



Where the Wild Things Are...

As cities and towns expand, they creep ever farther into fields, forests and deserts that are home to a multitude of animals and plants. As these wild places are replaced by buildings, parking lots and highways, the species that live there are squeezed into ever-smaller habitats. But if there are still suitable connections between those areas — for example, a lush urban park, a golf course that includes stands of native trees, or even a railway line flanked with grasses— animals and plants can move from one habitat to

These corridors, as ecologists call them, allow animals to travel in search of food and mates and to escape habitat changes or catastrophes like forest fires. They also allow animals and plants to replenish dwindling populations, and to colonize new areas. That keeps the whole population healthy, with a robust gene pool that's more resilient to disease and environmental changes. On the other hand, if an area of habitat gets cut off by urban sprawl, animals that can't fly or make their way through yards and parking lots and across roads have nowhere to go. They can easily be decimated by disease or wiped out when trees are cut down or wildfire strikes. Over time, an isolated population can become inbred, making it even less resilient to diseases, habitat changes and natural disasters.

Because many of the world's wild areas have been fragmented by development, it's crucial to preserve and restore connections between the remaining habitat areas, ecologists say, and that's now a top priority in conservation planning.

With so many species in peril and so many pressures on their habitats, ecologists, government agencies and conservation groups must make tough decisions about where to spend the limited funds available to protect habitats. They have to figure out which corridors are the most important so they can be preserved or restored.

"We're always going to have limited resources and we've got to be able to figure out where to spend our money," says Brad McRae, a postdoctoral fellow at UCSB's National Center for Ecological Analysis and Synthesis (NCEAS).

McRae has developed a new way of thinking about and modeling landscape connectivity that reveals the most crucial linkages between habitats and predicts how animals move through them, and hence how landscape affects gene flow. He's used the approach to model the movement of mountain lions in Southern California, greater sage-grouse in the intermountain West, and jaguars in South America.

With help from UCSB computer scientists, McRae has produced detailed models of wildlife movement across areas as big as whole continents. His work will

help protect rare species that are losing their habitats to development, and his technique is catching on with researchers and planners around the world.

McRae's new approach grew out of his earlier work in electrical engineering. His bachelor's degree, from Clarkson University, was in electrical and computer engineering, and he worked as an engineering intern at Texas Instruments before taking a job as an electrical and computer engineer at NCR Corporation, a technology company in Ithaca, New York. It was in the mid-90s that he changed his focus to ecology. He completed a Masters of Science, with a thesis on effects of landscape composition on songbird populations, at the University of Wisconsin-Madison and then a doctorate in Forest Science at Northern Arizona University, with a thesis on gene flow between mountain lion populations. McRae came to NCEAS in 2005, and is one of about 3,500 researchers who have spent time at the renowned center, which was established in 1995 with funding from the National Science Foundation.

McRae began pondering the similarities in how animals and plants move through fragmented landscapes, and how electrical currents flow through circuits. In a circuit, current will travel through any path available from one node to another. If there are multiple routes available, more current will flow.

In McRae's analogy, animals and plants are the equivalent of electrical current, and they'll take advantage of whatever pathways are available to travel between habitat areas, which are like nodes in a circuit. If there are many connections—corridors, that is—they will move more easily. When animals

encounter a barrier like a road, their movement is reduced, just as less electrical current travels through materials with high resistance, like silicon. In some cases, a barrier may stop movement altogether: a major highway may thwart the travel plans of animals that try to scamper across it, just as electricity can't travel through rubber.

Electrical engineers have equations to describe how electricity moves through a circuit. McRae decided to use those equations—circuit theory—to model animal and plant movement over large, complex landscapes.



JPL engineer Matt Dickey took the photograph opposite from the bridge at the center of this photo, between the parking lot and the main campus at Jet Propulsion Laboratory, in La Cañada (near Pasadena), CA. The creek bed in which the mountain lion is crouched is a good example of the corridors through urban sprawl identified in McRae's studies.

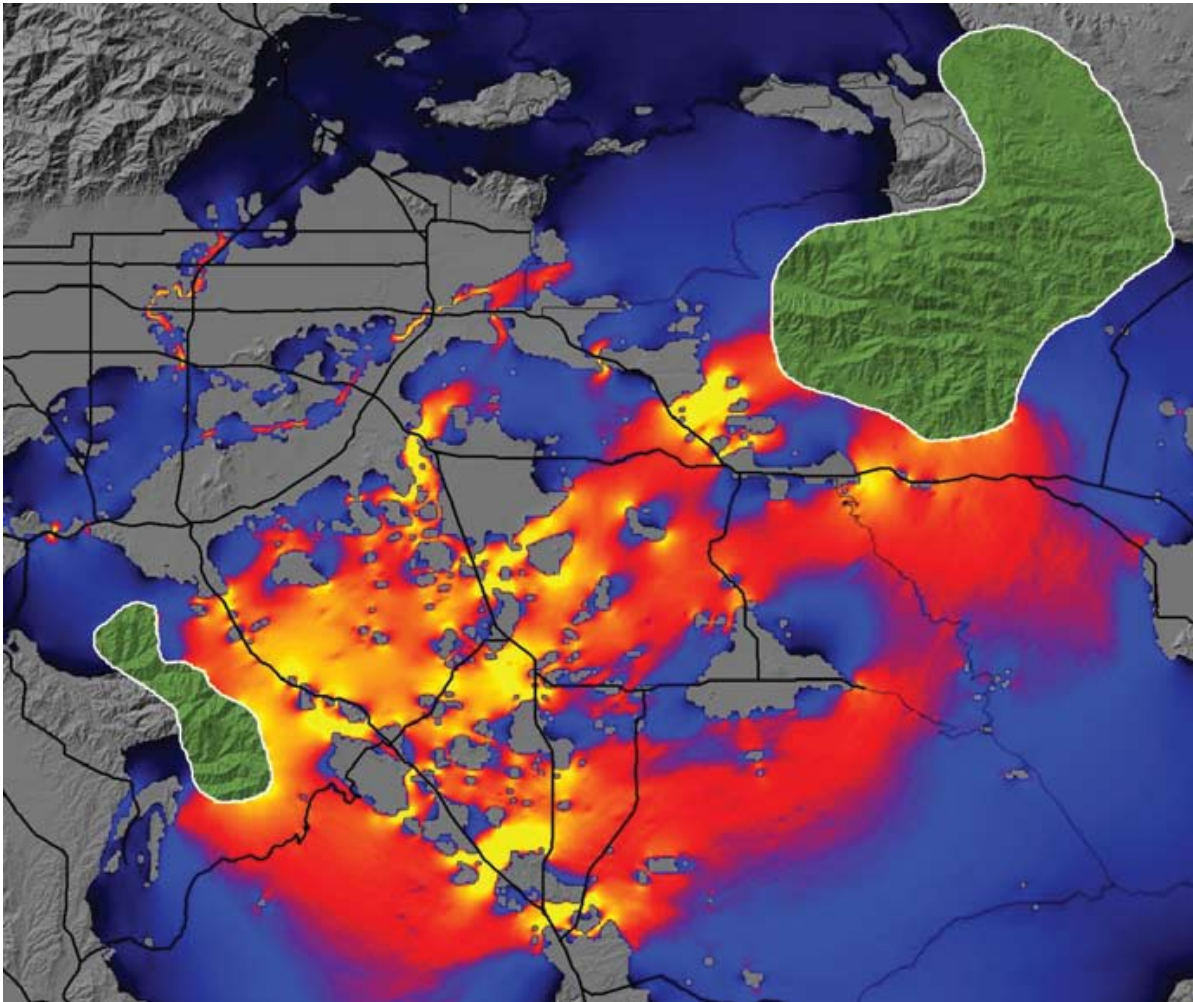
McRae tested the idea using data on two threatened species: big leaf mahogany, a tropical tree that grows in parts of Central America, and wolverines, the largest land-dwelling members of the weasel family, which roam widely in western and far northern North America.

Genetic connectivity for these species had already been studied using conventional approaches, but McRae revisited the data, applying circuit theory to the problem. He found that for both species, his technique worked better using landscape and genetic data than standard methods, and he published his work in the highly respected *Proceedings of the National Academy of Sciences* last year.

In McRae's model, landscapes are represented as conductive surfaces, and features like forests, roads, and grassland have differing degrees of resistance to animal or plant movement. To perform an analysis, McRae must first break down a large landscape into smaller cells, so that he can analyze how species move between those cells, and consequently through the landscape as a whole.

Using his new approach, McRae found that the shape of habitats can dramatically affect how animals and plants move around and breed—a factor that couldn't be taken into account using conventional models of movement—and that barriers to movement don't have as big an influence as had been assumed in standard models. Unlike conventional approaches, the circuit theory technique allows all the possible pathways through a landscape to be analyzed at the same time. "With one single computation," McRae says, "you can consider every possible corridor, every possible linkage in the landscape."

Over the last couple of years, McRae collaborated with Brett Dickson at Northern Arizona University and wildlife biologist Rick Hopkins of Live Oak Associates to use circuit theory to examine how mountain lions move through Southern California. There are populations of mountain lions in mountain ranges in the region, but relentless urban sprawl has created plenty of barriers for the animals: choked six-lane highways, condo complexes and shopping malls.



Habitat connectivity in Southern California: Warmer colors show areas important for mountain lion movement between mountain ranges. Yellow indicates "pinch points," or areas where connectivity is most vulnerable to being cut off by development.

“We set out to figure out which areas between those mountain ranges are most crucial for connectivity,” McRae says. “Where are those critical areas, those pinch points?” If those connections are lost to development he says, mountain lion populations could become dangerously isolated.

McRae has produced maps of mountain lion movement in Southern California which will be submitted for publication soon. In those maps, areas where connectivity is not threatened are indicated in blue, and red is used for places that are critical for maintaining movement. If these pinch points were to be cut off altogether, whole populations of mountain lions could be cut off from each other, McRae says, leaving them genetically isolated and vulnerable to disease, habitat destruction and natural disasters. He’s identified a crucial linkage between lion habitats in the San Bernardino and San Jacinto mountains, but to move between those two areas, mountain lions must cross Interstate 10, one of the region’s busiest highways.

McRae initially did the work using the popular programming language MATLAB, and it took several days to run his models. “I had very slow, clunky code because I’m not a very good programmer,” McRae said. He “struggled” with the code for years before attending a talk at NCEAS by Viral Shah, then a doctoral candidate working with John Gilbert, a professor of computer science at UCSB, who is trying to make powerful parallel computing techniques “available to people who don’t have experience in high performance computing,” Gilbert says.

Shah, who now works for Interactive Supercomputing and is a visiting scientist in Gilbert’s lab, set to work to try to make McRae’s task less onerous and his computations much quicker. McRae says Shah’s work transformed his “clunky MATLAB code that took 3 days to run into something that takes a few minutes,” using an 8-core processor at NCEAS. “All of a sudden it’s just whizzing,” McRae says. “It’s just a few hundred lines of code,” he adds, “but it accomplishes a great deal.”

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Shah then set up McRae’s code to run in Star-P, a parallel computing environment developed by Shah and Gilbert together with Steve Reinhardt of Interactive Supercomputing Inc. Star-P allows users to work in a familiar programming language like MATLAB, while Star-P translates the codes so they can be run effectively on multiple parallel processors.

“The trick was to stay in an environment that Brad was familiar with,” Shah says.

Shah’s contribution has allowed McRae to produce models of wildlife movement across larger areas, and to produce more detailed and accurate results by dividing landscapes into many smaller cells than he could using traditional computing methods. Because McRae can run his models so much faster, he can also refine them much more quickly.

McRae now wants to use his technique to model habitat connectivity for groups of species, such as forest carnivores, since it’s generally more practical to try to conserve suites of species in an ecosystem rather than single animals.

Scientists and conservationists have long argued that connections need to be preserved and restored to save species. With McRae’s new method of modeling habitat, they should have a much stronger case and a better idea of where to put the limited funds available for such efforts.

“It gives us an objective way to quantify the benefits of protecting those habitats,” McRae says. 

Brad McRae’s Home Page: www.nceas.ucsb.edu/~mcrae

Using Circuit Theory To Design Connected Landscapes: www.nceas.ucsb.edu/~mcrae/design.html

National Center for Ecological Analysis and Synthesis: www.nceas.ucsb.edu

Viral Shah’s Home Page: allthingshpc.nfshost.com/drupal

John Gilbert’s Home Page: www.cs.ucsb.edu/~gilbert

National Science Foundation: www.nsf.gov

Los Angeles Times coverage of the mountain lion at JPL: www.latimes.com/news/local/la-me-cougar26jan26,0,323028.story