used to calculate the phylogenetic distance between all species pairs.

References Appendix S3

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Appendix S4 –nectar sugar concentration data sources and collection methodology

European plants: Baude *et al.* in prep.

To assess the amount of nectar offered by 126 of the most common North European plants, we collected nectar samples from 24h bagged flowers (bridal mesh) in South Great Britain. Nectar was collected with 1-5 µL microcapillaries from ten to twenty flowers of each species (direct sampling by capillary action when possible or indirect sampling by rinsing twice the nectaries with 1-5µL of water which was recollected) between 0900h and 1600h. We measured nectar volume and quantified sugar concentration with a hand-held refractometer (Eclipse, Bellingham & Stanley).
In five to ten floral units, the number of open flowers was counted in order to scale-up estimates of nectar sugar content from flower to floral unit (volume × concentration × open flowers number; µg of sugar/floral unit). In addition to the 126 species from Great Britain, all species that were classified as pollen flower in the Flora databases were considered as flowers with no nectar.

Seychelles plants: Kaiser-Bunbury *et al.* in prep.
To assess the amount of nectar offered by Seychelles inselberg plants to flower visitors, we collected nectar samples from freshly opened flowers from 34 of the 38 plant species included in our study. We collected nectar with 0.5-5µl microcapillary tubes from on average 17.8 ± 12.1 SD (range 3-44, median 13.5) flowers per plant species (2–10 different plants) between 0600h and 1030h (for plant species with nocturnal anthesis between 1900h and 2100h). We measured nectar volume in µl and quantified sugar concentration with a hand-held refractometer (Eclipse 45–81, Bellingham & Stanley). Both readings were used to calculate sugar content as mg sugar/flower. Nectar from several tiny small palm flowers were pooled to obtain a volume and sugar concentration reading, but sugar content was always expressed per flower. Where no nectar was detected with the microcapillary tubes, flowers were examined with a magnifying glass to check for small amounts of nectar.

Supplementary Tables and Figures

Table S1. Details of the 28 flower-visitor datasets used in the analyses. Some studies collected visitor information on all pollinator groups; others only on certain groups, and for some pollinator groups within each study data was too scarce to be included in analyses (see methods description). Studies which were used for the analyses (Binomial and/or Gaussian models) of influence via shared bees (B), flies (D), beetles (C) and butterflies and moths (L) are indicated under column 'Group'. The survey methods refer to (T) for "Timed surveys" done by observing each plant species for a fixed period or (A) for "Area base survey" done by walking slowly on a fixed area. More details of the studies are described in Appendix 1. Studies that were included in analyses with nectar sugar content are indicated with '[S]'.

Study code	Country	Habitat	Group	Survey method	Nb of networks selected	Nb of sites selected	Nb of plant sps	Nb of pollinator sps
	Africa							
1	Kenya	Savannah	B,D,C,L	T	5	2	69	244
2	Mauritius	Heathlands	B,D,C,L	T	16	2	84	159
3	Seychelles	Granitic inselbergs [S]	B,D,C,L	T	46	6	38	98
4	South Africa	Heathland/Fynbos	B,D,C	A	13	4	50	43
	Europe							
5	England	Calcareous gorge [S]	B,D,C,L	T	12	1	85	138
6	England	Calcareous gorge [S]	B,D,C,L	T	11	1	64	243
7	England	Mesotrophic grassland [S]	B,D		1	1	13	16
8	England	Heathland [S]	B,D,L	A	39	14	10	131
9	England	Riverine vegetation [S]	B,D,C,L	A	48	8	39	172
10	Germany	Alpine [S]	B,D,L	A	61	6	159	408
11	Germany	Meadow [S]	B,D	A	50	31	147	248
12	Germany	Fallow [S]	B,D,L	A	21	9	47	60
13	Germany	Fallow strip [S]	B,D,L	A	37	12	47	54
14	Germany	Forest edge [S]	B,D,L	A	36	12	64	64
15	Germany	Intensive grassland [S]	B,D,L	A	15	7	31	50
16	Germany	Fallow [S]	B,D,C,L	T	6	1	57	256
17	Greece	Crop field margins	B,D	T	6	2	7	27
18	Greece	Disturbed coastal shrubland	B	T	16	5	6	25
19	Ireland	Intensive grassland [S]	B,D	A	19	12	31	21
20	Ireland	Low intensity grassland [S]	B,D,L	A	21	14	33	17
21	Spain	Shrublands	B,D,C	T	2	2	11	21
22	Spain	Shrublands	B,D,C,L	T	58	12	33	128
23	Sweden	Intensive grassland [S]	B,D	A	20	4	62	55
24	Sweden	Margins-linear habitat [S]	B	A	30	23	82	18
25	Sweden	Semi-natural grassland [S]	B,D,L	A	49	16	119	131
	North America							
26	Canada	Semi-natural grassland	B	A	77	24	54	72
	South America							
27	Argentina	Desert shrubland	B,D,L	T	24	2	61	132
	Oceania							
28	Australia	Coastal Heathland	B,D,C,L	T	11	1	21	69

Table S2. Classification of flower shape according to BiolFlor, see Klotz *et al.* 2002*, LEDA, see Fitter and Peat 1994*.

Open	Closed
Syrphidae flowers	Tubular (Asteraceae inclusive)
Ichneumonoidea flowers	Stalk disc flowers with stamina and pistil within or outside tube
Wind flowers;	Bell shaped
Disk flowers	True lip flowers
	Funnel flowers
	Butterfly flowers
	Moth flowers

* Fitter, A . H. & Peat , H. J. 1994. The ecological flora database*. Journal of Ecology.* 82, 415-425.
Klotz, S., Kühn, I., Durka, W. 2002. *BIOLFLOR - Eine Datenbank zu biologisch-ökologischen Merkmalen der Gefäßpflanzen in Deutschland. - Schriftenreihe für Vegetationskunde* 38. Bundesamt für Naturschutz. [http://www2.ufz.de/biolflor/index.jsp]

Table S3. Effect of plant traits, phylogenetic distance, resource availability (flower unit number and nectar sugar content) and geographic origin on the probability of one (acting) plant influencing the pollination of another (target) plant (Binomial model), when using only plant species for which nectar sugar content was available (reduced dataset). Estimates of the terms included in the most parsimonious model are listed. For the three best models BIC and variation in BIC (ΔBIC) are provided. Terms not included in the three best models are not listed. The variables included in the models were: colour similarity (ColourSim); shape similarity (ShapeSim); display similarity (DisplaySim); height similarity (HeightSim); phylogenetic distance between acting and target plant (PD); acting plant floral abundance relative to the whole community (ARF), target-acting plant floral abundance balance (TAB); nectar sugar content of the acting plant (Sugar); target plant nectar sugar content relative to acting plant (TAsugar); nectar tube length of acting plant species (TL); nectar splitting level of the acting plant species (NS); Flower shape of acting plant species (Ashape, reference level is 'closed'); visitor density (VD), interaction evenness (IE) and plant richness (PR).. No variable related with hypothesis 4 was selected. For the similarity factorial variables the reference level is 'similar'.

	Estimates for model 1				Best models		
Terms	**bee**	**flies**	**beetles**	**but**	**model1**	**model2**	**model3**
Group	-1.26	-2.61	-3.20	-4.15	x	x	x
PD	-0.70	-0.21	-0.31	-0.03	x	x	x
PD*Group					x	x	x
ColourSim	-0.15	-0.15	-0.15	-0.15	x	x	x
DisplaySim	-0.07	-0.07	-0.07	-0.07	x	x	x
ARF	0.43	0.52	0.13	0.41	x	x	x
ARF*Group					x	x	x
TAB	0.14	0.18	0.02	0.11	x	x	x
TAB*Group					x	x	x
Sugar	0.17	0.17	0.23	-0.16	x	x	x
Sugar*Group					x	x	x
TAsugar	-0.81	1.20	-0.06	0.35	x	x	x
TAsugar*Group					x	x	x
TL	-0.22	-0.46	-0.41	-1.06	x	x	x
TL*Group					x	x	x
TL*Sugar	0.06	-0.07	-0.01	0.01	x	x	x
TL*Sugar*Group					x	x	x
NS	-0.38	0.55	-0.30	-0.81	x	x	x
NS*Group					x	x	x
NS*Sugar	-0.06	-0.01	0.10	0.41	x	x	x
NS*Sugar*Group					x	x	x
TL*NS	0.07	0.35	0.06	0.46	x	x	x
TL*NS*Group					x	x	x
Ashape	0.19	-0.22	-0.30	0.82	x	x	x
Ashape*Group					x	x	-
PR	-	-	-	-	-	x	-
VD	0.04	0.04	0.04	0.04	x	x	x
IE	-0.89	-0.89	-0.89	-0.89	x	x	x
BIC					29457	29466	29472
Δ BIC					0	9	15

Table S4. Effect of plant traits, phylogenetic distance, resource availability (flower unit number and nectar sugar content) and geographic origin on the average influence of one (acting) plant influencing the pollination of another (target) plant (Gaussian model), when using only plant species for which nectar sugar content was available (reduced dataset). Estimates of the terms included in the most parsimonious model are listed. For the three best models BIC and variation in BIC (ΔBIC) are provided. Terms not included in the three best models are not listed. The variables included in the models were: display similarity (DisplaySim); phylogenetic distance between acting and target plant (PD);acting plant floral abundance relative to the whole community (ARF), target-acting plant floral abundance balance (TAB); nectar sugar content of the acting plant (Sugar); target plant nectar sugar content relative to acting plant (TAsugar); nectar tube length of acting plant species (TL); nectar splitting level of the acting plant species (NS); visitor density (VD), interaction evenness (IE).No variable related with hypothesis 4 was selected. For the similarity factorial variables the reference level is 'similar'. Total variance deviance by the most parsimonious Gaussian model was 21.0% (15.7% by random terms and 5.3% by fixed terms). The proportion of the fixed variance explained by each variable is indicated for the Gaussian model (PDEF).

	Estimates for model 1				**Best models**		
Terms	**bee**	**flies**	**beetles**	**but**	**model1**	**model2**	**model3**
Group	-3.60	-0.77	-1.59	-1.04	x	x	x
PD	-0.45	-0.15	0.04	0.26	x	x	x
PD*Group					x	x	x
DisplaySim	-	-	-	-	-	-	x
ARF	0.38	0.38	0.38	0.38	x	x	x
TAB	-0.21	-0.21	-0.21	-0.21	x	x	x
Sugar	0.54	-0.11	0.07	0.07	x	x	x
Sugar*Group					x	x	x
TAsugar	-	-	-	-	-	x	x
TL	-0.81	0.06	-1.09	-0.09	x	x	x
TL*Group					x	x	x
TL*Sugar	0.10	0.01	0.08	0.15	x	x	x
TL*Sugar*Group					x	x	x
NS	0.65	-0.01	0.20	1.05	x	x	x
NS*Group					x	x	x
NS*Sugar	-0.25	-0.02	0.02	-0.12	x	x	x
NS*Sugar*Groupp					x	x	x
TL*NS	0.36	-0.02	0.32	-0.25	x	x	x
TL*NS*Group					x	x	x
VD	-0.01	-0.01	-0.01	-0.01	x	x	x
IE	0.77	0.77	0.77	0.77	x	x	x
BIC					27446	27451	27460
Δ BIC					0	5	14

Table S5. Six best models found for the effect of floral traits, phylogenetic distance, floral abundance and geographic origin on the average influence of one (acting) plant on another (target) plant (Gaussian model). All other combinations of variables were tested, but are not presented in this table. Only the variables included in these six best models are listed: shape similarity (ShapeSim), phylogenetic distance (PD), acting plant floral abundance relative to the whole community (ARF), target-acting plant floral abundance balance (TAB), acting plant's nectar tube length (TL) and nectar splitting level (NS), visitor density (VD), interaction evenness (IE), plant richness (PR). 'x' indicates terms included in the models; '-' indicates that a term was not included in the model.

	Best models					
Terms	**model1**	**model2**	**model3**	**model4**	**model5**	**model6**
Group	x	x	x	x	x	X
PD	x	x	x	x	x	X
PD*Group	x	x	x	x	x	X
ShapeSim	-	-	x	-	-	-
ARF	x	x	x	x	x	X
ARF*Group	x	x	x	x	x	-
TAB	x	x	x	x	x	X
TAB*Group	-	x	x	-	x	-
ARF*TAB	-	-	-	x	x	-
TL	x	x	x	x	x	X
TL*Group	x	x	x	x	x	X
NS	x	x	x	x	x	X
TL*NS	x	x	x	x	x	X
PR	x	x	x	x	x	X
VD	x	x	x	x	x	X
IE	x	x	x	x	x	X
PR*VD	x	x	x	x	x	X
PR*IE	x	x	x	x	x	X
BIC	49327	49328	49329	49329	49329	49331
Δ BIC	0	1	2	2	2	3

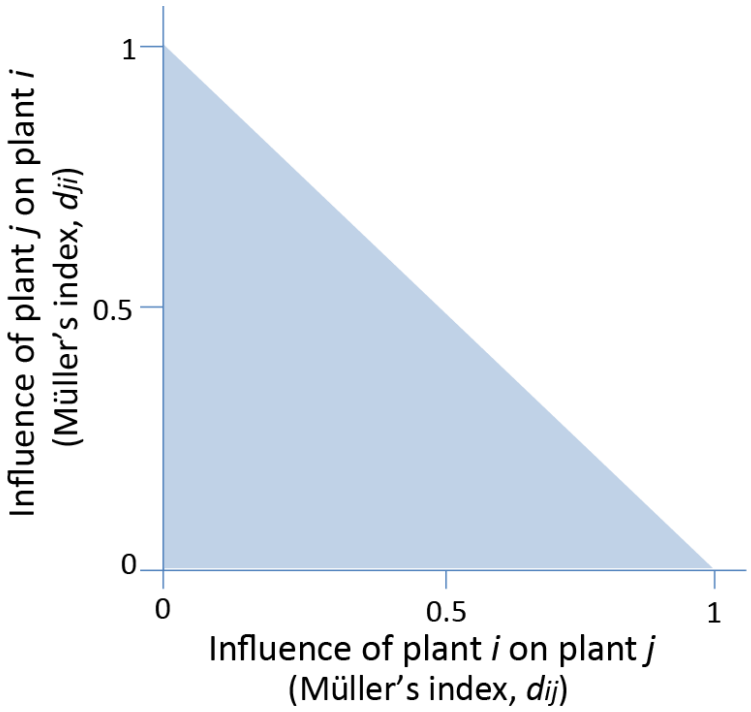

Figure S1. Constrains of Müller's index. While Müller's index is not a symmetric measure, the average influence of plant *i* on plant *j* will be negatively related with the average influence of plant *j* on plant *i*. If plant *i* has a small contribution to the diet of the flower visitors of plant *j* (i.e. lower Müller index), the Müller index of plant *j* on plant *i* can vary from 0 to approximately 1, depending on the contribution of plant *j* to the diet of flower visitors of plant *i*. However if plant *i* has a large contribution to the diet of the flower visitors of plant *j* (i.e. high Müller index, d_{ij}), the contribution of plant j to plant i will always be small and Müller index of plant *j* on *i* (d_{ji}) will be constrained between 0 and $1 - d_{ij}$.

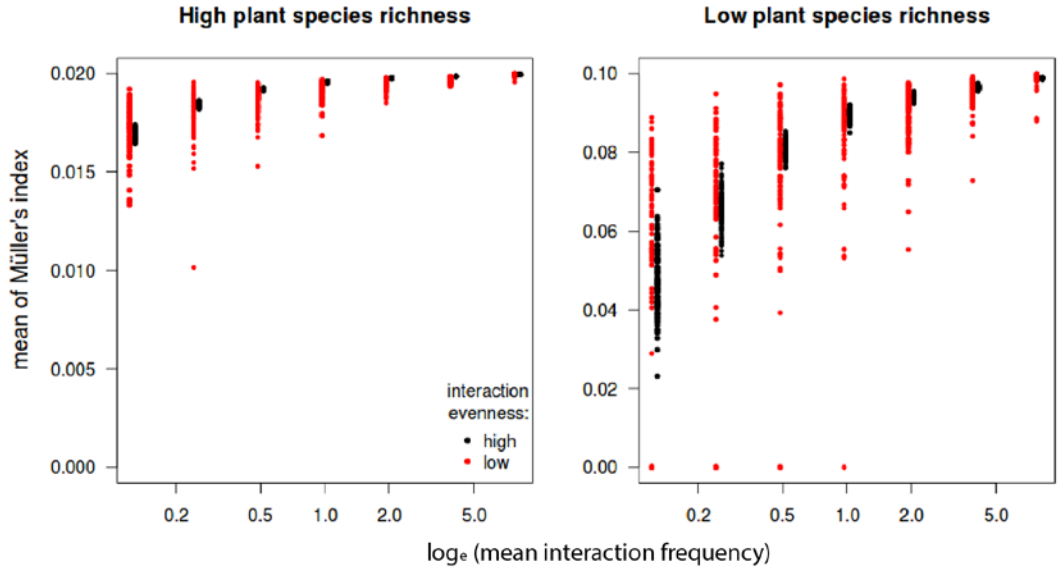

Figure S2. Effect of interaction frequency, interaction evenness and plant species richness on Müller's index. Each graph shows the relationship between interaction frequency (mean number of interactions per potential link) and the mean of Müller's index across all plant species pairs in a network for 100 artificial networks with high interaction evenness (black) and 100 networks with low interaction evenness (red). Simulations were performed with high plant species richness (50 plant species, 20 pollinator species, left panel) and low plant species richness (10 plant species, 20 pollinator species, right panel). Note the difference in the scale of the y-axis between the two panels. For clarity, data points of high and low evenness have been shifted slightly to the right and to the left, respectively. For each simulation, 100 artificial networks with given species numbers and maximum interaction frequency (8 interactions per potential link) were created in the following manner: First, relative interaction frequencies for each species in a guild (plants or pollinators) were determined by drawing random numbers from a lognormal distribution (with parameters mu = 20, sigma = 0.5 for high interaction evenness and mu = 20, sigma = 4 for low interaction evenness) and dividing by their sum to ensure that interaction frequencies summed to 1. In a second step, each species in a guild was assigned one interaction to make sure that no species would be left without any interactions. The remaining interactions were then distributed among species according to the calculated interaction frequencies and rounded to a full integer. These total numbers of interactions per species were used as marginal totals for the creation of networks using the Patefield algorithm (available as function "r2dtable" in the R package "bipartite"). Networks with lower interaction frequency were created by sampling a fixed number of interactions from the networks with maximum interaction frequency. For each simulated network, the mean of Müller's index was calculated for all possible combinations of acting and target species, but excluding target species with zero interactions.

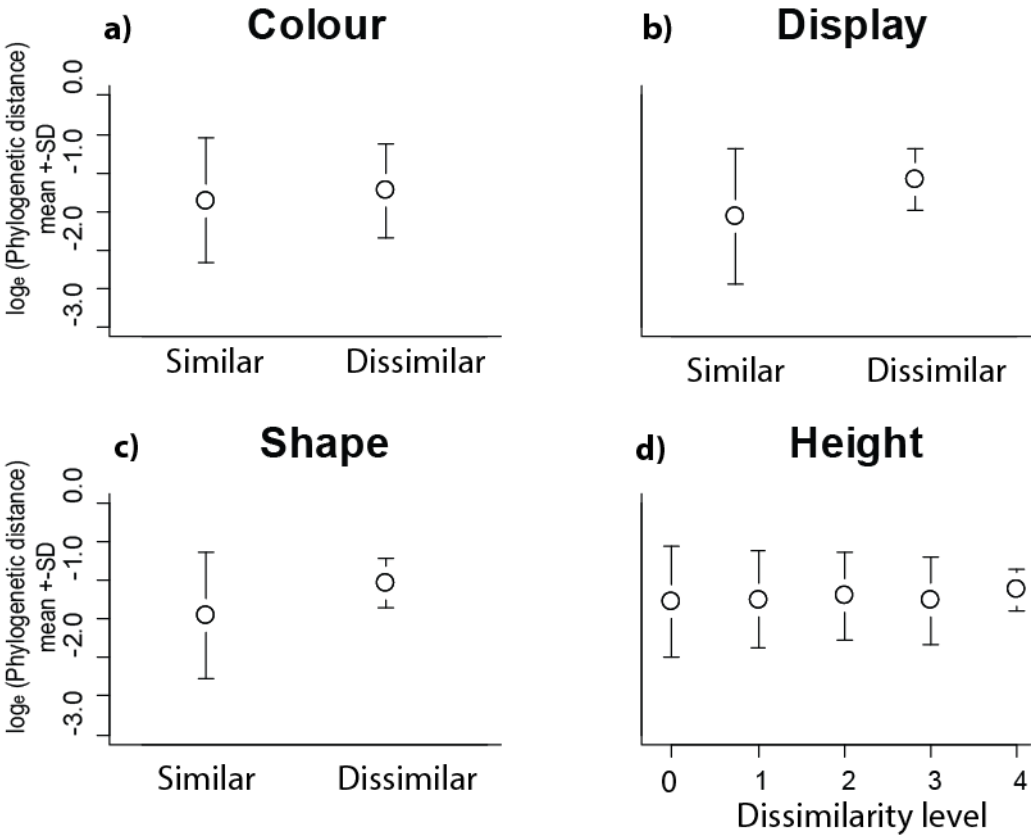

Figure S3. Phylogenetic distance between species with similar or dissimilar plant flower traits. Phylogenetic distance a) was not related with dissimilarity in flower colour (as seen by humans); b) was higher for plants with dissimilar floral display (isolated flowers vs. inflorescences) (N = 20231, F = 2541.5 P-value < 0.0001); and c) for plants with dissimilar floral shape (close vs. open) (N = 20231, F = 1998.5; P-value < 0.0001); d) Phylogenetic distance did not significantly change among species with different levels of floral height similarity (N = 20231, F = 0.1; P-value = 0.721)

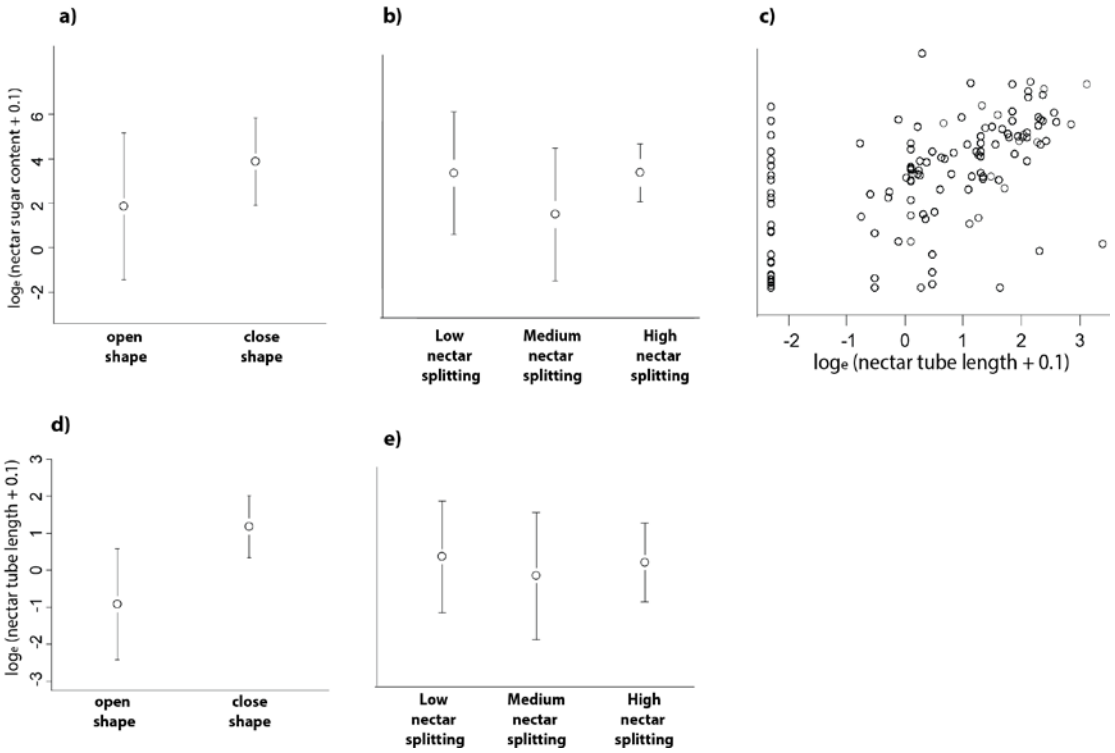

Figure S4. Relation between flower shape, tube length, nectar splitting and nectar sugar content per floral unit. a) nectar sugar content is higher for flower with close shape (N = 135; F-value = 24.2; P-value < 0.0001; b) nectar sugar content does not increase with nectar splitting level (N = 135; F-value = 0.1; P-value = 0.7046); c) nectar sugar content increases with nectar tube length (N= 135; F-value = 78.3; P-value <0.0001); d) length of nectar tube is greater for flowers with close shape (N = 135; F-value = 96.3; P-value < 0.0001); e) length of nectar tube does not change significantly with nectar splitting level (N = 135; F-value = 2.9; P-value < 0.0881). Data consists of a list of all species for which we had information on nectar sugar content, and remaining flower traits, and were analysed using general linear models.

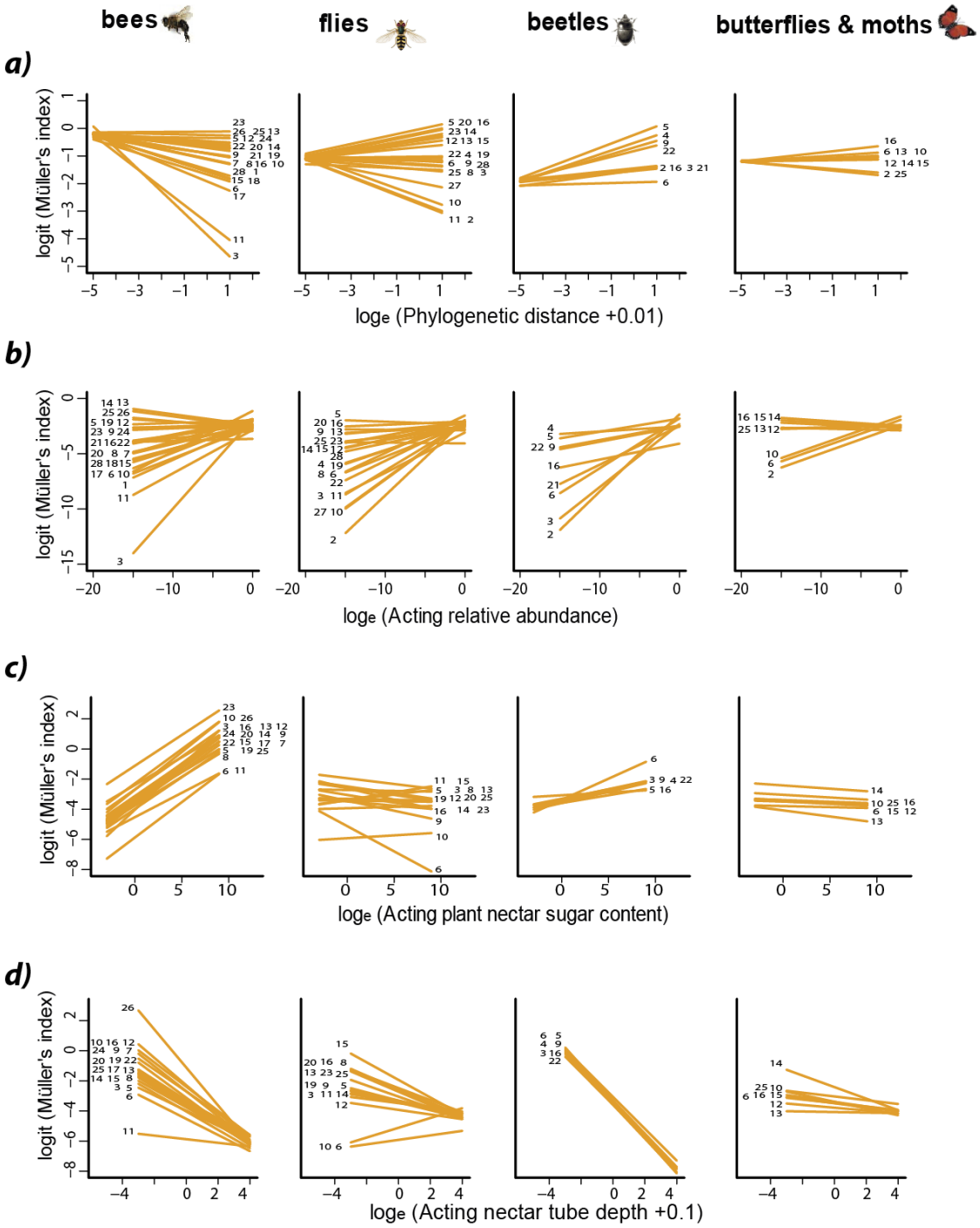

Figure S5. Variation of the effect of a) phylogenetic distance, b) relative abundance of the acting plant, c) nectar sugar content per flower unit of the acting plant and d) nectar tube length of the acting plant on the Müller's Index (Gaussian model) among studies and groups. Codes of the study indicated next to the regression lines are provided, and study information can be seen in Table S1. To obtain estimates of slopes for each individual study, the model allows for random slopes of each of the variables selected for the most parsimonious Gaussian model. For a) and b) the model based in the full dataset is used (Table 2), and for c) and d) the model based in the reduced dataset, which accounts for nectar sugar content, is used (Table S4).

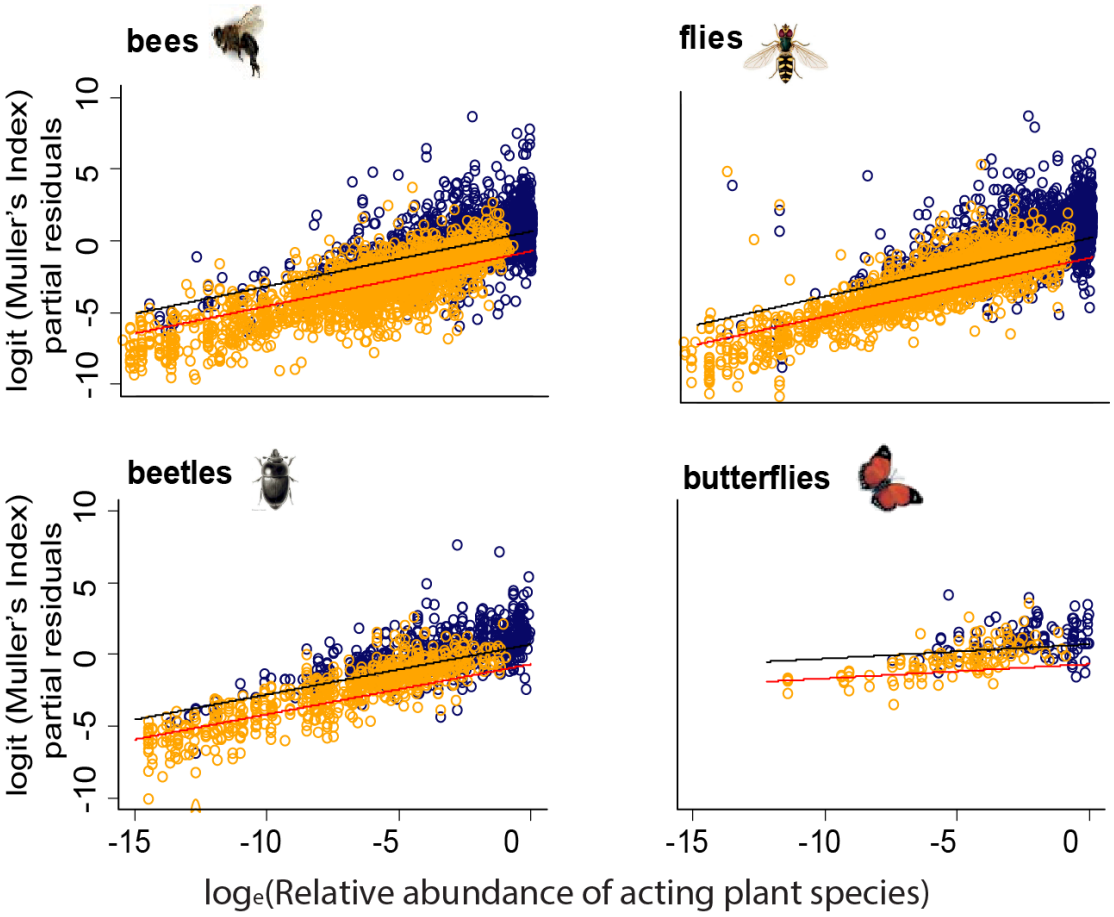

Figure S6. Influence of acting plant relative abundance (relative to the whole community) on target plants that are less (blue: ratio of abundance of target and acting plant lower than zero) or more (orange: ratio of abundance of target and acting plant higher than zero) abundant than itself. Statistical details are presented in Table 2.

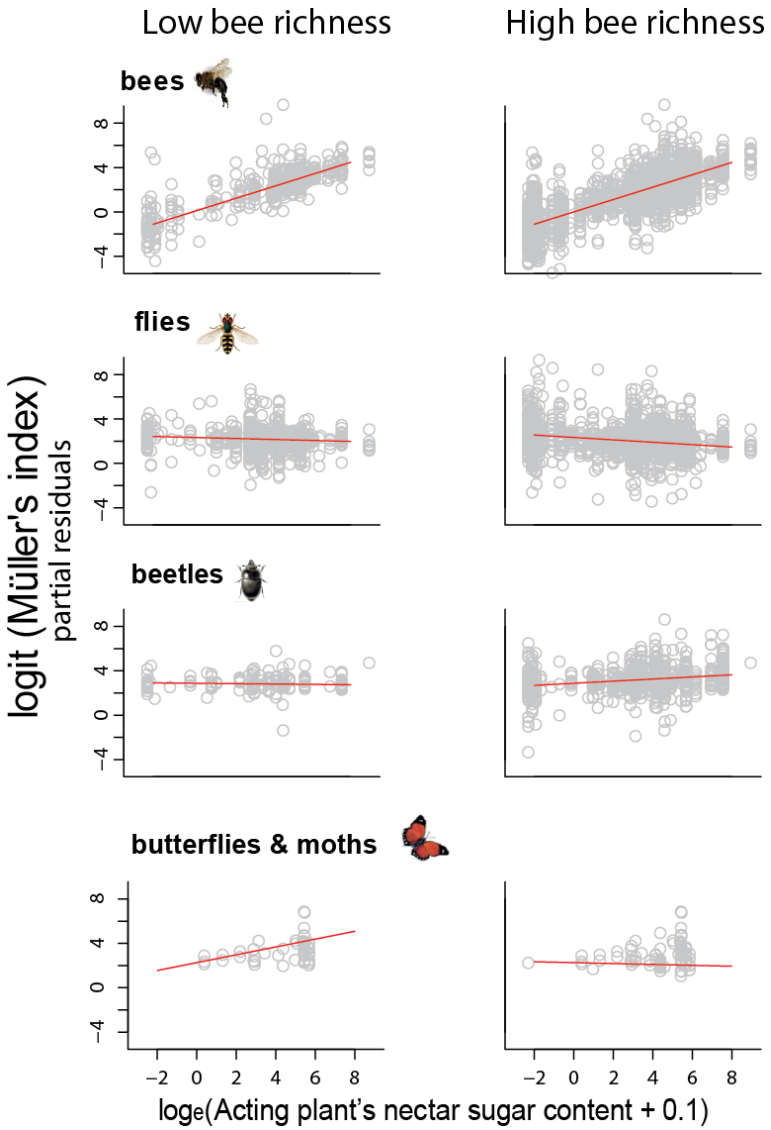

Figure S7. Variation of the effect of nectar sugar content with bee richness. Data obtained by adding the interaction between nectar sugar content and bee species richness and pollinator group to the most parsimonious Gaussian model (Table S4). Although bee species richness was a continuous variable, for illustration purposes in this graph low bee diversity includes pairs of plants from networks with more than 10 species, and high richness includes pairs of plants from networks with more than 10 species of bees.

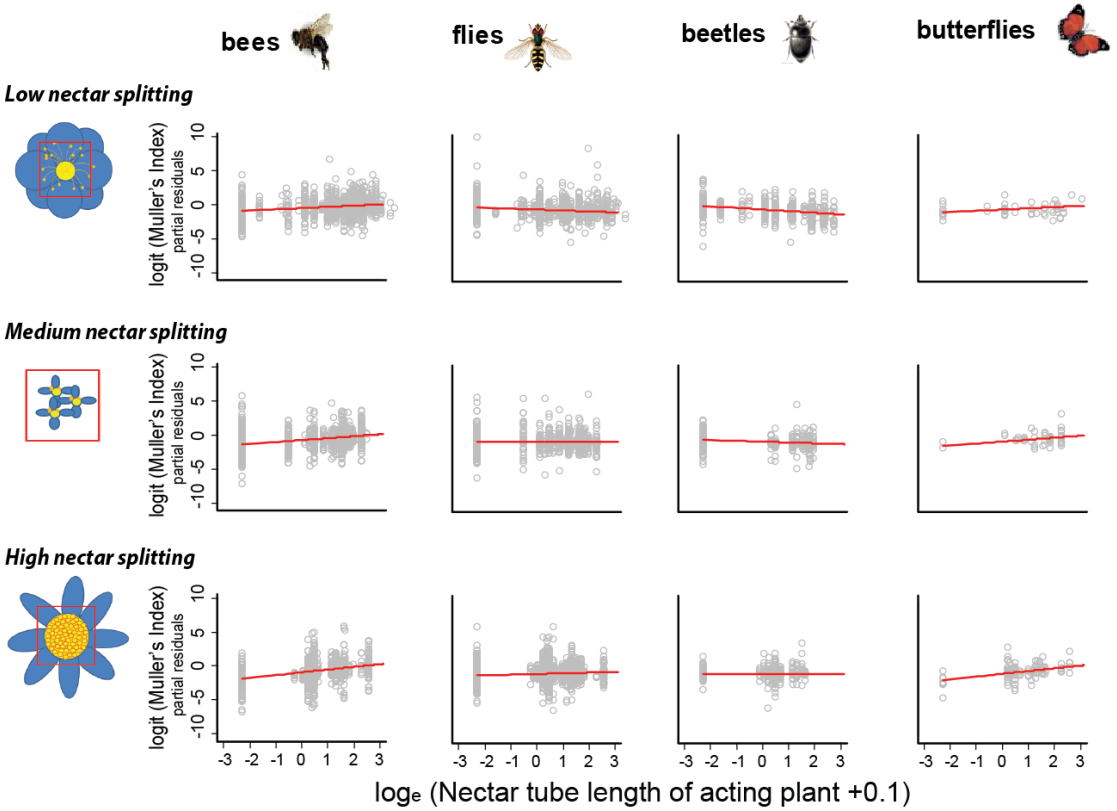

Figure S8. Effect of nectar tube depth ($\log_e$ transformed) and level of nectar splitting within floral unit on the influence that a plant has on another via shared pollinators (Müller's index), before removing the effect of nectar sugar content. As nectar tube length and nectar splitting level are significantly correlated with nectar sugar content (Figure S4), slopes presented here are positively biased in relation to those presented in Figure 4 (which represents effects after removing the effect of nectar sugar content). Dots represent partial residuals (i.e. residuals after removing the variation explained by other variables). Regression line is presented in red. Statistical details are presented in Table 2 (Gaussian model).