### Appendix B from A. C. Iles and M. Novak, "Complexity Increases Predictability in Allometrically Constrained Food Webs" (Am. Nat., vol. 188, no. 1, p. 87)

#### **Trophic versus Dynamical Connectance**

The measure of connectance we report is trophic connectance, or the proportion of all possible direct feeding links (L) between species (S),  $C = L/S^2$ . Calculated from the feeding matrix of who-eats-whom, trophic connectance includes only direct feeding interactions of consumers on their resources, including cannibalistic links. Increasing the connectance of a food web results not only in a greater link density but also in a greater proportion of generalist versus specialist consumers. The multispecies functional response describes how the realized fraction of a generalist consumer's maximum ingestion rate is diffused across its resources. The ingestion rate of each resource species depends not only on the biomass density of the focal resource but also on the biomass densities of a generalist consumer's other resources. Thus, the multispecies functional response causes an interaction modification (Wootton 1994*b*; Kéfi et al. 2012), in the form of a weak apparent mutualism in which the presence of an alternate prey modifies the strength of predation for the other prey (Abrams and Matsuda 1996; Yodzis 2000).

Although conceptually apparent mutualisms are an interaction modification, they appear as direct effects in the community matrix because they do not require a change in the biomass density of a third, intermediate species. That is, by the mathematical definition of the community matrix (see "Community Matrix"), its elements represent the direct effect of species *j* on species *i*, with all other species abundances held constant. In the case of apparent mutualism, the intermediate species is the consumer that the prey species share in common. Competition between basal producers also appears as a direct effect between producers in the community matrix, even though, conceptually, competition is an indirect effect. In this case, the intermediate "species" is the system's overall carrying capacity, which is shared by all producers. Similarly, intraspecific effects do not depend on an intermediate species. Thus, apparent mutualism, producer competition, and intraspecific effects appear as direct effects in the community matrix.

The dynamical connectance of a network is a measure of connectance that includes all effects as encapsulated by the nonzero elements of the community matrix. These include not only consumer-resource effects but also intraspecific effects, apparent mutualisms, and competition between producers. Dynamical connectance thus reflects both the direct links between species (as reflected in trophic connectance) and any other effects that do not require a numerical response from an intermediate species. We use the term "dynamical" connectance because it is the community matrix that encapsulates the dynamical properties of the system. As opposed to trophic connectance, dynamical connectance reflects the actual pathways along which perturbations propagate. In linear Lotka-Volterra models, dynamical connectance and trophic connectance are equivalent. However, in multispecies allometric trophic network models, as trophic connectance increases consumers feed on wider range of resources, and the resulting dynamical connectance increases even faster (fig. B1).



Figure B1: Relationship between each network's trophic connectance and its effective dynamical connectance.

## Appendix A from A. C. Iles and M. Novak, "Complexity Increases Predictability in Allometrically Constrained Food Webs" (Am. Nat., vol. 188, no. 1, p. 87)

#### **Species Body Mass Distributions**



Figure A1: Probability density functions (pdf) of consumer body mass distributions in the allometric trophic network models by trophic level (TL).

## Appendix D from A. C. Iles and M. Novak, "Complexity Increases Predictability in Allometrically Constrained Food Webs" (Am. Nat., vol. 188, no. 1, p. 87)

# Predictability Related to Stability, Matrix Condition Number, and Matrix Determinant

Assessing asymptotic stability by the maximum eigenvalue ( $\lambda_{max}$ ) shows no relationship with predictability, as defined by directional determinacy, or the sensitivity of qualitative predictions to an order-of-magnitude (F = 10) variation in interaction strength estimates (fig. D1*A*, D1*D*). The matrix condition number ( $|\lambda_{max}/\lambda_{min}|$ ) is often used to quantify the sensitivity of a matrix to inversion. The networks of our analyses were all well conditioned and evidence no relationship between condition number and predictability (fig. D1*B*, D1*E*). The determinant of the community matrix, det(**A**), scales the magnitudes of  $-\mathbf{A}^{-1}$  and reveals a positive relationship between predictability and the overall magnitude of species responses. Like network predictability, the matrix determinant is sensitive to network size and connectivity (fig. D1*C*, D1*F*).



**Figure D1:** Relationship between network predictability (as measured by directional determinacy) and asymptotic stability  $(\log_{10} (|\lambda_{max}|) (A, D), \text{ matrix condition number } (\log_{10} (|\lambda_{max}/\lambda_{min}|) (B, E), \text{ and the matrix determinant } (\log_{10} (\det(\mathbf{A}); C, F) \text{ for networks of varying size } (A-C) and connectance } (D-F). Predictability reflects the mean proportion of net effects with the correct sign after up to an order-of-magnitude error is introduced to all interactions (<math>F = 10$ ).

### Appendix C from A. C. Iles and M. Novak, "Complexity Increases Predictability in Allometrically Constrained Food Webs" (Am. Nat., vol. 188, no. 1, p. 87)

#### Choosing an Error Distribution for Evaluating Directional Sensitivity

Here we compare our results based on a uniform distribution for the error introduced to species interaction strengths (presented in the main text) to results obtained with a lognormal distribution of error. Both constrain an interaction's magnitude in such a way as to not alter its sign. The mean of the lognormal error distribution is centered on the interaction strength's true magnitude. Three functions relating the magnitude of an interaction's uncertainty to its mean were assessed, as the existing empirical relationship between an estimate's mean and variance is as yet unknown (but see Berlow et al. 1999): (1) a constant proportional error, F, that was independent of an interaction strength's magnitude, (2) an increasing proportional error that scaled positively with an interaction's magnitude, and (3) a decreasing proportional error that scaled negatively with an interaction's magnitude. For case 1, we specified the standard deviation of the lognormal distribution ( $\sigma$ ) to affect a magnitude of proportional uncertainty that corresponded to our results presented in the main text (table C1). For each standard deviation value, the corresponding uniform distribution of the main text captured 99% of the lognormal distribution. For case 2, the smallest nonzero-magnitude  $\log_{10}$  interaction strength was given no error ( $\sigma = 0, F = 1$ ), while the largest was given an order-of-magnitude error ( $\sigma = 0.895, F = 10$ ). The remaining log<sub>10</sub> interaction strengths were assigned a standard deviation along this range, in proportion to their magnitude. The same procedure was used in case 3, except that the largest interaction strength was assigned no error ( $\sigma = 0, F = 1$ ), while the smallest interaction strength received an order-of-magnitude error ( $\sigma = 0.895, F = 10$ ). These analyses show that a lognormal error distribution produces results that are qualitatively similar to the uniform error distribution (fig. C1A, C1B) yet also highlight how important the scaling relationship between estimation uncertainty and interaction strength magnitude is for evaluating directional insensitivity (fig. C1B-C1D). If stronger interaction strengths exhibit less variation, as some empirical evidence suggests (Berlow 1999), or are estimated with less uncertainty (fig. C1D), then net effects should be highly insensitive to any error in the remaining weak interactions.



**Figure C1:** *A*, *B*, Decline in directional insensitivity, or mean proportion of net effects with the correct sign, when all interactions have an equal likelihood of a uniform error distribution (*A*) or a lognormal error distribution with corresponding levels of uncertainty (*B*). *C*, *D*, Lognormal error distributions for which maximum proportional uncertainty is positively (*C*) or negatively (*D*) related to the true magnitude of the log<sub>10</sub> interaction strength. SIS = species interaction strength.

Proportional error, $F$ , of the uniform error distribution	Standard deviation, $\sigma$ , of the lognormal distribution
1	0
1.01	.0050
1.05	.0190
1.10	.0371
1.15	.0543
1.25	.0867
1.50	.1576
1.75	.2174
2	.2699
3	.4268
4	.5381
5	.6284
10	.8950

**Table C1:** Standard deviations of the lognormal distribution of interaction strength uncertainties and corresponding F values of the uniform error distribution