Developing a 'gravitational theory' for ecology

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Credit: EPFL

An important breakthrough by EPFL researchers could lead to the discovery of a set of general laws applicable to the environmental sciences.

Is there a link between a given species' body mass and its abundance, or between the size of an ecosystem and its level of biodiversity? Ecologists often find that similar relationships of this type exist in different ecosystems. These relationships are called scaling laws, and they have been shown to apply in both marine and terrestrial environments and to various types of organisms (e.g., microorganisms, mammals and trees). But until now, no clear link has been drawn between these laws. That is now changing: in a recent study, EPFL researchers proved the existence of common macroecological patterns exhibited by these ostensibly independent scaling laws. These patterns could even lead to the discovery of a set of general laws governing the environmental sciences. The study was recently published in *Proceedings of the National Academy of Sciences* (*PNAS*).

The researchers began by testing their hypothesis on three sets of empirical data on tropical forests and communities of mammals and reptiles living on islands with similar climates. Using a computer model, they then replicated the laws that they had observed in the field and developed general algebraic formulas that tie them all together. "Our goal was to rationalize macroecological patterns observed in various ecosystems and position them in a unified framework from which they all derive," says Silvia Zaoli. "In other words, we wanted to find their shared origin." Zaoli is a PhD student at EPFL's Laboratory of Ecohydrology (ECHO) and the study's lead author.

Scaling laws describe the relationship between two quantities. The probability of finding an organism in an ecosystem, for example, declines with the organism's size: there are more bacteria than blue whales in the ocean. "Scaling laws are defined by their exponent," Zaoli continues. "They are used at several levels, such as for predicting how many species will survive if their habitat shrinks or for modeling the distribution of species' body mass in a marine community relative to their environmental functions. They also come in handy for determining the most common body mass within a community, as well as the smallest and largest. The theoretical framework that we discovered shows that, even if the value of each exponent varies from one ecosystem to the next, all the exponents that describe an ecosystem are connected by universal relationships that apply to all ecosystems. For example, these relationships link an increase in the number of mammals, in proportion to the size of an ecosystem, to an increase in the abundance of each species."

One of the two reviewers at *PNAS* took the highly unusual step of sending encouraging feedback. In a short comment, the reviewer situates the researchers' work in a broad, historical perspective. For him, this study has set the environmental sciences on a path towards discovering a physical theory that encompasses all previously observed laws. He compares it to Tycho Brahe's catalog of the positions of stars, planets and comets – a 17th-century work that formed the empirical basis for Johannes Kepler's laws of planetary motion, which in turn laid the groundwork for Isaac Newton's universal law of gravitation. "It is true that we have plotted a course in that direction," says Zaoli, "but we know that we have a long way to go."

More information: Silvia Zaoli et al. Covariations in ecological scaling laws fostered by community dynamics, *Proceedings of the National Academy of Sciences* (2017). DOI: 10.1073/pnas.1708376114

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