Ranking Hotspots of Varying Sizes: a Lesson from the Nonlinearity of the Species-Area Relationship

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In the face of the current rapid loss of biodiversity, there is no doubt that prioritizing conservation efforts is highly important. Indeed, one of the most popular topics in conservation biology is hotspots. There are different types of hotspots—for example, endemic (Myers et al. 2000) and rare (Prendergast et al. 1993) species-rich areas—but almost all share the same basic goal of identifying unprotected areas characterized by high concentrations of species threatened by habitat degradation.

One of the central questions is how to best detect qualitative differences in species richness between areas of varying sizes. The most intuitive way is to compare their species-area ratios. Using this ratio is problematic, however, because it ignores the nonlinearity of the species-area relationship (Rosenzweig 1995). Ecologists and biogeographers have long recognized that species richness (S) increases with area size (A) at a decreasing rate and thus eventually levels off (Rosenzweig 1995). The relationship between the two can be described by a power function, $S = cA^z$, where c and z are positive coefficients.

This nonlinearity means that the species-area ratio is negatively correlated with area size. Specifically, small areas have more species per unit area than large ones. This is misleading in that larger areas will be skewed toward lower rankings than they should have and vice versa. A qualitative difference in species richness between areas exists only when they pertain to different species-area curves (Rosenzweig 1995). Therefore, to detect such differences, the c values of the power function should be calculated and compared. The higher the c value, the faster the increase in species richness, and consequently the higher the qualitative rank for the area.

Recently, an updated report on biodiversity hotspots has been published (Myers et al. 2000). This joint effort of scientists from all over the globe revealed a remarkable pattern. As many as 44% of all species of vascular plants and 35% of all non-fish vertebrates are endemic to 25 separate hotspots comprising only 1.4% of the Earth's land surface (Myers et al. 2000). I used data from Myers et al. (1) to illustrate how qualitative differences in species richness between hotspots of varying sizes should be measured by estimating their c values, and (2) to test whether the ranking of hotspots changes when species-area ratios are replaced with c values.

I estimated the c values for the 25 hotspots assuming that $z = 0.18$, a typical z value for mainland curves (Rosenzweig 1995). There are substantial differences between c values and species-area ratios (Table 1). For example, Tropical Andes, Indo-Burma, and Mediterranean Basin appear in the top 10 listings for endemic-plant c values but not for the species-area ratio. Eastern Arc and Coastal Forests of Tanzania/Kenya have the highest species-area ratios but do not appear in the top 10 listing for c values.

Originally, five factors were used to rank the 25 hotspots: number of endemic plants, number of endemic vertebrates, species-area ratio of endemic plants, species-area ratio of endemic vertebrates, and habitat loss (Myers et al. 2000). Hotspots that appeared at least three times in the top 10 listings for each factor were selected as "hottest hotspots." I replaced the species-area ratios with the c values and used the same ranking process to generate a new set of leading hotspots. The number of leading hotspots increased from eight to nine, and there was a change in their composition (Table 2). Three hotspots were added to the leading set: (1) Tropical Andes, (2) Mediterranean Basin, and (3) Mesoamerica. Two hotspots were removed from this set: (1) Western Ghats/Sri Lanka and (2) Eastern Arc and Coastal Forests of Tanzania/Kenya.

This simple exercise illustrates how, by estimating c values, we can detect qualitative differences in species richness between areas of varying sizes that pertain to different species-area curves. These fundamental differences in species richness should be the basis for large-scale conservation planning such as identifying and ranking hotspots.

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Table 1. Species-area ratios and *c* values for endemic plants and vertebrates of 25 biodiversity hotspots (Myers et al. 2000).*

Hotspot	*Endemic plants-area ratio (species per 100 km²)*	*Endemic plants* c *value*	*Endemic vertebrates-area ratio (species per 100 km²)*	*Endemic vertebrates* c *value*
Tropical Andes	6.4 (15)	2049 (1)	0.5 (14)	160.5 (1)
Sundaland	12.0 (10)	1814 (2)	0.6 (11)	84.8 (6)
Mediterranean Basin	11.8 (11)	1609 (3)	0.2 (19)	29.1 (15)
Madagascar	16.4 (8)	1343 (4)	1.3 (7)	106.7 (4)
Philippines	64.6 (2)	1132 (5)	5.7 (2)	100.5 (5)
Caribbean	23.5 (6)	1096 (6)	2.6 (4)	121.9 (3)
Brazil's Atlantic Forest	8.7 (12)	1023 (7)	0.6 (10)	72.5 (8)
Cape Floristic Province	31.6 (5)	974 (8)	0.3 (16)	9.1 (22)
Indo-Burma	7.0 (13)	881 (9)	0.5 (12)	66.5 (9)
Southwest Australia	13.0 (9)	664 (10)	0.3 (15)	15.3 (19)
Polynesia and Micronesia	33.3 (4)	635 (11)	2.2 (5)	42.5 (12)
New Caledonia	49.1 (3)	547 (12)	1.6 (6)	18.0 (18)
Mesoamerica	2.2 (22)	541 (13)	0.5 (13)	125.5 (2)
South-Central China	5.5 (16)	477 (14)	0.3 (17)	24.3 (16)
Brazilian Cerrado	1.2 (25)	441 (15)	0.03 (24)	11.7 (20)
Western Ghats and Sri Lanka	17.5 (7)	399 (16)	2.9 (3)	65.0 (10)
Eastern Arc and Coastal Forests of Tanzania and Kenya	75.0 (1)	382 (17)	6.1 (1)	30.8 (14)
Choco–Darien–Western Ecuador	3.6 (17)	308 (18)	0.7 (9)	57.2 (11)
Succulent Karoo	6.5 (14)	303 (19)	0.15 (20)	7.0 (25)
California Floristic Province	2.7 (21)	278 (20)	0.09 (22)	9.3 (21)
Guinean Forests of West Africa	1.8 (24)	272 (21)	0.2 (19)	32.6 (13)
New Zealand	3.1 (19)	258 (22)	0.2 (18)	18.8 (17)
Caucasus	3.2 (18)	228 (23)	0.1 (21)	8.4 (23)
Wallacea	2.9 (20)	212 (24)	1.0 (8)	74.9 (7)
Central Chile	1.8 (23)	206 (25)	0.07 (23)	7.8 (24)

**The* c *values were estimated assuming* z = 0.18 *(a typical* z *value for mainland curves; Rosenzweig 1995). Numbers in parentheses represent the rank with respect to each of the factors.*

Table 2. Leading hotspots of biodiversity in terms of five factors; numbers represent rank with respect to each of the five factors.

Hotspot	*Number of endemic plants*	*Number of endemic vertebrates*	*Endemic plants* c *values*	*Endemic vertebrates* c *values*	*Habitat loss*	*Times appearing in top 10 for each of 5 factors*
Philippines	7	9	5	5	1	5
Indo-Burma	6	8	9	9	3	5
Brazil's Atlantic Forest	5	6	7	8	6	5
Sundaland	2	5	2	6	7	5
Madagascar	4	4	4	4	9	5
Caribbean	6	3	6	3	12	4
Tropical Andes	1	1	1	1	20	4
Mediterranean Basin	3	12	3	15	2	3
Mesoamerica	9	2	13	2	14	3

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