The Structure of Ecological Networks Across Levels of Organization—Supplemental Material

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1. Types of "ecological networks"

Networks are used to describe multiple aspects of ecological systems. In this review, I focus on interactions involving individuals of different species. I do not address the structures of other types of "ecological networks", such as networks describing social interactions within animal populations (Farine & Whitehead 2015), transport by social animals (Pinter-Wollman et al. 2011), sexual interactions (McDonald & Pizzari 2018), the spatial structure of landscapes (Dale & Fortin 2010), environments (Jongman 1995), and urban metabolism (Zhang 2013), because these systems strongly differ from interspecific interactions in both their natural history and eco-evolutionary consequences.

2. Types of network representation

A wide variety of graphs allow the characterization of ecological systems as networks. In this sense "graph" and "network" are often used synonymously: vertices or nodes depict the interacting units, whereas edges or links depict the interactions between pairs of units. Different types of graphs are defined by the properties of the vertices and the edges used to represent the empirical or theoretical studied system. When exploring ecological problems, it is natural to ignore the variation across the units of the system and across the different types of interactions that these units perform. These simplifications lead to the depiction of an ecological system as a simple graph **(Supplemental Figure 1)**. In most simple graphs, the presence of an edge is defined by the occurrence of a single event of an interaction between two ecological units. However, alternative definitions can be used to delimit an edge (see an example in **Supplemental Figure 1**). By definition, simple graphs do not allow edges to connect the vertices directly to themselves, i.e., loops, such as the links describing cannibalistic interactions in a food web. However, the incorporation of loops is a simple generalization of the representation of an ecological system using simple graphs.

Supplemental Figure 1. Simple graphs depict ecological units as a set of vertices. These vertices are connected by interactions depicted as edges, ignoring variations in direction, strength, or type. Here, two sea otters (vertices) are connected by an edge if their pairwise niche overlap (sensu Araújo et al. 2008) in food resource use is higher than the population average (32.1% of average pairwise niche overlap). Data from the sea otter population in Monterey Bay, California (Tinker et al. 2012).

In some ecological systems, such as those involving interactions between hosts and their parasites, there are two classes of ecological units (plants and animals), and interactions only occur between units from these different classes. These systems are naturally described as bipartite graphs (**Supplemental Figure 2**). Bipartite graphs represent a particular type of *k*-partite graph, in which *k* is the number of partitions of vertices, as defined by the fact that interactions only occur between vertices from different partitions.
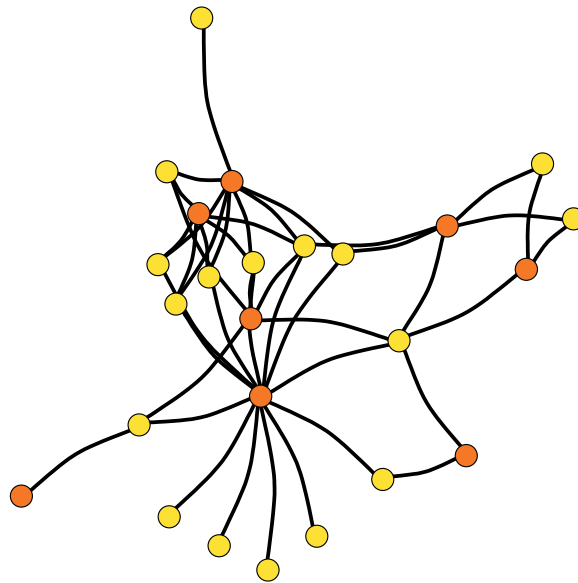
Supplemental Figure 2. Bipartite graphs depict systems in which there are two sets (partitions) of ecological units (vertices). Edges only connect vertices from different partitions. Here, a bipartite graph describing a network between mammalian hosts (orange vertices) and fleas (yellow vertices) in Central Yakutia, Russia (Hadfield et al. 2013) is shown.

One fundamental aspect of ecological systems is that not all interactions are equivalent. For instance, ecological interactions often vary in interaction strength, which is often measured as the interaction frequency (Bascompte et al. 2003), interaction rate (Valdovinos 2019), or impact of the removal of that interaction on some ecosystem properties (Paine 1966). Theoretical studies have provided strong support for the notion that interaction strengths affect the stability of ecological systems (Allesina & Tang 2012, Bascompte et al. 2006). In exploring the role of the interaction strength in network organization, it is possible to depict ecological systems using weighted graphs (**Supplemental Figure 3**).
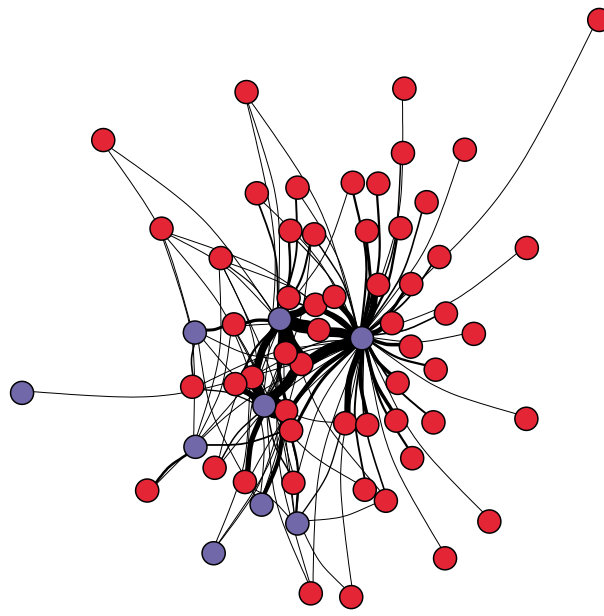
Supplemental Figure 3. Weighted graphs depict systems by incorporating some quantitative information regarding ecological interactions as interaction strengths. In this example, a weighted bipartite graph describes the interactions among flowering plants (red vertices) and floral visitors (purple vertices) in the Atlantic Forest, Brazil (Vizentin-Bugoni et al. 2016). Variations in the frequency of interactions are described by the link widths.

Similarly, many ecological interactions are characterized by directionality, and this directionally may have major impacts on ecological (Neutel et al. 2002) and coevolutionary dynamics (Nuismer & Thompson 2006). Directionality can be depicted by directed graphs. Food webs represent a classical example of ecological systems often depicted as directed graphs, but insight into other ecological interactions is obtained by incorporating directionality into the network representation (**Supplemental Figure 4**).

Some ecological questions require the simultaneous consideration of distinct types of units and ecological interactions. Multilayer graphs allow the incorporation of different types of edges, vertices, or additional information (i.e., time and space) as layers into a network representing an ecological system. For example, a multilayer graph allows the assessment of antagonistic and mutualistic interactions between frugivorous mammals and their food plants (**Figure 5**) and, consequently, the investigation of how patterns of interaction vary between different interaction outcomes in plants.
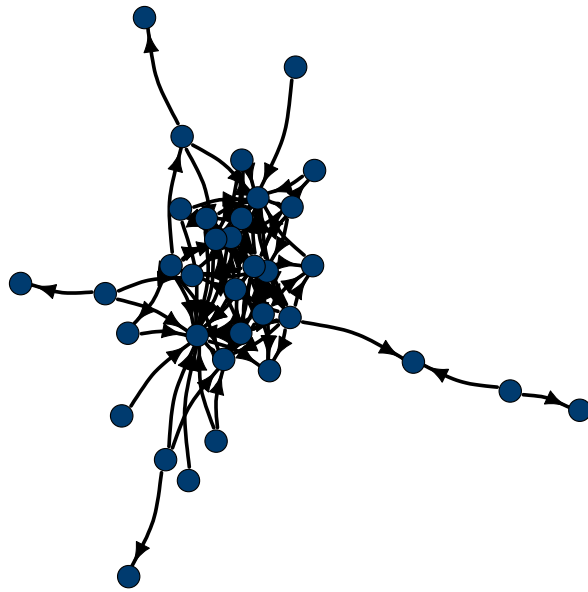
Supplemental Figure 4. Directed graphs depict systems by incorporating the directionality of ecological interactions. For example, in marine environments, some fish species follow other species in a commensal interaction (nuclear-follower interactions, Sazima et al. 2007). In this graph, the vertices represent fish species, and an arc points from a following species to a nuclear species in Fernando de Noronha Island, Brazil (Inagaki et al. 2020).
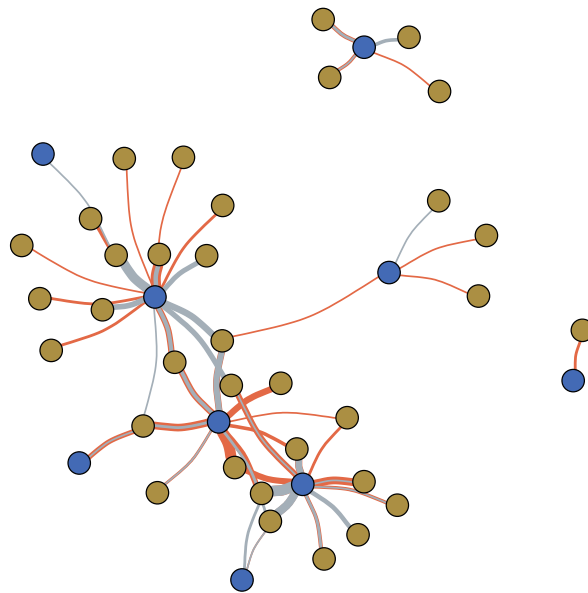
Supplemental Figure 5. Multilayer graphs allow the incorporation of information regarding the types of ecological interactions. Here, antagonistic (red edges) and mutualistic (gray edges) interactions connect marsupial and rodent species (blue vertices) to different plant species (ochre vertices) in an urban protected area in Belo Horizonte, Brazil (Genrich et al. 2017).

In this section, I provided a non-exhaustive list of the types of graphs used in different ecological problems. There are multiple alternative descriptions (see Harary 1969). For example, some ecological problems, such as the study of local adaptation and ecological fitting in parasite-host interactions across habitats, may benefit from hypergraphs in which an edge connects more than two vertices simultaneously (Golubski et al. 2016, Valverde et al. 2020). Therefore, network descriptions are highly flexible and allow the incorporation of the complexity of ecological systems in various ways. This immense catalog creates multiple opportunities for ecological research, especially if used to address fundamental questions in ecology and evolution.

### 3. Number of possible network configurations

The binary structure of a network (i.e., the presence/absence of pairwise interactions) can be completely described by an adjacency matrix **A** in which the element $a_{ij} = 1$ if there is an interaction between two species, with $a_{ij} = 0$ otherwise. The number of network configurations can be computed by enumerating all possible labeled graphs (Harary 1969), i.e., graphs in which each node is identified by a unique label, such as the Latin binomial in a species-based network. For a set of A frugivorous species and P plant species, the number of possible labeled graphs is 2^{AP}. I used information based on the 34 networks describing interactions between frugivores and fruiting plants available on the *Web of Life* website (http://www.web-of-life.es/) to compute the mean number of frugivorous birds and plants per network. Notably, 2^{AP} includes nonrealistic network configurations, such as empty graphs (networks without any link). However, the fast increase in the number of network configurations with species richness (A and P) illustrates the almost endless diversity of possible networks in species-rich interacting assemblages.

4. Metrics allowing the characterization of the network structure

A wide variety of metrics allow the characterization of network structures (Albert and Barabási 2002, Costa et al. 2007, Delmas et al. 2019, Wasserman & Faust 1994). The development of network metrics is a field of intense research, and there are multiple alternative ways to quantify a given network pattern. Associating network metrics with network visualization often develops intuition regarding these patterns.

Here, I illustrate some macroscopic patterns commonly explored in ecological networks by combining macroscopic metrics and network visualization.

Connectance (**Supplemental Figure 6**)*:* A fundamental aspect of the network structure is the number of interactions recorded in the network. The maximal number of interactions increases with the number of nodes in the network. In food webs, the maximal number of undirected links increases with $S^2/2$. In networks depicted by bipartite graphs, such as many plant-animal networks, the maximal number of links increases with $S_1 S_2$, in which S_r is the species richness of the set r. To circumvent the association between the species richness and the number of interactions, the density of interactions in a network is usually described by computing the connectance, C (Gardner & Ashby 1970), which is the fraction of all possible links recorded in the network. The computation of the connectance depends on the type of graph used to describe the network (e.g., undirected versus directed, unipartite versus bipartite, or simple graph versus graph with loops). Regardless of the type of graph, the connectance always describes the density of links in a network. Connectance is such a crucial aspect of networks that many studies investigating network patterns contrast the empirical patterns against the metric values predicted by an Erdös-Rényi graph, i.e., a random graph in which each pair of nodes is connected by a link with probability equal to the connectance, C.
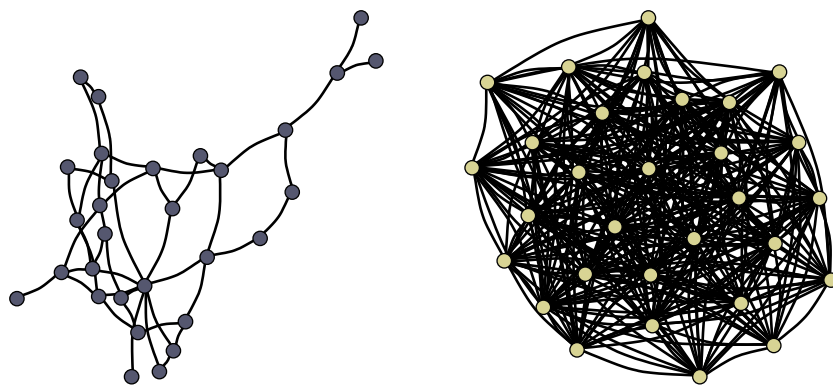
Supplemental Figure 6. Two theoretical networks that differ in their connectances (left: C = 0.101; right: C = 0.800; both networks have 30 nodes).

*Components (***Supplemental Figure 7)**: Two nodes are a part of the same component if there is a direct or indirect pathway of links connecting them (Newman et al. 2001). Thus, a network with multiple components is formed by multiple isolated subnetworks (in addition, see the sidebar: *The Emergence of a Giant Component*).
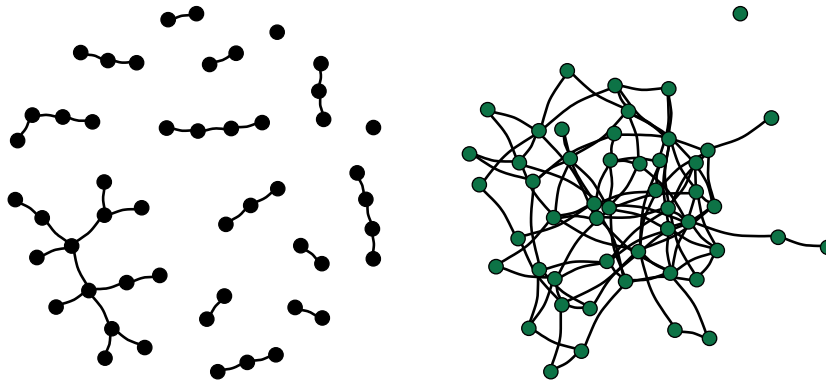
Supplemental Figure 7. Two theoretical networks that differ in their numbers of components (left: 15 components; right: two components; both networks have 50 nodes).

Degree distribution (**Supplemental Figure 8**): One of the most important findings of network science is the discovery that networks describing empirical systems are often more heterogeneous in terms of the number of links per node compared to Erdös-Rényi graphs (Barábasi & Albert 1999). The variation in the number of links per node can be described by the degree distribution, i.e., the distribution describing the frequency of nodes with k links in the network.

Modularity (**Supplemental Figure 9**): Modularity refers to the degree to which a network is formed by modules, i.e., semi-isolated, highly cohesive groups of nodes. The presence of such cohesive groups can be detected by multiple approaches, such as by measuring the average clustering coefficient of a network (Araújo et al. 2008, Watts & Strogatz 1998) or computing an index of modularity that considers the number of modules and the number of interactions within and among the modules (Barber 2007, Girvan & Newman 2002). If there is no *a priori* hypothesis regarding which node is in each module, modularity indexes allow the simultaneous quantification of the degree of modularity and identification of the subgroups of nodes, but they introduce the challenge of finding the partition of the nodes in modules that maximize the modularity index amid the almost endless number of possible partitions (Guimerà & Amaral 2005).
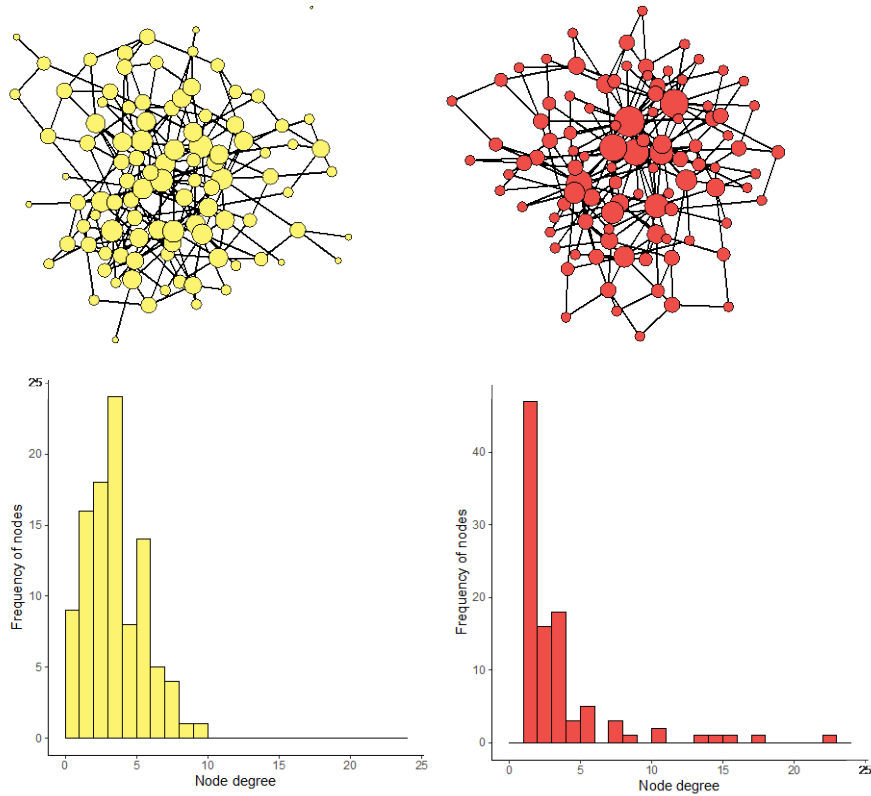
Supplemental Figure 8. (Upper plots) Two theoretical networks that have the same number of nodes (100 nodes) and the same number of links (200 links) but differ in their degree distributions (lower plots). The yellow network shows a smaller variance ($\sigma^2 = 4.1$) in the number of links per node compared to the red network ($\sigma^2 = 13.3$). The node size is proportional to the node degree.
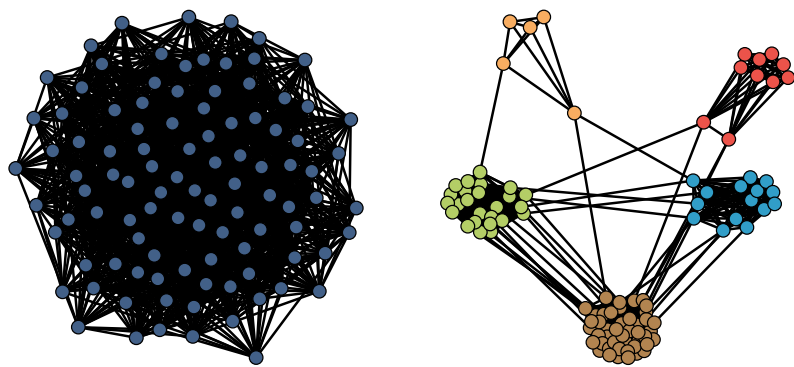
Supplemental Figure 9. Two theoretical networks that have the same number of nodes (100 nodes) and the same number of links (1480 links) but differ in their modularity. On the left, an Erdös-Rényi random graph shows low modularity ($Q = 0.12$). On the right, a network shows higher modularity ($Q = 0.47$) in which the colors indicate distinct modules. Q was estimated using Louvain's method (Blondel et al. 2008).

Nestedness (**Supplemental Figure 10**): Nestedness refers to the degree to which the interaction partners of a given node are a subset of the interaction partners of a node with a larger set of partners. Nestedness is often associated with asymmetries in the patterns of interaction between interacting nodes (Vázquez and Aizen 2004) but also leads to a core of highly connected nodes and generates a structure of nested subsets in the patterns of interaction. The concept of nestedness is present in graph theory as double-nested graphs (Staniczenko et al. 2013). However, the nestedness concept was introduced in the study of ecological networks by borrowing the approach developed in biogeography to characterize the nonrandom patterns of species compositions across sites (Atmar & Patterson 1993). Some popular indexes used to characterize nestedness, such as NODF (Almeida-Neto et al. 2008) and Bastolla's *N* (Bastolla et al. 2009), can be viewed as asymmetric Jaccard-like indexes.

Supplemental Figure 10. Two theoretical bipartite graphs that have the same number of nodes (14 nodes in each set) and the same number of links (105 links) but differ in their nestedness. On the left, a bipartite version of an Erdös-Rényi graph that shows intermediate levels of nestedness (*N* = 52.06). On the right, a network shows perfect nestedness (*N* = 100). The colors indicate different sets of nodes. *N* is the degree of nestedness estimated using NODF (Almeida-Neto et al. 2008).

Distance and centralization (**Supplemental Figure 11**): The distance between a pair of nodes in a network is the number of links in the shortest path connecting them. The shortest path length, ℓ, in the number of links is the core of many centrality metrics, such as closeness and betweenness centrality. Other centrality metrics also incorporate longer pathways, such as Katz centrality (Katz 1953), whereas the degree of a node is a measure of centrality assuming only direct interactions. Centrality metrics characterize whether a given node is central or peripheral in the network. At the network level, the average shortest pathway, $\langle \ell \rangle$, and largest ℓ recorded in the network (network diameter) characterize the distance among the nodes in a network. Accordingly, network centralization characterizes the variation in centrality across the

nodes in a network. In ecology, most studies focus on centrality values rather than on centralization measures (as in Gómez & Perfectti 2012).
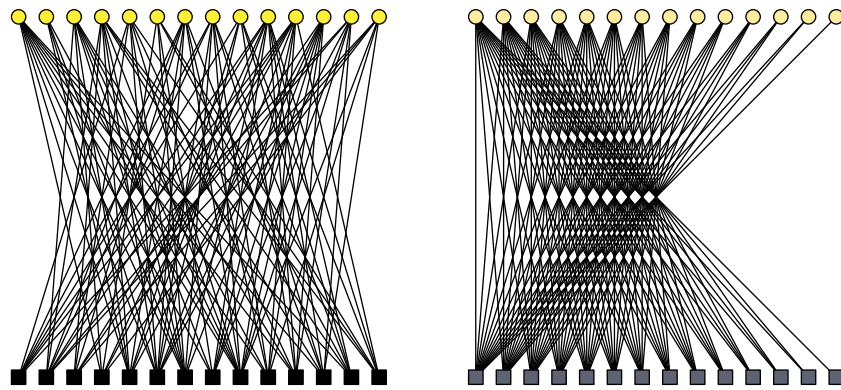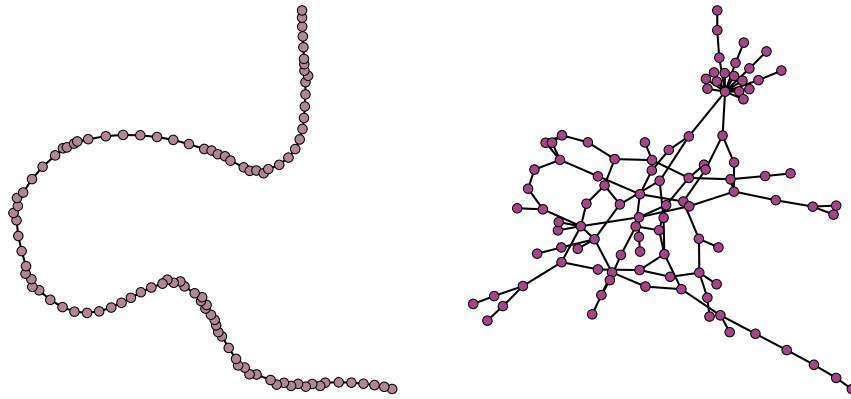

Supplemental Figure 11. Two theoretical graphs that have the same number of nodes (100 nodes) and the same number of links (114). On the left is a graph in which the distances between pairs of nodes in links are very large (average smallest path length, $\ell = 29.55$). On the right is a network in which short pathways connect pairs of nodes ($\ell = 5.97$).

Interaction weights (**Supplemental Figure 12**): The use of weighted graphs to incorporate quantitative information regarding links has led to multiple metrics. Some metrics are quantitative versions of the metrics first used to characterize unweighted graphs, such as the species strength (a weighted version of the degree, Bascompte et al. 2006), the distribution of interaction weights (a weighted version of the degree distribution, Bascompte et al. 2006), weighted clustering coefficients (Araújo et al. 2008), the weighted nestedness (Galeano et al. 2009), and the weighted modularity (Blondel et al. 2008). Other metrics focus on recording variations in interaction weights. Variations in interaction weights lead to descriptions of asymmetries in interaction weights (e.g., when all hosts of a parasite species i come from a single host species j, whereas the contribution of species i to the parasite load of individuals of species j is minimal). Variation in interaction weights across all links from a single node or across all links in the network is often characterized by entropy-based metrics, such as H^2, interaction diversity, and interaction evenness (Bersier et al. 2002, Blüthgen et al. 2006, 2008).
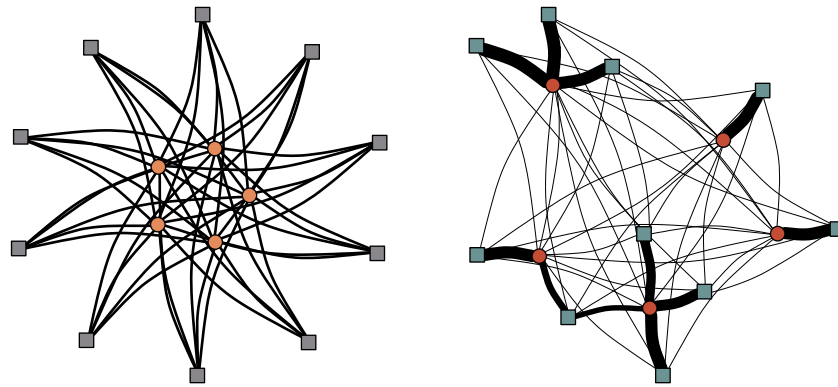
Supplemental Figure 12. Two theoretical bipartite graphs that have the same number of nodes in each set (5 and 10 nodes) and the same number of links (50 links) but vary in interaction weights (depicted as link widths). Here, the interaction weights represent the relative frequencies of the interactions. The distribution of the interaction weights can be described by entropy-based descriptors, such as the average species interaction diversity $\langle H_i \rangle$ (Blüthgen et al. 2008). The higher the H_i value is, the higher the entropy of the interaction weights, and consequently, the interactions are more evenly distributed across the links (in the left network, gray nodes show $\langle H_i \rangle = 1.61$, whereas the blue nodes of the right network show $\langle H_i \rangle = 0.55$).

5. Individual-based networks: overview, definition, and studied taxa

Overview of individual-based networks: I searched for papers concerning different forms of individual-based networks (Supplemental Table 1). I searched for papers including the terms "individual-based networks", "individual-individual networks", "individual-resource networks", "individual-species networks", or "niche-overlap networks" in their title, abstract or keywords in the *ISI Web of Science* and *Google Scholar* databases. I also included papers on parasite spreading in contact networks of individuals (White et al. 2017) if they involved descriptions of overlaps of parasite types across individual hosts. I also studied papers that (i) cited some highly cited papers concerning the topic or (ii) cited methodological papers introducing computer programs with which to analyze network metrics of individual variation, resulting in a sample of 167 taxa, among which at least one individual-based network was studied (Supplemental Table 2).

Supplemental Table 1. Different types of individual-based networks

Type	Nodes	Links
Individual-individual networks	Individuals of different species	Interactions between individuals of different species
Individual-resource networks	Two sets of nodes. One set of nodes represents individuals (of a single or different species), and the other set depicts resources (e.g., prey types or mutualistic partners)	Interactions between individuals and their resources
Individual-species networks	Two sets of nodes. One set of nodes represents individuals (of a single or different species), and the other set depicts species (e.g., parasite or mutualistic species)	Interactions between individuals and species
Niche overlap networks	Individuals of a single or different species	The overlap between individuals in their resource use, interacting partners, or natural enemies

Supplemental Table 2. Taxa in which at least one individual-based network has been studied

	Species studied at individual level	Type of interactions	Reference
Pinopsida			
	Abies sachalinensis (Pinaceae)	Competition among individuals	(Nakagawa et al. 2016)
Magnoliophyta			
	Bromeliad individuals (Bromeliaceae)	Interactions with visiting ants	(DaRocha et al. 2016)
	Trembleya laniflora (Melastomataceae)	Interactions with floral visitors	(Soares 2017)
	Heliconia aurantiaca (Heliconiaceae)	Hosting arthropod species	(Benítez-Malvido et al. 2016a)
	Heliconia collinsiana (Heliconiaceae)	Hosting arthropod species	(Benítez-Malvido et al. 2014)
	Heliconia latispatha (Heliconiaceae)	Hosting arthropod species	(Benítez-Malvido et al. 2014)
	Astrocaryum mexicanum (Arecaceae)	Interactions with floral visitors	(Dáttilo et al. 2015)
	Henriettea succosa (Melastomataceae)	Interactions with fruit-eating birds	(Crestani et al. 2019)
	Miconia irwinii (Melastomataceae)	Interactions with frugivore species	(Guerra et al. 2017)
	Cirsium arvense (Asteraceae)	Interactions with floral visiting *Apis mellifera* individuals	(Dupont et al. 2011)
	Cirsium palustre (Asteraceae)	Interactions with *Bombus* individuals visiting their flowers	(Dupont et al. 2014)
	Isoplexis canariensis (Plantaginaceae)	Interactions with vertebrate pollinators and insect antagonists. Mating network mediated by vertebrate pollinators	(Rodríguez‐Rodríguez et al. 2017)
	Stachytarpheta glabra (Verbenaceae)	Interactions with protective ants	(Dáttilo et al. 2014a)
	Tocoyena formosa (Rubiaceae)	Interactions with protective ants	(Queiroga & Moura 2017)
	Acca sellowiana (Myrtaceae)	Interactions with frugivore species	(Bogoni et al. 2018)
	Caryocar brasiliense (Caryocaraceae)	Interactions with protective ants	(Koch et al. 2018)
	Chamaecrista mucronata (Fabaceae)	Interactions with protective ants	(Dáttilo et al. 2014a)
	Chamaecrista repens (Fabaceae)	Interactions with protective ants	(da Silva et al. 2020)
	Prosopis flexuosa (Fabaceae)	Interactions with frugivore species	(Miguel et al. 2018)

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	Erysimum mediohispanicum (Brassicaceae)	Interactions with floral visitors	(Gómez & Perfectti 2012, Gómez et al. 2010, 2011, Valverde et al. 2016)
	Sinapis arvensis (Brassicaceae)	Interactions with floral and leaf visitors	(Kuppler et al. 2016, 2017)
	Prunus mahaleb (Rosaceae)	Sexual interactions among individuals estimated to model pollinating insect behavior	(Fortuna et al. 2008)
	Qualea grandiflora (Vochysiaceae)	Interactions with protective ants	(Dáttilo et al. 2014a)
Gastropoda			
	Nucella emarginata (Neogastropoda)	Interactions with prey resources	(Lemos-Costa et al. 2016)
	Vasula melons (Neogastropoda)	Interactions with prey resources	(Lemos-Costa et al. 2016)
	Calanus finmarchicus (Calanidae)	Overlap as hosts of microbiome communities. Nodes are microbiome UTUs, and links describe the co-occurrence across *C. finmarchicus* individuals	(Datta et al. 2018)
Crustacea	*Neomysis integer* and *Rhopalophthalmus tartessicus* (all Mysidacea)	Preyed by individual *Chedon ramada* (Mugilidae)	(Melián et al. 2011)
	Neomysis integer, *Mesopodopsis slabberi*, *Rhopalophthalmus tartessicus* (all Mysidacea)	Preyed by individual *Aphia minuta* (Gobiidae), *Argyrosomus regius* (Sciaeneidae), *Cyprinus carpio* (Cyprinidae), *Pomatoschistus spp.* (Gobiidae), *Dicentrarchus punctatus* (Moronidae), *Engraulis encrasicolus* (Engraulidae), *Chedon ramada* (Mugilidae), *Chedon saliens* (Mugilidae), *Pomadasys incisus* (Haemulidae), *Sardina pilchardus* (Clupeidae)	(Melián et al. 2011)
Insecta			
	Anthidium cingulatum (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
	Apis mellifera (Hymenoptera)	Visiting the flowers of individual *Cirsium*	(Dupont et al. 2011)

	arvense (Asteraceae)	
Apis mellifera (Hymenoptera)	Visiting flowers and pollen transport of multiple species	(Tur et al. 2014, Pornon et al. 2017)
Bembix merceti (Hymenoptera)	Interactions with Diptera prey	(Ballesteros et al. 2014, Polidori et al. 2013)
Bembix sinuate (Hymenoptera)	Interactions with Diptera prey	(Polidori et al. 2013)
Bembix zonata (Hymenoptera)	Interactions with Diptera prey	(Polidori et al. 2013)
Bombus bohemicus, B. campestris, B. sylvestris, B. norvegicus, B. hypnorum, B. pascuorum, B. lucorum, and *B. pratorum* (Hymenoptera)	Visiting flowers of *Cirsium palustre*	(Dupont et al. 2014)
Bombus lucorum (Hymenoptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Bombus pascuorum (Hymenoptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Bombus wurflenii (Hymenoptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Cerceris arenaria (Hymenoptera)	Interactions with Coleoptera prey	(Polidori et al. 2013)
Cerceris californica (Hymenoptera)	Interactions with Coleoptera prey	(Polidori et al. 2013)
Cerceris rubida (Hymenoptera)	Interactions with Coleoptera prey	(Polidori et al. 2013)
Chalibion fuscipenne (Hymenoptera)	Interactions with Araneida prey	(Polidori et al. 2013)
Halictus spp. (*H. scabiosae* and *H. fulvipes*) (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Halictus vestitus (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Isodontia mexicana (Hymenoptera)	Interactions with Orthoptera prey	(Polidori et al. 2013)
Megachile pilidens (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Oxybelus lamellatus (Hymenoptera)	Interactions with Diptera prey	(Polidori et al. 2013)
Pemphredon lethifer (Hymenoptera)	Interactions with Hemiptera prey	(Polidori et al. 2013)
Philanthus sanbornii (Hymenoptera)	Interactions with Hymenoptera prey	(Polidori et al. 2013)
Plagyolepis pygmaea (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Pogonomyrmex barbatus (Hymenoptera)	Harvesting seeds and dead arthropods	(Luna et al. 2018)
Pogonomyrmex naegelii (Hymenoptera)	Harvesting seeds and dead arthropods	(Anjos et al. 2018)

Rhopalum clavipes (Hymenoptera)	Interactions with Psocoptera prey	(Polidori et al. 2013)
Sceliphron caementarium (Hymenoptera)	Hunting spiders for offspring provisioning	(Powell & Taylor 2017)
Sceliphron spirifex (Hymenoptera)	Interactions with Araneida prey	(Polidori et al. 2013)
Stizus continuus (Hymenoptera)	Interactions with Orthoptera prey	(Polidori et al. 2013)
Stizus pulcherrimus (Hymenoptera)	Interactions with Orthoptera prey	(Polidori et al. 2013)
Tapinoma nigerrimum (Hymenoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Trypoxylon figulus (Hymenoptera)	Interactions with Araneida prey	(Polidori et al. 2013)
Attalus sp. (Coleoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Lasioglossum nitidulum (Coleoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Mordellistena sp. (Coleoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Oedemera flavipes (Coleoptera)	Pollen transport of different plant species	(Tur et al. 2014)
Oedemera virescens (Coleoptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Eristalis tenax (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Empis euempis (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Empis leptempis (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Eupeodes corolla (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Exoprosopa bowdeni (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Paragus tibialis (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Sphaerophoria sp. (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Sphaerophoria batava (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Sphaerophoria infuscate (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Sphaerophoria scripta (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)
Stomorhina lunata (Diptera)	Pollen transport of different plant species	(Tur et al. 2014)
Volucella bombylans (Diptera)	Visiting flowers and pollen transport of multiple species	(Pornon et al. 2017)

Actinopterygii

Pimelodus maculatus (Pimelodidae)	Interactions with prey resources	(da Cunha et al. 2018)
Aphanius iberus (Cyprinodontidae)	Interactions with prey resources; individuals grouped by ontogenetic stages	(Ramos-Jiliberto et al. 2011)
Aphia minuta (Gobiidae), *Argyrosomus regius* (Sciaeneidae), *Cyprinus carpio* (Cyprinidae), *Pomatoschistus spp.* (Gobiidae), *Dicentrarchus punctatus* (Moronidae), *Engraulis encrasicolus* (Engraulidae), *Chedon ramada* (Mugilidae), *Chedon saliens* (Mugilidae), *Pomadasys incisus* (Haemulidae), *Sardina pilchardus* (Clupeidae)	Preying upon individuals of *Neomysis integer*, *Mesopodopsis slabberi*, *Rhopalophthalmus tartessicus* (all Mysidacea)	(Melián et al. 2011)
Chaetodon citrinellus (Chaetodontidae)	Overlap in prey resource use	(Lawton et al. 2012)
Chaetodon lunulatus (Chaetodontidae)	Overlap in prey resource use	(Lawton et al. 2012)
Chaetodon trifascialis (Chaetodontidae)	Overlap in prey resource use	(Lawton et al. 2012)
Chedon ramada (Mugilidae)	Preying upon individuals of *Neomysis integer* (Mysidacea) and *Rhopalophthalmus tartessicus* (Mysidacea)	(Melián et al. 2011)
Crenicichla lepidota (Cichlidae)	Interactions with prey resources	(Mateus et al. 2016)
Diversifying Telmatherinidae (Atheriniformes)	Interactions with prey resources	(Pfaender et al. 2010)
Gasterosteus aculeatus (Gasterosteidae)	Overlap in prey resources among individuals	(Araújo et al. 2008, Ballare 2019, Ingram et al. 2011)
Gobiomorphus cotidianus (Eleotridae)	Interactions with prey resources in a mesocosm experiment	(Kerr 2018)
Perca fluviatilis (Percidae)	Interactions with prey resources	(Marklund et al. 2018)
Coregonus lavaretus (Salmonidae)	Interactions with prey resources	(Siwertsson et al. 2013)
Salvelinus fontinalis (Salmonidae)	Interactions with prey resources	(Jirka & Kraft 2017)
Salvelinus namaycush (Salmonidae)	Interactions with prey resources	(Chavarie et al. 2016a, 2016b).

Tetrapoda

Chiasmocleis albopunctata (Anura)	Interactions with prey resources	(Pires et al. 2011)
Elachistocleis bicolor (Anura)	Interactions with prey resources	(Pires et al. 2011)

|		
Eupemphix nattereri (Anura)	Interactions with prey resources	(Pires et al. 2011)
Hypsiboas leptolineatus (Anura)	Interactions with prey resources	(Carvalho-Rocha et al. 2018)
Ischnocnema penaxavantinho (Anura)	Interactions with prey resources	(Pires et al. 2011)
Leptodactylus chaquensis (Anura)	Hosts of parasite morphotypes	(Campião & Dáttilo 2020)
Leptodactylus fuscus (Anura)	Interactions with prey resources	(Pires et al. 2011)
Leptodactylus fuscus (Anura)	Hosts of parasite morphotypes	(Campião & Dáttilo 2020)
Leptodactylus sp. (Anura)	Interactions with prey resources	(Pires et al. 2011)
Leptodactylus podicipinus (Anura)	Hosts of parasite morphotypes	(Campião & Dáttilo 2020)
Physalaemus cuvieri (Anura)	Interactions with prey resources	(Pires et al. 2011)
Proceratophrys sp. (Anura)	Interactions with prey resources	(Pires et al. 2011)
Pseudis cardosoi (Anura)	Interactions with prey resources	(Carvalho-Rocha et al. 2018)
Pseudis paradoxa (Anura)	Hosts of parasite morphotypes	(Campião & Dáttilo 2020)
Pithecopus azureus (Anura)	Hosts of parasite morphotypes	(Campião & Dáttilo 2020)
Scinax granulatus (Anura)	Interactions with prey resources	(Carvalho-Rocha et al. 2018)
Didelphis albiventris (Didelphimorphia)	Fruit species consumed	(Cantor et al. 2013)
Didelphis aurita (Didelphimorphia)	Overlap as hosts of helminth parasites	(Costa-Neto et al. 2019)
Didelphis aurita and *Metachirus nudicaudatus* (Didelphimorphia)	Interactions with their prey and fruit resources	(Kuhnen et al. 2017)
Gracilinanus agilis (Didelphimorphia)	Interactions with fruits and prey resources	(de Camargo et al. 2019)
Gracilinanus microtarsus (Didelphimorphia)	Interactions with fruits and prey resources	(Araújo et al. 2010)
Marmosa paraguayana (Didelphimorphia)	Interactions with fruits and prey resources	(Pires et al. 2011, 2013)
	Overlap as hosts of strains of *E. coli*	(Blyton et al. 2014)
Trichosurus cunninghami (Diprotodontia)		
Alouatta palliata (Primates)	Interactions with plant resources	(Dáttilo et al. 2014b)
Alouatta pigra (Primates)	Interactions with plant resources	(Benítez-Malvido et al. 2016b)
Homo sapiens (Primates)	Plantations of ethnovarieties of *Manihot esculenta*	(Cavechia et al. 2014)
Homo sapiens (Primates)	Kills by *H. sapiens* and associated scavenging species	(Sebastián-González et al. 2016)
Homo sapiens (Primates), *Lynx lynx* (Carnivora), *Canis lupus* (Carnivora)	Kills by these species and dead ungulates and associated scavenging species	(Selva & Fortuna 2007)

Globicephala melas (Artiodactyla)	Hosts of helminth parasites	(Bellay et al. 2020)
Tursiops truncatus (Artiodactyla)	Predation on fishes in cooperation with fishermen	(Cantor et al. 2018b)
Giraffa camelopardalis (Artiodactyla)	Overlap as hosts of genetic subtypes of *E. coli*	(VanderWaal et al. 2014b)
Aepyceros melampus, Alcelaphus buselaphus, Bos indicus, Gazella granti, Gazella thomsonii, Giraffa camelopardalis, Syncerus caffer, Taurotragus oryx (all Artiodactyla)*, Diceros bicornis, Equus burchelli (both Perissodactyla)*	Overlap as hosts of genetic subtypes of *E. coli*	(VanderWaal et al. 2014a)
Nyctalus lasiopterus (Chiroptera)	Use of individual host trees	(Fortuna et al. 2009)
Pteronotus mesoamericanus (Chiroptera)	Interactions with insect resources	(de Oliveira 2018)
Sturnira lilium (Chiroptera)	Experimental study of the use of fruit resources of three plant species;	(Muylaert et al. 2014)
Apodemus sylvaticus (Rodentia)	Hosts of parasite species	(Rynkiewicz et al. 2019)
Bandicota savilei (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Mus cervicolor (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Rattus argentiventer (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Rattus exulans (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Rattus norvegicus (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Rattus tanezumi (Rodentia)	Overlap as hosts of parasite species	(Pilosof et al. 2015)
Oryctolagus cuniculus and hare *Lepus* spp (Lagomorpha)	Carcasses of these species and associated scavenging species	(Sebastián‐González et al. 2013)
Arctocephalus pusillus (Carnivora)	Overlap in prey resource use	(Kernaléguen et al. 2016)
Enhydra lutris (Carnivora)	Interactions with prey resources	(Tinker et al. 2012).
Podarcis lilfordi (Squamata)	Interactions with prey resources	(Santamaría et al. 2019)
Tiliqua rugosa (Squamata)	Overlap as hosts of *Salmonella* genotypes	(Bull et al. 2012)
Tropidurus hispidus (Squamata)	Interactions with prey resources	(Pires et al. 2011)
Testudo graeca (Testudines)	Interactions with oxyurid nematodes	(Benítez-Malvido et al. 2019)
Antilophia galeata (Passeriformes)	Interactions with fruit resources	(Pires & de Melo in press)

Pinaroloxias inornata (Passeriformes)	Interactions with their prey and floral resources	(Lemos-Costa et al. 2016)
Aquila fasciata (Accipitriformes)	Interactions with prey resources	(Moleón et al. 2012)
Cerorhinca monocerata (Charadriiformes)	Overlap in prey resource use	(Cunningham et al. 2018)
Uria lomvia (Charadriiformes)	Overlap in prey resources	(Provencher et al. 2013)

6. Networks at the community level

6.1. Are food webs species-based networks?

There are multiple definitions of food webs, ranging from chains of trophic interactions among plants and animals [Elton 2001 (1927)] to diagrams describing patterns of energy and matter flowing among organisms and nonliving organic matter (Lindeman 1942). Most food webs described in the literature are not species-based networks (**Supplemental Figure 13**). In some food webs, almost all nodes represent species; however, in most food webs more than half of the nodes depict nonliving matter, ontogenetic stages of species, and, most commonly, different forms of species aggregation. Species aggregation is not intrinsically a problem. The resolution at which a network is described is conditional on the questions investigated. Indeed, some of the most informative patterns recorded in food webs, such as the pyramids of numbers [Elton 2001 (1927)], are observed at coarse trophic levels with minimal detail regarding the underlying interaction patterns. In fact, species lumping may uncover the basic mechanisms shaping the network structure. For example, grouping individuals on the basis of their traits rather than their Latin binomials revealed trait-based nestedness in interactions between plants and their floral visitors (Rumeu et al. 2018). Accordingly, grouping individuals by body size in aquatic food webs provided new insight into the mechanisms shaping trophic interactions (Gilljam et al. 2011). However, species lumping is often study-dependent, preventing simple structural comparisons across systems (Paine 1988, Polis 1991), underestimating omnivory and generalism (Polis 1991), and limiting understanding of how specialization is distributed across food webs. For instance, a node depicting herbivorous insects may be a useful approximation for describing energy flow across ecosystems but could mask variation in specialization across herbivore lifestyles (Pires & Guimarães 2013). Hence, because the nodes in food webs only occasionally represent species in the community, caution is needed when comparing the structure of food webs with other forms of ecological networks at the community level.
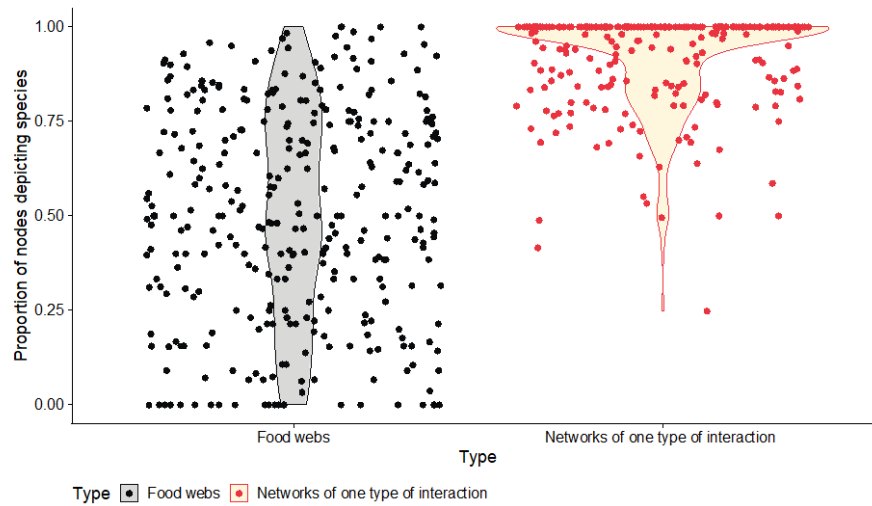
Supplemental Figure 13. The proportion of nodes depicting species or morphospecies in networks at the community level. Black points depict food webs, and red points depict networks of one type of interaction (e.g., plant-frugivore networks). Violin plots indicate the probability density functions of the proportion of nodes depicting species (or morphospecies) in food webs and networks of one type of interaction. Notably, in food webs, most nodes usually depict aggregations of species, whereas most nodes depict individual species (or morphospecies) in networks describing a single type of interaction. Data from 240 species-based networks and 323 food webs with at least 10 nodes are from the Web of Life (http://www.web-of-life.es/) and GlobalWeb (https://www.globalwebdb.com/) databases.

6.2. Examples of studied networks at the community level

Below, I provide a list of examples of species networks describing different ecological interactions. Additionally, I cite studies that used network descriptions to gain insight into the organization of these ecological interactions. Examples are provided at different levels of taxonomic resolution and detail regarding the natural history of ecological interactions to provide a broad perspective of the diversity of the ecological interactions studied in nature.

**Supplemental Table 3. Examples of networks studied at the community level**

Ecological interaction	Reference
Anemones and anemonefishes	(Ricciardi et al. 2010)
Ants and myrmecophilic Hemiptera	(Cagnolo & Tavella 2015)
Ants and myrmecophilic Lepidoptera caterpillars	(Cagnolo & Tavella 2015)
Bacteria and phages	(Weitz et al. 2013)
Cavity-nesting hymenoptera, parasitoids and kleptoparasites	(Nether et al. 2019)
Communication networks among herbivores	(Meise et al. 2019)
Clients and cleaning fish and shrimp	(Guimarães et al. 2007b)
Cohabiting associations among termites	(Campbell et al. 2016)
Dung beetles and fungi	(Epps 2013)
Fish and endoparasites	(Bellay et al. 2015)
Following associations among fish	(Inagaki et al. 2020)
Cooccurrences of wood-inhabiting fungi	(Abrego et al. 2017)
Hosts and parasites	(Vázquez et al. 2005)
Hosts and parasitoids	(Cagnolo et al. 2011)
Interspecific competition	(Keddy & Shipley 1989)
Lichen (algae and fungi)	(Chagnon et al. 2018)
Mammalian herbivores and cleaning birds	(Mikula et al. 2018)
Mammals and dung beetles	(Bogoni et al. 2019)
Mammals and ectoparasites	(Madinah et al. 2014)
Marine bacteria, archaea, and protists	(Steele et al. 2011)
Mixed bird flocks	(Mokross et al. 2014)
Müllerian mimetism	(Rodriguez et al. 2014)
Nurse plants and seedlings	(Verdú & Valiente-Banuet 2008)
Oil-producing plants and oil bees	(Ramírez et al. 2011)
Orchids and mycorrhizal fungi	(Jacquemyn et al. 2015)
Passerine birds and Haemosporidian parasites	(Ventim et al. 2012)
Phytoplanktonic microbes and viruses	(Ruiz Martinez 2017)
Plants and ants (ant gardens)	(Guimarães et al. 2007a)
Plants and ants (mediated by extrafloral nectar)	(Guimarães et al. 2006)
Plants and ants (mediated by floral nectar)	(Santos et al. 2014)
Plants and ants (myrmecophytes)	(Fonseca & Ganade 1996)
Plants and arbuscular mycorrhizal fungi	(Polme et al. 2018)
Plants and brood pollinating insects	(Thompson et al. 2017)
Plants and cavity-nesting birds	(Cockle et al. 2019)
Plants and climbing plants (e.g., lianas)	(Blick & Burns 2009)
Plants and ectomycorrhizal fungi	(Polme et al. 2018)
Plants and epiphytes	(Blick & Burns 2009)
Plants and ericoid mycorrhizal fungi	(Polme et al. 2018)
Plants and flowerhead tephritids	(Prado & Lewinsohn 2004)
Plants and flower-breeding drosophilids	(Cordeiro et al. 2020)
Plants and fruit-eating insects	(Thébault & Fontaine 2010)
Plants and gall-making insects	(Thébault & Fontaine 2010)
Plants and grazing insects	(Thébault & Fontaine 2010)
Plants and leaf-chewing insects	(Pearse & Altermatt 2013)
Plants and mammalian herbivores	(Pires & Guimarães 2013)
Plants and microbes	(Bennett et al. 2019)
Plants and mining insects	(Thébault & Fontaine 2010)
Plants and mistletoes	(Genini et al. 2012)
Plants and mycorrhyzal fungi	(Montesinos-Navarro et al. 2012)
Plants and pathogens	(Benítez-Malvido & Dáttilo 2015)
Plants and pollen-eating beetles	(Eben & Espinosa de los Monteros 2015)

Plants and pollinators	(Memmott 1999)
Plants and rhizobia	(Le Roux et al. 2016)
Plants and root endophytic fungi	(Polme et al. 2018)
Plants and root fungi	(Toju et al. 2016)
Plants and sap feeders	(Thébault & Fontaine 2010)
Plants and seed dispersers	(Jordano 1987)
Plants and sucking insects	(Oliveira et al. 2019)
Plants and tent-roosting bats	(Rodríguez-Herrera et al. 2018)
Plants and wood-boring insects	(Thébault & Fontaine 2010)
Predators and prey	(Owen-Smith & Mills 2008)
Territorialism and chasing among fish	(Cantor et al. 2018a)
Shrimps and gobies	(Thompson et al. 2013)

7. On the relationship between the number of links and generalism in networks

Poorly connected and highly connected species are often interpreted as specialists and generalists, respectively, but the association between the interaction number (or strength) and specialization is not straightforward (Blüthgen et al. 2008). Variations in abundance often affect the number of links recorded per species in the networks (see the main text for further details). Moreover, the natural history of interacting organisms leads to distinct lifestyles showing similar numbers of links in a network. For example, in plant-frugivore interactions in the Neotropics, poorly connected species include those with disparate lifestyles, such as the mahogany mistletoe *Phoradendron rubrum* that is, in some sites, almost exclusively dispersed by *Euphonia* bird species (Cazetta & Galetti 2007), and occasional frugivores, such as the insect-eating fork-tailed flycatcher *Tyrannus savanna* (Galetti & Pizo 1996). Accordingly, highly connected species can be opportunist species that feed on multiple resources in addition to fruits, such as the great kiskadee *Pitangus sulphuratus* (Galetti & Pizo 1996), or "supergeneralists", e.g., obligate frugivores such as the red-ruffed fruitcrow *Pyroderus scutatus*, which are indeed extremely specialized organisms that rely on a variety of fruits for survival (Pizo et al. 2002). Thus, to interpret network patterns, as with any ecological pattern, we need to incorporate information on the natural history of the studied system (Mello et al. 2014, Sebastián-González 2017). One way of incorporating this information and describing different lifestyles is by using networks with different types of nodes (**Supplemental Figure 14**).
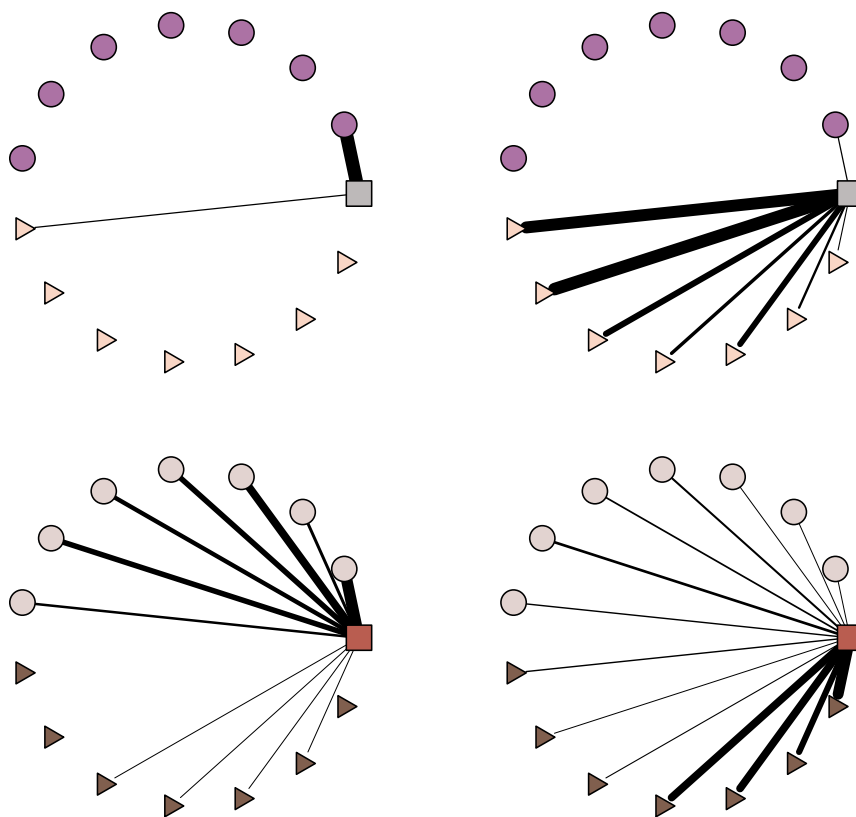
Supplemental Figure 14. Theoretical networks showing a focal species (square) interacting with a single species from a given set (circles). By incorporating a second set of species (triangles) into the network description, we can separate focal species into distinct lifestyles. For example, the focal species in the left upper network is an extreme specialist. In contrast, in the right upper network, the focal species is not a specialist but a species that mainly interacts with the species depicted as triangles and only weakly interacts with the species depicted as circles. The lower networks show focal species that are highly connected with species from a set (circle). Again, by considering a second set of species (triangles), it is possible to detect two distinct lifestyles. In the left lower network, the focal species is specialized in interacting with species from a given set (circles), whereas in the right lower network, the focal species is a generalist that interacts with multiple species of both sets.

8. Figure 4's additional information: disconnected and connected networks

In random bipartite graphs with fixed degree distributions a connectivity parameter controls the transition between a disconnected network characterized by multiple, small components and networks characterized by a giant component (see the sidebar: *The Emergence of a Giant Component* for additional details). **Figure 4** shows that the transition between disconnected networks and networks with a giant component in empirical species-based networks of antagonisms and mutualisms fit the prediction derived using random bipartite graphs with fixed degree distributions. Here I provide three supplementary plots describing how the size of the largest component varies with this connectivity parameter. I also provide information on the networks used to illustrate the

Supplemental Figure 15: I include an outlier network that I removed from **Figure 4** to improve plot legibility. This network shows an extremely large value for the connectivity parameter and in which all species are in the giant component.

Supplemental Figure 16: In this figure I identify antagonisms and mutualisms with different colors to show that both types of interaction are distributed along the transition between fragmented networks and networks with giant components.

Supplemental Figure 17: The maximal degree a species may achieve is constrained by the species richness of potential partners in a species-based network. Thus, the connectivity parameter is affected by the species richness in both sets of partners (e.g., plant and pollinator species). I computed a standardized version of the connectivity parameter to investigate whether the sharp transition between disconnected networks and networks with a giant component is independent of species richness by dividing the connectivity parameter by the species richness of both sets:

$$c_3 = \frac{1}{S_I S_J} \sum_{i=1}^{M_I} \sum_{j=1}^{M_J} i\,j(ij - i - j)p_i p_j$$

where M_I (M_J) is the largest degree recorded in set I (J), $p_i(p_j)$ is the relative frequency of nodes with a degree equal to i (j), and S_I (S_J) is the number of nodes of set I (J). Note that a similar transition is achieved even using this standardized index.

Networks used to illustrate disconnected and connected networks (Figure 4): (a) plants (grey nodes) and galling insects (blue nodes) (Tscharntke et al. 2001), (b) myrmecophytes (blue nodes) and ants (white nodes) (Guimarães et al. 2007a), (c) prey (red nodes) and predators (yellow nodes) (subnetwork depicting mammals weighing >

5kg, Baskerville et al. 2011) and (d) plants (red nodes) and frugivores (yellow nodes) (Galetti & Pizo 1996).
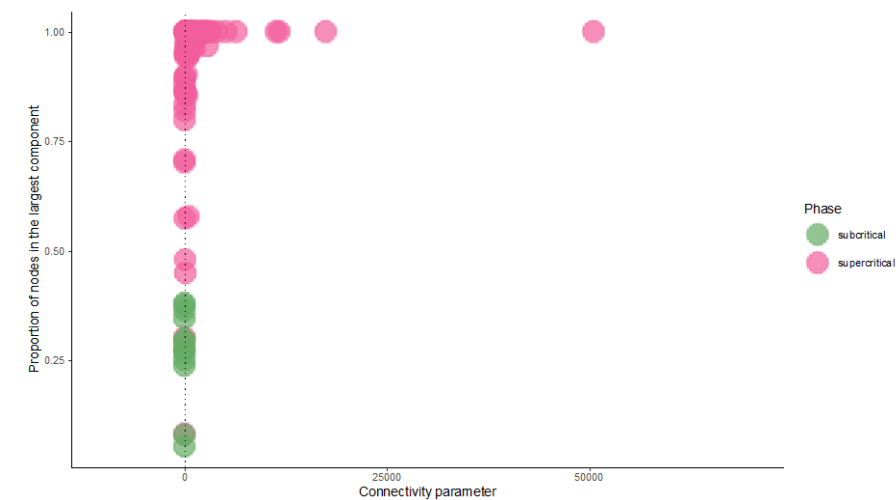
Supplemental Figure 15: This plot is similar to Figure 4, but an outlier network with an extremely high value for the connectivity parameter is included. Colors indicate empirical species-based networks that are predicted to show a giant component (supercritical networks, pink circles) or to be disconnected networks (subcritical, green circles). Note the sharp increase in the size of the largest component with the connectivity parameter. Dataset: **Supplemental Table 4.**
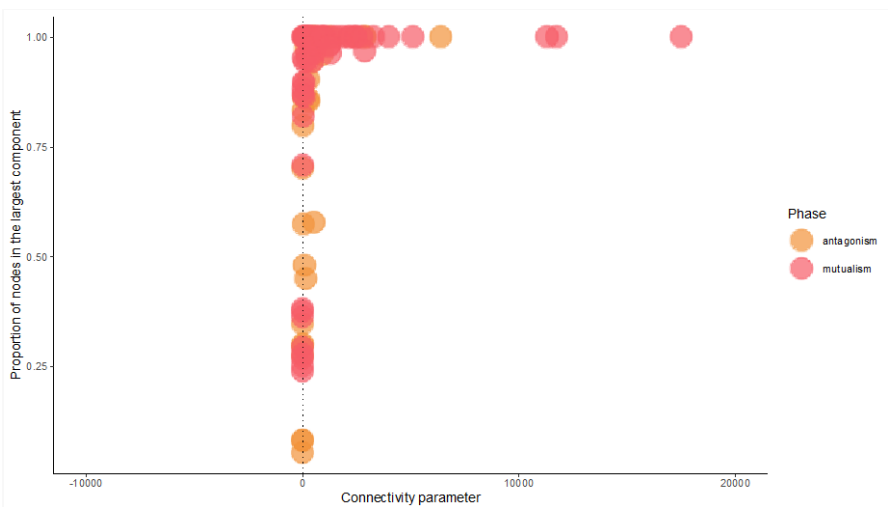
Supplemental Figure 16: This plot is identical to **Figure 4,** but now the type of interaction (antagonism or mutualism) is identified. Colors indicate mutualistic, species-based networks (red circles) or antagonistic, species-based networks (yellow circles). Dataset: **Supplemental Table 4.**
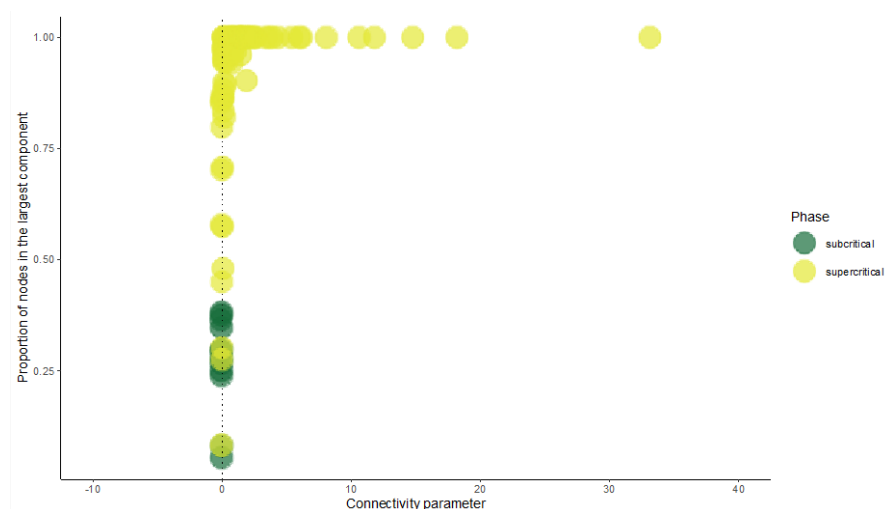
Supplemental Figure 17: This plot is similar to **Supplemental Figure 15,** but the connectivity parameter is now standardized to control the effects of species richness. Colors indicate empirical species-based networks that are predicted to show a giant component (supercritical networks, yellow circles) or to be disconnected networks (subcritical, green circles). Dataset: **Supplemental Table 4.**

Supplemental Table 4. Ecological networks used in Figure 4 (main text).

Interaction type	Reference
Anemone-anemonefish	Ricciardi et al. (2010)
Cleaning interactions	Wicksten (1998)
Cleaning interactions	Network kindly provided by C. Sazima
Cleaning interactions	Johnson & Ruben (1988)
Host - parasite	Dechtiar (1972)
Host - parasite	Bangham (1955)
Host - parasite	Arai & Mudry (1983)
Host - parasite	Dechtiar (1972)
Host - parasite	Leong & Holmes (1981)
Host - parasite	Chinniah & Threlfall (1978)
Host - parasitoid	Memmott et al. (1994)
Myrmecophyte-ant	Fonseca & Ganade (1996)
Myrmecophyte-ant	Davidson et al. (1989)
Myrmecophyte-ant	Network kindly provided by T. J. Izzo
Myrmecophyte-ant	Network kindly provided by T. J. Izzo
Myrmecophyte-ant	Network kindly provided by T. J. Izzo
Myrmecophyte-ant	Network kindly provided by T. J. Izzo
Myrmecophyte-ant	Network kindly provided by T. J. Izzo
Nectary bearing plant - ant	Network kindly provided by V. Rico-Gray
Nectary bearing plant - ant	Blüthgen et al. (2004)

Nectary bearing plant - ant	Network kindly provided by V. Rico-Gray
Nectary bearing plant - ant	Network kindly provided by V. Rico-Gray
Nectary bearing plant - ant	Network kindly provided by V. Rico-Gray
Plant - flowerhead tephritids	Prado & Lewinsohn (2004)
Plant - frugivorous tephritids	Novotny et al. (2005)
Plant - herbivore	Ueckert & Hansen (1971)
Plant - wood-boring beetles	Tavakilian et al. (1997)
Plant – galling insects	Cuevas-Reyes et al. (2007)
Plant – galling insects	Dawah et al (1995)
Plant – galling insects	Tscharntke et al. (2001)
Plant – leaf-chewing insects	Janzen et al. (2005)
Plant – leaf-chewing insects	Dyer & Gentry (2002)
Plant – leaf-chewing insects	Coley et al. (2006)
Plant – leaf-chewing insects	Henneman & Memmott (2001)
Plant – leaf-chewing insects	Henneman & Memmott (2001)
Plant – leaf-chewing insects	Blüthgen et al. (2006)
Plant – leaf-chewing insects	Basset & Samuelson (1996)
Plant – mining insects	Lewis et al. (2002)
Plant – sap sucking insects	Loye (1992)
Plant – sap sucking insects	Muller et al. (1999)
Plant – seed predator	Janzen (1980)
Plant – seed predator	Nakagawa et al. (2003)
Plant – seed predator	Nakagawa et al. (2003)
Plant-frugivore	Wheelwright et al (1984)
Plant-frugivore	Schleuning et al. (2011)
Plant-frugivore	kindly provided by E. Hasui, M. Vidal, and W. Silva
Plant-frugivore	Crome (1975)
Plant-frugivore	Galetti & Pizzo (1996)
Plant-frugivore	Mack & Wright (1996)
Plant-frugivore	kindly provided by Pedro Jordano
Plant-frugivore	Carlo et al. (2003)
Plant-frugivore	Carlo et al. (2003)
Plant-frugivore	Beehler (1983)
Plant-frugivore	Carlo et al. (2003)
Plant-frugivore	Carlo et al. (2003)
Plant-frugivore	Jordano (1985)
Plant-frugivore	Kantak (1979)
Plant-frugivore	Baird (1980)
Plant-frugivore	Sorensen (1981)
Plant-frugivore	Poulin et al. (1999)
Plant-frugivore	Poulin et al. (1999)
Plant-pollinator	Arroyo et al. (1982)
Plant-pollinator	Kaiser-Bunbury et al. (2009)
Plant-pollinator	Elberling & Olesen (1999)
Plant-pollinator	Inouye & Pyke (1988)
Plant-pollinator	Hocking (1968)
Plant-pollinator	Barrett & Helenurm (1987)
Plant-pollinator	Arroyo et al. (1982)
Plant-pollinator	Medan et al. (2002)
Plant-pollinator	Network kindly provided by C. Donatti
Plant-pollinator	Lambert (1989)
Plant-pollinator	Ramirez & Brito (1982)

Plant-pollinator	Dicks et al. (2002)
Plant-pollinator	Primack (1983)
Plant-pollinator	Santos et al. (2010)
Plant-pollinator	Arroyo et al. (1982)
Plant-pollinator	Medan et al. (2002)
Plant-pollinator	Ollerton et al. (2003)
Plant-pollinator	Dicks et al. (2002)
Plant-pollinator	Dupont et al. (2003)
Plant-pollinator	Small (1976)
Plant-pollinator	Vázquez (2002)
Plant-pollinator	Schemske et al. (1978)
Plant-pollinator	Vázquez (2002)
Plant-pollinator	Vázquez (2002)
Plant-pollinator	Vázquez (2002)
Plant-pollinator	Vázquez (2002)
Plant-pollinator	Mosquin & Martin (1967)
Plant-pollinator	Olesen et al. (2002)
Plant-pollinator	Bezerra et al. (2009)
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