Model demonstrates link between species' traits, competitive success, environmental conditions

August 7 2015, by Beth Gavrilles

Credit: Wikipedia.

Researchers at Yale University and the University of Georgia have developed and experimentally tested a new mathematical model that helps explain when and where species are likely to outcompete or coexist with one another. The results, just published in *Proceedings of the Royal*

Society B, are a first step toward understanding how changing environmental conditions may affect species distributions.

The Leonard Model is named for the late Ken Leonard, who received his doctorate in ecology from UGA in 2010. It is based on the idea that a species' competitive ability is linked to certain functional traits—attributes like growth rate or body size—and to environmental conditions.

"The concept's been out there a long time," said the paper's senior author Mark Bradford, who was Leonard's adviser and is now at Yale. "The question was, 'How do you actually take that very abstract idea and translate it into something tangible, something directly measurable?' That's essentially what this model does."

Leonard combined aspects of two different approaches to the question, both of which have strengths and weaknesses.

"One approach, known as Tilman's R* theory, is limited in that it addresses only one form of competition, resource extraction, and it's not based on functional traits that you can measure," said study co-author John Drake of the UGA Odum School of Ecology. "Then there's a whole host of different competition models; the most famous ones are the Lotka-Volterra competition equations. The flaw with those is that they're not from first principles, meaning that they don't measure the species individually, and they require a fudge factor. What Ken did was to take the best parts from both kinds of model, and it worked."

The Leonard Model first measures the performance of an individual species in the absence of competition. This determines the potential area the species could occupy based on functional traits and environmental conditions. It then uses those results to predict how the species will fare in different environments when it has to compete with other species.

To test the model's accuracy, the authors conducted experimental competitions-in this case competition for nutrients in the form of nitrogen and carbon-using six genetically related strains of a single-celled yeast.

Starting with two strains collected from the wild, they developed four more, some adapted to very low levels of nitrogen and some to very low levels of carbon, and measured their growth rates under a variety of carbon and nitrogen levels.

They ran the model using the measured growth rates of each strain and the different levels of nitrogen and carbon. The model predicted the outcome of competitions between the strains in the various environments, correctly predicting that in some scenarios certain strains would become dominant, but in others the strains would coexist.

"This is an elegant experimental demonstration that with the right theory, we're able to go from individual functional measurements on species to predictions about their coexistence," Drake said.

According to Bradford, Leonard was the right person to tackle this long-standing puzzle. He came to the Odum School of Ecology after a career in the U.S. Navy and the public and private sector in the IT field.

"When you have an intractable problem, you can often make inroads when you bring someone in with a very different perspective or approach," Bradford said. "Ken's background was in things like engineering and problem solving. Essentially, he took a skill set he'd developed over 25 years, long before he came into academic science, and took the same approach. He translated it to ecology and was successful."

Leonard and Bradford began working on a paper based on Leonard's dissertation as soon as it was completed, but after receiving his doctorate, Leonard started teaching at Georgia Gwinnett College. "He was passionate about teaching," said Bradford, and progress on the paper slowed for a time.

"Then, around the time that Ken was getting sick, I had another student come in, Dan Maynard, who was a very good mathematician and had similar interests as Ken," Bradford said. "So Dan, with Ken's blessing, picked up the baton and took it forward. He re-derived and ran the model and reanalyzed and recast the ideas. So this is really a collaboration between two people who never met."

The paper was published just a few weeks before the first anniversary of Leonard's death.

"I'm very happy we've published it," Bradford said. "Ken's ideas are solid and original, and take a big step forward in understanding the mechanisms behind competition and coexistence."

Bradford cautioned that, like much basic science, it was a long way from application in terms of predicting how individuals, populations and species are likely to change in abundance and distribution in the face of a changing environment.

"But as the translation of this mechanistic understanding eventually goes into the models that we use to help think about how we can adapt and mitigate environmental problems, we gain increasing confidence in the information we're providing to practitioners or policymakers," Bradford said. "So it's just one step, but it's an important one."

More information: "Modelling the multidimensional niche by linking functional traits to competitive performance." DOI: 10.1098/rspb.2015.0516

Provided by University of Georgia