# Food-Web Study Aids Management of Biodiversity

Biodiversity—typically defined as the variety and number of organisms in an ecosystem—is decreasing around the world as human activities fragment and destroy natural habitats.

Many scientists consider the loss of biodiversity—and the consequent loss of the "ecosystem services" that diverse, healthy ecosystems provide—as one of the most pressing environmental issues facing the planet.

A new paper by VIMS graduate student Kristin France and advisor Dr. Emmett Duffy in the prestigious international journal *Nature* adds a surprising wrinkle to biodiversity research by suggesting that increasing the connectivity among the patches of a fragmented habitat—the goal of many of ecosystem restoration efforts—may in some cases be counterproductive.

Ecosystem services are fundamental processes—like nutrient cycling and the transfer of sunlight into plant matter—that nature provides to humanity. Previous studies have suggested that losses in biodiversity would render these services unstable through time—thus stressing the inhabitants of an ecosystem by continually exposing them to changing conditions.

The studies suggest that the flip side is also true. "The consensus has been that the more diversity you have, the more stable the system is," says Duffy. "It's less variable through time."

Ecologists like Duffy and France describe biodiversity's stabilizing effect on ecosystem services by borrowing from the world of finance. "The analogy that's often used is the 'portfolio effect,'" says Duffy.

"The more diverse your portfolio, the less variable your total stock value is through time," explains France. "Likewise, the more species you have in an ecosystem, the more stably your ecosystem functions."

The application of the portfolio effect to ecological theory makes common sense. "It's essentially saying that it's better not to put all your eggs in one basket," says Duffy.

But the analogy conceals an important caveat that reflects the limitations of basing management decisions on the early experimental studies that inform much of biodiversity theory.

These seminal studies examined changes in biodiversity and ecosystem function through time, using small plots of prairie grasses or a Petri dish full of microbes—organisms that are readily available and don't move.

France and Duffy's research added an extra layer of complexity, and realism, by adding mobile animals—small shrimp-like creatures called amphipods—to a collection of five seawater tanks containing seagrass. The researchers then monitored the health and diversity of these experimental systems both when pipes connected the tanks and when the tanks were isolated.

In doing so, they more closely mimicked conditions in the natural world, where the movement of individuals and species among different habitats is the mechanism that creates and maintains diversity.

"What Kristin has done is to turn the issue on its side," says Duffy. "She looked at how biodiversity influences the predictability of ecosystem services in space. At first glance, you might expect that predictability would be the same in space as it is in time. But it turns out that at least in this system, it's not."

*VIMS graduate student Kristin France checks the status of her experimental seagrass communities, five-gallon buckets filled with clumps of seagrass and small shrimp-like crustaceans called amphipods. The buckets were either isolated or connected by plastic tubing. The tubing provides "dispersal corridors" for the mobile crustaceans.*

"The thinking has been that when you increase diversity you are going to increase predictability in space," says France. "We found the exact opposite. The more species we had in a system, the more different the patches were from each other, in terms of the variety of species, the variability of the grass biomass, and the total number of grazers in each patch."

France's research holds important implications for the management of natural resources, as it suggests that complete connectivity among patches within a fragmented habitat may not always be the optimal goal. It also suggests that maintaining stable ecosystem services will require preservation of a variety of both species and habitats.

"Ordinarily, we think of connecting patches as a good thing," says France. "Often you need to have habitats connected so that animals across all the patches can immigrate and emigrate to keep populations viable. But we found that when the patches were unconnected, having a greater variety of species across the patches stabilized production across that whole landscape through time."

"It might be an important thing to think about when designing marine reserves," she adds. "There may be an optimum level of connectivity for maintaining populations and yet not having the populations fluctuate exactly in synch, so that their ecosystem processes can be somewhat buffered through time."

Duffy clarifies the importance of limited connectivity by returning to the portfolio analogy.

"The mechanism for the portfolio effect is that the individual elements—whether they be stocks or species—are doing things more or less independently. Individual stocks are fluctuating out of phase with one another. The same thing is likely to happen when you have a collection of unconnected patches, because they are not interacting with one another."

France and Duffy's unconnected patches are thus akin to a portfolio that consists of stocks from different industries. "If you have several diverse, unconnected industries in a portfolio, you're likely to have more stability at any given point in time than you would among the stocks within a single industry," says Duffy.

But when the patches are connected, "all bets are off," says France. "The patches become more synchronized,

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presumably because the animals can move where they want to."

Adding mobile animals to an experimental system is a major undertaking, and helps explain why it has rarely been done in previous experiments.

"As soon as you add another level of interaction, the whole thing gets much more complicated," says Duffy. "That has been a really big reason why people haven't tackled it."

The logistics of working with plants is relatively easy. Seeds are readily available through scientific catalogs. A researcher can order seeds from several different kinds of plants, sow a plot, then return repeatedly to monitor the plants as they grow and interact.

France and Duffy, on the other hand, have to find and collect their animals in the field, then keep track of them as they move within and between their experimental tanks. "What's always the biggest problem in setting up the experiment," says Duffy, "is finding enough "bugs" of different kinds."

The amphipods or "bugs" that France and Duffy use for their experiments are common inhabitants of Chesapeake Bay's seagrass beds. Related to beach fleas and more distantly to pill bugs, these small creatures play a key role in seagrass ecology by eating the algae that would otherwise grow on seagrass blades, thereby helping to allow passage of the sunlight that the grasses need for photosynthesis.

Amphipods are ideal creatures for experimental studies of biodiversity, says France. "Our system is really tractable for looking at animal diversity because the critters we use are big enough to see with the eye and tell apart live, and yet at the same time they make babies quickly."

France says that the take-home message from her research is that there is an important spatial component to biodiversity and its effects on ecosystem processes.

"We need to be conscious about scaling-up the research we've done in isolated patches to making predictions across landscapes. There are important things about landscapes, such as patchiness and connections through dispersal and disturbance. Those processes can affect both the magnitude and stability of the ecosystem services that we rely on."

"Because the spatial component is so important," she adds, "it's essential to do these kinds of experiments with animals, because they interact with their habitats in a more complex way. Sometimes that can undermine completely what we have expected from theory."