

## THRESHOLD EFFECTS OF LANDSCAPE STRUCTURE ON BIOLOGICAL CONTROL IN AGROECOSYSTEMS

KIMBERLY A. WITH,<sup>1</sup> DANIEL M. PAVUK, JENNIFER L. WORCHUCK,<sup>2</sup> RHONDA K. OATES, AND JAMIE L. FISHER<sup>3</sup>

Department of Biological Sciences, Bowling Green State University, Bowling Green, Ohio 43403 USA

**Abstract.** Habitat fragmentation may adversely affect the ability of natural enemies to control pest outbreaks in agricultural landscapes by interfering with their search behavior and ability to aggregate in response to prey. We determined how landscape structure affected the ability of two ladybird beetles (Coleoptera: Coccinellidae) to track aphid populations in experimental landscapes that differed in the abundance and degree of fragmentation of red clover (*Trifolium pratense*). One coccinellid was a native species (*Coleomegilla maculata* Pallas) and the other (*Harmonia axyridis* Timberlake) was introduced specifically for the biological control of crop pests such as pea aphids (*Acyrtosiphon pisum* Harris; Homoptera: Aphididae).

Landscape structure exhibited a threshold in lacunarity (a measure of interpatch distances) below 20% habitat, at which point clover patches became significantly more isolated. This threshold in landscape structure was mirrored by a similar threshold in the distribution of pea aphid populations. The distribution of the biocontrol agent, *H. axyridis*, tracked this threshold in aphid distribution, but the native coccinellid, *C. maculata*, was unable to do so in fragmented clover landscapes. Although *C. maculata* was a more active forager within clover cells, overall it was less mobile and moved significantly less among clover cells and between landscapes than *H. axyridis*, which may have contributed to its inability to track aphid populations in fragmented landscapes. The two coccinellids did not differ in their search success within fragmented landscapes, however, and it was only in clumped landscapes that *H. axyridis* maximized search success and foraged within clover cells that had 2.5–3 times more aphids than those in which *C. maculata* occurred.

Thus, the potential of predators to control pest populations in fragmented landscapes may ultimately reflect the extent to which thresholds in landscape structure interfere with the aggregative response of predators. In this system, the aggregative response of coccinellids was more closely tied to thresholds in the distribution of clover than aphids. With its greater mobility, *H. axyridis* was more effective than the indigenous *C. maculata* at tracking aphids when they occurred at low patch occupancy (below the threshold in landscape structure), which is a requisite for successful biocontrol. If native insect predators are generally more sensitive to habitat fragmentation, greater reliance may be placed on the introduction of exotic species for biocontrol, which is not without economic cost and potential ecological impacts to native insect communities. Our study demonstrates that, in addition to economic thresholds, there are also ecological thresholds that must be surmounted if biocontrol measures are to be successful. In addition to enhancing vegetational diversity within agroecosystems, conservation biological control should also strive to mitigate fragmentation effects on natural enemies, especially if thresholds in landscape structure disrupt predator–prey interactions and compromise the efficacy of biocontrol programs.

**Key words:** aphids; coccinellids; conservation biological control; experimental model systems; fractal landscapes; habitat loss and fragmentation; landscape ecology; movement behavior; predator–prey interactions.

### INTRODUCTION

Habitat loss and fragmentation are becoming a serious impediment to the biological control of insect

pests, particularly within managed systems such as agroecosystems. Habitat fragments support a less diverse community of natural enemies, resulting in lower predation or parasitism rates on pest populations (Kruess and Tschardt 1994, Roland and Taylor 1997) which may release insect pests from control by their natural enemies, thus increasing the potential for economically devastating outbreaks in fragmented landscapes. Understanding how landscape structure affects species interactions, and determining the scale at which such interactions occur relative to the scale of habitat

Manuscript received 8 June 2000; revised 23 February 2001; accepted 26 February 2001.

<sup>1</sup> Present address: Division of Biology, Kansas State University, Manhattan, Kansas 66506 USA.  
E-mail: kwith@ksu.edu

<sup>2</sup> Present address: Department of Zoology, Miami University, Oxford, Ohio 45056 USA.

<sup>3</sup> Present address: Interdisciplinary Ecology Program, University of Florida, Gainesville, Florida 32611 USA.