INTERACTIONS BETWEEN LANDSCAPE STRUCTURE AND LADYBIRD BEETLES (COLEOPTERA: COCCINELLIDAE) IN FIELD CROP AGROECOSYSTEMS

By

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ABSTRACT

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Management of agroecosystems to enhance natural regulation of insect pests requires an understanding of predator ecology and how predatory insects use the landscape and respond to its structural characteristics. A group of predatory insects, ladybird beetles, were selected to study patterns of habitat utilization in response to vegetation type, management practices, and habitat succession in a complex agricultural landscape.

The field work was conducted at the Long Term Ecological Research (LTER) site at the Kellogg Biological Station (KBS), in southwest Michigan. First, a life systems study of *Coleomegilla maculata lengi* was conducted by sampling wooded habitats to determine beetle aggregation sites in the landscape, and by using stable isotopes to determine paths of energy flow in the beetle-crop system. Secondly, abundance patterns of fourteen species of coccinellids were monitored

weekly during the growing season using yellow-sticky traps. The sampled landscape consisted of an array of field crops under different management practices, interspersed with perennial biomass plantations and vegetation in a state of secondary succession. Seven years of weekly abundance records were analyzed using Shannon Wiener and richness indices, Kendall's coefficient of concordance, and principal component analysis. The results of the analysis were used to produce a spatially explicit population model for comparative analysis of landscape-predator interactions.

The main finding of the study were:

a) Habitat Succession. Ladybird beetle species diversity peaked during the second year of secondary succession with a successive decrease in diversity thereafter. In the Poplar plantation, the assemblage of beetle species showed a succession of dominance by three beetle species;

b) Management Practices. Reduced chemical inputs (herbicides and fertilizers) decreased beetle abundance and species diversity in corn fields but these components increased in wheat. In the corn-soybean rotation sequence, *C. m. lengi*, an important native predator, was most abundant when corn vegetation was dominant and least abundant when soybean dominated the landscape; and

c) Habitat type. Adults of *C. m. lengi* used habitats associated with woodlots, hedgerows, and rows of trees to aggregate prior to the onset of winter. Large aggregations occurred near agricultural fields where corn or alfalfa was grown the previous summer. In early spring, flowers constitute important sources of food for beetles before they move to field crops to search for prey. After feeding on flower pollen, adults beetles move to alfalfa or wheat, and finally to corn in the late summer prior to selecting sites for overwinter.

Within the framework of the KBS LTER theme that ecological knowledge can replace chemical subsidies, this work contributes to the role that management practices can have on beneficial insects and identifies landscape characteristics conducive to maintaining higher numbers of beneficial insect predators within agroecosystems.

DEDICATION

I dedicate this dissertation primarily to my wife, Maria Guadalupe, for all her understanding, support, and patience that made possible this work. I also dedicate it to my children, Sara Gabriela, Maria Elizabeth, and Miguel Angel, because their presence constantly encouraged me, specially during the difficult moments I had to go through.

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INTRODUCTION

IMPORTANCE OF LONG TERM ECOLOGICAL RESEARCH

General perspective

Global, international, worldwide... are some of the words used to describe several of the current human activities and their repercussions, particularly when referring to environmental issues (di Castri and Hansen 1992). Our environment is experiencing global change with regard to loss of habitats, earth warming, water and air pollution, soil erosion and salinization (de la Court 1992, Mohrmann 1992, Olson, 1992). Policies in different parts of the world are addressing issues in conservation, restoration, and ecosystem management to achieve a sustainable development. In this context, ecologists are challenged to provide the necessary knowledge to ensure that outcome. Ecological phenomena occur at different scales in time and space, and there is currently a need to obtain ecological information that occur on long time scales (Callahan 1984).

Agriculture

Several environmental problems have originated from agricultural practices (Gilpin et al. 1992, Poincelot 1990). For example, when in the 70's the Green Revolution changed agriculture into a high input activity, an era of prosperity was visualized for humans (Gilpin et al. 1992). For some time, this expectation became reality. However, the long term environmental impact and repercussions of this high input agriculture counter the economic benefits. Intensive use of chemical products such as fertilizers and pesticides, intensive irrigation, and increase of monoculture cropping, have altered the equilibrium of nature (Altieri 1987, Edwards 1990, Claridge 1991, Pimentel et al. 1992). Ecological management of agriculture, proposed as a counteraction for the excesses mentioned above, is still in the process of development. Pest management for example, needs to evolve toward agroecological management, particularly in relation to scales and strategies (Levins 1986, Barret 1992, Pimbert 1991). Spatial scales should evolve from single farms or small regions defined by one pest toward an agro-geographic regional perspective, while temporal scales will traverse from single season to long-term steady state or oscillatory dynamics (Levins 1986). Design of appropriate agroecosystems should be the main strategy for pest management programs, thus minimizing the need for human interventions (Levins 1986). The transition toward an ecological-managed agriculture will cause, however, an increase in complexity that has yet to be fully addressed in ecological theory.

THE KBS-LTER

To promote research on ecological phenomena that occur at large scales, the Long Term Ecological Research (LTER) network was established as a NSF funded program aimed to conduct and facilitate ecological research of ecological phenomena that occur over long temporal and broad spatial scales (Franklin et al. 1990). The only program within the LTER network which focused on agricultural ecology is located at the Kellogg Biological Station (KBS). The KBS LTER, established in 1987, shares with the other programs a commitment to conduct research in five core areas: a) pattern and control of primary production, b) pattern and control of organic matter accumulation in surface layers and sediments, c) patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters, d) patterns and frequency of site disturbances, and e) spatial and temporal distribution of populations selected to represent trophic structure (Callahan 1984).

The general hypothesis of the KBS LTER is that "agronomic management based on ecological concepts can effectively substitute for reliance on chemical subsidies in production-level cropping systems" (Van Cleve and Martin 1991). Several disciplines including entomology, are involved in ecological research toward this end.

COCCINELLIDS AS THE SUBJECT OF THIS STUDY

In 1988, Dr. Stuart H. Gage designed a long term program, within the KBS LTER framework, aimed to monitor the flow of organisms in agricultural landscapes (Gage et al. 1993). Among the species sampled is a complex of coccinellids which receive special attention in the sampling program because:

a) they represent an important trophic structure in agroecosystems (predatory insects).
b) their diversity can be an indicator of the integrity of the ecosystem
c) they are easy to identify in the field
d) they can be present in most habitats in agroecosystems
e) they can be monitored at larger scales.

Early publications showed that these expectations were being met (Maredia et al. 1992 a,b,c).

When I joined the LTER program in 1992, I decided to continue the focus on coccinellids. They are part of the complex of natural enemies in several agroecosystems because they prey principally on aphids and scale insects (Hodek 1970). As most beneficial insects, coccinellids are susceptible to agricultural practices (VanderBosch 1982) an therefore they

can be used as ecological indicator to assess the integrity of agroecosystems. Ground beetles have been commonly used as ecological indicatots in agroecosystems (Desender et al. 1994, Luff and Woiwod 1995), however they provide insight only at the ground level scale. A more complete view of the system can be obtained if the above-ground dimension is incorporated with the study of plant dwelling predators, such as coccinellids.

GOALS, HYPOTHESIS, AND OBJECTIVES

Goals

My goals in conducting this research were personal and scientific.

My personal interest was to expand the temporal and spatial scope of my knowledge since my entomological background was focused on working at smaller scales. Usually, Ph.D. students are constrained (because of time) to conduct short term studies, and therefore, the future researcher must learn later how to conduct research at larger scales. Working at the KBS LTER was an excellent opportunity to fulfill my desire by gaining expertise during my Ph.D. program in the implementation, analysis, and integration of a long term study in an agroecological context.

The scientific goal of this research was to analyze patterns of seven years of habitat utilization by a complex of coccinellids in all the different habitats and management practices that occur in the KBS LTER main site and synthesize that information in a landscape-coccinellids model.

Hypothesis

This work was conducted with the hypothesis that assemblages of coccinellid predators with high mobility and a wide range of habitat utilization can be affected by changes in the temporal and spatial diversity of the landscape.

Objectives

To pursue the scientific goal of my research four specific objectives were proposed:

a) gain insight into the life system of coccinellids using *Coleomegilla maculata lengi* Timberlake as a case study

b) determine an adequate scale for the analysis of interaction patterns between coccinellids and agricultural landscapes.

c) analyze the effect of temporal diversity and management practices in the assemblage of coccinellids species

d) integrate results in a computer simulation model

METHODS

This thesis was organized into five chapters (Figure 1) and a detailed explanation of the methodology used is provided within each chapter.

Chapter 1 describes a study of the life system of coccinellids in the landscape using *C.m. lengi* case studies. The first case deals with the use of wooded habitats in agricultural landscapes by overwintering adults, and the second case characterizes patterns of habitat utilization in field crop agroecosystems during the Summer (May - August).

Chapter 2 is an analysis of the issue of scale to provide a framework for ecological studies in agroecosystems. It includes the assessment of the use of sticky traps as a sampling tool for long term studies of coccinellid patterns as well as the analysis of long term patterns of coccinellids in different habitats in the landscape.

Chapter 3 is an analysis of temporal diversity in the assemblage of coccinellid species which include two case studies: a) the effect of habitat maturation in alfalfa, poplar, and secondary plant succession, and b) the effect of a corn-soybean rotation.

Chapter 4 is an assessment of the effect of agricultural management in the assemblage of coccinellids, and Chapter 5 is the development of a model of interactions between the landscape and coccinellids to assess the effect of spatial diversity on the assemblages of coccinellids.

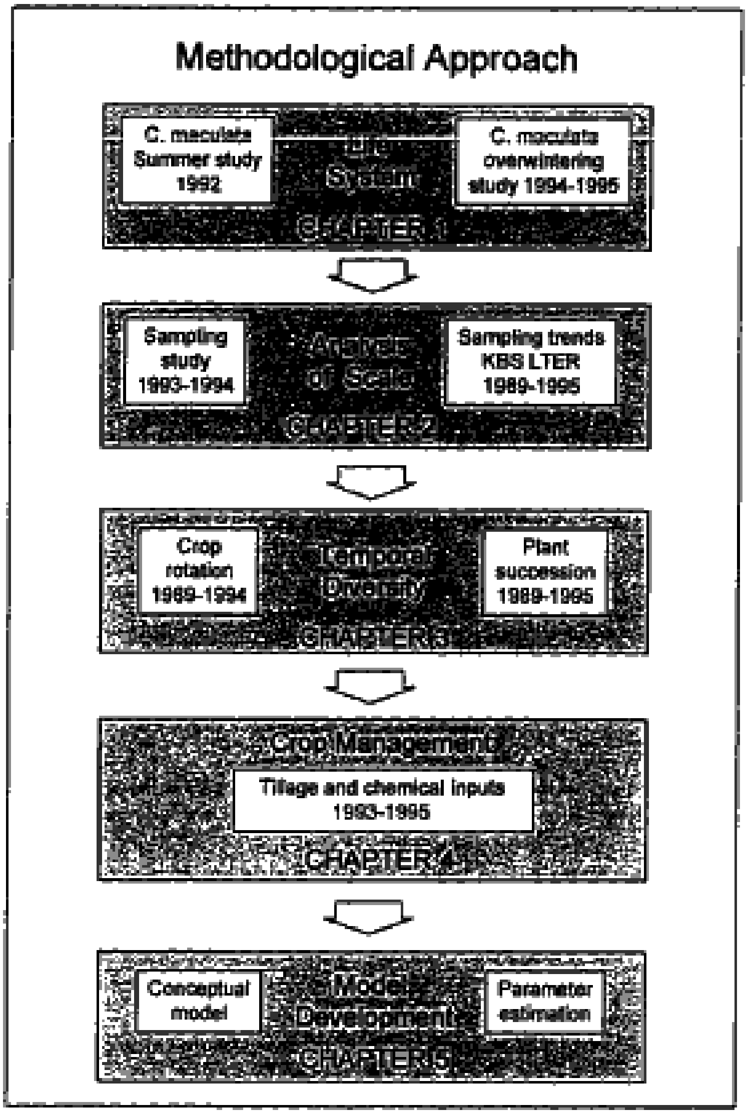

Figure 1 Phases in the development of the coccinellid-landscape model.