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Movement Ecology and the Minimal Animal

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Abstract

Among ecologists, movement is on the move. Over the past decade or so, a growing number of researchers have begun to focus their attention on how and why individual animals move across landscapes through time. Research programs come and go, and there is no way of knowing how long this new filed of movement ecology will retain its promise or what new forms it might take. Nonetheless the emergence of this approach to studying animals and landscapes can tell us something about the way scientific practices and conceptions of the animal are changing in an era of Big Data and of growing concerns about the impact of humanity on global ecological processes.[1]

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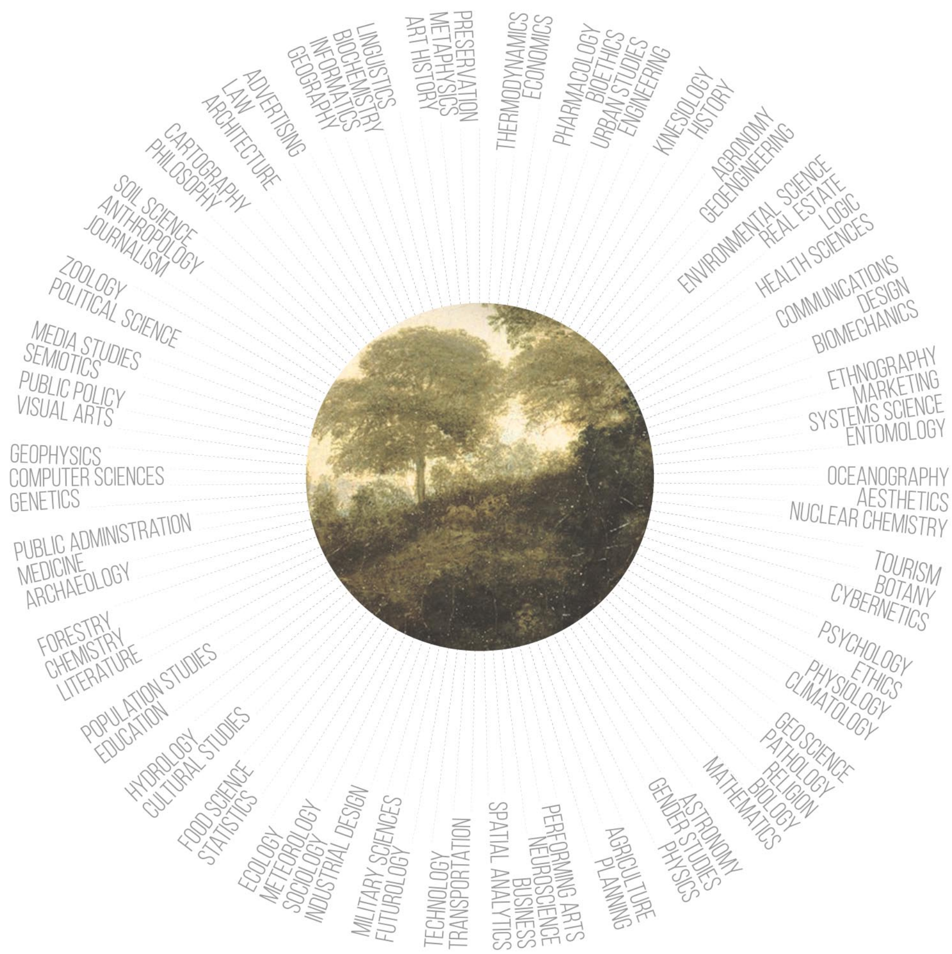

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MOVEMENT ECOLOGY AND THE MINIMAL ANIMAL

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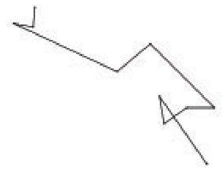
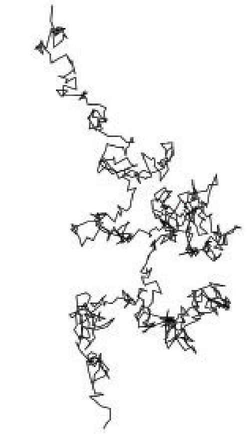




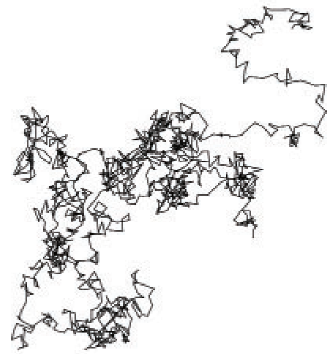
Among ecologists, movement is on the move. Over the past decade or so, a growing number of researchers have begun to focus their attention on how and why individual animals move across landscapes through time. Research programs come and go, and there is no way of knowing how long this new field of movement ecology will retain its promise or what new forms it might take. Nonetheless the emergence of this approach to studying animals and landscapes can tell us something about the way scientific practices and conceptions of the animal are changing in an era of Big Data and of growing concerns about the impact of humanity on global ecological processes.[1]

The term 'movement ecology' is not new in the scientific literature, but it was only with the articulation of a theoretical program by ecologist Ran Nathan in 2008 that it began to be understood as something around which an epistemic community could be organized, generalized theories could be developed, and broad appeals for support could be made.[2] Since then movement ecology has become one of ecology's fastest-growing sub-specialties. Numerous conferences have been held, major grants have been awarded, and journals such as *Movement Ecology* and *Animal Biotelemetry* have been founded. Movement ecologists often attribute the recent expansion of their field to technological advances in communications, surveillance, and computing. Nathan, for example, has written that the rise of movement ecology can be explained in large part by new tracking methods that promise to "revolutionize our understanding of movement phenomena because they allow us to address key questions that we were not able to examine before."[3] Similarly, ornithologist Martin Wikelski has envisioned a future in which satellite-based sensors and animal-borne tags will allow biologists to fill in the "white spaces that we still have on the globe for animal movement" and even to "use animals as distributed sensor networks around the globe."[4] Technology, rather than any particular theoretical insight or empirical discovery, seems to be leading the way.

At the same time, as one group of leading movement ecologists has written, "the explosion of data volume and variety has created new challenges and opportunities for information management, integration, and analysis."[5] The perceived urgency of overcoming these challenges originates both from ecologists' desire to work at the cutting edge of their field and from their sense that the Earth faces a crisis of human making. Developing adequate data-analysis and data-management practices has thus become central to at least some ecologists' understanding of their moral obligations as scientists and as environmentalists. This is one reason that theoretical frameworks such as the one proposed by Nathan have been so warmly received. In addition to positioning movement as a legitimate object of ecological inquiry–rather than merely an indicator of more important underlying processes–such frameworks help to discipline and render comparable inherently unwieldy and diverse biological data. For this project, the otherwise distant domain of genomics has frequently served as a comparison. Nathan, for example, writes that the "scientific revolution potentiated by genome sequencing can be compared with insights about movement drawn from mapping every step and stop of an individual during its lifetime track from birth to death."[6] Reduced to a series of locations, the individual's life thus becomes amenable to analysis.

The establishment of centralized data repositories such as Movebank, which currently contains data from more than 2,000 movement ecology studies, is also helping to render manageable the overwhelming amount of movement data now available.[7] As with the pioneering genetics database GenBank, Movebank aims to facilitate the establishment of an international epistemic community around a novel object of study: the movement track, understood as a sequence of latitude-longitude pairs in time.[8] While genomics casts a long shadow over the recent development of movement ecology, there is also a longer history of ecologists' efforts to develop workable models of real-world animal movements – a history that can teach us something about what is at stake in movement ecology's data-management practices and its imagination of animal life. The first digital representations of what movement ecologists call the 'lifetime track' of an animal date to the 1960s, when mainframe computers first became widely available on American university campuses. While mathematical models of animal movement had existed since the early 20th century, digital computers suddenly made it feasible to statistically model the movements and decision-making processes of a single animal. What was probably the world's first digital simulation of animal movement was developed at the University of Minnesota by statistical ecologist Donald B. Siniff in 1967. Titled SIMPLOT, the program was intended less as an accurate representation of animal behavior than as a way of identifying real-world deviations from statistical models. In a way that would have been impossible with real animals moving through real landscapes, it allowed the scientist to experiment with the consequences of his or her own assumptions.[9]

Since the 1960s, efforts to model animal movement in the digital medium of the electronic computer have been powerful accelerators of ecologists' tendencies toward 'behavioral minimalism.' This is a



term that ecologists Steven Lima and Patrick Zollner have used to describe a research strategy focused "on only those few behavioral traits that are likely to be important to the question under study."[10] It requires shutting out of view all of the irrelevant factors, which in turn–and this is where things get tricky–requires deciding in advance which factors are relevant or irrelevant. As Lima and Zollner argue, behavioral minimalism is useful and often even necessary; without it, much of the enormous complexity of animal life would remain intractable to scientific inquiry. It becomes problematic, however, when it becomes an ontological claim about what animals and other organisms really are – that is, when a strategy of behavioral minimalism is taken as evidence of the existence of what might be described as "minimal animals."[11] With the help of digital computers, minimal animals have proliferated over the past several decades.

Even as they pursue the strategy of behavioral minimalism described by Lima and Zollner, movement ecologists today are careful to acknowledge the complexity of animal movement. In Nathan's theoretical framework, for example, the individual animal's movement track is conceptualized as the result of environmental, physical, and cognitive processes that cannot be reduced to latitude-longitude pairs. Similarly, Wikelski and others have been careful to leave room in data repositories such as Movebank for other forms of data besides location.[12] Nonetheless, as movement ecologists develop generalized theories with the help of highly abstracted mathematical models, and as they aggregate data about diverse species into central repositories, they are implicitly embracing a data-driven version of behavioral minimalism – one in which the movements of animals become self-evidently comparable to the Brownian motion of particles or the dispersal of seeds by wind.

Behavioral minimalism is nothing new in animal ecology, but the intensity with which it is now being pursued and the extent to which it is dependent on a particular set of research technologies is unprecedented. However sophisticated their underlying models may be, most studies by movement ecologists focus on the landscape-scale movements that are easily observed with modern tracking techniques. Factors that are harder to measure and to model become secondary considerations: at best 'annotations' around the scaffolding provided by location data, at worst endlessly deferred desiderata for some future experiment. Similarly, the desire to develop models and build data repositories that work for any species in any environment has

1 Sabine Leonelli, "What Difference Does Quantity Make? On the Epistemology of Big Data in Biology," *Big Data & Society* 1, no. 1 (2014): 1–11; Christophe Bonneuil & Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History, and Us*, trans. David Fernbach (Brooklyn, NY: Verso, 2016).

2 Ran Nathan, et al., "A Movement Ecology Paradigm for Unifying Organismal Movement Research," *Proceedings of the National Academy of Science* 105, no. 49 (9 Dec. 2008): 19052–59.

3 "Ran Nathan on the Growing Importance of Movement Ecology," (October 2010), http://archive.sciencewatch.com/inter/aut/2010/10-oct/10octNath1/ (accessed December 20, 2015).

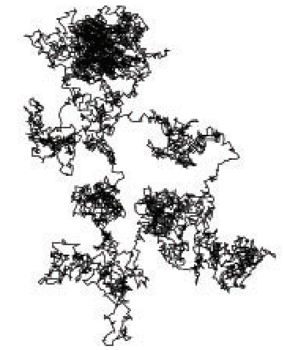
4 Martin Wikelski, "Move It, Baby!" talk delivered at the 2014 Symposium on Animal Movement and the Environment held at the North Carolina Museum of Natural Sciences in Raleigh, North Carolina, on May 5, 2014, https://www.youtube.com/watch?v=PxtJAXQQU40 (accessed December 20, 2015).

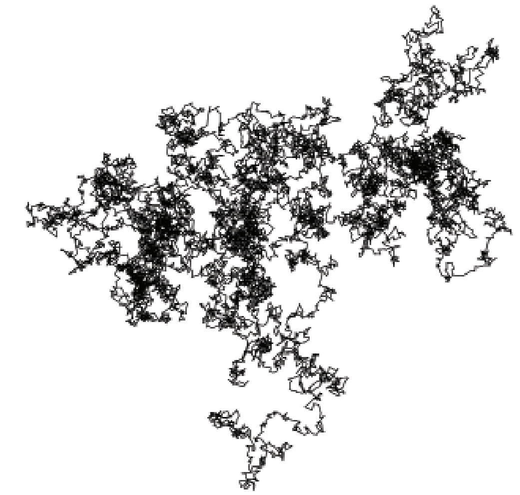
5 Roland Kays, et al., "Terrestrial Animal Tracking as an Eye on Life and Planet," *Science* 348, no. 6240 (12 June 2015), DOI: 10.1126/science.aaa2478.

6 Nathan et al. "A Movement Ecology Paradigm for Unifying Organismal Movement Research," 19053.

7 "About Movebank," https://www.movebank.org/node/2 (accessed December 20, 2015).

8 "BD&I: MoveBank: Integrated Database for Networked Organism Tracking," Award Abstract #0756920, US National Science Foundation, http://www.nsf.gov/awardsearch/showAward?AWD_ID=0756920 (accessed December 20, 2015). On GenBank, see Hallam Stevens, *Life Out of Sequence: A Data-Driven History of Bioinformatics* (Chicago: University of Chicago Press, 2013).





encouraged a reduction of the phenomenon of movement to the lowest common denominator, the latitude-longitude pair. By focusing on tracking methods that produce enormous amounts of data at ever-lower costs, movement ecologists are implicitly adopting a locational form of behavioral minimalism as the ontological foundation of their work.

In the long run this may prove to be a risky path toward scientific success, even judging by the narrowest of criteria. A few years ago, biologists Alistair Boettiger and George Wittemyer and their colleagues conducted a movement-ecology study of African elephants in northern Kenya. Using a mathematical model derived from signal processing theory, remote-sensing data from satellites, and movement data collected with GPS collars, they were able to predict elephant movements on the basis of landscape features as well as past behavior. One of their findings was that the incorporation of landscape and behavior significantly improved the accuracy of the prediction, but only in areas relatively unaffected by human activity. When the elephants moved through human-dominated areas, the accuracy of the prediction fell dramatically, "probably because movement behavior was reactive to the presence, movements, and threats of humans and livestock in such areas."[13]

This is a conclusion that seems likely to be relevant well beyond the specifics of the particular landscapes and animals under study, and it is one that suggests the limits of a minimalistic approach to animal movement that is driven primarily by the technological affordances of present-day tracking and computing technologies. The increasing human domination of the planet is precisely the reason that the theoretical models and central data repositories of movement ecology seem so urgent; it is also the reason that ecologists' models may become less and less predictive over time, no matter how much location data they are able to collect. Technological affordances and theoretical frameworks may run up against the contingencies of history, which is increasingly rendering chimerical the idea of a 'human-free zone' of precise prediction. In that case, movement ecologists may want to consider incorporating other methods that can articulate the movement of animals across landscapes in an idiom richer and wider than a series of points on a map.[14]

9 On the context in which Siniff developed SIMPLOT, see Etienne Benson, *Wired Wilderness: Technologies of Tracking and the Making of Modern Wildlife* (Baltimore: Johns Hopkins University Press, 2010), 5–51. A live version of the program is available at http://etiennebenson.com/simplot/.

10 Steven L. Lima & Patrick A. Zollner, "Towards a Behavioral Ecology of Ecological Landscapes," *Trends in Ecology and Evolution* 11, no. 3 (March 1996): 132–35, 133.

11 Etienne Benson, "Minimal Animal: Surveillance, Simulation, and Stochasticity in Wildlife Biology," *Antennae: The Journal of Nature in Visual Culture* 30 (Winter 2014): 39–53.

12 In 2013, Wikelski and his colleagues introduced a software tool called Env-DATA that simplifies the process of matching animal movements to the environmental factors that may be influencing them. Somayeh Dodge, et al., "The Environmental-data Automated Track Annotation (Env-DATA) System: Linking Animal Tracks with Environmental Data," *Movement Ecology* 1, no. 3 (December 2013), http://www.movementecologyjournal.com/content/1/1/3.

13 Alistair N. Boettiger, et al., "Inferring Ecological and Behavioral Drivers of African Elephant Movement Using a Linear Filtering Approach," *Ecology* 92, No. 8 (August 2011), 1648–57, 1656.

14 S. Eben Kirksey & Stefan Helmreich, "The Emergence of Multispecies Ethnography," *Cultural Anthropology* 25 (2010): 545–76.

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