Species are to ecosystems as cells are to the human body, according to a mathematical model

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n ecosystem is like a great organism in that the species in it behave in a manner similar to the manner in which cells behave within the human body: the group forms a permanent entity, although the entities that form it are constantly being substituted. This is is the conclusion that can be drawn from a theoretical study carried out by researchers at the Universidad Carlos III de Madrid.

The scientists have developed a mathematical model that recreates the behavior of an ecosystem in order to observe its dynamics and its reactions in different situations. And what they have discovered is that the ecosystem reaches a state in which it remains more or less unchanged, in spite of the fact that the species that make it up are continuously substituted by others, even to the point that a complete change takes place, similar to the change that occurs inside a human organism. "In short: the species change, but the structure does not", comments Professor José A. Cuesta, one of the authors of the study, along with José A. Capitán. Both are members of the Mathematics Department of UC3M. Jordi Bascompte, of the Consejo Superior de Investigaciones Científicas (CSIC – the Spanish National Research Council), is the third author of the study, which was recently published in the *Journal of Theoretical Biology*.

The authors comment that from this perspective, it could be stated that multiccellular beings are also ecosystems. That is, we are formed by different types of cells that cooperate and compete for resources; we are colonized by diverse types of bacteria (in the intestines, in the skin, etc.) whose activity is linked to other processes in our organism: we are invaded by viruses, which can be harmful or can take part in processes that regulate our DNA. "These beings are constantly being changed, in such a way that after a long enough time passes, all of the entities that form us have been substituted one or more times. Nevertheless, throughout the process, we continue to be ourselves. This is the same thing that happens with ecosystems," explains Prof. Cuesta.

The most important implication of this finding is that it forces us to see ecosystems in a different light, as self-contained entities rather than as collections of species. "We are obsessed with the preservation of species, but it is much more important to preserve ecosystems", these scientists point out. Seen this way, for example, at times it could be beneficial to substitute an endangered species with another one – with similar interactions with the other species in the ecosystems – so that the ecosystem will not be threatened, because then we would lose one species, but we would save the ecosystem.

In the field of evolution when the term 'ecosystem' is used, a distinction is always made between species and environment. The former evolves in order to adapt to the latter and it changes along with its environment. In light of of this dichotomy, there is a tendency to think of species and environments as separate entities. However, ecosystems demonstrate that the species themselves form the most important part of the environment or ecosystem. "The species interact: they eat each other, they fight for territory... and this causes the presence or absence of certain species to be the most influential factor in the survival of another species", comments the researcher. "This property that species have, which allows them to generate their own environment and form an ecosystem, is the aspect that we were most interested in when we approached this study", comments José A. Cuesta, who is also part of the Grupo Interdisciplinar de Sistemas Complejos (Complex Systems Interdisciplinary Group) at UC3M.

The mathematical model that these researchers have created allows them to observe ecosystems over long periods of time, as well as during their formation, thus allowing them to form other hypotheses as well. They have seen, for example, that an ecosystem is formed as it is invaded by new species, but that there is a point at which the ecosystem becomes robust and no longer permits further additions to its structure, although it does allow the exchange of elements. Another piece of evidence that they have proved is the "large predator" effect, which has been observed in real ecosystems. This effect occurs when the extinction of a large predator that consumes a variety of species leads to the subsequent extinction of the species the predator had previously preyed upon. The reason is that the predator had acted as a regulator of the prey's population. Consequently, when the predator is no longer present, the prey's population grows to the point that depletes its resources, which leads to its extinction, as well.

There are several advantages to creating a mathematical model when studying Nature. First, the temporal scale of an ecosystem's evolution can be enormous and it would require data to be gathered over centuries and even millennia, which would be unviable. Second, the empirical analysis of ecosystems is extremely difficult, because it requires observing all of the species involved over long periods of time, having sufficient observations of predators and prey so that reliable food chain relationships can be inferred and the parameters of competition among the species can be estimated... Also, throughout the period in which the ecosystem is being observed, it may be subject to seasonal or climatic changes that may influence all of these relationships. "Mathematical models turn out to be very helpful for focusing on the type of data to be gathered in order to verify hypotheses. In fact, mathematical ecology has a long tradition in this discipline and ecologists themselves are doing very interesting things by applying mathematical techniques that were developed for use with other phenomena ", assures Prof. José Cuesta.

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