Plant – herbivore relationships

VOJTECH NOVOTNY:
COMMUNITY ECOLOGY,
LECTURE NO 2
University of S. Bohemia

Modes of exploitation:

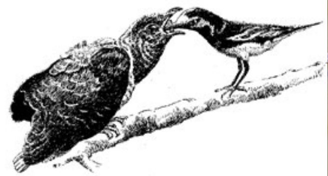
• **Grazers**: one grazer negatively impacts many individuals

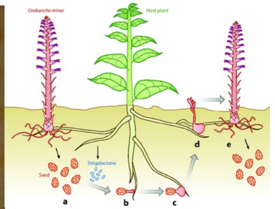

many herbivores (also flower nectar robbers ...)

• **Predators**: one predator kills many individuals


many carnivores, also seed-eating herbivores …

• **Parasites**: one parasite impacts one individual





macroscopic parasites, pathogens incl. plants…

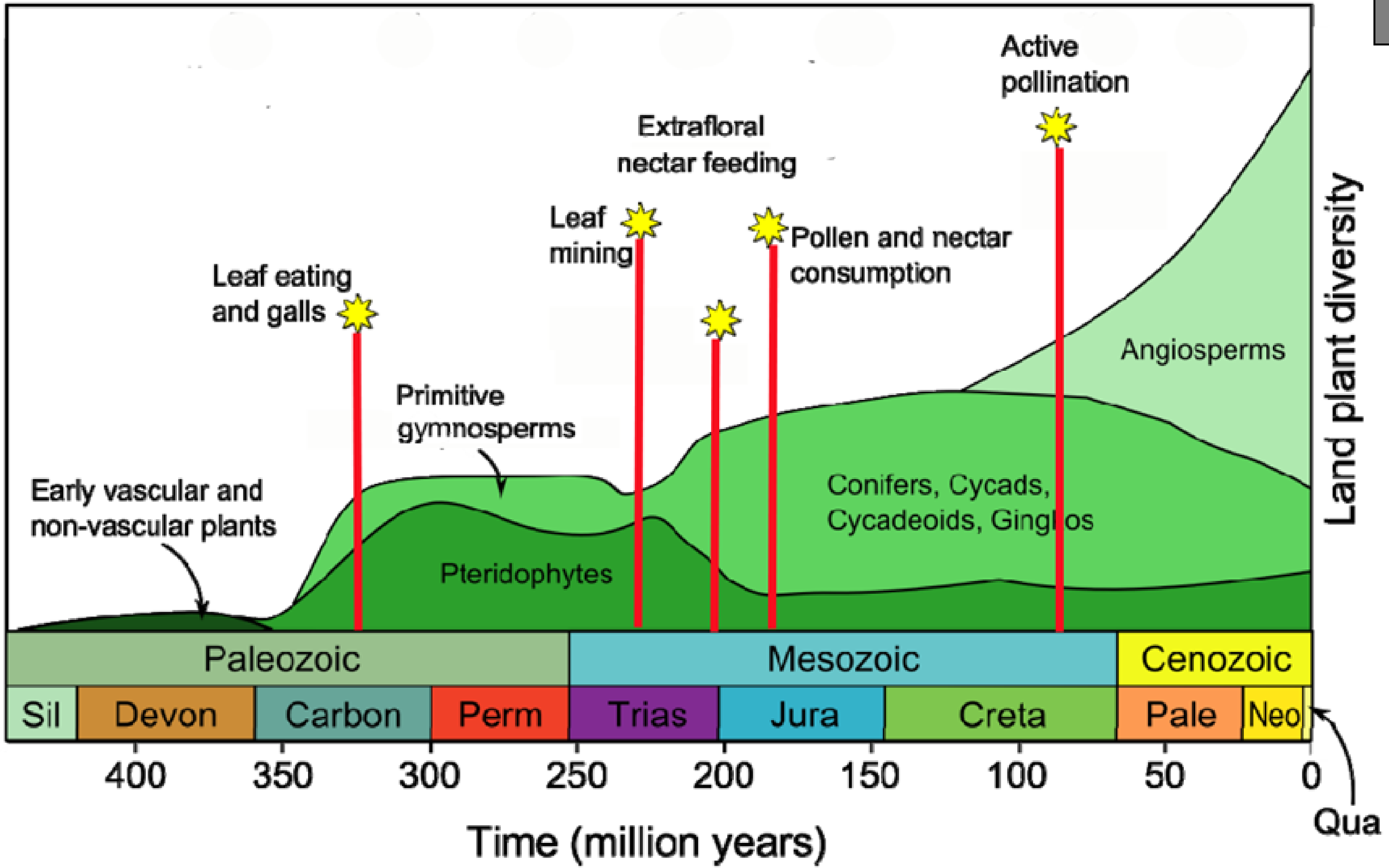
• **Parasitoids**: one parasitoid kills one individual


insect parasitoids Hymenoptera…

Why is the world green?

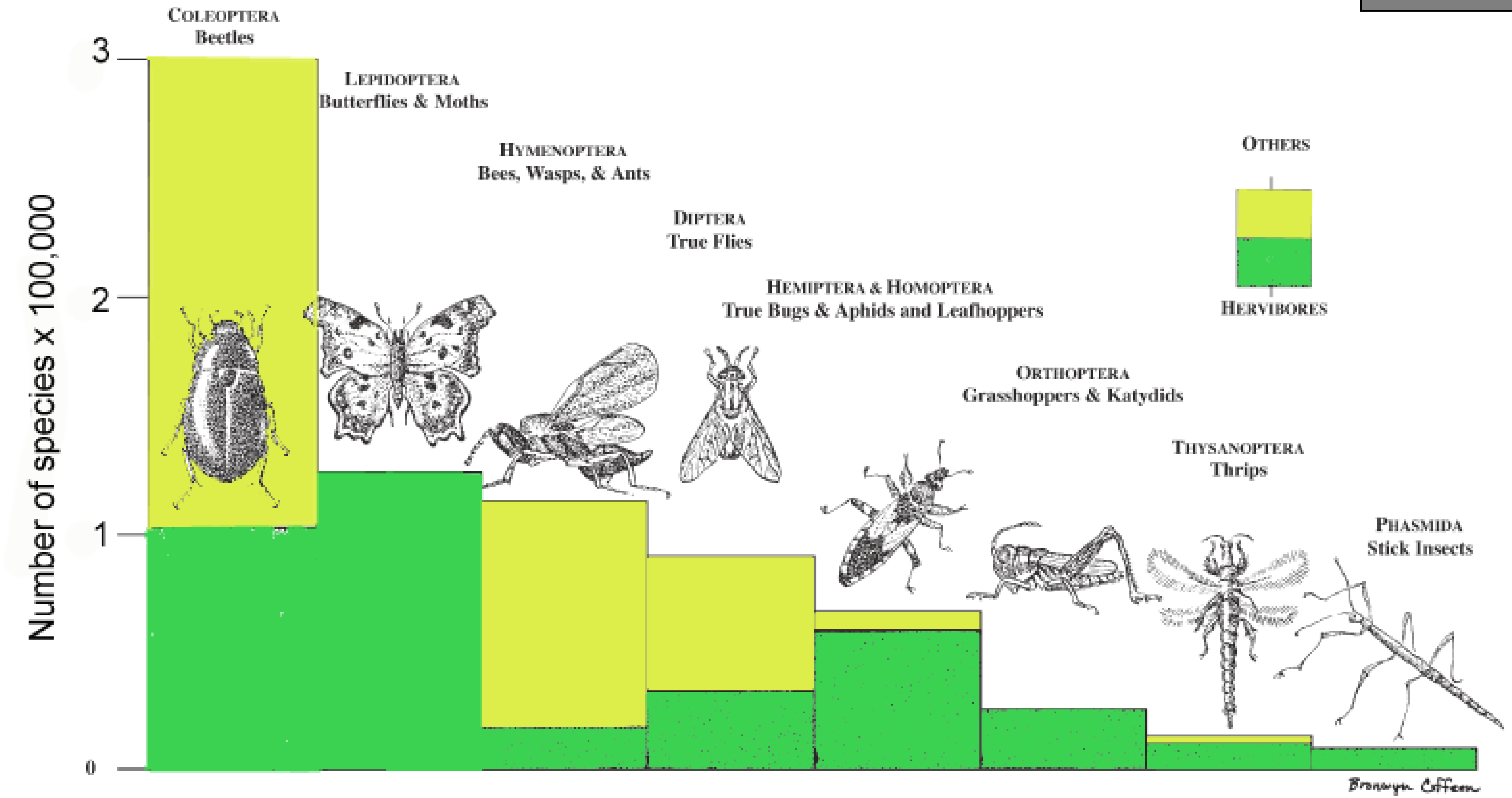
Herbivores are controlled by
- their enemies (top-down control): “world is green”
- their plant resources (bottom-up control): “world is green but the greens taste awful”

Herbivory is rather old…

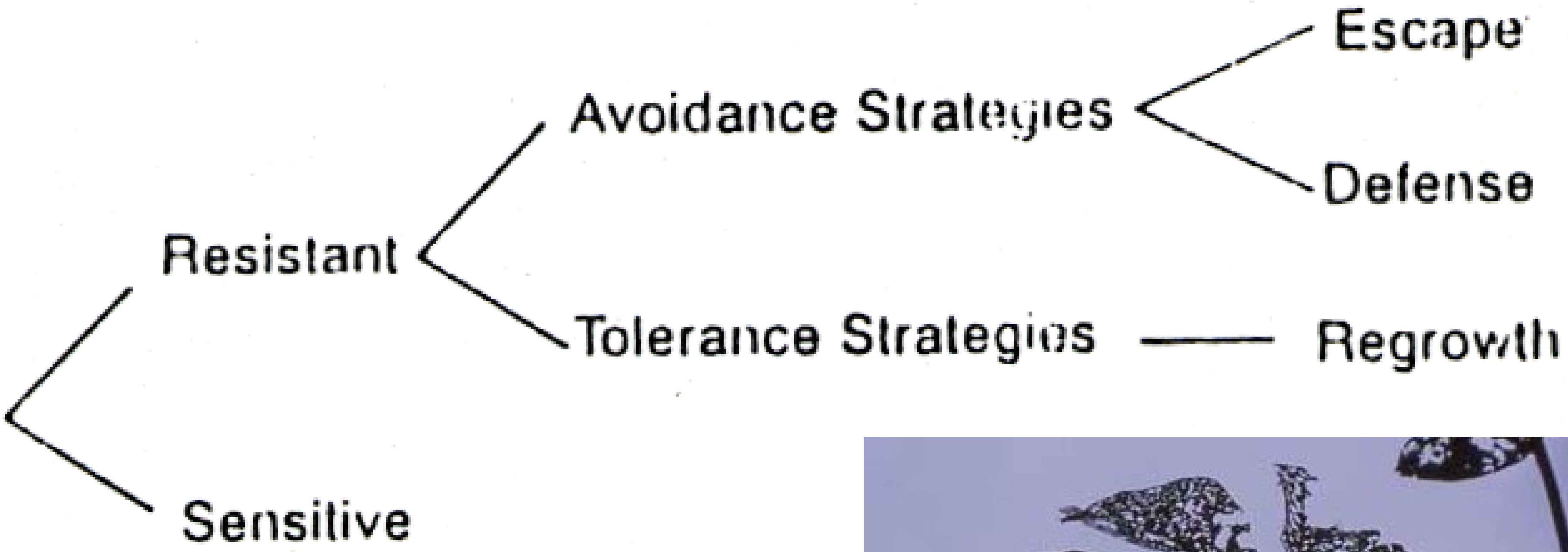


Furstenberg-Hagg et al. Int. J. Mol. Sci. **2013**, *14*, 10242

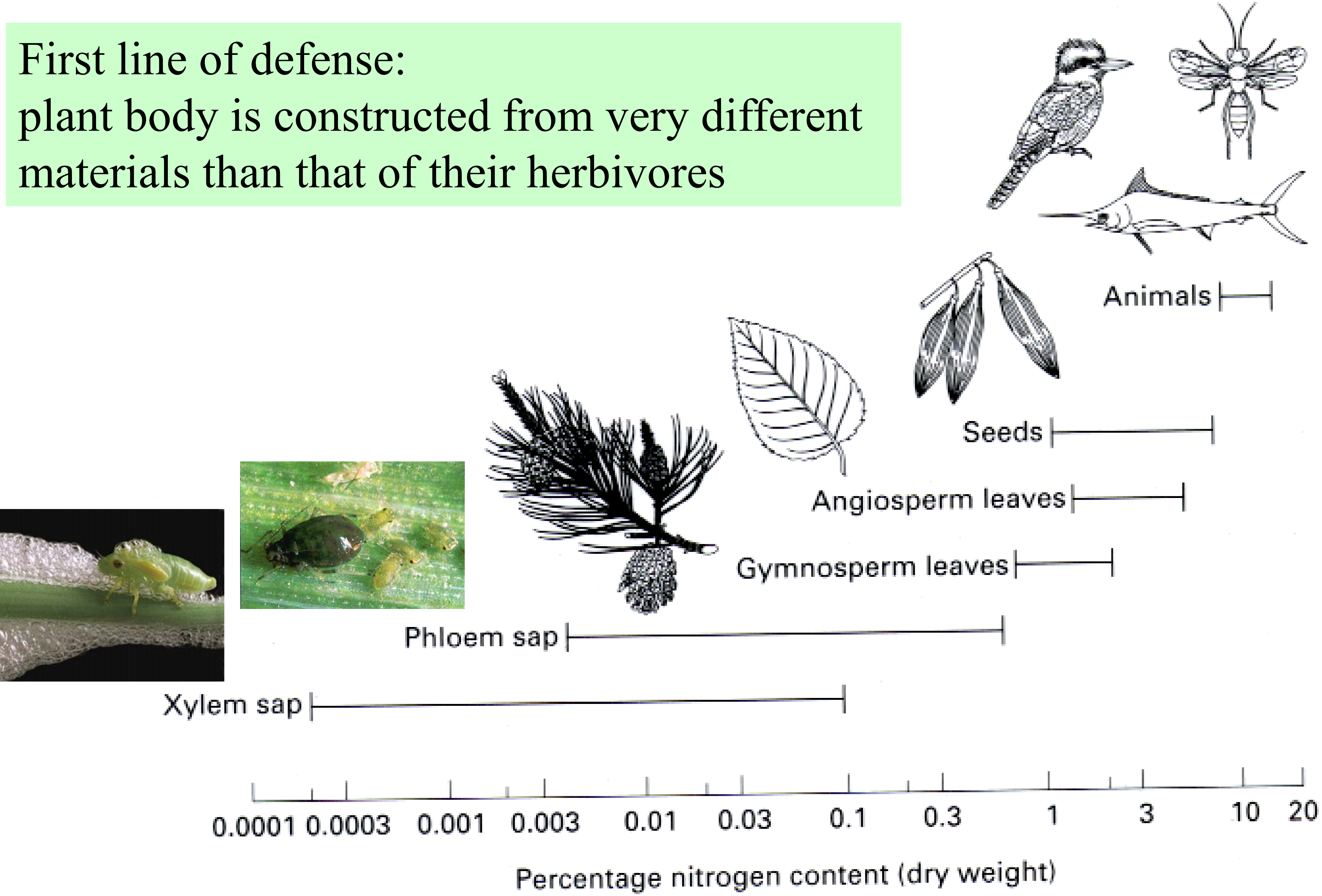
Insects herbivores: the most species-rich herbivore group
(although recent DNA barcoding may boost parasitoid Hymenoptera and sarcophagous Diptera numbers)



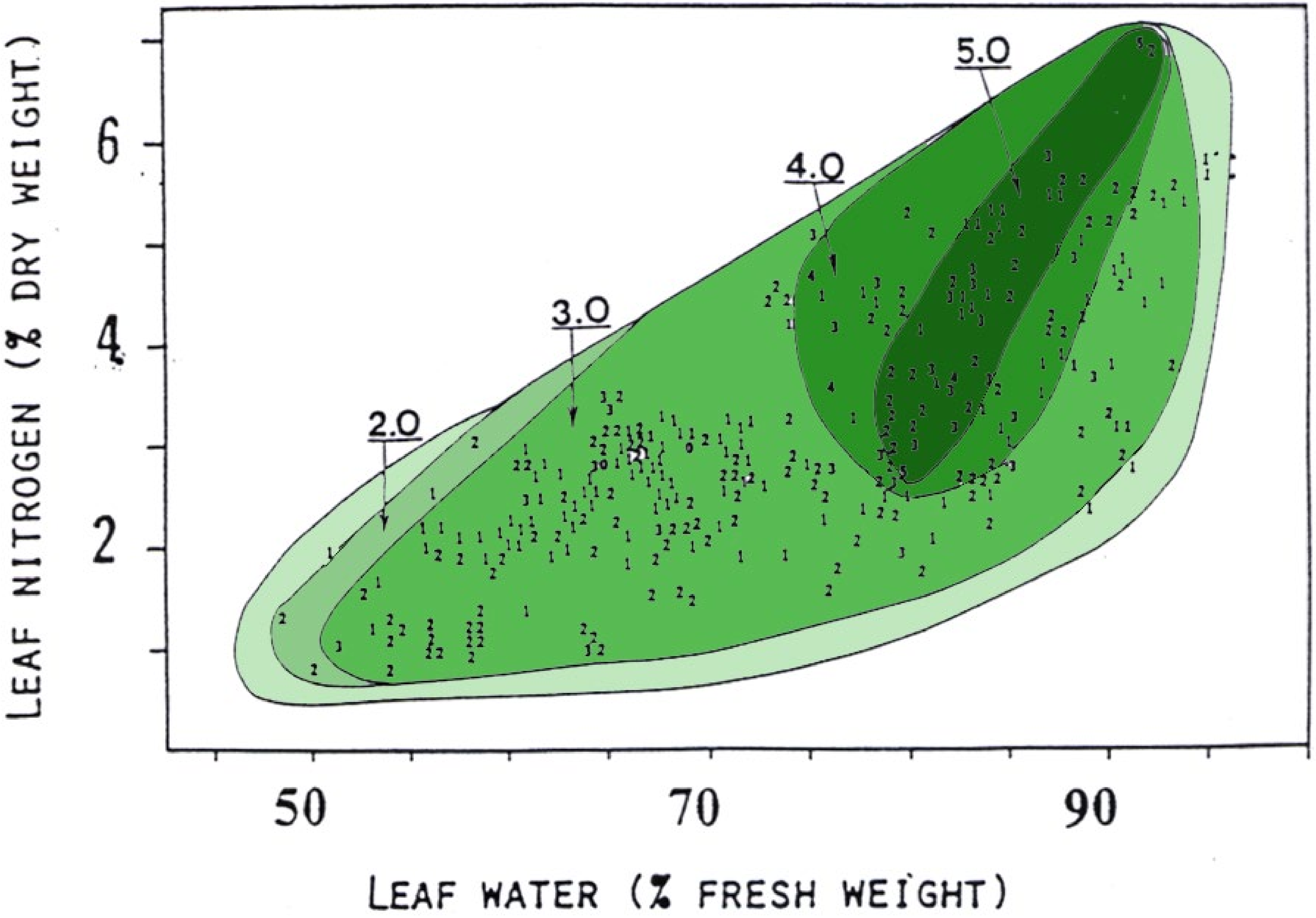
Plant defense strategies



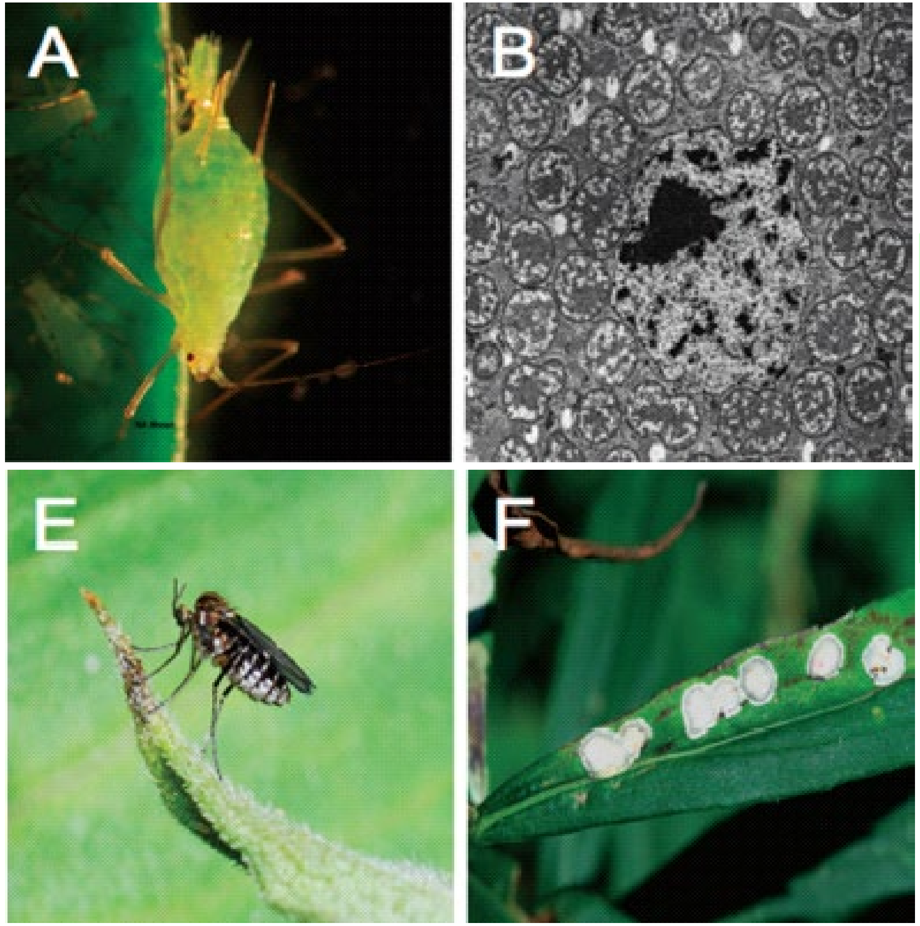
First line of defense:
plant body is constructed from very different materials than that of their herbivores



Relative consumption rate of caterpillars vs. leaf water & nitrogen



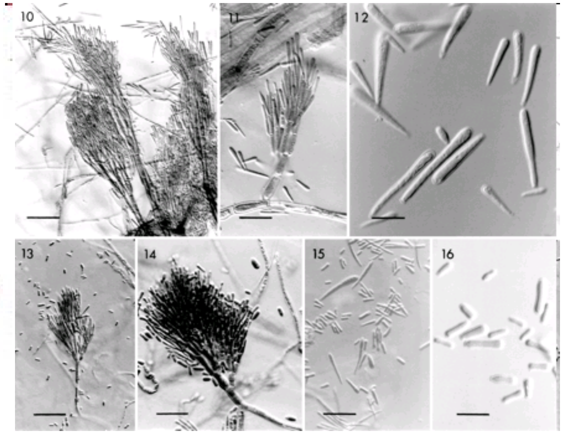
Aphid *Acyrtosiphon pisum* and bacterium *Buchnera aphidicola* from its mycetocyte



Cecidomyid fly *Asteromyia carbonifera* and galls with *Bostryosphaeria* fungus

Poor quality of plants leads to various mutualisms with fungi, bacteria and protozoans, helping herbivores to digest plant matter

Termites and a protozoan *Trichonympha flagellate* from their guts, decomposing cellulose



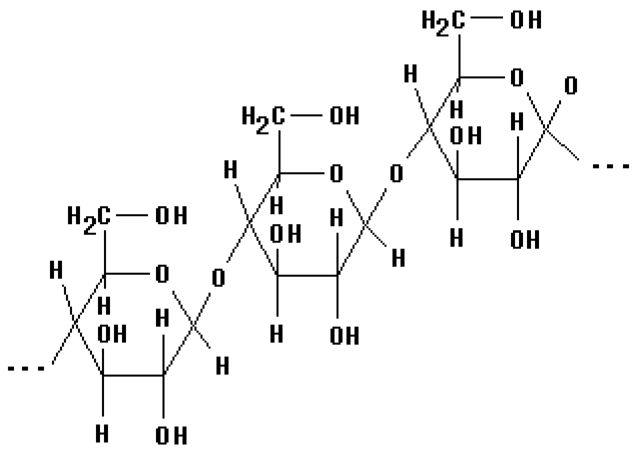
Ambrosia beetles and *Ophiostoma clavigerum*, one of fungi from their galleries

Janson et al. 2008, Evolution 62:997

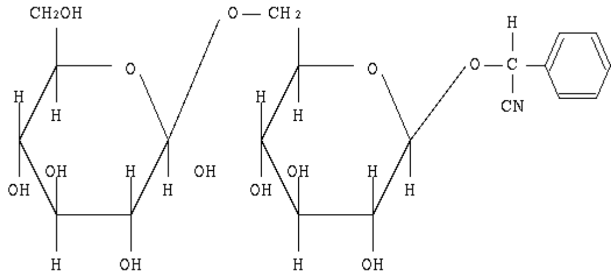
Chemical defense compounds:

quantitative vs. qualitative

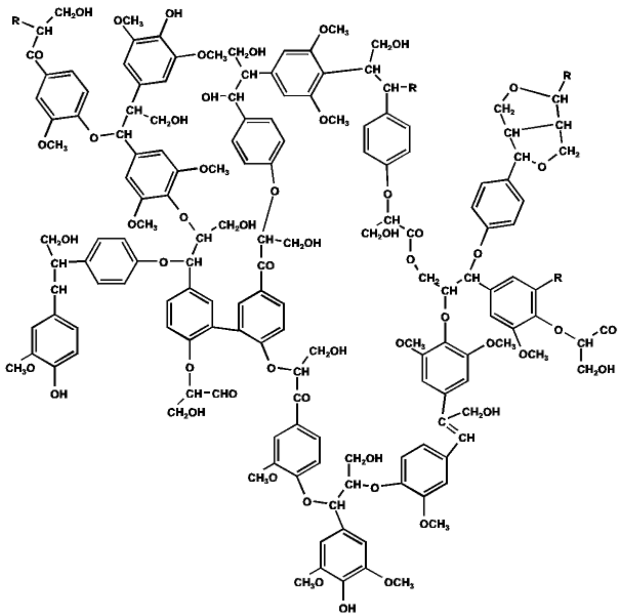
cellulose



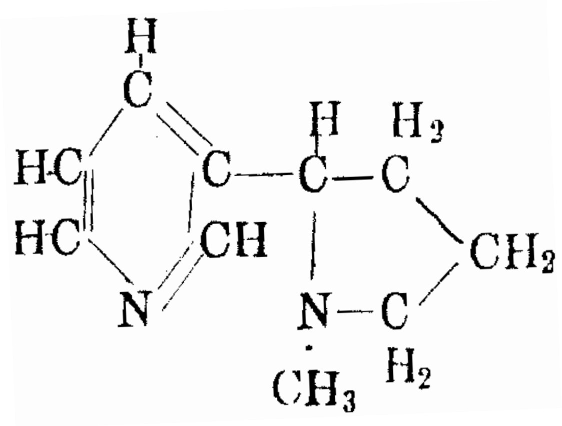
amygdalin
(cyanogenic glycosides)



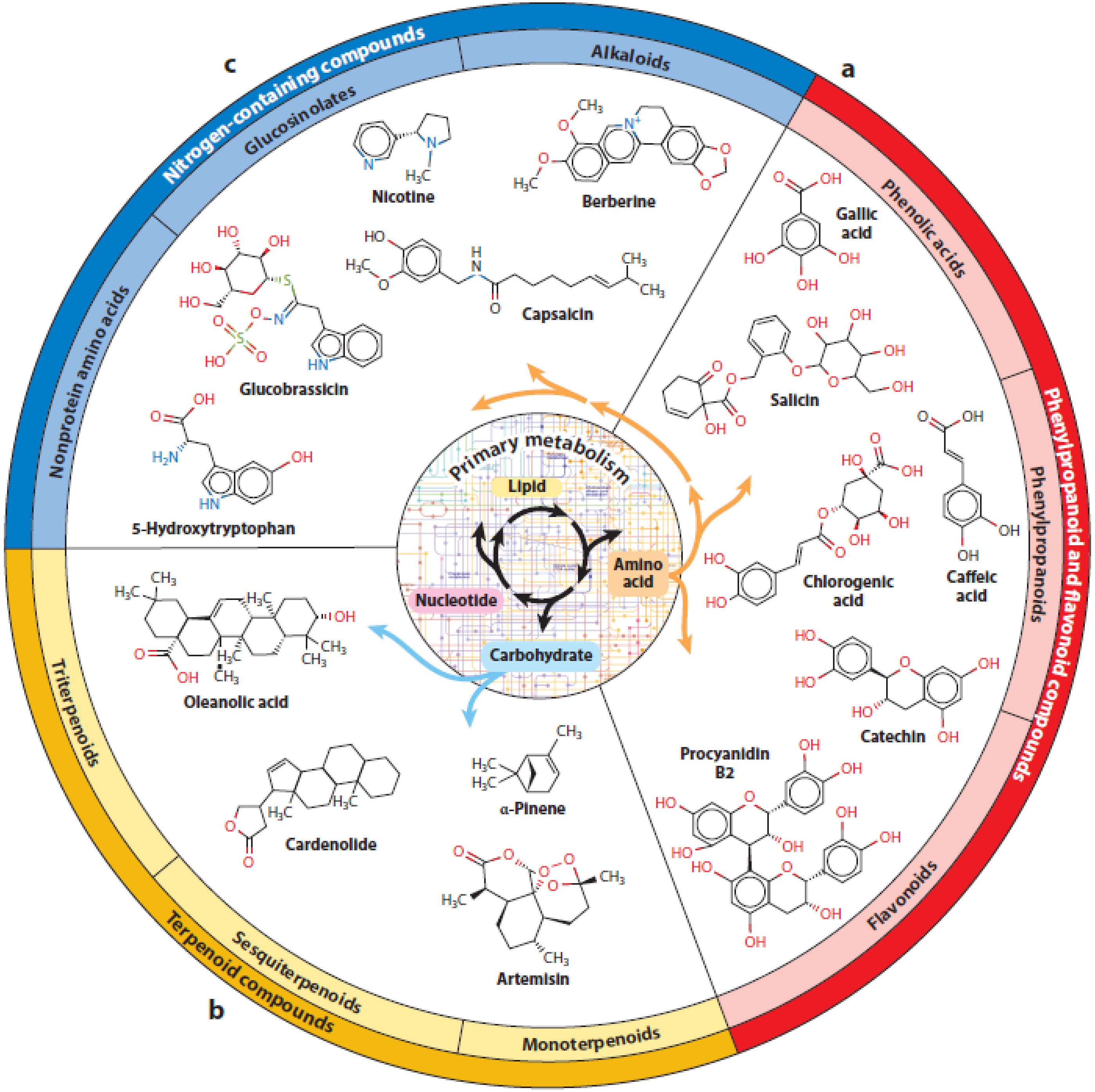
lignin



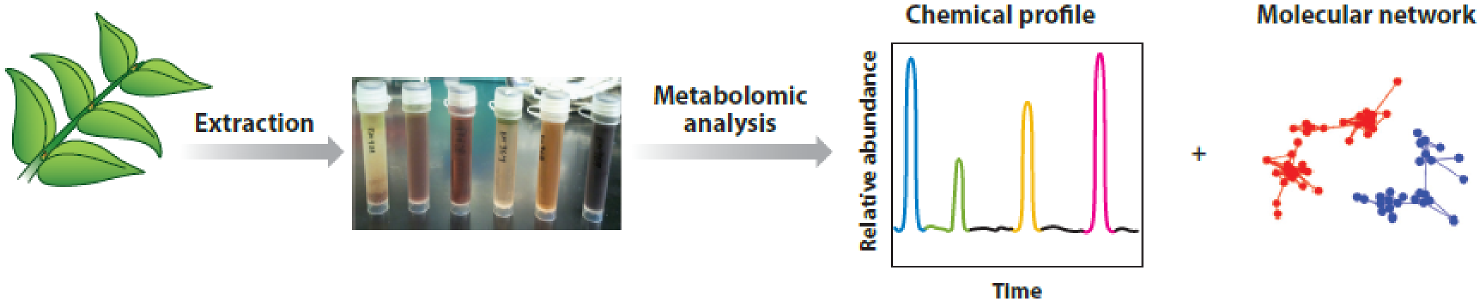
nicotine
(alkaloids)



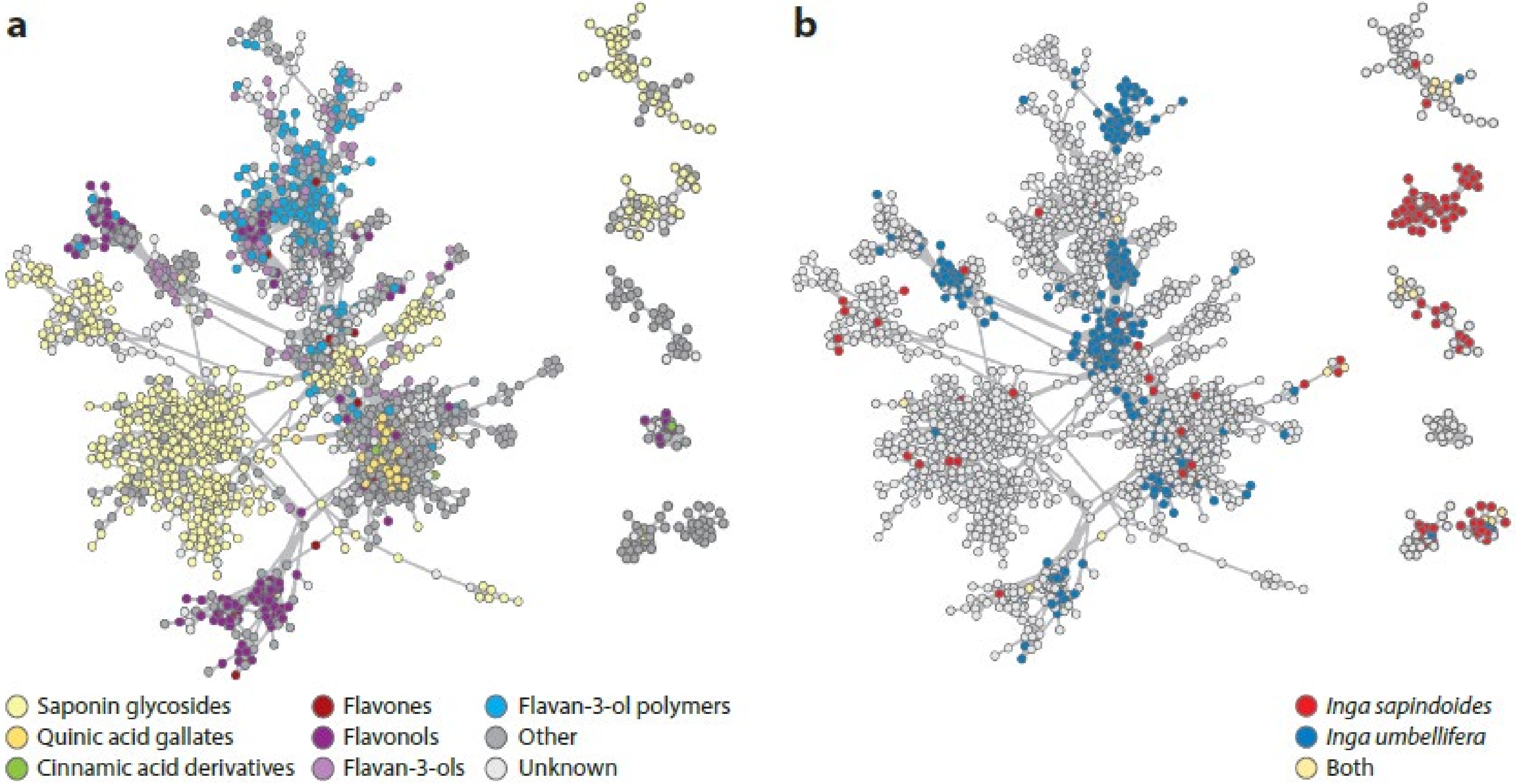
Principal small-molecule secondary metabolites in plants



Endara et al Annu. Rev. Ecol. Evol. Syst. 2023. 54:107–27

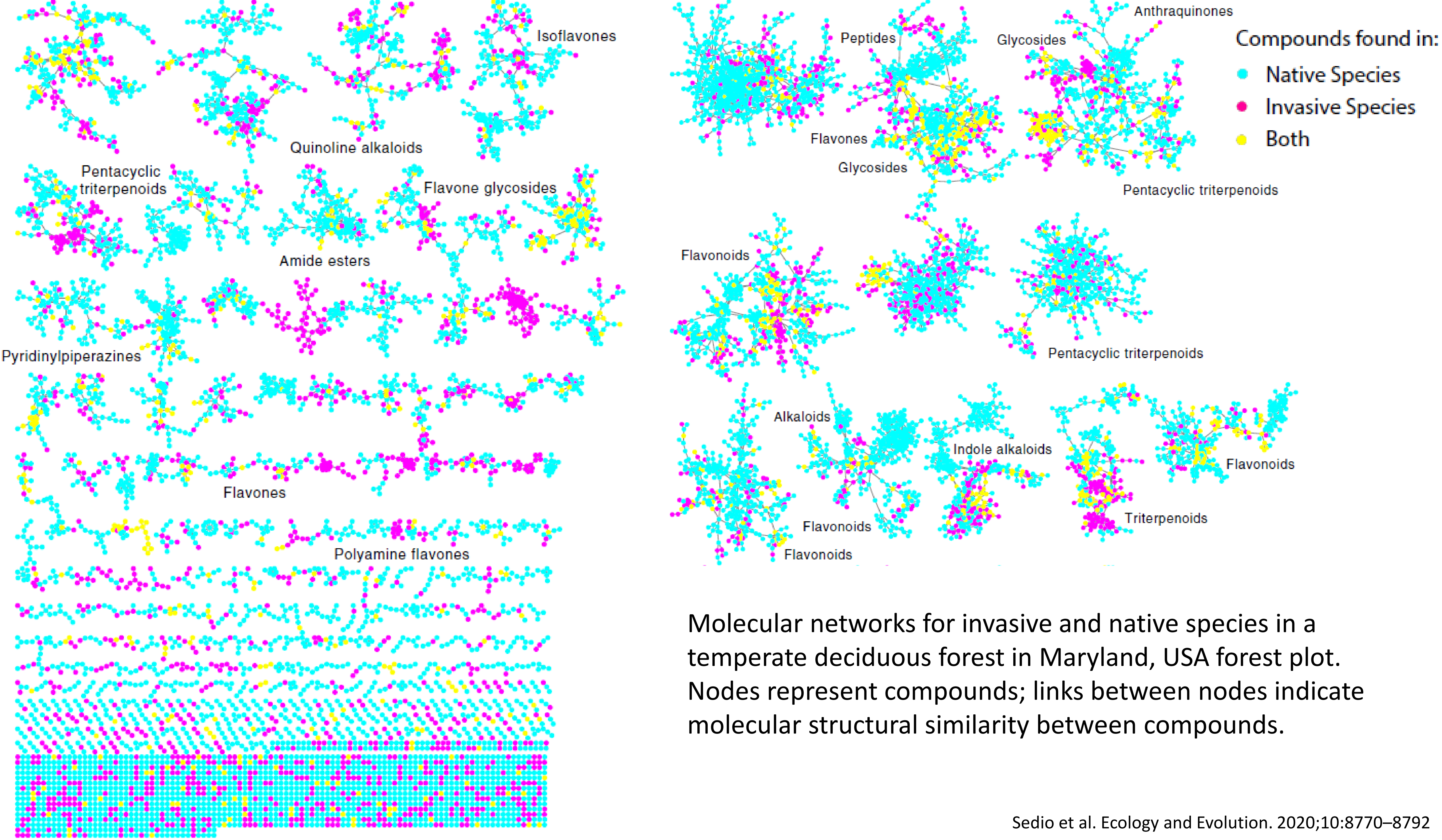


Molecular networks of metabolites



98 tropical species of Inga (Fabaceae).

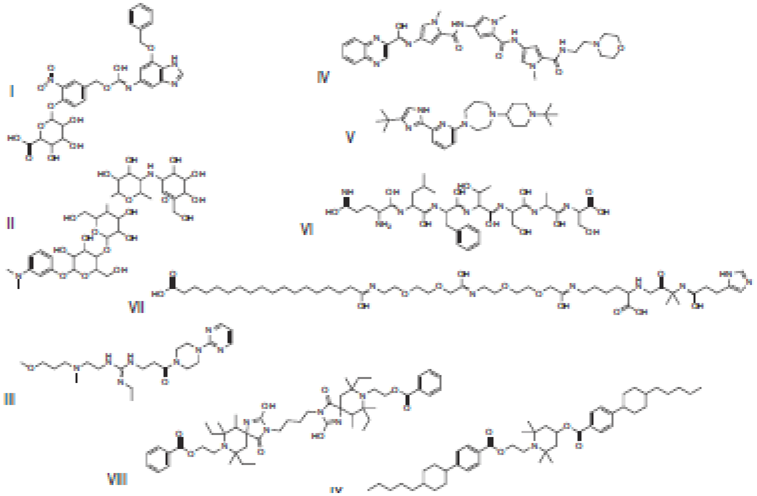
Endara et al Annu. Rev. Ecol. Evol. Syst. 2023. 54:107–27



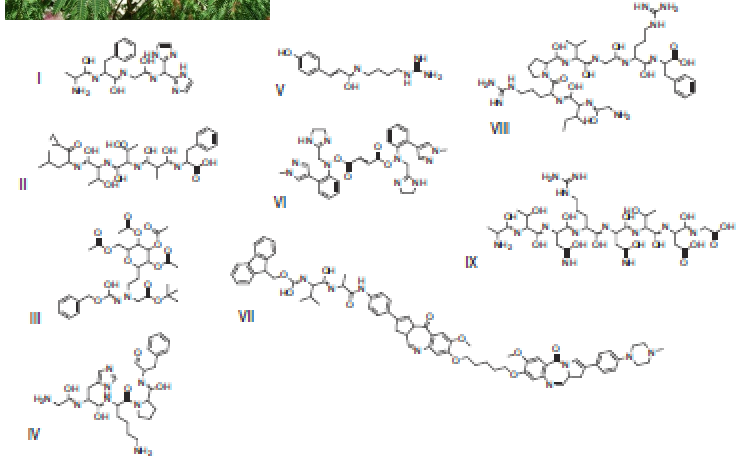
Molecular networks for invasive and native species in a temperate deciduous forest in Maryland, USA forest plot. Nodes represent compounds; links between nodes indicate molecular structural similarity between compounds.

Sedio et al. Ecology and Evolution. 2020;10:8770–8792

AILANTHUS ALTISSIMA

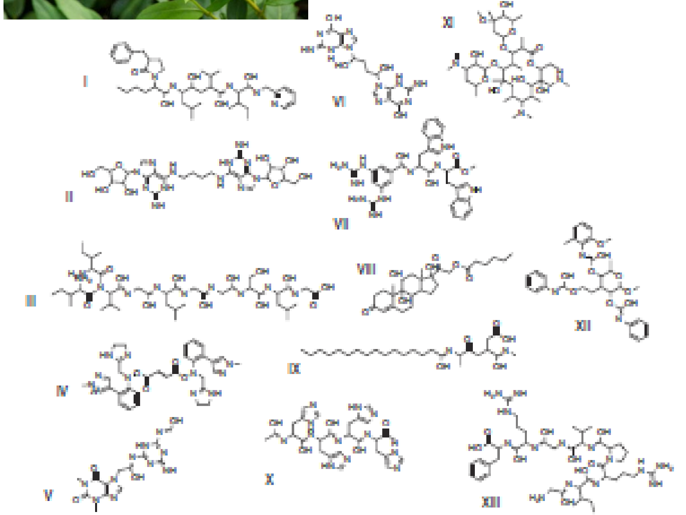


ALBIZIA JULIBRISSIN

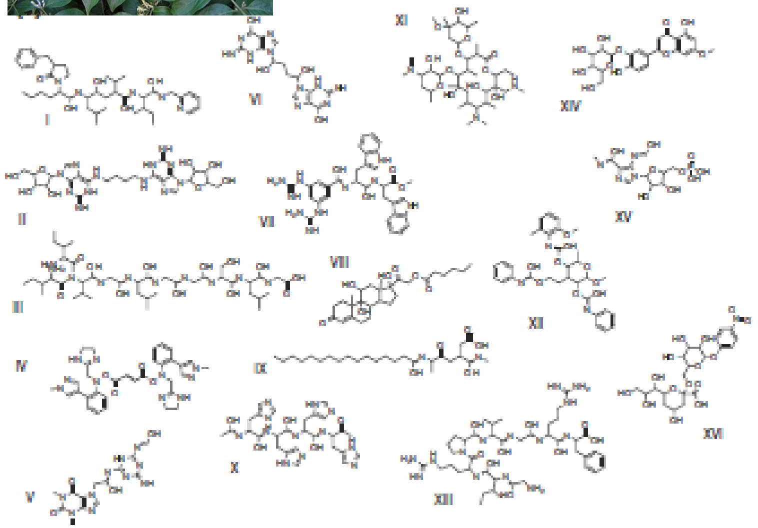


The most abundant compounds unique to each invasive species

LONICERA JAPONICA

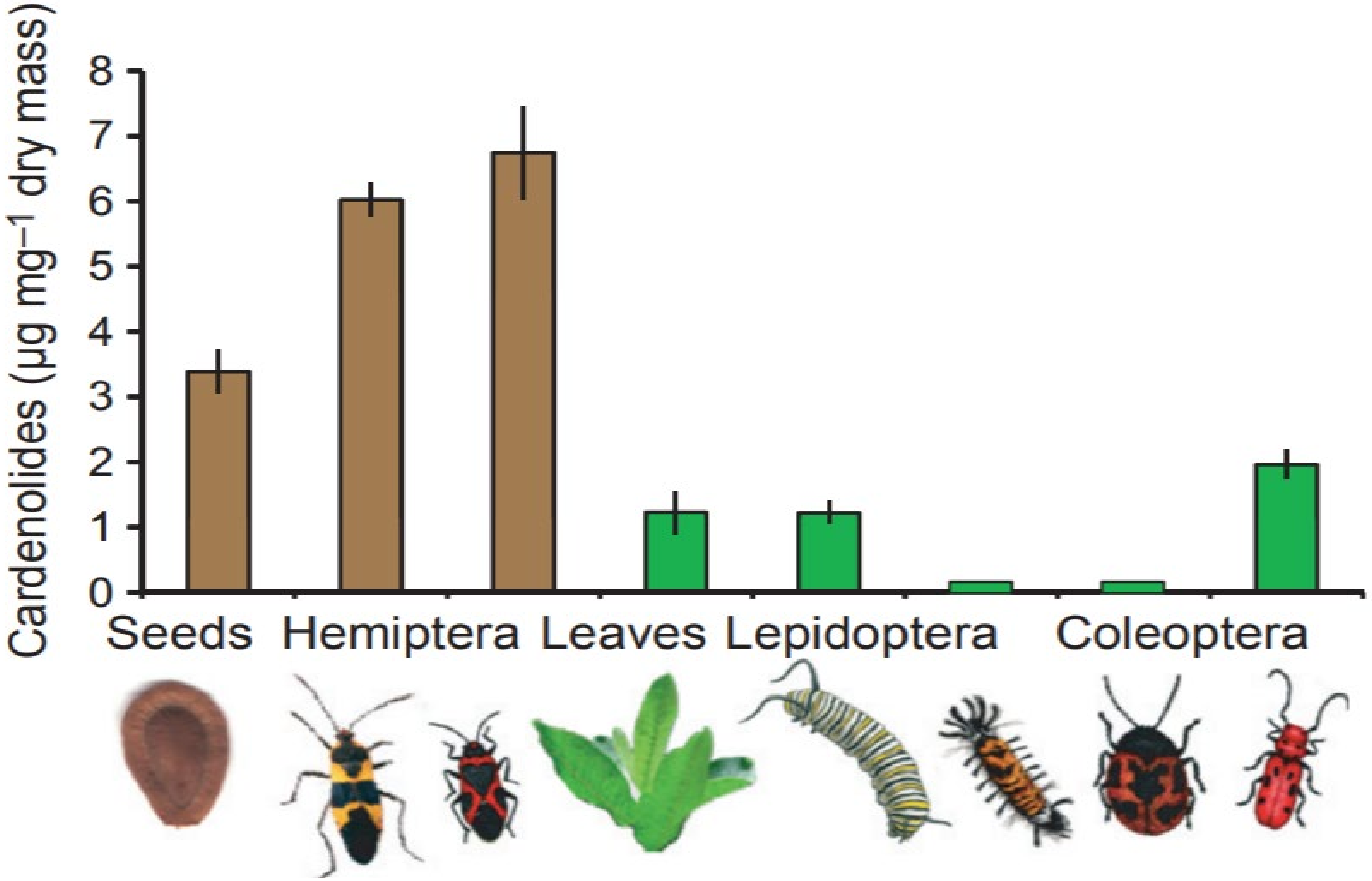


LONICERA MAACKII

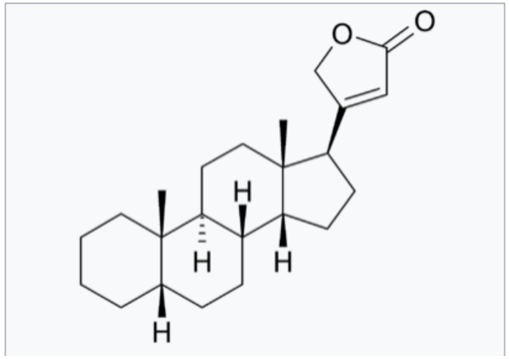


Sedio et al. Ecology and Evolution. 2020;10:8770–8792

Cardenolide sequestration in *Asclepias* herbivores



Cardenolide



Tetraopes tetraophthalmus

Labidomera clivicollis

Euchaetes egle

Danaus plexippus

Lygaeus kalmii

Oncopeltus fasciatus

Agrawal et al. New Phytologist (2012) 194: 28

Ecological correlates of qualitative x quantitative mode of defense

	quantitative	qualitative
Examples	cellulose hemicellulose lignins tannins silica	alkaloids toxic amino acids cyanogens glucosinolates terpenoids
Ecological traits	large polymer molecules immobile costly to produce effective in large doses present in long-lived tissues present in apparent plants effective against most herbivores	small toxic molecules mobile cheap to produce effective in small doses present in growing tissues present in unapparent plants effective against generalists

Cecropia plants - *Azteca* ants, America; plants produce glykogen rich muellerian bodies

Endospermum plants - *Camponotus* ants, New Guinea

Macaranga plants - *Crematogaster* ants, South East Asia

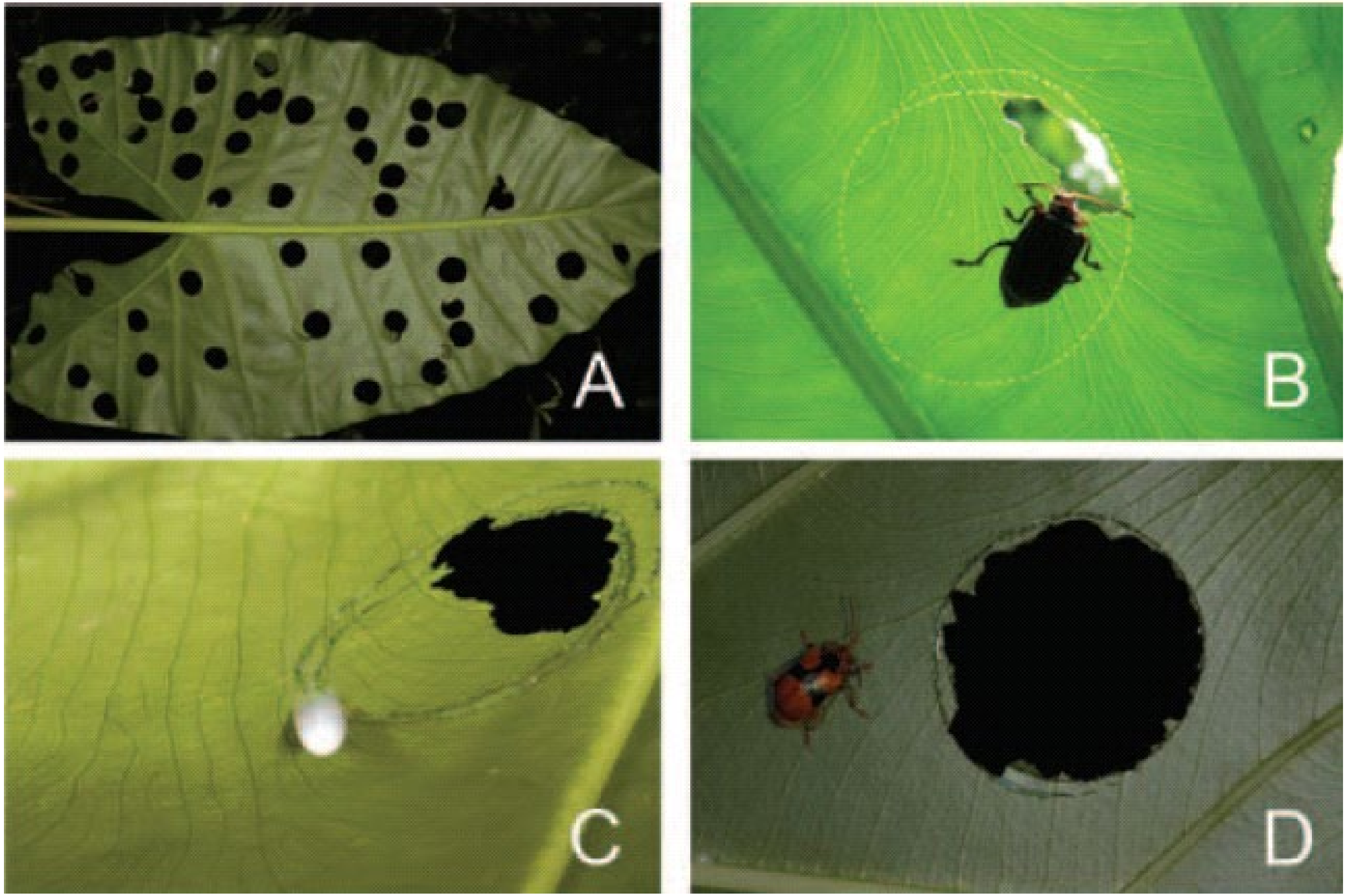
Mutualistic ants: biological defense

Thorns – mechanical defense

Latex – mechanical and/or toxic defense

How to circumvent latex defence: leaf trenching

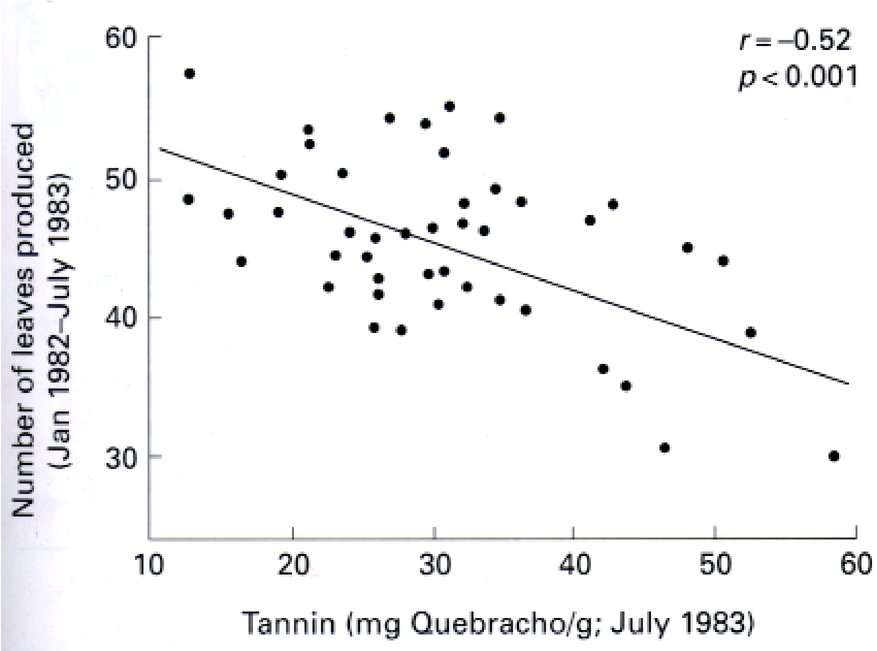
Trenching of aroid leaves [*Alocasia*, *Colocasia*] by chrysomelid beetle [*Aplosonyx ancora*]



Darling, 2007. Biotropica 39: 555–558

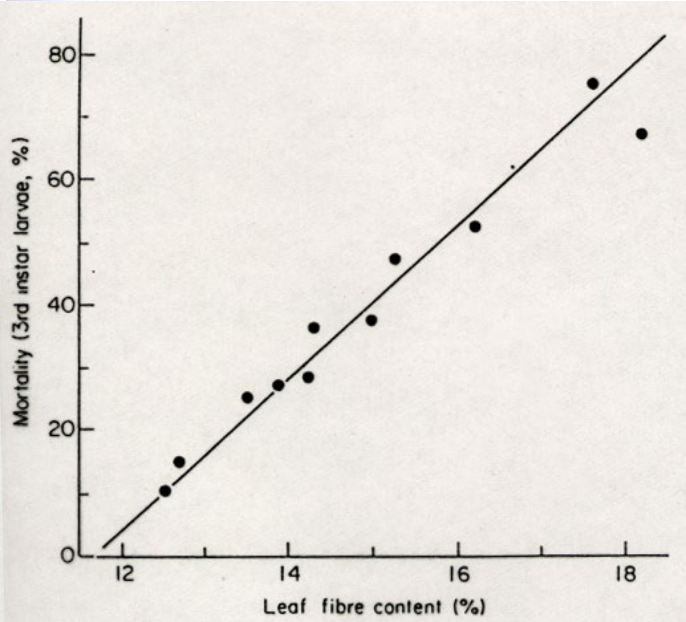
FIGURE 1. Circular trenching of aroid leaves (Araceae) by *Aplosonyx ancora* (Chrysomelidae). (A) Heavily damage leaf of *Alocasia navicularis.* (B) Leaf of *Colocasia gigantea* with circular trenches. (C) Latex exuding from partly eaten trenched leaf of *Colocasia gigantea*. (D) Beetle and almost completely consumed hole on *Colocasia gigantea*. (E) Beetle and feeding damage on heavily attacked leaf of *Alocasia navicularis.* (A, E) Cuc Phuong National Park; (C, D) Ba Be National Park; (B) Bach Ma

Production of secondary metabolites is costly…



Cecropia

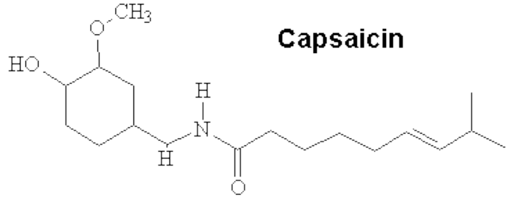
… but it works (sometimes)



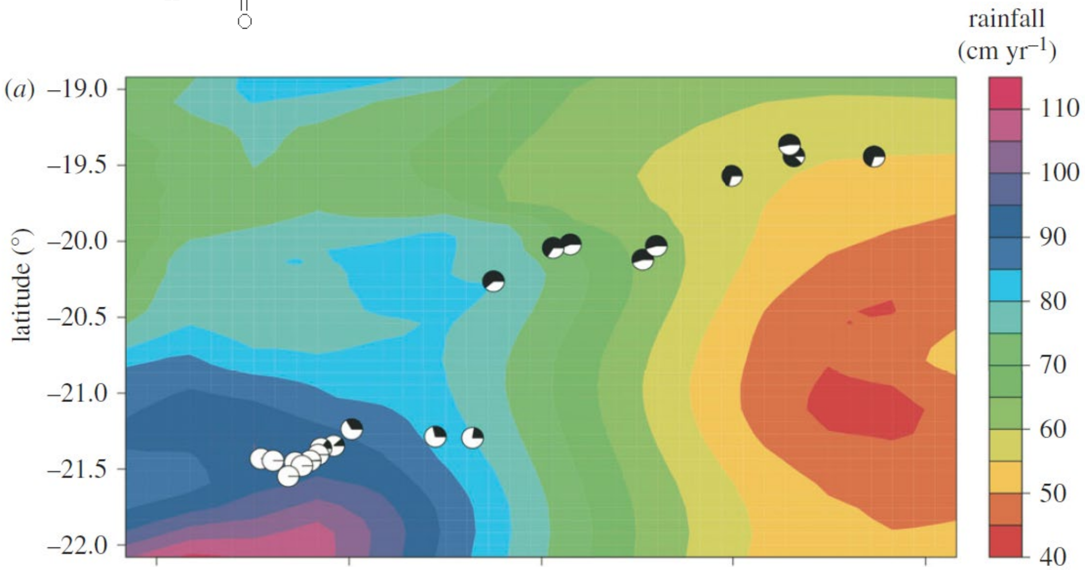
Operophtera brumata

Fig. 3.17 Relationship between tannin concentration in the foliage of *Cecropia* and the number of leaves produced per plant. Investment in tannin appears to occur at the expense of leaf production, and may represent the cost of defence. (From Coley 1986, with permission from Springer-Verlag New York,

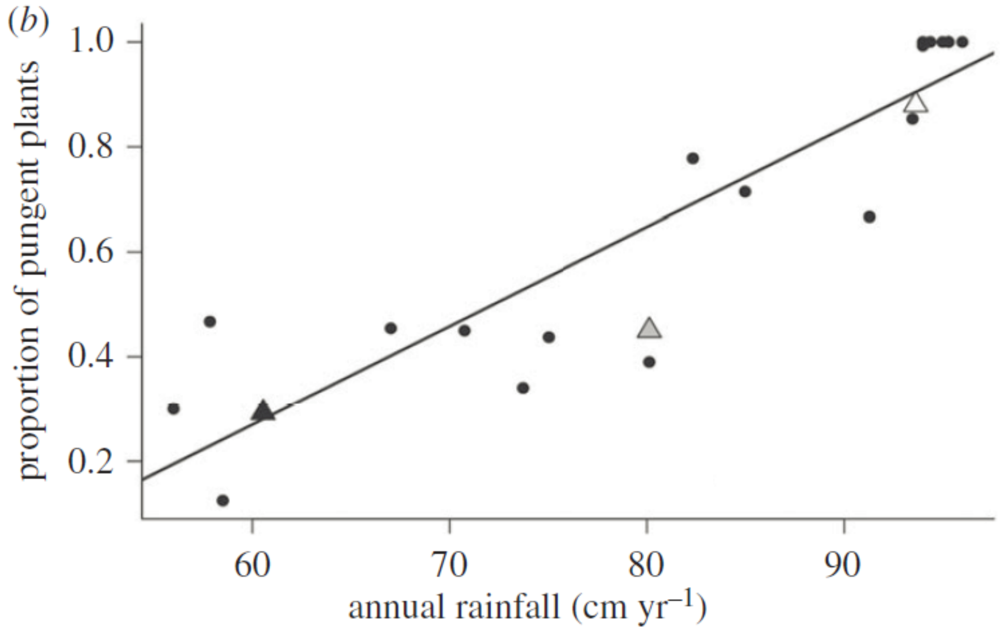
Why are not all chilies hot?

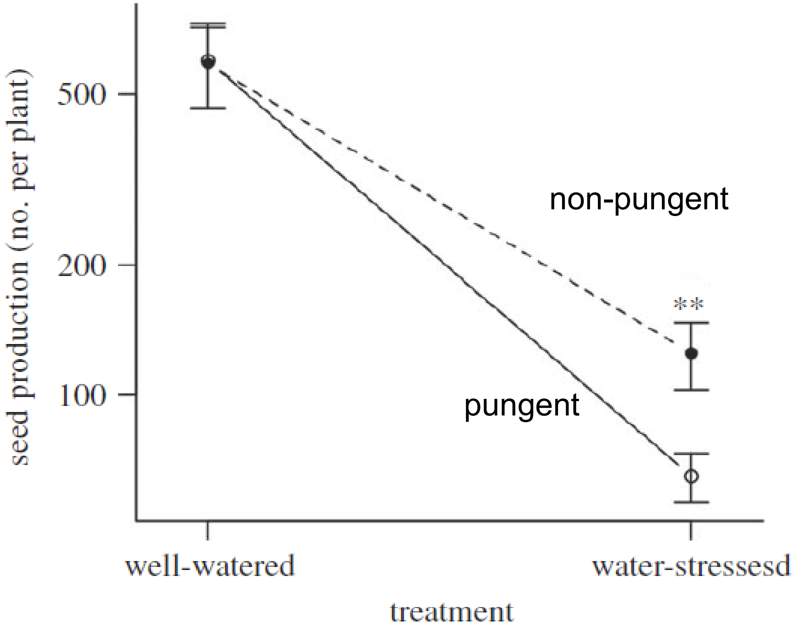


Capsicum chacoense



Area in Bolivia with proportion of pungent (white) and non-pungent (black) chilies





Production of capsaicinoids is costly in dry environment where its costs are apparently higher than benefits from protection against herbivory

Haak et al. Proc. R. Soc. B (2012) 279, 2012–2017

Three plant strategies:

• high investment in growth and low in defense in resource-rich environment

-- apparent plants: tolerance to herbivory

-- unapparent plants: escape from herbivory in time or space

• low investment in growth and high in defense in resource-poor environment

Apparent vs. unapparent plants

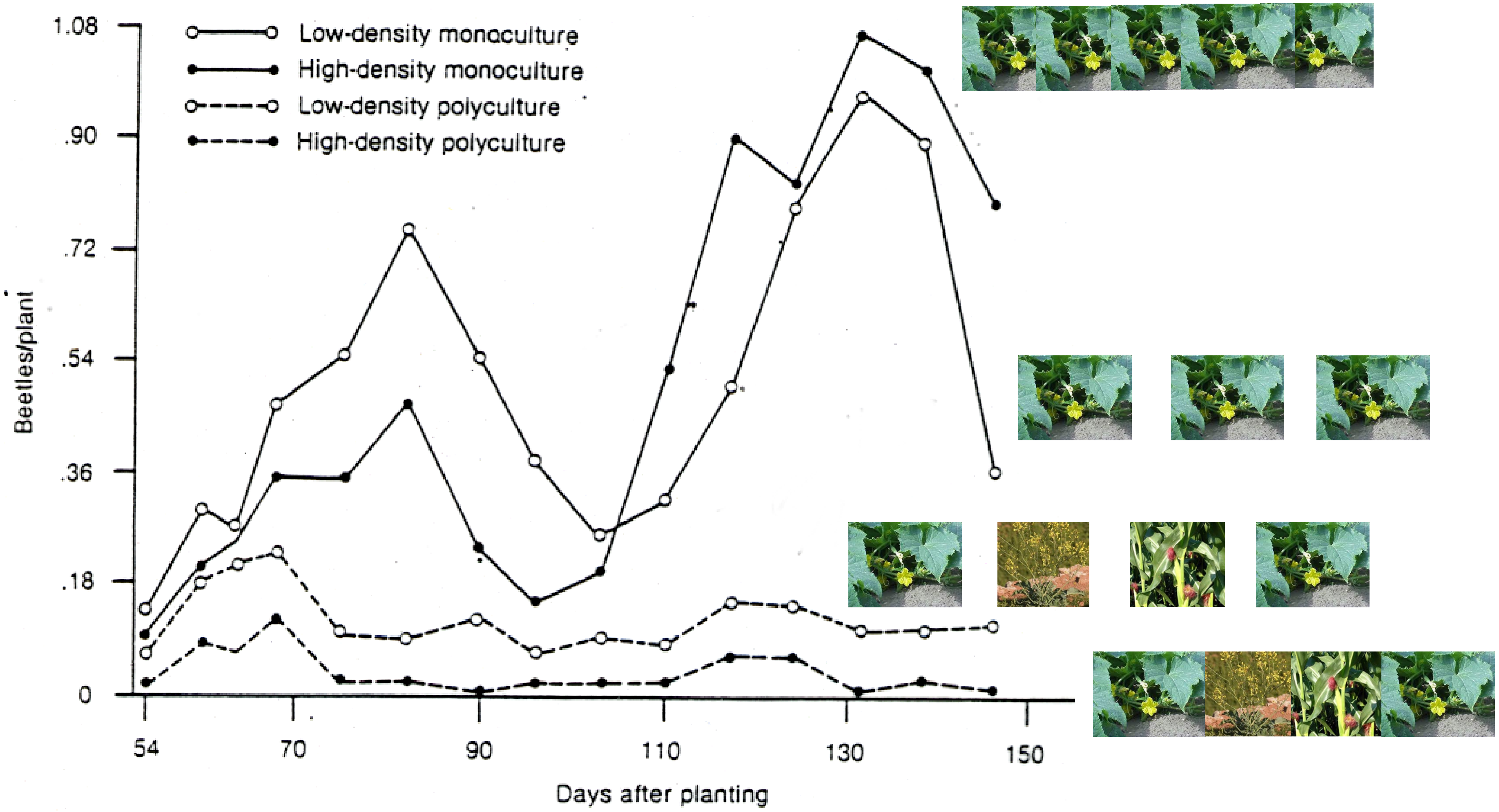
Juncus bufonius

Coleanthus subtilis

Phragmites communis

Carex bohemica

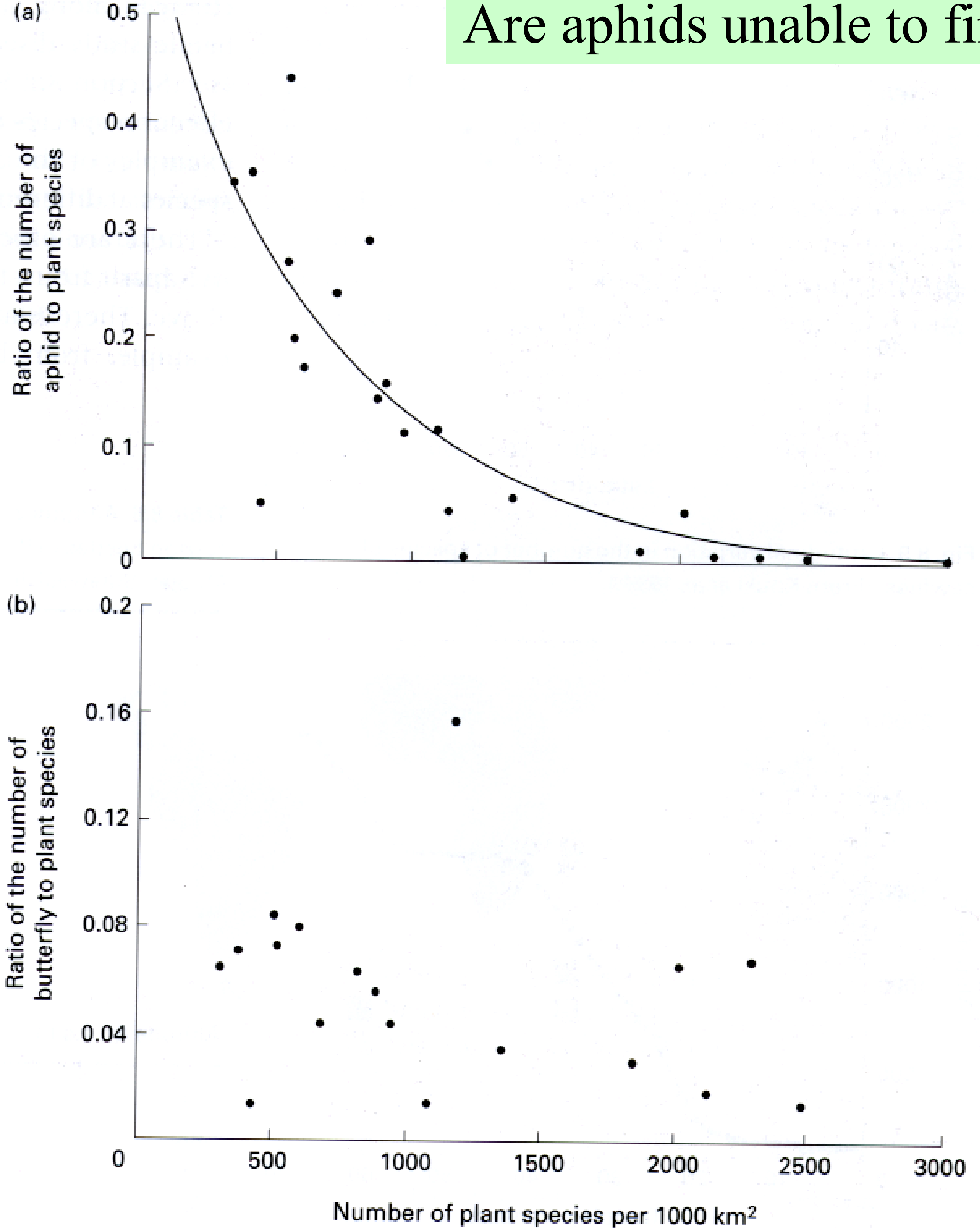
Finding a rare host plant: difficult in diverse vegetation



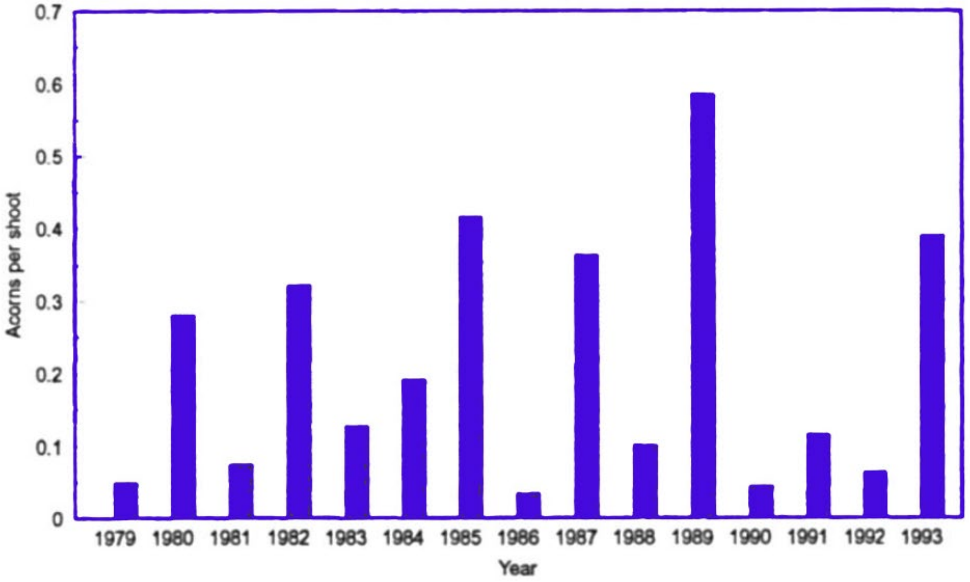
Acalymna vittate on cucumber plants

Fig. 10-7 Mean number of striped cucumber beetles *(Acalymma vittata)* on cucumber plants *(Cucumis sativus)* in garden plots in monocultures, or in polycultures planted with corn *(Zea mays)* and broccoli *(Brassica oleracea)*. Density of cucumber plants (289 or 144/100 m^2), by itself, has little influence on beetle density. (●——●) Monoculture high density; (○——○) monoculture low density; (● - - - ●) polyculture high density; (○ - - - ○) polyculture low density. After Bach (1980).

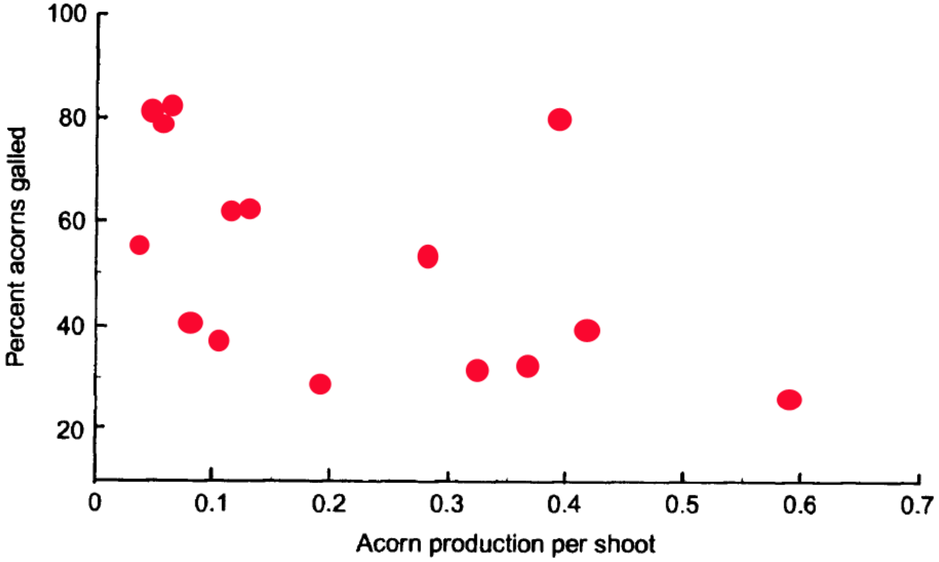
Are aphids unable to find their hosts in diverse vegetation?



Mass fruiting and seed predator saturation:
Quercus robur and cynipid wasp *Andricus quercuscalicis* in UK



Acorn production highly variable between years



% of galled acorns decreases with acorn production

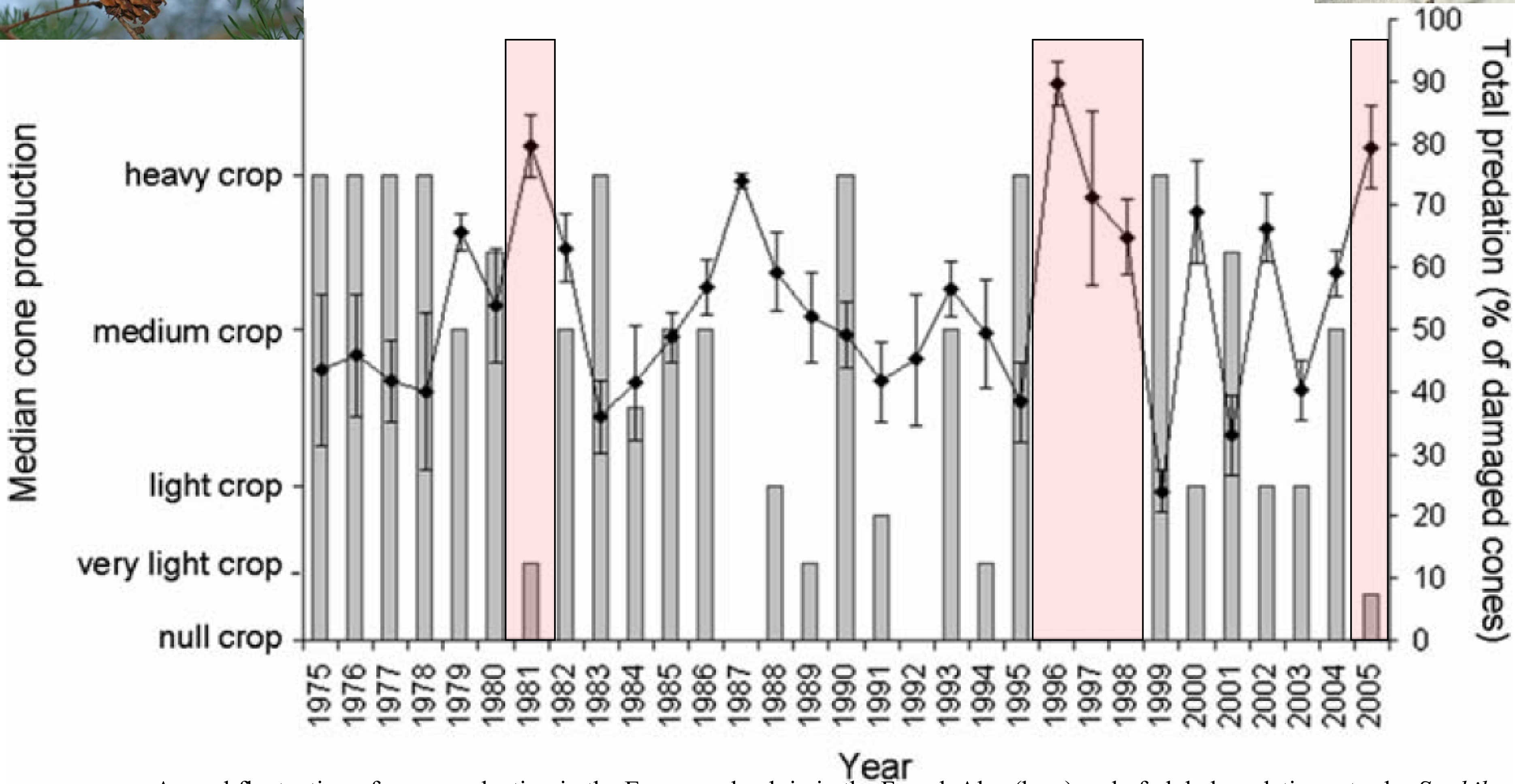
Andricus quercuscalicis

Crawley & Long Journal of Ecology 1995, 83, 683-696

Mass fruiting and seed predator saturation: *Larix* trees and *Strobilomyia* flies in the French Alps

Heavy crop = lower % predation

Strobilomyia



Annual fluctuation of cone production in the European larch in in the French Alps (bars) and of global predation rates by *Strobilomyia* species

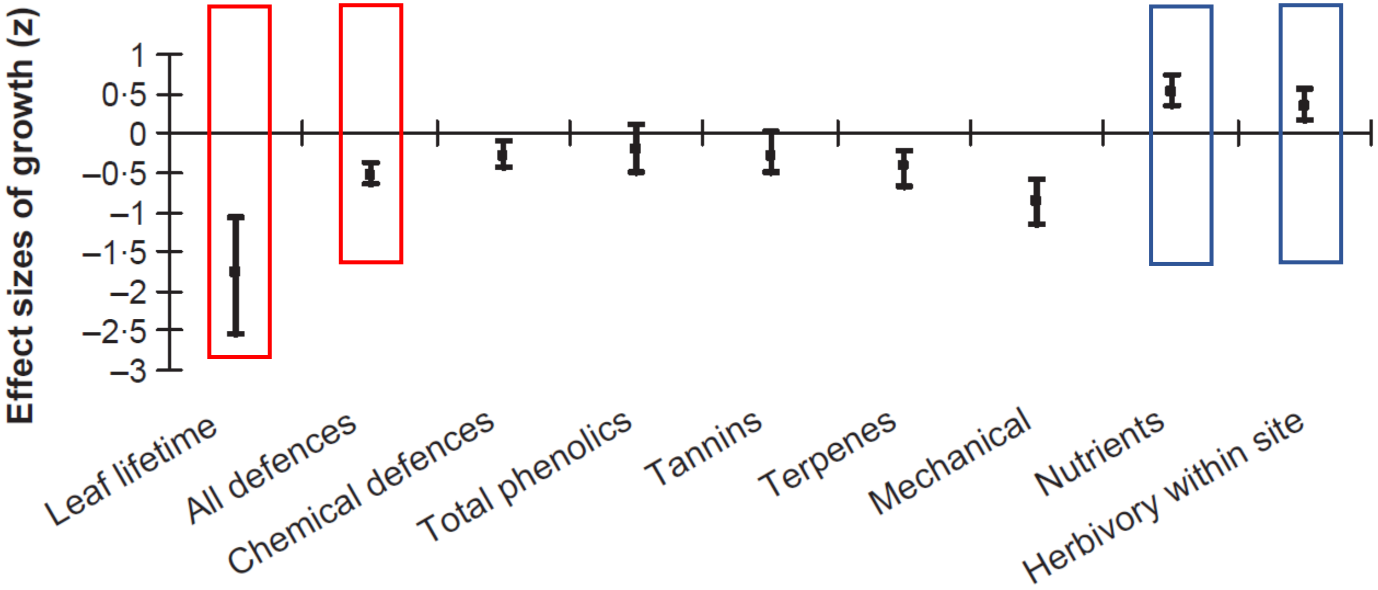
Poncet et al. Oecologia (2009) 159:527–537

Pioneer apparent plants: the main enemy is other plants; the herbivores are thus “ignored” (and tolerated)

Resource availability hypothesis

(i) species adapted to resource-rich environments have intrinsically faster growth rates than species adapted to resource poor environments
(ii) fast-growing species have shorter leaf lifetimes than slow-growing species
(iii) fast-growing species have lower amounts of constitutive defences than slow-growing species
(iv) fast-growing species support higher herbivory rates than slow-growing species

Meta-analysis of effects on plant growth rate [50 studies]



Endara & Coley 2011:
Functional Ecology, 25, 389

… although herbivory is still costly.

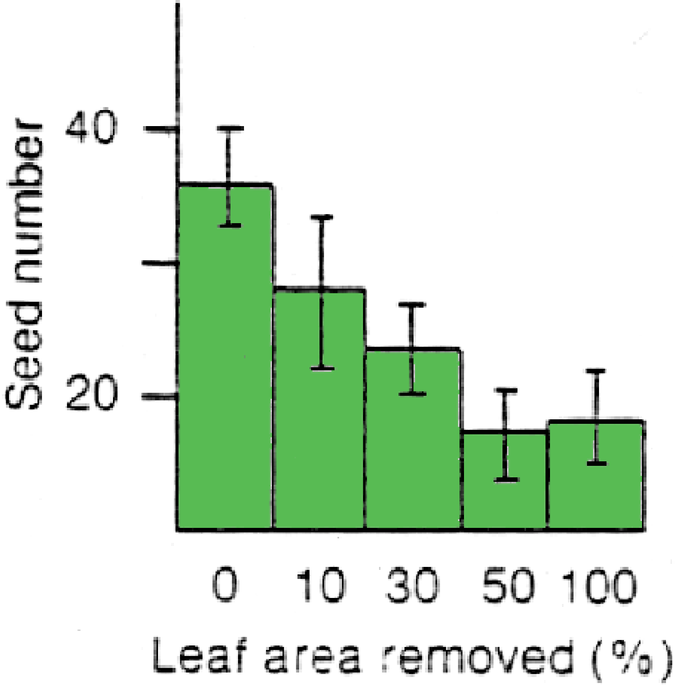
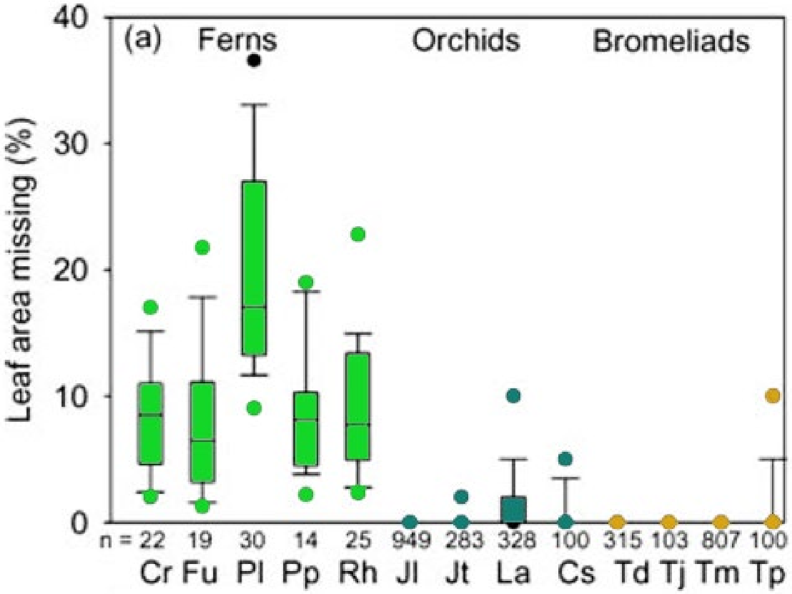


Fig. 4-2 Effects of leaf area removal from *Piper arieianum* shrubs on seed production 1 year (left) and 2 years (right) after a single defoliation in Costa Rica. Partial defoliation has lasting effects on both seed number and viability. This experiment simulates natural weevil (*Perdinetus* sp.; *Ambetes* sp.) herbivory. After Marquis (1984).

Epiphytic orchids & bromeliads: extremely well-defended plants in low-resource environment



Winkler et al. 2005

Leaf economics spectrum: one-dimensional trend in correlated traits

Herbivory

Leaf mass per area (LMA)

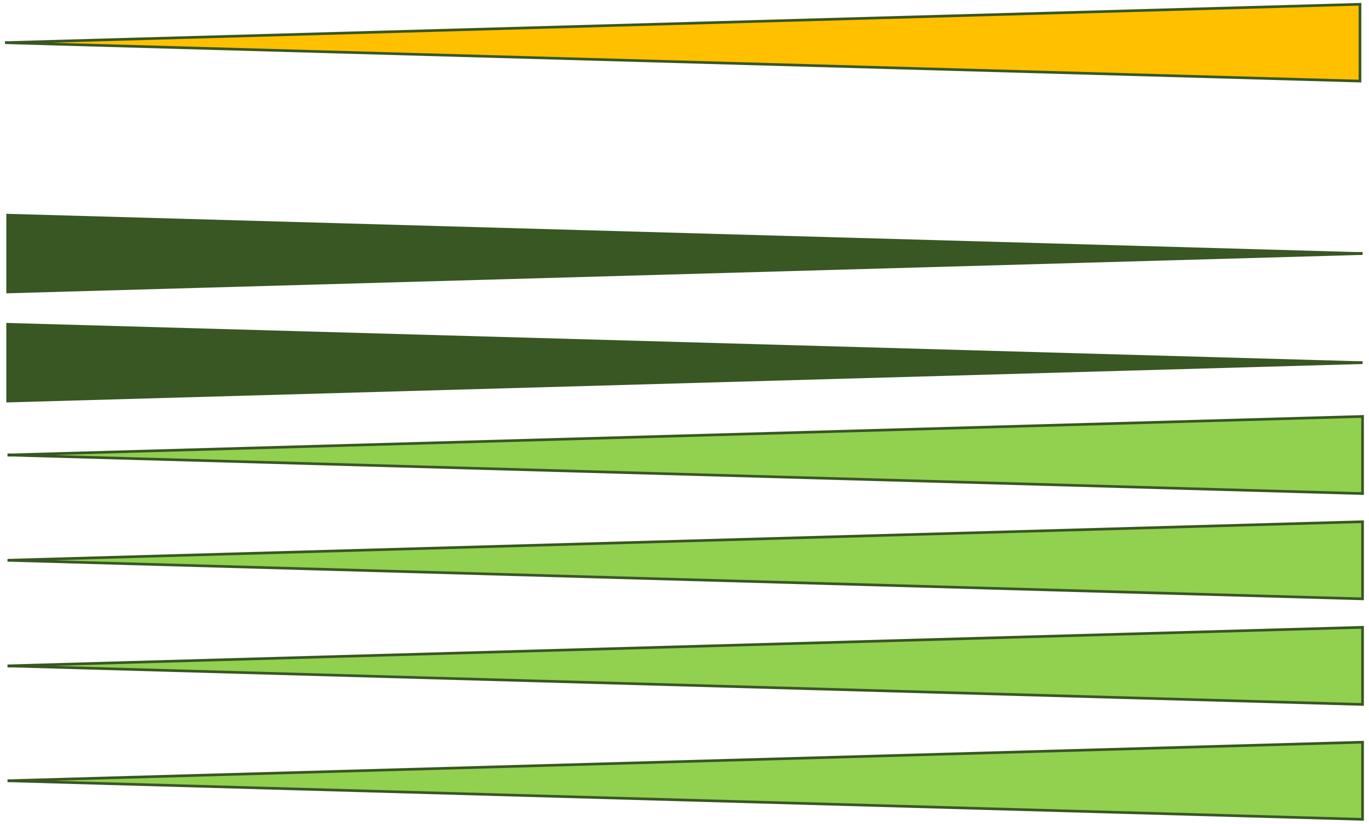
Leaf lifespan (LL)

Photosynthetic capacity (A_{mass})

Dark respiration rate (R_{mass})

Leaf nitrogen (N_{mass})

Leaf phosphorus (P_{mass})



return on investments of nutrients and dry mass in leaves

SLOW

Intsia

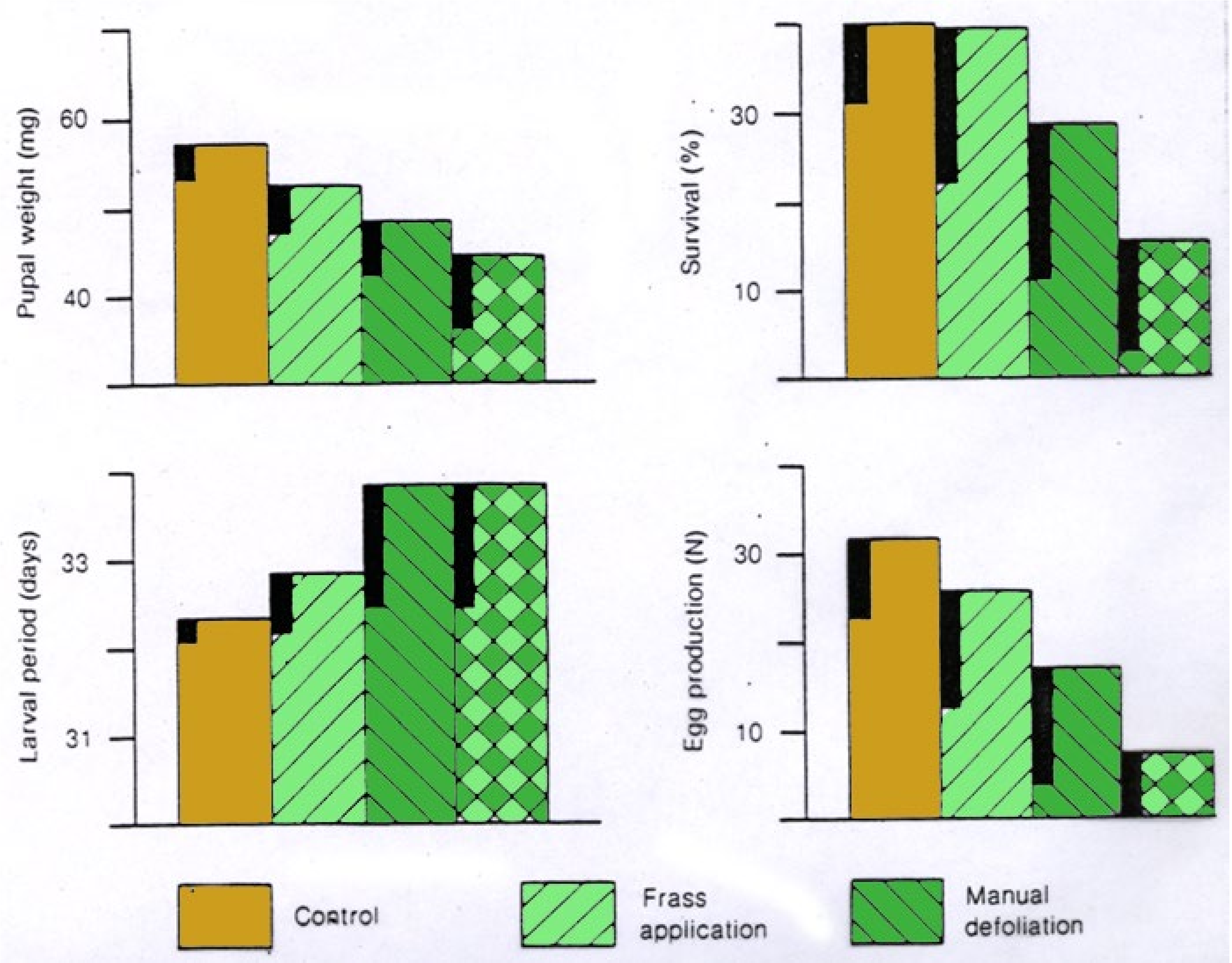
Macaranga

QUICK

J. Wright et al. 2004, Nature 428, 851

And now for something completely different

Induced defense



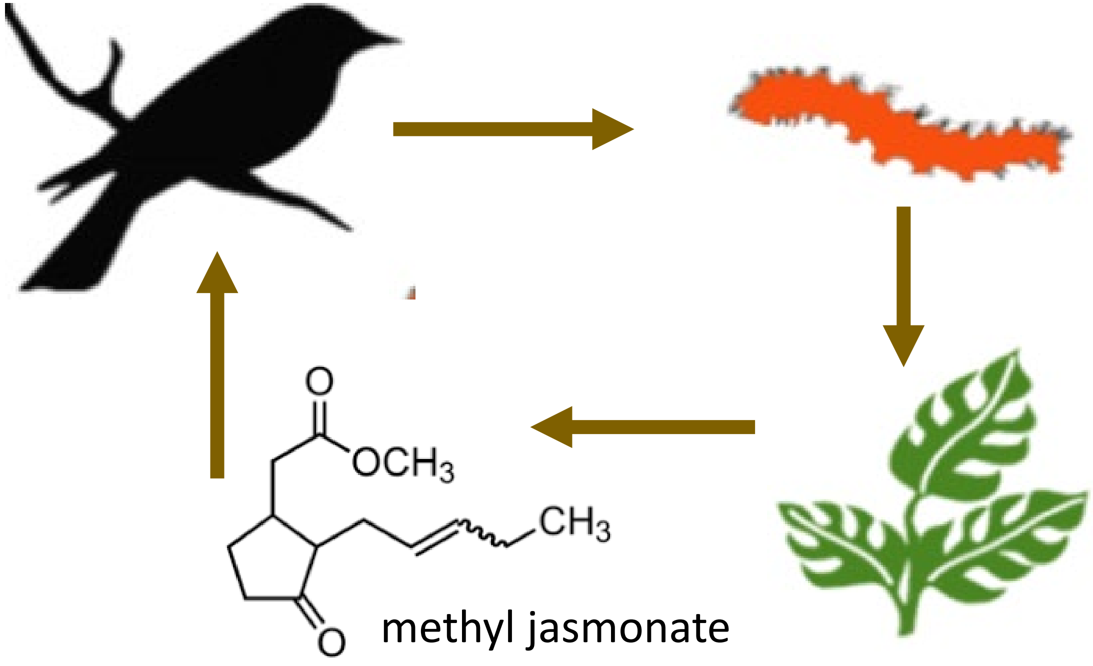
Induced defence can be advantageous, as investment takes place only when there is a real risk of herbivory, but sometimes can come too late

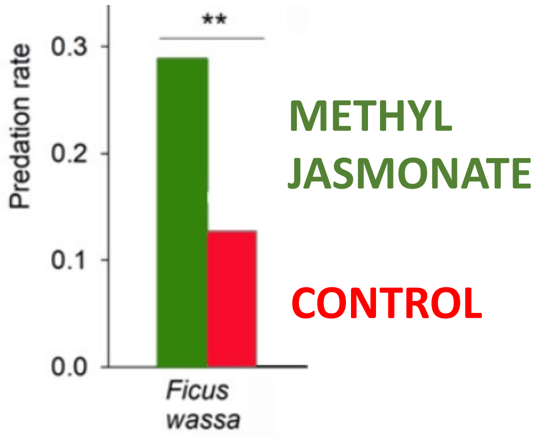
Epirrita autumnata

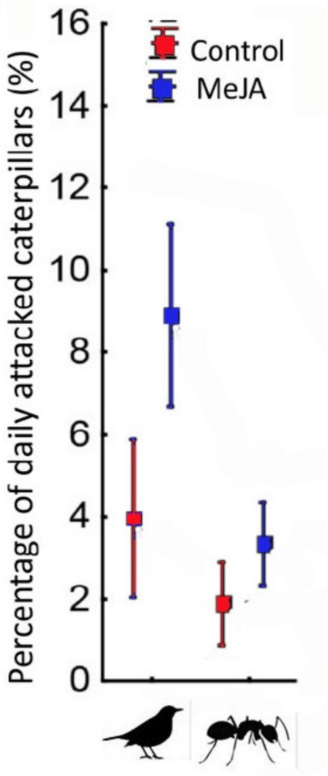
Betula pubescens

Fig. 4-9· Survival and fecundity of moth larvae *(Epirrita autumnata)* on leaves of birch trees *(Betula pubescens* spp. *tortuosa)*. Either leaf damage or application of caterpillar droppings (frass) increases the resistance of the trees, and consequently decreases correlates of moth fitness. Bars indicate standard deviations. After Haukioja et al. (1985b).

How plants cry for help: signalling herbivory to predators







E. MÄNTYLÄ, K. SAM , A. HUMLOVA

Mrazova & Sam 2017. Arthropod-Plant Interactions DOI 10.1007/s11829-017-9558-9

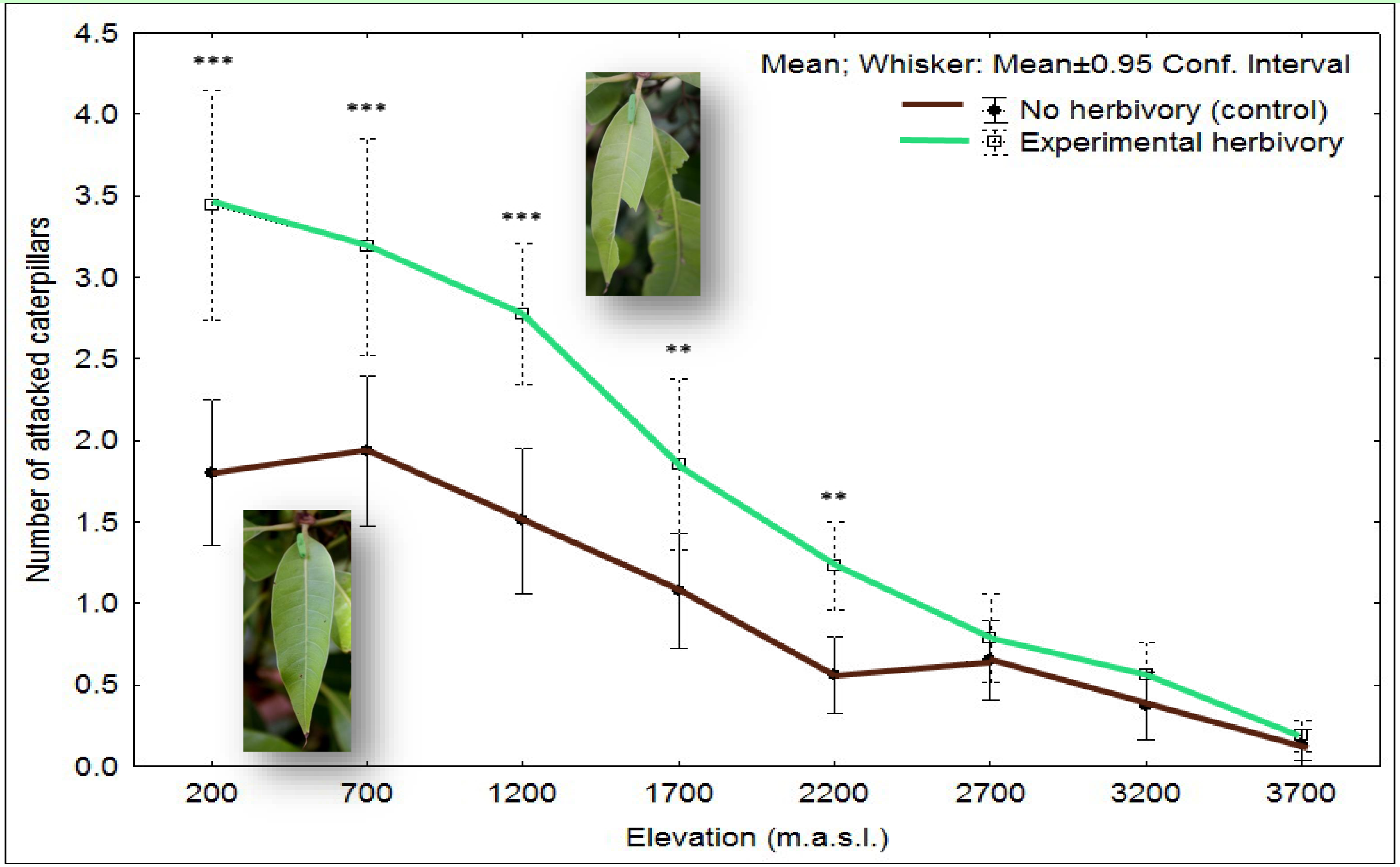
Discoveries of the effects of herbivore induced volatile organic compounds

Discovery of the herbivore induced volatile organic compound (HI-VOC) receivers:

- other plants
- predatory mites
- parasitoid wasps
- predatory bugs
- predatory lady beetles
- herbivorous moths, which are repelled
- parasitic plants
- nematodes
- systemic parts of the same plant
- predatory birds
- resistance to pathogens

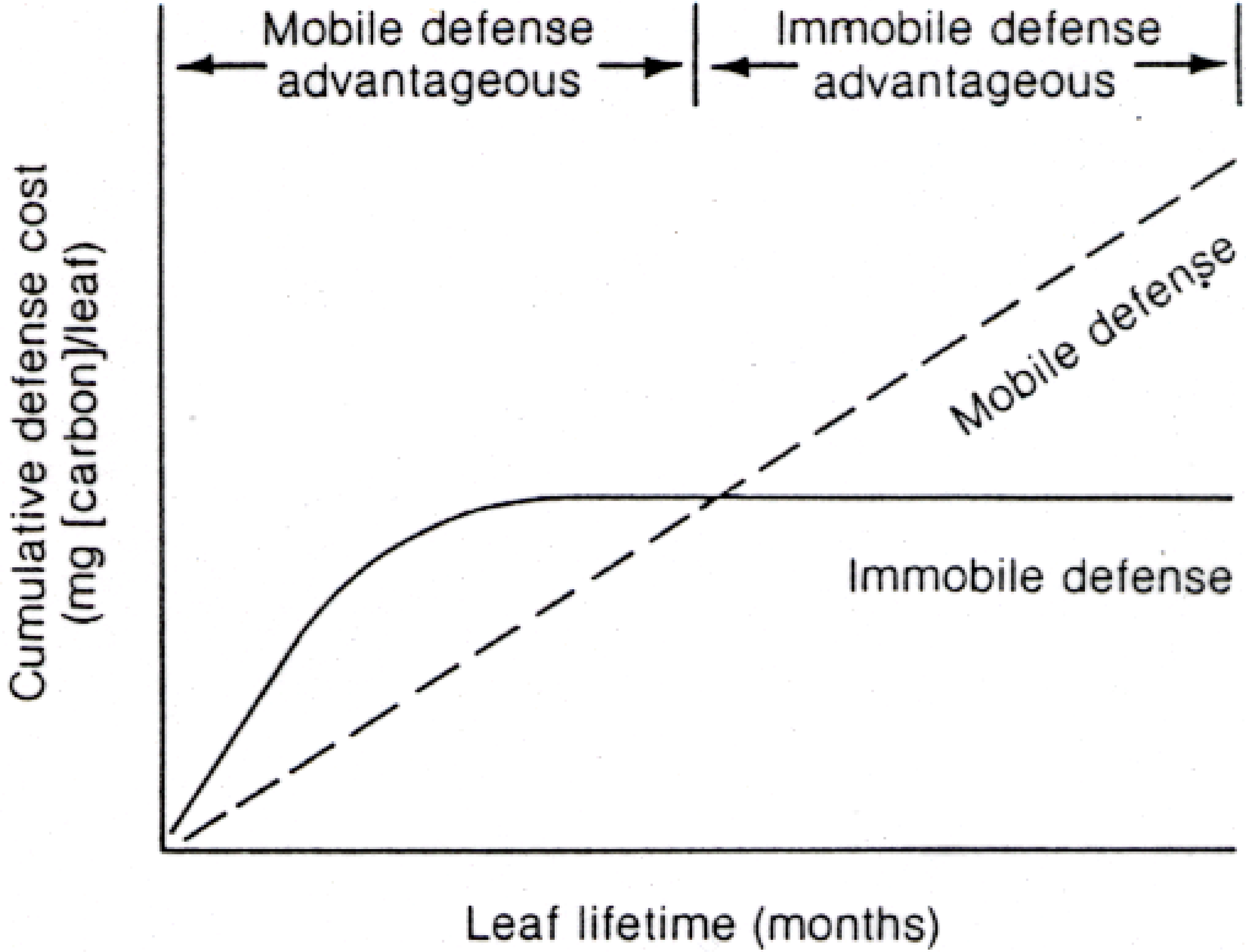
Heil, New Phytol. (2014) 204: 297

Leaf damage increases attack rate on caterpillars by birds and ants along altitudinal gradient in tropical forest



Tvardikova & Novotny
2012 J Trop Ecol.

Costs of mobile and immobile defenses: mobile defenses have to be produced constantly, immobile last for long time



Defended vs. non-defended plants: a game

	Defended p	Non-defended 1-p
Defended	hB-hH-C	hB-hH-C
Non-defended	hB-hH-C	hB-hH-C

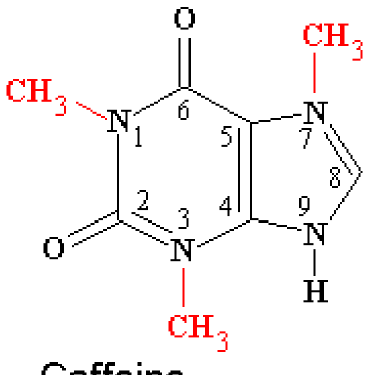
h = probability of herbivory, H = fitness cost of herbivore damage, C = cost of defence, B = competitive benefit from the opponent being damaged by herbivores; orange terms are zero;
p = frequency of defended plants in the population

$$-pC + (1-p)(hB-C) = -phH + (1-p)(hB-hH)$$

$$-pC+hB-C-phB+pC = -phH+hB-hH-phB+phH$$

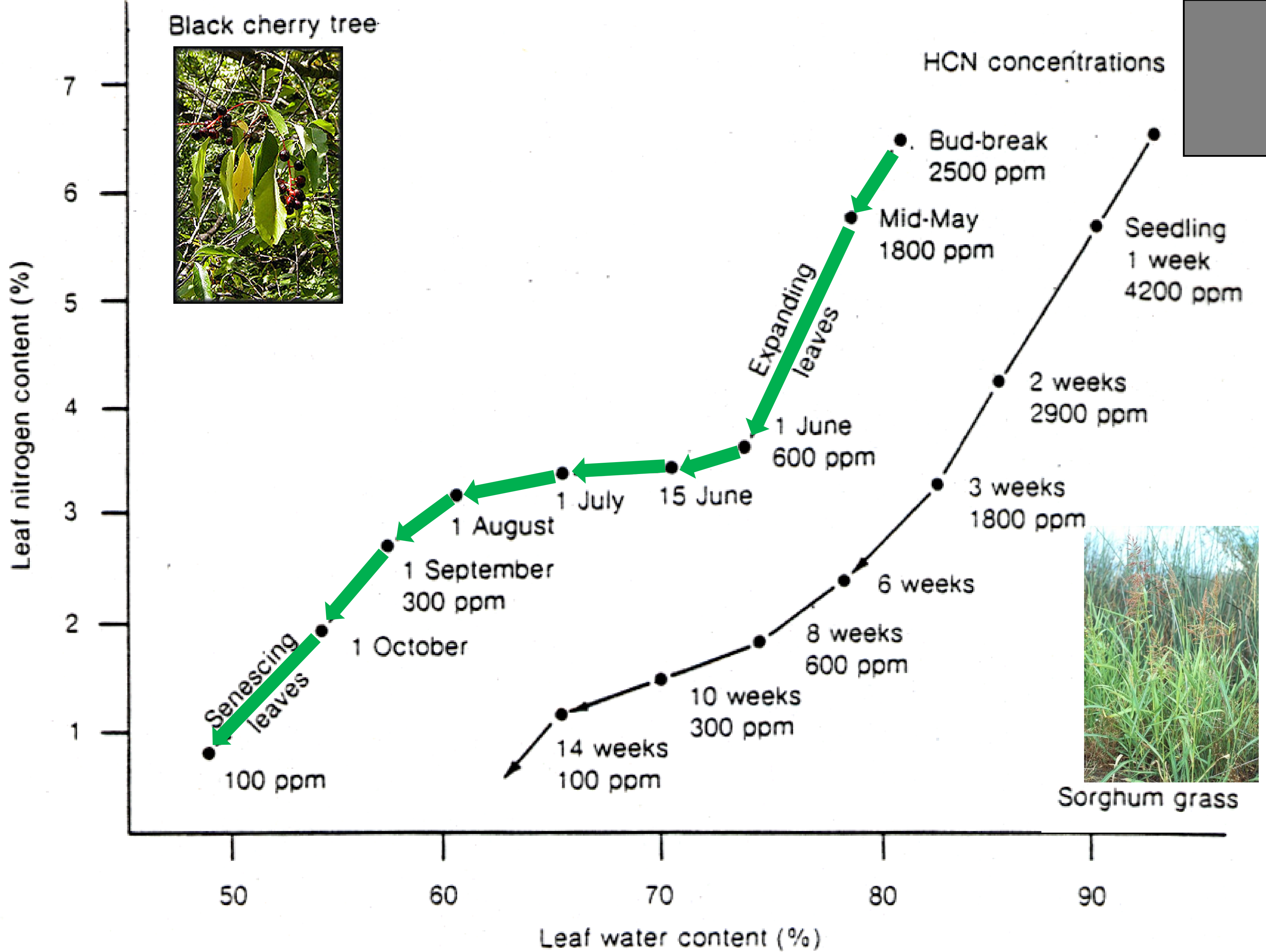
$$C = hH$$

Caffeine: one of the ecologically most successful alkaloids enabling *Coffee arabica*, via a mutualistic relationship with a vertebrate species, to outcompete hundreds of plant species

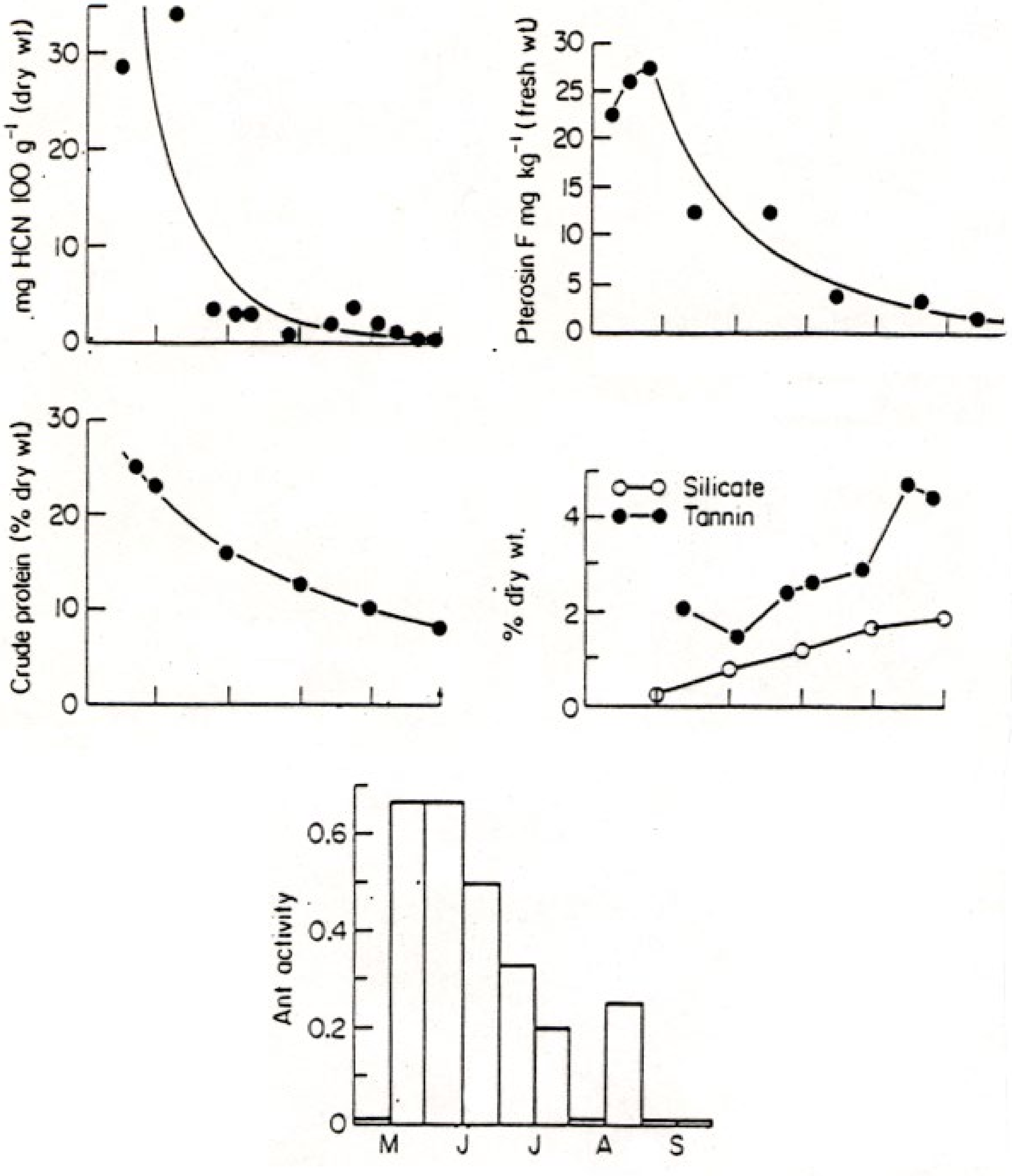


And now for something completely different

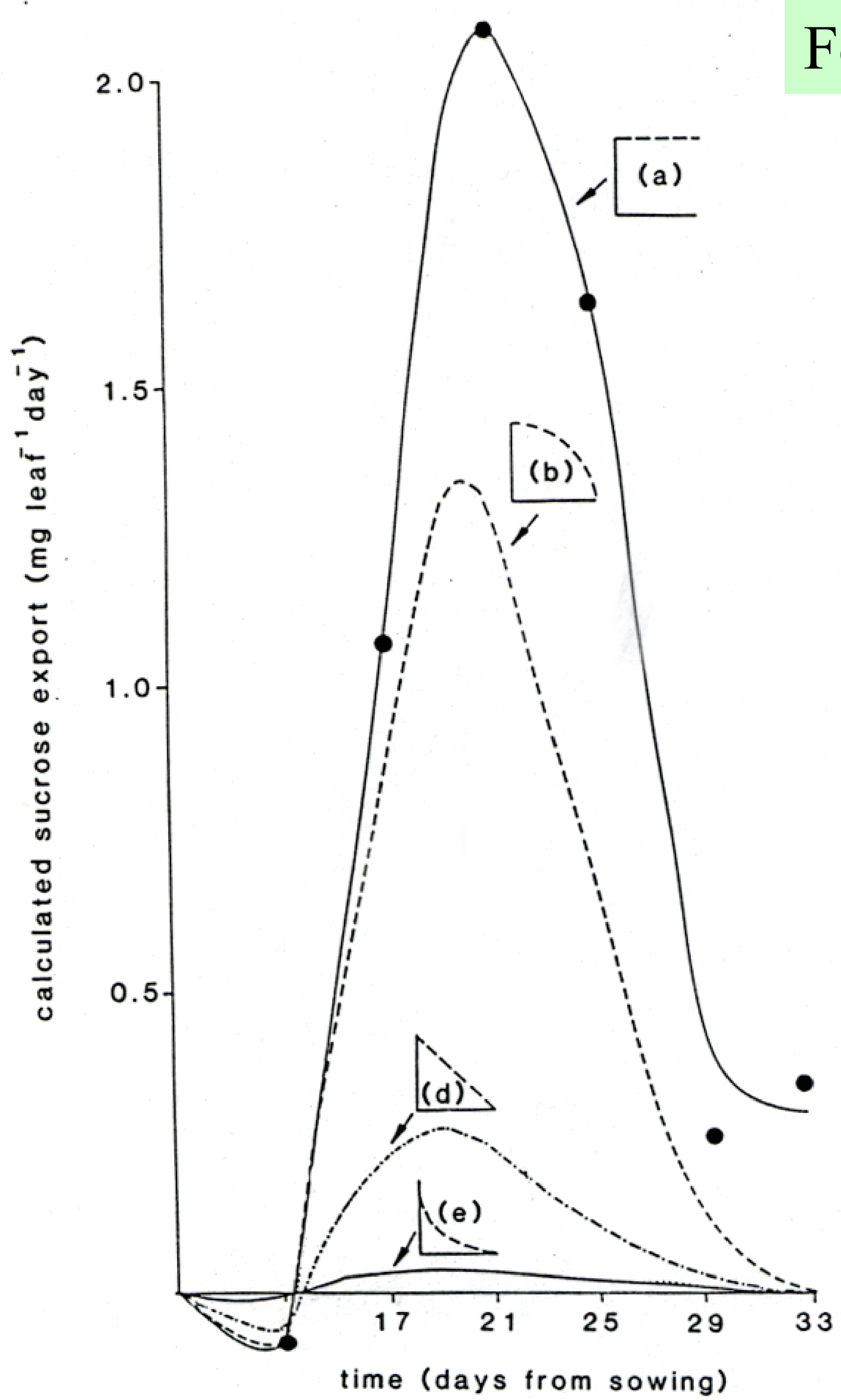
Young vs. mature leaves:
unapparent high-quality vs. apparent low-quality resources


Black cherry tree
HCN concentrations
Leaf nitrogen content (%)
Leaf water content (%)
7
6
5
4
3
2
1
50
60
70
80
90
Bud-break
2500 ppm
Mid-May
1800 ppm
Expanding leaves
1 June
600 ppm
15 June
1 July
1 August
1 September
300 ppm
1 October
Senescing leaves
100 ppm
Seedling
1 week
4200 ppm
2 weeks
2900 ppm
3 weeks
1800 ppm
6 weeks
8 weeks
600 ppm
10 weeks
300 ppm
14 weeks
100 ppm
Sorghum grass

Defense of maturing bracken fern leaves



Pteridium aquilinum, UK



Feeding on young leaves is costly for the plant

Photosynthetic production of a population of leaves that
(a) has no mortality
(b) mortality risk increases with leaf age
[usual physiological pattern]
(d) mortality risk is constant
(e) mortality decreases with leaf age
[high herbivory pattern]

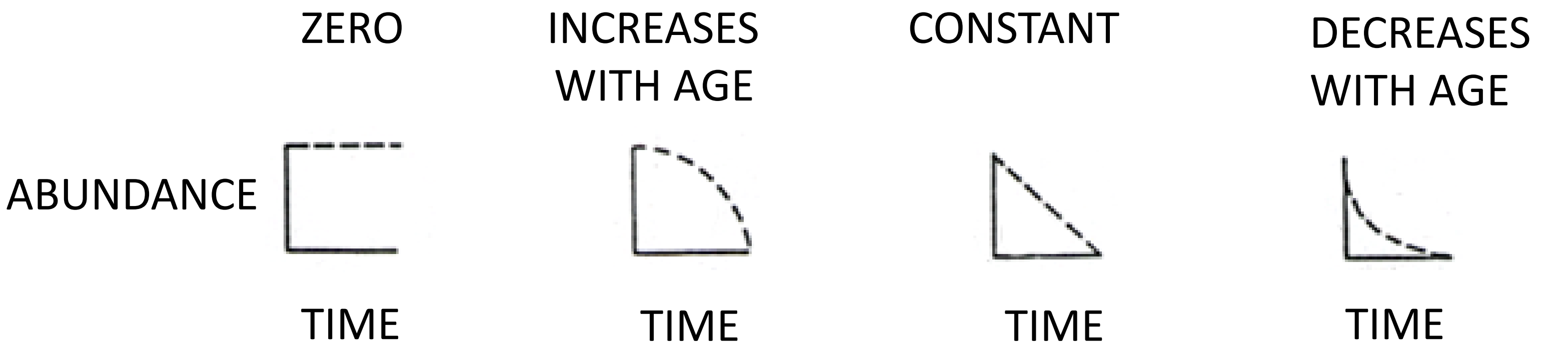
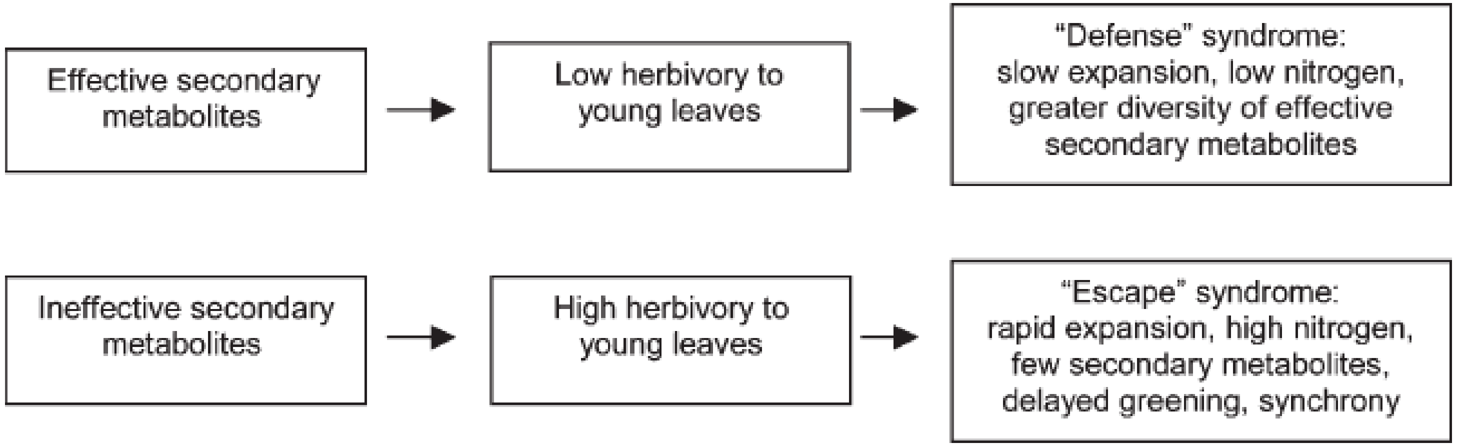


Fig. 3. The effects that different patterns of leaf survivorship l(x would have on the rate of "reproduction" of fixed carbon. Th survivorship curves are shown on a logarithmic scale. **a** There i no significant risk of death until the leaf loses its capacity fo carbon export. **b** The risk of death increases continuously wit age of the leaf. This appears to be the most common form o survivorship for leaves that do not suffer predation or other exter nal causes of death (Harper 1987). **c** The survivorship curve ressem bles that in Fig. 3b except that the risk of death declines amon very old leaves. **d** The risk of death is constant throughout th

Young leaf: a precious resource difficult to defend

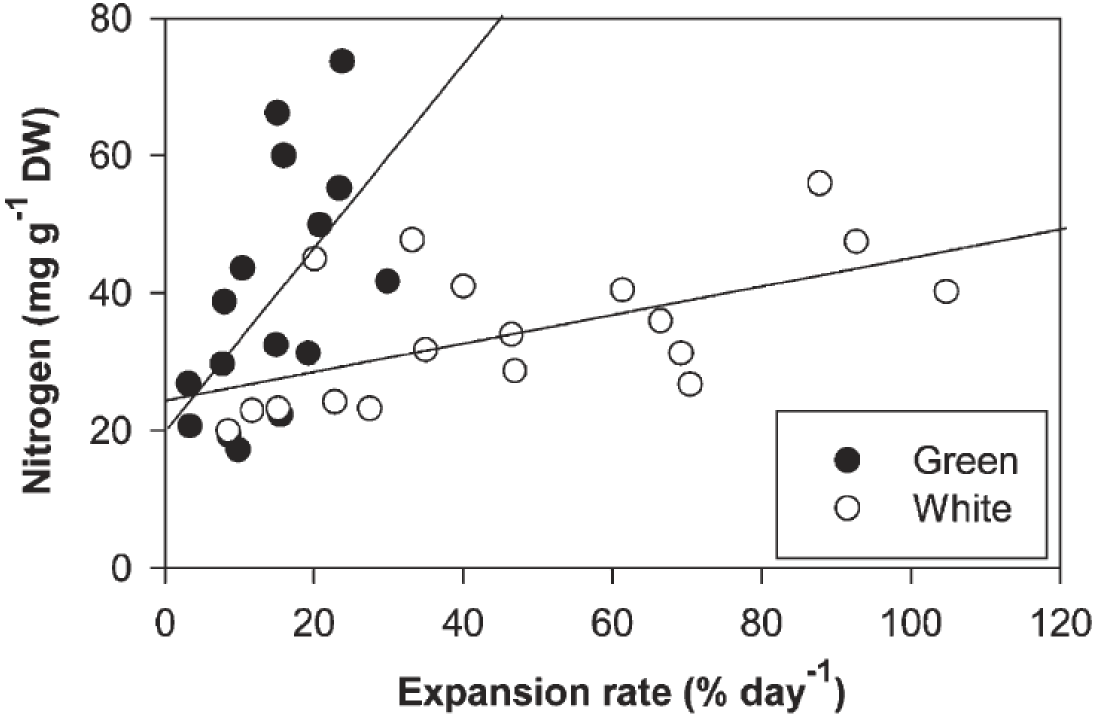


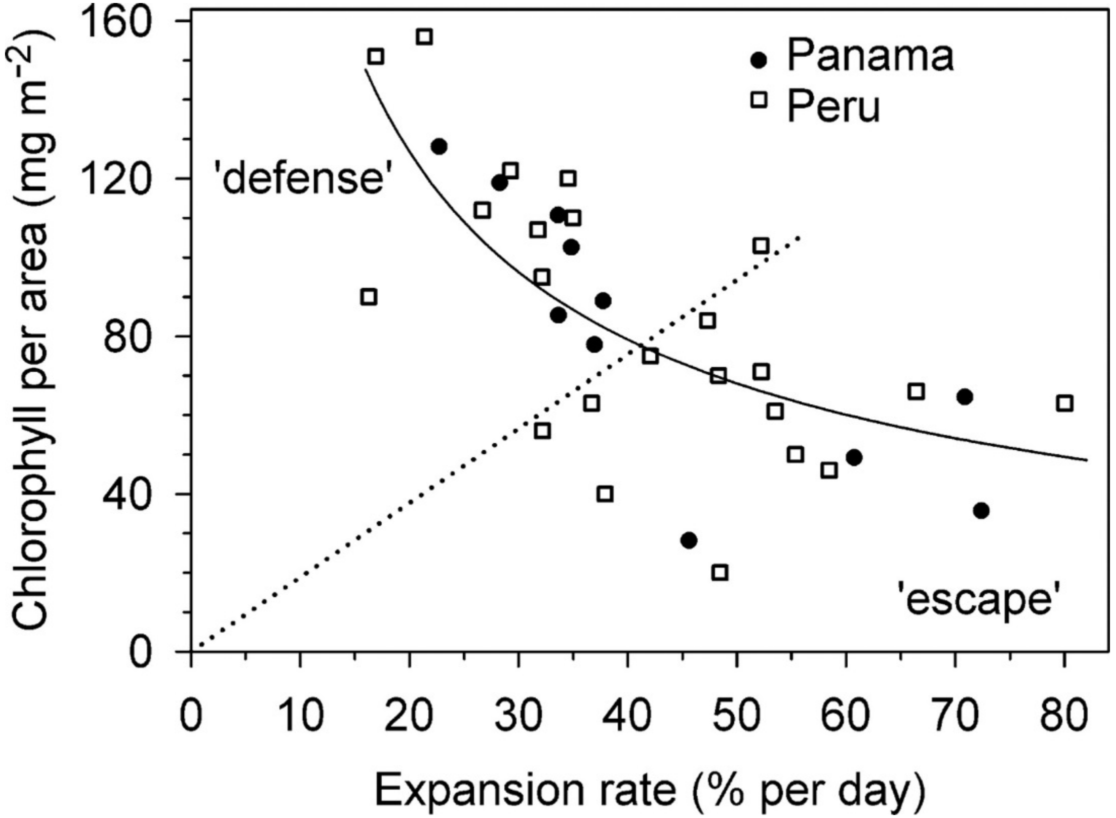
Young leaf characteristics for species with 'escape' and 'defense' syndromes

	Escape	Defense
Herbivory	high	low
Toughness	low	low
Leaf expansion rate	fast	slow
Nitrogen for growth	high	low
Chemical defenses	low	high
Chloroplast development	delayed	normal
Nitrogen for greening	low	high
Synchrony of leaf production	high	low

Kursar & Coley 2003

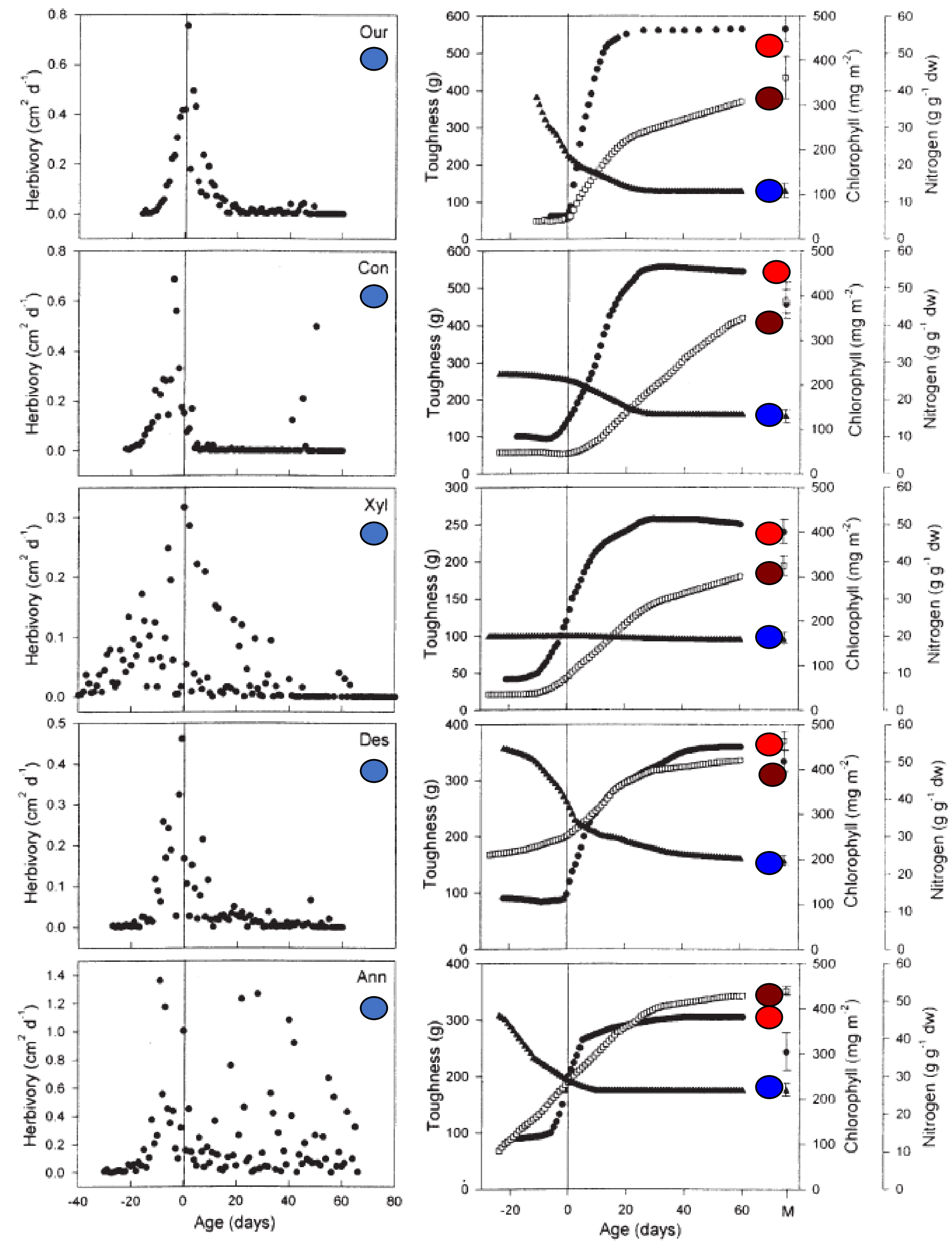
Delayed greening: faster expansion with lower N concentrations





Inga spp: defense vs. escape strategy

Kursar & Coley 2003 Kursar et al. PNAS 2009;106:18073-18078

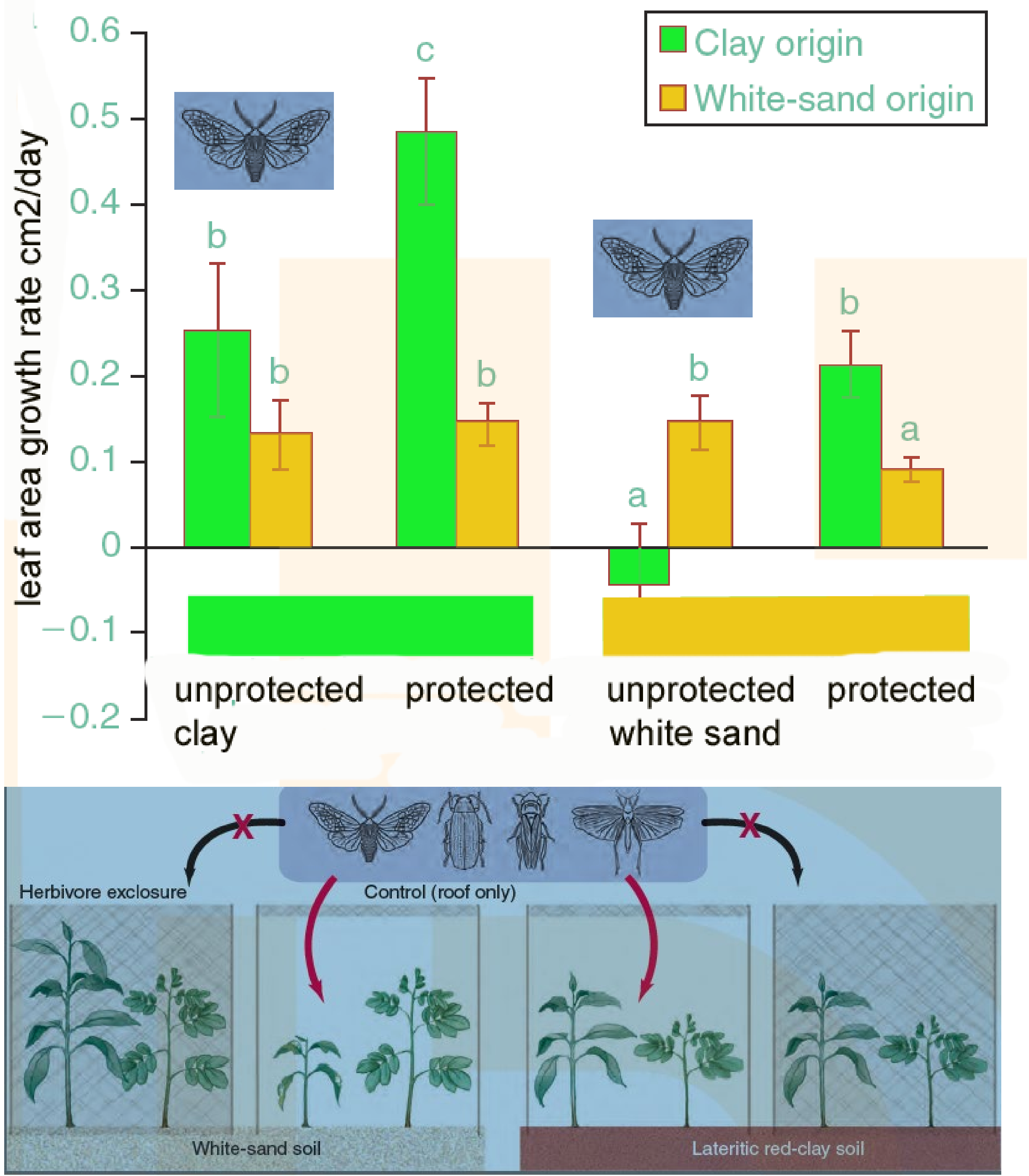


Leaf:
- damage
- toughness
- nitrogen
- chlorophyll

Tropical herbivory: young leaf is the critical stage

Kursar & Coley 2003

And now for something completely different



Herbivores determine plant competitive hierarchy

reciprocal transplants of plants between clay and white sands in tropical forest

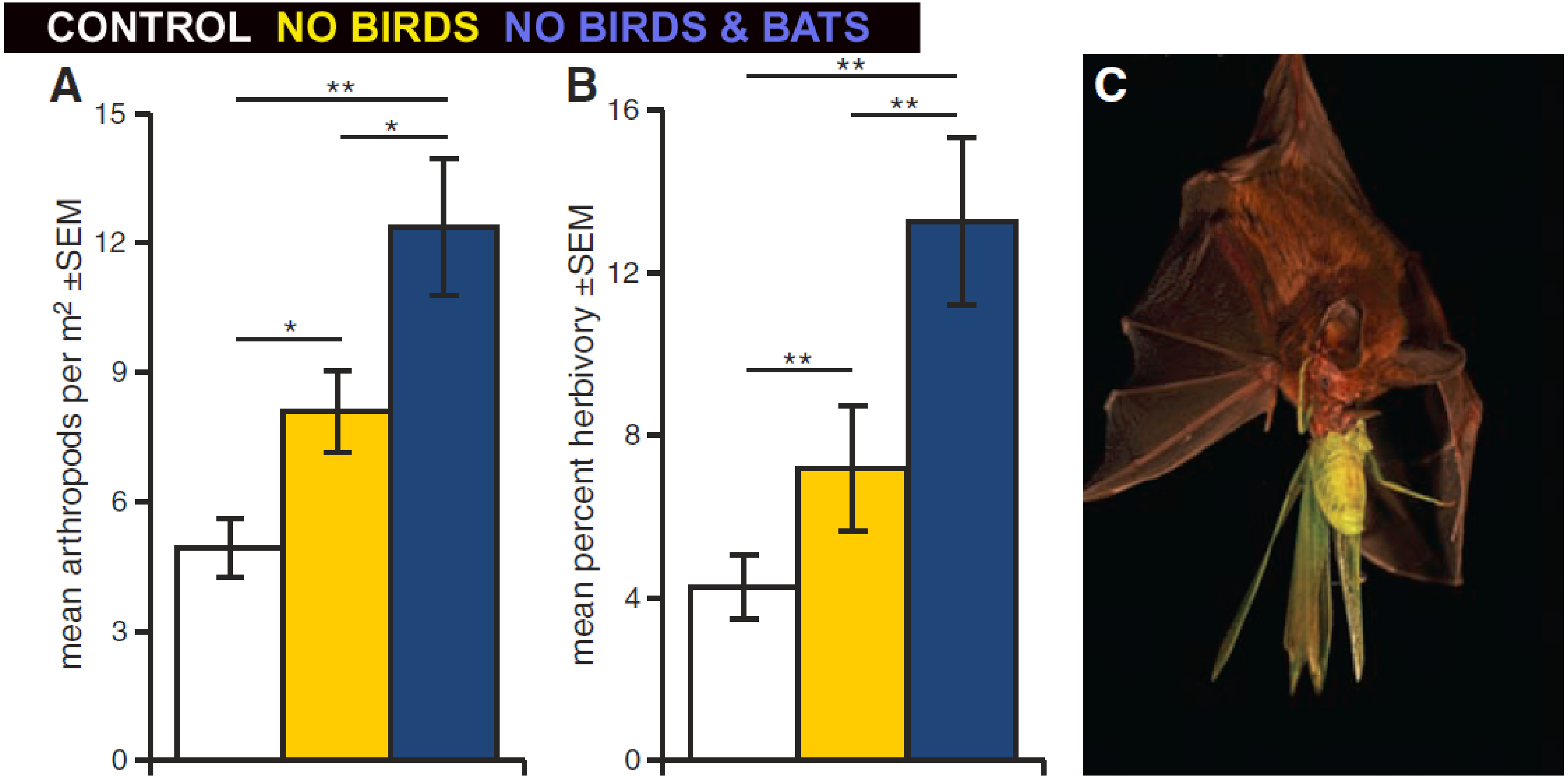
clay plants do better on clay than white-sand plants

but

white-sand plants do better on white-sand only when insect herbivores are present

Fine et al. 2004, Science 305: 663

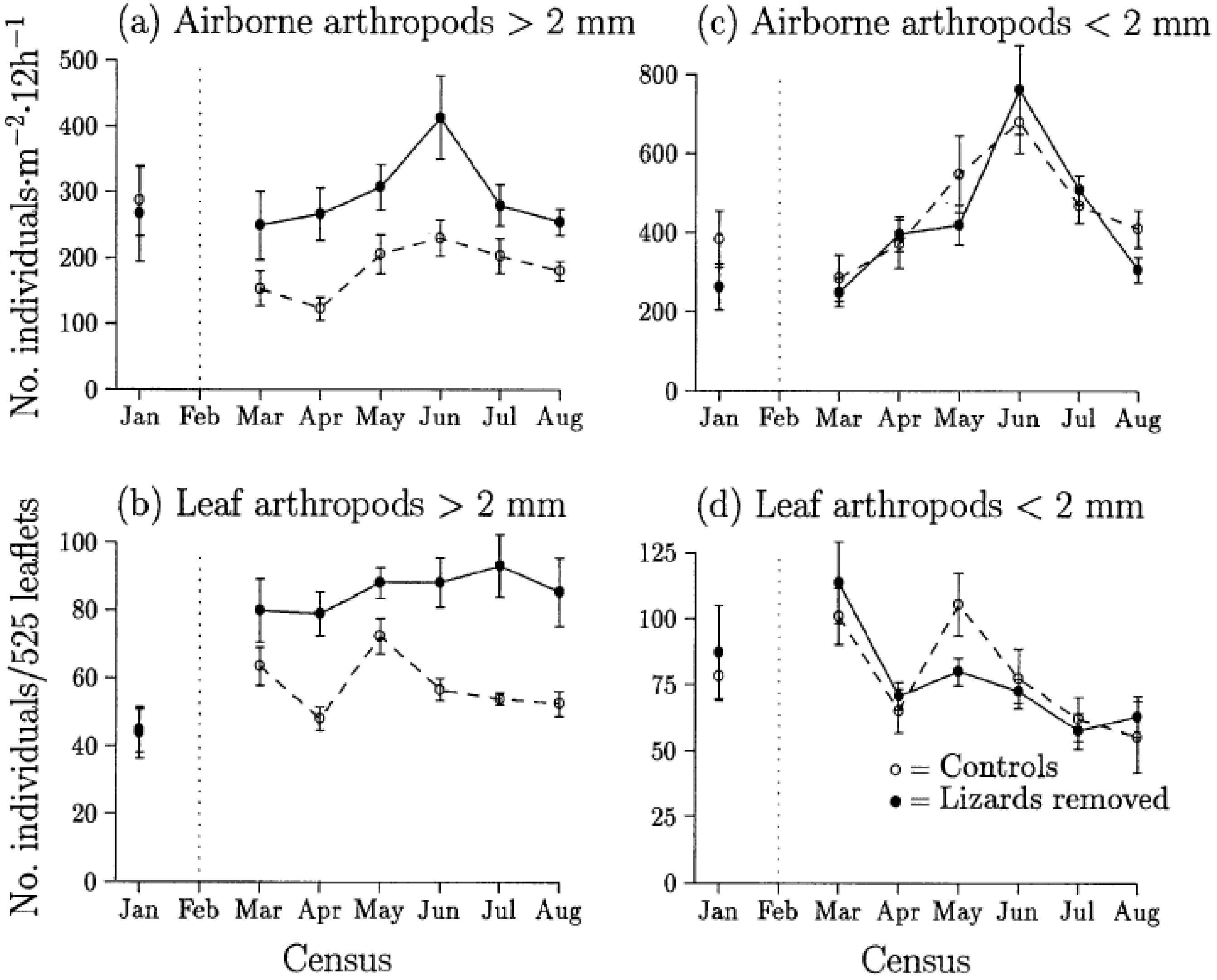
Top-down control:
birds and bats control arthropods on tropical foliage



(A) Mean number of arthropods per m2. (B) Mean herbivory as percent of total leaf area.
(C) Micronycteris microtis consuming a katydid. Barro Colorado Island, Panama.

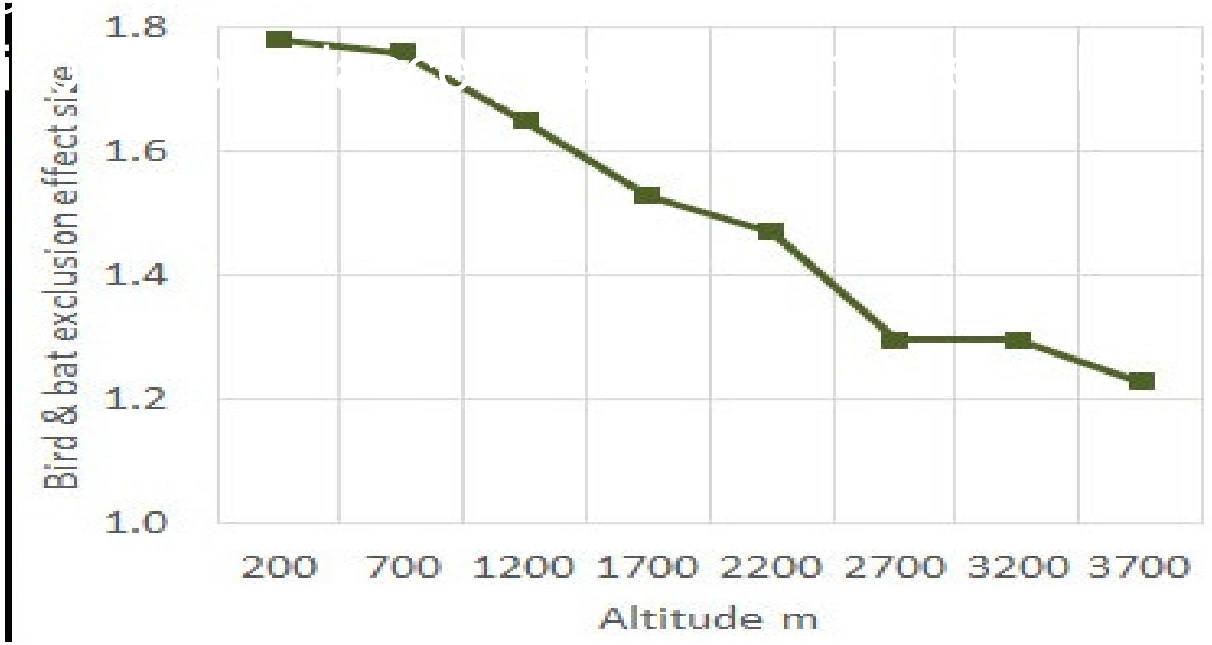
Kalka et al. 2008. Science 320: 71

Responses of arthropods to lizard removal: rainforest in Puerto Rico



In arthropods >2 mm, predatory (spiders), parasitic (Hymenoptera), and nonpredatory (Diptera, Coleoptera, Orthoptera, and Blattaria) spp. responded to lizard removal.

Dial & Roughgarden 1995. Ecology, 76: 1821-1834

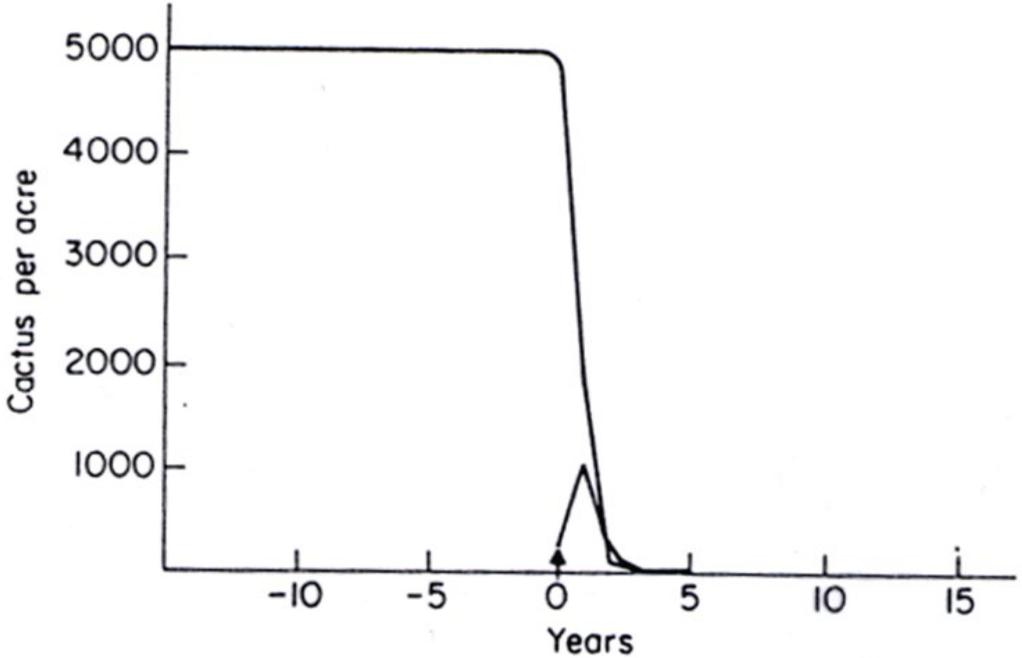


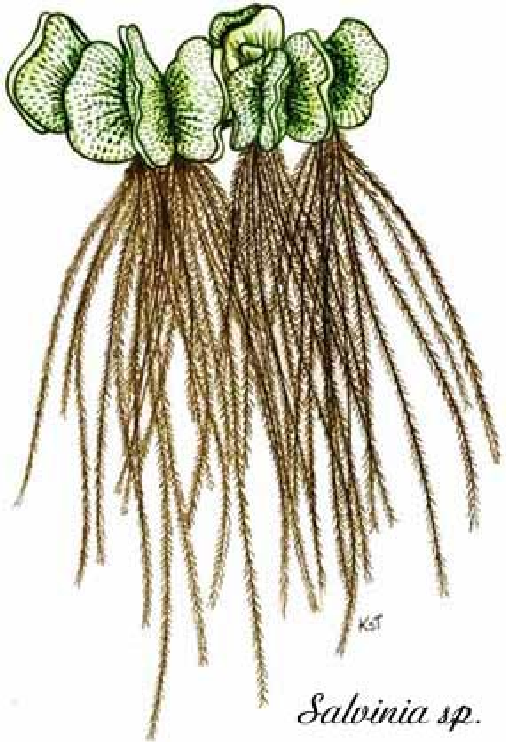
Predator exclusion:

Herbivore abundance increases (to 120-180% of original abundance)
In arthropod communities, % of predators increases (compensation)
In plants, damage of leaves increases (trophic cascade)

Katerina Sam   Bonny Koane

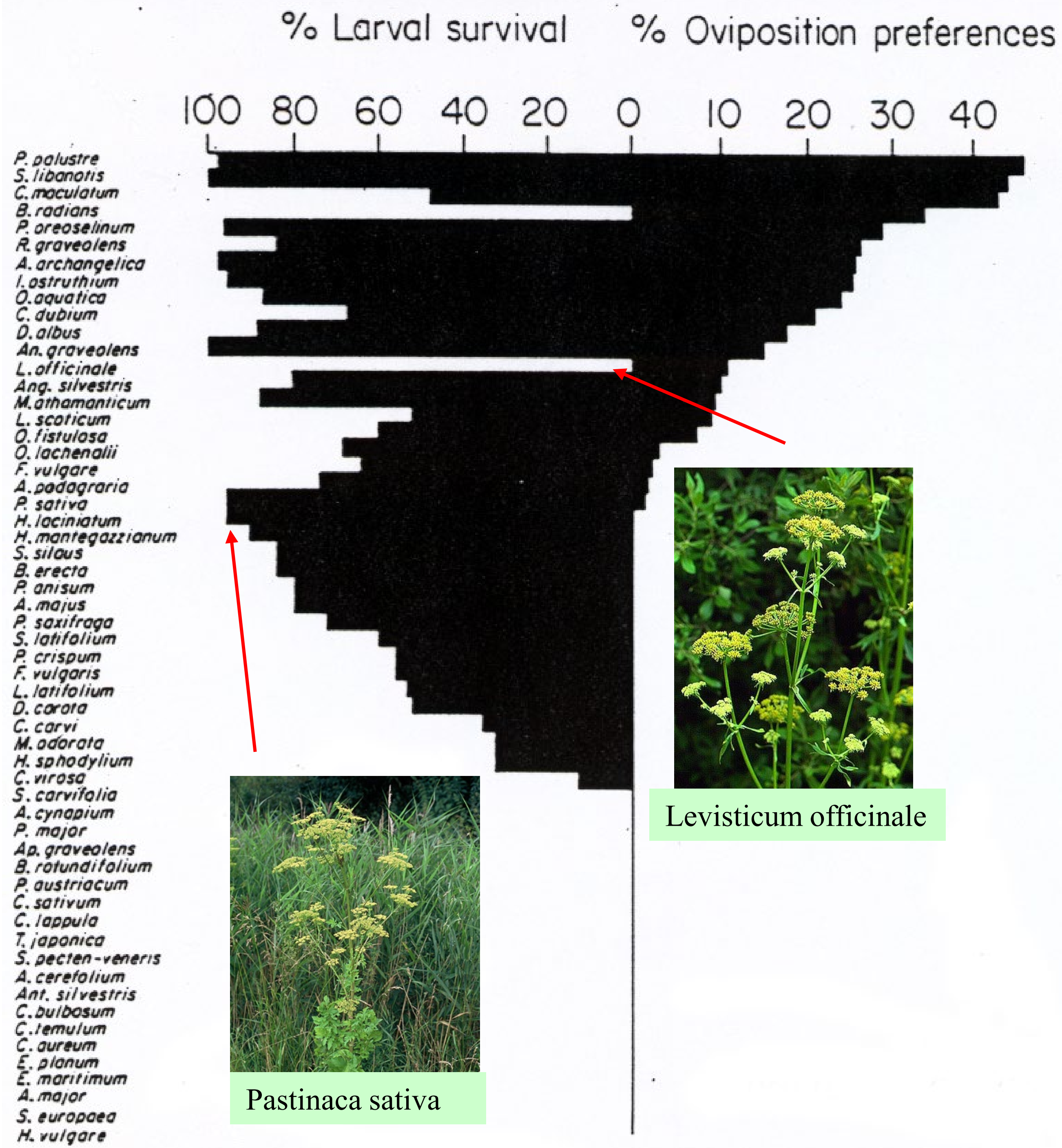
Biological control of plants by herbivores: the success story of *Cactoblastis cactorum* controlling *Opuntia* (Australia)





Salvinia molesta
and
Cyrtobagous salviniae

And now for something completely different

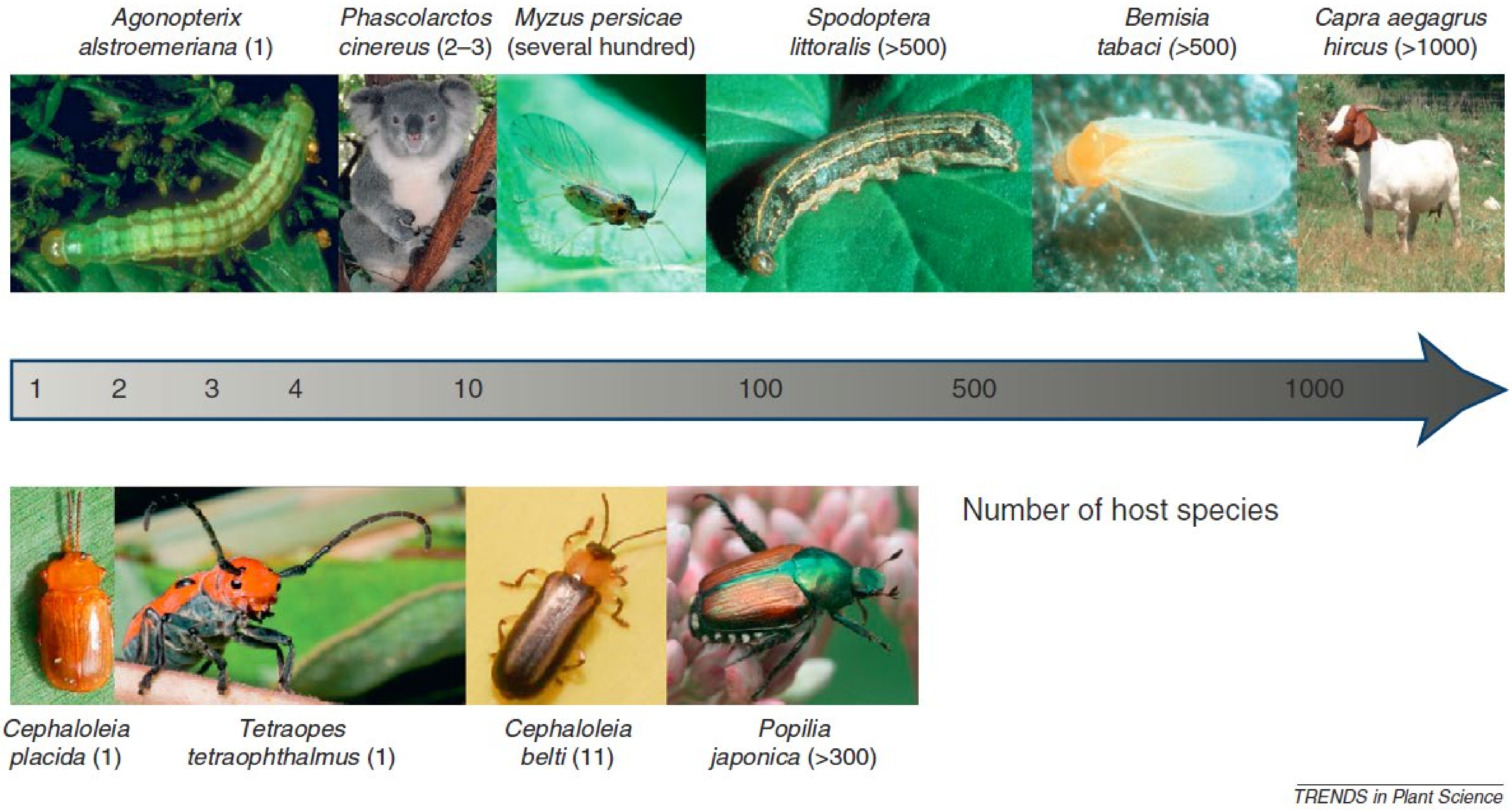


Peucedanum palustre

Levisticum officinale

Pastinaca sativa

Does the host selection follows optimality rules?



Herbivore host ranges are variable...

Why are there host specific herbivores?

- genetically based trade-offs in performance between host species
- interspecific competition for food or enemy-free space
- increased resistance to generalist predators on some host plants
- similarity of some hosts to unsuitable hosts
- facilitated mate finding
- facilitated defence against enemies [sequestering plant metabolites]
- ability to aggregate and overwhelm plant defences

Why are there generalists?

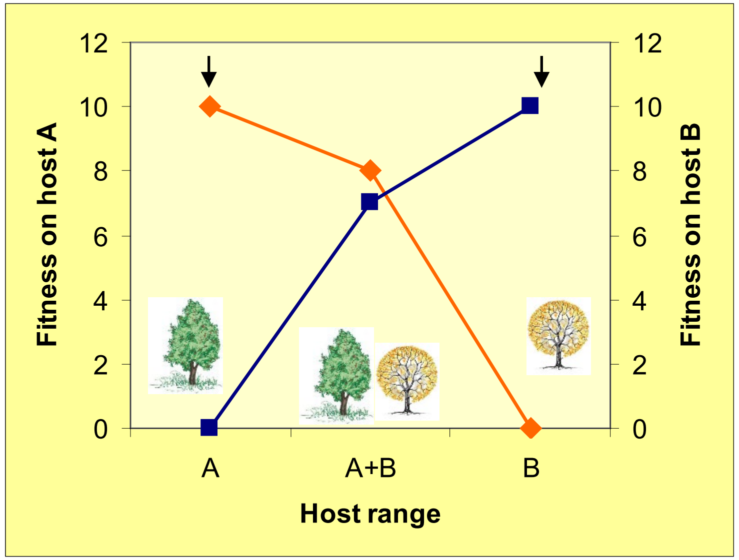
- hosts are rare, unpredictable, unapparent
- small plants favouring larval grazing
- risk spreading strategies due to temporal/spatial variability in host quality
- intraspecific competition
- predator and pathogen functional/numerical response

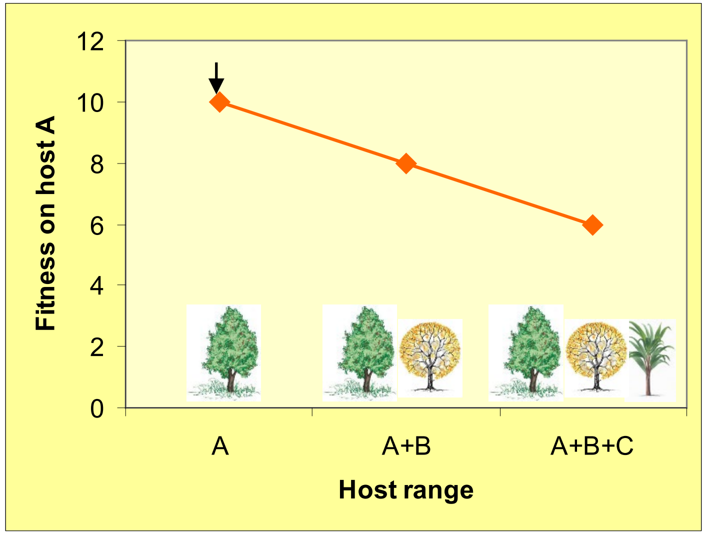
Jaenike, J. 1990. Annu. Rev. Ecol. Syst. 21:243-73

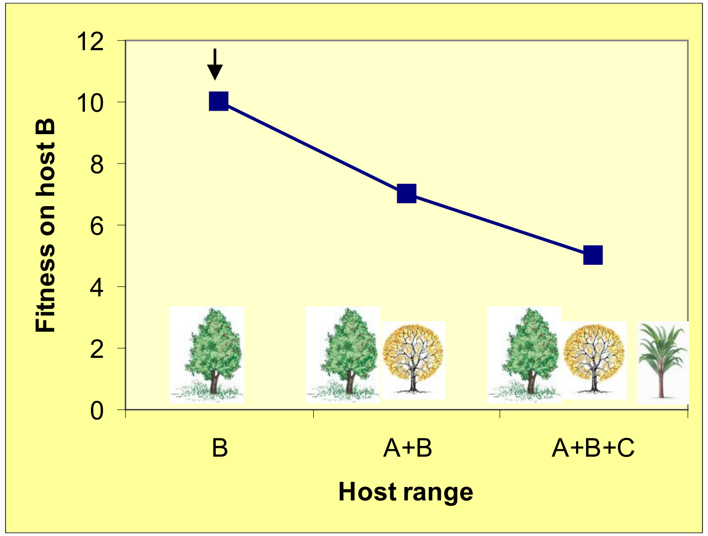
Why are there host specific herbivores?

- genetically based trade-offs in performance between host species

simultaneous specialization to multiple hosts decreases fitness on any host plant species

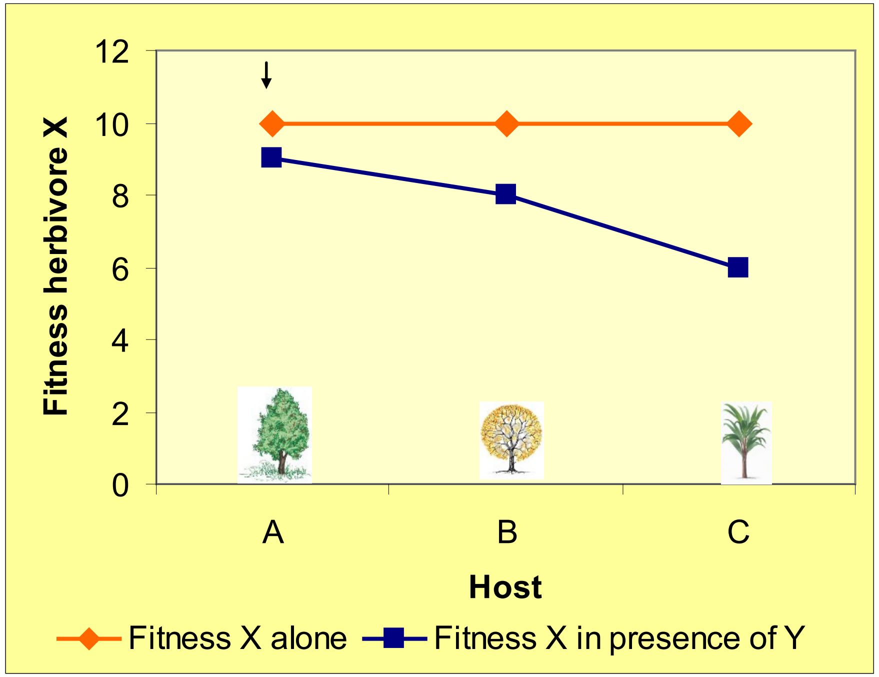






Why are there host specific herbivores?

interspecific competition for food or enemy-free space

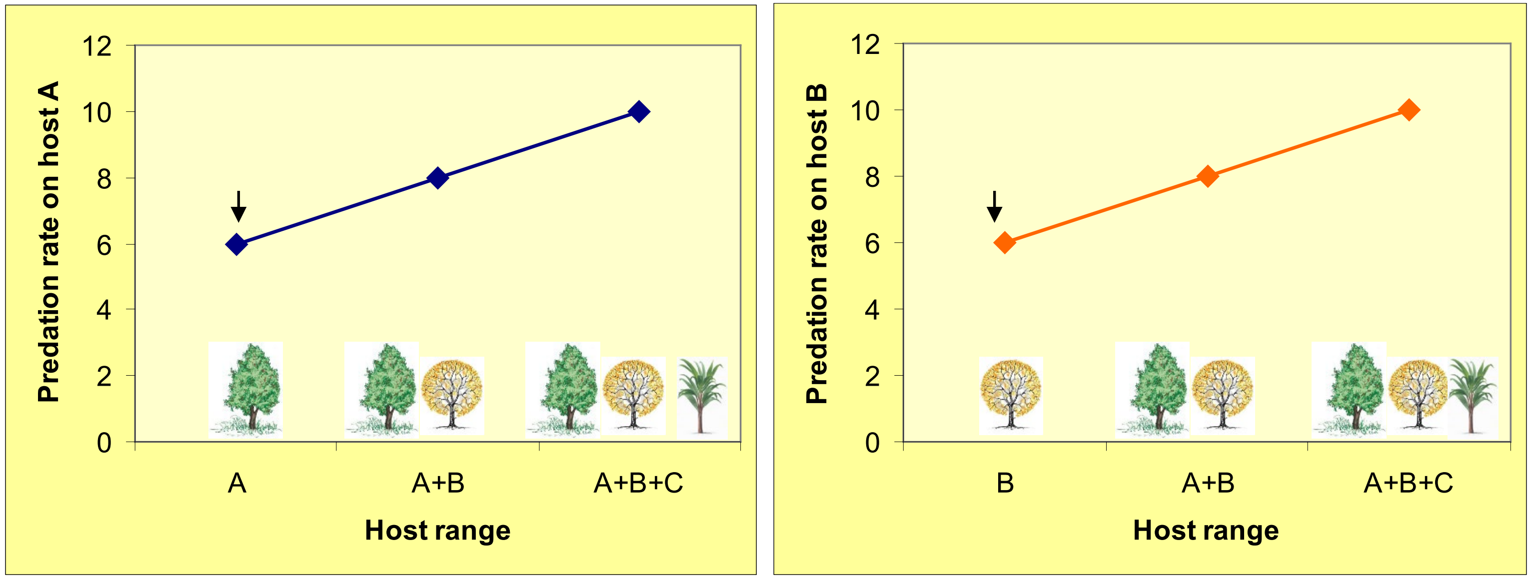


Fitness of herbivore X can be reduced on some plant species by competition from herbivore Y

Jaenike, J. 1990. Annu. Rev. Ecol. Syst. 21:243-73

Why are there host specific herbivores?

increased resistance to generalist predators on some host plants

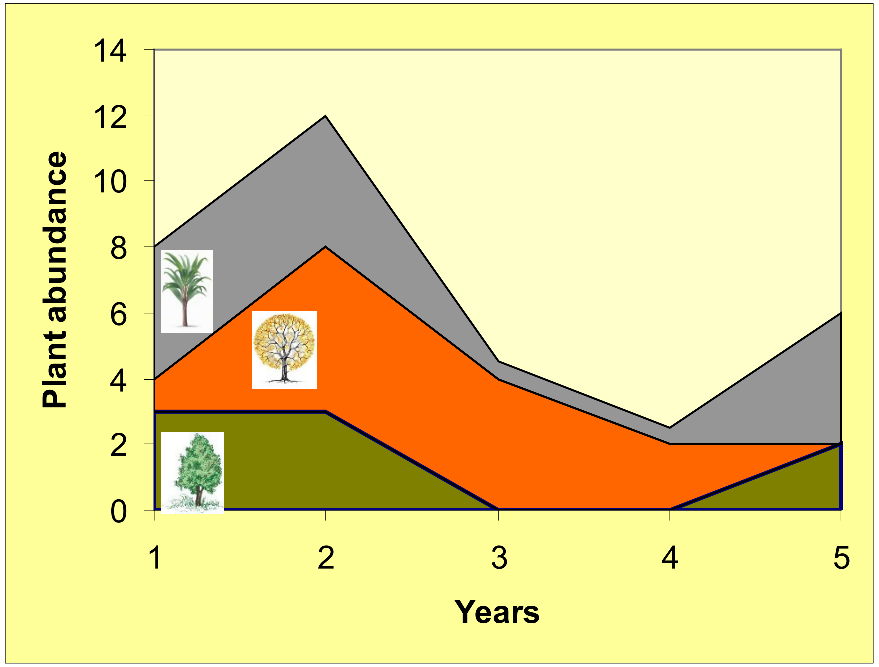


Specialists are better protected on their host plant species from generalist predators

Jaenike, J. 1990. Annu. Rev. Ecol. Syst. 21:243-73

Why are there generalists?

- hosts are rare, unpredictable, unapparent
- small plants favouring larval grazing
- risk spreading strategies due to temporal/spatial variability in host quality

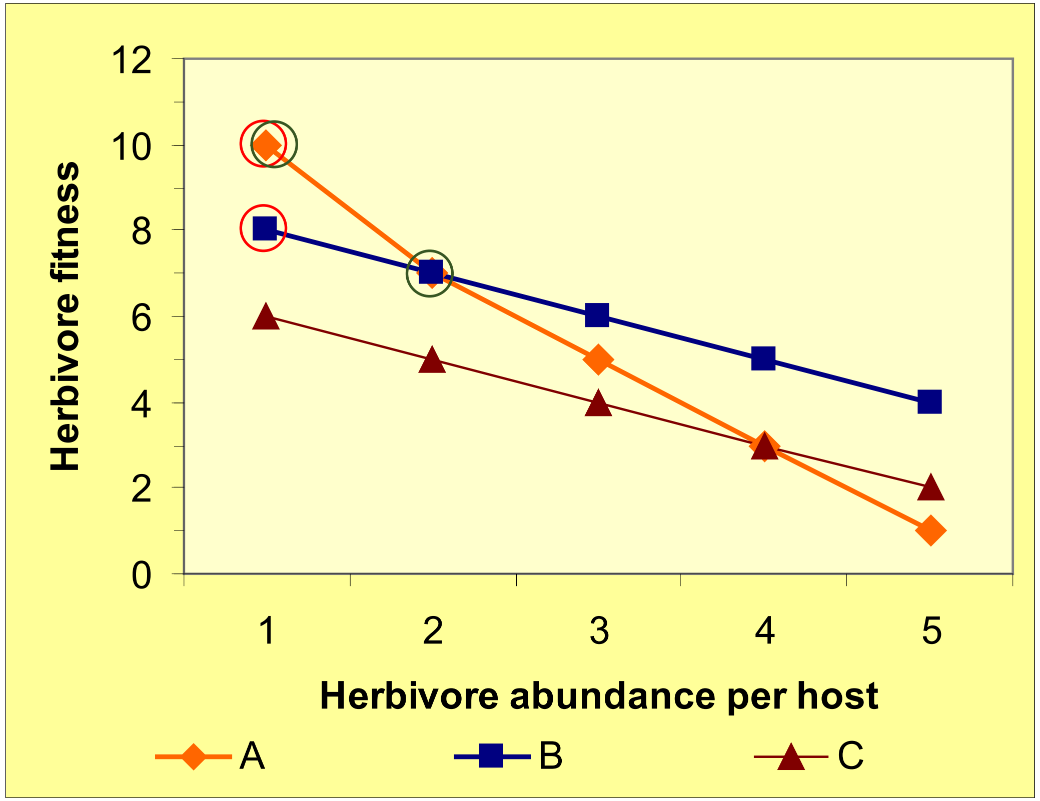


Total supply of plant species A + B + C more abundant and less variable than for individual plant populations

Jaenike, J. 1990. Annu. Rev. Ecol. Syst. 21:243-73

Why are there generalists?

- intra-specific competition
- predator and pathogen functional/numerical response



optimum host selection:

N[herbivores] = 1 

1A 

N=2

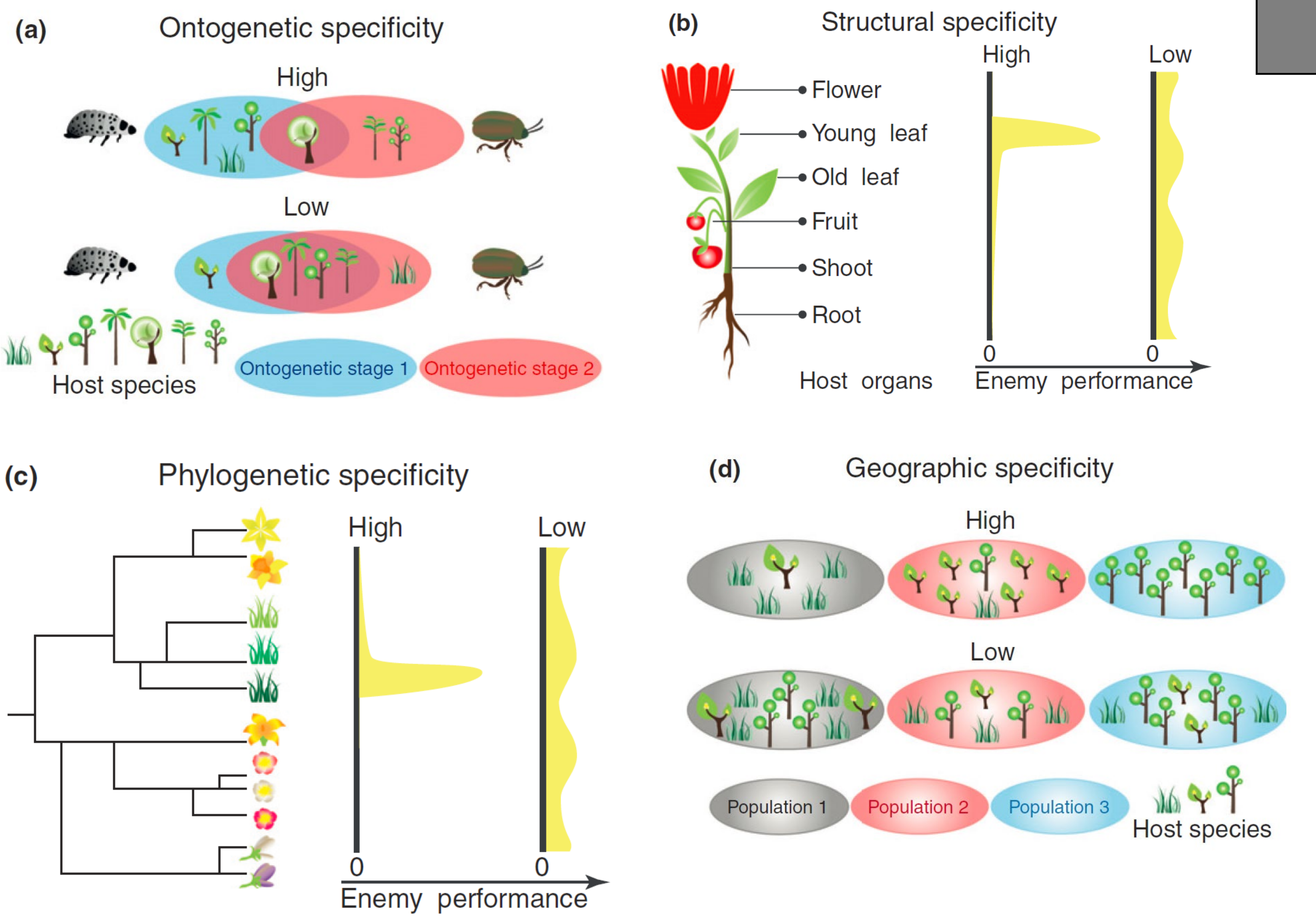
1A, 1B 

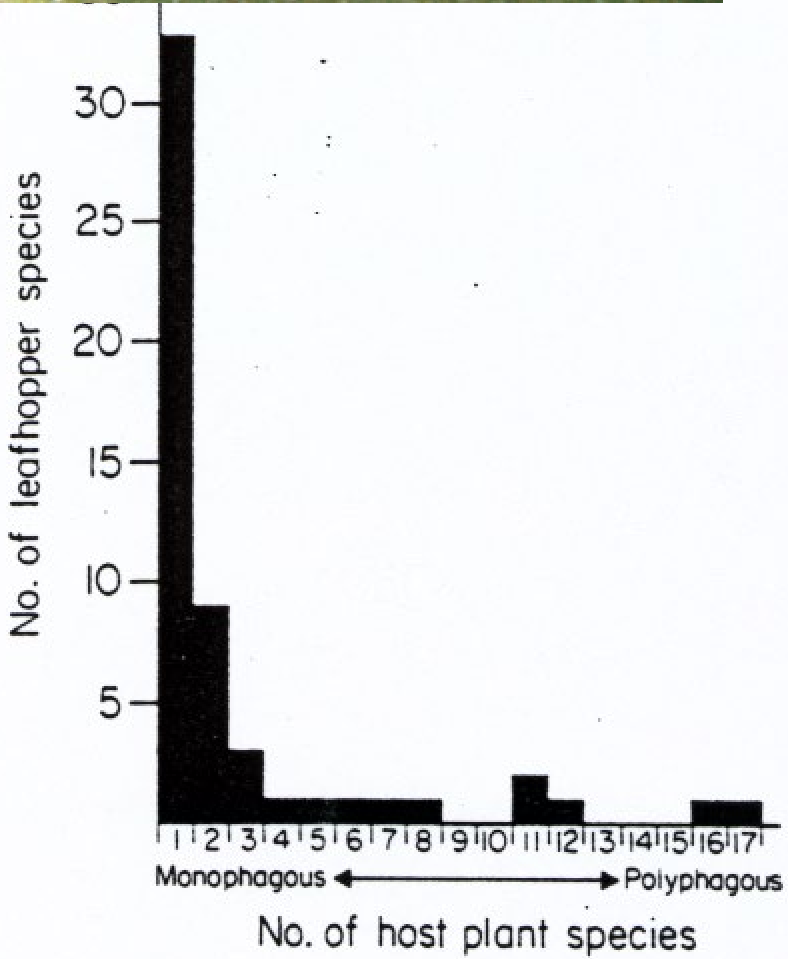
N=3

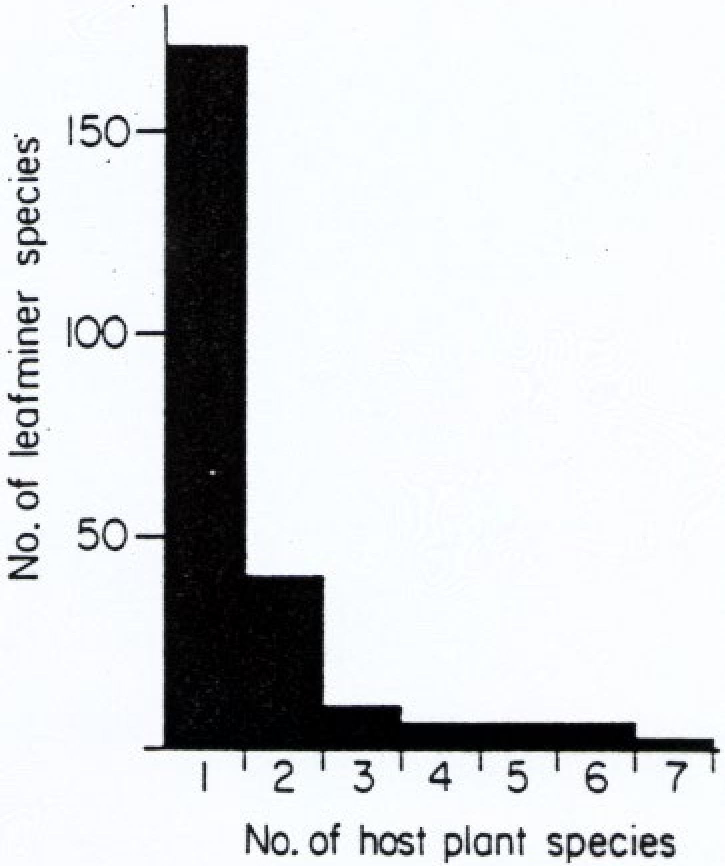
2A, 1B 

Jaenike, J. 1990. Annu. Rev. Ecol. Syst. 21:243-73

Multiple meaning of host specificity







Host specificity mostly relatively narrow in insects and wide in vertebrates

Fig. 3.18 Monophagy and polyphagy in insect herbivores. For mesophyll-feeding leaf-hoppers and leaf-miners on British trees most species are monophagous and there are few broad polyphages (Claridge & Wilson 1981). Vertebrates and larger, leaf-chewing insects tend to show much less pronounced monophagy.

Herbivores on aliens: Cytisus scoparius

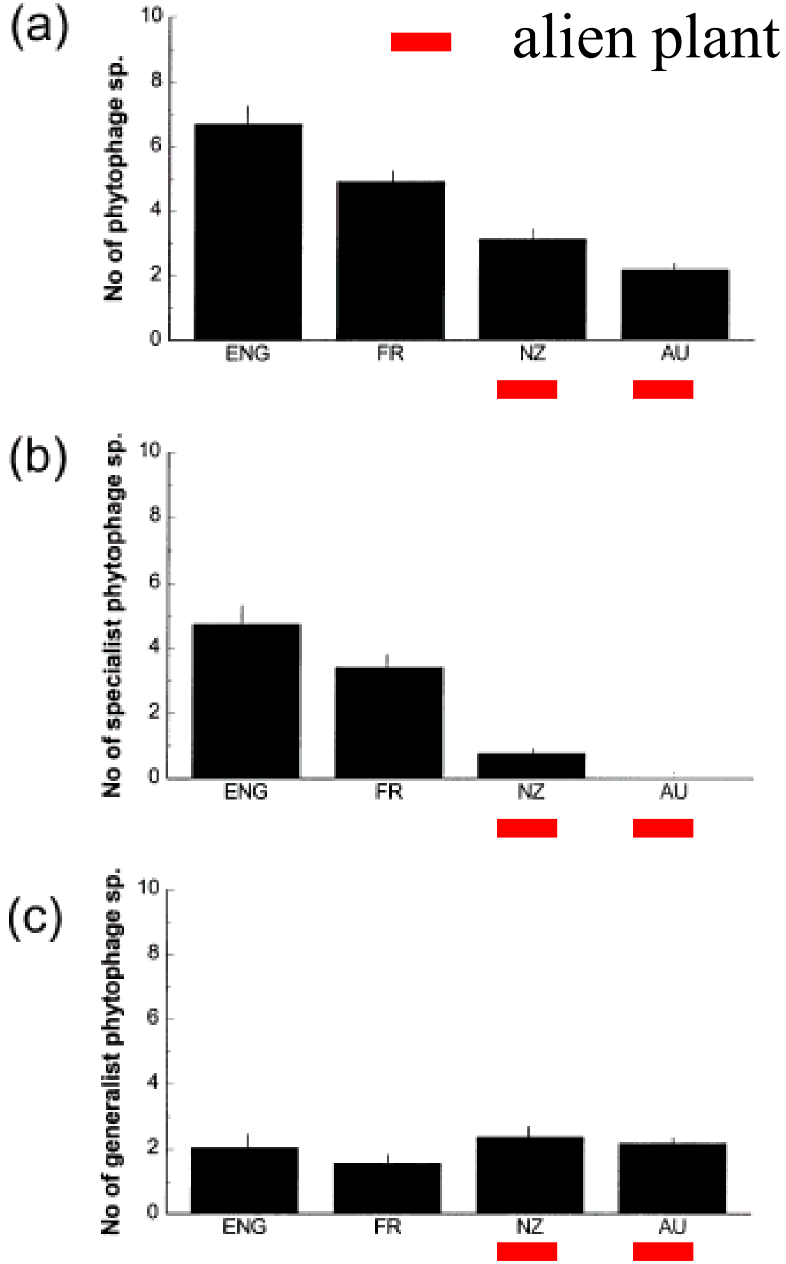


Figure 1. Average phytophage diversity per bush in the four countries: (a) total number of phytophage species; (b) specialist phytophage species; (c) generalist phytophage species. The bars show the standard error; ENG, England; FR, France; NZ, New Zealand; AUS, Australia.

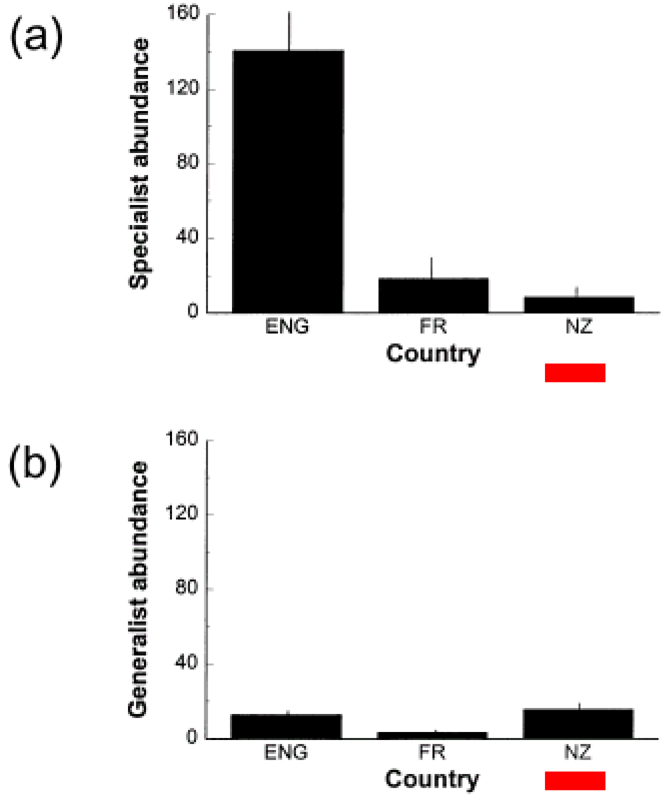
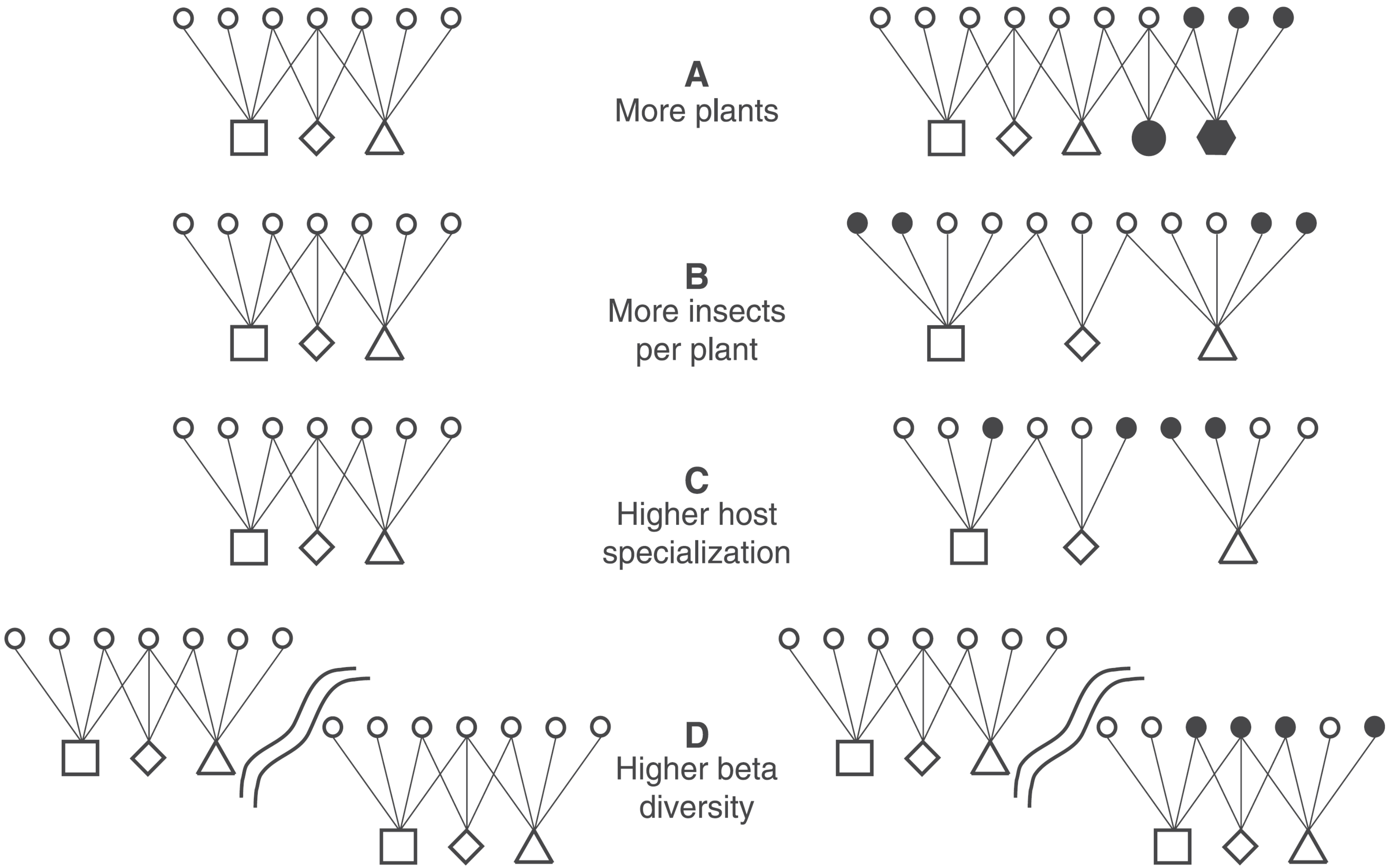


Figure 3. (a) The average abundance of specialist phytophages per bush in England, France and New Zealand and (b) the average abundance of generalist phytophages in England, France and New Zealand.

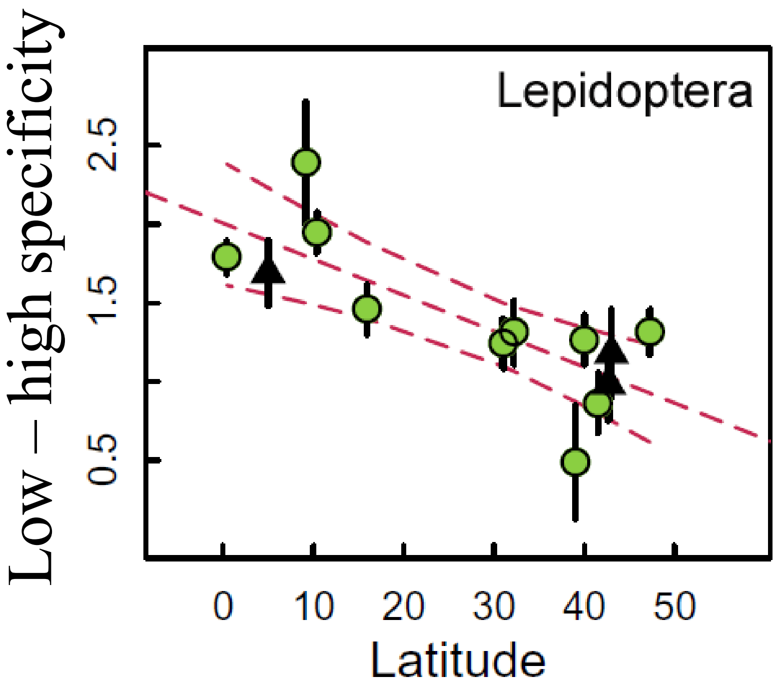
Memmott et al. 2000, Acta Oecol. 21:23

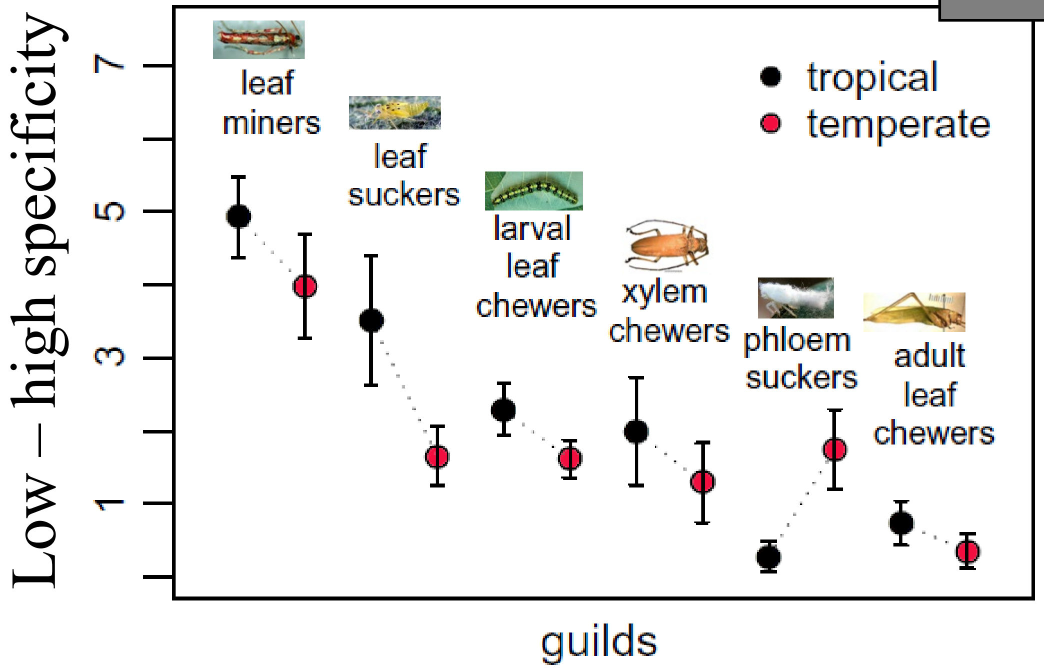
“Four ways towards tropical herbivore megadiversity”

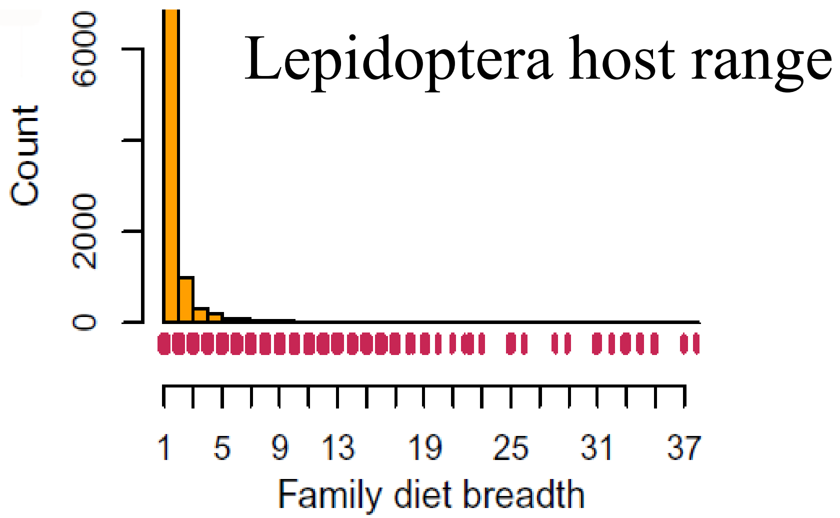


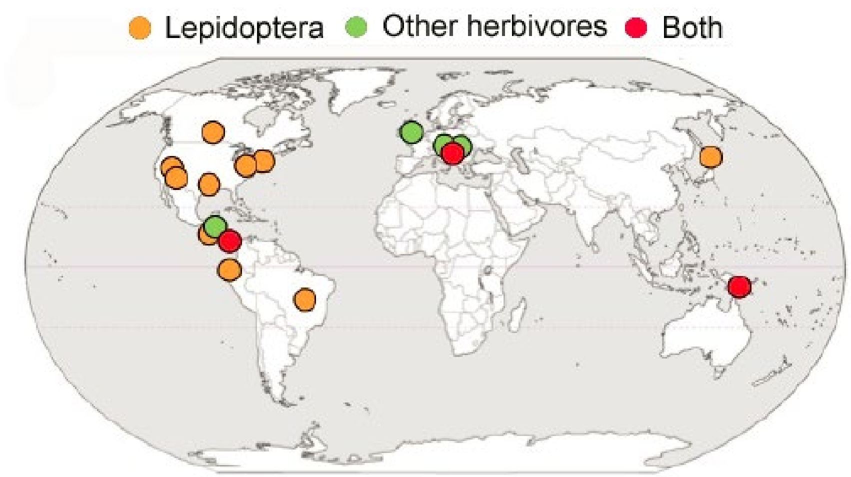
Lewinsohn and Roslin (2008)

Latitudinal gradients in host specificity: no plant standardization included







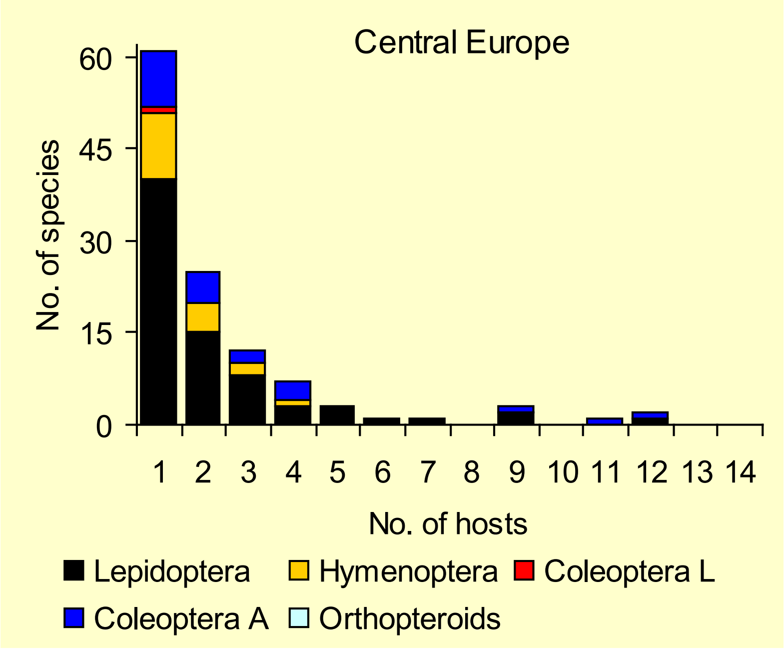


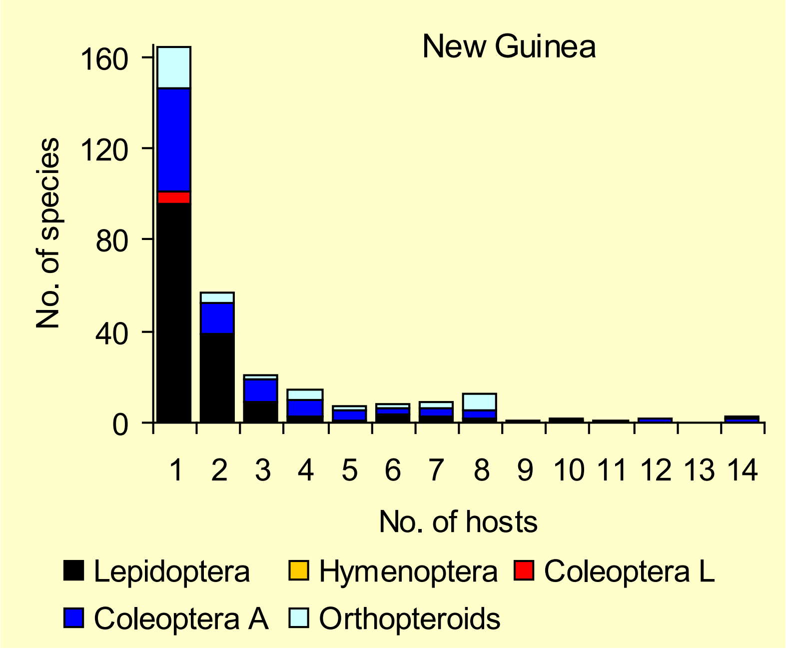
Standardising phylogenetic diversity among food webs along latitudinal gradients

Temperate trees

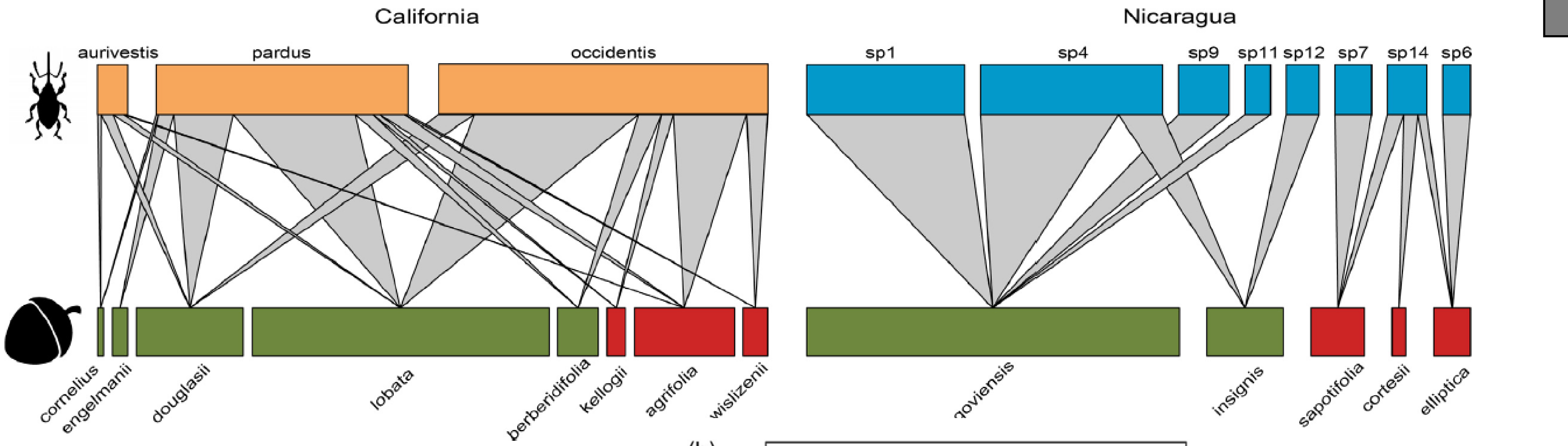
Tropical trees

Novotny et al. 2006, *Science* **313**:1115

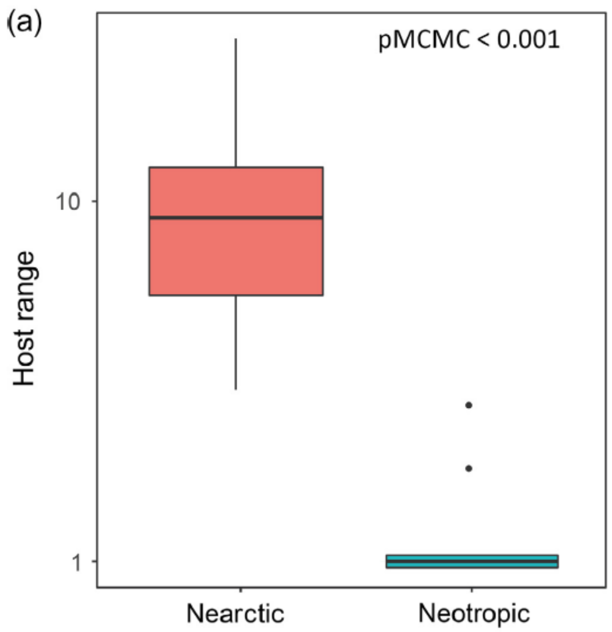


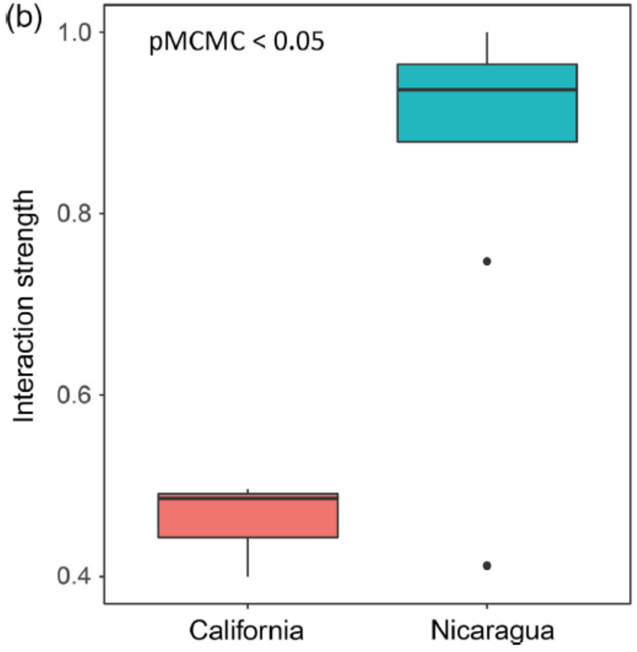


Higher host specificity in the tropics: a naturally standardized Curculio – Quercus system



Quantitative Quercus-Curculio trophic web for California and Nicaragua. Green and red color shows oak species affiliation to Quercus or Lobatae genus sections respectively



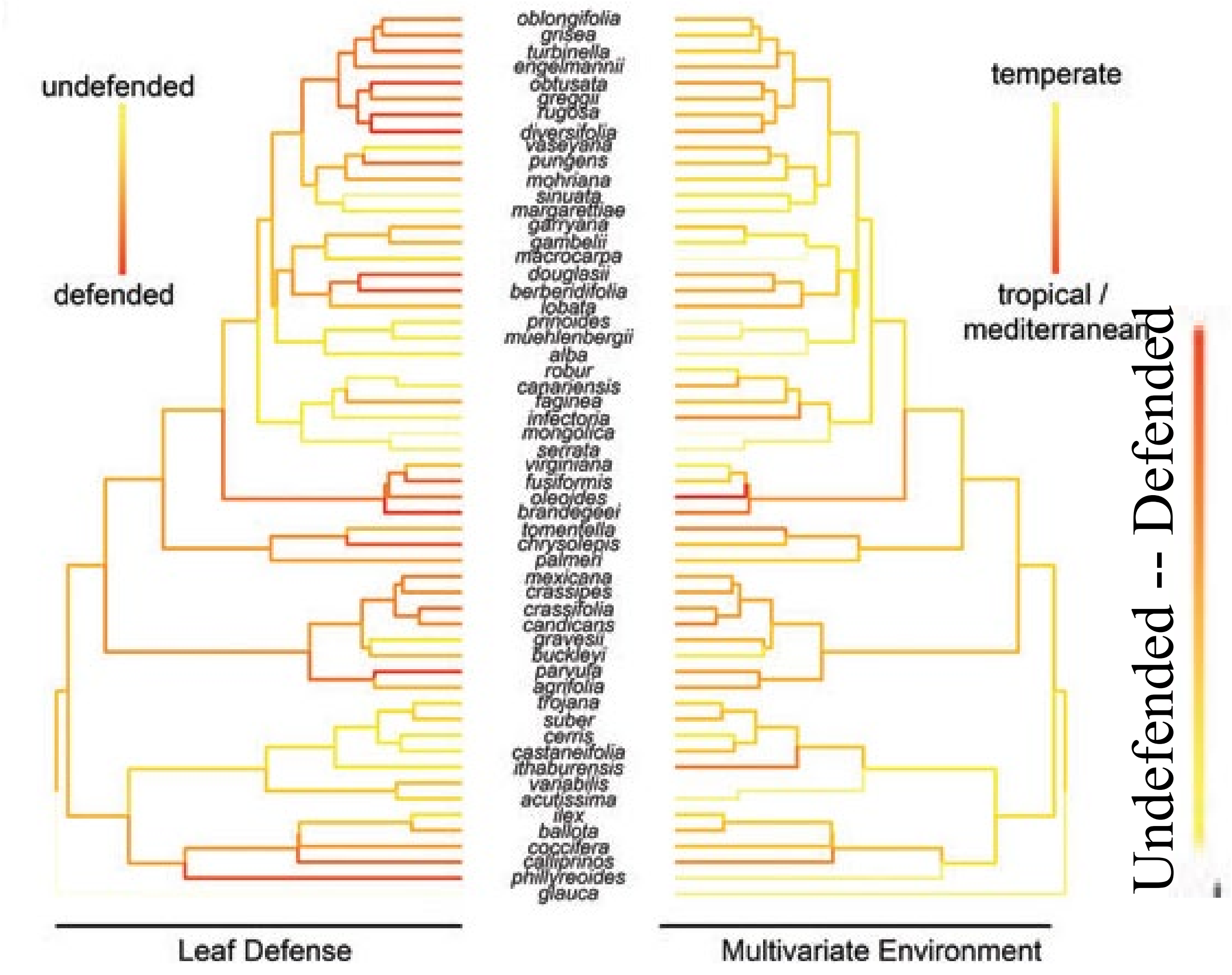


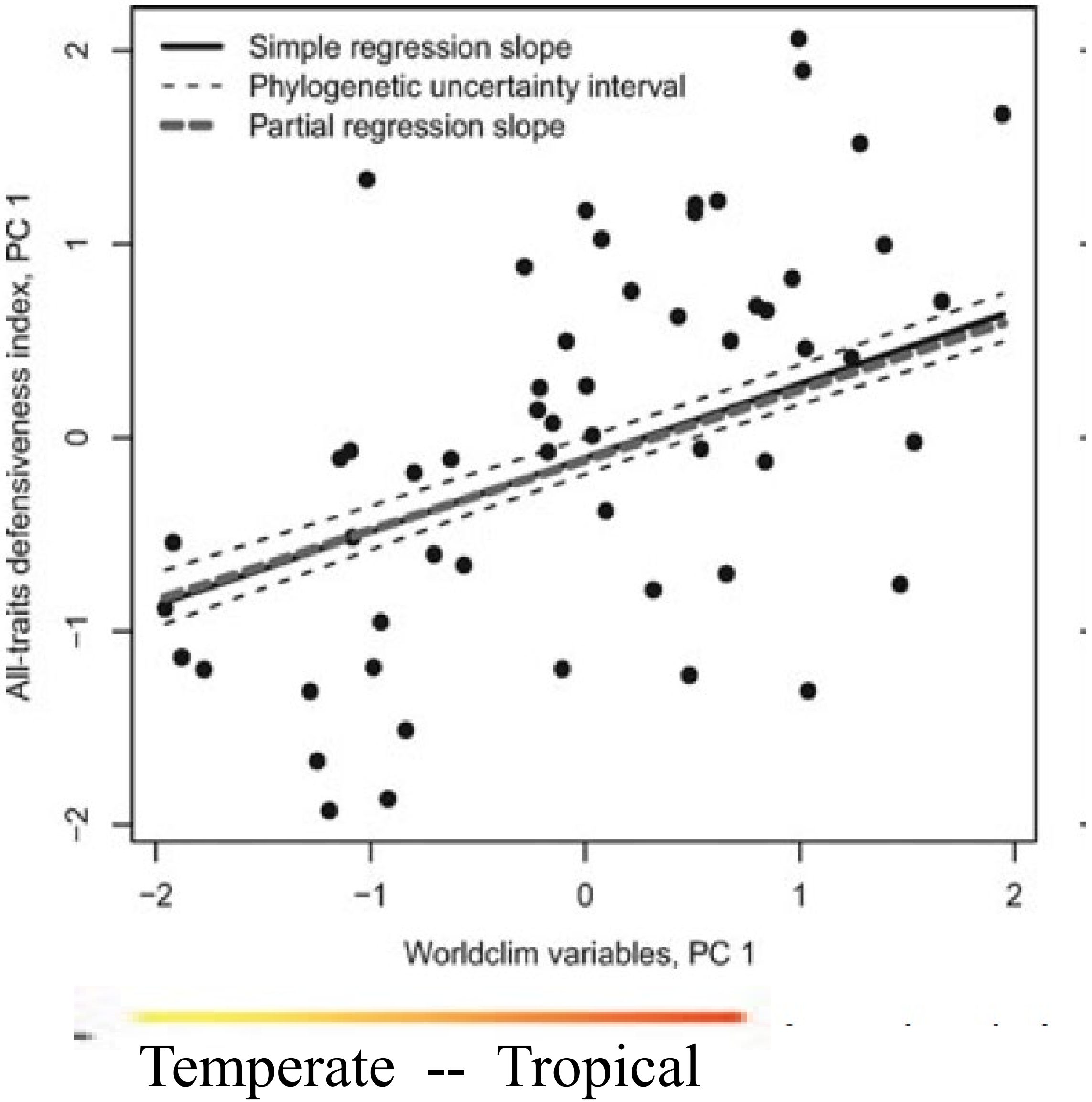
host range (a) and interaction strength (b) between weevil species (Curculio sp.) from California and Nicaragua. Host range = the number of oak hosts per weevil species, interaction strength = the number of larval emergences from the main host relative to all emergences

Peguero et al., Ecology, 98(8), 2017, pp. 2180

Oak leaf defenses:

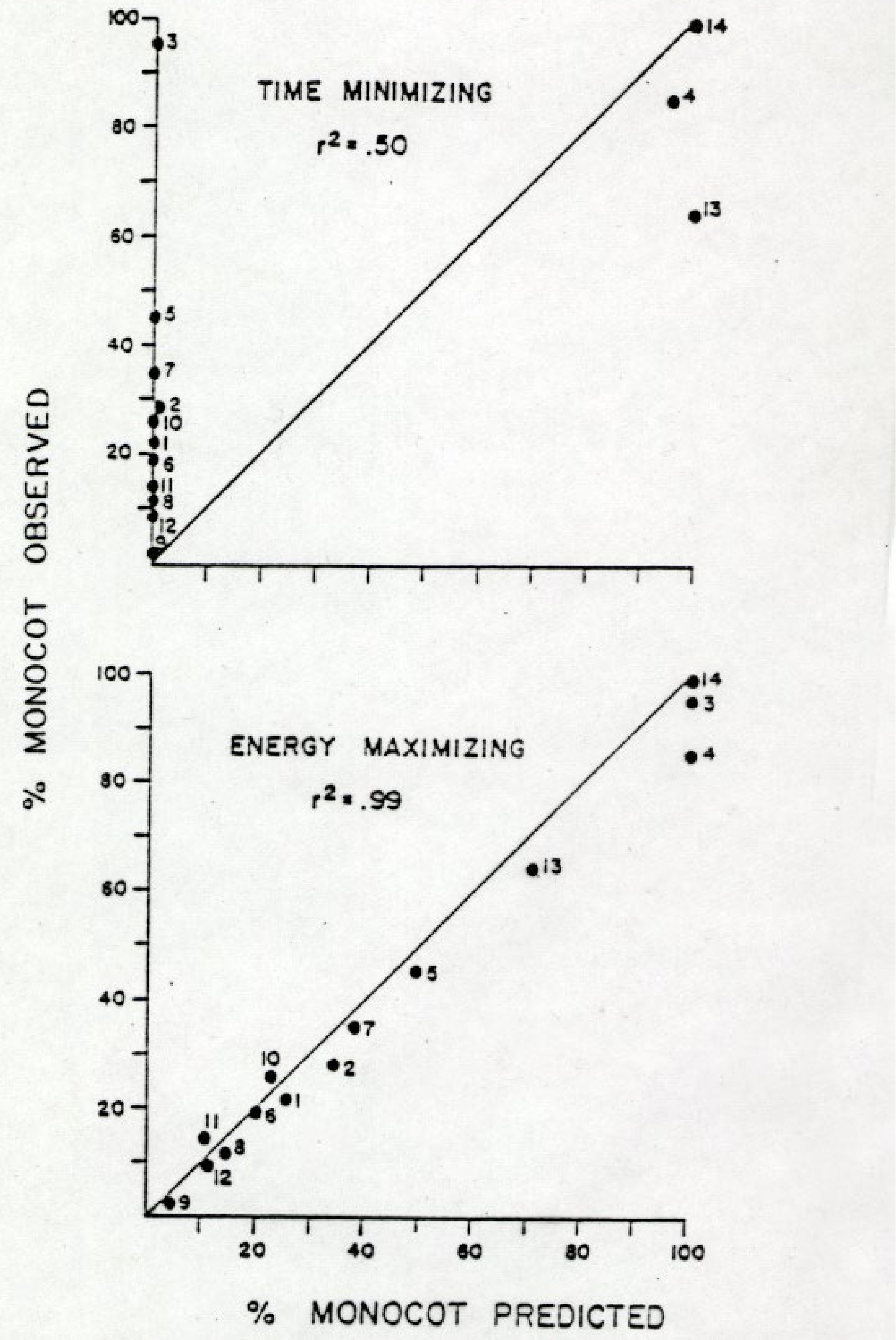
higher in the tropics, and this gradient follows the climate.





Pearse & Hipp, Evolution 2012

Vertebrate herbivores: mostly generalists, but with preferences



Generalists' plant choice: minimizing time or maximizing energy

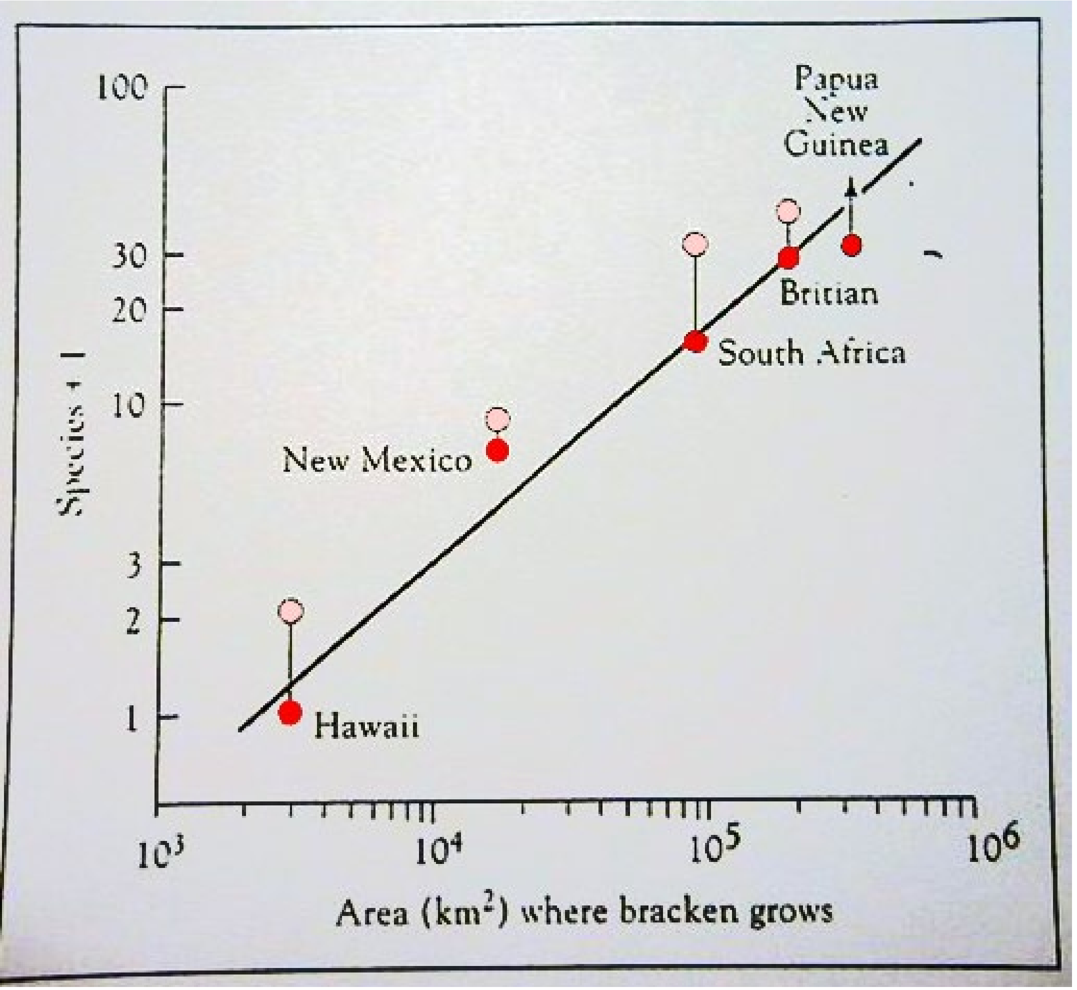
Fig. 3. The time-minimized and energy-maximized diets predicted by the linear programming model versus the observed diets are presented, demonstrating that time-minimizers are predicted to be either monocot or dicot specialists. The energy-maximizing diet explains the observed diets better. Each number represents a different species: 1 *Melanoplus femur-rubrum*, 2 *Melanoplus sanguinipes*, 3 *Circotettix undulatus*, 4 *Dissosteira carolina*, 5 *Microtus pennsylvanicus*, 6 *Spermophilus columbianus*, 7 *Sylvilagus nuttalli*, 8 *Marmota flaviventris*, 9 *Antilocapra americana*, 10 *Ovis canadensis*, 11 *Odocoileus virginianus*, 12 *Odocoileus hemionus*, 13 *Cervus canadensis* (or *elaphus*), and 14 *Bison bison*

And now for something completely different

Niche structure of herbivorous communities: ecological optimization or accidents of evolution?

Herbivores on bracken (*Pteridium aquilinum*):
replicated food web assemblage from different species pools

Regional species – area curve for bracken insects



Regional species pools vs. local communities

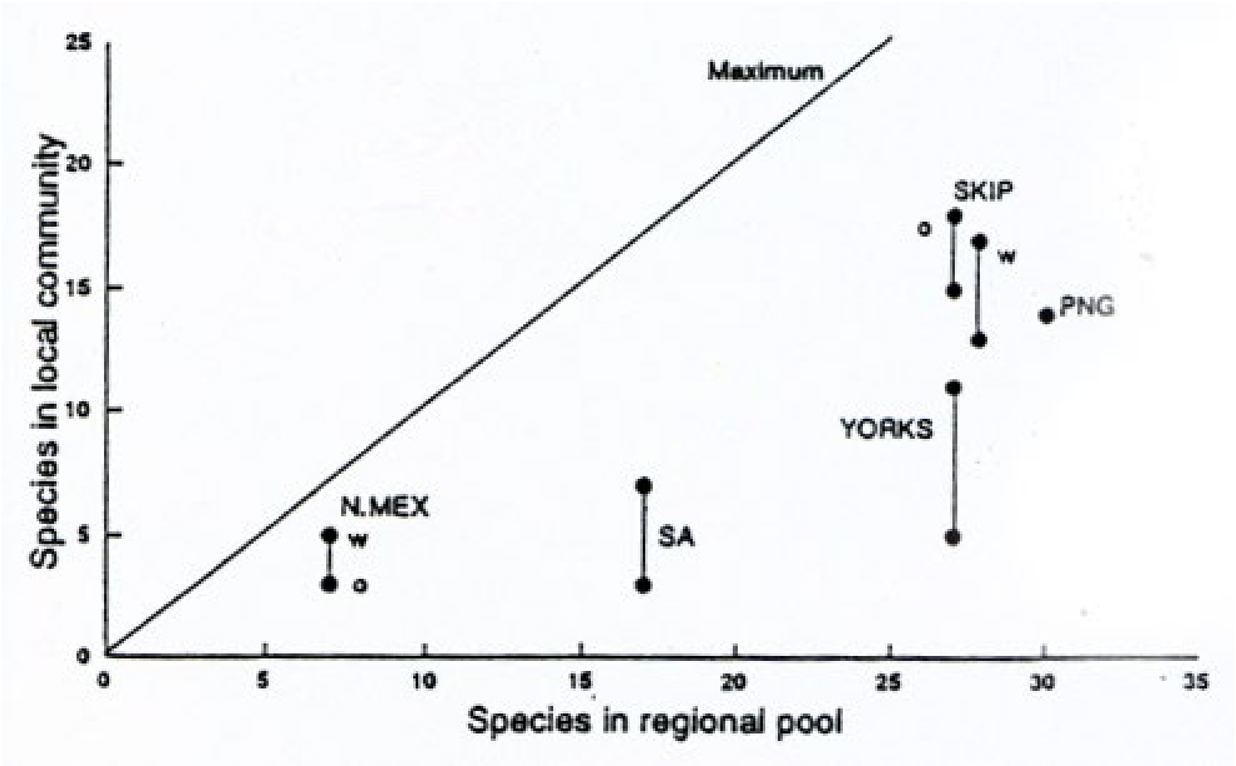
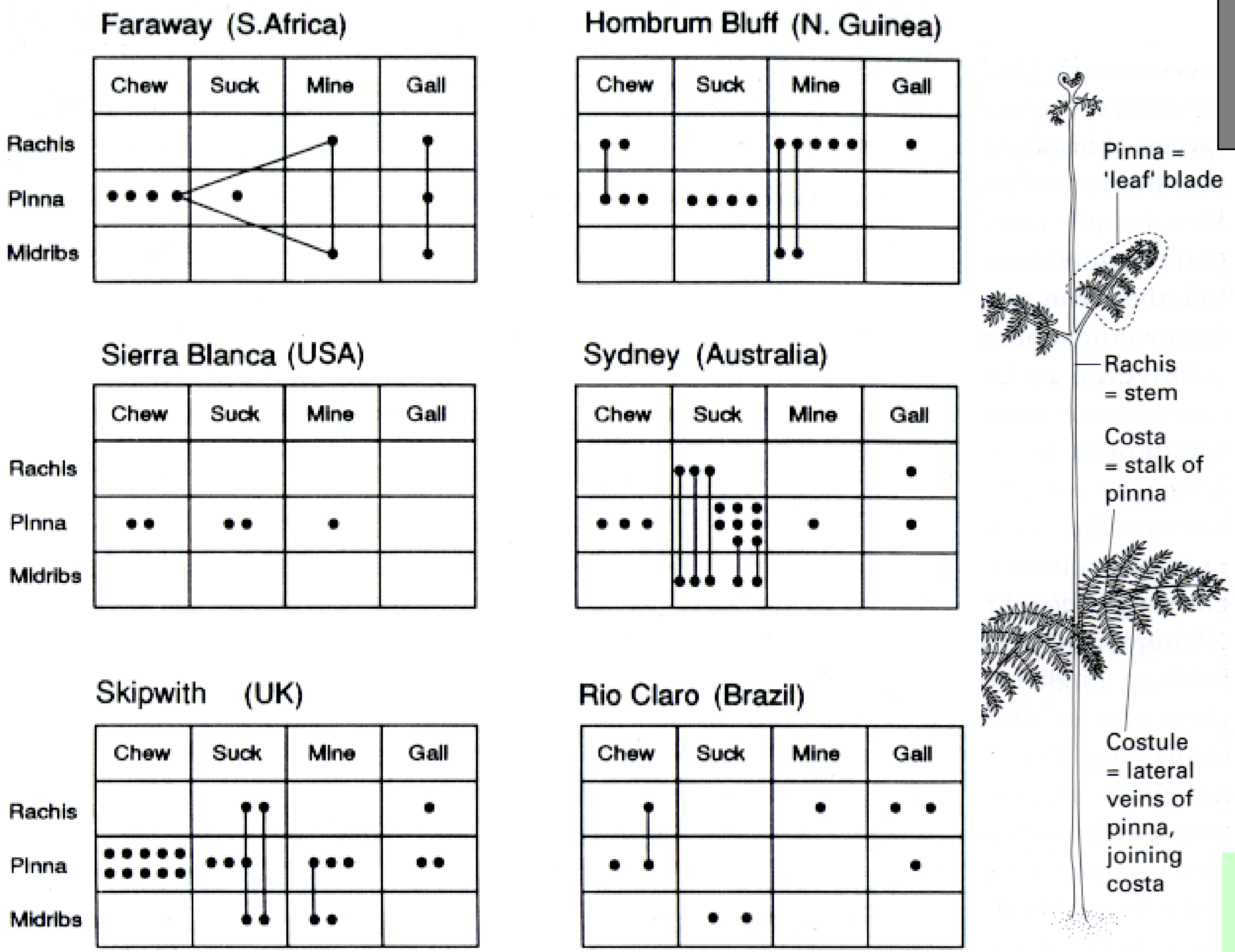
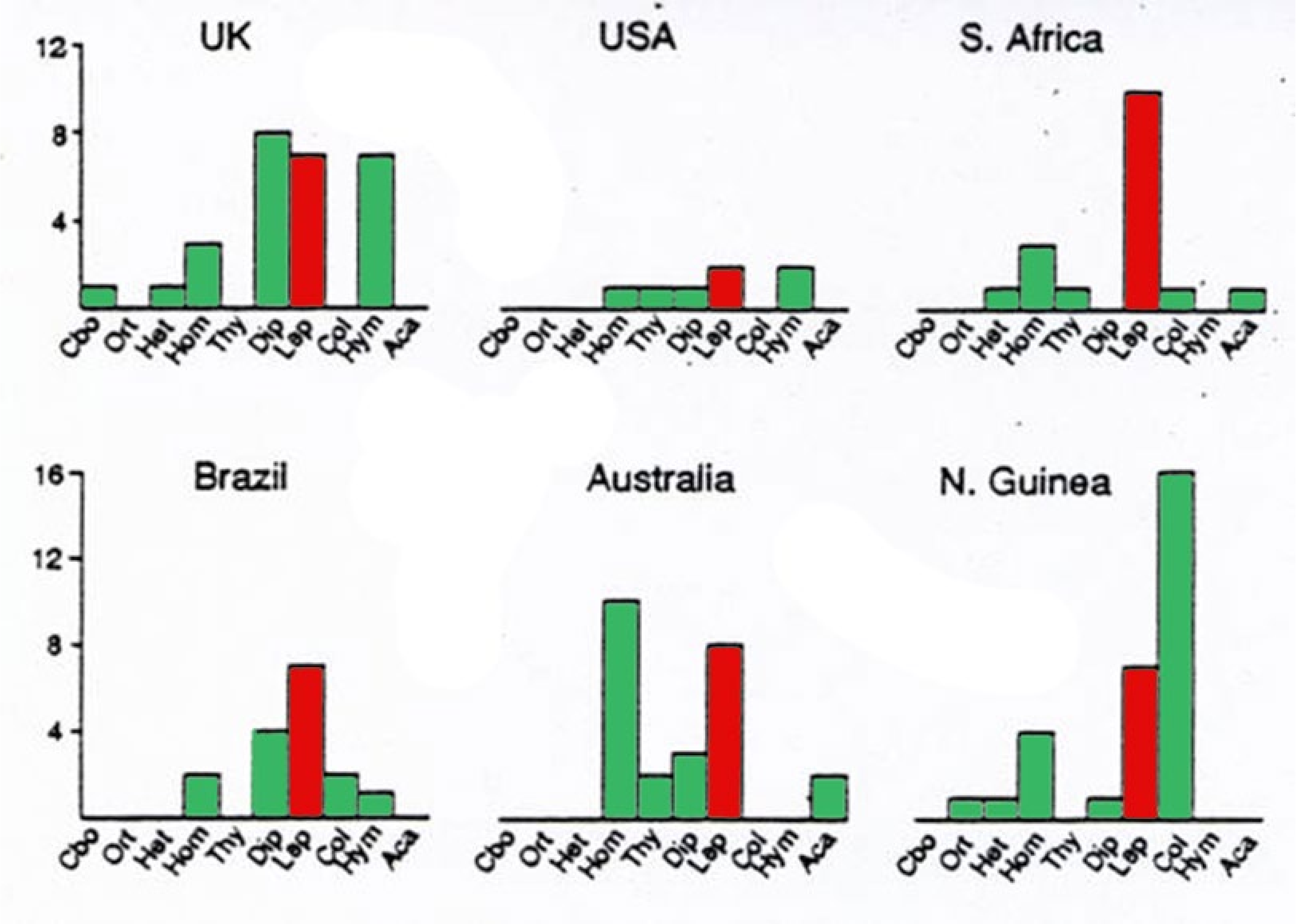


Figure 16.4 The relationship between local and regional species richness of herbivores feeding on bracken in different parts of the world. The "maximum" line has a slope of 1.

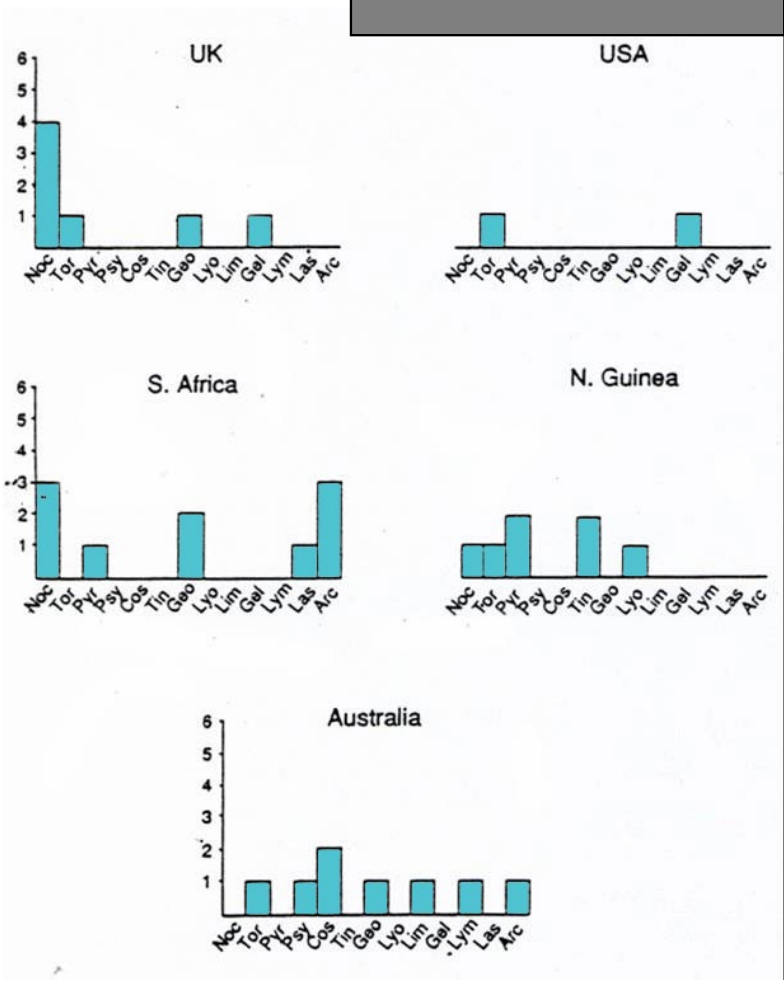
Community niche structure



Taxonomic composition of replicated herbivore communities on bracken



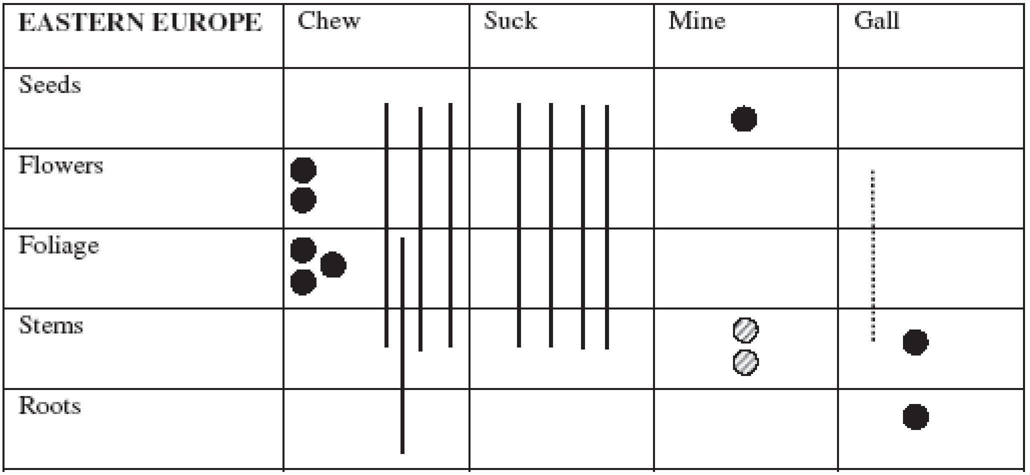
Cbo - Colembolla, Ort - Orthoptera, Het - Heteroptera, Hom - Homoptera, Thy - Thysanoptera, Dip - Diptera, Lep - Lepidoptera, Col - Coleoptera, Hym - Hymenoptera, Aca - Acarina

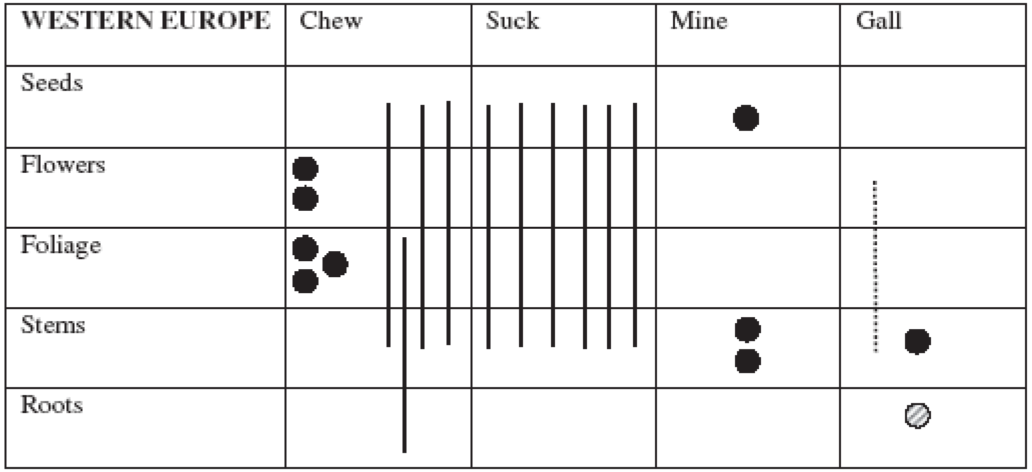


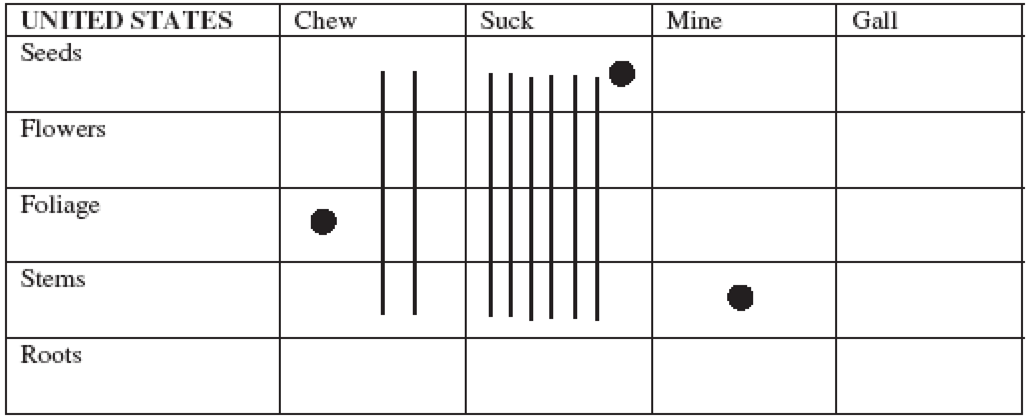
Noctuidae, Tortricidae, Pyralidae, Psychidae, Cosmopterigidae, Tineidae, Geometridae, Lyonettidae, Limacodidae, Gelechiidae, Lymantriidae, Lasiocampidae, Arctiidae

Figure 16.1 Taxonomic composition of the arthropod assemblages feeding on bracken in different parts of the world. Abbreviations:

Figure 16.2 The families of Lepidoptera with species that feed on bracken in different parts of the world. Abbreviations: *Noc*, Noctui... dae; *Tor*, Tortricidae; *Pyr*, Pyralidae; *Psy*, Psychidae; *Cos*, Cosmop... terigidae; *Tin*, Tineidae; *Geo*, Geometridae; *Lyo*, Lyonetiidae; *Lim*... Limacodidae; *Gel*, Gelechiidae; *Lym*, Lymantriidae; *Las*, Lasiocam... pidae; *Arc*, Arctiidae. Data sources as in figure 16.1.

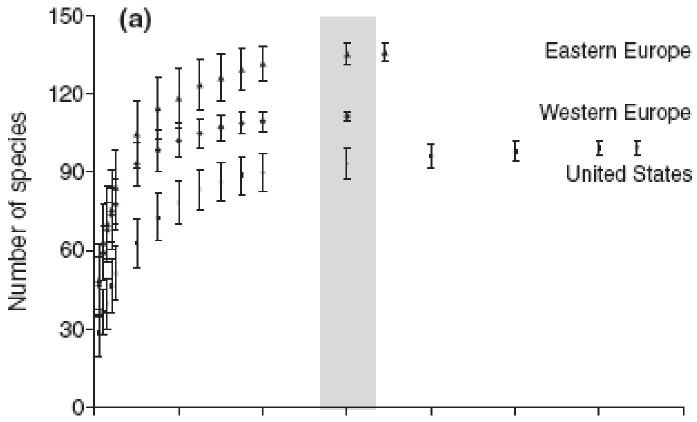


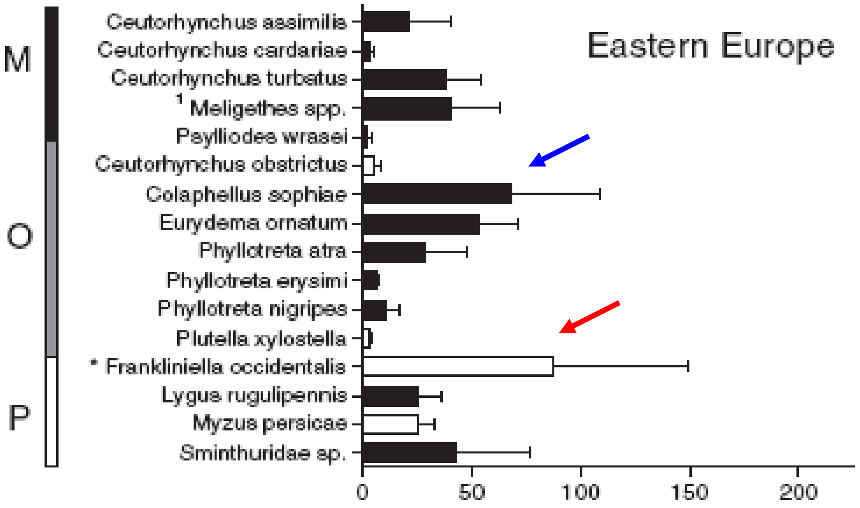


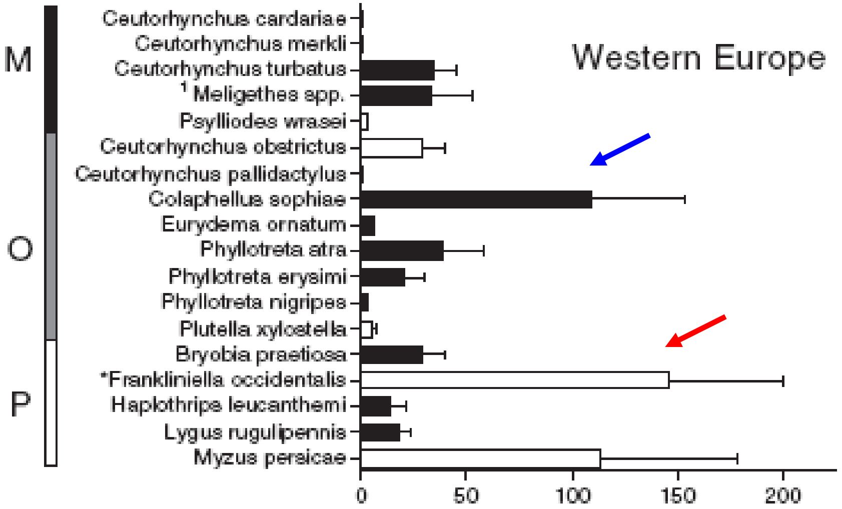


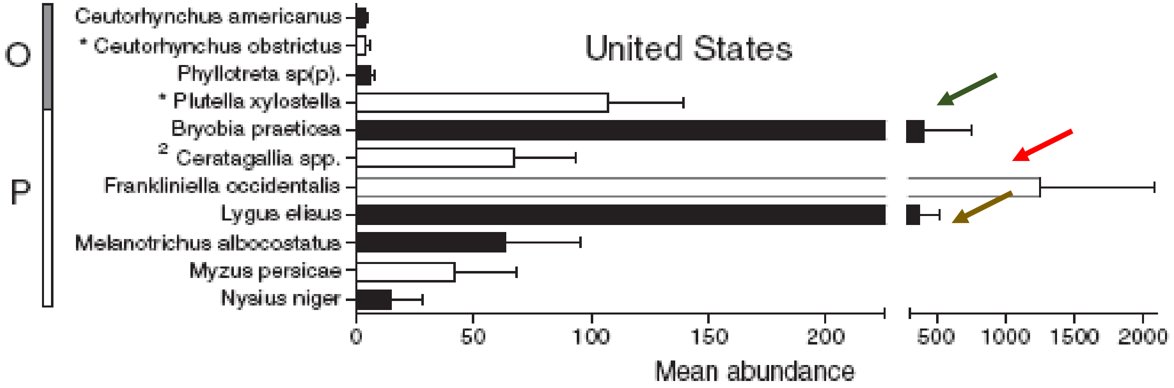
Biogeographical comparison of the arthropod herbivore communities associated with *Lepidium draba* in its native, expanded and introduced ranges

Michael G. Cripps[1*], Mark Schwarzländer[1], Jessica L. McKenney[1], Hariet L. Hinz[2] and William J. Price[3]



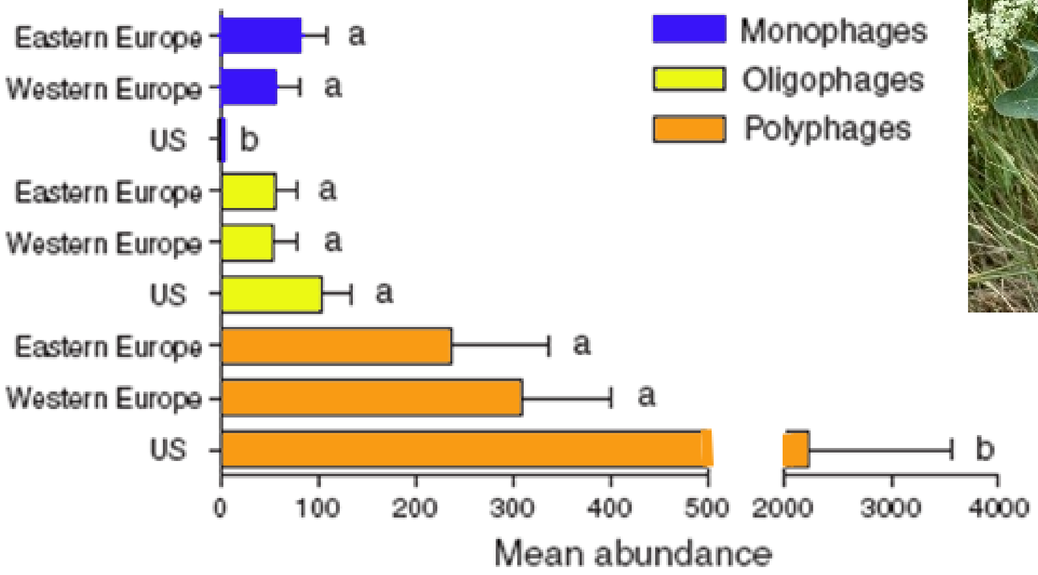






Frankliniella occidentalis ●

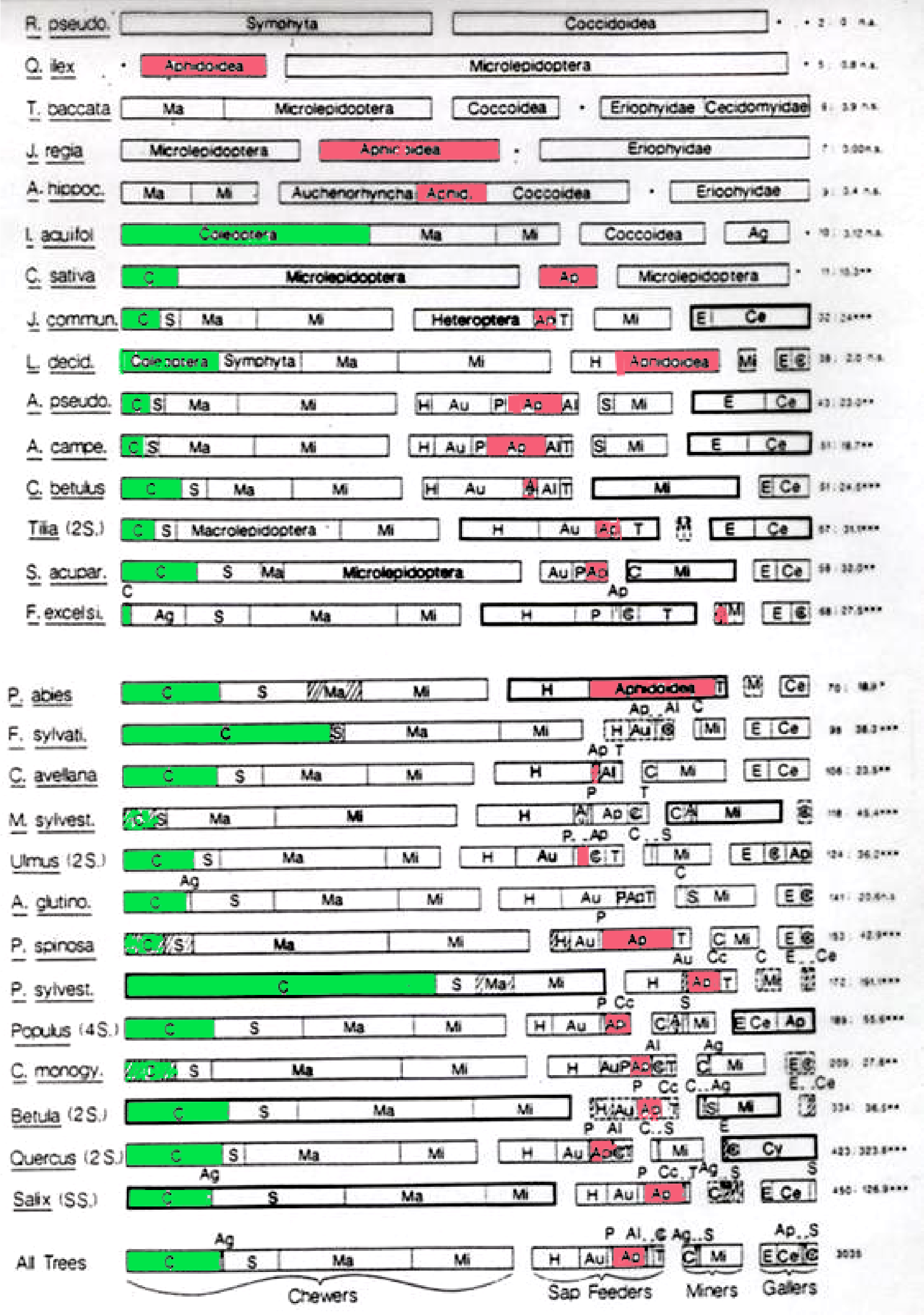
Colaphellus sophiae ●



Bryobia praeticea ●

Lygus elisus ●

Figure 2 Core species (see text for details) and their respective mean (± SE) abundances for each range surveyed in 2003. White bars indicate species that occurred in all three ranges. Species in each range are grouped according to feeding specialization (M, monophages; O, oligophages; P, polyphages).

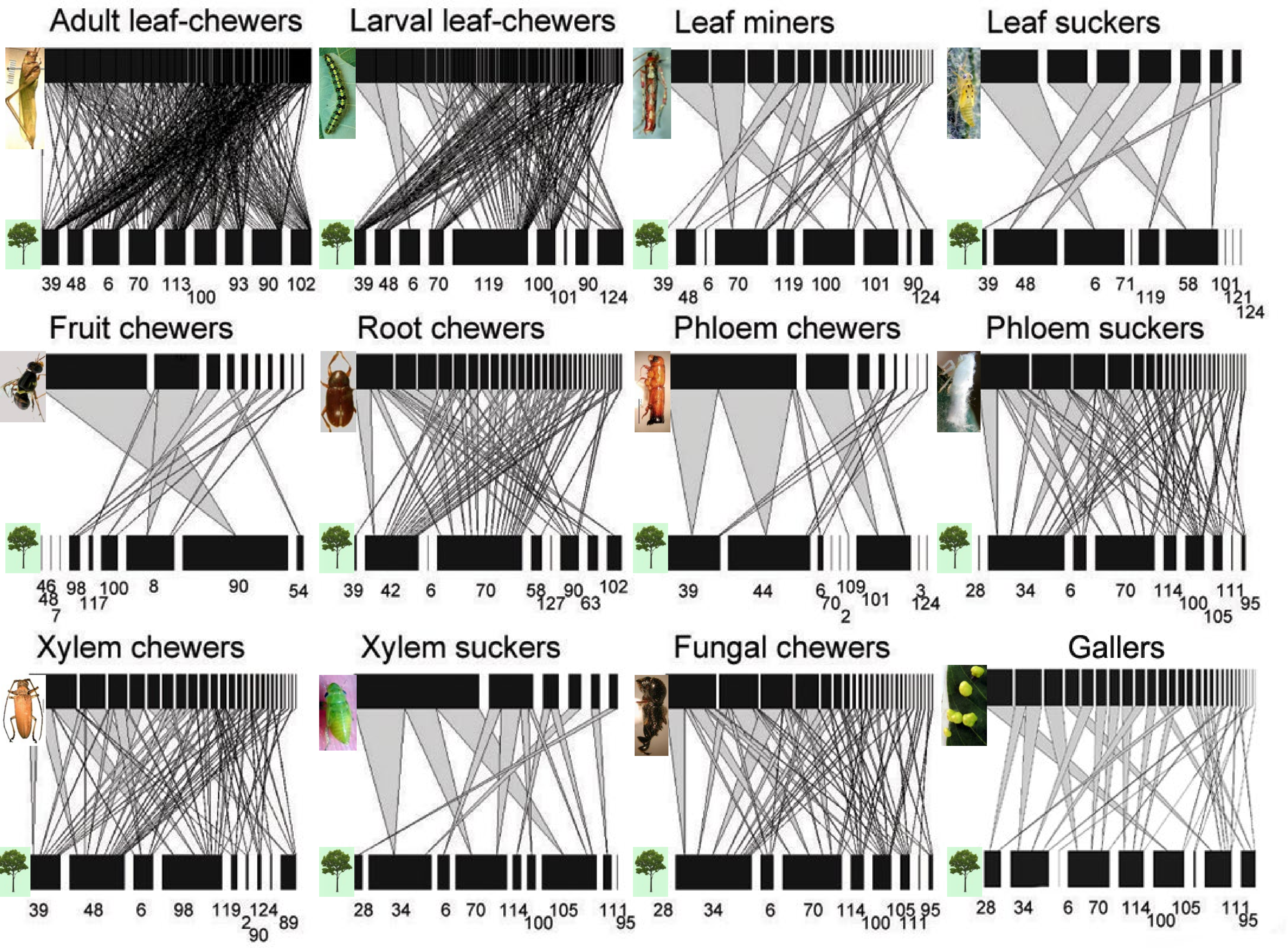


Herbivore guild structure:

- is it predictable?
- is there between-guild compensation?

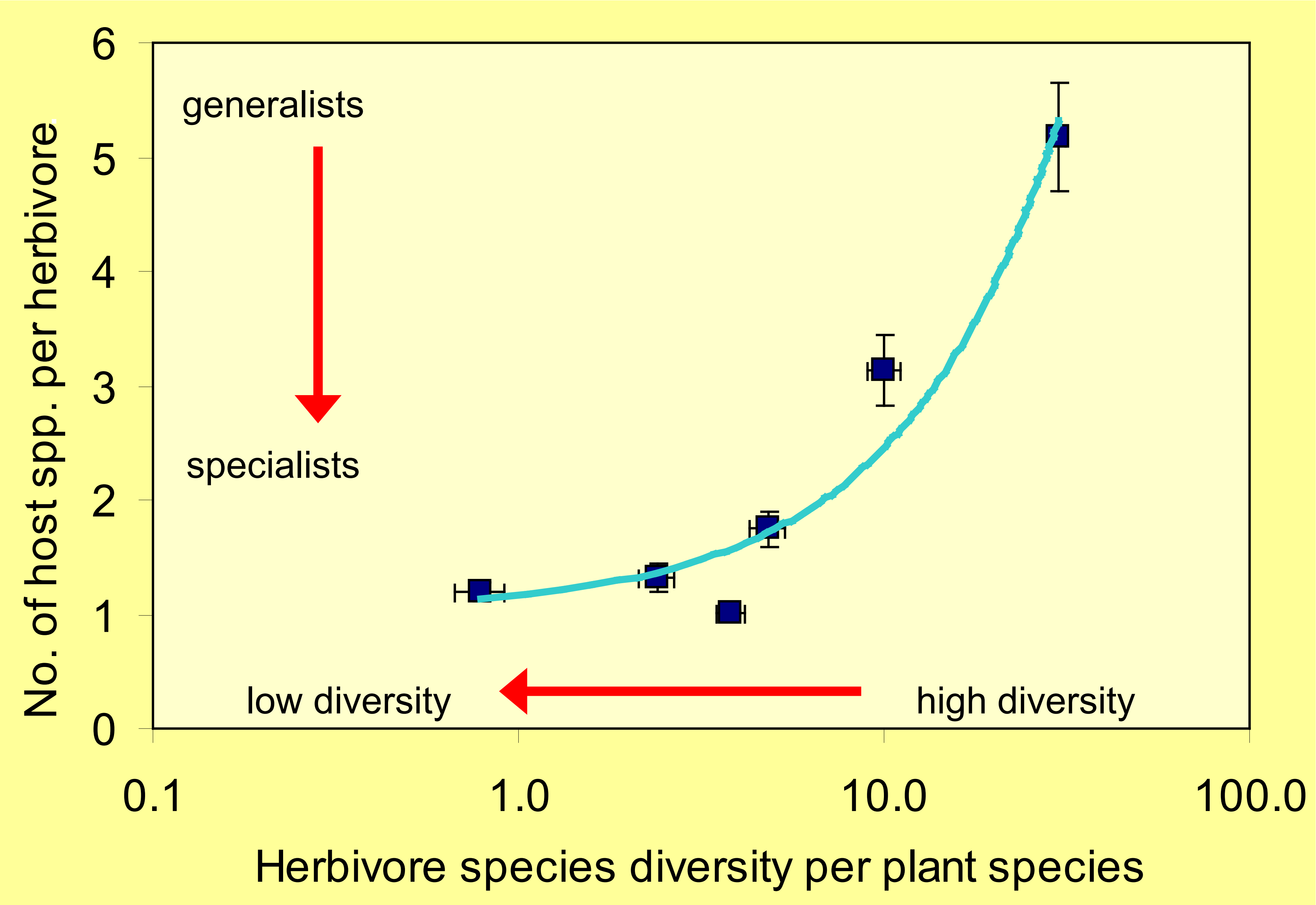
beetles and **aphids** highlighted just to illustrate general point of variability in guild composition among host tree species

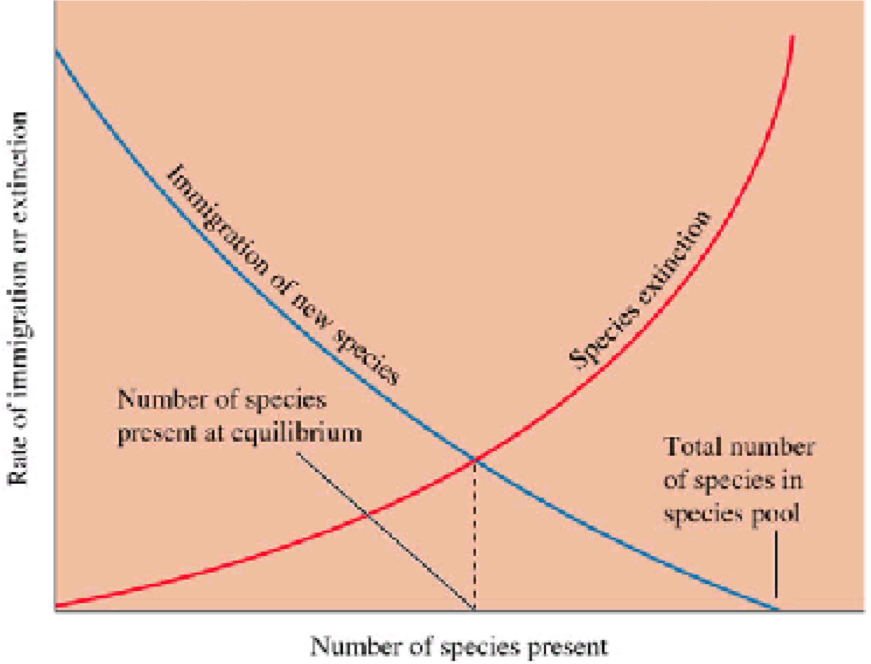
Figure 22.4 Guild and taxonomic spectra for the herbivorous arthropods on British tree species. Each guild spectrum is represented by four bars separated by spaces; the lengths of the bars indicate the proportion of each guild on each tree. Asterisks indicate guilds missing on a tree. The bars are subdivided, and each subdivision indicates the proportion of each guild represented by a particular arthropod taxon. *Ag*, Agromyzidae; *Al*, Aleyrodoidea; *Ap*, Aphidoidea; *Au*, Auchenorhyncha; *C*, Coleoptera; *Cc*, Coccidoidea; *Ce*, Cecidomyidae; *Cy*, Cynipoidea; *E*, Eriophyidae; *H*, Heteroptera; *Ma*, Macrolepidoptera; *Mi*, Microlepidoptera; *P*, Psylloidea; *S*, Symphyta; Thysanoptera. Thick-walled and dash-walled bars are over- and u dersized guilds respectively. Shaded and cross-hatched subdivisio are over- and undersized taxa respectively. Numbers at right marg are the total number of herbivores species on each tree and the ch square values for the goodness-of-fit tests of each individual tr spectrum to the standard spectrum (all trees). $^{*}P < .05$, $^{**}P < .0$ $^{***}P < .001$. (From Cornell and Kahn 1989; by permission Blackwell Scientific Publications, Ltd.)



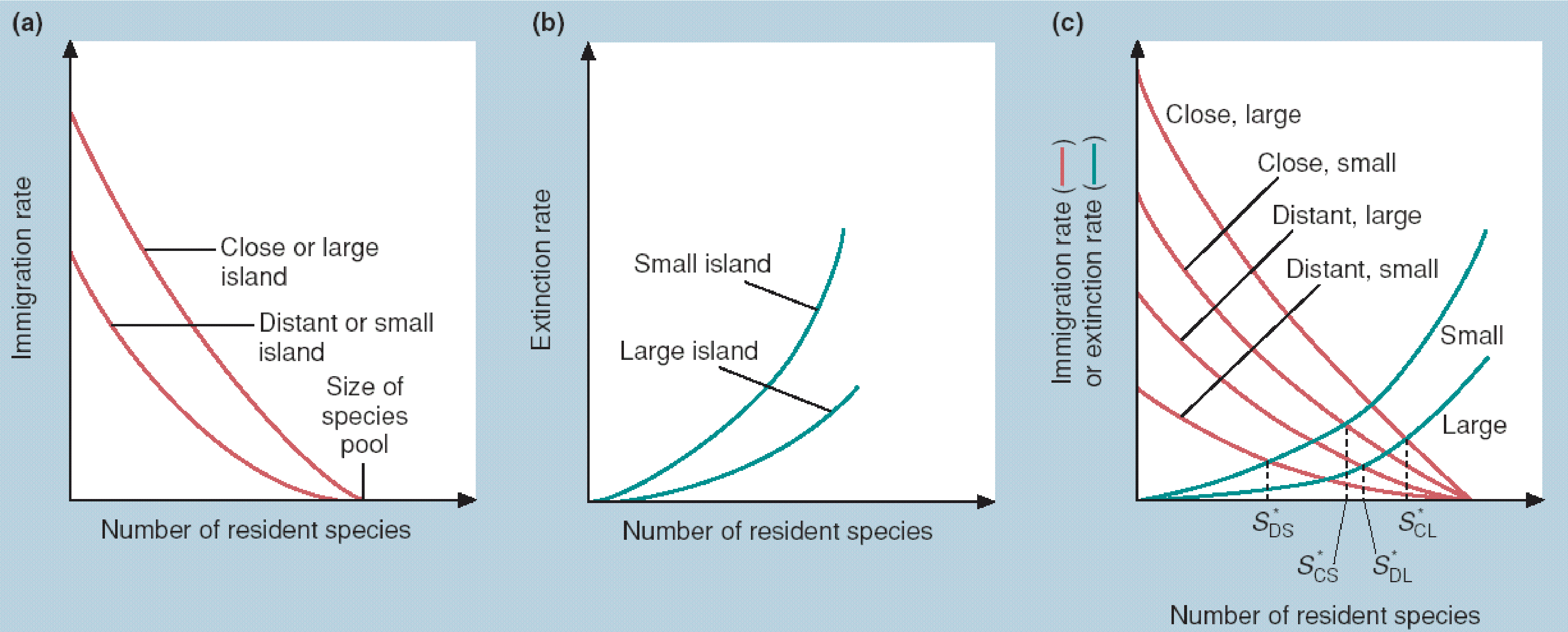
Guilds differ in their host specialization

Specialized guilds tend to be species poor

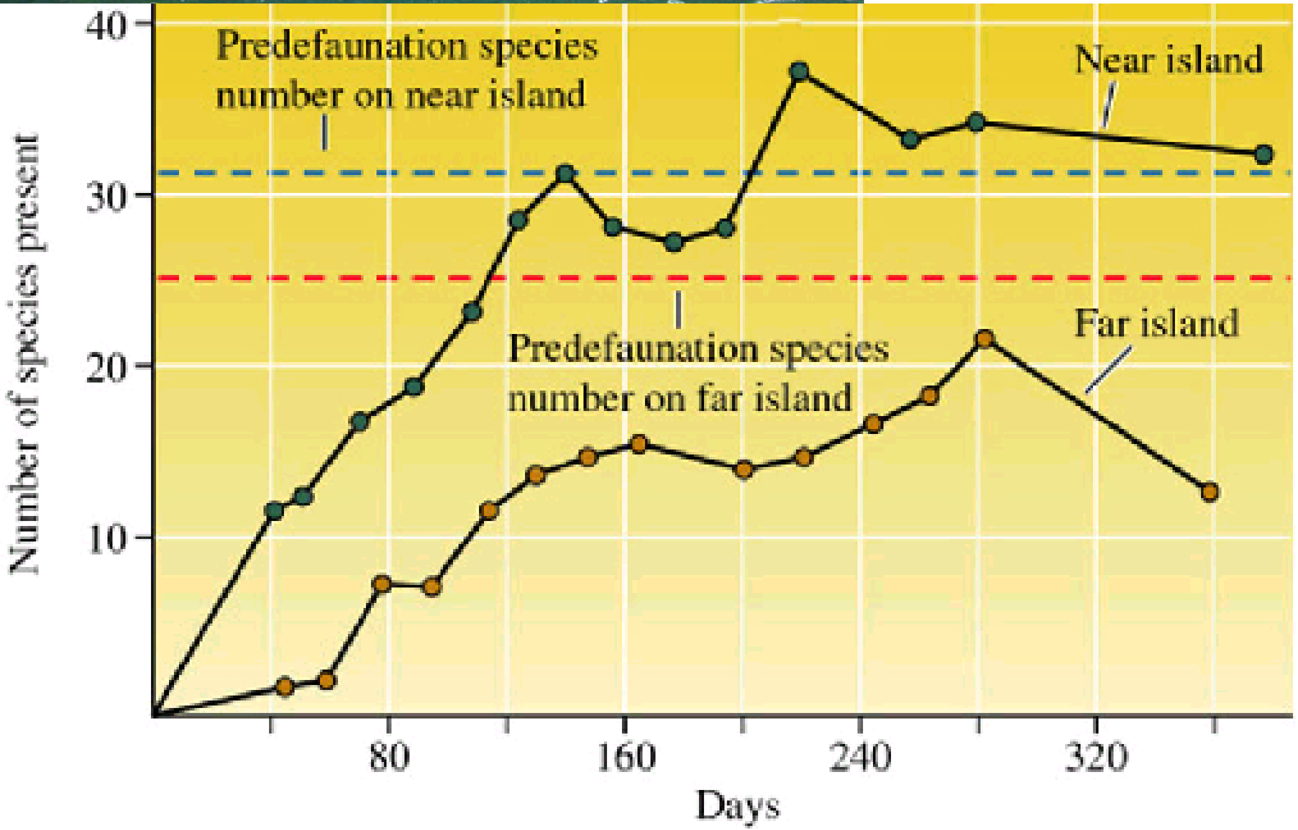




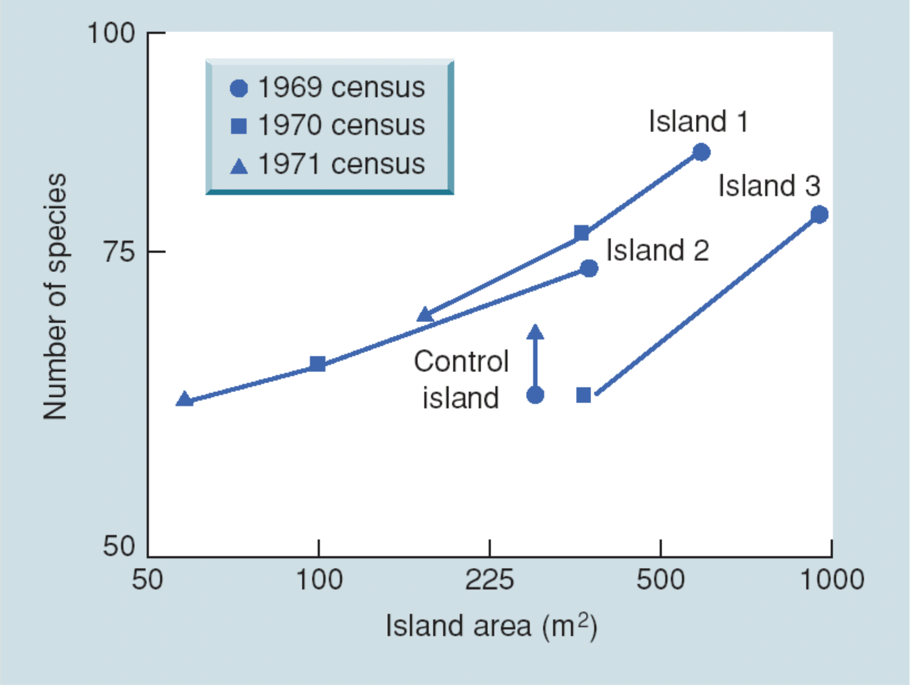
Island biogeography: trees are “habitat islands”



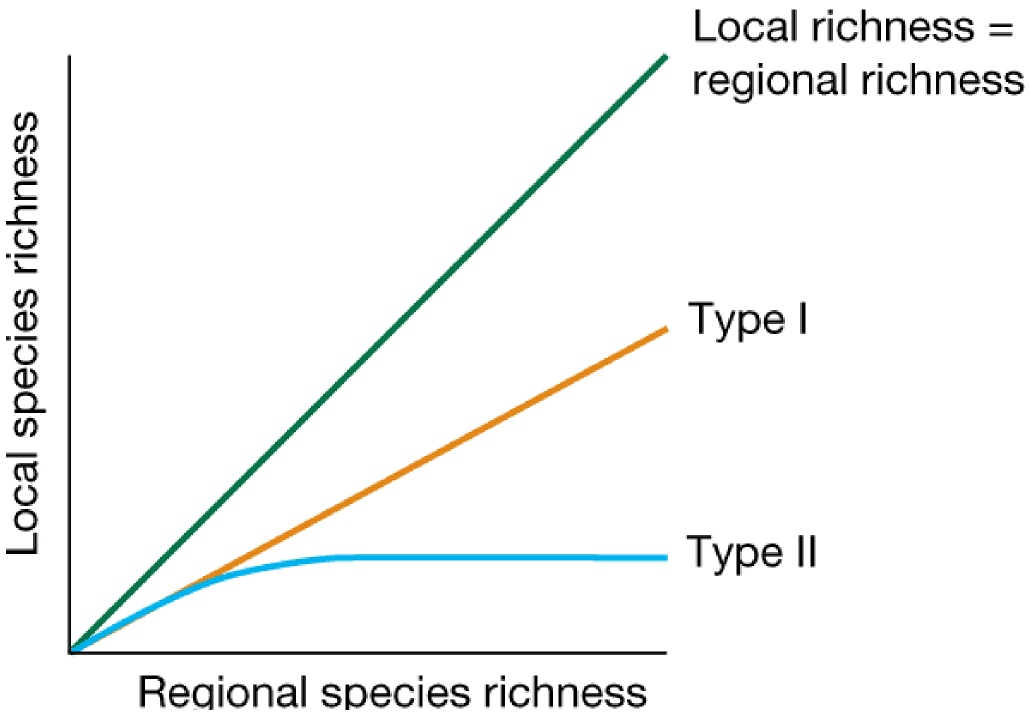
Wilson and Simberloff (1970): experimental tests of the theory, monitoring arthropod immigration and extinction after complete defaunation of small mangrove islands offshore Florida

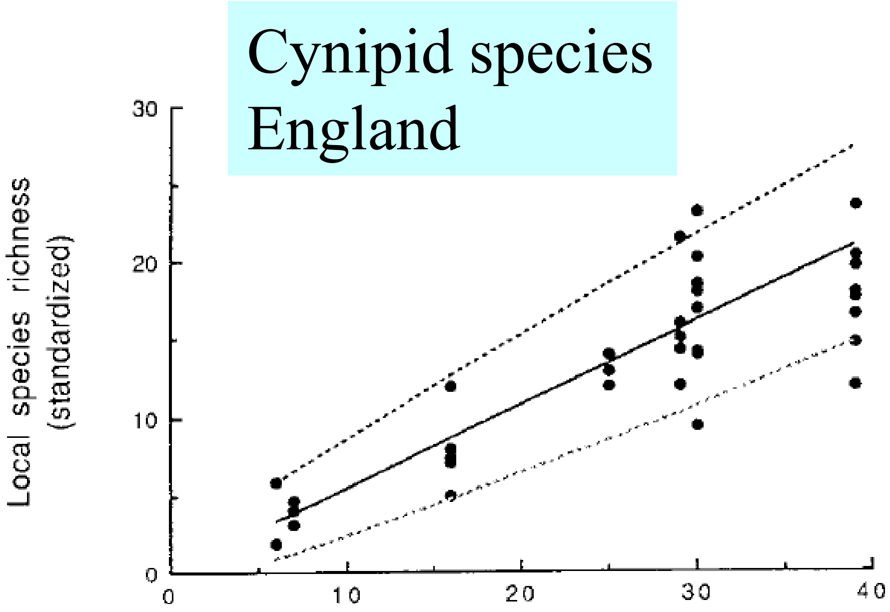


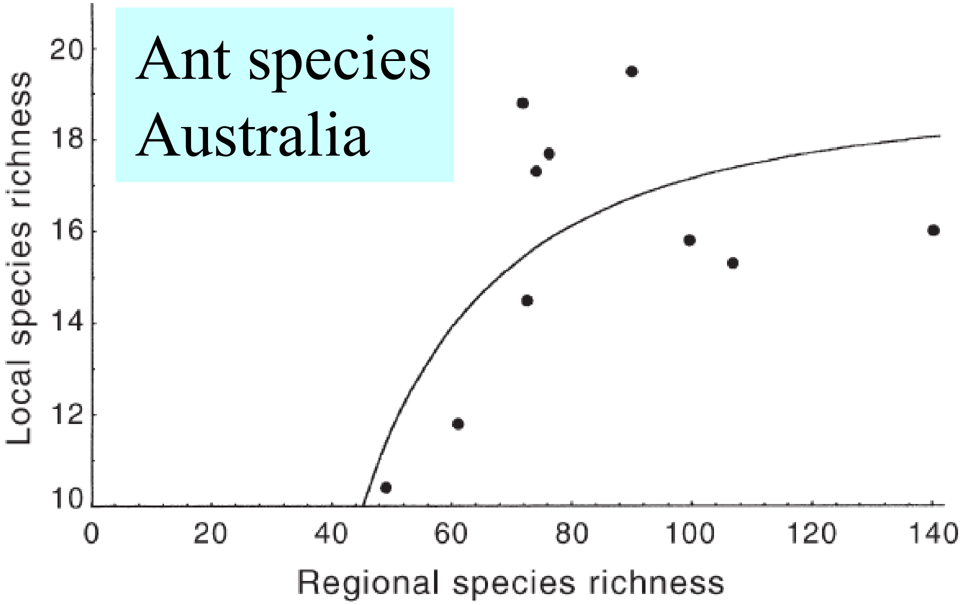
Experimental test of the effect of island area on species richness



Assembly of local communities from regional species pool

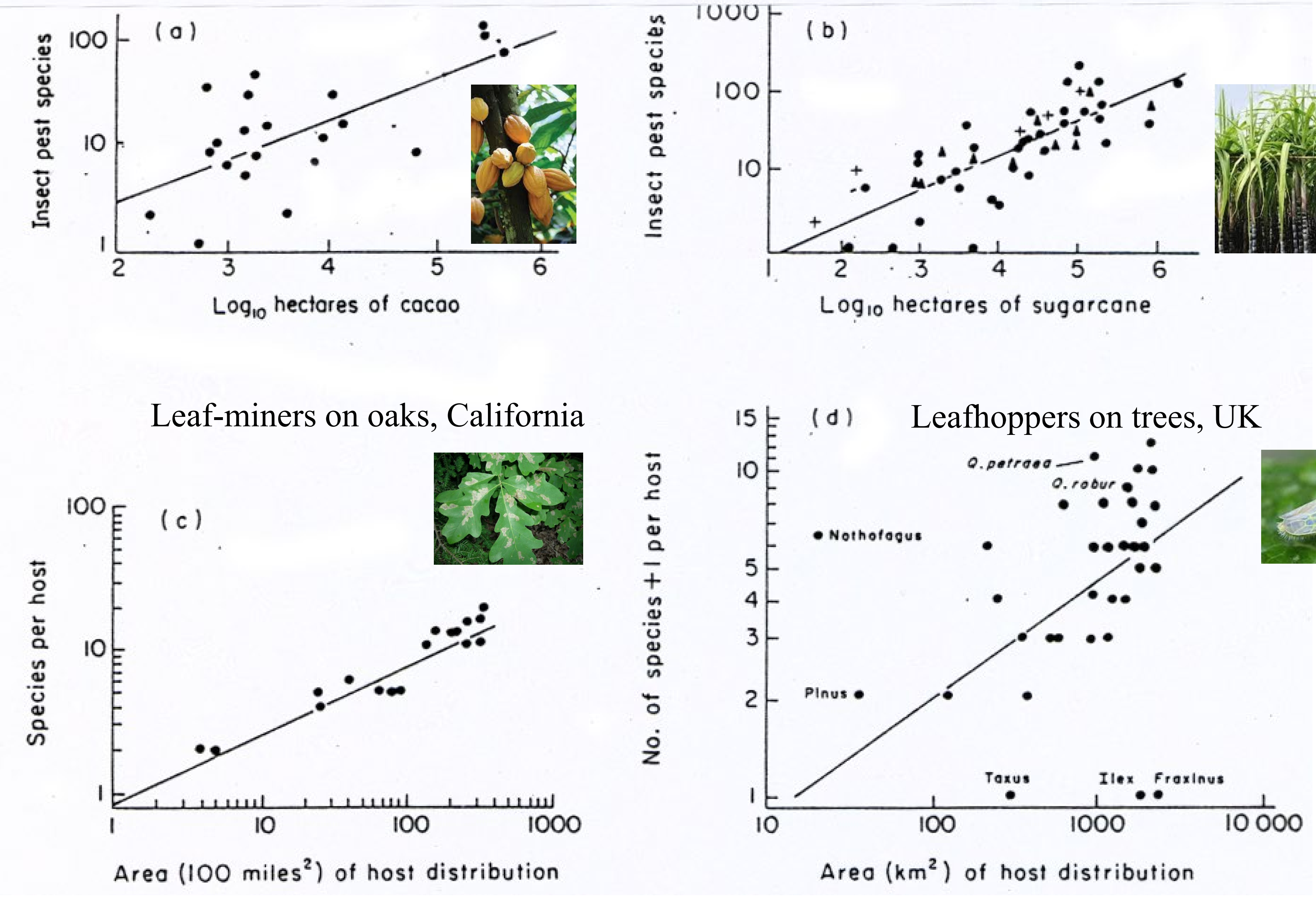






Hugueny & Cornell 2000
Soares et al. 2001

Species richness of herbivore communities: determined by plant abundance



same plant host
different locations

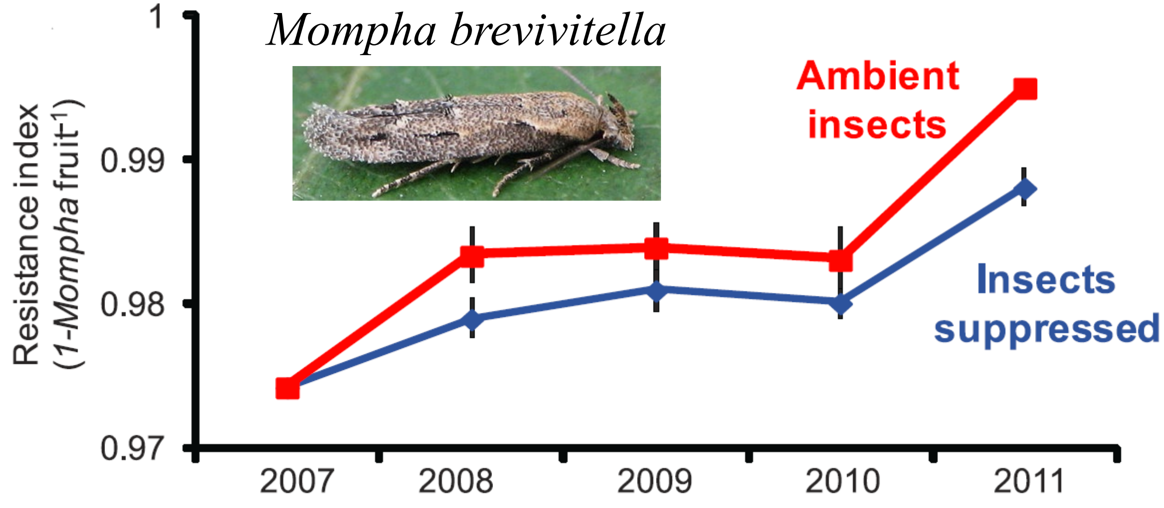
same geographic location
different host species

Plant evolution in real-time: changes after insect exclusion for 5 years

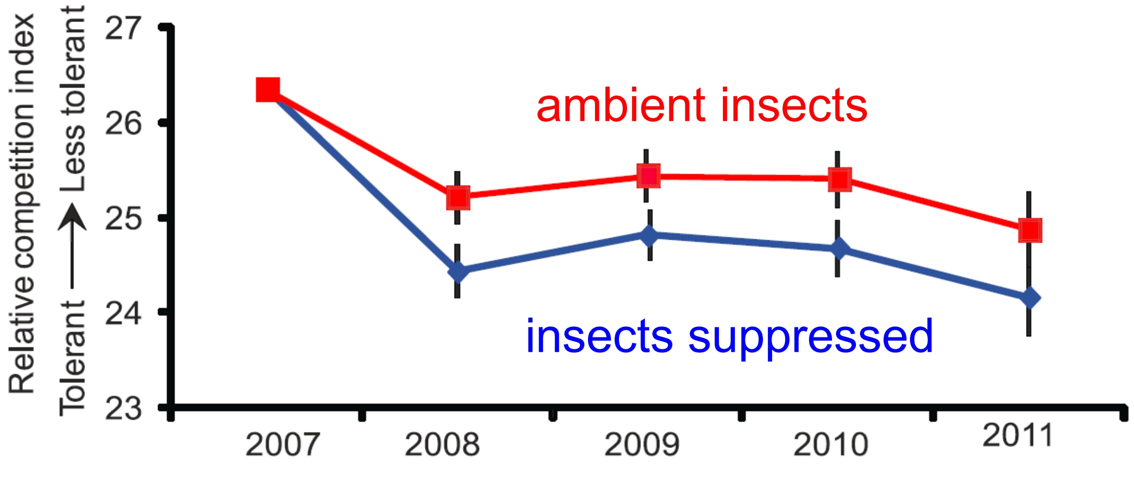
control plot - insects present

insects excluded

Oenothera biennis

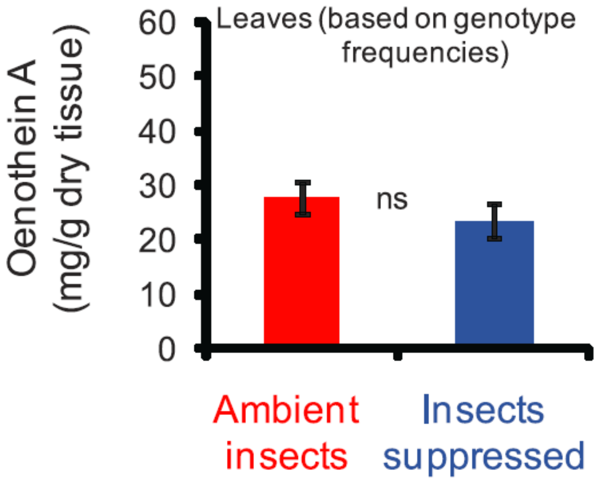


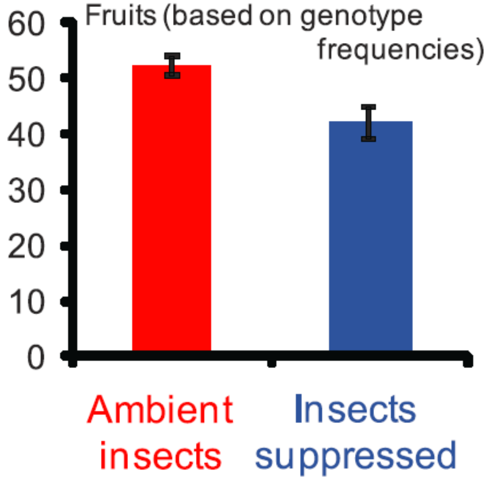
Lower resistance to seed-eating insects

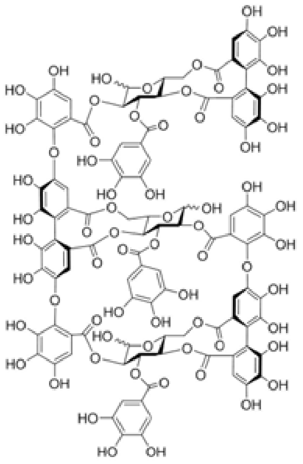


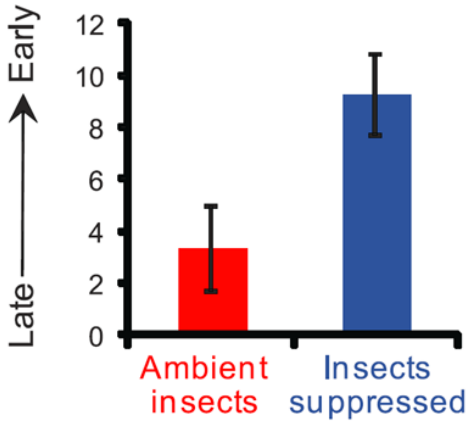
Higher competitive ability (with Taraxacum officinale)

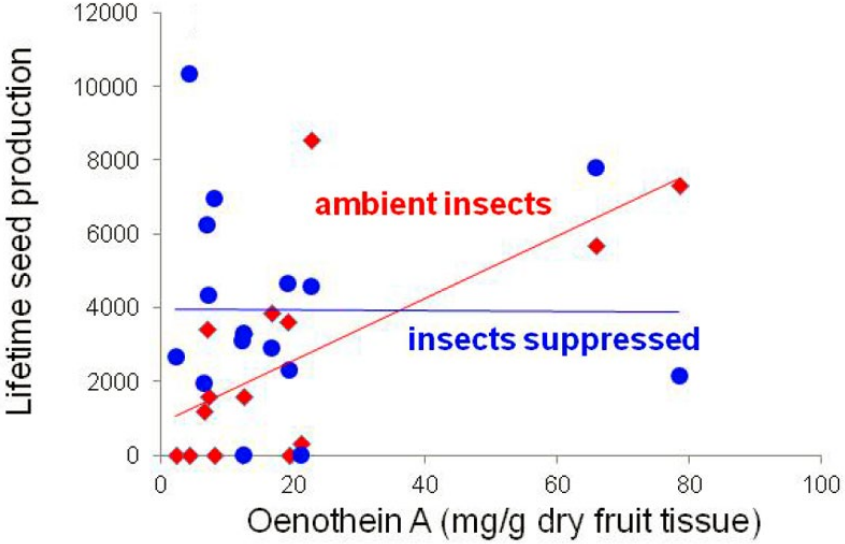
Tannins (Oenothein A): decreased in fruits in the absence of insects



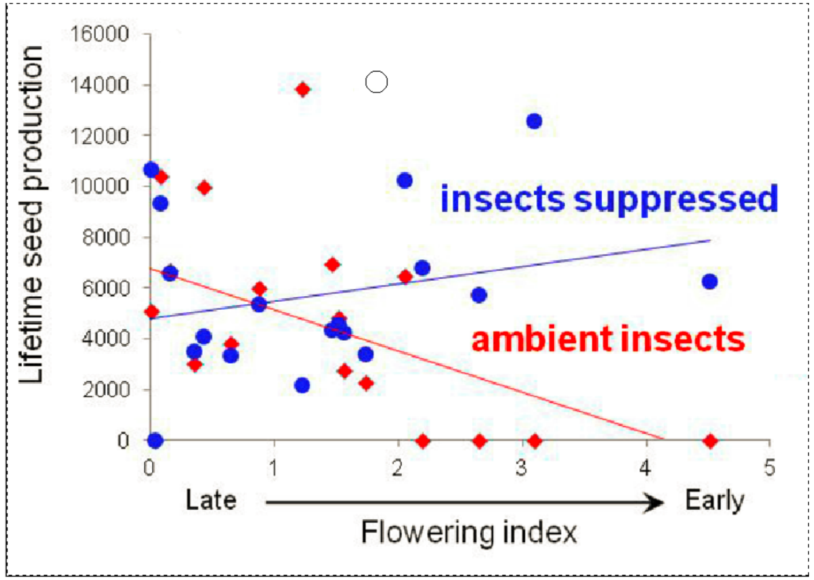








Lifetime seed production: correlated with oenothein but only when insects are present



Early flowering: advantageous response in the absence of insects

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THE END