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The high-throughput revolution in movement ecology

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Movement characterizes life, constitutes a basic interaction between organisms and the environment, and occurs in all organisms – plants, microorganisms, animals and humans – forming diverse manifestations, which are crucial for our environment and human life. Many major environmental concerns that challenge humanity, such as infectious diseases, invasive species, and climate changes, are directly related to the movement of organisms. In an era of dramatic global environmental changes, understanding the drivers of critical ecological/environmental processes necessitates delving into the mechanisms underlying organismal movement.

The rapidly growing field of Movement Ecology, established 15 years ago [1], aims at elucidating movement patterns, the underlying movement processes and their ecological and evolutionary consequences across all types of organisms and movement phenomena. Focusing on the level of the individual, the conceptual framework of movement ecology depicts how the internal state, the motion and the navigation capacities of the individual, and the external environmental factors affecting its movement, are linked to shape the resulting movement pattern [1]. As such, movement ecology provides a natural platform for examining the mechanisms underlying movement processes and patterns, merging the random walk / diffusion paradigms with several other central research paradigms developed in biomechanics, cognitive sciences and economy [1].

Technological advances are now transforming movement ecology into a big-data discipline, enabling rapid, cost-effective generation of large amounts of data on movements of animals in the wild. High-throughput systems provide new research opportunities beyond simply enlarging datasets and sample sizes, allowing thorough investigations of fine-scale variation among individuals, the true nature of biological interactions, behavioral decisions in response to the physical and anthropogenic environment, and behavioral shifts across spatiotemporal scales [2].

ATLAS (Advanced Tracking and Localization of Animals in real-life Systems) is a new powerful wildlife tracking system that provides new opportunities for movement ecology research at a regional scale (10-100 km wide). This high-throughput system, developed over the past decade by the Minerva Center for Movement Ecology, is based on “reverse GPS” technology and is capable to automatically and simultaneously track multiple small animals at high sampling frequency and GPS-level accuracy. The first ATLAS system was established at the Hula Valley (Israel) in 2014, followed by 15 additional systems that have been established in 10 different countries around the world. The high-throughput merits of ATLAS enabled exciting new research insights, including the first comprehensive field evidence for the existence of a cognitive map in wild animals [3], the discovery of mobile sensory networks formed by insectivorous bats [4] and the elucidation of how predation risk selects for spatial memory in young birds during home-range development [5].

Although the integration of organismal movement research under the movement ecology umbrella is fairly new, studies of movement phenomena have long benefited from insights gained from random walk and diffusion theories. The recent high-throughput revolution in movement ecology offers numerous new opportunities for further integration between physics, biology and ecology. Examples for recent research using tools developed in physics to analyze ATLAS-derived big data include the demonstration of ergodicity breaking in area-restricted search of avian predators [6], and the discovery

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of a strong phase transition in the foraging movements of fruit bats, reflecting a mixture of tendencies to visit known resources (i.e., memory) and to search for new ones (i.e., exploration) [7]. Further enhancing cooperation among traditionally separated disciplines such as ecology, cognitive sciences, and statistical physics is crucial for understanding the key drivers of organismal movement in globally changing environments.

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