Justin Kitzes and John Harte. 2015. Predicting Extinction Debt from Community Patterns. *Ecology* **96:2127-2136.**

Appendix A: Additional description of species abundance distributions and detailed results for hotspots.

Parameterization of canonical lognormal distribution

Initially described by Preston (1962), the mathematical properties of the canonical lognormal distribution were examined at length by May (1975), and the notation here and in the main text follows May (1975).

The canonical lognormal distribution is traditionally described on a scale of "octaves", or base 2 logarithms, such that each unit of R represents a doubling of population. From May's Eq. 3.5,

$$\phi(R) = S_0 \exp(-a^2 R^2) \tag{A.1}$$

The parameter S_0 here is a constant and should not be confused with the count of the number of species in an area A_0, as this notation is used in the main text. As the parameters $S_0 = \exp(\Delta^2)$ and $a = \ln(2)/2\Delta$ in May's notation, the equation above can be equivalently expressed as

$$\phi(R) = \exp(\Delta^2) \exp\left(-\frac{\ln(2)^2}{4\Delta^2} R^2\right) \tag{A.2}$$

The number of species in any interval of R is given by the definite integral of the above equation. The integral of this equation from the minimum to the maximum values of R, $R_{\min}$ to $R_{\max}$, which are defined by the values of R for which $\phi(R) \approx 1$, gives the total number of species in the community.

Given the definition of $R = \log_2(N/\exp(2\Delta^2))$ and using integration by substitution, the above equation for $\phi(R)$ can be converted to an equation for $\phi(n)$, which simplifies to

$$\phi(n) = \frac{\exp(\Delta^2)}{n \ln(2)} \exp\left(-\frac{(\ln n - 2\Delta^2)^2}{4\Delta^2}\right) \tag{A.3}$$

The integral of the above equation from $n_{\min} = 1$ to $n_{\max} = \exp(4\Delta^2)$ (see May Eq. A.3) gives the same total species richness as the integral of Eq. A.1 from $R_{\min}$ to

A1

$R_{\max}$. Note that this equation differs from May's Eq. 3.3, which substitutes n for R in the lognormal distribution but does not convert the variable of integration from R to n.

The equations for the total number of species and individuals in a community as a function of Δ are given by May's Eq. A.7 and A.10 and reproduced in the main text.

Invariance of α parameter of logseries distribution

As discussed in the main manuscript text, a key assumption of our analysis is that the steady-state species abundance distribution describing a community takes the same parametric form both before and after habitat loss. In the case of the logseries distribution, we additionally presume that the α parameter of the abundance distribution is the same before and after habitat loss. There are three lines of reasoning that support this assumption, as described below.

First, although there is little empirical data on the relationship between area and α at large scales, analysis of tropical tree communities suggests that α changes relatively slowly with area. Hubbell et al. (2008), for example, estimate $\alpha = 743$ for all of Amazonia and $\alpha = 212$ for the metacommunity that provides immigrants to a 50 ha plot in Yasuni National Park, Ecuador, undoubtedly a substantially smaller area. Similarly, if the $\alpha = 48$ value calculated for the 50 ha tropical forest plot on Barro Colorado Island (BCI) (Volkov et al. 2007) is taken roughly to refer to a metacommunity with the area of the island, the increase 10^5 in area between BCI and Amazonia is associated with an increase in α of only 10^1.

Second, from a phenomenological perspective, Fisher et al. (1943) noted that the α parameter of the logseries is invariant to random sampling, such that if a subset of individuals are chosen randomly from a large-scale logseries abundance distribution, the abundance distribution describing the sample will also be logseries with an identical α to the large-scale distribution. This exercise formally describes the construction of a collector's curve and describes nested species-area relationships when species are randomly distributed in space (Harte and Kitzes 2012). To the extent that this same process can be viewed as leading to or approximating island species-area relationships, α will also be invariant across steady state communities. This same type of invariance has also been demonstrated in neutral communities described by a zero sum multinomial abundance distribution (Etienne and Alonso 2005), of which the logseries is a special case.

Finally, a constant α also has a mechanistic interpretation if the steady state communities before and after habitat loss are described by neutral dynamics. The

metacommunity abundance distribution in neutral theory is asympotically equivalent to a logseries distribution (Hubbell 2001; Volkov et al. 2003), with Fisher's α parameter being equivalent to Hubbell's fundamental biodiversity number θ. In this framework, α is proportional to the total speciation or immigration rate for a community, and a constant α thus presumes that the total speciation or immigration rates for steady state communities are independent of area.

Canonical lognormal extinction debt for combinations of S_0 and a

Figure A1 shows extinction debt predictions for canonical lognormal communities exhibiting random spatial placement for different combinations of initial species richness and area loss. Extinction debt exists for all combinations of parameters and, as a proportion of initial species richness, is largest for large communities and large area losses.

Additional hotspots analysis results

Table A1 shows predictions of the proportion of initial species remaining immediately following habitat loss, S_I, and at long-term steady state, S_E, for the twenty-five biodiversity hotspots described by Myers et al. (2000). Calculation methods are described in the main text. Table A2 shows the fraction of plant species expected to remain at steady state under three different assumed density levels.
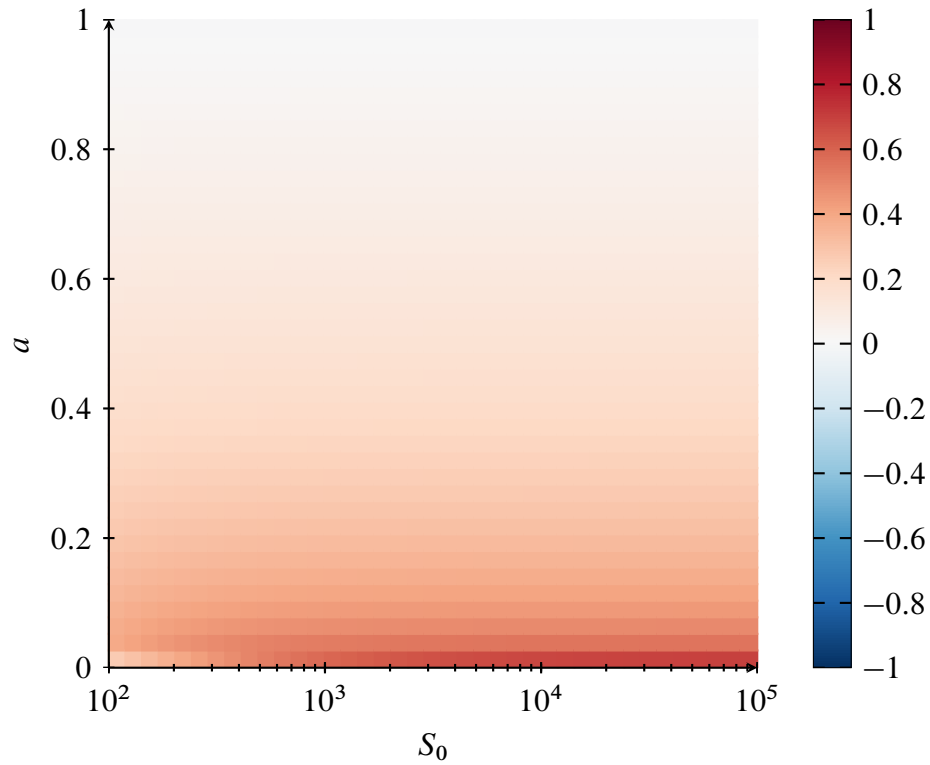
Figure A1: Ratio of time-delayed extinctions (extinction debt) to initial species richness for canonical lognormal communities exhibiting random spatial placement. Positive extinction debts are observed for all combinations of parameters. The fraction of delayed extinctions ranges from 0–70%, with the largest debts found in large communities at high levels of habitat loss (low a). Fractional debt increases strongly with decreasing a and weakly with increasing initial species richness.

		Birds			Plants		
Hotspot	a	S_0	S_I (%)	S_E (%)	S_0	S_E (%)	PL (%)
Tropical Andes	0.25	1,666	1.00	0.71	45,000	0.94	0.71
Mesoamerica	0.20	1,193	1.00	0.67	24,000	0.94	0.67
Caribbean	0.11	668	0.99	0.58	12,000	0.91	0.58
Brazils Atlantic Forest	0.08	620	0.98	0.52	20,000	0.90	0.52
Choco-Darien-W Ecuador	0.24	830	1.00	0.70	9,000	0.94	0.70
Brazils Cerrado	0.20	837	0.99	0.67	10,000	0.94	0.67
Central Chile	0.30	198	0.99	0.74	3,429	0.95	0.74
California Floristic Prov	0.25	341	0.99	0.70	4,426	0.95	0.70
Madagascar	0.10	359	0.97	0.56	12,000	0.91	0.56
E Arc and Coastal Forests	0.07	585	0.98	0.51	4,000	0.89	0.51
W African Forests	0.10	514	0.98	0.56	9,000	0.91	0.56
Cape Floristic Province	0.24	288	0.99	0.70	8,200	0.94	0.70
Succulent Karoo	0.27	269	0.99	0.72	4,849	0.95	0.72
Mediterranean Basin	0.05	345	0.95	0.47	25,000	0.88	0.47
Caucasus	0.10	389	0.98	0.56	6,300	0.91	0.56
Sundaland	0.08	8,315	1.00	0.53	25,000	0.90	0.53
Wallacea	0.15	697	0.99	0.62	10,000	0.92	0.62
Philippines	0.03	556	0.95	0.42	7,620	0.86	0.42
Indo-Burma	0.05	1,170	0.98	0.47	13,500	0.89	0.47
SC China	0.08	686	0.98	0.53	12,000	0.90	0.53
Western Ghats-Sri Lanka	0.07	528	0.97	0.51	4,780	0.89	0.51
SW Australia	0.11	181	0.96	0.57	5,469	0.91	0.57
New Caledonia	0.28	116	0.98	0.73	3,332	0.95	0.73
New Zealand	0.22	149	0.97	0.68	2,300	0.94	0.68
Polynesia-Micronesia	0.22	254	0.98	0.68	6,557	0.94	0.68

Table A1: Predictions of the proportion of species remaining immediately following habitat loss, S_I, and at long-term steady state, S_E, for each of 25 biodiversity hotspots. For birds, a very small fraction of species is lost immediately but a large extinction debt is present ($S_E \ll S_I$). For plants, there is no extinction debt (see main text), and the fraction of species expected to remain at steady state is substantially higher than predicted by a classic power law extinction analysis, PL, given by $S = S_0 a^{0.25}$. Plant density is assumed to be 100 individuals / m^2 (see also Table A2).

Hotspot	a	S_E-H (%)	S_E-M (%)	S_E-L (%)
Tropical Andes	0.25	0.95	0.94	0.93
Mesoamerica	0.20	0.95	0.94	0.92
Caribbean	0.11	0.93	0.91	0.89
Brazils Atlantic Forest	0.08	0.92	0.90	0.88
Choco-Darien-W Ecuador	0.24	0.95	0.94	0.93
Brazils Cerrado	0.20	0.95	0.94	0.93
Central Chile	0.30	0.96	0.95	0.94
California Floristic Prov	0.25	0.95	0.95	0.93
Madagascar	0.10	0.92	0.91	0.89
E Arc and Coastal Forests	0.07	0.90	0.89	0.86
W African Forests	0.10	0.93	0.91	0.89
Cape Floristic Province	0.24	0.95	0.94	0.93
Succulent Karoo	0.27	0.96	0.95	0.93
Mediterranean Basin	0.05	0.90	0.88	0.86
Caucasus	0.10	0.93	0.91	0.89
Sundaland	0.08	0.92	0.90	0.88
Wallacea	0.15	0.94	0.92	0.91
Philippines	0.03	0.88	0.86	0.83
Indo-Burma	0.05	0.90	0.89	0.86
SC China	0.08	0.92	0.90	0.88
Western Ghats-Sri Lanka	0.07	0.91	0.89	0.87
SW Australia	0.11	0.93	0.91	0.89
New Caledonia	0.28	0.95	0.95	0.93
New Zealand	0.22	0.95	0.94	0.93
Polynesia-Micronesia	0.22	0.95	0.94	0.92

Table A2: Predictions of the proportion of species at long-term steady state for plants in each of 25 biodiversity hotspots under different density assumptions: S_E-H (10,000 individuals / m^2), S_E-M (100 individuals / m^2), and S_E-L (1 individual / m^2). The predicted fraction of remaining species varies by less than 5% over four orders of magnitude of assumed density.

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