One law to rule them all – sizes within a species appear to follow an universal distribution

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Topics: Biodiversity

Researchers at Eawag and EPFL discovered what might be a universal property of size distributions in living systems. If valid throughout the animal kingdom, it could have profound implications on how we understand population dynamics of large ecosystems.

Flocks of birds, schools of fish, and groups of any other living organisms might have a mathematical function in common. Studying aquatic microorganisms, Andrea Giometto, a researcher EPFL and Eawag, showed that for each species he studied, body sizes were distributed according to the same mathematical expression, where the only unknown is the average size of the species in an ecosystem. His article was published in PNAS in March 2013.

Several observations suggest that the size distribution function could be universal. Giometto made his observations in the lab on 14 species of aquatic microorganisms, including unicellular and multicellular ones that are very distant from an evolutionary point of view. The microorganisms he studied varied by four orders of magnitude, the difference in size between a mouse and an elephant.

Furthermore, the mathematical function describing the size distribution remained unchanged even when the species adapted to new environments - changes in water temperature, the presence or absence of competitors - by changing their average size.

Based on these observations, Giometto and his collaborators suggest that two separate factors work in tandem to shape the size distribution of a species. First, environmental factors influence the average size of a species. Second, physiological factors, or genetics, cause the observed variability of species sizes around the average size.

From species to communities

So far the focus has been on the size distribution of individuals of a single species. But Giometto's findings become particularly interesting in light of an observation that is well known to ecologists. “If you take a cup of water from the sea and analyze all of the microorganisms it contains, you find that in an ecological community no size tends to be over or underrepresented,” says Florian Altermann, the ecologist in the team. Mathematically, the sizes can be described by a power-law distribution.

Taken together, these observations of size distributions within a species and within all the species in a given ecological community have interesting implications. If in an ecosystem several species begin to converge around the same size, a balancing force will kick in to restore the power-law distribution, either by acting on the abundance or size of each species.

If, as Giometto and his co-authors speculate, their observations are valid beyond the species they studied, they may provide additional evidence for the existence of universal laws that govern natural ecosystems. These laws would regulate not only the size and abundance of organisms in an ecosystem, but also other properties, such as the number of species that co-exist.

Finding power-laws and using them to describe complex systems already has a successful track record. “In physics, the observation that systems followed power-laws was instrumental in understanding phase transitions. We believe that power-laws can be similarly helpful to gain a deeper understanding of how systems of living matter work,” says Giometto, a physicist, who is seeking to apply methods from his field to understand biological ecosystems.

Original publication

Scaling body size fluctuations; Andrea Giometto, Florian Altermatt, Francesco Carrara, Amos Maritan, Andrea Rinaldo. PNAS / March 2013,
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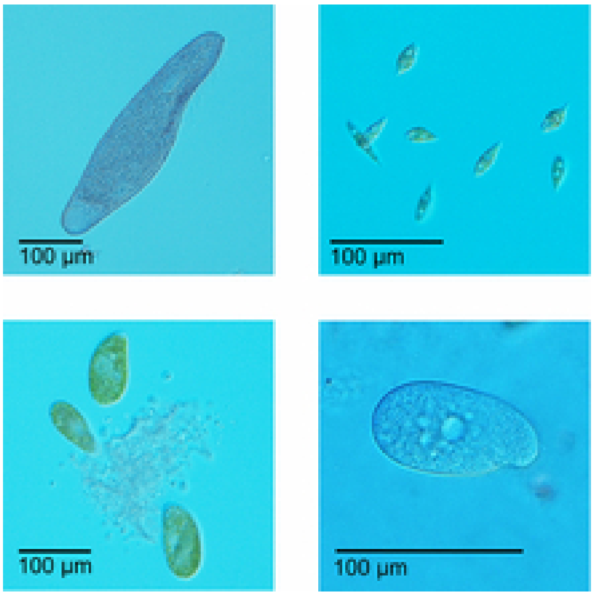

Four protist species, exhibiting different sizes.

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