Theory provides more precise estimates of large-area biodiversity

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Studies of biodiversity at sites such as Colorado's 12,100-foot Hasley Pass are used to estimate total plant species richness over extensive alpine habitat in the Colorado Rocky Mountains. (John Harte/UC Berkeley)

Ask biologists how many species live in a pond, a grassland, a mountain range or on the entire planet, and the answers get increasingly vague. Hence the wide range of estimates for the planet's biodiversity, predicted to be between 2 million and 50 million species.

A new way of estimating species richness reported this month in the journal Ecology Letters by University of California, Berkeley, ecologist John Harte and colleagues, will make such estimates more precise for habitats of all sizes and types, from deserts to tropical rainforests.

"We know how to census the number of species in a square-meter plot or within an acre, but a major problem in conservation biology and ecology is estimating the diversity of biota at very large spatial scales, such as in the Amazon," said Harte, UC Berkeley professor of energy and resources. "This theory provides a much more accurate means of doing that."

The method, derived from the field of information theory, will affect not only conservation efforts to save species facing habitat loss, but also estimates of the impact of global warming, Harte said.

"Quantifying the magnitude of the extinction crisis involves estimating the richness of life in different habitats," he said. "The new theory is probably going to reduce the direness of the predictions of species loss under either habitat loss or climate change at the largest spatial scales, but it will increase (the direness) of estimates of loss at smaller scales."

Losing half of a small biome, for example, will have a worse impact than people think, while losing half of a large area would turn out better, he said.

Harte, who spends his summers in the Rocky Mountains studying the impact of climate change on plants, has for decades mulled over the problem of extrapolating from small study plots to large areas. Census takers have mastered this art, profiling the U.S. population by sampling small representative subsets. When biologists try to profile specific animals, plants or microbes of the Amazon, however, the estimates based on a small number of meter- or acre-size plots can vary by a factor of 10.

Ecological estimates of the number of species at large scales come from a hypothetical curve based on fractals, which predicts that the number of species will increase with area, but increase more slowly for larger and larger areas - a power-law rise with the number of species proportional to the ? power of the area.

"You can sample an area and count the number of species, and then double the area and find more species, but not twice as many, because the species overlap," Harte said.

He and colleague Jessica Green showed in 2003 that the theory of fractals, which posits that physical patterns such as the distribution of plants look similar on small and large scales, does not explain species richness over large areas. In addition, experimental tests of the species-area relationship showed that the curve has to be tweaked for every class of organisms and habitat studied.

Harte and colleagues Adam Smith of UC Berkeley and David Storch of Charles University in Prague, Czech Republic, decided to approach the problem from the perspective of information theory, which has provided key insights into thermodynamics and statistical mechanics.

In their report, they say that maximizing the information entropy - making full use of what is known from small plots without assuming anything about the unknown, larger areas - "provided a formal and robust derivation of the relationship between number of species and area."

The method not only scales up from measurements in small plots to provide more precise estimates of the number of species over large areas, but provides a universal species-area relationship, Harte emphasized.

"People have been finding different curves when looking at different organisms or in different habitats, but in fact, all these curves are the same," he said. "There really is a universal curve people are sampling, they are just sampling along different parts of the curve depending on the habitat or class of organisms."

Harte, Smith and Storch tested their theory with data from one of the few areas on Earth that has been thoroughly studied on both the small and large scale - the Western Ghats mountain range of India overlooking the Arabian Sea. A "biodiversity hotspot" of nearly 60,000 square kilometers, the Western Ghats are partially protected and have been studied extensively by Indian scientists in small sections - 48 quarter-hectare plots - and through large-scale surveys, Harte said.

While earlier species-area theories predict between 400 and 500 species of trees throughout the range of low hills, Harte's theory estimates around 1,070. To date, Indian scientists have documented more than 900 tree species in the preserve. Because a handful of new species is discovered each year, scientists guess that the Western Ghats contain between 1,000 and 1,100 species in all, Harte said.

"Before our publication, there really was no solidly-based theory that provided a means of making such estimates," he said.

The newly derived relationship between number of species and area is mathematically more complicated, but it does predict that as the area increases, the number of new species found approaches zero. This is more realistic than the previous species-area curve, which theoretically predicts an infinite number of species.

Harte has already received several dozen requests for reprints, and he predicts "it will generate a lot of discussion. I think the debate is going to be interesting."

Source: University of California - Berkeley (news : web)

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