The evolution of cooperation on fragmented landscapes: the spatial Hamilton rule

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ABSTRACT

\textbf{Question:} How does habitat destruction affect the evolution of cooperation?

\textbf{Methods:} Differential equations of the probabilities for different states in pairwise sites based on the Prisoner’s Dilemma game in a regular network.

\textbf{Key assumptions:} Individuals play the Prisoner’s Dilemma game with other individuals on directly connected (adjacent) sites. Individuals’ average payoff affects the birth rate. The population undergoes a birth–death process. Habitat loss and fragmentation in the network affect the population dynamics and the invasion and persistence of cooperation.

\textbf{Predictions:} (1) The evolution of cooperation is made possible through non-random encounters in a spatially local process. (2) Derive a spatial Hamilton rule whereby the proportion of cooperators among the neighbouring individuals of a cooperator serves the same role of relatedness as in kin selection, which is consistent with other forms of Hamilton rules. (3) The evolution of cooperation becomes easier in harsh environments. (4) The co-existence of multiple strategies in a species can maintain population size at a constant level.

\textit{Keywords:} evolutionary game, habitat loss, invasion analysis, pair approximation, Prisoner’s Dilemma.

INTRODUCTION

The evolution of cooperation and altruism remains a conundrum in biology and social science (Doebeli and Hauert, 2005). Cooperative individuals benefit others at personal cost and are easily exploited by other, selfish individuals (defectors). Therefore, cooperative behaviour is not an evolutionarily stable strategy (ESS) and fosters incompatibility with Darwinian natural selection. Nonetheless, examples of cooperation abound in nature, both between
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