Conservation Biology

Obituary

A tribute to a true conservation innovator, Brad McRae, 1966–2017

Powerful innovations can occur when a concept is taken from one field and used to solve a problem in an unrelated field. In fact, it has been shown that as the distance between a problem solver's field of technical expertise and the focal field of a problem increases, so does the probability of success. We celebrate Brad McRae, the innovator who brought circuit theory to conservation science and practice. Brad was a senior landscape ecologist for The Nature Conservancy's (TNC) North America Region when he died on 13 July 2017 after a brief battle with cancer. He is survived by his wife, Theresa Nogeire, also a conservation scientist, and their young children Eliza and Jake.

After earning a bachelor's degree in electrical and computer engineering from Clarkson University in 1989, Brad worked as an electrical engineer with National Cash Register in Ithaca, New York, for 4 years before shifting gears to get a master's degree in wildlife ecology under Stanley Temple at the University of Wisconsin-Madison in 1995. After completing his MS, he worked for the Okanagen-Wenatchee National Forest until 1998. He then entered the PhD program at Northern Arizona University to work with Paul Beier on landscape genetics of pumas (*Puma concolor*) across the southwestern United States. Beier had good maps of habitat and genetic patterns but no good way to model the relationship between them. At the time, the dominant paradigm was least-cost path modeling, an intuitively appealing approach for modeling animal movement but less suited for gene flow.

Tapping his previous career as an electrical engineer, Brad reasoned that gene flow across a complex landscape should follow the same rules as electrical conductance in a complex circuit with many resistors (McRae et al. 2008). Electricity flows from source to ground not along the single path that has the lowest sum of resistance (i.e., ohms) but via all possible paths. Moreover, the net resistance from source to ground can be calculated using simple equations (Kirchhoff's laws). Thus, the concept of modeling species movement with circuit theory was born.

The Eureka moment occurred in 2004, but Brad was not content with justifying his new approach based on the intuitive analogy with circuit flow. So, he spent another year thinking about how to ground circuit theory in ecological theory and particularly how circuit theory could take a place alongside the venerable concept of isolation by distance, which had dominated landscape genetics since Wright (1943) first coined the term. McRae (2006) provided that theoretical foundation, demonstrating that a model of "isolation by resistance" is equivalent to the classical analytic theory of isolation by distance in unbounded binary landscapes. More importantly, this article showed that the model closely approximated analytic results from precise Markov chain and coalescent theory algorithms for complex 2-dimensional landscapes—allowing it to be applied to real landscapes and real-world problems. Soon after, he showed how circuit theory better predicted patterns of, and barriers to, gene flow for plants and animals inhabiting real landscapes than did traditional connectivity models (McRae & Beier 2007).

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Brad continued his career as a postdoc with the U.S. Environmental Protection Agency, where he worked for 6 months before moving to Santa Barbara, California, to take another postdoc with the National Center for Ecological Analysis and Synthesis from late 2005 to July 2008. In 2008, he joined TNC's office in Seattle, Washington, and eventually shifted to their North American team.

If Brad had simply conceived of a circuit-theory-based connectivity model, that alone would have been an impressive contribution to conservation. But he went further to partner with others to build open-source software to model and map connectivity (e.g., Circuitscape [McRae et al. 2013]). The latest major release of Circuitscape has been downloaded more than 25,000 times since 2014. Circuitscape has been used in at least 274 peer-reviewed studies. The software is easy to use, its outputs are relatively easily interpreted, and its intuitive nature makes it easy to explain. In addition to Circuitscape, Brad designed and released other freely accessible software packages to facilitate connectivity analyses. He created Linkage Mapper, a set of Python scripts packaged as an ArcGIS toolbox that facilitates much of the process of wildlife habitat connectivity planning. With colleagues, Brad developed Gnarly Landscape Utilities, to aid in "less glamorous tasks of connectivity modeling" (http://www.circuitscape.org/gnarly-landscape-utilities).

Researchers using Circuitscape have addressed a range of topics, including identifying where diseases originated and how they spread, determining how species will move across the western hemisphere to track climate change, modeling hydraulic resistance of root systems, and exploring whether early modern humans left the African continent in one or more waves. Researchers have used Circuitscape to look at a variety of taxa from protists to humans and have even applied the approach more generally to explore structural connectivity.

From a conservation practitioner's standpoint, his work has been integrated into local and regional conservation-planning efforts around the world. Some of it, Brad did himself and some he facilitated through his contributions to countless working groups and projects. For example, Brad worked with different groups across the United States to map landscape permeability and integrate it into a broader framework for prioritizing areas likely to be more resilient to climate change. In the U.S. northwest, TNC has acted on these priorities, making investments in more connected, more topographically diverse landscapes. The results of these analyses are being used by TNC and by land trusts and foundations.

At his first TNC position, Brad became part of the Washington Wildlife Habitat Connectivity Working Group (WHCWG), a collaboration among state and federal wildlife, transportation, and land management agencies, academics, conservation organizations, and independent researchers. Unlike the traditional fee-for-service model in which managers hire scientists to produce a product, in this effort, all the parties jointly developed (and endlessly redeveloped) the research questions, the work plan, the scientific procedures, the scientific inferences, and the guidance on how the science should be applied to conservation decisions. Brad described his years with WHCWG as the most meaningful and rewarding work of his career. He encouraged others to embrace coproduction and to appreciate that the creation of actionable science is a social enterprise.

Brad was a brilliant scientist and a humble and generous collaborator. Brad had a kind and gentle nature that invited colleagues in and kept them close. He clearly knew the importance of informal discussions over coffee or margaritas. He was deeply thoughtful and always willing to share his knowledge. As an affiliate assistant professor at the University of Washington, he guest lectured, served on graduate committees, and introduced many a student to the world of connectivity modeling. He bridged an important gap between TNC and the University, bringing TNC's research questions to the world of academia and connecting UW's students to TNC. Perhaps more importantly, he served as an informal mentor to students and researchers around the world wanting to learn how to use his tools and techniques. He realized the key role of supporting Circuitscape and spent countless hours on the phone and email helping with distant projects that he was likely never to see.

Brad worked hard. But, he played hard too. He had a true love of backcountry and downhill skiing, mountain biking, paddle boarding, and other water sports. He delighted in practical jokes and ribald (but never demeaning) quips and puns. Most importantly, he was a caring husband, father, and friend—as well as a dedicated conservationist.

By 2009, Brad McRae's conceptualization of circuit flow became a dominant paradigm for modeling gene flow and ecological connectivity, such that young conservation scientists might find it hard to imagine a time before this paradigm. His career amply illustrates the idea that fusion across widely disparate disciplines is the surest path to innovation. Because most conservation scientists believe that biodiversity supports ecological and evolutionary processes, we should be predisposed to accept that disciplinary diversity supports the scientific enterprise, without the risk of potential negative impacts that non-native biodiversity can bring. His generous sharing of his time and insights, his embrace of coproduction, and his strong desire to understand how the world works—and to change how the world works—will continue to propagate through our global community. For those of us who had the privilege to work with him, we are stronger scientists and closer colleagues for it. In our work together, Brad reminded us to always question our assumptions and to be rigorous and thorough but to never forget to be creative and have fun.

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