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A Spatially Explicit Analogue of Charnov's Marginal Value Theorem

Charnov's Marginal Value Theorem describes the maximally efficient way for a foraging animal to harvest patchily distributed resources. The predictions of this theorem provide a useful benchmark against which to measure real-world foragers. Departures from these predictions imply that an animal is foraging sub-optimally, and hence that other factors must be influencing its behavior. Charnov's theorem has several important limitations: it does not explicitly model the spatial distribution of resources, it assumes that patches have well-defined boundaries, and it represents resource harvesting as a deterministic and continuous process. In reality, foragers often encounter resources stochastically as discrete events, and the spatial configuration of these resources can have important consequences. In this work, we use random search theory to construct a spatially explicit optimal foraging model. The predictions of this new model provide a benchmark for assessing foraging performance. This model makes very basic assumptions about the forager's perceptual and cognitive abilities, and hence maintains much of the simplicity and generality that make Charnov's theorem appealing. Unlike Charnov's theorem, it directly incorporates the spatial components of foraging behavior. We argue that it represents the most natural spatial extension of Charnov's theorem.

Our benchmark model determines when an optimal forager should switch between extensive and intensive search behavior, analogous to the way that Charnov's theorem determines when a forager should switch from harvesting a patch to leaving it. We examine how resource distribution affects these analytic predictions about optimal search behavior. We also simulate commonly invoked hypothetical foraging strategies, such as Lévy walks and intermittent searches based on giving-up times, and compare the efficiencies of these strategies with that of our benchmark model. Our findings emphasize the importance of resource distribution in assessing foraging efficiency.