Delayed adaptation favors coexistence

January 8 2019

Credit: Mick Lissone/public domain

Soil bacteria must be able to adapt to varying environmental conditions. – But a new study by LMU researchers indicates that rapid adaptation can be counterproductive, while delayed adjustment facilitates coexistence of different species.

A single gram of soil can contain up to 10,000 different species of bacteria. How such an extraordinary degree of biodiversity can be maintained within populations that consist of species with widely varying levels of fitness is a central question in ecology. When mixtures of soil bacteria are grown under defined conditions in the laboratory, the strain or species with the highest growth rate will eventually dominate the population and all the others will die out. LMU physicist Professor Erwin Frey and his colleague Dr. Marianne Bauer have now asked why this does not occur under natural conditions in the soil. The results of their study, which appears in the journal *Physical Review Letters*, show that delayed adaptation to changes in ecological parameters can lead to the stable coexistence of diverse species.

Soil is an extremely complex habitat, not only biologically, but also from a structural point of view – it is characterized by labyrinthine systems of interconnecting pores. Depending on its water content, this network of pores allows nutrients to be distributed and enables bacteria to come into contact with neighboring populations. "We were interested to know whether the characteristic spatial variability of this habitat has an impact on the stability of bacterial populations," says Marianne Bauer. To find the answer, Bauer and Frey considered a simple system made up of two mobile species that differ in certain traits, and used mathematical simulations to model changes in the makeup of the population in response to fluctuations in the composition of the environment. In their model, one of the species continually synthesizes and secretes a diffusible growth-promoting substance, which has a beneficial effect on the whole population. However, because biogenesis of the compound entails an energy cost, the growth rate of the producer cells is lower than that of the other species. Under laboratory conditions, such a combination of traits would cause the slow-growing species to be outcompeted and driven to extinction.

However, the model incorporates one other feature: The authors assume that members of both species are unable to respond rapidly to sudden fluctuations in environmental conditions. Thus they continue to grow at the same rate as before for some time after entry into a zone in which the pH value or the nutrient supply differs from that which prevailed in their previous niche. Simulations based on this model indicate that the delay in adapting to novel conditions has a positive effect on the population as a whole, and in fact permits the long-term coexistence of the two species. As the growth rates of both species depend on the availability of the growth factor, a local sub-population that contains many of the slow-growing producer cells will grow at a faster rate than one in which there are far fewer producers – and correspondingly lower levels of the growth factor. "And because the pores in the soil system allow for exchange between populations, members of species with very different growth rates can occur together within the same pore, which allows both to survive indefinitely," Bauer explains. "This works for a broad spectrum of pore systems and for surprisingly large differences in growth rates between the two species."

According to the authors, the fact that stable coexistence of the two species is possible over a broad range of parameter spaces suggests that delayed adjustment to changes in living conditions plays a significant role in the maintenance of biodiversity. "This implies that experiments which take account of the spatial structure of ecological niches offer a promising approach to the exploration of biodiversity in realistic systems," says Frey.

More information: Marianne Bauer et al. Delays in Fitness Adjustment Can Lead to Coexistence of Hierarchically Interacting Species, *Physical Review Letters* (2018). DOI: 10.1103/PhysRevLett.121.268101