

Indirect effects among biodiversity loss of mutualistic ecosystems

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January 21, 2022

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1 Mutualistic networks used in the study

Table S1. The simulated 29 mutualistic networks.

Network	Type	Size	connectivity	Modularity	Nestedness
<i>M_PL_016</i>	plant-pollinator	205	0.0885	0.4391	0.2198
<i>M_PL_017</i>	plant-pollinator	104	0.1514	0.3335	0.4284
<i>M_PL_023</i>	plant-pollinator	90	0.0871	0.5458	0.2467
<i>M_PL_026</i>	plant-pollinator	150	0.0392	0.5329	0.2827
<i>M_PL_028</i>	plant-pollinator	180	0.0656	0.4520	0.1643
<i>M_PL_029</i>	plant-pollinator	167	0.0598	0.4853	0.1577
<i>M_PL_048</i>	plant-pollinator	266	0.0948	0.3521	0.2623
<i>M_PL_049</i>	plant-pollinator	262	0.0709	0.4105	0.1813
<i>M_SD_001</i>	seed-dispersal	28	0.3401	0.3248	0.5098
<i>M_SD_002</i>	seed-dispersal	40	0.4265	0.2244	0.6766
<i>M_SD_003</i>	seed-dispersal	41	0.1700	0.3921	0.4470
<i>M_SD_004</i>	seed-dispersal	52	0.1499	0.3863	0.4660
<i>M_SD_005</i>	seed-dispersal	34	0.1742	0.4844	0.3779
<i>M_SD_007</i>	seed-dispersal	79	0.2837	0.3345	0.5167
<i>M_SD_009</i>	seed-dispersal	25	0.3016	0.3934	0.3424
<i>M_SD_010</i>	seed-dispersal	64	0.3343	0.2734	0.4892
<i>M_SD_012</i>	seed-dispersal	64	0.1438	0.3746	0.3549
<i>M_SD_016</i>	seed-dispersal	85	0.3415	0.2060	0.5884
<i>M_SD_019</i>	seed-dispersal	209	0.0985	0.3997	0.3287
<i>M_SD_022</i>	seed-dispersal	317	0.0492	0.3731	0.1681
<i>M_PA_001</i>	plant-ant	9	0.5714	0.3750	0.2879
<i>M_PA_002</i>	plant-ant	10	0.5417	0.2485	0.5913
<i>M_PA_003</i>	plant-ant	28	0.2164	0.5807	0.2114
<i>M_PA_004</i>	plant-ant	11	0.1443	0.2856	0.4482
<i>M_AF_001</i>	anemone-fish	36	0.3077	0.2816	0.5568
<i>M_AF_002_01</i>	anemone-fish	11	0.3333	0.4400	0.3800
<i>M_AF_002_02</i>	anemone-fish	3	1	0	1
<i>M_AF_002_03</i>	anemone-fish	5	0.6667	0.2500	0.7500
<i>M_AF_002_04</i>	anemone-fish	9	0.4000	0.4375	0.3438

2 Correlation of different indicators upon random removal of single species

M_{SD_010} is a biconnected network, where randomly removing single species does not trigger secondary extinction.

Table S2. Correlation coefficients of coextinction size and indicators.

Network	Type	Size	T^{out}	degree	k^w	B^c
M_{PL_016}	plant-pollinator	205	0.9825	0.9232	0.9232	0.9546
M_{PL_017}	plant-pollinator	104	0.9421	0.8486	0.8232	0.8146
M_{PL_023}	plant-pollinator	90	0.9882	0.9778	0.9778	0.9648
M_{PL_026}	plant-pollinator	150	0.9884	0.9577	0.9577	0.9602
M_{PL_028}	plant-pollinator	180	0.9479	0.8385	0.8385	0.8987
M_{PL_029}	plant-pollinator	167	0.9333	0.7469	0.7469	0.8674
M_{PL_048}	plant-pollinator	266	0.9763	0.9252	0.9252	0.9740
M_{PL_049}	plant-pollinator	262	0.9428	0.9217	0.8217	0.8396
M_{SD_001}	seed-dispersal	28	0.8926	0.7753	0.6293	0.7642
M_{SD_002}	seed-dispersal	40	0.8291	0.6962	0.6979	0.6513
M_{SD_003}	seed-dispersal	41	0.9368	0.8723	0.8196	0.7970
M_{SD_004}	seed-dispersal	52	0.8710	0.8088	0.7328	0.8152
M_{SD_005}	seed-dispersal	34	0.8638	0.7984	0.7232	0.8819
M_{SD_007}	seed-dispersal	79	0.9699	0.9825	0.9525	0.9671
M_{SD_009}	seed-dispersal	25	0.9253	0.7363	0.7152	0.7230
M_{SD_012}	seed-dispersal	64	0.6462	0.4912	0.4460	0.6964
M_{SD_016}	seed-dispersal	85	0.7943	0.5945	0.5945	0.8810
M_{SD_019}	seed-dispersal	209	0.9589	0.8853	0.8853	0.9557
M_{SD_022}	seed-dispersal	317	0.7447	0.5639	0.5639	0.7040
M_{PA_001}	plant-ant	9	0.8438	0.8731	0.7146	0.9942
M_{PA_002}	plant-ant	10	0.7240	0.5886	0.5194	0.6469
M_{PA_003}	plant-ant	28	0.6855	0.6090	0.3172	0.7334
M_{PA_004}	plant-ant	11	0.7919	0.6533	0.6655	0.7543
M_{AF_001}	anemone-fish	36	0.8527	0.7452	0.7452	0.9120
$M_{AF_002_01}$	anemone-fish	11	0.9024	0.9334	0.9334	0.9916
$M_{AF_002_02}$	anemone-fish	3	0.9999	1	1	1
$M_{AF_002_03}$	anemone-fish	5	0.9999	1	1	0.9958
$M_{AF_002_04}$	anemone-fish	9	0.7955	0.8694	0.8694	0.9710

3 Fitness of different indicators upon random removal of single species

M_{SD_010} is a biconnected network, where randomly removing single species didn't trigger secondary extinction.

Table S3. Adjusted- r^2 and ΔAIC of linear models.

Network	Type	Size	Adjusted- r^2				ΔAIC			
			T^{out}	degree	k^w	B^c	T^{out}	degree	k^w	B^c
M_{PL_016}	plant-pollinator	205	0.9797	0.9302	0.9302	0.9113	0	246.95	246.95	295.01
M_{PL_017}	plant-pollinator	104	0.9080	0.7950	0.8024	0.6635	0	160.22	152.87	259.36
M_{PL_023}	plant-pollinator	90	0.9931	0.9807	0.9807	0.9121	0	206.07	206.07	509.36
M_{PL_026}	plant-pollinator	150	0.9906	0.9733	0.9733	0.9276	0	208.60	208.60	408.02
M_{PL_028}	plant-pollinator	180	0.9323	0.8134	0.8134	0.8076	0	202.74	202.74	208.87
M_{PL_029}	plant-pollinator	167	0.9347	0.7657	0.7657	0.7787	0	255.44	255.44	243.95
M_{PL_048}	plant-pollinator	266	0.9713	0.9061	0.9061	0.9487	0	237.08	237.08	116.25
M_{PL_049}	plant-pollinator	262	0.9191	0.7813	0.7813	0.7065	0	198.75	198.75	257.63
M_{SD_001}	seed-dispersal	28	0.8599	0.7611	0.5554	0.5840	0	106.73	230.99	217.69
M_{SD_002}	seed-dispersal	40	0.7296	0.5758	0.5242	0.4242	0	90.03	112.98	151.15
M_{SD_003}	seed-dispersal	41	0.9147	0.8482	0.7381	0.6351	0	115.24	224.27	290.61
M_{SD_004}	seed-dispersal	52	0.8106	0.7411	0.5724	0.6646	0	62.54	162.89	114.37
M_{SD_005}	seed-dispersal	34	0.9683	0.9100	0.8027	0.9057	0	208.64	365.60	217.95
M_{SD_007}	seed-dispersal	79	0.9575	0.9363	0.9363	0.9354	0	81.10	81.10	83.96
M_{SD_009}	seed-dispersal	25	0.9298	0.8081	0.7616	0.5228	0	201.11	244.48	383.27
M_{SD_012}	seed-dispersal	64	0.7060	0.4401	0.3435	0.6000	0	128.82	169.58	61.56
M_{SD_016}	seed-dispersal	85	0.6597	0.4075	0.4075	0.7761	83.75	194.64	194.64	0
M_{SD_019}	seed-dispersal	209	0.9319	0.8329	0.8329	0.9133	0	179.63	179.63	48.49
M_{SD_022}	seed-dispersal	317	0.6161	0.3816	0.3816	0.4956	0	95.32	95.32	54.59
M_{PA_001}	plant-ant	9	0.9995	1	0.8624	0.9139	-	0	-	-
M_{PA_002}	plant-ant	10	0.8695	0.7594	0.8258	0.6126	0	122.36	57.76	217.66
M_{PA_003}	plant-ant	28	0.9727	0.9682	0.8607	0.8600	0	30.51	325.68	326.70
M_{PA_004}	plant-ant	11	0.6620	0.4922	0.4821	0.5689	0	81.40	85.35	48.64
M_{AF_001}	anemone-fish	36	0.7766	0.6657	0.6645	0.8317	56.66	137.95	137.95	0
$M_{AF_002_01}$	anemone-fish	11	0.9991	1	1	0.9060	-	0	0	-
$M_{AF_002_02}$	anemone-fish	3	1	1	1	1	4466	0	0	16.00
$M_{AF_002_03}$	anemone-fish	5	1	1	1	0.9917	4885	0	0	6044
$M_{AF_002_04}$	anemone-fish	9	0.9992	1	1	0.9841	-	0	0	-

10 **4 Fitness of different indicators upon increasing removal range**
 11 **of species**

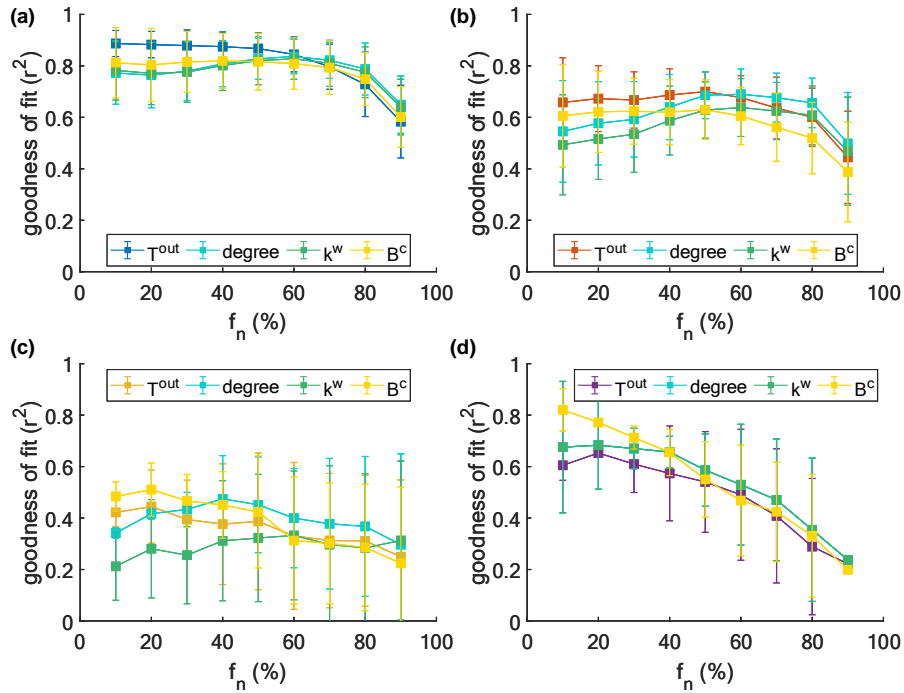


Fig. S1. Fitness of different types of mutualistic networks with different indicators after multi-species are removed. (results of 200 independent simulation runs). T^{out} of networks with low connectivity and nestedness, and high modularity, heterogeneity and biodiversity, namely, higher indirect effects, can better indicate the coextinction size. Thus, T^{out} has better fitness in plant-pollinator (a) and seed-dispersal (b) ecosystems than plant-ant (c) or anemone-fish (d) ecosystems.

5 Synthetic networks

We perform analysis on artificial networks in order to further investigate the generality of the proposed influence indicator T^{out} on predicting secondary extinction. Here, we build up 150 bipartite networks of different sizes using the BiMat package: 50 small networks sized between 10 and 50 nodes, 50 medium networks sized between 50 and 100 nodes, and 50 large networks sized between 100 and 200 nodes, where the weights of interactions are randomly assigned. These scenarios strongly support the effectiveness of the proposed indicator T^{out} can predict the size of secondary extinction according to the high Adjusted- r^2 (>0.8). Also it draws the same conclusion with our analyzation of realistic networks.

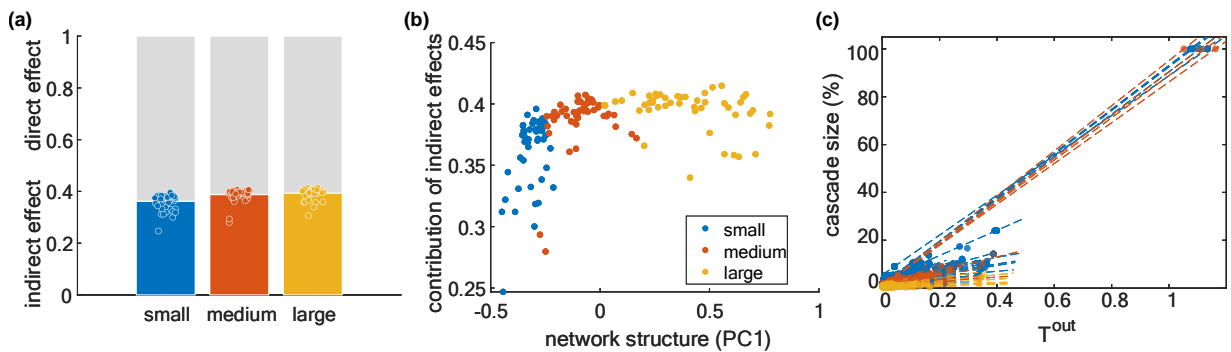


Fig. S2. Results of 150 synthetic networks. (200 independent simulation runs) (a) Indirect effects on different sized networks. (b) Well connected and nested networks (negative PC1 values) have small indirect effects, and modular, heterogeneous, large networks (positive PC1 values) have large indirect effects. (c) Species with higher impact on the network (larger T^{out}) have a disposition to cause massive secondary extinction. Different colors represent networks of different scale groups.