Why many similar species coexist within complex ecosystems

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View of an Amazon rainforest

Scientists from the universities of Granada and Warwick have published an article in the journal *PNAS* (*Proceedings of the National Academy of Sciences*), in which they suggest one possible answer for the enigma of stability in complex ecosystems like the Amazon rainforest or coral reefs. Many similar species coexist in these complex ecosystems without one of them prevailing above all the rest and displacing them.

Researchers have established that so-called trophic networks, which schematically represent who feeds on whom within an ecosystem, have a certain capacity—which had so far gone unnoticed—called 'trophic coherence', which can help solve this mystery. This is something that experts in the environmental sciences have been trying to solve for decades.

For decades, scientists have been fascinated by the amount and variety of life forms that coexist in certain complex ecosystems like the Amazon rainforest or coral reefs. How can such enormous biodiversity have been spontaneously generated, and then managed to survive? How can many, very similar, species coexist without one of them displacing all the rest?

One of the authors of this article, Miguel Ángel Muñoz, says that interest in these two questions has increased dramatically during the last few years, "given the pace that the extinction of species is gaining as a result of human activities. This is the reason why it is vital to understand the factors and mechanisms that facilitate the stability of ecosystems, so we can protect them by acting in the most efficient way".

When, for some reason, one species prospers, it can result in the detriment of others, for instance its prey or its competitors, which can in turn affect third-party species. Within a specific ecosystem, this can result in great changes that may lead to mass extinction.

Up until the 1970s the consensus was that the bigger and the more complex an ecosystem was—because it included multiple interactions within a large variety of species—the less dramatic the impact of these fluctuations would be upon it. This would explain why the more stable ecosystems tend to be those which display a large biodiversity.

However, in 1972, an eminent physicist and environmental scientist, Sir Robert May, demonstrated mathematically—and employing very simple models—that it should be quite the opposite: Size and complexity should tend to unsettle any dynamic system, such as an ecosystem or a financial network. This result, which has since then been known as the 'May paradox', set off a lively debate on the effects of diversity upon stability.

Organization in different levels

In this article published in *PNAS*, scientists from the universities of Granada and Warwick have analysed a series of trophic networks from many different types of ecosystems. These networks have been patiently gathered by research groups all over the world.

The authors of this article measured to what extent species are structured in levels, so that most of the preys of any predator are in a level immediately below it. For example, within a perfectly coherent network, herbivores in the first trophic level only feed on plants (which are at the zero level), primary carnivores in the second level only eat herbivores, and so on.

Although this structuring of trophic networks in strata (called 'trophic coherence') is not perfect in natural networks (for instance, there are omnivores who feed from different levels) it is, without any doubt, much larger in actual networks than what is normally predicted or estimated by the current mathematical models employed in environmental sciences.

Coherence and stability

As this research has proved, "such coherence is closely related to the stability of networks: the more coherence, the more stability", Muñoz says. In their article, these researchers suggest a new mathematical model to generate artificial or synthetic networks (by a computer) which do not just reproduce more faithfully than currently existing models the different properties of trophic networks, but which also shows unequivocally that stability can increase in parallel with size and complexity.

"It is not that May was wrong: As he already pointed out in his original work, ecosystems must have a certain type of structural property that makes them behave differently from the predictions of his simple theory based upon aleatory trophic structures. In other words, May himself suggested that the answer to this enigma must lie in the particular design or architecture of trophic networks", Muñoz concluded.

This debate, however, is not necessarily closed, since the sort of stability that has been measured is a necessary but not sufficient condition for an ecosystem to survive: "This result promises to alter our vision of ecosystems, and perhaps also other systems with similar properties, such as neuronal, genetic, commercial or financial networks." Besides, as these researchers emphasize, knowing whether a system will become more or less stable with the loss of some of its elements (the extinction of species, or the bankruptcy of financial institutions) is key to developing strategies that can avoid their collapse.

More information: S. Johnson, V. Domínguez-García, L. Donetti, and Miguel A. Muñoz, "Trophic coherence determines food-web stability." *Proceeddings Nat. Acad. of Sciences PNAS* 2014 DOI: 10.1073/pnas.1409077111

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