College Basketball Study Tests a Landmark Theory of Biodiversity

By Adam Aston

What does a court full of towering collegiate basketball players have in common with a forest full of vertiginous trees?

For legions of basketball fans, the answer may not go beyond *height*. But for ecologists who study species dynamics, the answer promises to alter our understanding of the success of species. It could also help better guide how conservation is practiced in an era of fast-multiplying extinctions.

In a study published on March 9 in *PLoS ONE*, a team of four ecologists at F&ES outlined a connection between basketball and ecology that is, at first glance, deceptively simple. They concluded that the pattern of wins and losses by basketball teams is essentially identical to how species flourish or fail in nature.

Straightforward as these similar distribution patterns may seem, the findings bring into question a landmark theory of species dynamics known as the unified neutral theory of biodiversity.

Developed in recent decades, neutral theory offers ecologists a tantalizingly powerful tool. As a statistical approach, it suggests that for any species—from trees to fish to microbes—patterns of diversity can be modeled solely on the basis of random fluctuations in births, deaths and new arrivals of species rather than on particular traits.

For many ecologists, the implications are jarring. By this reasoning, competitive aspects—whether drought tolerance in trees or poisonous glands in frogs—have little to do with a species' long-term success relative to its competitors.

As a test of neutral theory, however, the basketball study proves otherwise, says Robert Warren, lead author of the study and a postdoctoral researcher at F&ES. "Some scientists say that the theory of survival of the fittest predicts which species are abundant; some say it is just random," says Warren.

Scientists cannot assume that because "a mathematical model is simple, the underlying processes are simple," says Warren. "This assumption is where unified neutral theory becomes problematic."

To understand the allure of the neutral theory of biodiversity, it's helpful to take a step back. Compared with physics or math, ecology has relatively few grand unified theories—as yet, there's no $E = MC^2$ to describe species dynamics.

Unlike more theoretical, mathematical sciences or experiment-based laboratory studies, field biology is messy. Collecting observational data on flora and fauna in their habitats is painstaking. And the data sets from studying trees for decades, for example, are relatively small.

The upshot is that sweeping laws are notoriously difficult to make foolproof in ecology and, so, are rare.

The best-known example of such an insight is, of course, Charles Darwin's quest to develop and refine his theories of natural selection to explain the process and history of the evolution of species that he observed in a mix of living animals and related fossil records.

In 1859, following decades of observation, he noted that "... rarity is the attribute of vast numbers of species in all classes ..." in his landmark *On the Origin of Species by Means of Natural Selection, or the Preservation of*

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Matt Garrett

Yale basketball players Jeremiah Kreisberg, left, and Greg Mangano underneath a stand of trees at Edgewood Park in New Haven.

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> *Robert Warren*

Favoured Races in the Struggle for Life.

That's why, in 2001, when ecologist Stephen Hubbell published a statistical explanation of the diversity and relative abundance of species in ecological communities, it caused such a stir.

Using statistical methods to assess tree populations in a tropical forest, Hubbell suggested that biodiversity derives from randomness more than from species-by-species attributes.

Put another way, variables such as species dominance, food supply, climate or competition can be treated as neutral, or ignored, in predicting a species' success. For its methodological elegance, Hubbell's 2001 book, *The Unified Neutral Theory of Biodiversity and Biogeography*, changed the paradigm for the way ecologists modeled ecosystems.

"It had long been assumed that competition and the theory of survival of the fittest created the diversity patterns observed in nature as species evolved unique niches to coexist," says Warren. "Then unified neutral theory came along; it could explain species abundance as well, or better, than competition models."

The theory set up a troubling dilemma, however, fueling a debate that has simmered ever since. As correct as the math of Hubbell's unified neutral theory may be, it suggests that factors ecologists had long toiled to map and understand didn't matter in the success or failure of a given species.

Ecology is a field where careers can be spent—as Darwin did sailing the seas—in remote study, meticulously assessing the effects of geography, environment or competitors on species. Against this backdrop, the implication of unified neutral theory suggests that, on average, none of these factors matter much more than any other—i.e., they are all neutral.

And while Hubbell didn't necessarily intend for his study to guide conservation thinking, it nevertheless has big implications there, too.

On one hand, it offered a new tool: since unified theory mathematically combines the study of species abundance and biogeography—or how the distribution of organisms relates to the Earth's physical features—it offers conservationists a tool to guide the sizing of reserves to harbor the greatest diversity of species.

But on the other hand, if competitive factors are truly neutral, then decisions made by conservation biologists about how best to protect a struggling species could easily be off target or even, at worst, a waste of time and money.

"Neutral theory would say just roll your dice," says Oswald Schmitz, a co-author and Oastler Professor of Population and Community Ecology at F&ES. "But if there are rules about how species associate themselves on the landscape and there are mechanisms behind the rules, then that has very different management implications than a neutral-theory approach."

At the middle of this scientific tug of war is the question of randomness. To model species abundance and distribution, unified neutral theory assumes that the mechanisms that guide success or failure have no pattern.

Yet for Warren and other ecologists who disagree, it's a vexing challenge to disprove, because identifying the mechanisms that affect a species' success is so devilishly difficult.

A population of frog species, for example, could grow one year because of good rains but ebb in similar conditions another year because of a blight or the shift to a new region as a result of land use changes. Simply identifying the vast number of mechanisms affecting the frogs' numbers is a challenge. Connecting these interrelated factors with effects is even trickier.

What if, Warren wondered, one could identify a population whose mechanisms of competition are well-understood and which also generated population dynamics consistent with neutral-theory methods?

This would prove, a priori, that mechanisms are not neutral. If mechanisms do matter, unified neutral theory would still be useful in describing population dynamics at a high level, but it would be inappropriate to use the theory to devalue the close study of ecological mechanisms in the field.

Enter the basketball test. A native of Indiana, home of Larry Bird and arguably the most basketball-crazed state, Warren considers himself a die-hard basketball fan. The idea for the study came to him one day in North Carolina's Appalachian mountains, while he was counting seed-carrying ants as part of his research on herbaceous forest plants. Warren realized that the pattern of basketball wins is similar to the distribution curves that underpin unified neutral theory.

Warren isn't the first ecologist to look to examples beyond biology to test aspects of neutral theory. Other researchers have identified even more eclectic sample groups where much is understood about the underlying dynamics. Stock prices, the occurrence of scientific citations and even set lists for the Cowboy Junkies have all been used to generate species abundance distributions, a core piece of evidence for neutral theory.

Basketball seemed like a particularly ripe prospect to Warren. What you'd need, he figured, is lots of species, and there are hundreds of basketball teams. In his approach, each team is analogous to a species, with each of their wins counting as an individual being born. Losses, therefore, are akin to an individual dying. And because basketball teams play many games each year, over many years, the resulting data set is big enough for solid statistical analysis.

Most of all, though, basketball makes an apt case, because the underlying mechanisms of success and failure are so well-understood by so many. As even casual fans can attest, winning in a season or over many years comes from a combination of strategies. Among dominant teams—such as Duke, North Carolina, UCLA, or this season's winner, Connecticut—some combination of great coaching and strong recruiting, among other factors, has led to long runs of dominance.

For the statistical trial, Warren crunched won-lost records from 327 NCAA Division I men's basketball teams, a pool of data covering some 20,000 games spanning 2004 through 2008. It may come as no surprise that, across so many games, the most competitive teams generated many more individuals, or wins.

As he suspected, Warren found that his data pool of winning basketball species produced abundance distributions pretty much identical to those observed in countless ecological communities. For most teams, wins are rare, but for a few they are very common.

In short, if basketball wins are not random, then neither is species success. Conversely, if the logic of unified neutral theory were applied to basketball, "then our findings would suggest that the top seed in the tournament is no more likely to win than the last seed in each bracket," says Mark Bradford, a co-author and assistant professor of terrestrial ecosystem ecology at F&ES. "We know that's not true."

For ecology writ large, the implication of the basketball study isn't to disprove neutral theory. The study does knock out a cornerstone piece of evidence, though, says Warren: "We show that a community, in this case college basketball—which is undoubtedly structured by competition —appears random when current methods for assessing biodiversity are used."

Understanding what drives these dynamics is critical to both explaining species distribution today and guiding species conservation policy.

Reflecting on decades spent studying amphibian ecosystems—searching for causes of an ongoing population decline in frog, toad and related species—Dave Skelly, a co-author and professor of ecology at F&ES, acknowledged that the drive to infer process from pattern is one of science's greatest animating forces.

Yet that search shouldn't take away from on-the-ground study of mechanisms affecting species diversity. The hunt for a culprit in amphibian decline, for example, has led researchers to multiple causes. In the tropics, the chief culprit is a fungus. But in North America, most amphibians are immune to the fungus. Here, habitat loss is the greater threat.

"The upshot is that if you tried to ascribe a single cause to all this, you'd get it right in one environment, but dreadfully wrong in others," says Skelly.

For conservation practices, the stakes for finding the balance are getting higher. In addition to fitting mathematical models to broad biodiversity patterns, "we need to put on our boots and head back to the woods to figure out why some species are common and so many are uncommon," says Warren.

"Otherwise, we may find ourselves unable to manage species in the face of global environmental change."

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