Supporting Information

The non-random assembly of network motifs in plant-pollinator networks

TABLES

FIGURES

Table S1. List of studies ordered by author with the year of publication, number of contributed networks and digital object identifier.

First author	Year	Number of networks	Country	DOI
Arroyo-Correa	2019	3	New Zealand	https://doi.org/10.1111/1365-2745.13332
Bartomeus	2008	6	Spain	https://doi.org/10.1007/s00442-007-0946-1
Bartomeus	2015	16	Spain	https://github.com/ibartomeus/BeeFunData
Bundgaard	2003	1	Denmark	Unpublished, Master thesis
Burkle	2013	1	United States	https://doi.org/10.1126/science.1232728
Dicks	2002	2	England	https://doi.org/10.1046/j.0021-8790.2001.00572.x
Dupont	2003	3	Denmark	https://doi.org/10.1111/j.1365-2656.2008.01501.x
Elberling	1999	1	Sweden	https://doi.org/10.1111/j.1600-0587.1999.tb00507.x
Fang	2008	1	China	https://doi.org/10.1111/1749-4877.12190
Inouye	1988	1	United States	https://doi.org/10.1111/j.1442-9993.1988.tb00968.x
Kaiser-Bunbury	2017	8	Seychelles	https://doi.org/10.1038/nature21071
Kaiser-Bunbury	2011	6	Seychelles	https://doi.org/10.1111/j.1365-2745.2010.01732.x
Kaiser-Bunbury	2010	2	Mauritius	https://doi.org/10.1016/j.ppees.2009.04.001
Lundgren	2005	1	Denmark (Greenland)	https://doi.org/10.1657/1523-0430(2005)037[0514:TDAHCW]2.0.CO;2
Olesen	2002	2	Mauritius and Portugal (Azores)	https://doi.org/10.1046/j.1472-4642.2002.00148.x
Peralta	2006	4	Argentina	https://doi.org/10.1111/ele.13510
Small	1976	1	Japan	/13960/t4km08d21
Souza	2017	1	Brazil	https://doi.org/10.1111/1365-2745.12978

Table S2. List of the 503 plant species used in this study.

List of plant species		
Acantholippia seriphioides	*Erica umbellata*	*Peponidium carinatum*
Achillea millefolium	*Erigenia bulbosa*	*Pereskia sacharosa*
Achillea wilsoniana	*Erophaca baetica*	*Persicaria runcinata*
Aciphylla glacialis	*Eryngium campestre*	*Persicaria vivipara*
Aciphylla simplicifolia	*Erythronium albidum*	*Phlomis atropurpurea*
Acrothamnus montanus	*Erythrospermum monticolum*	*Phlomis purpurea*
Actaea yunnanensis	*Erythroxylum macrocarpum*	*Phlomis tatsienensis*
Adenophora capillaris	*Erythroxylum sechellarum*	*Phlox divaricata*
Adenophora jasionifolia	*Eugenia kanakana*	*Phoenicophorium borsigianum*
Adenophora khasiana	*Eugenia orbiculata*	*Phyllanthus phillyreifolius*
Aeschynomene mollicula	*Euphorbia pyrifolia*	*Picris hieracioides*
Agarista salicifolia	*Euphorbia segetalis*	*Pilosella officinarum*
Agrimonia pilosa	*Euphrasia collina*	*Pimelea ligustrina*
Ajuga forrestii	*Euphrasia regelii*	*Pinguicula alpina*
Allium ampeloprasum	*Excoecaria benthamiana*	*Pittosporum senacia*
Allium atrosanguineum	*Faujasiopsis flexuosa*	*Plantago lanceolata*
Allium cyathophorum	*Filipendula ulmaria*	*Pleurospermum davidii*
Allium wallichii	*Flagellaria indica*	*Pleurostylia leucocarpa*
Aloysia gratissima	*Freesia refracta*	*Polemonium reptans*
Alstonia macrophylla	*Gaertnera petrinensis*	*Polyscias mauritiana*
Anacamptis morio	*Gaertnera psychotrioides*	*Portulaca fluvialis*
Anaphalioides alpinum	*Gaertnera rotundifolia*	*Potentilla crantzii*
Anaphalis nepalensis	*Galactites tomentosus*	*Potentilla erecta*
Anchusa azurea	*Galeopsis bifida*	*Potentilla fallens*
Andromeda glaucophylla	*Galium saxatile*	*Potentilla griffithii*
Andryala integrifolia	*Galium verum*	*Potentilla lancinata*
Anemone rivularis	*Gastonia crassa*	*Potentilla rubricaulis*
Anemonella thalictroides	*Gaylussacia baccata*	*Premna serratifolia*
Angelica archangelica	*Geniostoma borbonicum*	*Primula poissonii*
Anthriscus sylvestris	*Genista anglica*	*Primula secundiflora*
Antidesma madagascariense	*Genista hirsuta*	*Primula veris*
Antirhea borbonica	*Genista pilosa*	*Prosopis flexuosa*
Aphloia theiformis	*Gentiana chungtienensis*	*Prosopis rubriflora*
Arabis alpina	*Gentiana crassicaulis*	*Prostanthera cuneata*
Arachis microsperma	*Gentianella diemensis*	*Prunella vulgaris*
Arctium lappa	*Geranium delavayi*	*Pseudognaphalium affine*
Arctotheca calendula	*Geranium maculatum*	*Psiadia terebinthina*
Arenaria yunnanensis	*Glionnetia sericea*	*Psidium cattleyanum*
Argusia argentea	*Gomphrena celosioides*	*Psychotria pervillei*
Armeria velutina	*Gomphrena elegans*	*Psychotria terniflora*
Arnica montana	*Grangeria borbonica*	*Pterocephalus hookeri*
Aronia melanocarpa	*Halenia elliptica*	*Pyrola grandiflora*
Asphodelus fistulosus	*Halimium commutatum*	*Pyrostria bibracteata*
Aster diplostephioides	*Halimium halimifolium*	*Pyrostria fasciculata*
Aster oreophilus	*Hancea integrifolia*	*Ranunculus acris*
Aster souliei	*Harrimanella hypnoides*	*Ranunculus hispidus*
Aster vestitus	*Harungana madagascariensis*	*Reseda luteola*

Aster yunnanensis
Astragalus alpinus
Astragalus pullus

Atamisquea emarginata
Ayenia tomentosa
Azorina vidalii
Badula insularis
Badula platyphylla

Baeckea gunniana
Bakerella hoyifolia
Bartsia alpina
Bertiera zaluzania
Beta vulgaris

Bistorta macrophylla
Bistorta sinomontana
Bituminaria bituminosa
Brassica fruticulosa
Buddleja mendozensis

Calendula arvensis
Calluna vulgaris
Calophyllum eputamen
Calopogon tuberosus
Camassia scilloides

Campanula giesekiana
Campanula rotundifolia
Campnosperma seychellarum
Camptosema paraguariense
Canthium bibracteatum

Cardamine concatenata
Carduus crispus
Carpobrotus acinaciformis
Casearia coriacea
Cassiope tetragona

Castela coccinea
Celmisia asteliifolia
Celmisia graminifolia
Centaurea nigra
Cerastium alpinum

Cerastium fontanum
Cereus hildmannianus
Chamaedaphne calyculata
Chamomilla suaveolens
Chassalia coriacea

Chassalia petrinensis
Chrysobalanus icaco
Cinnamomum verum
Cirsium arvense
Cirsium eriophoroides

Cirsium palustre
Cirsium pratense

Helenium donianum
Helichrysum proteoides
Helichrysum stoechas

Herissantia nemoralis
Herpetospermum pedunculosum
Heteropterys glabra
Hibiscus tiliaceus
Hieracium praealtum

Hieracium umbellatum
Homalanthus populifolius
Hydrophyllum appendiculatum
Hydrophyllum virginianum
Hypericum perfolatum

Hypericum perforatum
Hypochaeris radicata
Impatiens chungtienensis
Ipomoea macrantha
Isostigma hoffmannii

Ixeridium biparum
Ixora parviflora
Ixora pudica
Juncus allioides
Kalmia angustifolia

Kalmia polifolia
Kunzea muelleri
Labourdonnaisia calophylloides
Larrea divaricata
Larrea nitida

Lathyrus clymenum
Lathyrus pratensis
Lavandula pedunculata
Lavandula stoechas
Lecanophora heterophylla

Ledum palustre
Leontodon saxatilis
Lepidaploa pseudomuricata
Leptospermum scoparium
Leucaena leucocephala

Leucanthemum vulgare
Leucochrysum albicans
Ligularia cymbulifera
Ligularia dictyoneura
Ligularia lankongensis

Lilium duchartrei
Linaria viscosa
Linum bienne
Lippia alba
Lobularia maritima

Lotus corniculatus
Lotus pedunculatus

Rhododendron lapponicum
Richea continentis
Rosa rubiginosa

Roscheria melanochaetes
Rosmarinus officinalis
Roussea simplex
Rubus alceifolius
Rubus plicatus

Ruellia tweediana
Ruta chalepensis
Salix fragilis
Salix lanata
Salix polaris

Salix repens
Salix reticulata
Salvia przewalskii
Sanicula odorata
Saussurea wardii

Saxifraga aizoides
Saxifraga oppositifolia
Scabiosa atropurpurea
Scabiosa stellata
Scaevola taccada

Schinus fasciculata
Scoparia montevidensis
Scorzonera humilis
Sedum roseum
Sedum sediforme

Senecio lautus
Senecio pinnatus
Senna aphylla
Sida rhombifolia
Sideroxylon cinereum

Sideroxylon puberulum
Silene acaulis
Silene dioica
Silene flos-cuculi
Silene gracilicaulis

Silene suecica
Silene vulgaris
Silene yunnanensis
Smilax anceps
Solidago sempervirens

Solidago virgaurea
Sonchus tenerrimus
Soulamea terminaloides
Spartium junceum
Spenceria ramalana

Spermacoce eryngioides
Spiraea alba

Cirsium vulgare
Cistus albidus
Cistus crispus
Cistus ladanifer
Cistus libanotis
Cistus monspeliensis
Cistus salviifolius
Claoxylon linostachys
Claytonia virginica
Cleistocactus baumannii
Clematis akebioides
Clematis campestris
Cleome guianensis
Clinopodium repens
Cnidoscolus urens
Coccoloba guaranitica
Codonopsis convolvulacea
Coffea macrocarpa
Coffea mauritiana
Colea seychellarum
Condalia microphylla
Convolvulus althaeoides
Convolvulus arvensis
Corokia cotoneaster
Craterispermum microdon
Crepis capillaris
Crithmum maritimum
Croton fothergillifolius
Croton grangerioides
Cuphea thymoides
Cyananthus delavayi
Cynoglossum amabile
Daucus carota
Deckenia nobilis
Delphinium tricorne
Dianthus armeria
Dianthus caryophyllus
Diapensia lapponica
Dicentra cucullaria
Digitalis purpurea
Dillenia ferruginea
Dillenia suffruticosa
Diospyros revaughanii
Diospyros seychellarum
Diplotaxis virgata
Dipsacus asperoides
Dipsacus chinensis
Dodonaea viscosa
Doratoxylon apetalum
Dorycnium pentaphyllum
Lupinus angustifolius
Lycium chilense
Lysimachea europaea
Maianthemum racemosum
Maianthemum trifolium
Malva multiflora
Medusagyne oppositifolia
Melampyrum pratense
Melicope chapelieri
Melicope lunu-ankenda
Memecylon eleagni
Memecylon ovatifolium
Menodora decemfida
Mentha canadensis
Mertensia virginica
Microseris lanceolata
Microtea scabrida
Microula sikkimensis
Mimosa hexandra
Mimosa sensibilis
Mimulus moschatus
Mimusops erythroxylon
Mimusops sechellarum
Molinaea arborea
Molinaea macrantha
Mollugo verticillata
Monarda bradburiana
Morinda citrifolia
Muehlenbeckia axillaris
Muehlenbeckia complexa
Murdannia nudiflora
Mycelis muralis
Myosotis alpestris
Nematolepis ovatifolia
Nemopanthus mucronatus
Nepenthes pervillei
Nepeta stewartiana
Nephrosperma vanhoutteanum
Neptunia plena
Northia seychellana
Ochna kirkii
Ochna mauritiana
Ocotea laevigata
Olea lancea
Olearia bullata
Onosma confertum
Opuntia elatior
Opuntia stricta
Opuntia sulphurea
Origanum vulgare
Stachys sylvatica
Stachytarpheta indica
Stachytarpheta jamaicensis
Stellaria graminea
Stellaria yunnanensis
Stillingia lineata
Stylosanthes hamata
Succisa pratensis
Suriana maritima
Swertia forrestii
Syzygium commersonii
Syzygium coriaceum
Syzygium glomeratum
Syzygium jambos
Syzygium mauritianum
Syzygium petrinense
Syzygium venosum
Syzygium wrightii
Tabernaemontana persicarifolia
Talinum fruticosum
Tambourissa peltata
Taraxacum campylodes
Teucrium fruticans
Thalictrum delavayi
Thalictrum rostellatum
Thapsia villosa
Thespesia populnea
Thymelaea hirsuta
Thymus mastichina
Tibetia himalaica
Tillandsia didisticha
Timonius sechellensis
Toddalia asiatica
Torilis japonica
Tradescantia virginiana
Trifolium arvense
Trifolium dubium
Trifolium pratense
Trifolium repens
Tripogandra glandulosa
Tristemma mauritianum
Trochetia blackburniana
Trollius europaeus
Trollius vaginatus
Tuberaria guttata
Turnera angustifolia
Turraea rigida
Ulex parviflorus
Urospermum picroides
Uvularia grandiflora

Dracaena concinna	*Orites lancifolius*	*Vaccinium myrtilloides*
Dracaena reflexa	*Oxalis violacea*	*Vaccinium myrtillus*
Dryas integrifolia	*Oxylobium ellipticum*	*Vaccinium uliginosum*
Dryas octopetala	*Ozothamnus leptophyllus*	*Vaccinium vitis-idaea*
Dubyaea bhotanica	*Pandanus barkleyi*	*Verbascum thapsus*
Echinopsis candicans	*Pandanus rigidifolius*	*Veronica brachysiphon*
Echinopsis rhodotricha	*Pandanus wiehei*	*Vicia cracca*
Echium plantagineum	*Paragenipa wrightii*	*Vicia lutea*
Echium sabulicola	*Paraserianthes serratifolia*	*Vicia sativa*
Eleutherine bulbosa	*Parkinsonia praecox*	*Viola biflora*
Embelia angustifolia	*Parnassia palustris*	*Viola pubescens*
Empetrum nigrum	*Passiflora suberosa*	*Viola sororia*
Enemion biternatum	*Pavonia sidifolia*	*Wahlenbergia albomarginata*
Epacris petrophila	*Pedicularis cephalantha*	*Wahlenbergia ceracea*
Epilobium angustifolium	*Pedicularis densispica*	*Waltheria indica*
Epilobium gunnianum	*Pedicularis dichotoma*	*Warneckea trinervis*
Epilobium hirsutum	*Pedicularis rex*	*Wikstroemia indica*
Epilobium latifolium	*Pedicularis siphonantha*	*Xylopia lamarckii*
Epilobium tibetanum	*Pedicularis tricolor*	*Ziziphus mistol*
Erica scoparia	*Pemphis acidula*	*Zuccagnia punctata*
Erica tetralix	*Pentachondra pumila*	

Table S3. Traits used to delimit the different plant functional groups divided in quantitative and categorical traits.

Quantitative traits		**Categorical traits**	
Type	**Traits**	**Type**	**Traits**
Vegetative	Plant height (m)	**Vegetative**	Lifepan
Floral	Flower width (mm)	**Vegetative**	Life form
Floral	Flower length (mm)	**Floral**	Flower shape
Floral	Inflorescence width (mm)	**Floral**	Flower symmetry
Floral	Style length (mm)	**Reproductive**	Compatibility system
Floral	Ovules per flower	**Reproductive**	Breeding system
Floral	Flowers per plant		
Reproductive	Autonomous selfing (fruit set)		

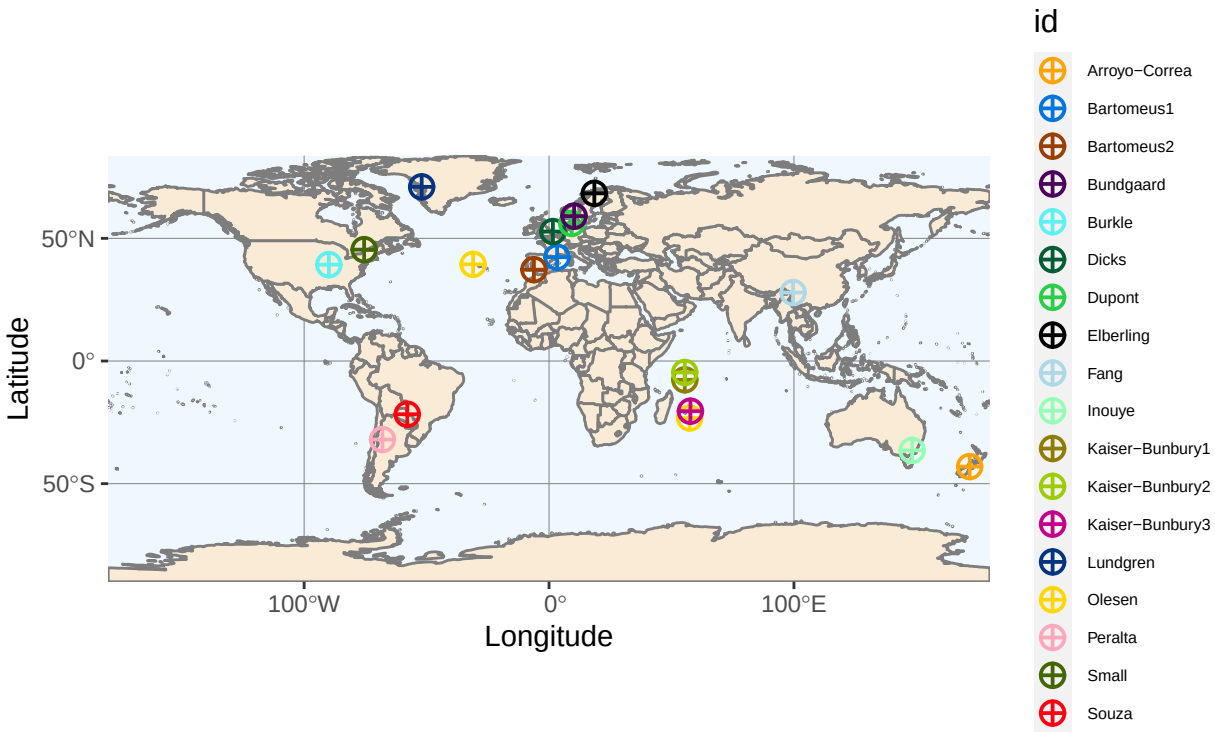

Figure S1. Map with the different locations of the plant-pollinator studies used in this work to explore woldwide patterns at the meso-scale level. For each study just one location is shown except for the study of Olesen that was conducted in two very different locations (Mauritius and Azores).

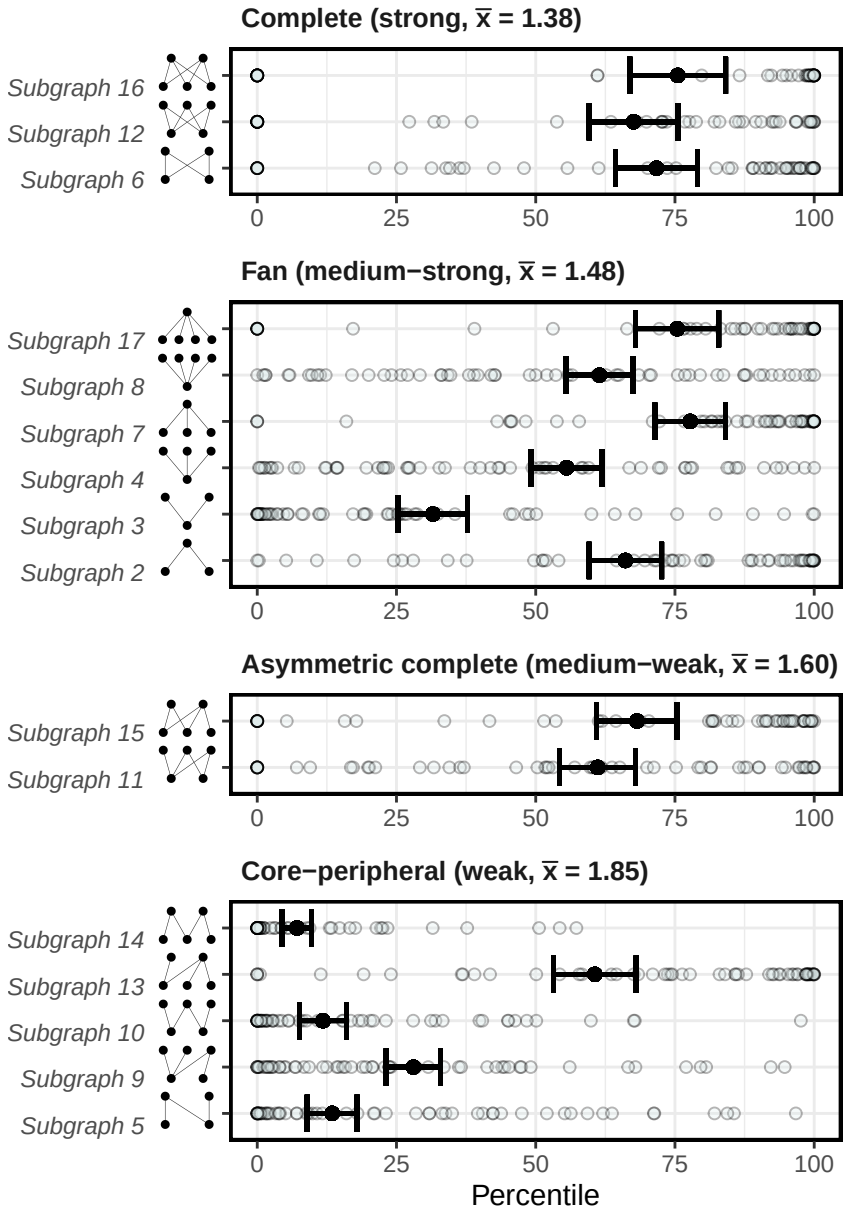

Figure S2. Comparison of network subgraph frequencies between empirical and simulated networks grouped by average path length (plots a, b, c and d) as determined in Simmons et al. (2020) without considering singletones. This is shown with the mean percentage of network subgraph frequencies in empirical networks that were over the subgraph frequencies of the simulated ones (percentiles). This was done by network (light blue dots) and then averaged for all networks (black dots with error bars that correspond to the standard deviation).

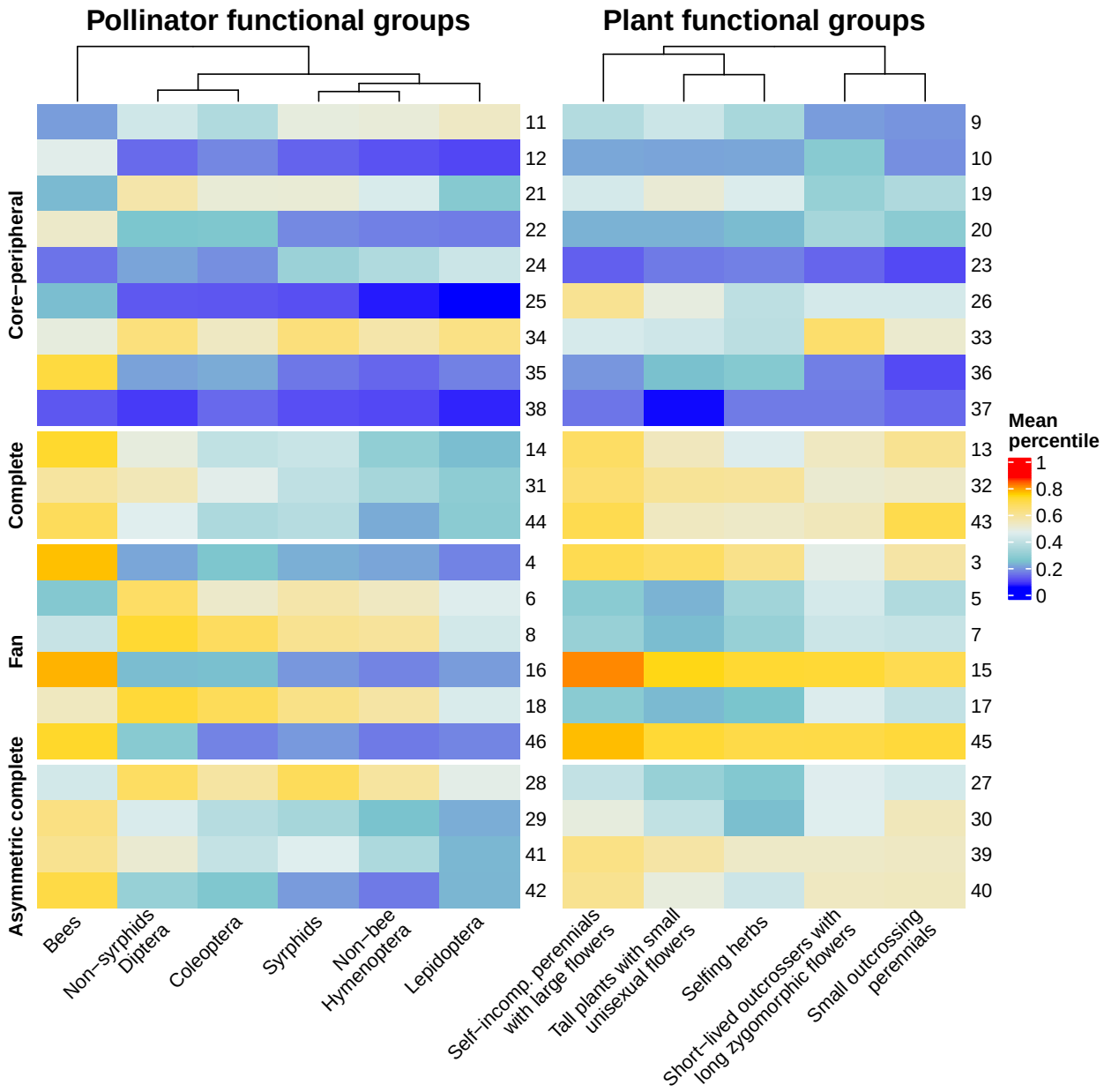

Figure S3. Heatmap indicating under- and over- representation of pollinator and plant functional groups in the different network subgraph positions after removing non-robust links (singletones). The different subgraph positions are dividied by the average path length clasification determined by Simmons et al. (2020). The superior dendrogram indicates the differences across functional groups with the more separated groups showing larger differences.

Plant functional group composition

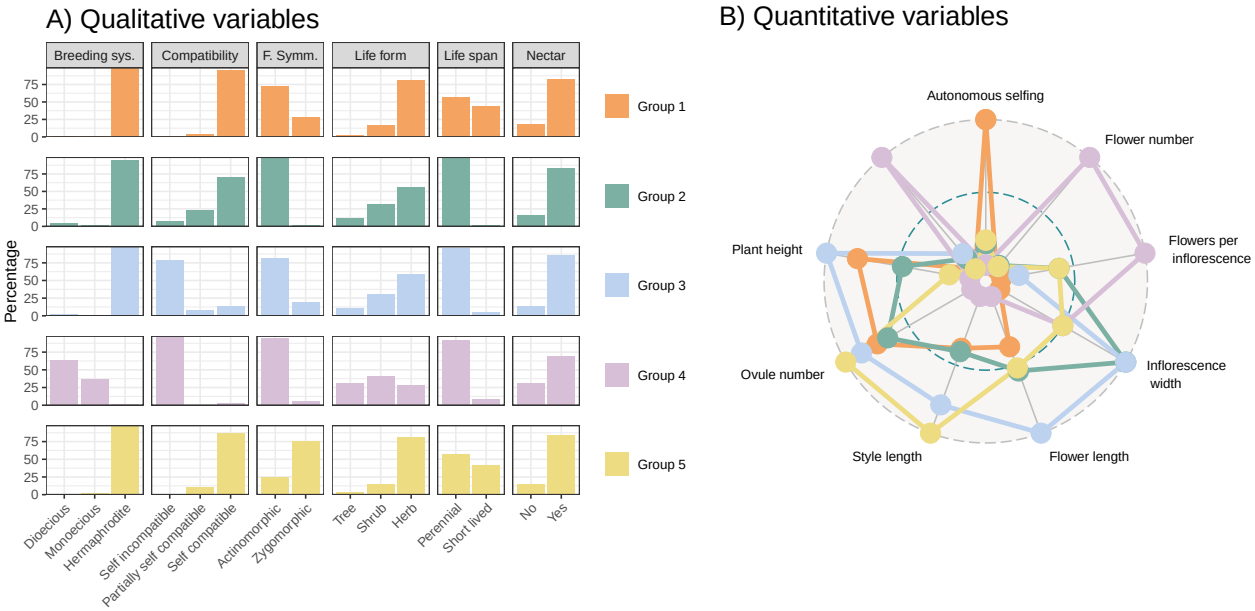

Figure S4. Plant functional group composition separated in qualitative and quantitative variables. Panel A) shows the percentage of the different categories within trait represented with different colours for each functional group. Plot B) shows the radar plot of the different scaled quantitative variables. Both quantitative and qualitative variables are coloured with the same pattern of colours by functional group. Group 1 corresponds to short-lived selfers; group 2 to small outcrossing perennials; group 3 to self-incompatible perennials with large flowers; group 4 to tall plants with small unisexual flowers; and, group 5 to short-lived outcrossers with long zygomorphic flowers.

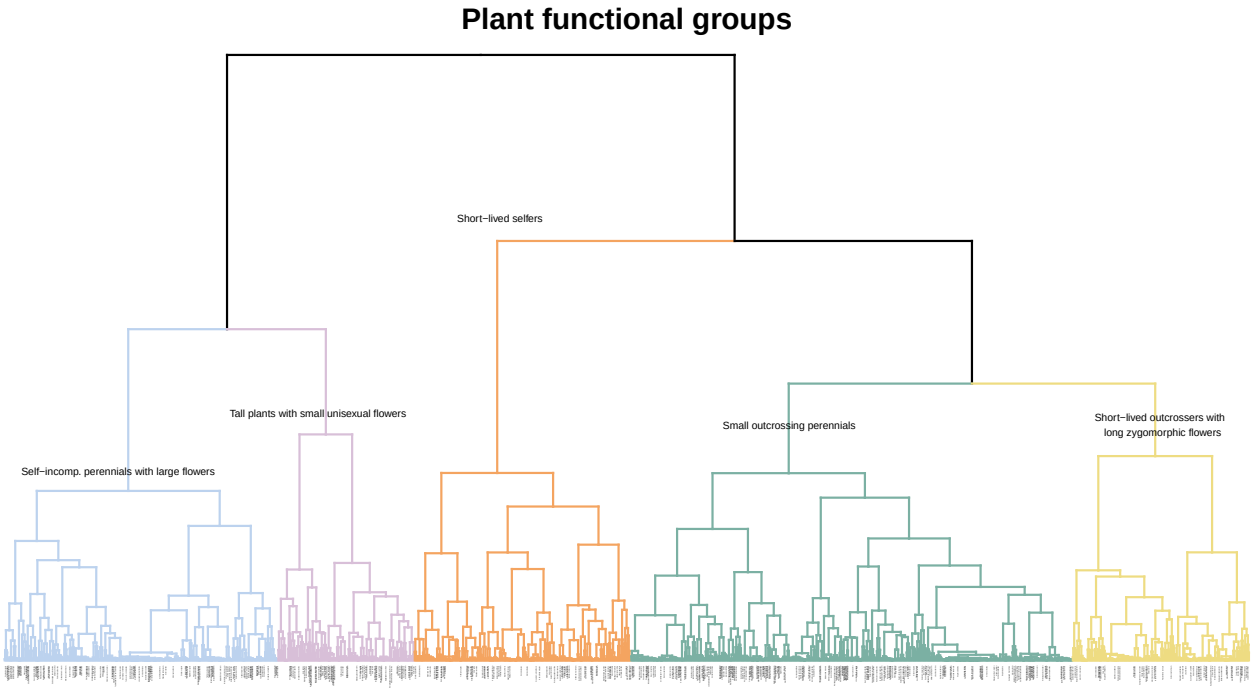

Figure S5. Hierarchical clustering dendrogram with the branches coloured by the optimal number of clusters (5). The labels of the subgroup of species (N = 524) used in this study are coloured in black in order to show the evenness of the distribution of the species across clusters. The rest of species labels are omitted for visualization purposes (N = 982).

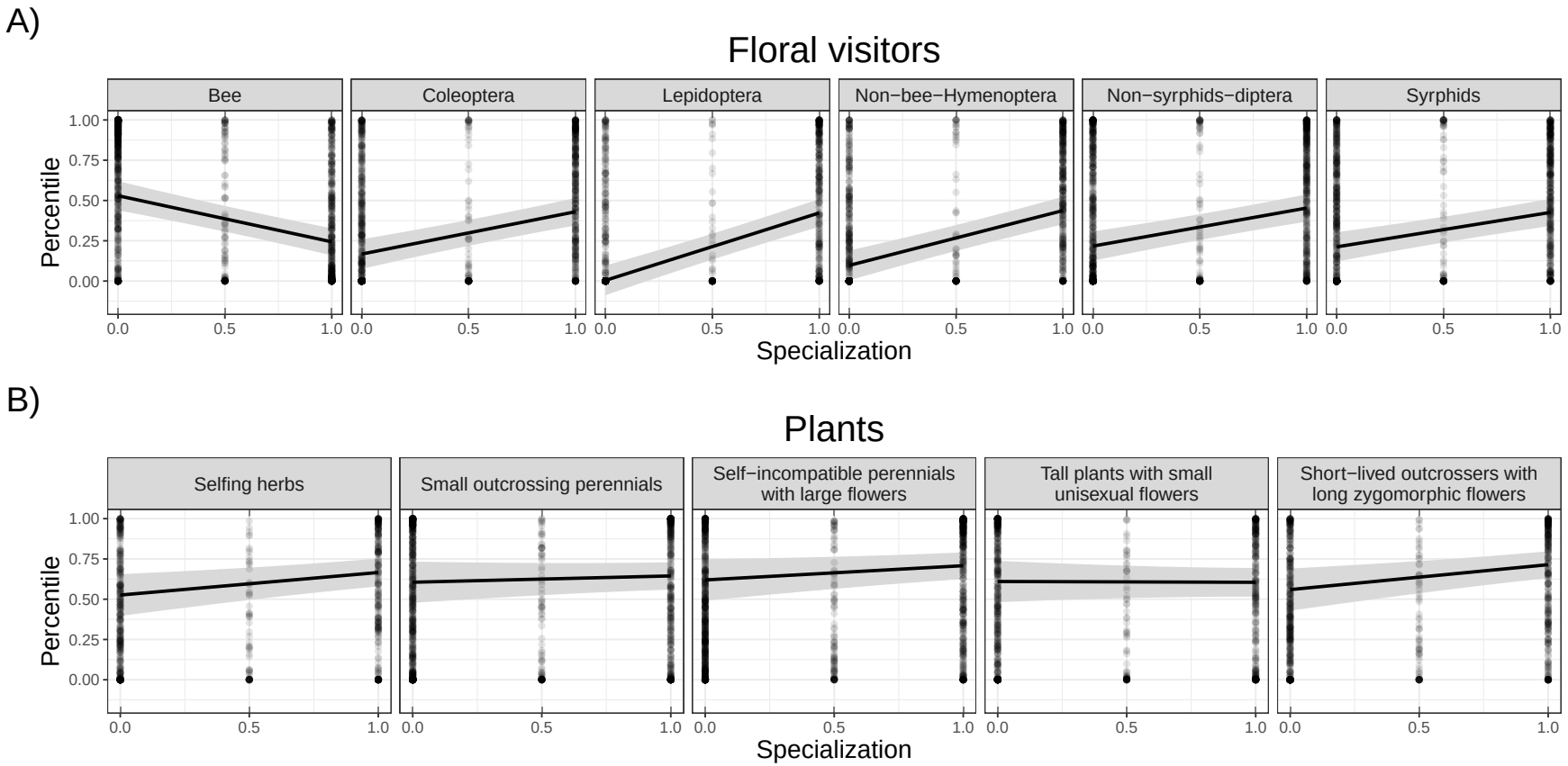

Figure S6. Association between the percentile (see main text) and specialization of the different plant and floral visitor functional groups on network subgraph positions. Here we consider that percentiles above 0.75 indicate over-representation and percentiles below 0.25 under-representation in the comparison between empirical and simulated networks.

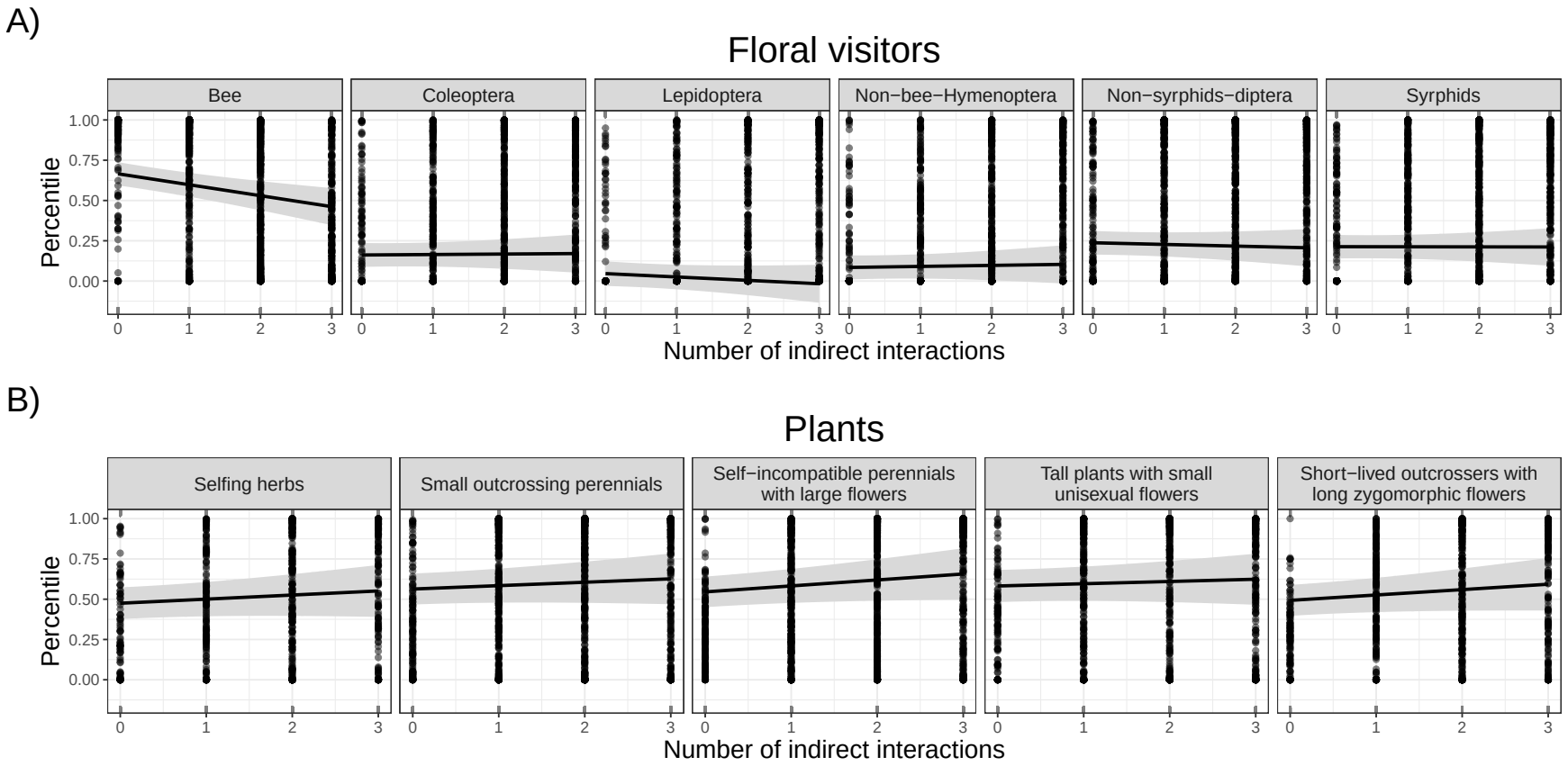

Figure S7. Association between the percentile (see main text) and number of indirect interactions of the different plant and floral visitor functional groups on network subgraph positions. Here we consider that percentiles above 0.75 indicate over-representation and percentiles below 0.25 under-representation in the comparison between empirical and simulated networks.

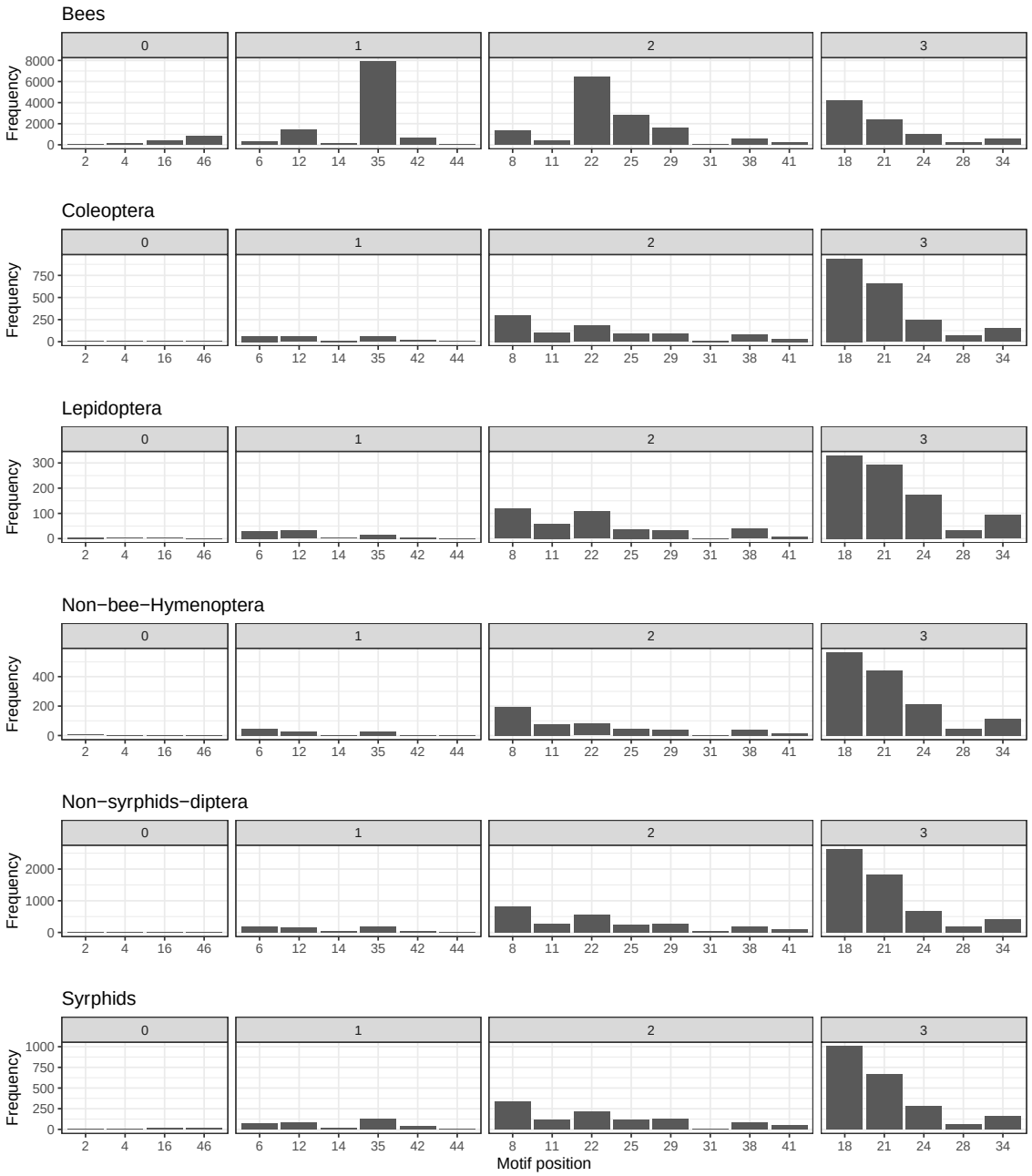

Figure S8. Frequency of the different floral visitor functional groups on the different network subgraph positions aggregated by the number of indirect interactions for the different subgraph positions.

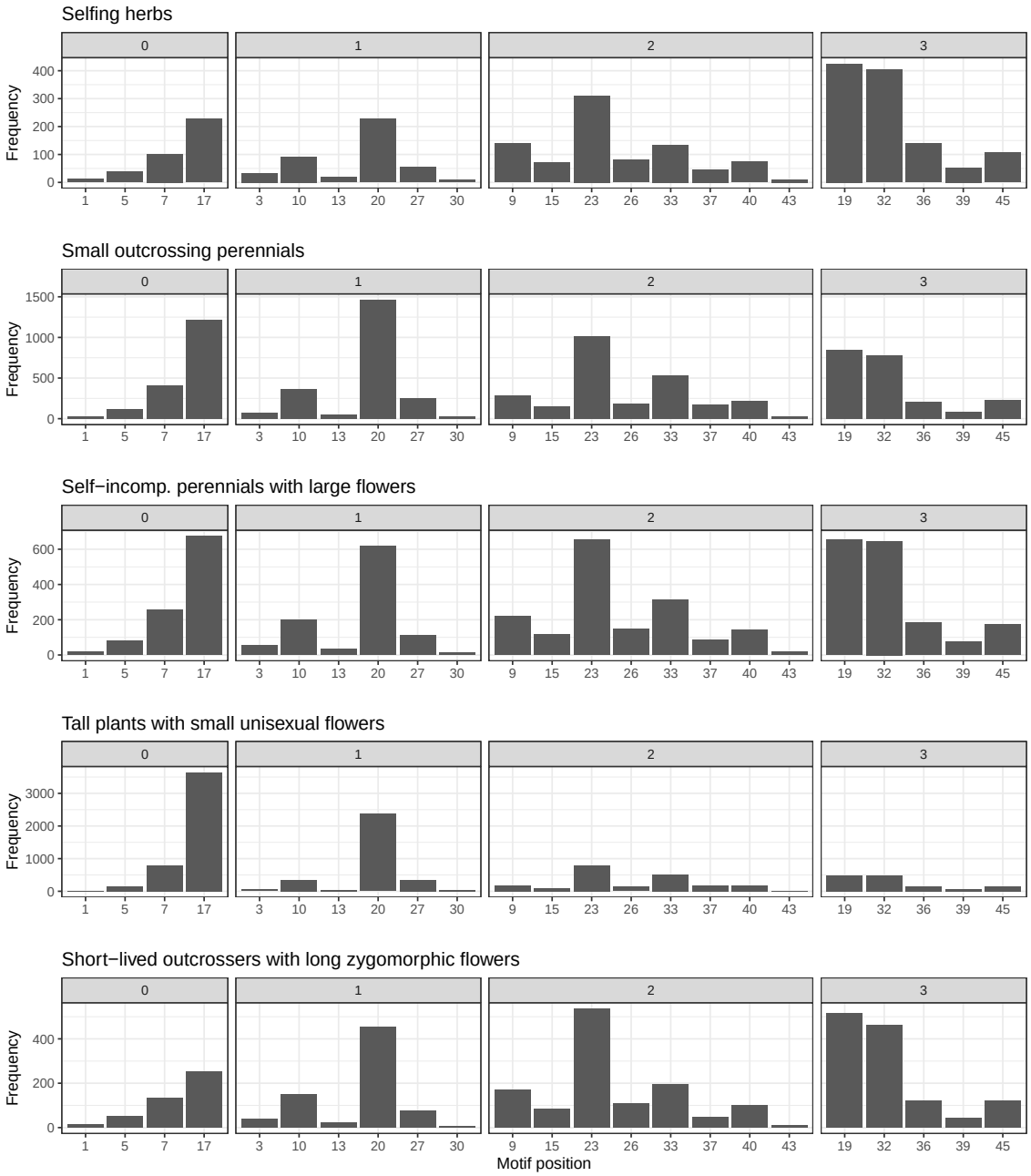

Figure S9. Frequency of the different plant functional groups on the different network subgraph positions aggregated by the number of indirect interactions for the different subgraph positions.