Oikos

o20830

Valdovinos, F. S., Moisset de Espanés, P., Flores, J. D. and Ramos-Jiliberto, R. 2013. Adaptive foraging allows the maintenance of biodiversity of pollination networks. – Oikos 122: 907–917.

Appendix A1

Table A1. Model parameters and state-variables: short definition, units and mean values of parameters and initial conditions used in the simulations. Values were drawn from a uniform random distribution with the specified mean, and variances of 10% and 0.01% of means for plants' and animals' parameters, respectively. Asterisks indicate initial conditions and k_{aj} is the number of interactions of animal j.

Definition	Symbol	Dimension	Mean value
Density of plant population i	p_i	individuals /area	0,5*
Density of animal population j	a_j	individuals /area	0,5*
Total density of floral resources of plant population i	R_i	mass/ area	0,5*
Foraging effort	α_{ij}	None	1 /k_{aj}*
Visitation efficiency	τ_{ij}	(visits *area) / (time*individuals*individuals)	1
Expected number of seeds produced by a pollination event	e_{ij}	Individuals / visits	0.8
Per capita mortality rate of plants	μ_i^P	1 / time	0.002
Conversion efficiency of floral resources to pollinator births	c_{ij}	individuals/ mass	0.2
Per capita mortality rate of pollinators	μ_j^A	1 / time	0.01
Pollinator extraction efficiency of resource in each visit (linear model)	b_{ij}	individuals / visits	0.4
Maximum pollinator extraction efficiency of resource in each visit (nonlinear model)	b_{ij}^{max}	mass / visits	0.4
Half saturation parameter (nonlinear model)	κ_{ij}	mass / individuals	0.4
Maximum fraction of total seeds that recruit to plants	g_i	None	0.4
Inter-specific competition coefficient of plants	u_i	area / individuals	0.002
Intra-specific competition coefficient of plants	w_i	area / individuals	1.2
Production rate of floral resources	βi	mass / (individuals * time)	0.2
Self-limitation parameter of resource production	ϕ_{ij}	1 / time	0.04
Adaptation rate of foraging efforts of pollinators	G_j	None	2
Carrying capacity of pollinators (self-limitation model)	K_j	Individuals / area	20

Sensitivity analysis

The results presented in the main text were obtained from model simulations run with parameter values drawn from uniform random distributions, whose means are shown in Table A1. Our sensitivity analysis of the model consisted of evaluating how robust are the model outputs to different combinations of parameter means, varying all of them simultaneously. Following Thébault and Fontaine (2010), we used Latin hypercube sampling to select different parameter combinations. This sampling technique allows examining wide areas of the parameter space from a relatively small number of simulations (McKay et al. 1979, Downing et al. 1985). The range of means for each parameter was defined as between one fourth and four times the baseline values shown in Table A1. Each range was then equally divided into 100 intervals. Secondly, we randomly generated a Latin hypercube sample of size 100. In such sampling each one of the 100 intervals is sampled once and only once. With this sampling procedure, we obtained 100 different combinations of selected intervals for the 12 parameters of the LFR model (see main text), corresponding to 100 sets of simulations. We applied this procedure to the model with and without adaptive foragers. For each simulation we recorded the following response variables: 1) the fraction of persistent plants, 2) the fraction of persistent animals, 3) the mean abundance of plant species, 4) the mean abundance of animal species, 5) the variance of plant abundances, and 6. the variance of animal abundances. Values of these response variables were obtained after 6000 iterations of the model. The results of this part of the sensitivity analysis are shown in Fig. A1.

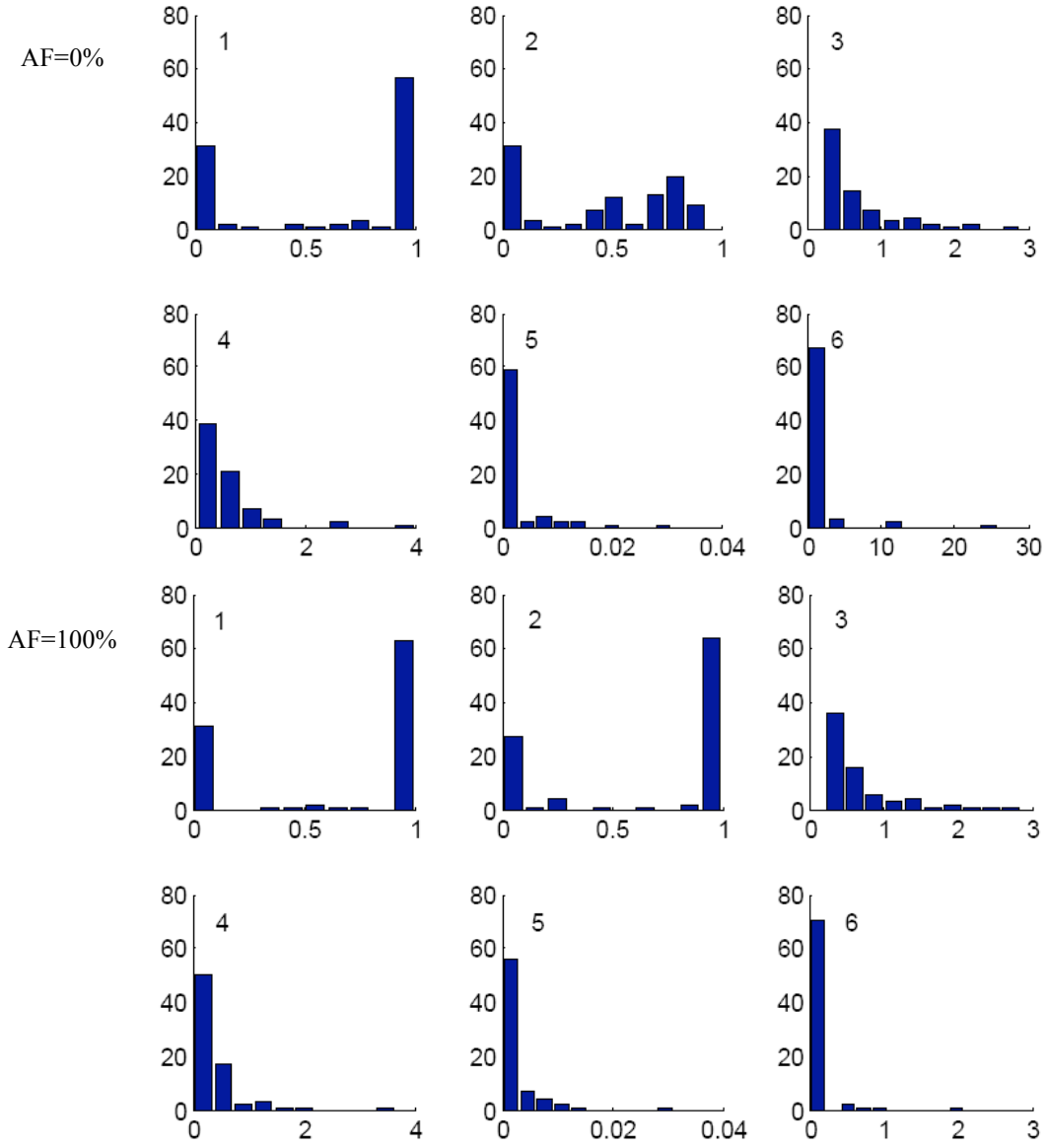

Figure A1. Results of the sensitivity analysis. By mean of Latin hypercube sampling, 100 parameter combinations were drawn. Here it is shown the frequency histograms of the corresponding 100 simulations for the six response variables, whose labels are: 1 = fraction of persistent plants, 2 = fraction of persistent animals, 3 = mean abundance of plant, 4 = mean abundance of animal, 5 = variance of plant abundances, and 6 = variance of animal abundances. AF refers to the percentage of pollinators that were adaptive foragers

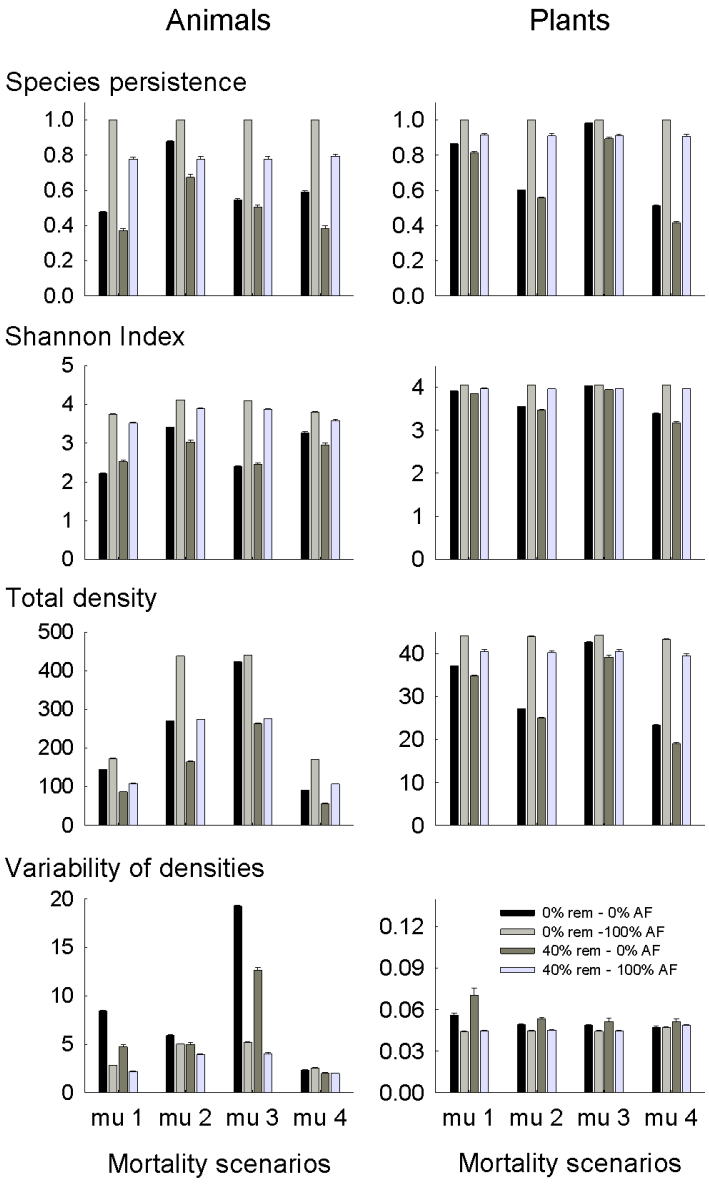

Figure A2. The effect of AF on the stability and diversity of pollination networks using the NFR model. This figure illustrates four variables characterizing animal and plant species at the end of simulations of the NFR model (see Fig. A2 and A3 for the other two versions of the model), parameterized with the four mortality rate scenarios used in this study: 1) mu1: high mortality rate for animals and low for plants,2) mu2: low mortality rates for animals and high for plants, 3) mu3: low mortality rates for animals and plants, and 4) mu4: high mortality rates for animals and plants; in which no removals (0% rem) and the removal of 40% of plant and animal species (for animal and plant response variables, respectively; 40% rem) were performed, where no pollinator (0% AF) and all pollinators (100% AF) exhibited AF. 'Total density' refers to the sum of densities over all species. Error bars are 95% confidence intervals.

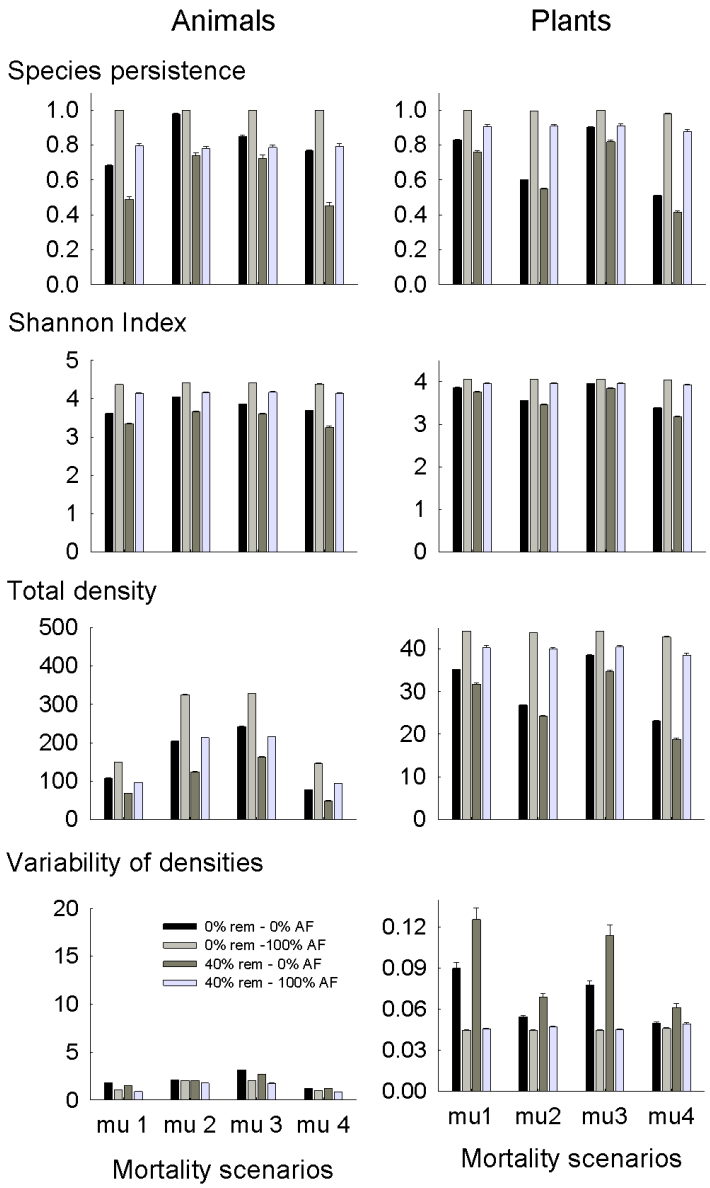

Figure A3: The effect of AF on the stability and diversity of pollination networks using the self-limited-LFR model. This figure illustrates four variables characterizing animal and plant species at the end of simulations of the self-limited-LFR model (see Fig. A2 and A3 for the other two versions of the model), parameterized with the four mortality rate scenarios used in this study: 1) mu1: high mortality rate for animals and low for plants, 2) mu2: low mortality rates for animals and high for plants, 3) mu3: low mortality rates for animals and plants, and 4) mu4: high mortality rates for animals and plants; in which no removals (0% rem) and the removal of 40% of plant and animal species (for animal and plant response variables, respectively; 40% rem) were performed, where no pollinator (0% AF) and all pollinators (100% AF) exhibited AF. 'Total density' refers to the sum of densities over all species. Error bars are 95% confidence intervals.

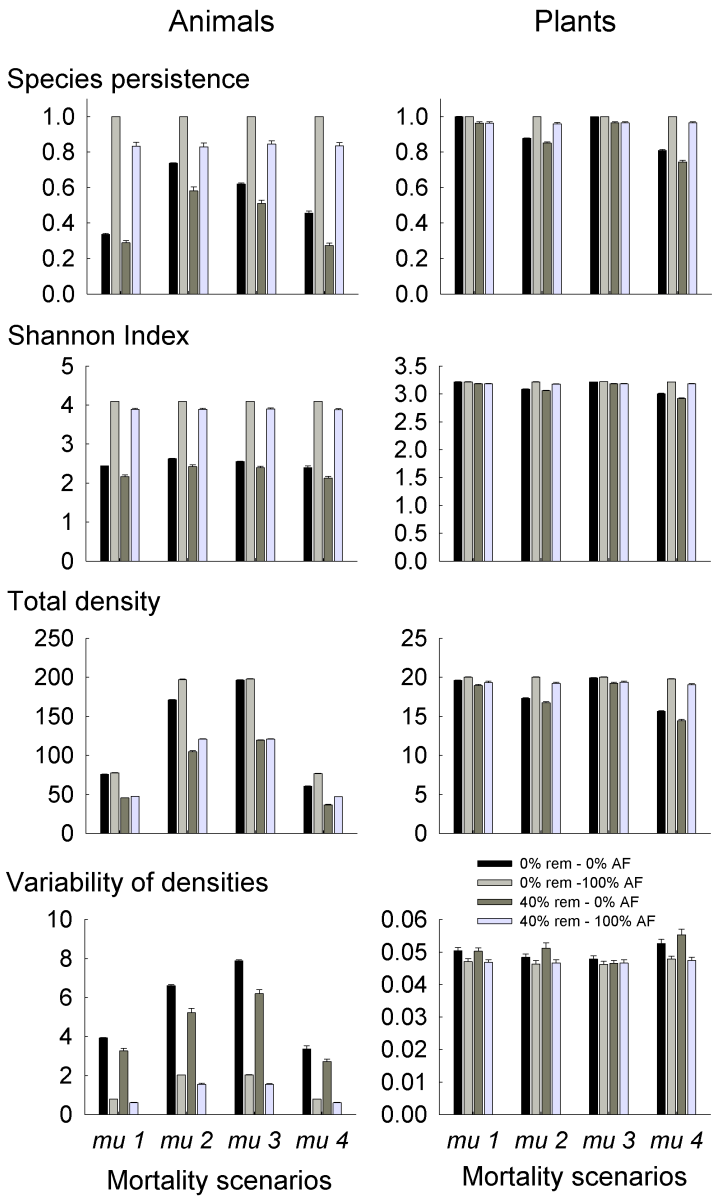

Figure A4: The effect of AF on the stability and diversity of pollination network described by Memmott et al. (1999) using the LFR model. This figure illustrates four variables characterizing animal and plant species at the end of simulations of the LFR model, parameterized with the four mortality rate scenarios used in this study: 1) mu1: high mortality rate for animals and low for plants, 2) mu2: low mortality rates for animals and high for plants, 3) mu3: low mortality rates for animals and plants, and 4) mu4: high mortality rates for animals and plants; in which no removals (0% rem) and the removal of 40% of plant and animal species (for animal and plant response variables, respectively; 40% rem) were performed, where no pollinator (0% AF) and all pollinators (100% AF) exhibited AF. 'Total density' refers to the sum of densities over all species. Error bars are 95% confidence intervals.

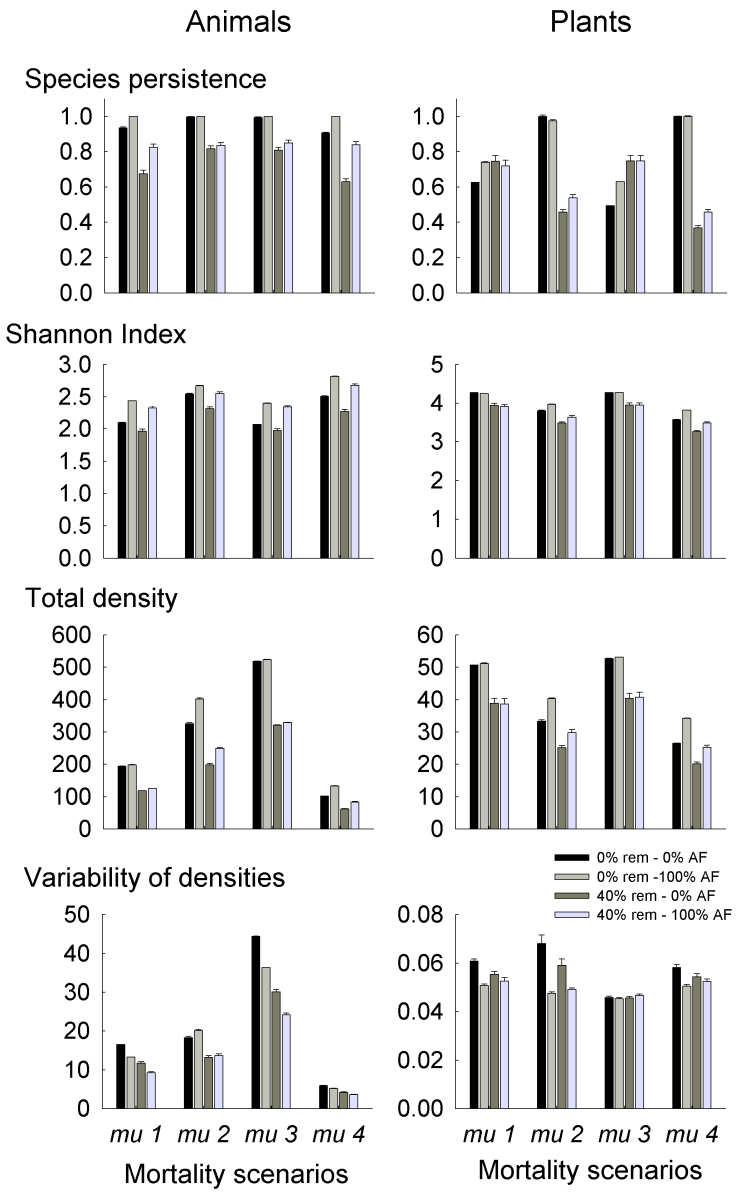

Figure A5: The effect of AF on the stability and diversity of pollination network described by Medan et al. (2002) using the LFR model. This figure illustrates four variables characterizing animal and plant species at the end of simulations of the LFR model (see Fig. A2 and A3 for the other two versions of the model), parameterized with the four mortality rate scenarios used in this study: 1) mu1: high mortality rate for animals and low for plants, 2) mu2: low mortality rates for animals and high for plants, 3) mu3: low mortality rates for animals and plants, and 4) mu4: high mortality rates for animals and plants; in which no removals (0% rem) and the removal of 40% of plant and animal species (for animal and plant response variables, respectively; 40% rem) were performed, where no pollinator (0% AF) and all pollinators (100% AF) exhibited AF. 'Total density' refers to the sum of densities over all species. Error bars are 95% confidence intervals.

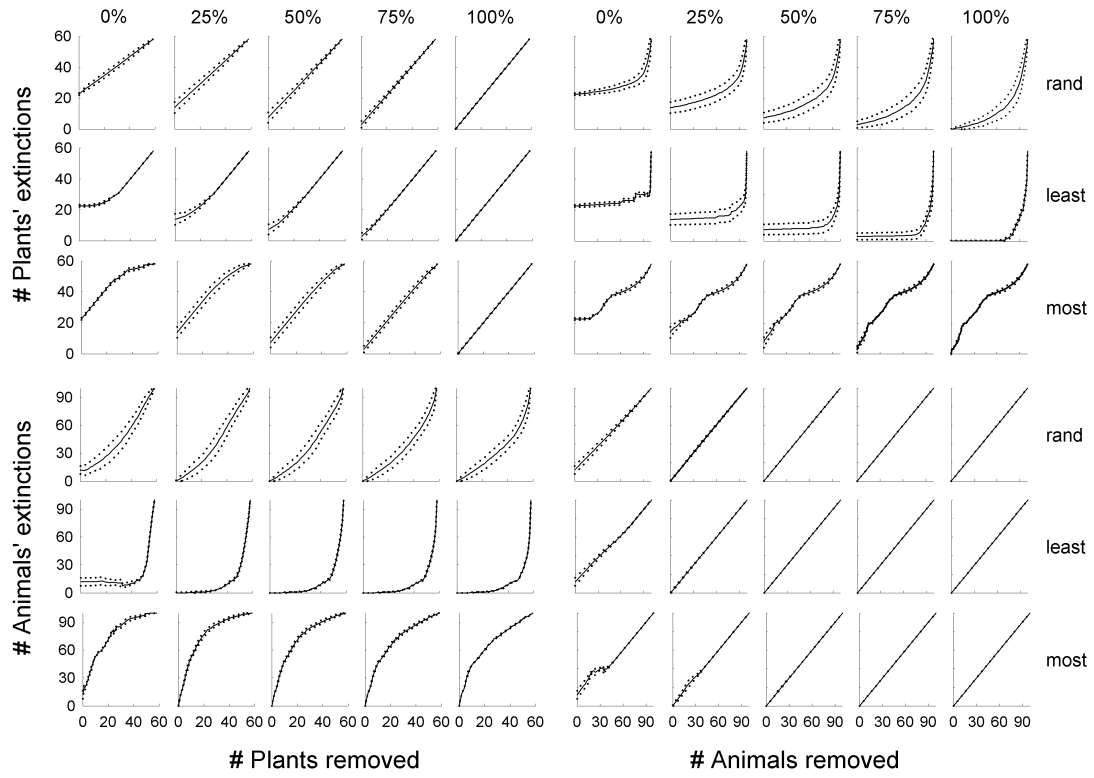

Figure A6. Extinction patterns for the LFR model parameterized with mortality scenario mu2. In each of the quadrants, sequential removals were organized in rows (from top to bottom: random, least to most connected and most to least connected species), while in columns are plotted 0, 25, 50, 75 and 100% of pollinators exhibiting AF. Solid lines show the mean of 100 model runs and dashed lines show 95% confidence intervals.

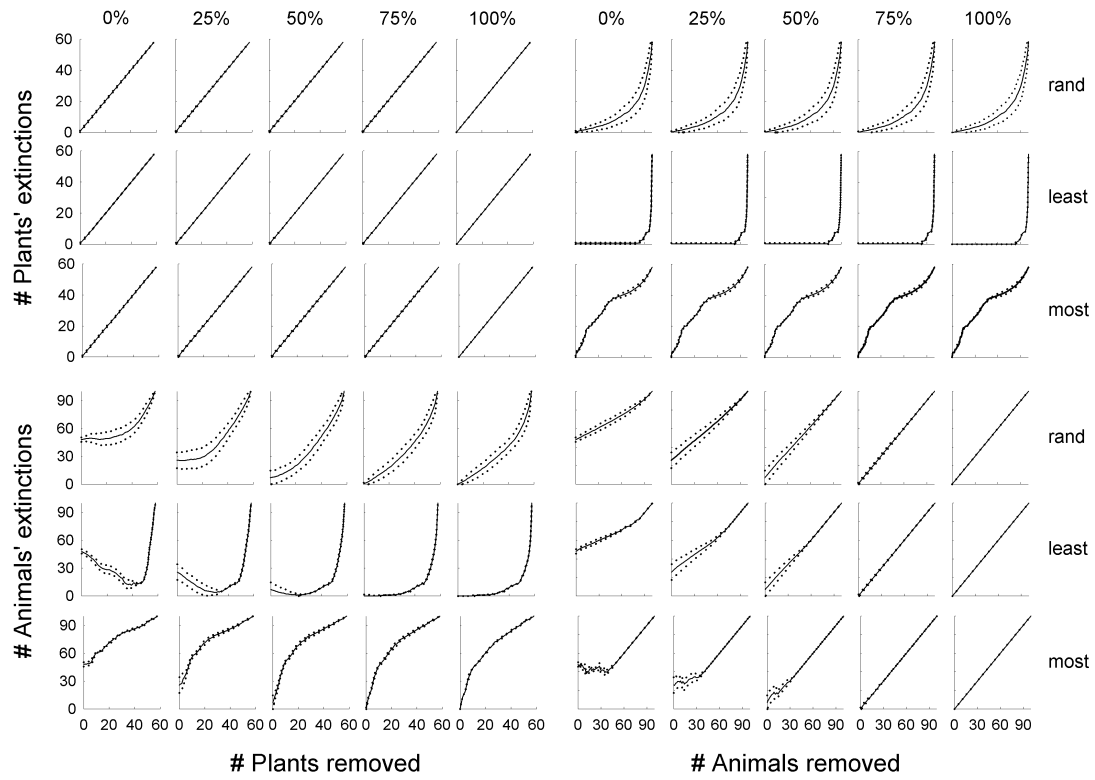

Figure A7. Extinction patterns for the LFR model parameterized with mortality scenario mu3. In each of the quadrants, sequential removals were organized in rows (from top to bottom: random, least to most connected and most to least connected species), while in columns are plotted 0, 25, 50, 75 and 100% of pollinators exhibiting AF. Solid lines show the mean of 100 model runs and dashed lines show 95% confidence intervals.

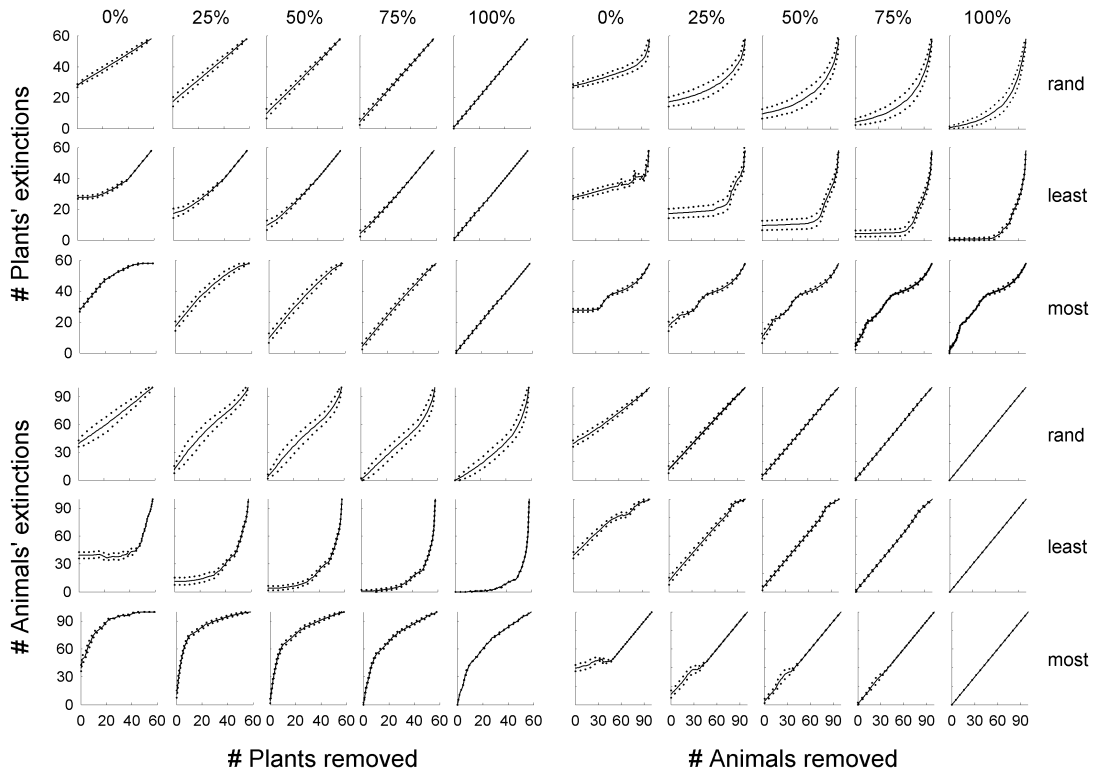

Figure A8. Extinction patterns for the LFR model parameterized with mortality scenario mu4. In each of the quadrants, sequential removals were organized in rows (from top to bottom: random, least to most connected and most to least connected species), while in columns are plotted 0, 25, 50, 75 and 100% of pollinators exhibiting AF. Solid lines show the mean of 100 model runs and dashed lines show 95% confidence intervals.

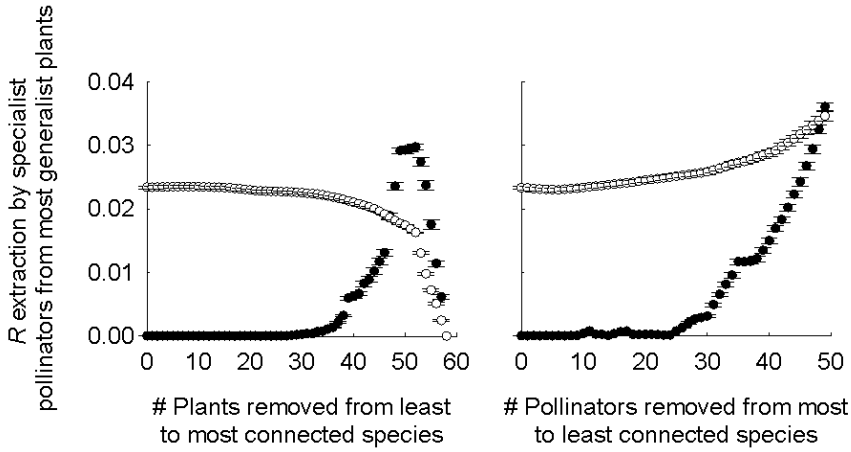

Figure A9. Floral resource (R) extraction by specialist pollinators from super-generalist plants. Open and solid circles represent systems whose pollinators were and were not adaptive foragers, respectively.

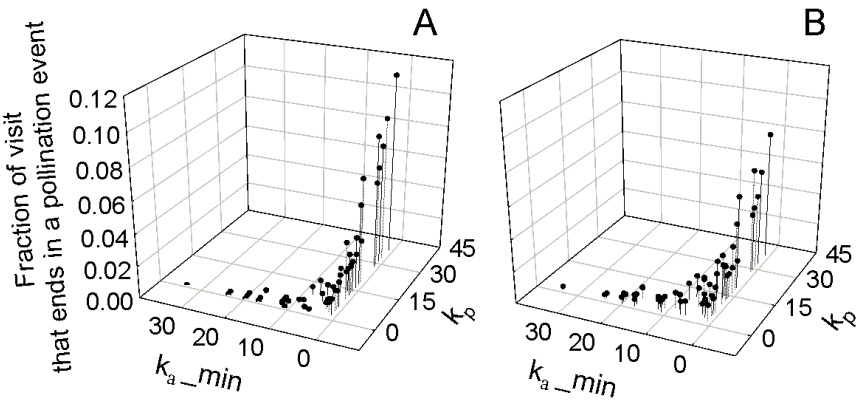

Figure A10. Fraction of visits that ends in a pollination event of each individual plant. This figure shows average (over 100 simulations) of the model variable σ_{ij} / p_i at the end of simulations for each plant species, against its own degree (k_p) and the minimum degree of its visitor species (k_a_min), for systems whose pollinators did not (panel A) and did (panel B) exhibit AF.

References

McKay, M. D. et al. 1979. A comparison of three methods for selecting values of input variables in the analysis of output from a computer code. – Technometrics 21: 239–245.

Downing, D. J. et al. 1985. An examination of response-surface methodologies for uncertainty analysis in assessment models. – Technometrics 27: 151–163.