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Trackable life: Data, sequence, and organism in movement ecology

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ABSTRACT

Over the past decade an increasing number of ecologists have begun to frame their work as a contribution to the emerging research field of movement ecology. This field's primary object of research is the movement track, which is usually operationalized as a series of discrete "steps and stops" that represent a portion of an animal's "lifetime track." Its practitioners understand their field as dependent on recent technical advances in tracking organisms and analyzing their movements. By making movement their primary object of research, rather than simply an expression of deeper biological phenomena, movement ecologists are able to generalize across the movement patterns of a wide variety of species and to draw on statistical techniques developed to model the movements of non-living things. Although it can trace its roots back to a long tradition of statistical models of movement, the field relies heavily on metaphors from genomics; in particular, movement tracks have been seen as similar to DNA sequences. Though this has helped movement ecology consolidate around a shared understanding of movement, the field may need to broaden its understanding of movement beyond the sequence if it is to realize its potential to address urgent concerns such as biodiversity loss.

1. Introduction

Since the early 2000s, a number of ecologists have rallied around the banner of movement ecology, a nascent and perhaps ephemeral subfield organized around a newly salient object of inquiry.[1] The object in question is the movement path, trajectory, or track, typically operationalized as a sequence of discrete "steps and stops" taken by an organism within a Cartesian space on time scales ranging from minutes to decades.[2] Although distinctive in its focus, movement ecology is not an isolated development. It is one of a number of data-centric approaches that have emerged in recent decades across the life sciences as the amount of data that can be collected and stored and the computing capacity to analyze them have grown exponentially.[3] As "big data" are mobilized to address concerns about biodiversity conservation and wildlife management, movement ecology is coming to serve in many cases as a useful conceptual framework, methodological toolkit, and epistemic community. A close examination of its primary object of concern, the track, as revealed through the discourse of some of the subfield's leading figures and through the design of its primary data repository, offers insight both into the practice of data-centric science and into its potential to pose long-standing ecological

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[1] For overviews, see Holyoak, Casagrandi, Nathan, Revilla, & Spiegel (2008); Kays et al. (2015).

[2] Nathan et al. (2008), p. 19053.

[3] On big data and data-centric methods in the life sciences and ecology, see Aronova, Baker, & Oreskes (2010); Strasser (2012); Leonelli (2012, 2014); Stevens (2013); Sepkoski (2013). On histories of data in science, see Daston (2012); Gitelman (2013).

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questions in new ways—in particular, its potential to shift attention from the relationship between populations and territories to the dynamic interaction of bodies moving in space.[4]

It has been suggested that data-centric or data-intensive science renders traditional models of the scientific method obsolete by replacing hypothesis-testing with pattern-identification.[5] Such claims are clearly exaggerated; in practice, data-centric or data-intensive sciences show no sign of abandoning hypothesis-testing. Nonetheless, data-centric approaches do tend to shift the focus from a search for underlying causes to the reliable identification of recurring surface patterns. This means that research in fields such as movement ecology often begins, even if it does not end, with agnosticism as to the causal forces that produce a particular observable pattern. What matters in the first instance is that the pattern is identifiable. For movement ecology, the primary object of investigation and site of pattern-seeking is the track. Once identified and characterized, the track may be brought into relation to other variables or causal models, but the initial goal is to understand it on its own terms. By privileging the observable track over the "deeper" evolutionary or ecological processes that divide the living from the non-living and various forms of living things from each other, movement ecologists have been freed to search for commonalities in surface patterns of motion across widely disparate domains: the Brownian motion of particles, the dispersal of wind-borne seeds, the territoriality of rodents, the migrations of birds, and so forth.

This approach to understanding organisms as a subset of a broader class of bodies in motion has important implications both for how research is done and for how it is deployed to address problems of biodiversity and biosecurity. Historians of laboratory-based experimental biology have shown that one of the preconditions for the success of such research is that the organisms under investigation are, or can be rendered, tractable. The "doability" and ultimate success of biological research is tightly tied to the choice of the proper research organism. At the same time, the choice of tractable organisms places more or less well-recognized limits on the ability of scientists to generalize their results.[6] Unlike laboratory biologists, movement ecologists do not attempt to standardize their organisms, but they do focus on organisms that make their research doable, and they do intervene in their lives in ways that expand or improve their suitability for study. The key criterion for them is not tractability but *trackability*: the ability of an organism, as it has been selected, modified, or instrumented for research purposes, to produce movement paths or tracks that can be recorded and analyzed in productive ways.[7] This focus on trackability has significant consequences beyond the practice of ecological science. As movement ecologists make an increasing number of organisms trackable by developing ever-smaller radiotags, geolocators, and other devices and techniques, they are also changing the affordances available for the management of individuals and populations in space.

Because movement ecology and related approaches are becoming increasingly important for the scientific understanding and management of life, their core ontologies—that is, the fundamental scientific objects around which they are organized—deserve close scrutiny. The need to operationalize abstractions such as movement in concrete practices of data collection, management, and analysis means that contingent choices must be made as to the properties of those objects that will be considered most important. These choices are not an inevitable consequence of the focus on movement. They are the path-dependent products of technological advances, research programs, funding opportunities, personal idiosyncrasies, and chance. In the case of movement ecology, the most important historical condition has been the explosion of research in genomics and bioinformatics since the 1990s, which has provided movement ecologists with powerful data-processing tools and perhaps even more powerful metaphors. The metaphor of the sequence, in particular, has helped movement ecologists make strong claims about the commensurability of different kinds of movement, but it has also oriented the field toward certain understandings of movement and away from others. The remainder of this paper explores the origins of movement ecology, its operationalization of tracks and of trackability in the shadow of genomics, and the way in which those choices have influenced the field's understanding of the organism.

2. The data-centrism of movement ecology

The term "movement ecology" can be found in the scientific literature as early as the 1970s, but it was only in the 2000s that it began to circulate widely as a label for a coherent domain of inquiry.[8] Since then, a small but very active network of ecologists has rapidly constructed the apparatus of a subfield around it, starting with special sections of prominent journals such as *Science* (2006) and the *Proceedings of the National Academy of Science* (2008) on themes of movement, dispersal, and migration. Growing interest in the field has resulted in the establishment of a centralized data repository called Movebank (launched in 2007), a dedicated journal, *Movement Ecology* (launched in 2013), and several large research centers. Two of the most active of these centers are the Department of Migration and Immuno-Ecology led by Martin Wikelski at the Max Planck Institute for Ornithology in Radolfzell, Germany, since 2008 and the Minerva Center for Movement Ecology led by Ran Nathan at the Hebrew University of Jerusalem since 2012. A series of workshops, symposia, and conferences—such as the Symposium on Animal Movement and the Environment held at the North Carolina Museum of Natural Sciences in 2014—have helped knit an international community of movement ecologists together.[9]

[4] The following analysis is based on a close reading of the published scientific literature in movement ecology and of public statements on the state and goals of the subfield by some of its leading figures. It also draws on a growing body of work examining the history and present role of movement-tracking techniques in conservation biology; see Mitman (1996); Benson (2010, 2011, 2014); Koelle (2012); Reinert (2013); Blavascunas (2013); Stokland (2014); Whitney (2014).

[5] E.g., Anderson (2008).

[6] On doability and the importance of the choice of the right organism, see Clarke & Fujimura (1992); Lederman & Burian (1993). On model organisms, see Bolker (1995); Joyce & Palsson (2006); Leonelli & Ankeny (2012).

[7] I use the term *trackability* here rather than *traceability* to emphasize the specifically spatial nature of the object that is the focus of movement ecology; cf. the discussion of biological tracers in Griesemer (2007) and Creager (2013).

[8] The term can be found in the ecological literature as early as the 1970s with many of the same meanings and connotations that it holds today, including a close connection to technological developments in animal tracking and an interest in drawing generalizable, cross-species conclusions about motion (Brown & Parker, 1976). A search of the ISI Web of Science citation database with the phrase "movement ecology" as topic conducted on 22 October 2014 resulted in 204 results. More than half of the articles using this term have been published since 2011. Movement ecologists have recently begun to reflect on the origins of the field. Fagan & Calabrese (2014) argue that an article by Kareiva & Shigesada (1983) on correlated random walks provided an important model for movement ecologists of how abstract spatial models could be brought into relation to empirical data.

[9] Relevant links: the Minerva Center: http://move-ecol-minerva.huji.ac.il/; Wikelski's department: http://www.orn.mpg.de/wikelski; the 2014 North Carolina workshop: http://amovee2014.com/; the *Movement Ecology* journal: http://www.movementecologyjournal.com/; Movebank: https://www.movebank.org/.

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