Oikos

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Fowler, M. S. 2010. Extinction cascades and the distribution of species interactions. – Oikos 119: 864–873.

Appendix 1

Methods

Randomly assembled communities
I started by examining the probabilities of feasibility and local stability in randomly assembled competitive communities, with interaction strengths (α-values) drawn from uniform or beta distributions. Communities were assembled over a range of community sizes (S = 2 to 24), with α-values drawn at random from the different distributions (mean $^1/_4$, variance $^1/_{48}$). Feasibility and local stability were assessed for each S-species community, and the probability of being either unfeasible (UF), feasible and locally stable (F-LS) or feasible and locally unstable (F-US) was calculated from 10 000 replicates for each S and distribution form. 1000 sample F-LS communities were selected for further analysis, as outlined in the Methods section in the main text, to investigate the distribution of interaction strengths before and after primary deletion, as well as community responses to species deletion.

Supplementary results

Randomly assembled communities
Communities formed by drawing the interaction strengths at random from either beta- or uniform distributions with the same expected value ($\mu = {}^1/_4$), and variance ($\sigma^2 = {}^1/_{48}$) were assembled to determine the effect of the global distribution of interaction strengths on assembly processes (Fig. A1). While there was a statistical difference in the probability of being F-LS between communities whose interaction strengths were drawn from either a beta- or uniform distribution [logistic regression results: uniform intercept = 5.259 (± 0.024 SE), beta intercept = 4.817 (± 0.022); uniform coefficient = –0.523 (± 0.002), beta coefficient = –0.495 (± 0.002)], this was unlikely to be biologically important.

It was not straightforward to compare random or sequential assembly methods, however, it could be argued that it was easier to assemble large S-species communities sequentially than randomly. For example, ~1 in 143 randomly assembled 20 species communities were F-LS (probability = 0.007 for both uniform and beta distributions, Fig. A1), while sequential communities required on average ~19 (uniform) or 16 (beta) repeated invasion attempts to find a F-LS 20 species community.

The distribution of interaction values in randomly assembled communities differed from the initial uniform global distribution in medium and large communities (S ≥ 9 in uniform and S ≥ 7 from beta distributions; Table A1, Fig. A2, A3). MLE's were not representative of the pooled data from randomly assembled uniform communities when S ≥ 9 (due to an increase in intermediate, rather than weak, competition values), but differed only for three very large random beta communities (S = 19, 21 and 23). Small F-LS communities were easy to form, therefore matched the global distribution. The fact that interaction values differed to the original global distribution in larger communities shows that some selection (for species with intermediate interactions) occurred in the random assembly process (Fig. A3). Communities randomly assembled from a beta distribution had a lower sample median and variance than those from a uniform distribution, though neither declined much with increasing community size (Fig. A2e–f).

There was little difference in the responses of uniform and beta communities to primary species deletion (Fig. A5), either in the probability of extinction cascades or the number of species lost. As in sequentially assembled communities, increasing the abundance rank of the deleted species lead to an increase in both the probability of extinction cascades and the number of species lost. Randomly assembled communities were less robust and lost more species than sequentially assembled communities.

Another interesting question is whether a randomly assembled S-species community (e.g. S = 4 species) is more likely to be feasible and locally stable than a (S-1, e.g. S = 5) community that has gone through primary species deletion. Figure A6 clearly shows that S-1 communities are more likely to be stable than randomly assembled communities of the same size (Table A2). Again, beta communities are more stable than uniform, and sequentially assembled communities are more stable than randomly assembled.

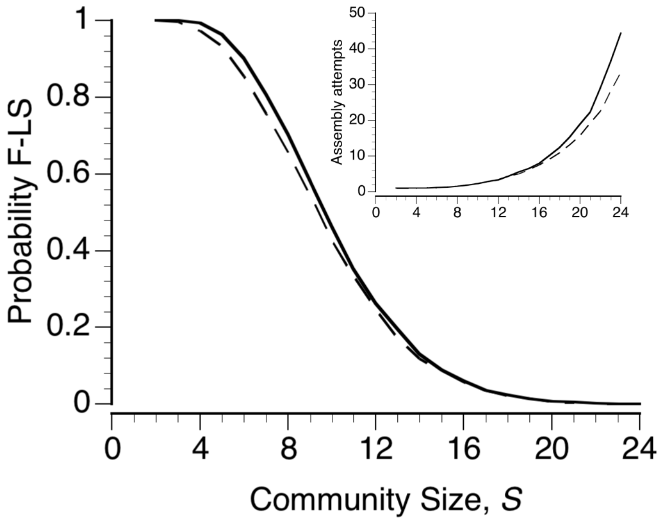

Figure A1. Increasing community size reduced the probability that randomly assembled communities would be feasible and locally stable (F-LS), when α_{ij} values were drawn from uniform (solid line) or beta (dashed line) global distributions. Inlay shows the number of invasion attempts required for sequentially assembled communities for comparison (Fig. 1b, main text).

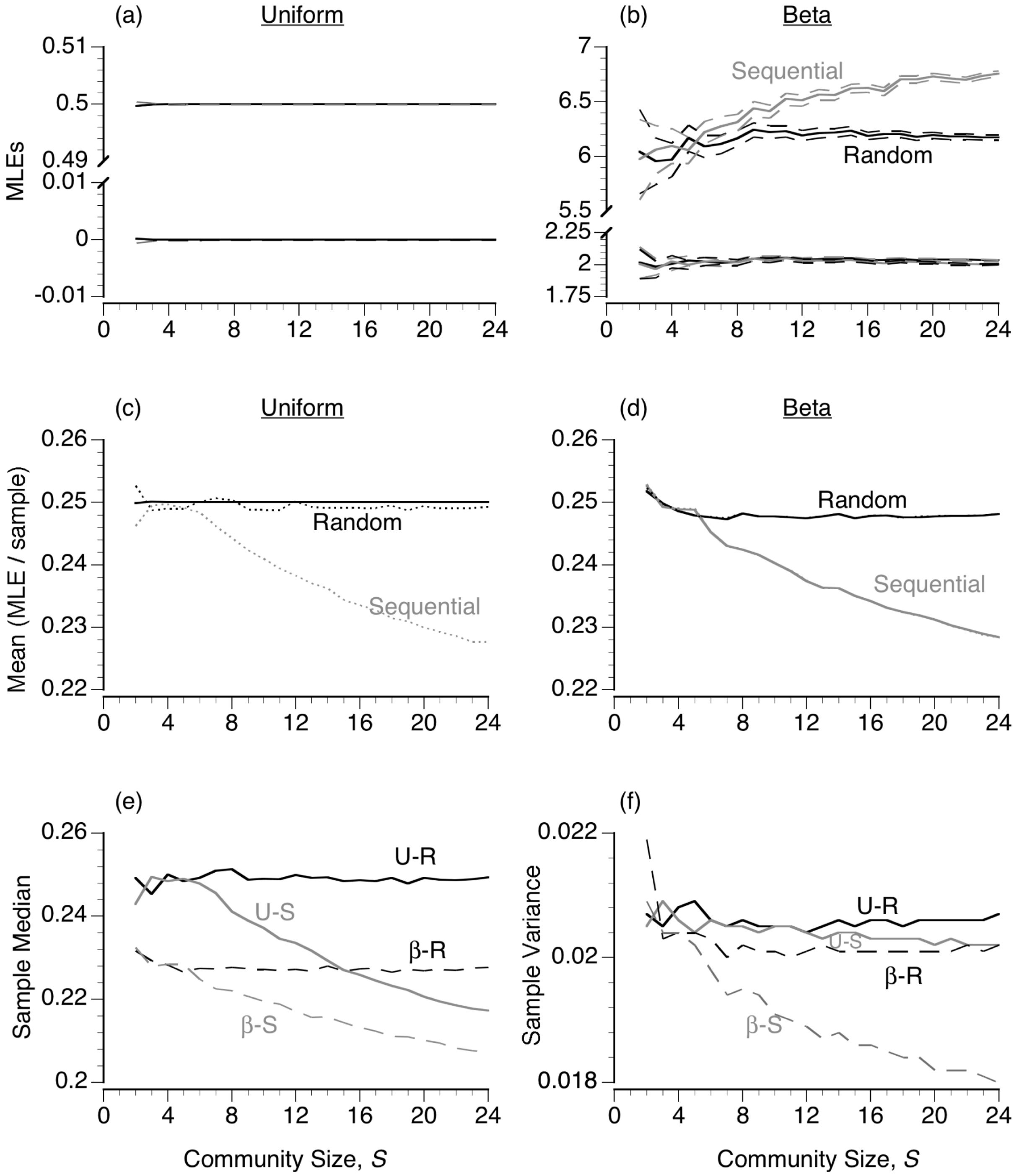

Figure A2. Properties of the interaction strengths (α_{ij}) in randomly assembled competitive communities (black lines) with species interactions drawn from a uniform or beta distribution. (a, b) Maximum likelihood estimates (±95% confidence intervals, dashed lines) are used to derive the mean interaction strength (c, d) for the interspecific interaction values from 1000 F-LS communities from uniform (a, c) and beta (b, d) global distributions. Dotted lines in (c, d) show the sample mean interaction strengths, which match those from the MLEs for the beta distributions but not the uniform. Panels (e and f) show the sample median and variance for all uniform (solid) and beta (dashed lines) distribution types. Grey lines show the same results from sequentially assembled communities for comparison (Fig. 2, main text).

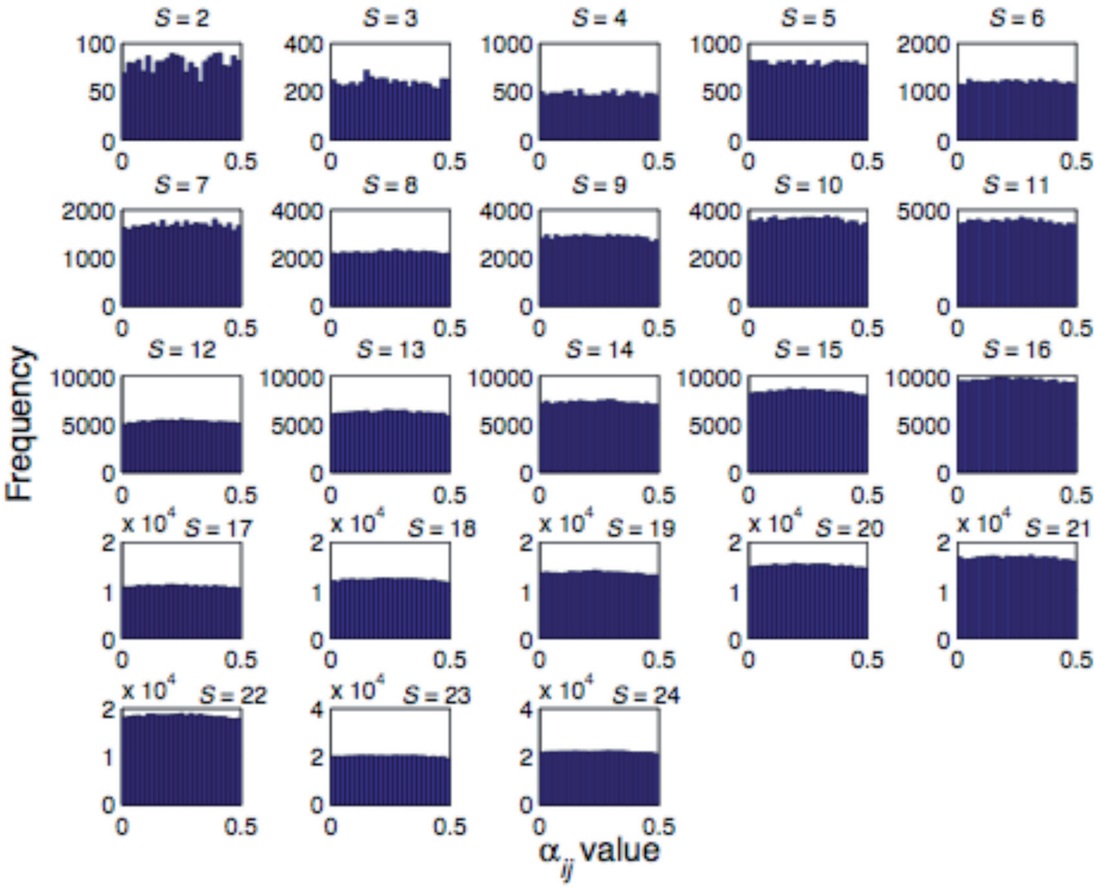

Figure A3. Pooled interaction strengths from 1000 randomly assembled communities with α_{ij} values drawn from a uniform distribution. When $S \geq 9$, the distributions differed from both the initial global distribution (uniform distribution with limits [0, 0.5]) and from a distribution using parameters derived by MLEs from the above data. This shows that the MLEs do not represent the data well in medium and large communities, due to an increase in intermediate interaction strengths ($\alpha_{ij} \approx 0.25$).

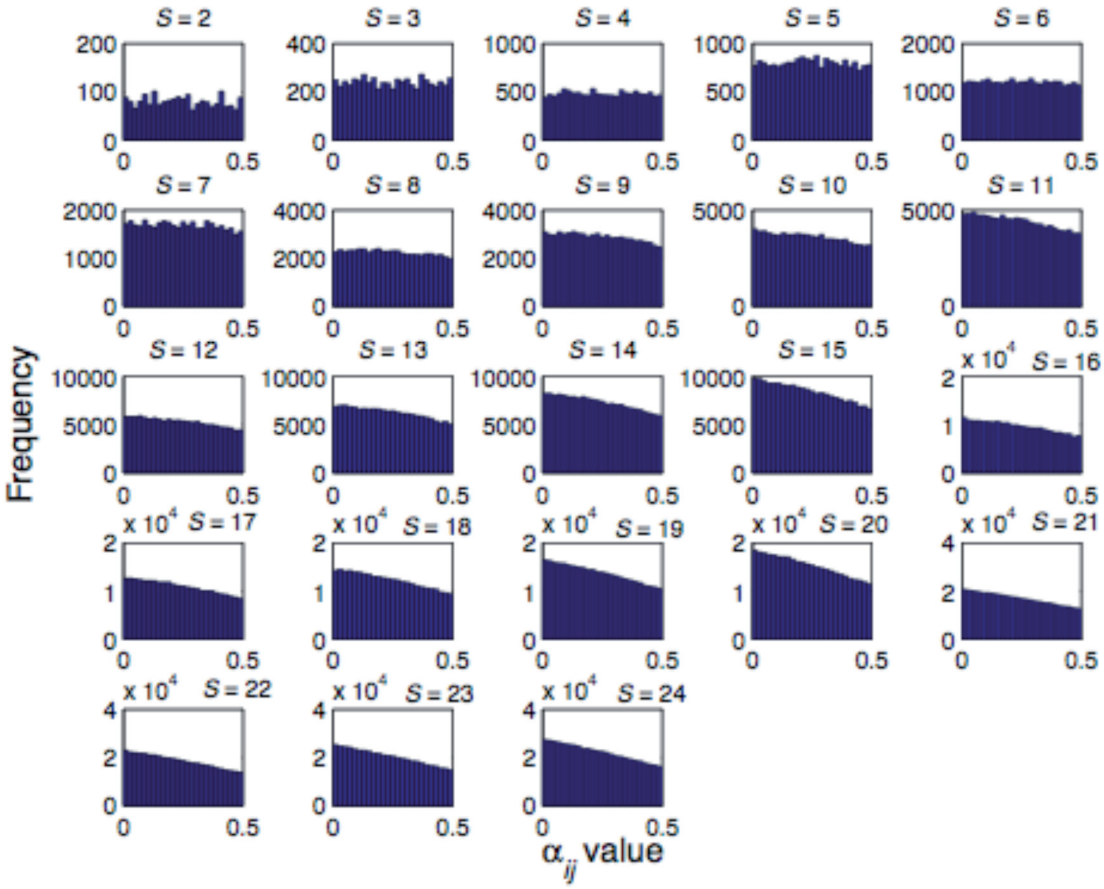

Figure A4. Pooled interaction strengths from 1000 sequentially assembled communities with α_{ij} values drawn from a uniform distribution. When S ≥ 9, the distributions differed from both the initial global distribution (uniform distribution with limits [0, 0.5]) and from a distribution using parameters derived by MLEs from the above data. This shows that the MLEs do not represent the data well in medium and large communities, due to an increase in weak interaction strengths.

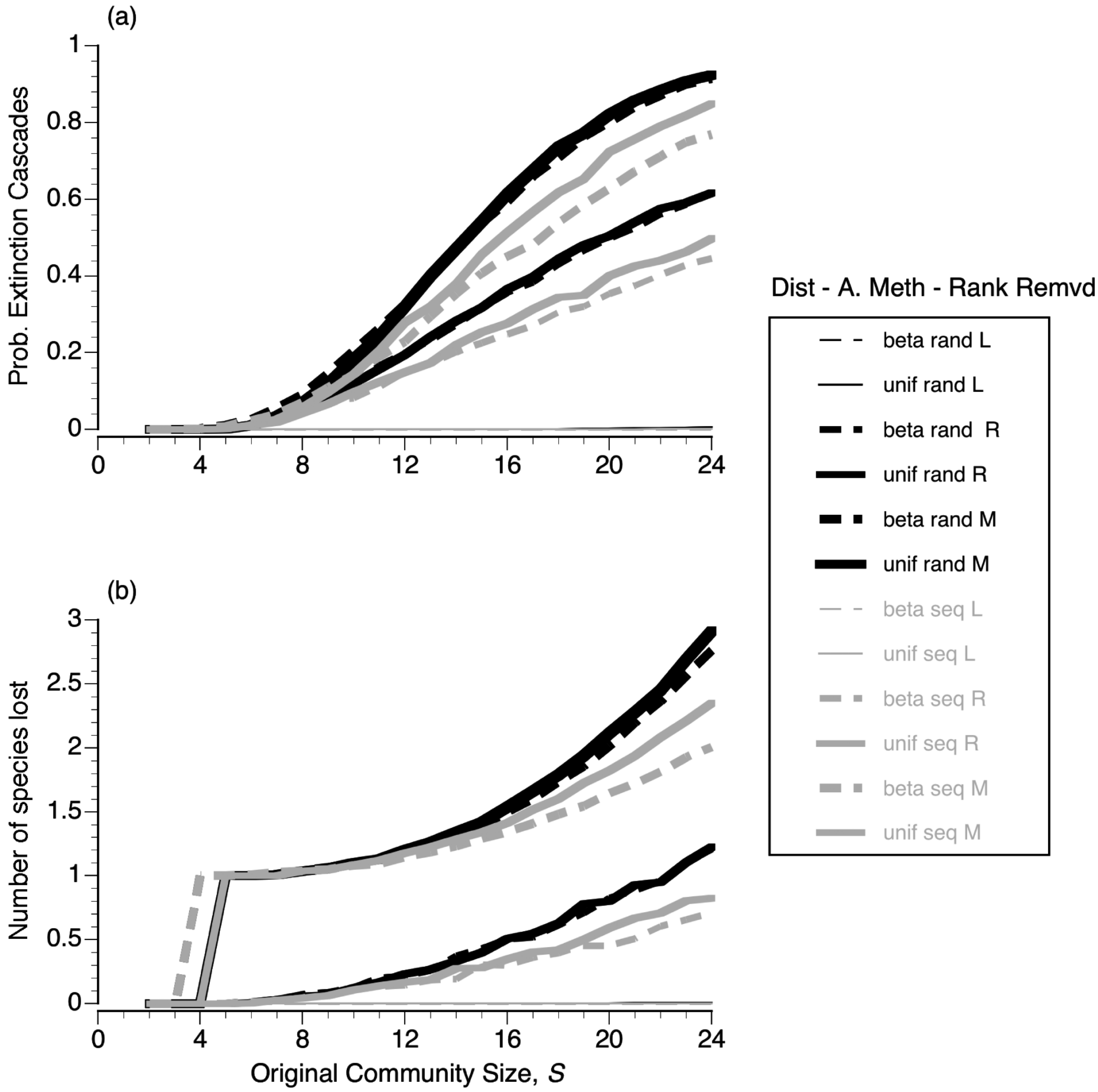

Figure A5. Randomly assembled community responses to forced extinction events (black lines). (a) The probability of extinction cascades and (b) the mean number of species lost, in S species communities following the removal of the least abundant (thin lines), a random (intermediate) or the most abundant species (thick lines). Communities were formed from a uniform (solid lines) or beta (dashed lines) distribution. Results are based on 1000 F-LS communities for each scenario. Removing the most abundant species led to extinction cascades more often, with more species lost. There was little difference between uniform and beta communitied. Grey lines show the equivalent results for sequentially assembled communities, which were more robust to species deletion. Legend shows the distribution type (beta, uniform), Assembly method (random, sequential) and rank abundance of the removed species (least, random, most).

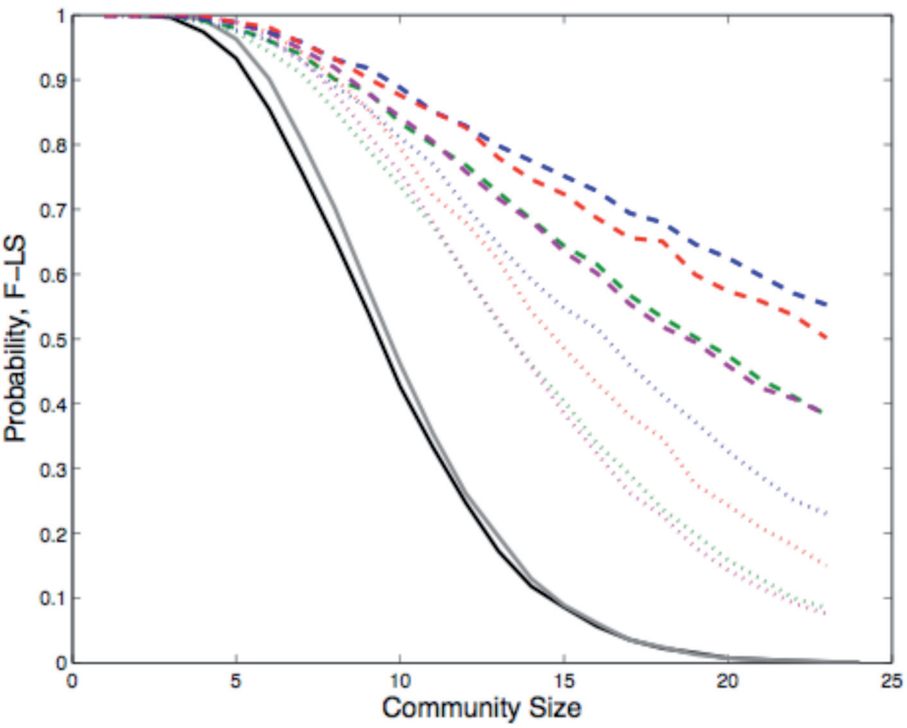

Figure A6. The probability of feasibility and local stability is lower in randomly assembled S species communities (black line = uniform distribution, grey line = beta distribution) than communities that contained S species following a primary extinction event. This holds regardless of which species was removed (most abundant = dotted lines, random = dashed lines), distribution type or the assembly process (blue = beta sequential; red = uniform sequential, green = beta random, magenta = uniform random).

Table A1. Results from Kolmogorov-Smirnov (KS) tests to investigate the distribution of realised interaction strengths pooled across 1000 communities for different assembly methods. MLEs were derived for α_{ij} ($i \neq j$) values in S species communities for each assembly method and distribution form. Cell entries illustrate the confidence based on KS tests that the actual α_{ij} values differed from a hypothesised distribution predicted either from the initial global distribution or the MLEs. Key: – = $p > 0.05$, * $p = \leq 0.05$, ** = $p \leq 0.01$.

			Community size, *S*																						
	Assembly method	Distribution form	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Global	Random	Uniform	–	–	–	–	–	–	–	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
		Beta	–	–	–	–	–	**	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
	Sequential	Uniform	–	–	–	–	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
		Beta	–	–	–	–	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
MLE	Random	Uniform	–	–	–	–	–	–	–	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
		Beta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	*	–	*	–	*	–
	Sequential	Uniform	–	–	–	–	*	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
		Beta	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table A2. Multiple logistic regression confirms that there is a significant difference between the least stable reduced communities (uniform random) and randomly assembled communities of the same size. The regression table shows results for the full model and partial statistics from a test of redundancy for each of the following explanatory variables: (1) intercept, (2) effect of community size on the probability of F-LS in randomly assembled communities from a uniform distribution, (3) effect of community size on the probability of F-LS in randomly assembled communities from a uniform distribution after the most abundant species had been removed, (4) difference in intercept between the two treatments.

	Coefficient (± SE)	Deviance (full)	Deviance (null)	G^2	DF	p-value
Full Model		508.58	33365	32856.45	3	< 0.001
(1)	4.8022 (± 0.0688)		10978	10470	1	< 0.001
(2)	–0.4946 (± 0.0066)		17660	17152	1	< 0.001
(3)	–0.3369 (± 0.0042)		13870	13361	1	< 0.001
(4)	0.2472 (± 0.0939)		515.49	6.9086	1	0.009