

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

By

Manuel Colunga-Garcia

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY

Department of Entomology

1996

UMI Number: 9706467

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ABSTRACT

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

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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.

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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.

ACKNOWLEDGMENTS

I would like to express my sincere thanks to Dr. Stuart. Gage for all his support and direction throughout this study and during my personal development as a scientist. I would like to extend my appreciation to Dr. Mark Whalon, Dr. Edward Grafius, Dr. Peggy Ostrom, and Dr. Douglas Landis for serving on my graduate committee and reviewing this manuscript.

Several individuals helped during the field work and I thank them all.

I would also like to thank my friends, Rosemary Faber, Rod Murphy and Dawn Ciciora for their editorial assistance in the revision of this manuscript.

The Consejo Nacional de Ciencia y Tecnologia, and the Universidad Autonoma Chapingo of Mexico, as well as the Long Term Ecological Research at the Kellogg Biological Station are gratefully acknowledged for their financial support during this study.

Finally, I would like to extend my thanks to the faculty, staff, and graduate students of the Department of Entomology and the Kellogg Biological Station for all their encouragement.

TABLE OF CONTENTS

LIST OF FIGURES	xi
LIST OF TABLES	xv
INTRODUCTION	1
IMPORTANCE OF LONG TERM ECOLOGICAL RESEARCH	1
General perspective	1
Agriculture.....	1
THE KBS-LTER	2
COCCINELLIDS AS THE SUBJECT OF THIS STUDY.....	3
GOALS, HYPOTHESIS, AND OBJECTIVES	4
Goals	4
Hypothesis	5
Objectives	5
METHODS	5
CHAPTER 1: LIFE SYSTEM OF PREDATORY COCCINELLIDAE (COLEOPTERA) ON AGROECOSYSTEMS: CASE STUDIES ON <i>Coleomegilla maculata lengi</i> Timberlake.....	8
BIOLOGICAL CYCLE.....	8
SEASONAL HABITAT UTILIZATION	8
CASE STUDY I. Toward the Characterization of Landscape Use by Overwintering Aggregates of <i>Coleomegilla maculata lengi</i> Timberlake (Coleoptera: Coccinellidae) in Field Crop Ecosystems in Relation to Wooded Habitats.....	11
Introduction	11
General methodology.....	11
Results.....	15
Discussion.....	23
CASE STUDY II. Habitat Use Patterns of <i>Coleomegilla maculata lengi</i> Timberlake During Summer in Field Crop Agroecosystems.	25
Methodology.....	27
Results and Discussion.....	28

CHAPTER 2: THE ISSUE OF SCALE IN STUDIES OF PREDATORY COCCINELLIDAE (COLEOPTERA) IN AGRICULTURAL LANDSCAPES	32
FRAMEWORK OF SCALE	32
Importance.....	32
Coccinellids and scales of biodiversity.....	33
LONG TERM MEASUREMENTS OF ARTHROPOD POPULATIONS	35
Hierarchy theory and the concept of sampling.....	35
Characteristics of long term sampling.....	36
Sticky traps as sampling tools for coccinellids.....	37
Comparison of two sampling methods: sweep-net sampling and sticky trap in wheat at different time intervals.....	38
Temporal patterns of coccinellids at the KBS LTER main site.....	50
CHAPTER 3: ASSEMBLAGE OF PREDATORY COCCINELLIDAE (COLEOPTERA) IN RESPONSE TO TEMPORAL DIVERSITY WITHIN AN AGROECOSYSTEM	51
CASE 1: HABITAT MATURATION IN ALFALFA, POPLAR, AND SECONDARY SUCCESSION	53
METHODS	54
Data analysis.....	55
RESULTS	58
DISCUSSION	69
CASE 2: CORN-SOYBEAN ROTATION UNDER CONVENTIONAL TILLAGE	72
METHODS	72
RESULTS	74
DISCUSSION	77
CHAPTER 4: ASSEMBLAGE OF PREDATORY COCCINELLIDAE (COLEOPTERA) IN RESPONSE TO HABITAT MANAGEMENT (TILLAGE AND CHEMICAL INPUTS) WITHIN AN AGROECOSYSTEM	80
METHODS	82
RESULTS	85
Corn 1993.....	85
Soybean 1994.....	88
Wheat 1995.....	90
Principal Component Analysis.....	92
DISCUSSION	94

CHAPTER 5: DEVELOPING A MODEL OF INTERACTIONS BETWEEN PREDATORY COCCINELLIDS (COLEOPTERA) AND LANDSCAPE STRUCTURE IN FIELD CROP AGROECOSYSTEMS.	97
INTRODUCTION	97
OBJECTIVE	100
METHODOLOGY	101
RESULTS	103
1. Definition of the problem	103
2. Delimitation of the universe of concern	103
3. Object of control and associated environment	103
4. Determination of Stimuli-Results	104
5. Selection of model type	107
6. Selection of computer technology	107
7. Mathematical relationships	109
8. Parameter estimation	110
9. Programming	115
10. Sensitivity analysis	118
DISCUSSION	125
SUMMARY AND CONCLUSIONS	131
APPENDICES	136
BIBLIOGRAPHY	156

LIST OF FIGURES

Figure 1 Phases in the development of the coccinellid-landscape model. .	7
Figure 2. Biological cycle of predatory coccinellids and the role of each biological stage.	9
Figure 3. Life system of predatory coccinellids in agricultural landscapes.	10
Figure 4. Classification of tree-related habitats for <i>C.m. lengi</i> aggregates in the landscape.	15
Figure 5. a) South side of the Elsesser woodlot, MSU campus, East Lansing, MI. b) <i>Coleomegilla maculata lengi</i> adults feeding on "spring beauty" in the Elsesser woodlot, c) <i>C.m. lengi</i> feeding on dandelion flowers at the edges of the Box woodlot, MSU campus, and d) <i>C.m. lengi</i> adults hidden under leaves from the previous corn crop at the edges of the Box woodlot.....	16
Figure 6. Relative abundance of <i>C. maculata lengi</i> (measured as adults per flower) and dandelion flowers in one m ² quadrats along a transect on the south edge of the Box II woodlot. MSU, East Lansing MI. 1994. ...	17
Figure 7. Relative abundance of <i>C. maculata lengi</i> (measured as adults per flower) and dandelion flowers in one m ² quadrats along a transect on the south edge of the Elsesser woodlot, MSU, East Lansing MI. 1994.	18
Figure 8. Relative abundance of <i>C. maculata lengi</i> (measured as adults per flower) and dandelion flowers in one m ² quadrats along a transect on the south edge of the KBS woodlot, , Hickory Corners, MI. 1994.....	19
Figure 9. Spatial distribution of <i>C. maculata lengi</i> overwintering adults on a 100 m perimeters around the Elsesser woodlot. MSU, East Lansing MI. 1994.....	20
Figure 10. Distribution of aggregation sites (black squares) of <i>C. maculata lengi</i> in the Kellogg Biological Station landscape. Large polygon is the actual area observed. S= single tree, H= hedgerow, C = cluster of trees, R = row of trees, and W = woodlot.	21
Figure 11. Experimental design to study habitat utilization patterns by <i>C.m lengi</i> at the Kellogg Biological Station, MI.....	27
Figure 12. Mean trap captures (\pm S.E.) of <i>C. maculata lengi</i> in three habitats, as measured by sticky traps, at the Kellogg Biological Station, MI. 1992.	29

Figure 13. Surface maps of the spatial distribution of <i>C. maculata lengi</i> as measured by sticky traps in four field crops during two times of the season: May and August, 1992.	31
Figure 14. Expressions and dimensions of diversity at different scales on time and space in agroecosystems.....	35
Figure 15. Temporal dynamics of coccinellid adults in spring wheat measured by sticky traps (upper 1.2 m and canopy level) and sweep-net sampling. Kellogg Biological Station, 1993.	43
Figure 16. Temporal dynamics of coccinellid adults in winter wheat measured by sticky traps (upper 1.2 m and canopy level) and sweep-net sampling. Kellogg Biological Station, 1994.	45
Figure 17. Correlation between sticky trap sampling at two levels (upper=1.2m, and canopy) and sweep-net sampling considering whole season captures of coccinellid adults in wheat.	47
Figure 18. Patterns of coccinellid captures during a season measured as frequency of sticky trap catches in 100 degree days intervals using data collected from 1989 to 1995. Habitats included were corn, wheat, alfalfa, soybean, poplar and secondary succession.	52
Figure 19. Patterns of coccinellid captures during the year measured as frequency of sticky trap catches in 200 degree days intervals from 1989-1995. Habitats included are corn, wheat, alfalfa, soybean, poplar and secondary succession.....	53
Figure 20. Experimental design of the Long Term Ecological Research site Kellogg Biological Station showing the spatial distribution of treatments and replicates. Hickory Corners, MI.....	55
Figure 21 Relative abundance, species diversity, and richness of a complex of predatory coccinellids in alfalfa, poplar and secondary succession during seven years of habitat growth at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI..	61
Figure 22 Temporal distribution of three dominant coccinellid species in poplar during the seven years of habitat growth at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI.....	63
Figure 23 Habitat scores and principal components of fourteen species of coccinellids captured in poplar, alfalfa, and secondary succession during seven years of habitat growth at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI..	68
Figure 24. Experimental design of the Long Term Ecological Research site Kellogg Biological Station showing the spatial distribution of treatments and replicates. Hickory Corners, MI.....	73

Figure 25. Relative abundance, species diversity, and richness of a complex of predatory coccinellids in a six year corn-soybean rotation under high input conventional tillage at the Long Term Ecological research site at the Kellogg Biological station. Hickory Corners, MI..	76
Figure 26. Habitat scores and principal components of eleven species of coccinellids captured in a six year corn- soybean rotation under high input conventional tillage at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI.	79
Figure 27. Experimental design of the Long Term Ecological Research site Kellogg Biological Station showing the spatial distribution of treatments and replicates. Hickory Corners, MI, 1993-1995	82
Figure 28. Relative abundance, species diversity, and richness of a complex of predatory coccinellids in corn, soybean, and wheat under four agronomic practices at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI.1993-1995. CT =conventional tillage, NT =no tillage, LI =low chemical input, and ZI = zero chemical input.....	86
Figure 29. Habitat scores and principal components of thirteen species of coccinellids captured in corn, soybean, and wheat under four management practices at the Long Term Ecological Research site at the Kellogg Biological Station. Hickory Corners, MI, 1993-1995. CT =conventional tillage, NT =no tillage, LCI =low chemical input, and ZCI = zero chemical input.	93
Figure 30. Interactions of different subsystems in agroecosystems at different hierarchical spatial scales.	98
Figure 31. Life system of ladybird beetles in the landscape.....	100
Figure 32. Methodological approach followed during the development of the model on interactions between the landscape and ladybird beetles.	102
Figure 33. Factors involved in the interactions between beneficial insects and the landscape in agroecosystems.....	105
Figure 34. Stimuli (inputs) and response (outputs) of a landscape simulation model involving 13 species of ladybird beetles.	106
Figure 35. Spatially explicit population model in which temporal abundance of predators is evaluated on a cell by cell basis based on the habitat status in each cell for each time step (i).	108
Figure 36. Determination of levels of abundance for ladybird beetle species based on groups of abundance means of <i>C. septempunctata</i> after a pairwise comparison (Tukey HSD)......	111

Figure 37. Process of estimation of probabilities for levels of abundance using <i>C. septempunctata</i> in corn as an example.....	113
Figure 38. Modular organization of a model that simulates the response of thirteen species of ladybird beetles to landscape configurations. ...	116
Figure 39. Comparison between model output and field data in relation to total relative abundance, species richness, and species diversity of ladybird beetles.	119
Figure 40. Changes in abundance, species richness, and diversity of a complex of ladybird beetle species predicted by a simulation model on a corn-soybean-wheat rotation scheme in response to increasing from one initial crop (corn) to two initial crops (corn and wheat).....	126
Figure 41. Changes in abundance, species richness, and diversity of a complex of ladybird beetle species predicted by a simulation model on a corn-soybean-wheat rotation scheme in response to reduction on chemical inputs.	127
Figure 42. Changes in abundance, species richness, and diversity of a complex of ladybird beetle species predicted by a simulation model on secondary succession habitats in response to changes from natural succession to a managed succession (different succession ages, 1 to 3, and plowing after the four year).....	128

LIST OF TABLES

Table 1. Characteristics of tree-related aggregation sites of <i>C. maculata lengi</i> in the Kellogg Biological Station Landscape 1995.	22
Table 2. Number of trees with and without <i>C. maculata lengi</i> aggregations on four selected rows of trees at the Kellogg Biological Station, Hickory Corners MI. 1994.	23
Table 3. Yearly mean (\pm S.E.) trap captures of eleven species of coccinellids sampled in alfalfa using yellow sticky traps from 1989-1995. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI	60
Table 4. Kendall's coefficients for coccinellid species concordance (species = 9) between consecutive years in poplar, alfalfa, and secondary succession. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI.	62
Table 5. Yearly mean (\pm S.E.) trap captures of eleven species of coccinellids sampled in <i>Populus</i> using yellow sticky traps from 1989-1995. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI.....	65
Table 6. Yearly mean (\pm S.E.) trap captures of eleven species of coccinellids sampled in early secondary succession using yellow sticky traps from 1989-1995. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI.....	66
Table 7. Yearly mean (\pm S.E.) trap captures of eleven species of coccinellids sampled using yellow sticky traps in a six year corn soybean rotation under high input conventional tillage Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI.	75
Table 8. Kendall's coefficients for coccinellid species concordance between consecutive years in a corn-soybean rotation at the KBS LTER, Hickory Corners, MI.....	76
Table 9. Agronomic protocol for each one of the different field crops in the KBS-LTER. 1993-1995. CT =conventional tillage, NT =no tillage, LCI =low chemical input, and ZCI = zero chemical input.	84
Table 10. Yearly mean trap captures (\times 100) \pm S.E. of adults of thirteen species of coccinellids sampled using yellow sticky traps in corn under four management practices. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI. 1993.....	87
Table 11. Kendall's coefficients for coccinellid species concordance in corn under different management practices at the KBS LTER, Hickory Corners, MI. 1993.	

CT =conventional tillage, NT =no tillage, LCI =low chemical input, and ZCI = zero chemical input.	88
Table 12. Yearly mean trap captures ($\times 100$) \pm S.E. of adults of thirteen species of coccinellids sampled using yellow sticky traps in soybeans under four management practices. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI. 1994.	89
Table 13. Kendall's coefficients for coccinellid species concordance in soybean under different management practices at the KBS LTER, Hickory Corners, MI. 1994. CT =conventional tillage, NT =no tillage, LCI =low chemical input, and ZCI = zero chemical input.....	90
Table 14. Yearly mean trap captures ($\times 100$) \pm S.E. of adults of thirteen species of coccinellids sampled using yellow sticky traps in wheat under four management practices. Long Term Ecological Research- Kellogg Biological Station, Hickory Corners, MI. 1995.	91
Table 15. Kendall's coefficients for coccinellid species concordance in wheat under different management practices at the KBS LTER, Hickory Corners, MI. 1995. CT =conventional tillage, NT =no tillage, LCI =low chemical input, and ZCI = zero chemical input.....	92
Table 16. Mean and coefficient of variation (c.v.)(%) of the abundance, species richness and species diversity of a complex of ladybird beetles described by a simulation model in response to different landscape configuration treatments. Number of crops and chemical input treatments were applied on a rotation scheme of corn-soybean-wheat.	125

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) and therefore they

can be used as ecological indicator to assess the integrity of agroecosystems. Ground beetles have been commonly used as ecological indicators 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.

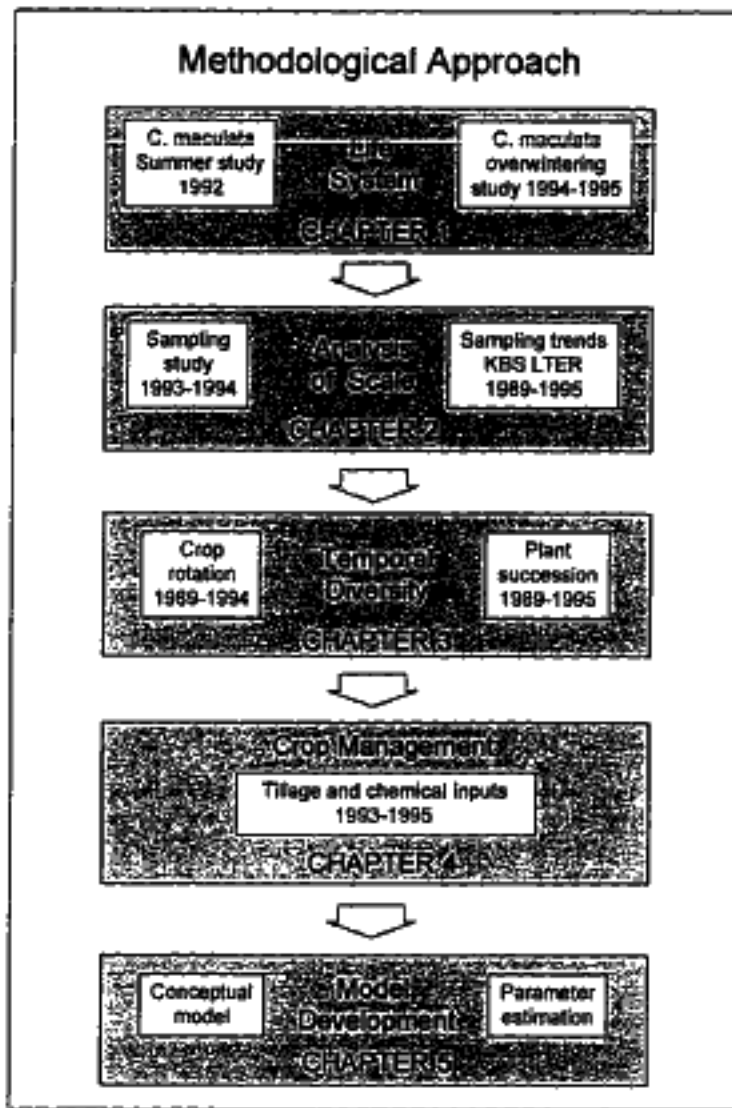


Figure 1 Phases in the development of the coccinellid-landscape model.