# Ecological complexity simpler than we thought

The effects of species loss in complex ecosystems is predicted by simple traits such as species abundance, body size, and the degrees of separation between them, say a group of researchers from the University of California, Darmstadt University of Technology and the Pacific Ecoinformatics and Computational Ecology Lab.

The mind-boggling complexity and connectedness of nature has spawned such phrases as "to pluck a flower is to disturb a star." If one species goes extinct, how will all the others change? This is the territory of chaos, where the flap of a butterfly's wings could trigger a hurricane on the other side of the world. There are just too many "what ifs", each depending on nuances of the myriad chains of interactions between species. Darwin's most famous book summed it up by describing an "entangled bank" of species "so different from each other, and dependent upon each other in so complex a manner." Yet, 150 years after Darwin's treatise on the connectedness of all life, scientists are just now discovering ways to accurately predict how the loss of one species will alter the abundance of others in a complex ecosystem. "We're learning with complex systems that often what is probable is a very small subset of the big universe of what is possible," says Dr Eric Berlow, lead author of the study and Director of the University of California at Merced's research station, Yosemite National Park. Even more surprisingly, their paper published this week in Proceedings of the National Academy of Sciences shows that predicting these effects becomes even easier as the ecosystem

The multidisciplinary group of scientists led by Berlow and Dr Ulrich Brose of the Darmstadt

University of Technology, Germany, built computer models of complex food webs, the feeding networks of plant and animal species that live together in an ecosystem. They modeled thousands of networks and randomly varied the structure of the networks as well as the traits of the species in a way that mimicked much of the variation found in nature. This allowed them to determine how the loss of one species will affect other species within a feeding network.
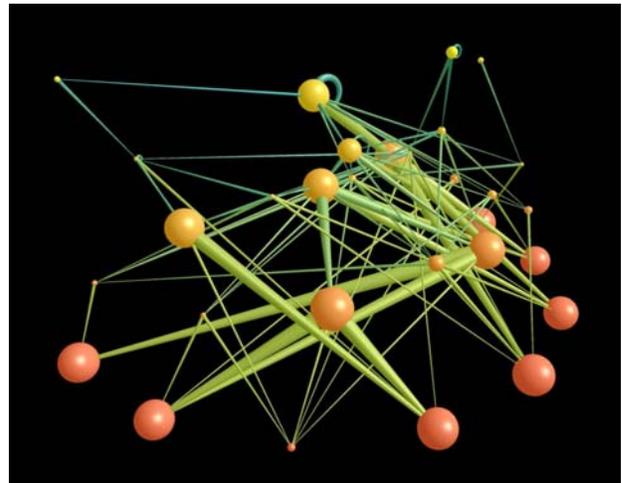
In this depiction of a food web simulated in this study, spheres represent species, and the links between them show feeding relationships. The size of the sphere represents the abundance of the species and the size of the link represents the rate at which a species feeds. Plants are at the bottom of the food web; herbivores above them, and carnivores are at the top. Image created by N. D. Martinez. Food web produced with Network3D software written by R. J. Williams (ricw@microsoft.com).

The scientists ran computer models of species networks and compared the statistical patterns against data collected from a field experiment. The models describe the interdependence among species based on how much they grow, eat, and are eaten. Brose's research group in Darmstadt recently developed ways to derive the many

parameters in these complex network models from information about species' body mass. "We have been learning that species' body mass in natural food webs are organized in exactly the right way to promote the stability of otherwise chronically unstable complex systems, " says Brose, a senior author of the study and the head of the Complex Ecological Networks Lab. This methodological breakthrough was necessary before the researches could tackle key questions about what happens when individual species are lost.

For each network, the researchers explored how removing every species in turn altered the abundance of every other species in the network. Interestingly, knowing the rules that governed each individual feeding link did not help predict species effects in a network. Yet, rather than being unpredictable, new simple patterns emerged when the entire network was considered: The strongest influences were between abundant species that were close to each other, for example, separated by only one or two links (or one or two "degrees of separation"). Effects of removing a rare species were strongest when that rare species had a large body size. The direction of these effects, that is whether removing a species increased or decreased another species' abundance, is predicted well by the shortest connections between the two. The influence of the many longer and less direct connections between species, ones that traverse many links within complex network, appear to be relatively weak probably due to a system of checks and balances being created by many connections with opposing influences. The checks and balances may counteract each other more thoroughly as web complexity grows.

The statistical patterns found by the computer models did remarkably well at predicting the results found in field experiments that measured

feeding interactions in a marine rocky shore ecosystem. Yet the model failed in a predictable way when the experiment included other non-feeding interactions. "While species can influence each other in many ways other than feeding – for example, kelp forests provide protection for small fish, trees serves as nesting habitat for birds – feeding is one of the most fundamental and universal forms of ecological interdependence," says Berlow. "Understanding this basic feeding signal in a network lays the foundation for describing the rest of nature's wonderful diversity. In other words, the failures of the model are as informative as the successes."

"Computer models of complex ecosystems have come a long way" said Neo Martinez, co-author of the study and Director of the Pacific Ecoinformatics and Computational Ecology Lab, a research group that includes all but one of the authors. "This study is some of our best evidence yet that ecological models can usefully predict the effects of dismantling our planet's life support systems through the catastrophic loss of biodiversity." Martinez adds, "Our study suggests that the loss of rare and endangered large-bodied species such as birds, mammals and fish will have an exceptionally strong effect on other species."