Allometric scaling of sustained movement speed in running, flying, and swimming animals

Understanding the ecological consequences of landscape connectivity requires animal dispersal models that are both sufficiently general and biologically realistic. We derive three alternative allometric movement models, of varying complexity, that consider active dispersal distance as the product of the active metabolic rate, the metabolic cost of locomotion, and the time spent moving: A simple allometric movement model that only considers the metabolic demands associated with sustained muscle activity predicts that the speeds sustained by animals during dispersal should follow a power-law scaling relationship with body mass; saturating and hump-shaped allometric movement models additionally consider how metabolic heat, a byproduct of muscle activity, constrains the sustained movements of larger animals. Using Bayesian parameter estimation and an extensive empirical dataset of sustained dispersal speeds, we show that an allometric movement model that includes allometric constraints on maximum heat-dissipation capacity best captures hump-shaped trends in the sustained movement speeds of running, flying, and swimming animals. Our results suggest that the inability to dissipate metabolic heat reduces the sustained speeds of the largest animals. This provides the mechanistic basis upon which to model the dispersal rates of animals in spatial networks such as meta-foodwebs.