

Species and interaction diversity in plants and their herbivores

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Outline

- biotic assemblages: from description to function
- plant-animal assemblages as ditrophic systems
- interaction diversity and its partitioning
- pattern and structure of interactive assemblages
- other avenues

The CBD definition

“Biodiversity is the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”.

Convention of Biological Diversity, 1992



**Biodiversity – from species surveys
to ecosystem processes**

From species lists to ecosystem properties

Inventories and surveys provide information on:

- assemblage / taxocoenosis **size** (richness)
- species **composition**
- variation across space, time, conditions

Not sufficiently informative on **dynamic** and **functional** properties of communities and ecosystems

Interaction diversity

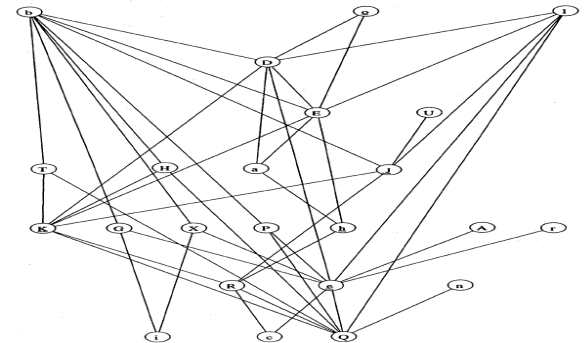
“The links between species and ecosystems occur through the interspecific interactions that shape the organization of biological communities. [...]

The continuing evolution of interactions as we change their spatial dynamics has important immediate effects on conservation efforts and priorities.”

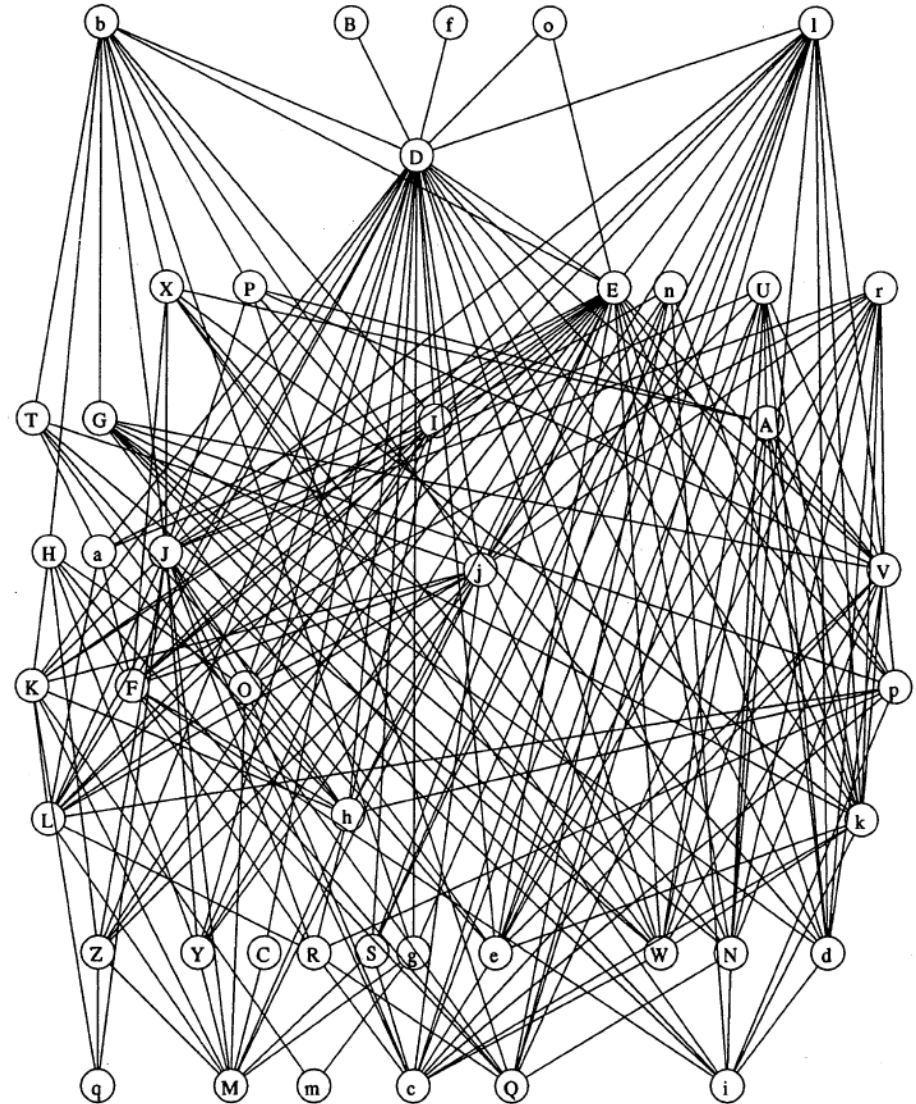
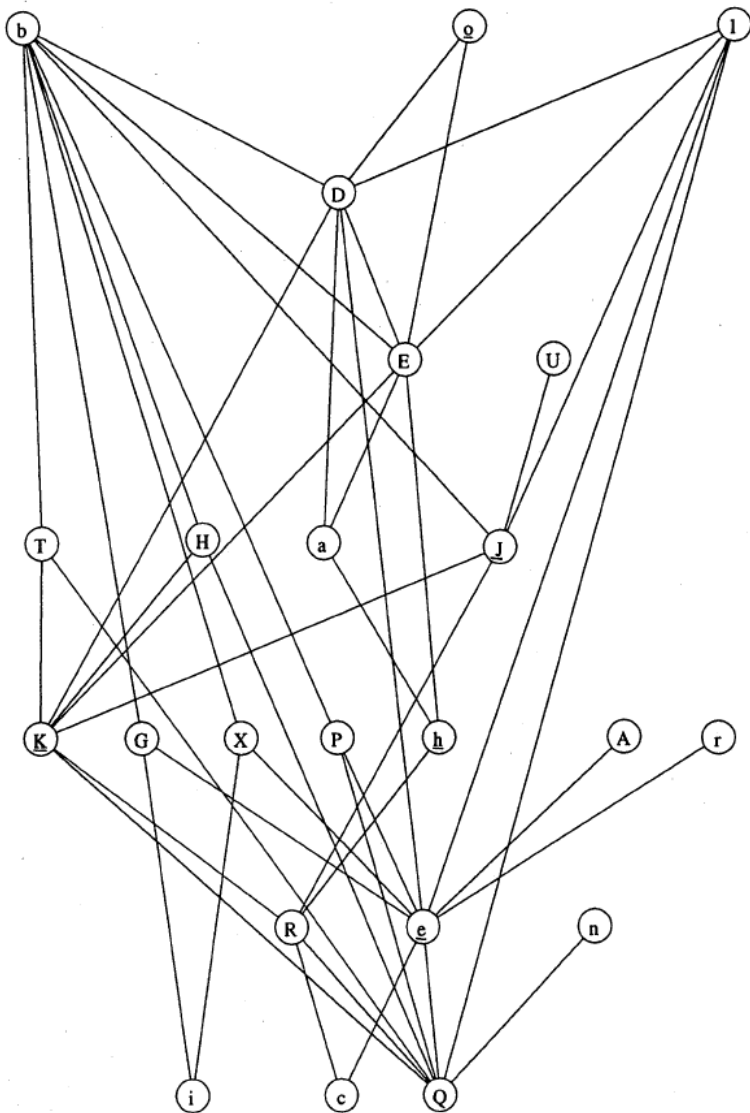
John Thompson, 1997

Trophic webs

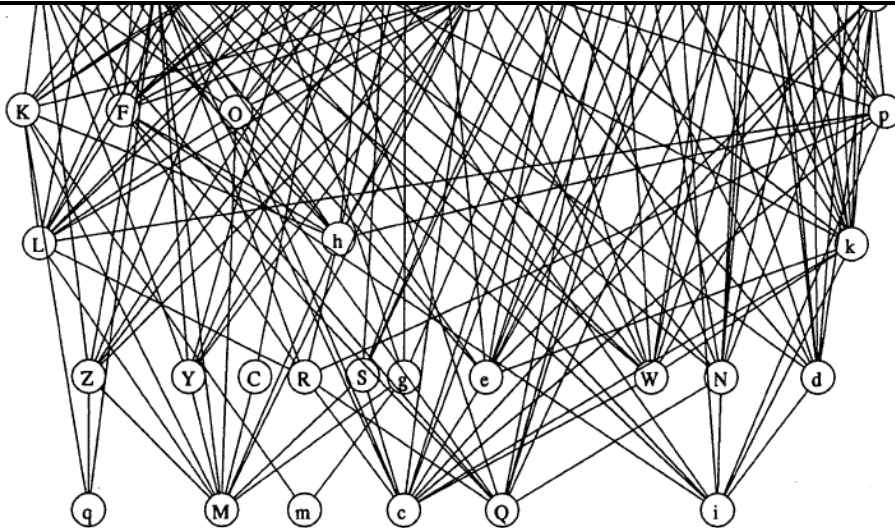
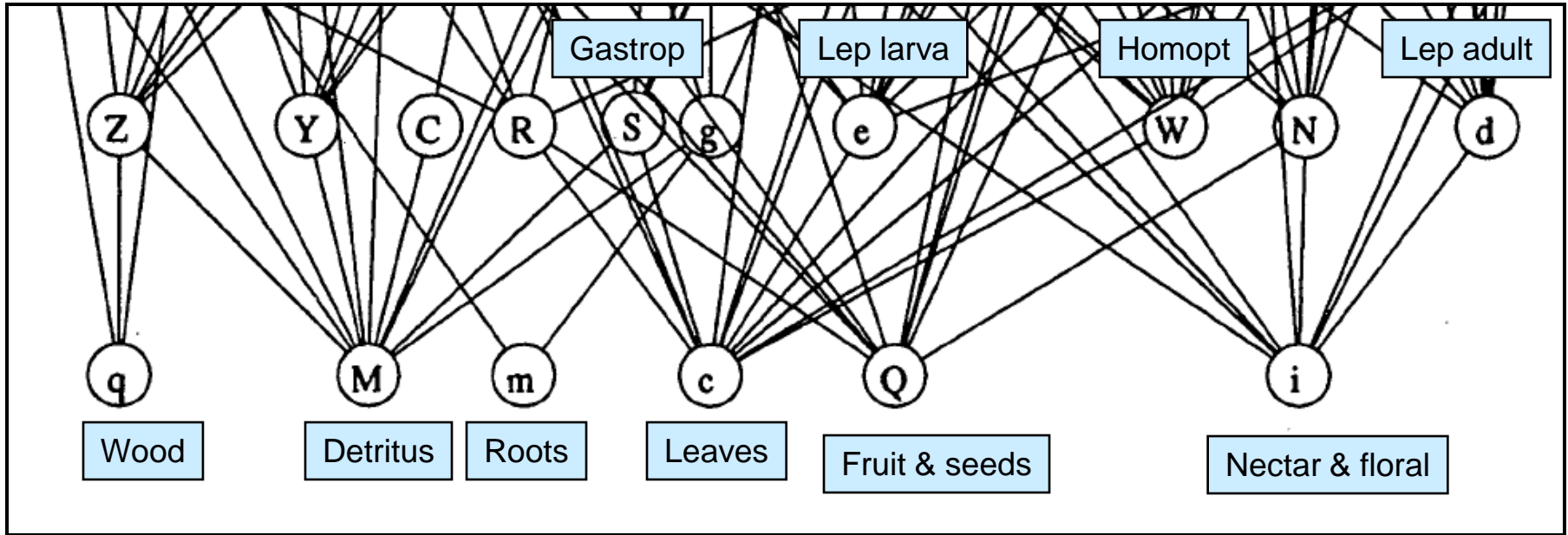
- trophic webs show topology (road map) of interactions
- web structure should reflect evolutionary and ecological processes that shape trophic components
- but webs are notoriously difficult to produce
- ... and usual biodiversity measures do not apply



Trophic webs: completeness

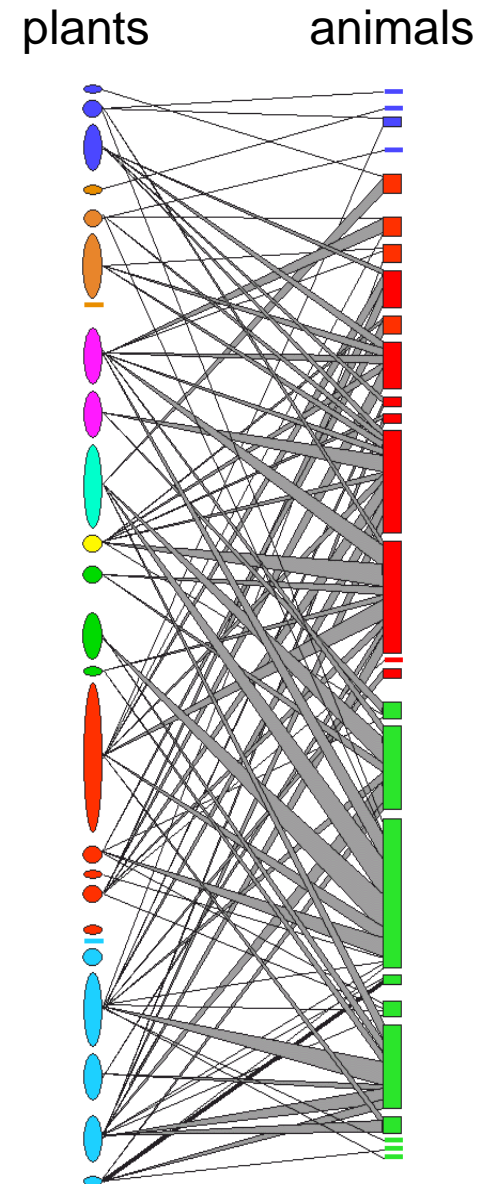


Trophic webs: resolution

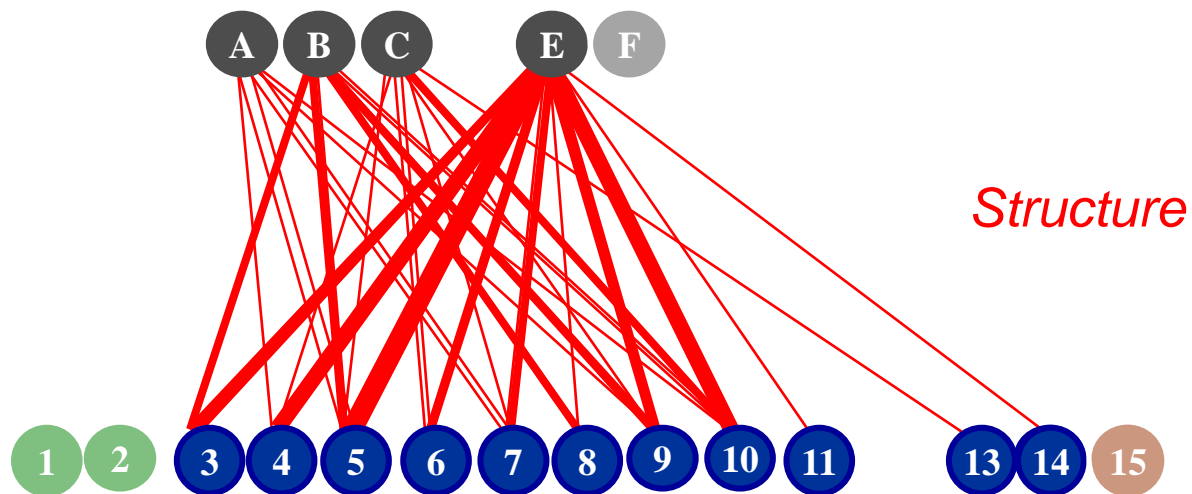


Ditrophic webs or networks

- ecological interactions are **well-defined**
- webs are **highly resolved**
- many current network measures can be applied
- employed for systems such as:
 - plants × pollinators, dispersers
 - plants × herbivores
 - animals × parasites

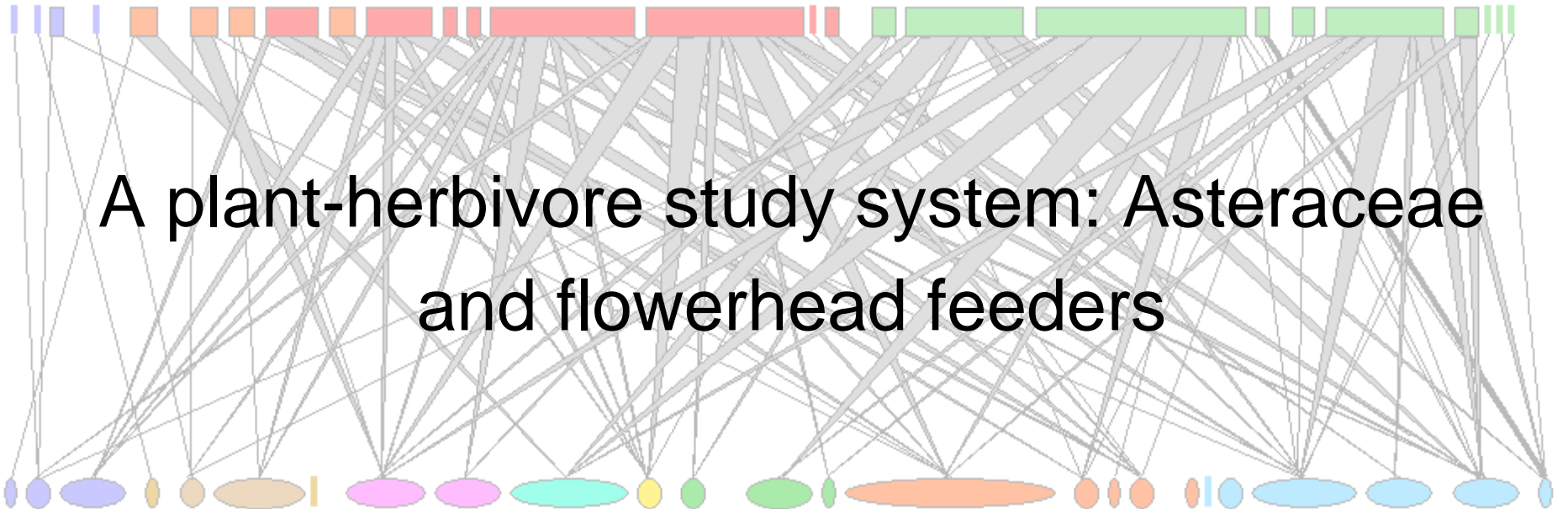


A broader concept of biodiversity



Species diversity

biodiversity (s.l.) = composition + structure



A plant-herbivore study system: Asteraceae
and flowerhead feeders



Asteraceae or Compositae

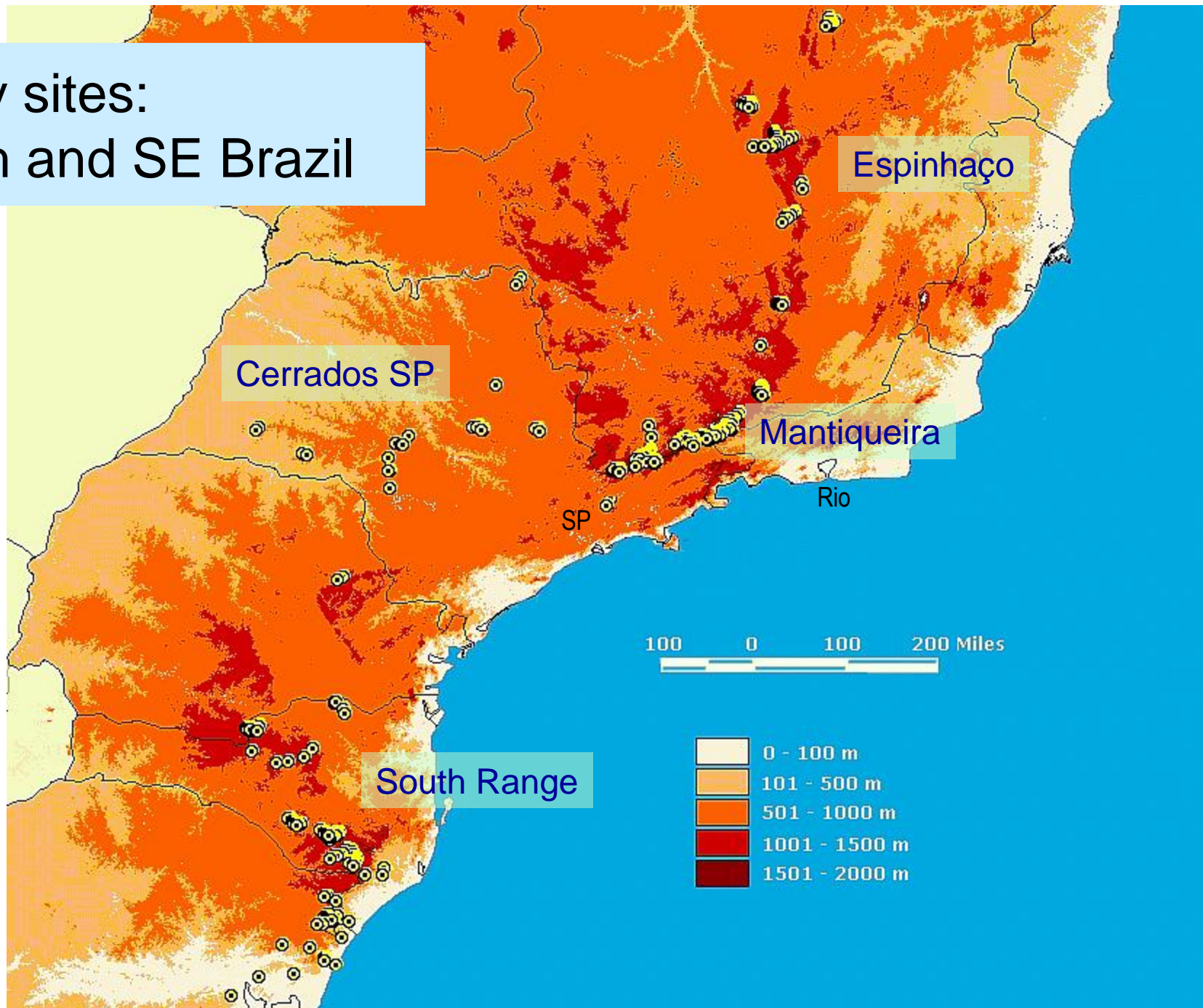
- more than 25,000 species worldwide, more than 2,000 in Brazil
- open, sunny habitats
- highest diversification in mountains and in *cerrado* (woody savannah)



Flowerhead-feeders

- focus on endophagous herbivores
- main groups: Diptera, Lepidoptera and Coleoptera

Study sites: South and SE Brazil



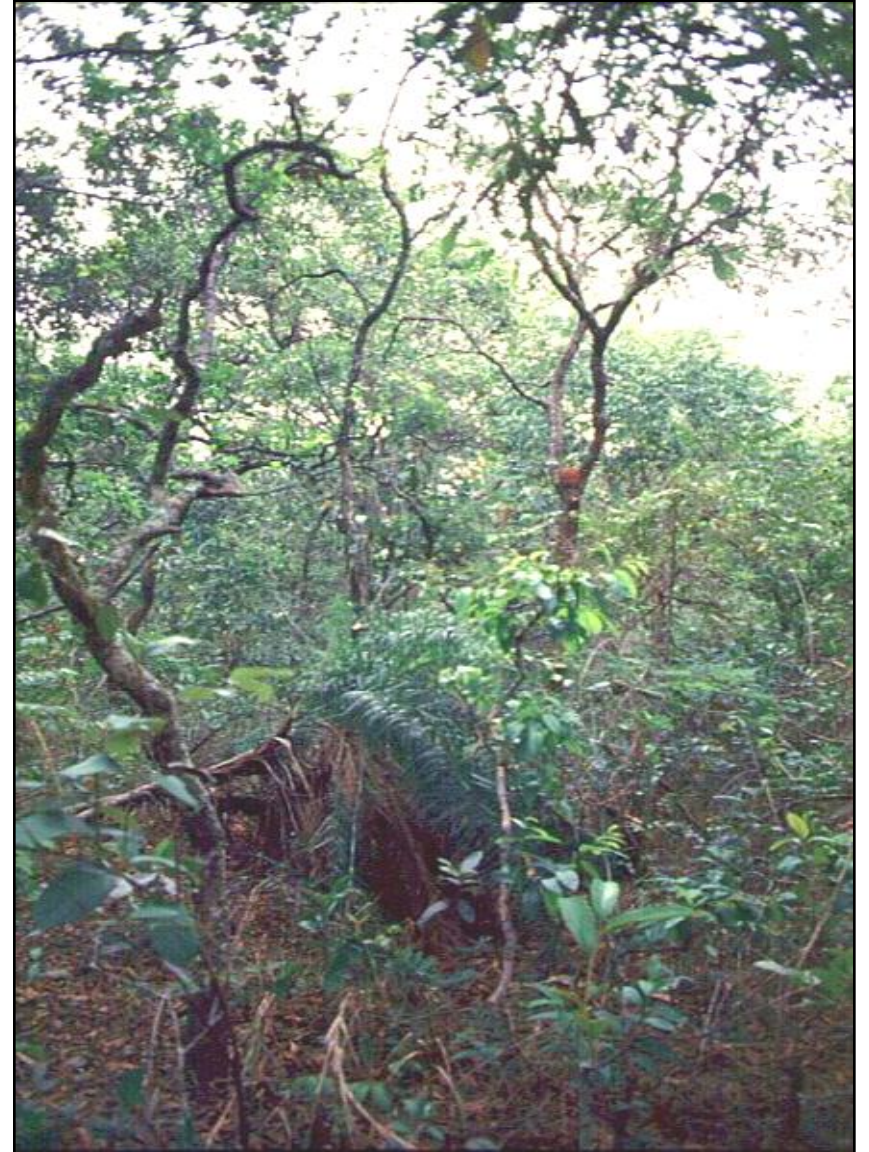
Study sites: mountain *campos*

Fortaleza dos Aparados, R.G. Sul



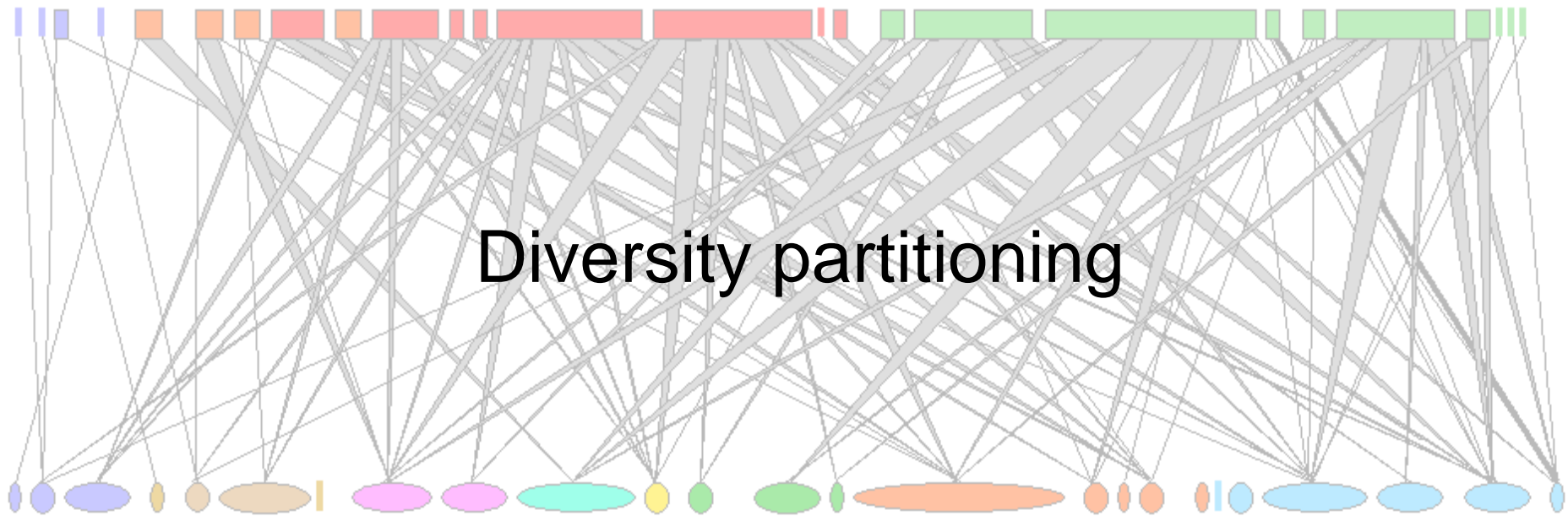
Conselheiro Mata, Minas Gerais

Study sites: *cerrado* savannah woodland



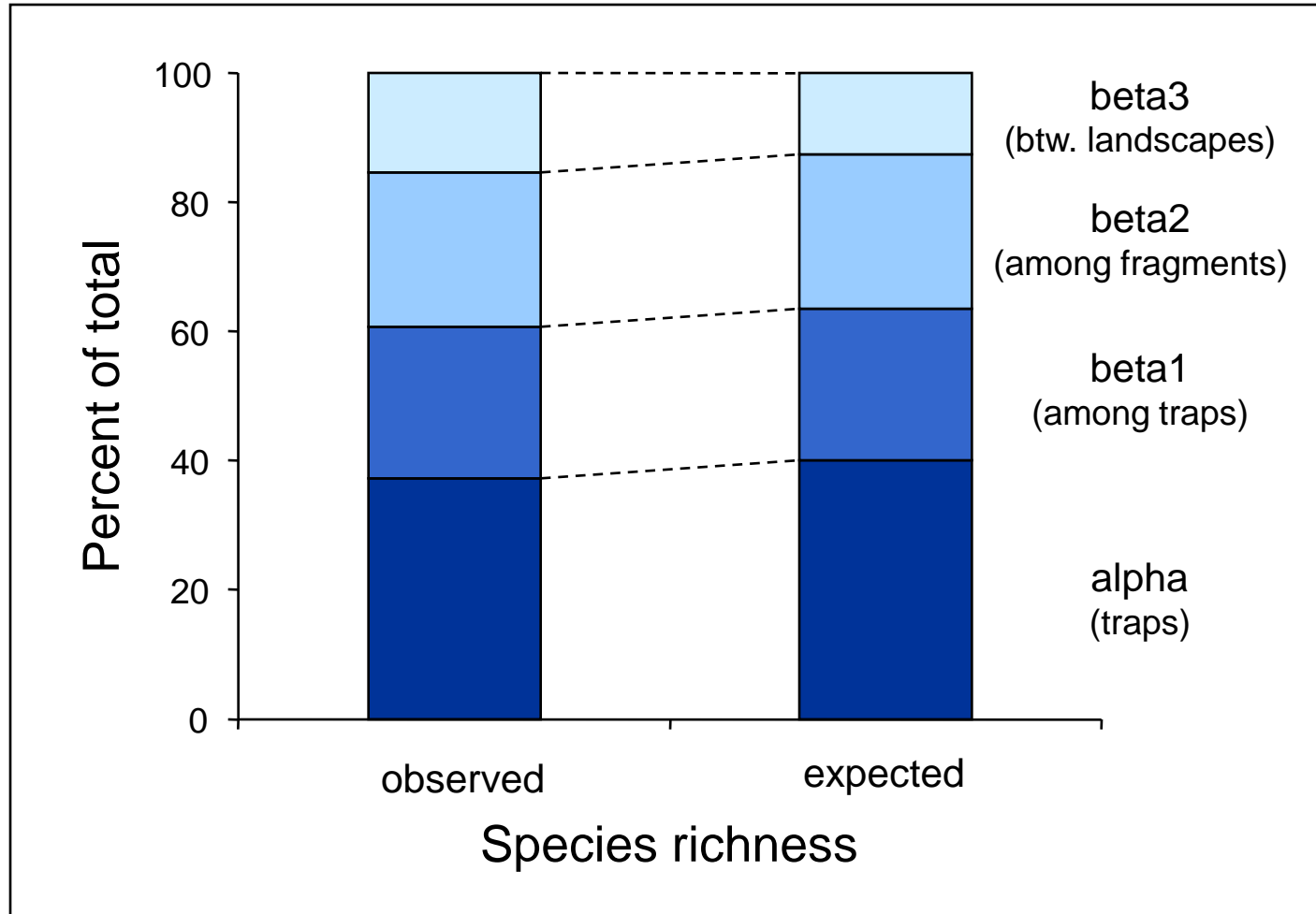
Martinho Prado, São Paulo

Diversity partitioning



Spatial partitioning of diversity

butterflies in Atlantic Forest fragments



Ribeiro et al. (2008) Additive partitioning of butterfly diversity in a fragmented landscape.
Diversity Distrib. 14:961-968

Partitioning a table of sites × resources × species

local diversity (α) =

average local richness per host species (α_H)

herbivore turnover among local host species (θ_H)

local host richness (H_L)

$$\alpha = \alpha_H \times \theta_H \times H_L$$

regional diversity (γ) =

(average assemblage on local host × average turnover among
local host species)

(local host richness × host turnover among sites)

number of sites

Partitioning a
table of
sites \times
resources \times
species

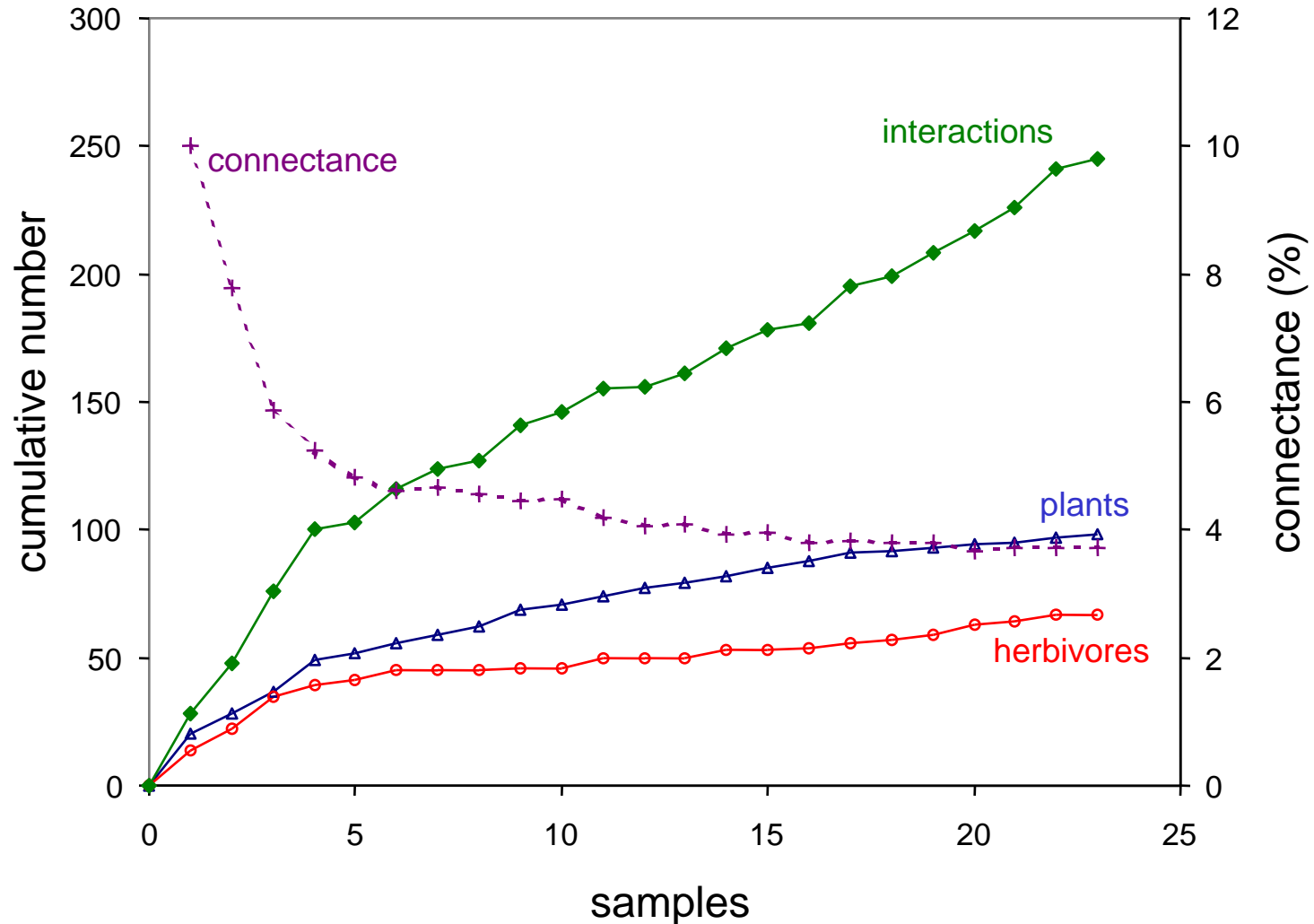
Site	H (number of hosts)	$\bar{\alpha}_H$ (average per host)	θ_H (turnover among hosts)	α (local diversity)
Diamantina	18	3.67	0.47	31
Grão Mogol	15	2.47	0.54	20
Serra do Cabral	18	3.39	0.49	30
Ouro Branco	8	1.88	0.67	10
Serra do Cipó	21	2.86	0.58	35
\bar{H} (average per site)	16			
H_T (total host diversity)	37			
θ_L (host turnover among sites)	0.46			
L (number of sites)	5			
$\bar{\alpha}_{HT}$ (insect average per host)		2.85		
θ_{HT} (insect turnover among hosts)			0.54	
γ (regional diversity)				57
$\bar{\alpha}$ (av. local diversity)				25.2
L (number of sites)				5
turnover among sites				0.45
γ (regional diversity)				57

Partitioning a
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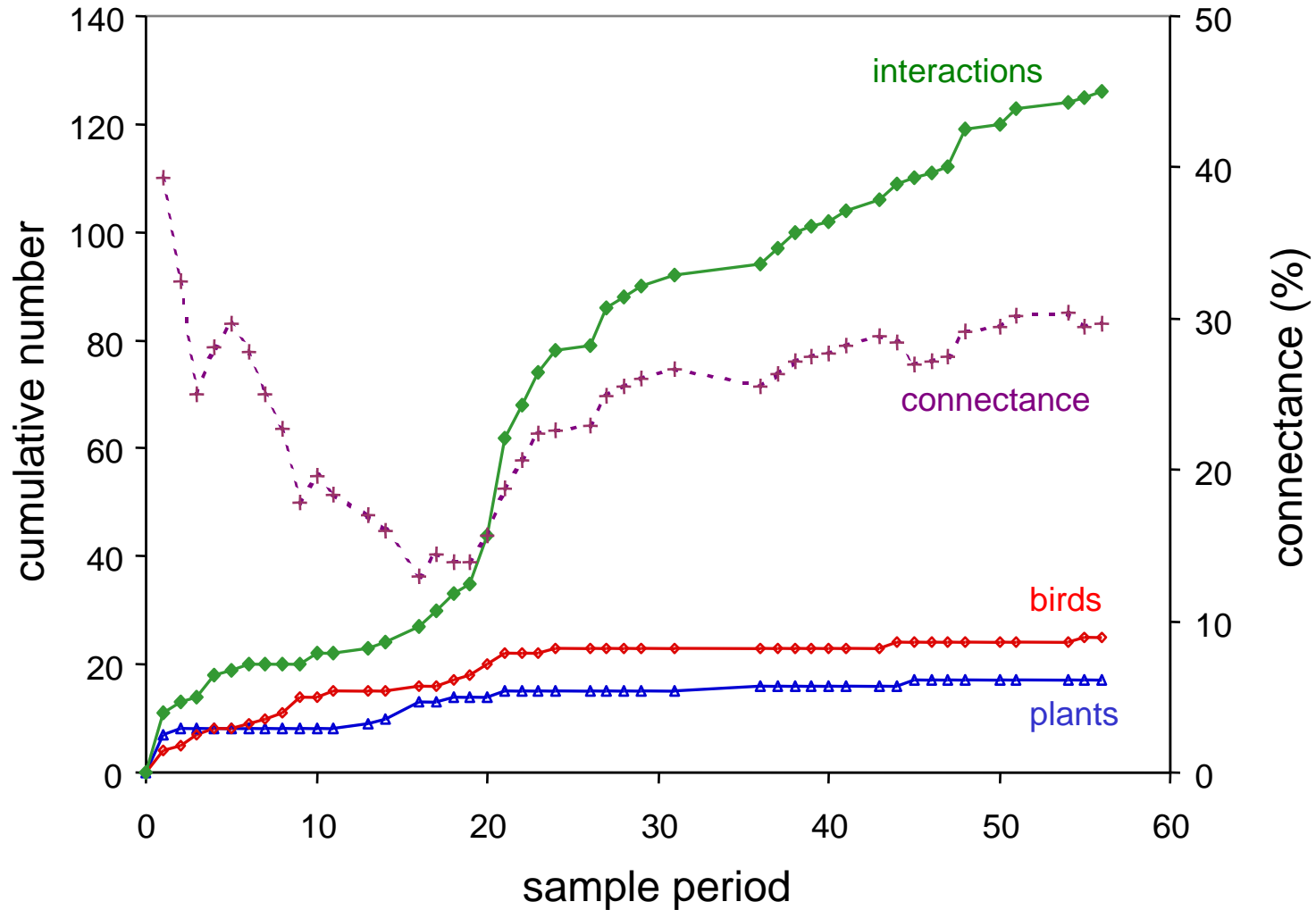
Collector's curves for interactions

Asteraceae and herbivores in cerrado, São Paulo, Brazil

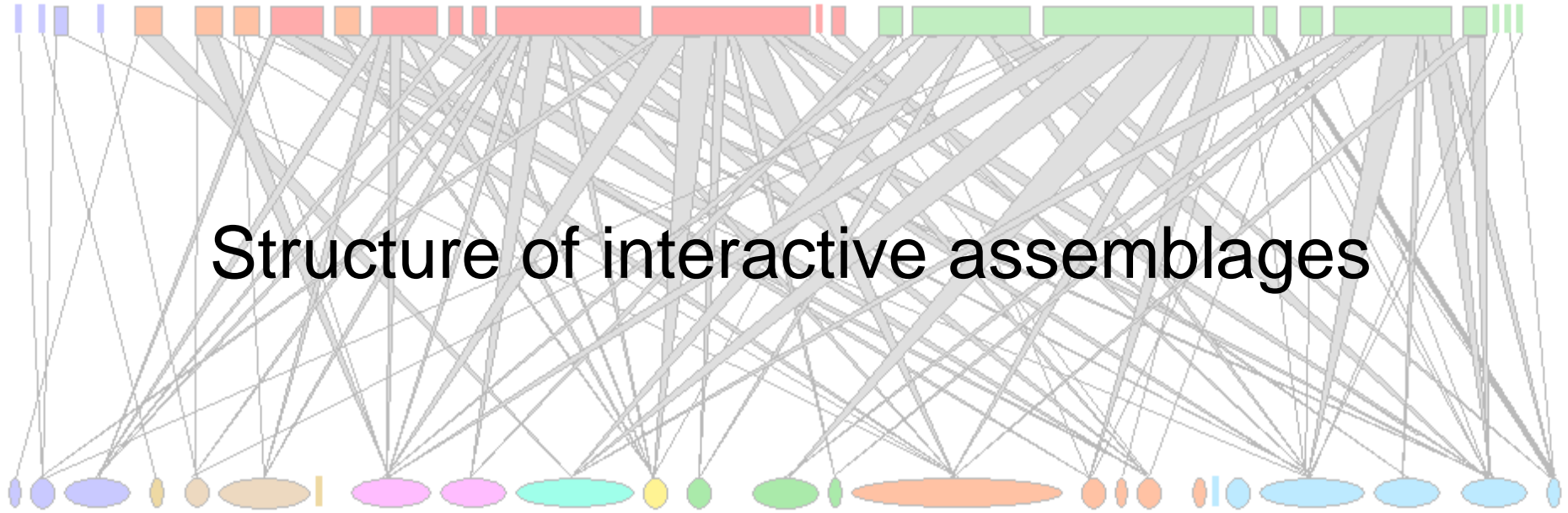


Collector's curves for interactions

tree species and frugivorous birds in Cazorla, Spain



Structure of interactive assemblages



From species records to interaction matrix

herbivores

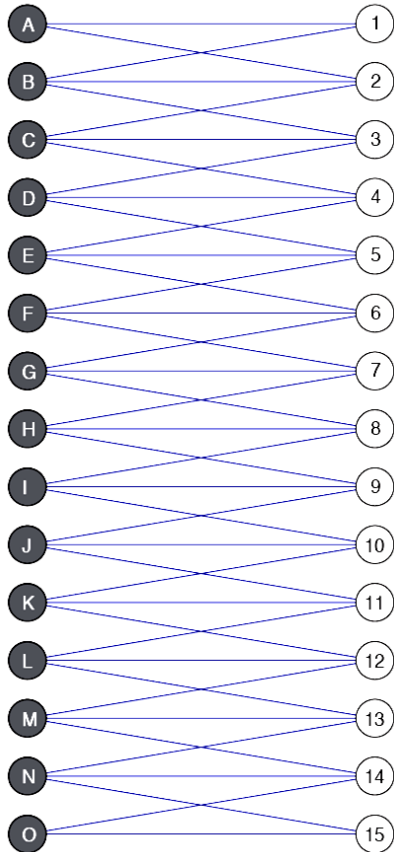
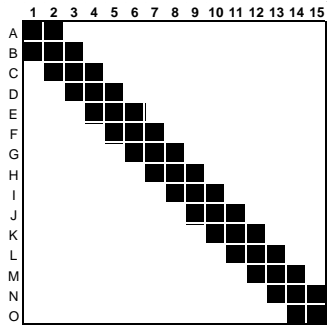


plants

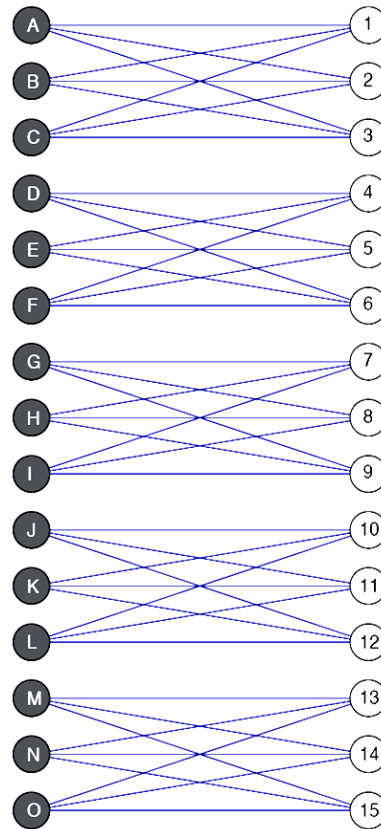
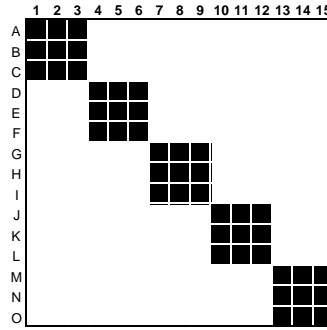


	<i>Tomoplagia cf. achromoptera</i>	<i>Dicyotripeta</i> sp.1	<i>Tomoplagia incompleta</i>	<i>Tomoplagia minuta</i>	<i>Tomoplagia reimoseri</i>	<i>Tomoplagia</i> sp.4	<i>Tomoplagia aff. deflorata</i>	<i>Cecidochara</i> sp.2	<i>Xanthaciura biocellata</i>	<i>Dioxyna</i> sp.1	<i>Trupanea</i> sp.1	<i>Xanthaciura</i> sp.1	<i>Cecidochara</i> sp.1	<i>Xanthaciura chrysur</i>	<i>Neomyopites paulensis</i>	<i>Euarestoides</i> sp.1	<i>Tomoplagia trivittata</i>	<i>Tetreauresta</i> sp.1	<i>Tetreauresta cf. obscuriventris</i>	<i>Tomoplagia</i> sp.7	<i>Trypanaresta</i> sp.1	<i>Tomoplagia</i> sp.5	<i>Tomoplagia</i> sp.3	<i>Caeraniata</i> sp.1	<i>Tomoplagia</i> sp.1	total de adultos
<i>Lessingianthus aff. bardanoides g</i>	3																									3
<i>Lessingianthus bardanoides</i>	110		1																							111
<i>Lessingianthus onoporoides</i>	4																									4
<i>Lessingianthus</i> sp.2	2																									2
<i>Lepidaploa salzmanii</i>		2	3																							5
<i>Vernonanthura ruficoma</i>				5	8																					13
<i>Lessingianthus</i> sp.3						32	16																			48
<i>Chromolaena maximilianii</i>									3				7	229	2											241
<i>Bidens gardneri</i>										12					4											16
<i>Chromolaena chaseae</i>								12						259												271
<i>Eupatorieae</i> n.i.1											3			1												4
<i>Chromolaena hominioides</i>								19							8											27
<i>Grazilia</i> sp.1														5												5
<i>Koanophyllon</i> sp.2									1																	1
<i>Chromolaena laevigata</i>									4					89	23											116
<i>Chromolaena peduncularis</i>									1	1	1	25	279	21												328
<i>Chromolaena minasgeraisensis</i>								19	9		4	7	83	7												129
<i>Mikania</i> sp.1														2	1											3
<i>Bidens</i> sp.1										11					1											12
<i>Chromolaena odorata</i>								38	11			1	15	556	30											651
<i>Chromolaena squalida</i>								18	5				17	562	7											609
<i>Gochnatia pulchra</i>																5	1									6
<i>Baccharis dracunculifolia</i>																1										1
<i>Elephantopus micropappus</i>																					9					9
<i>Elephantopus mollis</i>																					2					2
<i>Elephantopus biflorus</i>																							771			771
<i>Lepidaploa</i> sp.1																						1				1
<i>Baccharis subdentata</i>																						16				16
<i>Piptocarpha rotundifolia</i>																							1	5	2	83
Total de individuos	119	2	4	5	8	32	16	107	34	23	8	1	71	2078	91	6	1	11	771	1	16	1	5	2	83	3496

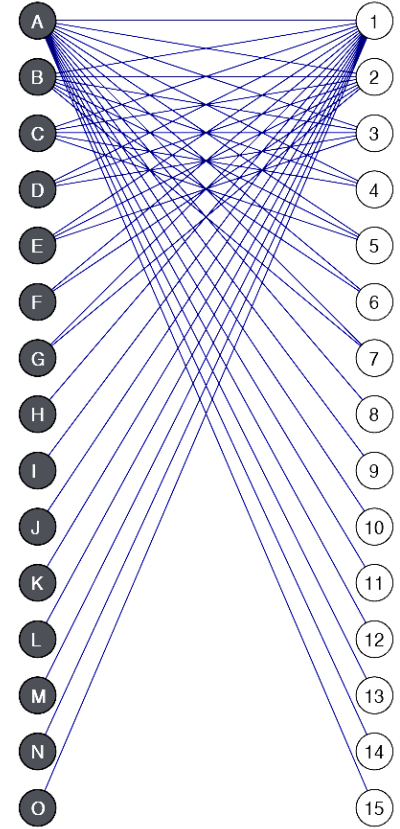
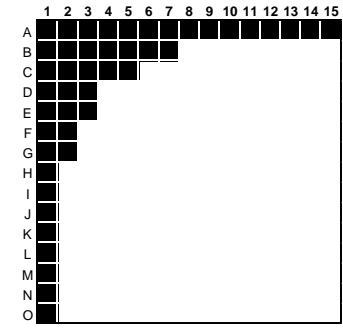
gradient



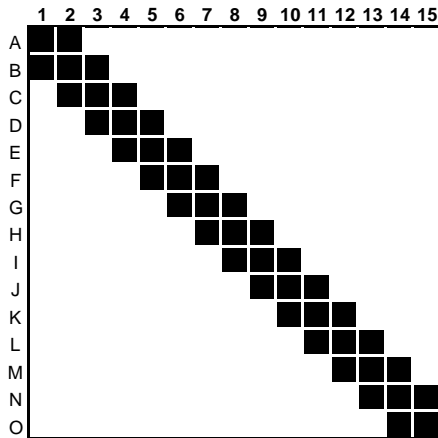
compartmented



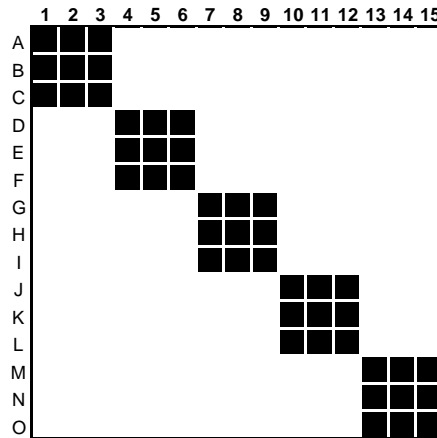
nested



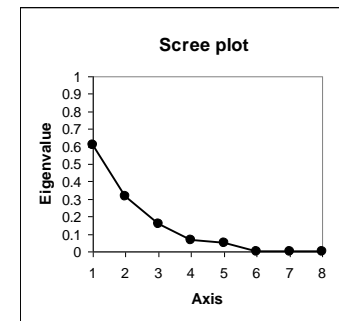
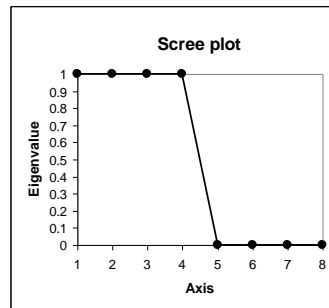
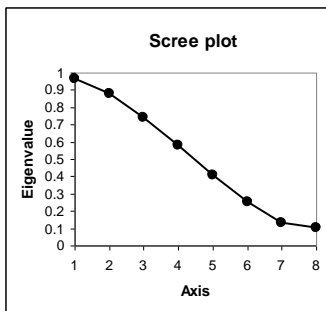
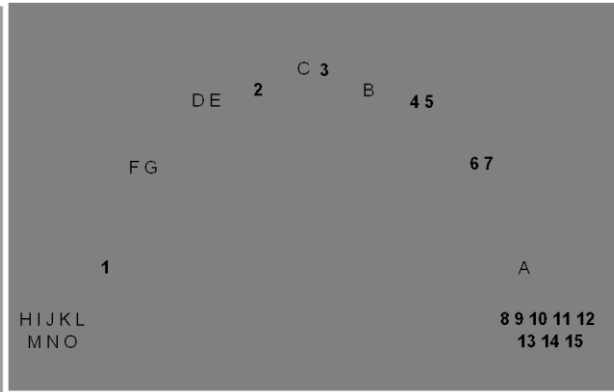
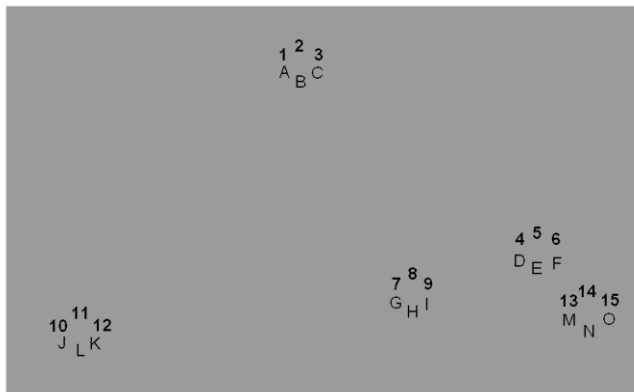
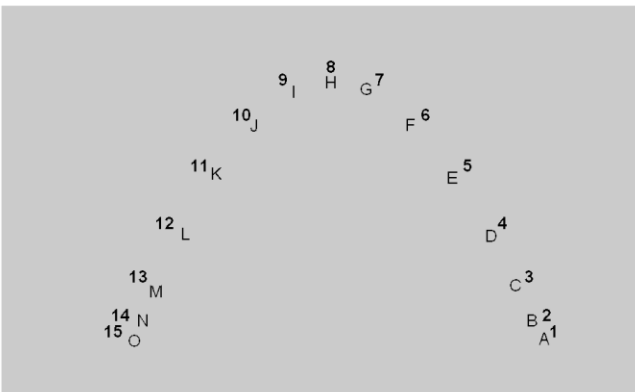
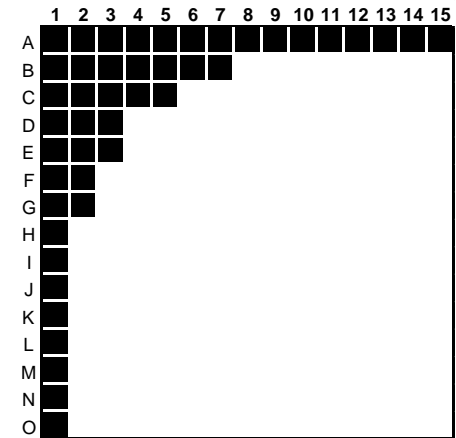
gradient



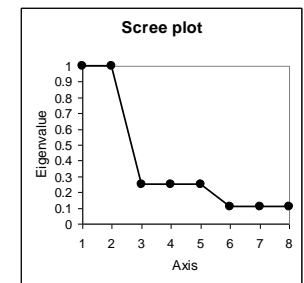
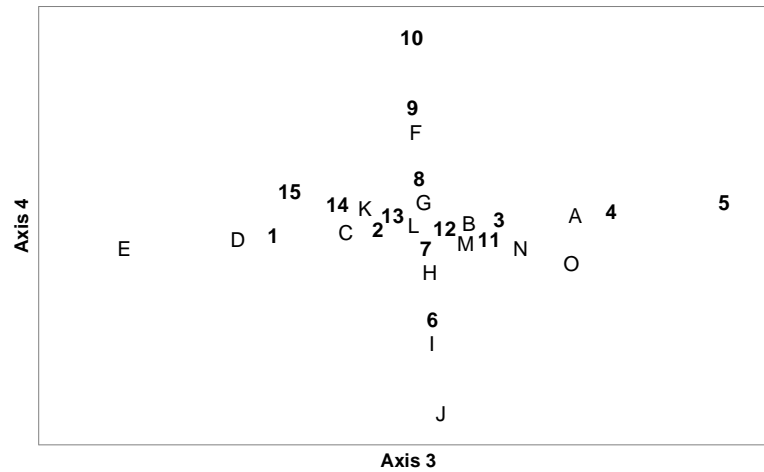
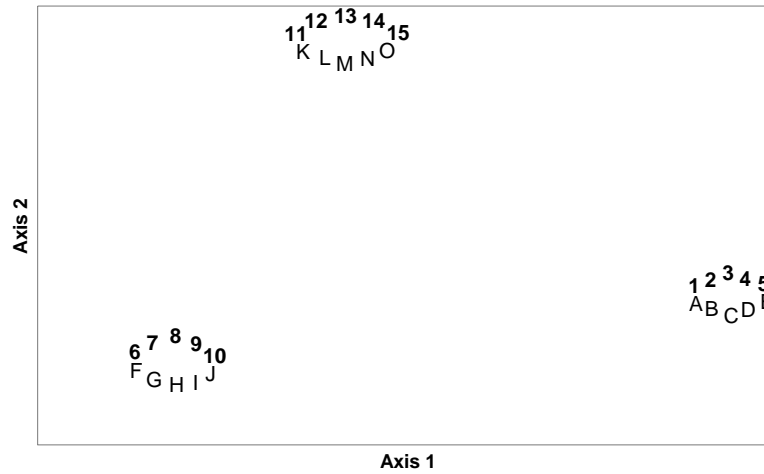
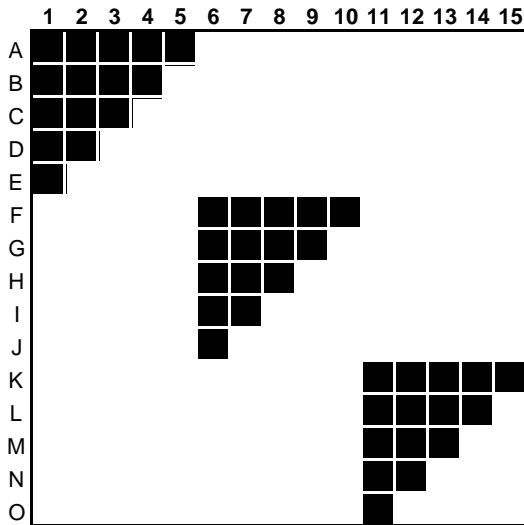
compartmented



nested



a combined (hierarchical) model



Nested assemblages

A

		Insects										
		<i>i</i>	<i>j</i>	<i>k</i>	<i>l</i>	<i>m</i>	<i>n</i>	<i>o</i>	<i>p</i>	<i>q</i>	<i>r</i>	
Plants	1	x	x	x	x	x	x	x	x	x	x	10
	2	x	x	x	x	x	x	x				7
	3	x	x	x	x	x						5
	4	x	x	x								3
	5	x	x	x								3
	6	x	x	x								3
	7	x	x									2
	8	x										1
	9	x										1
	10	x										1
		10	7	6	3	3	2	2	1	1	1	8.7

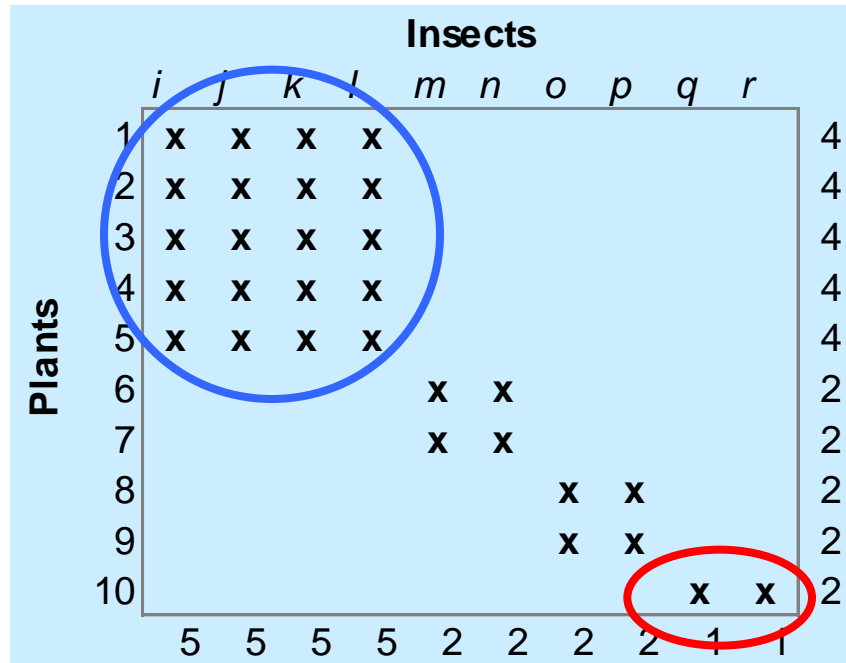
specialist insects
accumulate on
plants with large
faunas

species-poor
plants only
have
polyphagous
insects

An island-biogeographic scenario

Compartmented assemblages

polyphagous
insects only
on species-
rich plants

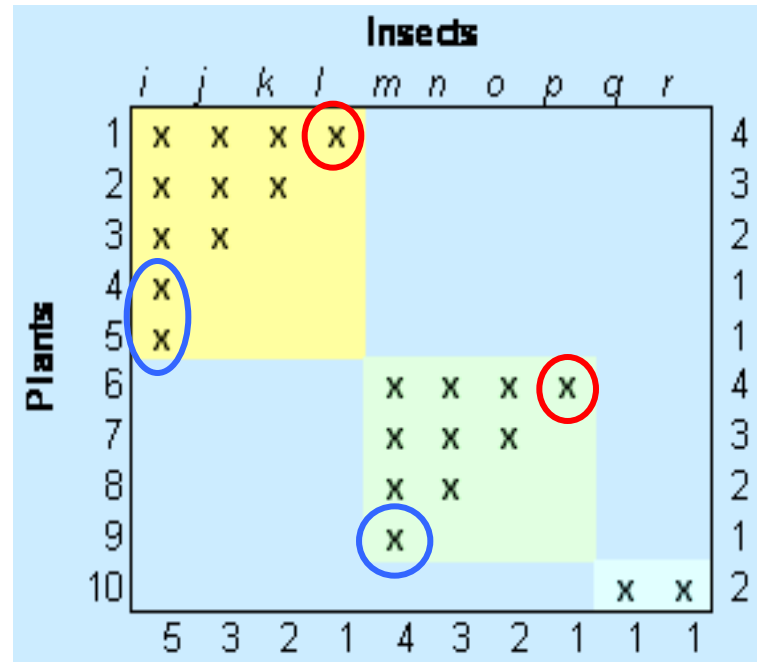


specialist
insects are found
on plants with
small faunas

A coevolutionary scenario

A combined model

Matrix has
disjunct
subsets;
species in
each
compartment
are nested

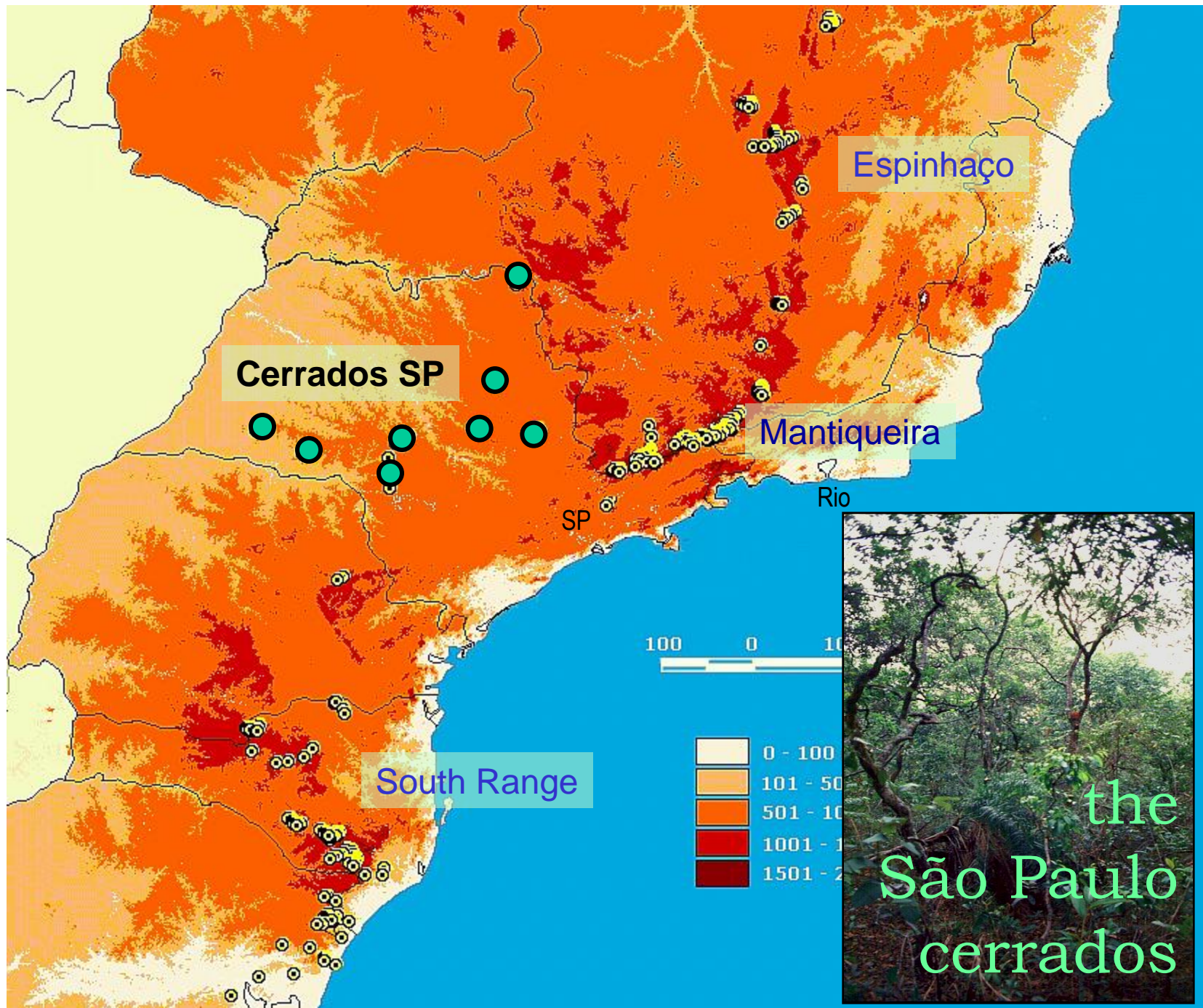


In each subset:
specialist
insects only on
species-rich
plants

plants with few
species have
only **polyphages**

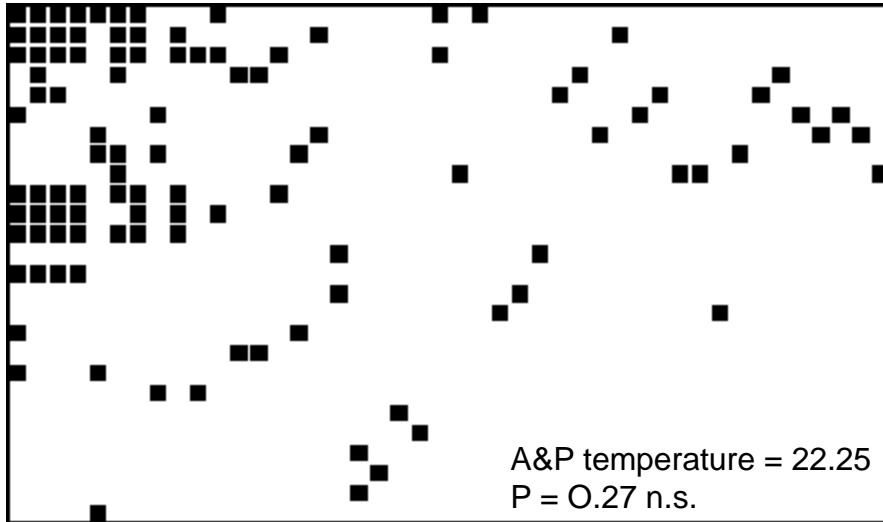
Plant-herbivore interaction structure at local and regional scales

- what are the essential traits of plant-herbivore assemblages?
- are patterns similar among different scales?

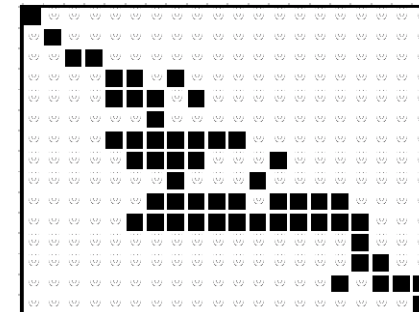
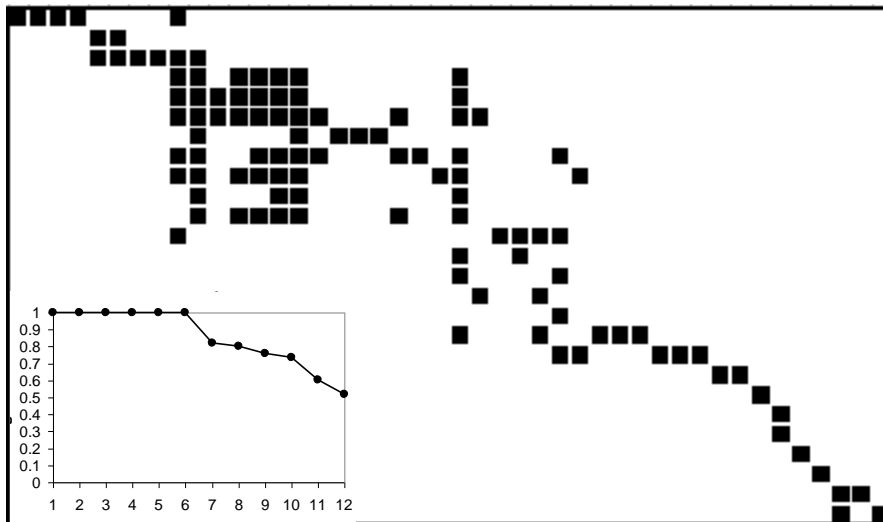
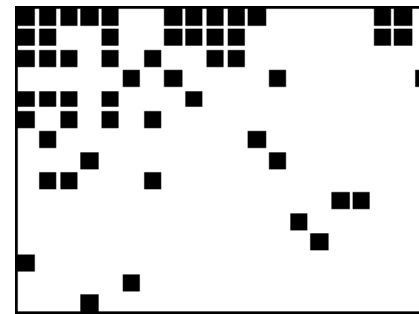


Cerrado local assemblages – two cases

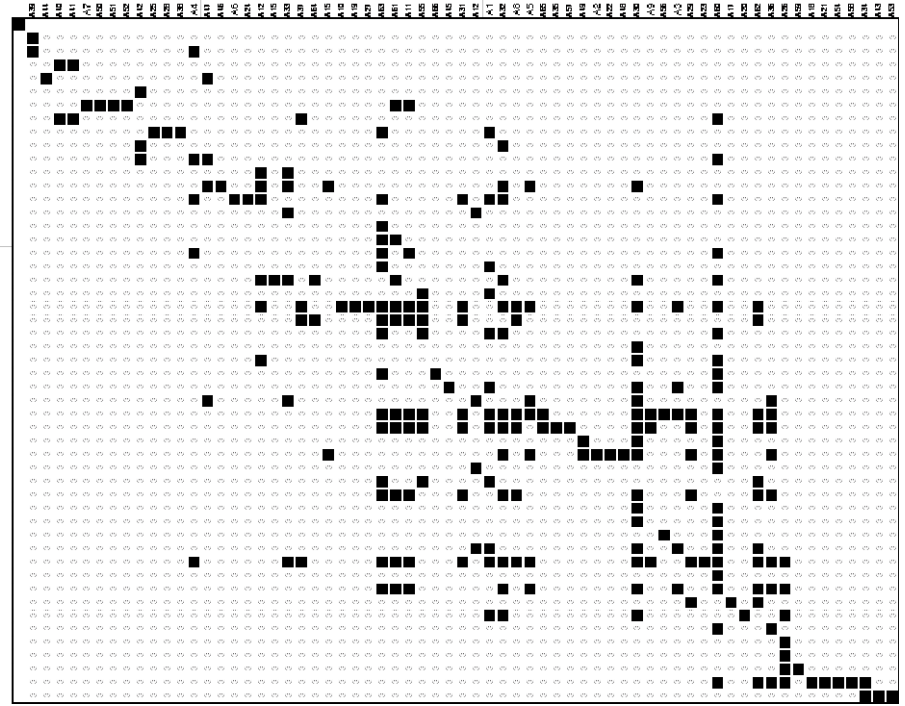
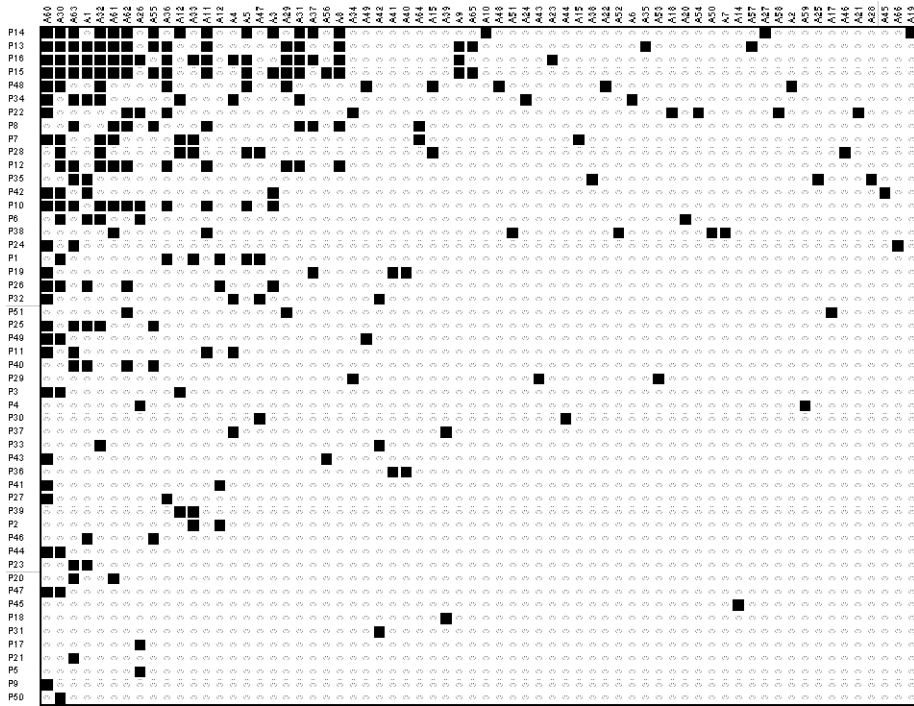
Itirapina



Mogi-Guaçu

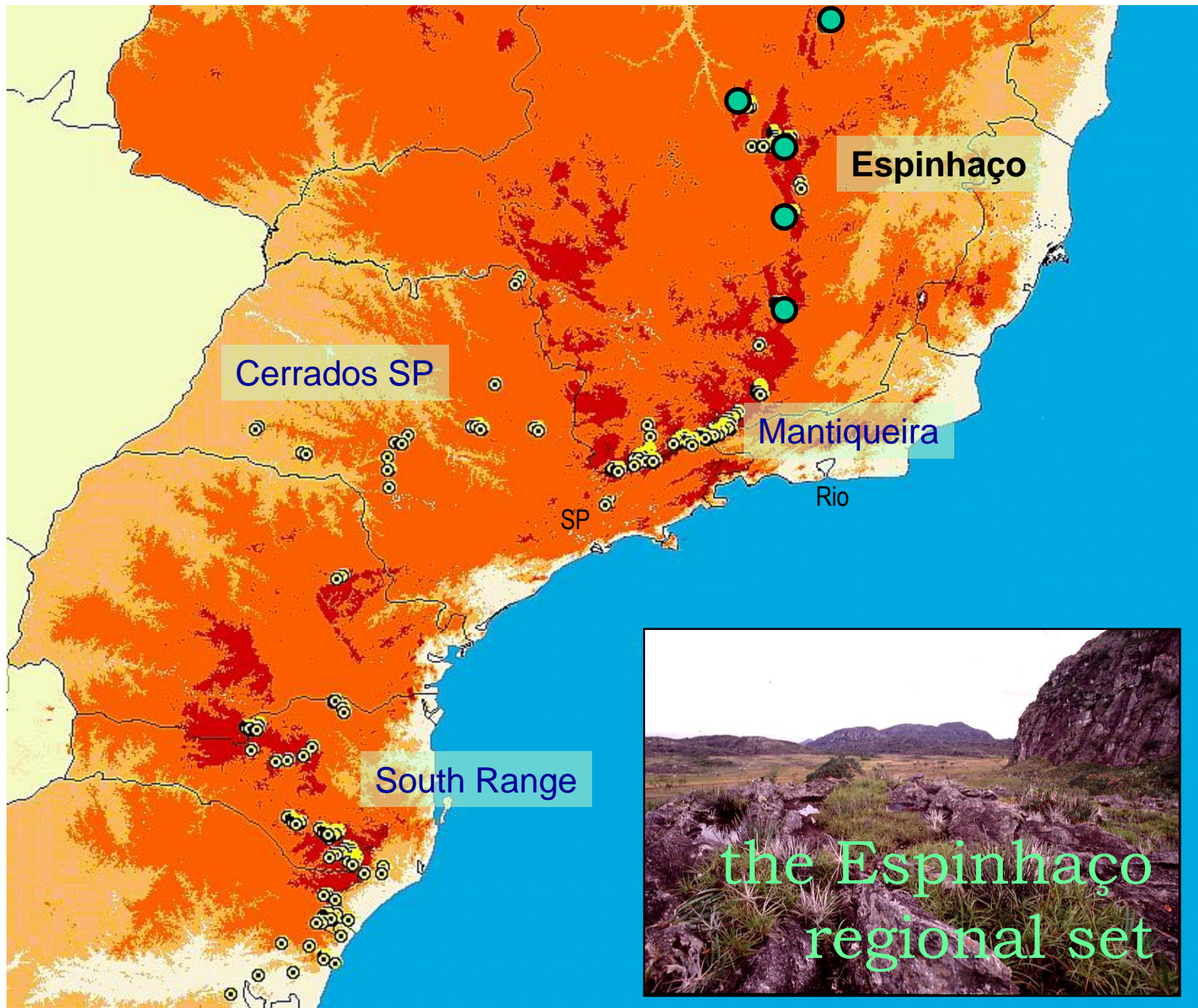


Cerrado regional assemblage

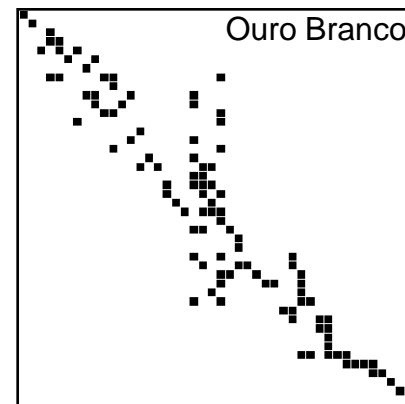
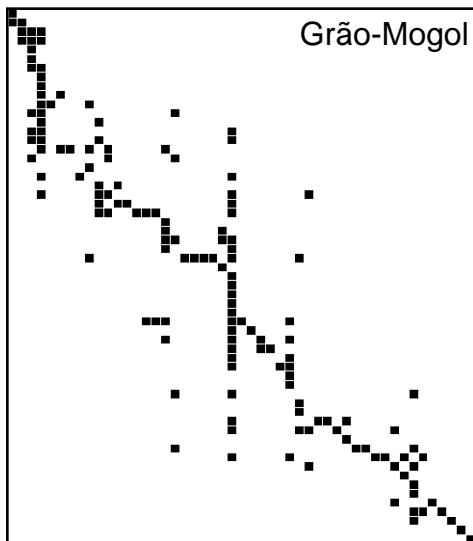
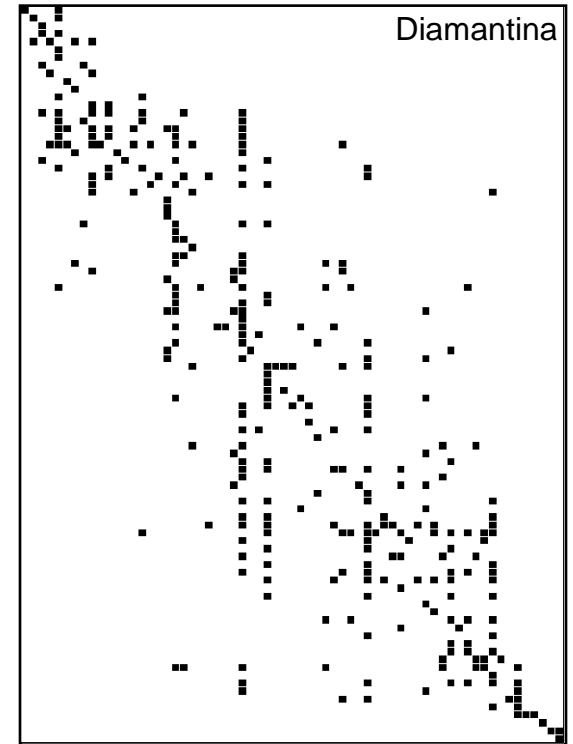
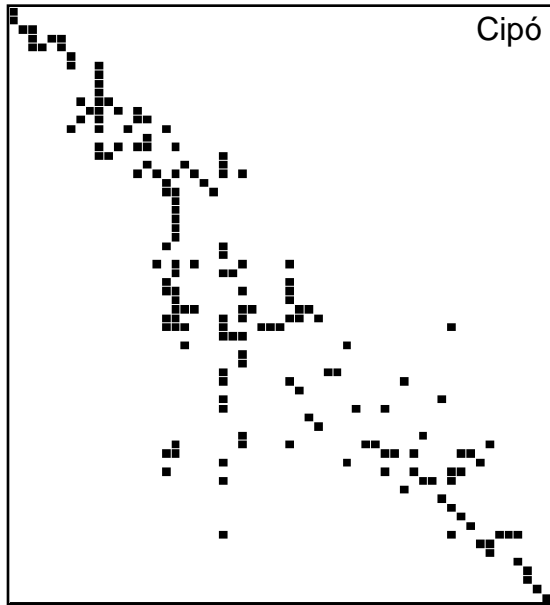


A&P temperature = 8.52

P = 7.8×10^{-19} *****

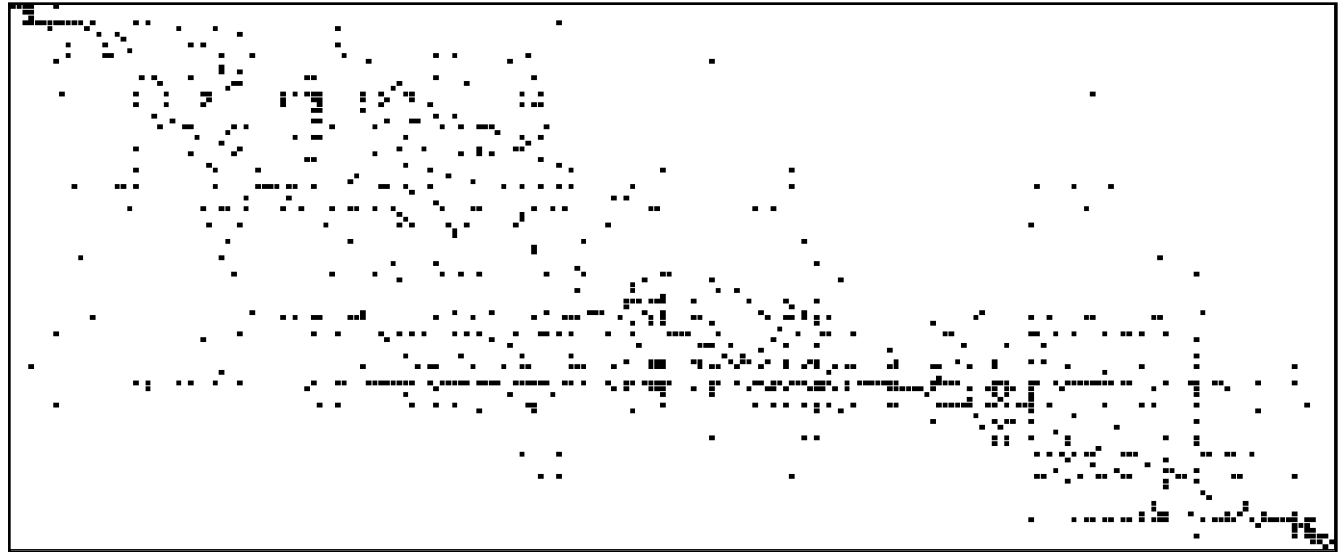


Espinhaço – local webs



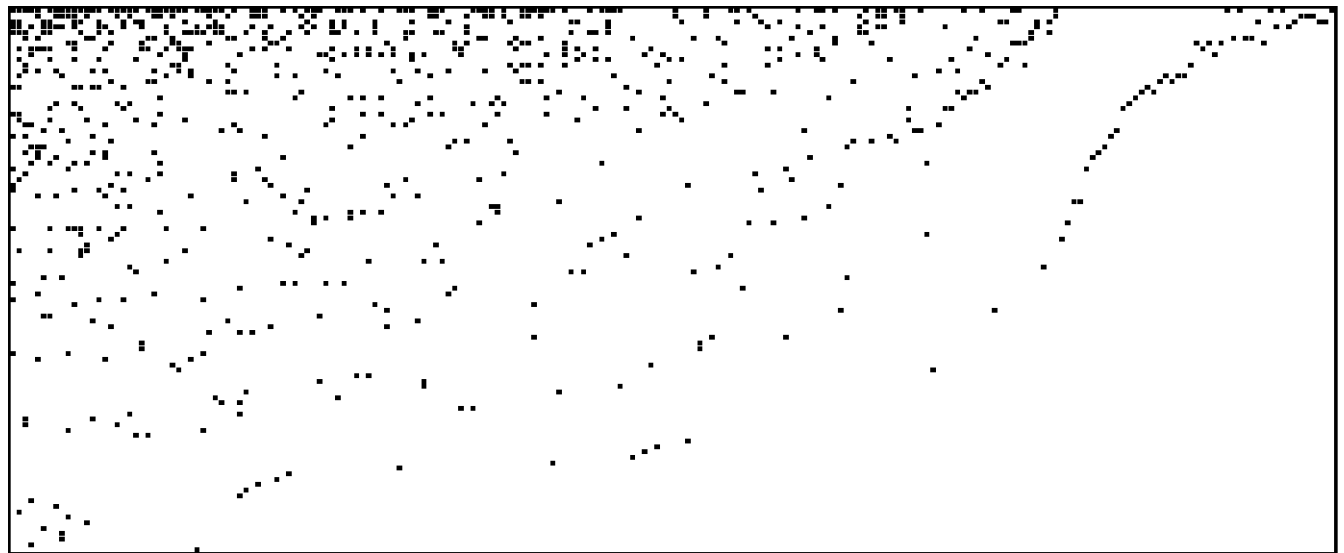
Espinhaço – regional matrix

CA



nested

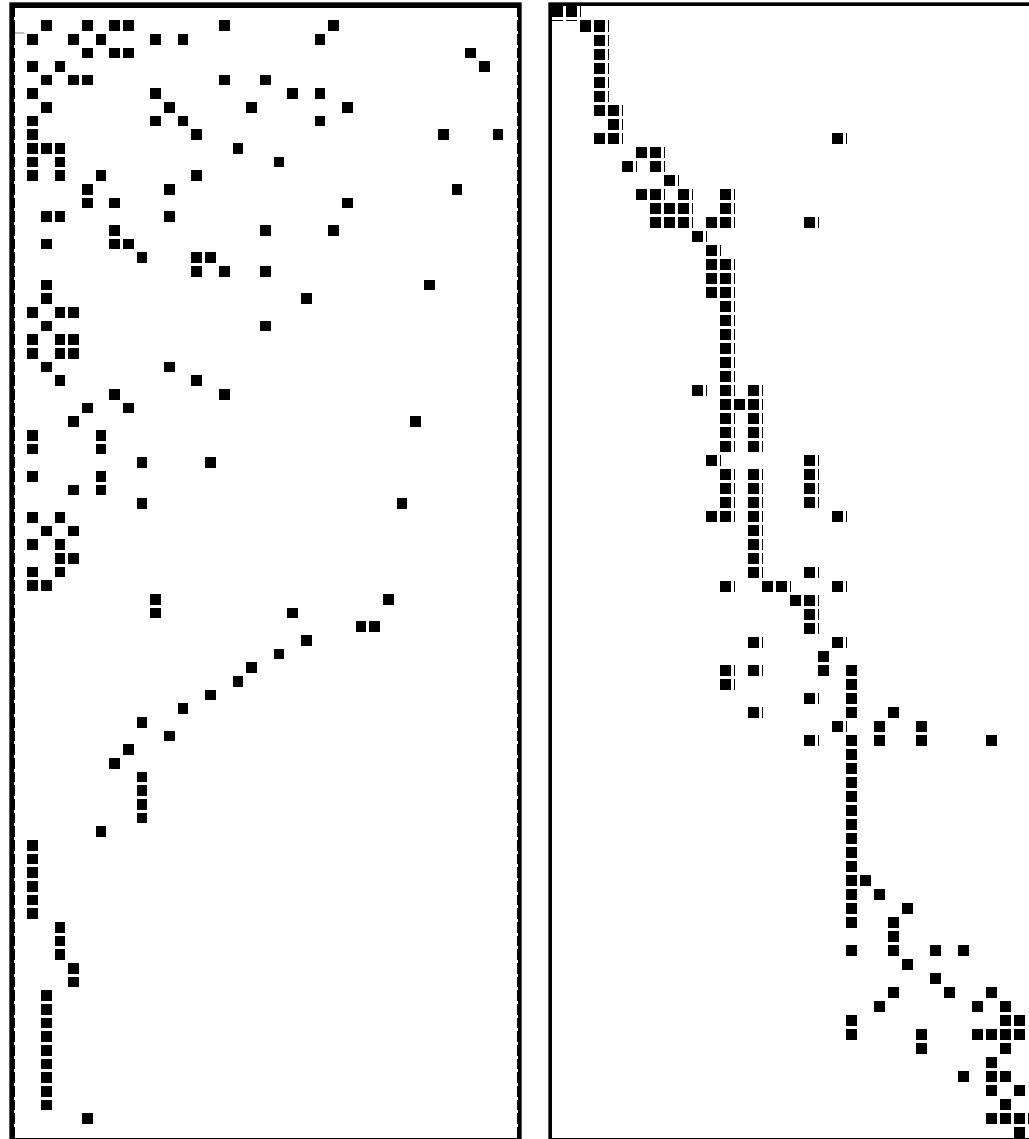
insects



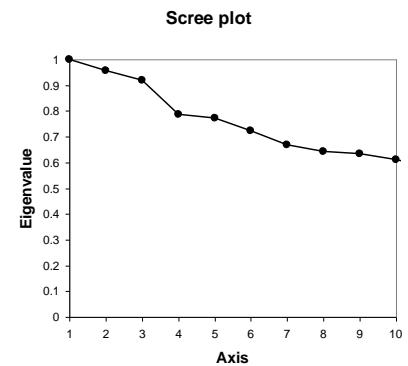
plants

Regional assemblage: Espinhaço range

Vernonieae and Tephritidae



Temp = 8.49
P = 0.000015



Compartmentation test: MRPP

(multi-response permutation procedure)

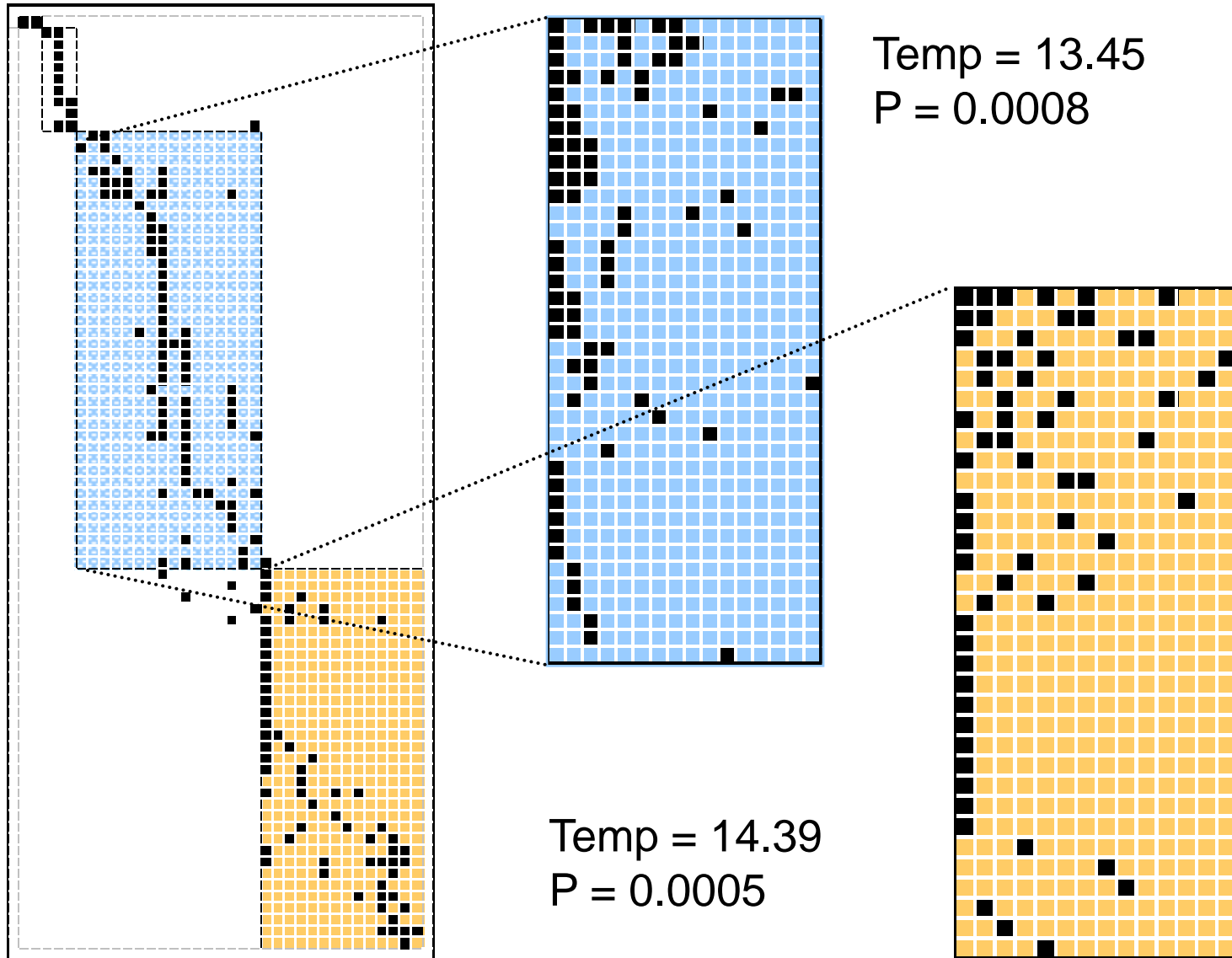
- average distance among species *within* compartments: **0.859**
- expected average distance with no compartmentation: **0.965**
- $p < 0.001$

Prado & Lewinsohn 2004 *J. anim. Ecol.*
(modified)

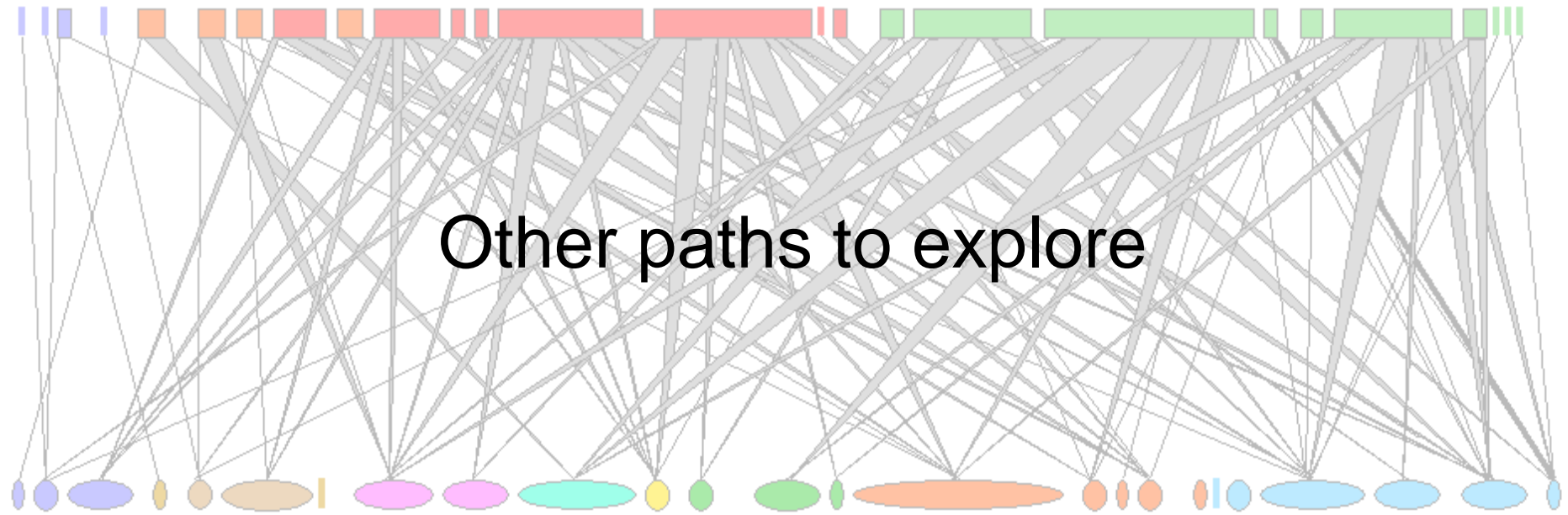
Subtribu das plantas	V	V	V	V	V	V	V	V	C	L	L	L	L	L	L	L
Tefritídeos	Cyrtocymura	Vernonanthura	Strophopappus	Chrysolaela	Chresta	Lessingianthus	Lepidaploa	Echinocoryne	Centratherum	Proteopsis	Minasia	Piptolepis	Eremanthus	Lychnophora	Anteranthus	Paralychnophora
Tomoplagia pseudopenicillata	1															
Tomoplagia argentinensis	1															
Tomoplagia fiebrigi		1														
Tomoplagia minuta		3														
Tomoplagia reimoseri		8														
Dictyotrypeta sp.a			1			1										
Tomoplagia formosa				1												
Tomoplagia aff. deflorata					1											
Tomoplagia gr. inc. sp.c						3										
Tomoplagia gr. inc. sp.d						1										
Tomoplagia sp.i						1										
Tomoplagia sp.l						3										
Tomoplagia tripunctata						7										
Tomoplagia sp.m	1		1	1	4	6	2			1						
Dictyotrypeta sp.6						1										
Tetreuaresta sp.d						2										
Dictyotrypeta atacta						4				1						
Tomoplagia aff. rudolphi						1				1						
Tomoplagia incompleta			1	2	14	4	1				1		1			
Xanthaciura biocellata	1				3										1	
Dictyotrypeta sp.23					4	1	2	1		1		1	1			
Tomoplagia punctata								1								
Dictyotrypeta sp.b											3					
Tomoplagia aff. heringi					1					1	6	3	3	6		1
Tetreuaresta sp.a										1			1	1	1	1
Tetreuaresta sp.c												1				
Tetreuaresta sp.e												1				
Acrotaeniini gen. nov.1 sp.a													3	4		
Tomoplagia sp.7													2	5		
Tomoplagia sp.k													3	2		
Acrotaeniini gen. nov.2 sp.a														4		
Tomoplagia sp.7b														2		
Tomoplagia sp.8														4		
Tomoplagia sp.a															1	1
Trupanea sp.5															1	1
Xanthaciura chrysur													1			
N de espécies de plantas	1	12	1	1	2	26	9	2	1	2	8	4	11	18	1	1

Regional assemblage: Espinhaço range

Vernonieae and Tephritidae

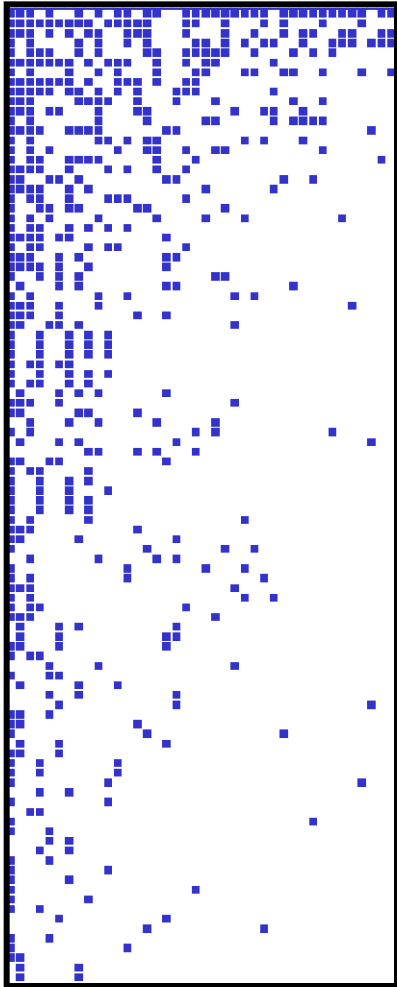


Other paths to explore

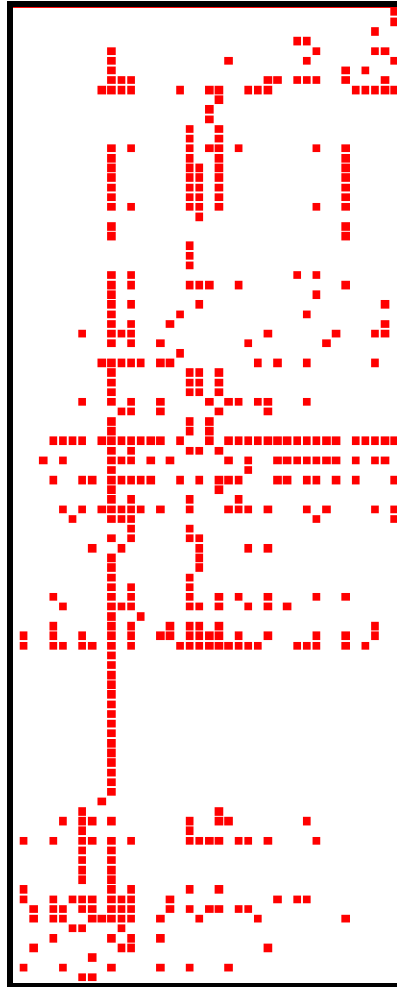


mutualistic \times antagonistic assemblages

Monteverde: trees & frugivorous birds

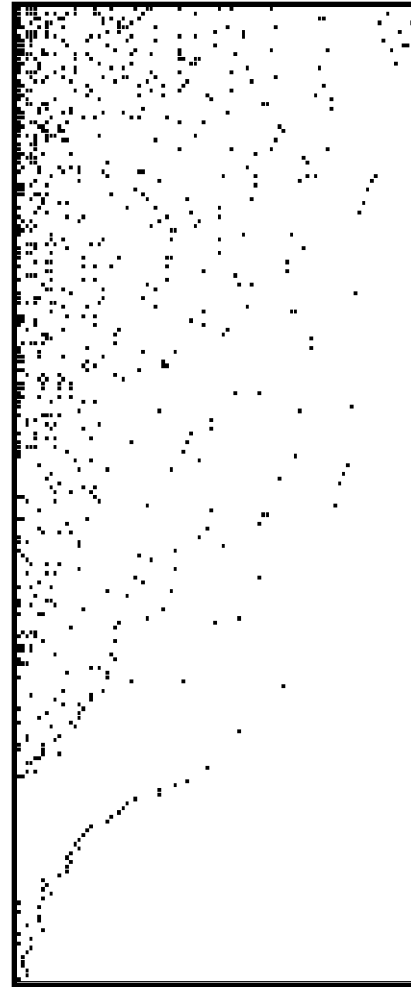


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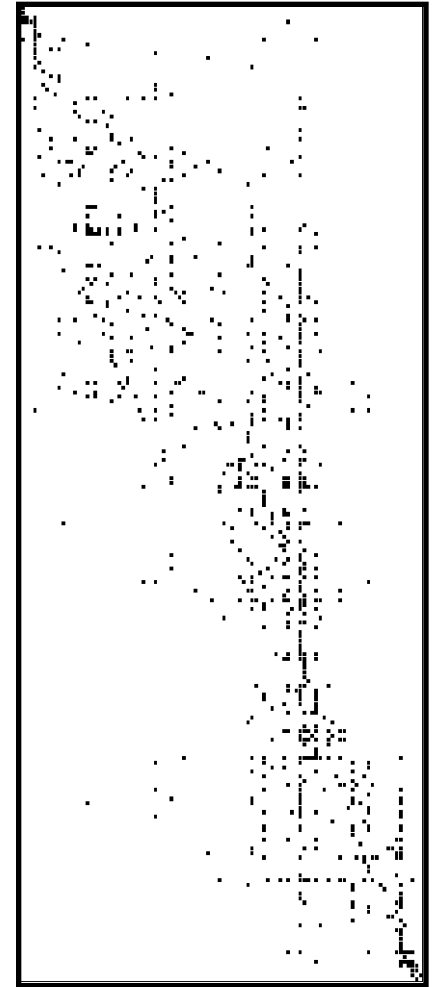


C.A.

Espinhaço: plants & flowerhead feeders



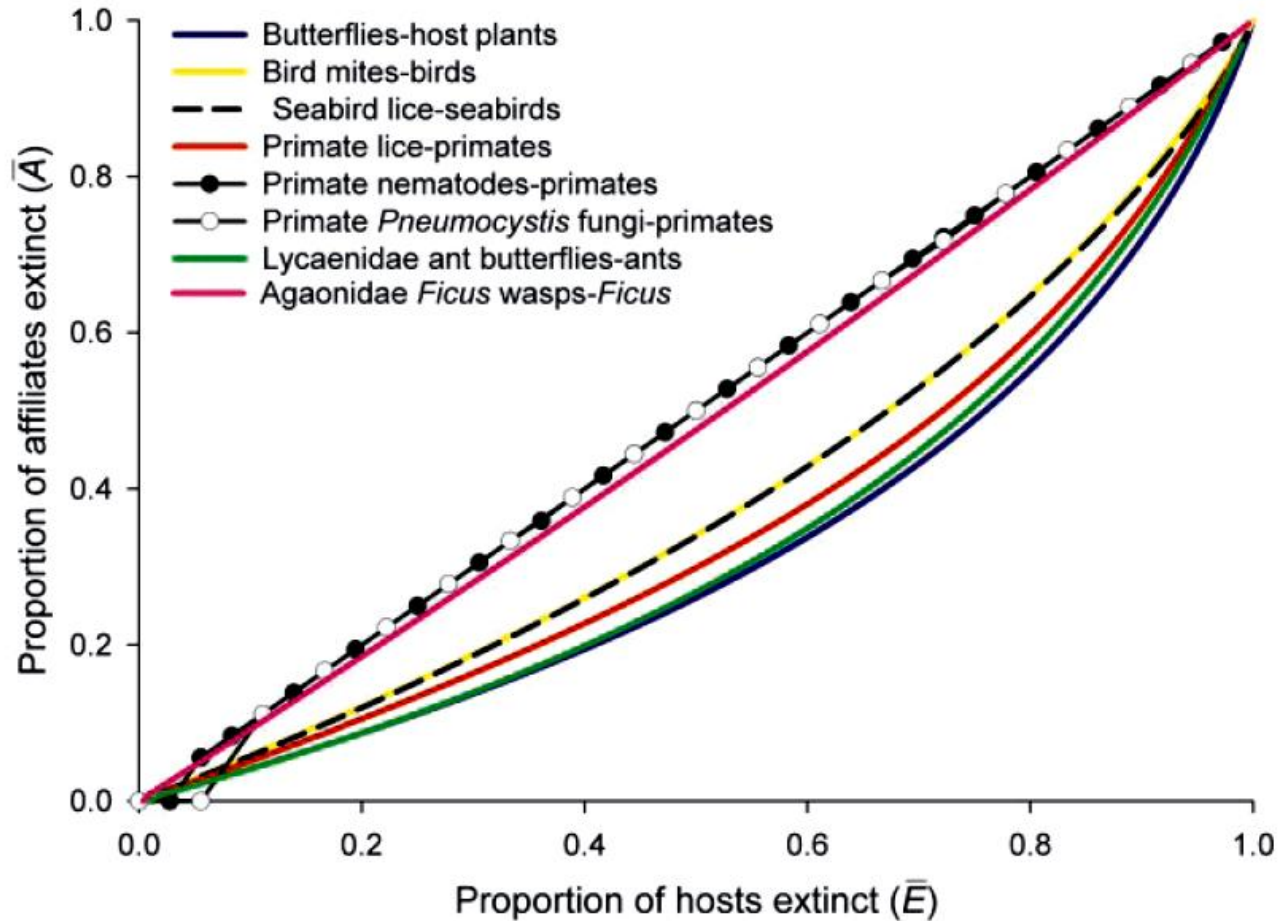
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C.A.

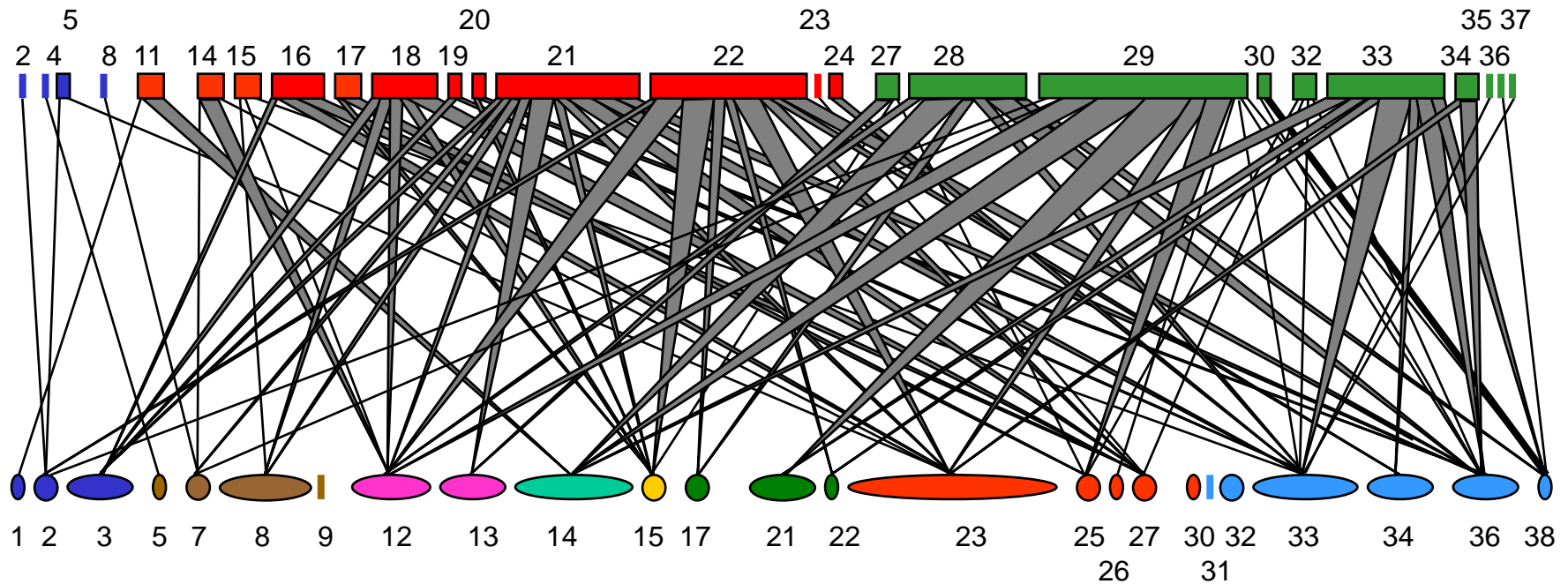
Coextinctions

domino effects in interactive assemblages



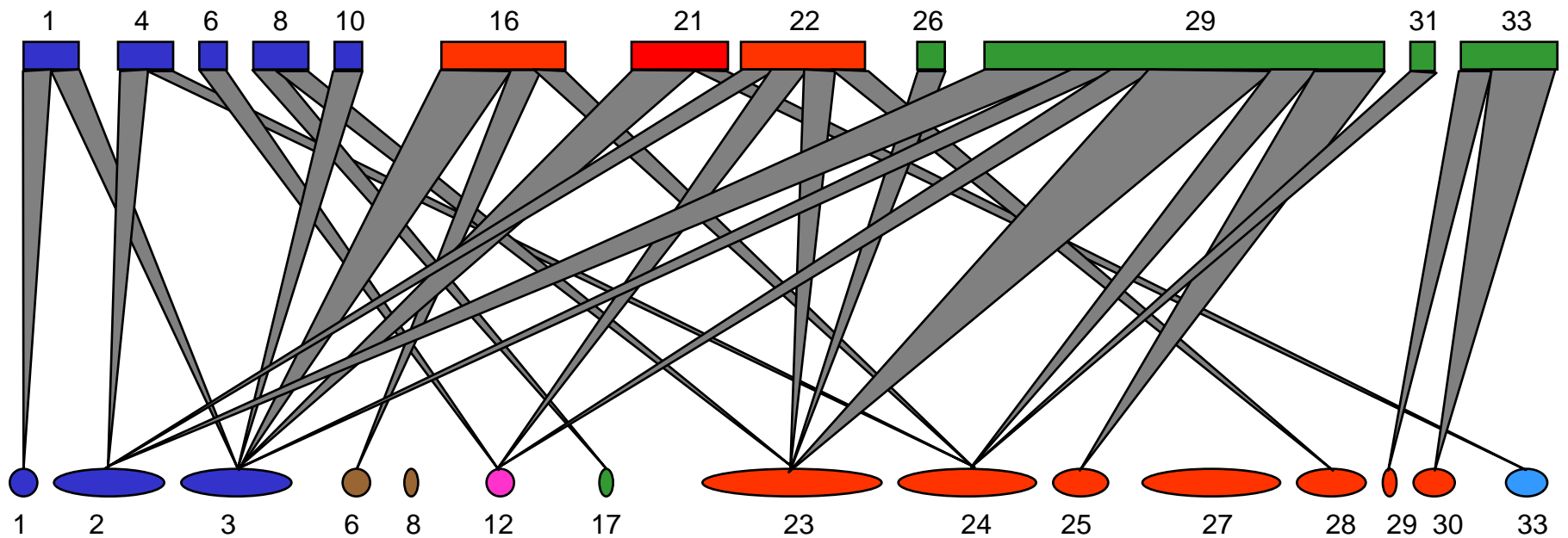
Quantitative plant-herbivore webs

Mantiqueira: **Campos do Jordão**

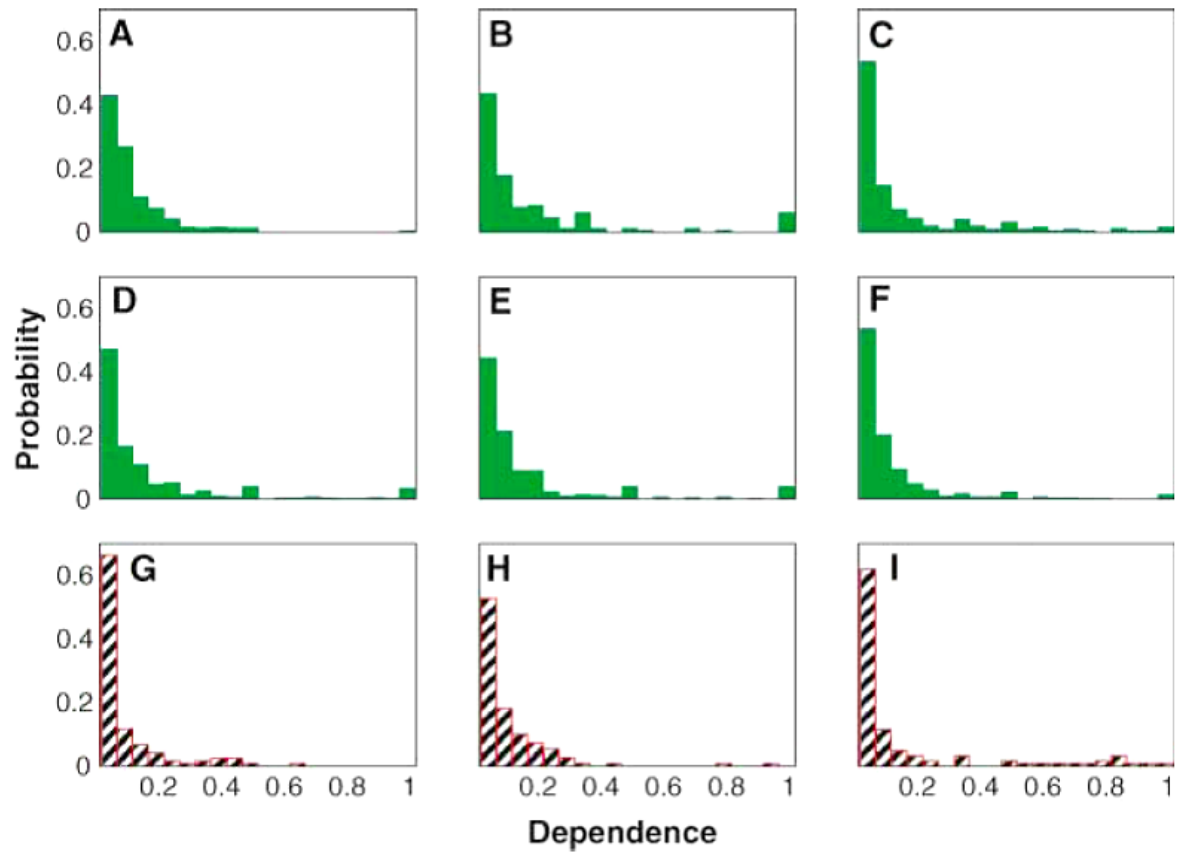
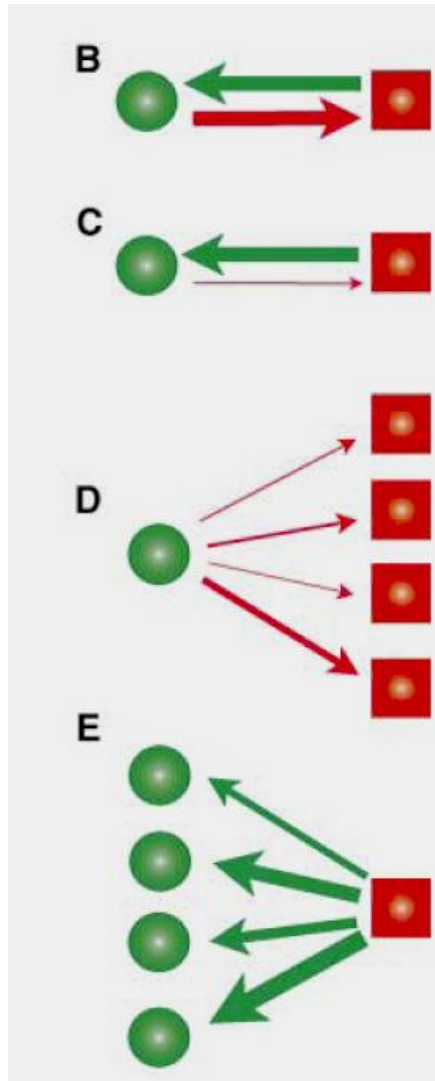


Quantitative plant-herbivore webs

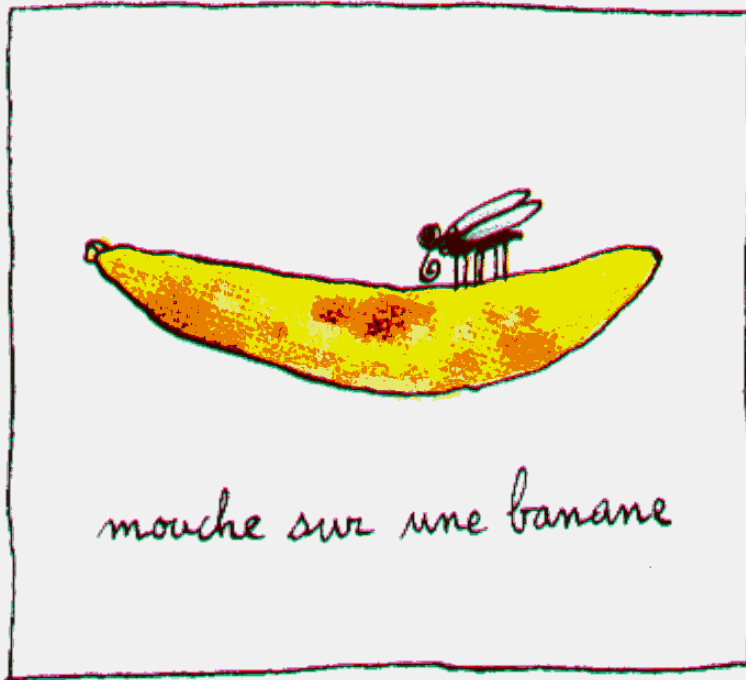
Mantiqueira: **Itatiaia**



Asymmetry between plants and animals



Asymmetry between plants and animals : the short version



In conclusion

- To assess biodiversity comprehensively, compositional descriptors have to be complemented with functional or structural information
- Interactive assemblages allow the combination of usual biodiversity measures with structural descriptors
- Ditrophic assemblages are especially suited for this, since they combine high taxonomic resolution with well-defined interaction patterns
- Nested and modular assemblage structures, among other configurations, illustrate promising approaches to integrate compositional with functional attributes for describing and assessing biodiversity in the larger sense.

