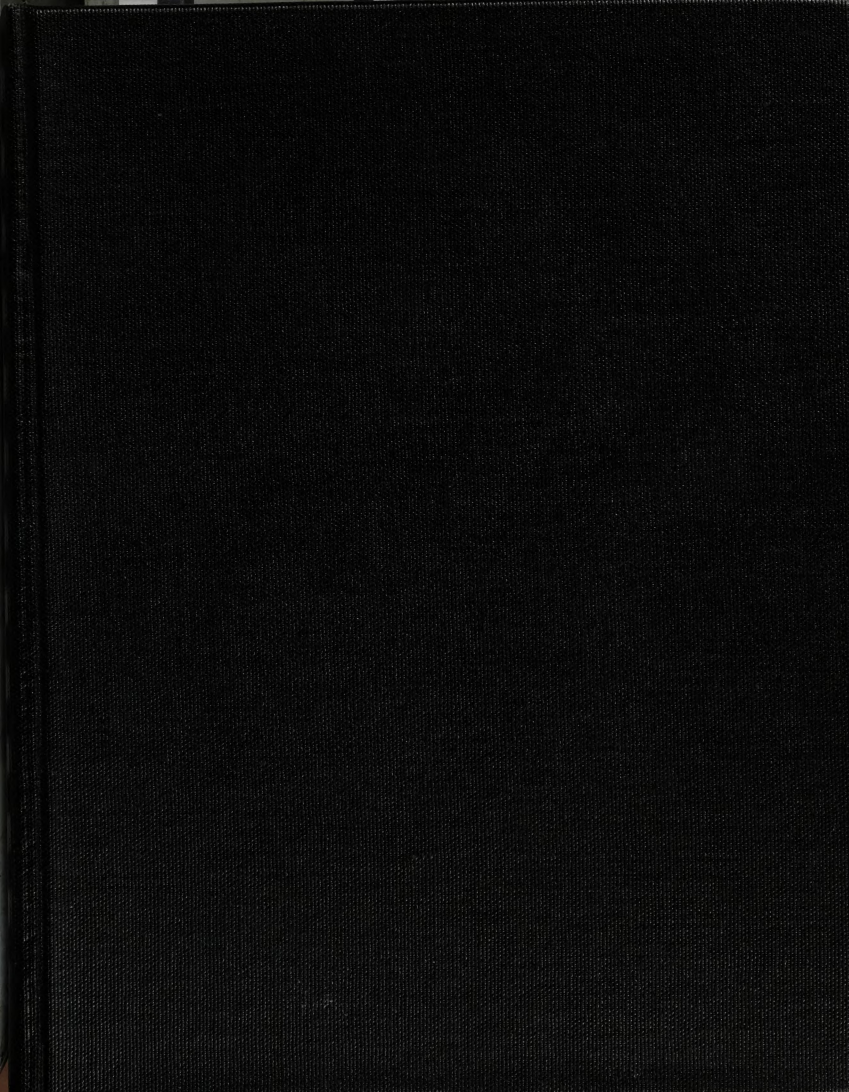






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COCCINELLA SEPTEMPUNCTATA L. (COLEOPTERA, COCCINELLIDAE)
IN ALFALFA

presented by

Judith Marie Sirota

has been accepted towards fulfillment
of the requirements for

MS degree in Entomology

Stewart H. Gage

Major professor

Date May 11, 1990

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COCCINELLA SEPTEMPUNCTATA L. (COLEOPTERA, COCCINELLIDAE)
IN ALFALFA

By

Judith Marie Sirota

A THESIS

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1990

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ABSTRACT

THE TEMPORAL AND SPATIAL DISTRIBUTION, AND SEX RATIO OF SUMMER ADULTS OF THE SEVEN-SPOTTED LADYBIRD BEETLE, COCCINELLA SEPTEMPUNCTATA L. (COLEOPTERA, COCCINELLIDAE) IN ALFALFA

By

Judith Marie Sirota

Yellow sticky traps and quadrat observations or hand-collected samples were used to examine the temporal and spatial distribution, and sex ratio of Coccinella septempunctata L. (C7) summer adults. C7 was univoltine, with activity starting in March, eggs and larvae produced in May and early June, and summer adults emerging in mid-June. Emigration to hibernation sites most likely occurred during late July and August. None of the weather factors measured were consistently associated with C7 activity. C7 showed a clumped spatial distribution in traps which was probably due to the attractiveness of traps. A random distribution in quadrats was accepted because there is no biological reason for interaction between individuals during summer. Sex ratio of hand-collected beetles was 1:1. A slight change in sex ratio in traps occurred during late summer. Males were captured on traps more often at the end of July and early August, and more females were captured later.

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TABLE OF CONTENTS

List of Figures.....	vii
List of Tables.....	viii
Introduction.....	1
Background.....	1
Literature Review.....	1
Control of prey populations.....	1
Prey preference.....	1
Larval and adult feeding habits.....	1
Effects of abiotic factors.....	2
Effects of biotic factors.....	2
Distribution of ladybird beetles.....	2
Dispersal.....	2
The seven-spotted ladybird beetle.....	5
Importation.....	5
Release.....	5
Establishment.....	5
Ecology.....	5
Problem statement, objectives and hypotheses.....	7
Primary focus of the study.....	7
Objectives.....	8
Hypotheses.....	8
Secondary focus of the study.....	8
Sex ratio of C7.....	8
Hypotheses.....	8
Thesis format.....	9
Materials and Methods.....	9
Site location and management.....	9
Sampling.....	11
Site location.....	11
Trap grid system.....	11
Sampling methods.....	11
Sampling regime.....	11
Weather station.....	12
Degree-day accumulations.....	12
Temporal distribution analysis.....	12
Characterization of phenology.....	12
Product-moment correlation analysis.....	12

Spatial distribution.....	13
Taylor's Power Law.....	13
Variance to mean ratio.....	15
Morisita's Index.....	15
Fit to distributions.....	15
Spatial variability analysis.....	15
Sex ratio study.....	17
Data.....	17
Sex determination.....	17
Analysis.....	17
Article 1: Description of the temporal distribution of the summer adults of <u>Coccinella septempunctata</u> L. (Coleoptera, Coccinellidae) in alfalfa using two sampling methods, and the interaction of prey, plant height and weather with its phenology and abundance.....	
Introduction.....	18
Origin, introduction and distribution of C7.....	18
Biology of C7.....	18
Problem statement.....	18
Objectives of the study.....	19
Materials and Methods.....	19
Study site characteristics.....	19
Sampling.....	20
Weather data collection.....	21
Analysis.....	21
Results and Discussion.....	22
Phenology and abundance.....	22
Comparison of sampling methods.....	26
Association of C7 with aphids and plant height.....	29
Association of C7 with weather factors.....	31
Conclusions.....	35
Article 2: Spatial distribution of the summer adults of <u>Coccinella septempunctata</u> L. (Coleoptera, Coccinellidae) in alfalfa.....	
Introduction.....	37
Background on C7 in U.S.....	37
Importance of spatial distribution.....	37
Focus of this study.....	37
Materials and Methods.....	38
Study site.....	38
Sampling.....	38
Spatial analysis.....	38
Analysis of spatial variability.....	39
Results.....	40
Distribution of C7 in traps.....	40
Distribution of C7 in quadrats.....	43
Distribution of aphids.....	43
Spatial variability.....	46
Discussion.....	48

C7 in traps.....	48
C7 in quadrats.....	50
Aphids.....	50
Spatial variability.....	51
Article 3: The sex ratio of <u>Coccinella septempunctata</u> L. in hand-collected and yellow sticky trap samples.....	52
Introduction.....	52
Background.....	52
Objectives.....	52
Materials and Methods.....	53
Experimental design.....	53
Sampling.....	53
Cleaning beetles from traps.....	53
Sex determination.....	53
Sex ratio analysis.....	54
Results and Discussion.....	55
Hand-collected samples.....	55
Trap samples.....	55
Unplanned tests.....	59
Seasonal changes in sex ratio.....	64
Summary and Conclusions.....	66
Phenology.....	66
Sampling methods.....	67
Correlations.....	68
Aphids and plant height.....	68
Weather factors.....	69
Spatial distribution.....	70
Sex ratio study.....	72
List of References.....	73
Appendix A: Alfalfa data.....	83
Appendix B: Degree-day data.....	100
Appendix C: Weather data.....	104

LIST OF TABLES

1. Summary of literature on coccinellid biology.....	3
2. Wilk-Shapiro rankits test for normality.....	14
3. Correlation of trap and quadrat data over the sampling period.....	27
4. Correlation of trap and quadrat data between cuttings.....	28
5. Correlation of trap and quadrat data with weather variables.....	32
6. Correlation of trap and quadrat data and weather variables between cuttings.....	34
7. Taylor's Power Law for C7 and aphids.....	41
8. Spatial distribution of C7 in traps (TC7) by date.....	42
9. Spatial distribution of C7 in quadrats (QC7) by date..	44
10. Spatial distribution of aphids by date.....	45
11. Homogeneity G-tests for sex ratio in C7.....	56
12. Homogeneity G-tests by date for sex ratio in hand- collected C7.....	57
13. Homogeneity G-tests by date for C7 in traps.....	60
14. Simultaneous unplanned test for C7 in traps.....	61
15. Unplanned tests for C7 in traps.....	63

LIST OF FIGURES

1. Study area, surrounding habitat and sampling grid system.....	10
2. Mean number of C7 in traps.....	23
3. Mean number of C7 in quadrats.....	23
4. Mean number of aphids per 20 stems.....	24
5. Observations of C7 larvae, pupae, and summer adults...	24
6. Contour map of C7 distribution in traps.....	47
7. Contour map of C7 distribution in quadrat samples.....	47
8. Contour map of aphid distribution.....	47
9. Contour map of plant height distribution.....	47
10. Proportion of males in hand-collected samples.....	58
11. Proportion of males in traps.....	62

INTRODUCTION

Predaceous coccinellids are important biological control agents. The establishment of the vedalia ladybird beetle (Rhodolia cardinalis (Mulsant)) in California for control of cottony cushion scale (Icerya purchasi Maskell) has been one of the most successful biocontrol projects in the U.S. Because of their potential use as biocontrol agents, ladybird beetles have been intensely studied. For example, entire books (Balduf 1935, Hodek 1973) and lengthy reviews (Hagen 1962, Hodek 1967, Hagen and van den Bosch 1968, Frazer and Gilbert 1976, Baumgärtner, et al. 1981b) have been devoted to the group. Predaceous coccinellids continue to be studied as a source of biocontrol for economically important pests.

Numerous studies of ladybird beetles (Table 1) have been concerned with: the control of prey populations (Hodek et al. 1962, Way and Banks 1962, Bombosch and Tokmakoglu 1966, Galecka 1966, Iperti 1966, Savoiskaya 1966, Sundby 1966, Way 1966, van Emden 1966, Dixon 1970, Shands et al. 1972, Tamaki and Weeks 1973, Frazer and Gilbert 1976, Whalon and Smilowitz 1979, Gutierrez et al. 1980, Frazer et al. 1981b, 1976, Mack and Smilowitz 1982a,b); prey preference (Dunn 1949, Blackman 1965, 1966, 1967a,b, Hodek et al. 1965, Smith 1965, Hagen and Sluss 1966, Okamoto 1966); larval and adult feeding habits (Banks 1957, Hodek 1957, 1966, Dixon 1959, Atwal and Sethi 1963, Hagen and Sluss 1966, Colburn and Asquith 1970, Murdock and Marks 1973, Frazer 1981a,

Risch et al. 1982); and the effects of abiotic factors (Sethi and Atwal 1964, Iperti and Prudent 1966, Sundby 1966, 1968, Ellingsen 1969a, Obrycki and Tauber 1978, 1981, 1982) and biotic factors (Banks 1955, Smith 1965, Ewert and Chiang 1966b, Smith and Bérubé 1966, Atallah and Killebrew 1967, Sundby 1968, Ellingsen 1969b, Smith 1969, 1976, Baumgärtner, et al. 1981a) on ladybird beetle development and population growth.

Distribution of ladybird beetles in North America has been reported by Angalet et al. (1979), Gordon (1985) and Schaefer et al. (1987); distribution in specific habitats has been reported in Britain (Banks 1954), Europe (Honék 1982a,b, 1985b, Lövei 1981, Radwan and Lövei 1982), and Canada (Putman 1964). Effects of environmental factors on within-habitat distribution was investigated by Ewert and Chiang (1966a), Smith (1971) and Ives (1981).

The study of dispersal of ladybird beetles has primarily concentrated on movement from hibernation sites (Ewert and Chiang 1966b, Ali and Azam 1977, Semyanov 1978, Rankin and Rankin 1980, Rubin 1981, Zaslavsky and Semyanov 1986) although some investigations have concentrated on within- or between-habitat movement (Skuhravy and Novak 1966, Kieckhefer and Olson 1974, Ives 1981, Risch et al. 1982, Wetzler and Risch 1984). Dispersive and predatory responses of ladybird beetles to diverse cropping patterns or in uncultivated areas has been described by Marcovitch

Table 1. Summary of literature on coccinellid biology.

Control of prey populations

Hodek et al. 1962	Dixon 1970
Way and Banks 1962	Shands et al. 1972
Bombosch and Tokmakoglu 1966	Tamaki and Weeks 1973
Galecka 1966	Frazer and Gilbert 1976
Iperti 1966	Whalon and Smilowitz 1979
Savoiskaya 1966	Gutierrez et al. 1980
Sundby 1966	Frazer et al. 1981b
Way 1966	Mack and Smilowitz 1982a,b
van Emden 1966	

Prey preference

Dunn 1949	Hagen and Sluss 1966
Hodek et al. 1965	Okamoto 1966
Blackman 1965, 1966, 1967a,b	Smith 1965

Larval and adult feeding habits

Banks 1957	Colburn and Asquith 1970
Hodek 1957, 1966	Murdock and Marks 1973
Dixon 1959	Frazer 1981a
Atwal and Sethi 1963	Risch et al. 1982
Hagen and Sluss 1966	

Effects of abiotic factors

Sethi and Atwal 1964
 Iperti and Prudent 1986
 Sundby 1966, 1968
 Ellingsen 1969a
 Obrycki and Tauber 1978, 1981, 1982

Effects of biotic factors

Banks 1955	Sundby 1968
Smith 1965	Ellingsen 1969b
Ewert and Chiang 1966b	Smith 1969, 1976
Smith and Bérubé 1966	Baumgärtner, et al. 1981a
Atallah and Killebrew 1967	

Table 1. (cont'd.)

Coccinellid distribution

Banks 1954	Lövei 1981
Putman 1964	Radwan and Lövei 1982
Ewert and Chiang 1966b	Gordon 1985
Smith 1971	Honék 1982b, 1985b
Angalet et al. 1979	Schaefer et al. 1987
Ives 1981	

Dispersal

Marcovitch 1935	Rankin and Rankin 1980
van Emden 1965	Ives 1981
Skuhravy and Novak 1966	Rubin 1981
Kieckhefer and Olson 1974	Tamaki et al. 1981
Smith 1969, 1976	Risch et al. 1982
Ali and Azam 1977	Wetzler and Risch 1984
Semyanov 1978	Zaslavsky and Semyanov 1986

(1935), van Emden (1965), Smith (1969, 1976), Tamaki et al. (1981) and Risch et al. (1982).

The seven-spotted ladybird beetle, Coccinella septempunctata L. (C7) is a Palearctic species first brought to the United States by the USDA in 1956 from India (Angalet et al. 1979). Subsequently, it was imported from various locations in Eurasia between 1958 and 1973, and released in 11 states (Angalet et al. 1979, Cartwright et al. 1979). An established population was not confirmed until 1973 in the Hackensack Meadowlands, New Jersey (Angalet et al. 1979). Recently, C7 collected from established populations in Delaware and Georgia were released in most western states (USDA 1987, 1988) as part of the ongoing USDA Aphid Predator Project. This intensive program is aimed at controlling several aphid species, in particular the Russian wheat aphid, Diuraphis noxia (Mordvilko) (Angalet et al. 1979, Tedders and Angalet 1980). C7 is now found as far west as Utah and is established in 42 states (USDA 1988).

Studies in Eurasia indicate that C7 has a wide plasticity in voltinism (Bodenheimer 1943, Hodek 1966), prey preference (Hodek 1973), and habitat preference (Honék 1982b, 1985b). Hodek (1966) refers to C7 as a "daring" species that can utilize marginally favorable conditions due to the flexibility of its developmental cycle. A given population may contain a mix of strains that enter diapause either obligately or facultatively. This heterogeneity may permit C7 to take advantage of a variety of habitats and

also may account for its extensive range (Hodek 1966). Univoltine, multivoltine and mixed populations have been reported for the Euro-Siberian region (Boddenheimer 1943, Bonnemaison 1966, Hodek 1966). Climatic conditions, especially in desert regions, influence the occurrence of a second generation in all parts of the range of C7. Obrycki and Tauber (1981) reported that, based on thermal requirements for development, C7 in New York could complete 3 generations per year. However, from the limited reports available (Obrycki and Tauber 1981, Tedders and Angalet 1980) it appears that North American C7 are normally univoltine with production of a partial second generation where climatic conditions are favorable. The multifarious nature of C7 populations may be a factor in their apparently successful establishment in North America.

C7 is a highly polyphagous aphid predator (see Hodek 1973). Angalet, et al. (1979) documented 26 prey species occurring in the Hackensack Meadowlands, New Jersey. Tedders and Angalet (1980) observed C7 preying on 3 species of pecan infesting aphids. Aphis fabae Scopoli, Acyrtosiphon pisum (Harris) and Myzus persicae (Sulzer) have been used in C7 development studies (Blackman 1966, Sundby 1968, Obrycki and Tauber 1981) and are commonly found in association with C7 in the field (Cartwright et al. 1979, Tedders and Angalet 1980, Honék 1982a, Obrycki et al. 1987).

Habitat preference of C7 has been studied extensively in Czechoslovakia by Honék (1979, 1982a,b, 1983, 1985b). C7

generally prefers herbaceous plants, sunny locations, and is associated with a wide range of aphid densities (Honék 1985b). In cultivated areas, C7 prefers forage legumes (alfalfa and clover) and spring cereals (mainly barley) over other agricultural crops, including winter wheat (Honék 1982b). C7 occasionally occurs at low densities in beans, sugar beets, maize and potatoes (Honék 1982b).

Approximately 70% of the recoveries of C7 in Iowa and Missouri were from leguminous crops (Obrycki et al. 1987). Conversely, in the tidal salt marsh and meadows of the Hackensack Meadowlands, New Jersey, C7 are found on a wide variety of plants (Angalet et al. 1979).

Evidence from the studies mentioned above suggest that C7 has the ability to colonize diverse habitats and may have the potential to become a significant predator of many economically important aphid species in the U.S. Further assessment of C7 ecology in the U.S. is needed before its potential as an agent of aphid control can be determined.

The primary focus of this study was to investigate the ecology of C7 by characterizing the temporal and spatial distribution of C7 and aphids in alfalfa. Temporal and spatial distribution are important characteristics of the ecology of a species (Andrewartha and Birch 1954) and are useful in both applied and basic studies. For example, temporal information can be applied to crop management decisions, and both temporal and spatial distribution information can be used to study the behavior of the

population. Alfalfa was chosen for the study because the abundance of prey usually found in this crop is attractive to C7 (Honék 1985b). Also, because the environment changes dramatically when the alfalfa is cut, the response of C7 temporal and spatial distribution to change could be investigated.

Specific objectives were to: 1) describe the temporal distribution of C7 adults, larvae, and aphid prey based on degree-day accumulation; 2) quantify the association of C7 with aphid abundance, plant height, and meteorological factors; 3) analyze the spatial distribution of C7 and aphids using distribution-fitting methods and mapping techniques; and 4) to compare yellow sticky traps and quadrat samples with respect to the above objectives. The following hypotheses or predictions were tested: C7 and aphid temporal distributions were expected to be similar and their abundance correlated; phenological timing of C7 was expected to be comparable to that found by Obrycki and Tauber (1981) in New York, and Angalet et al. (1979) in New Jersey; C7 was expected to be more active during warm, sunny periods than when cloudy or cool; spatial distribution of aphids was expected to be clumped due to their colonial nature; and the spatial distribution of C7 was expected to be clumped.

Additionally, the sex ratio of trapped and field collected C7 was determined to test if either sex was selectively attracted to the traps and if the sex ratio

changed during the sampling period. The hypotheses were: that the sex ratio from either method was 1:1; and that the sex ratio was homogeneous over time.

This thesis is divided into three articles: temporal distribution, spatial distribution, and sex ratio study. Each article is intended to be submitted for publication. An overall materials and methods section is provided to give an overview to the entire project. A summary section addresses the utility of the project results and possible application to future research.

MATERIALS AND METHODS

This study was conducted during the summer of 1988 in a 400 m X 400 m, periodically irrigated alfalfa field located on the Michigan State University Kellogg Biological Station (KBS), Hickory Corners, Mich. The field was bordered on the north by a small rye plot, a small abandoned alfalfa field, and a woodlot; on the west by residential areas and a lake; on the east by a soybean field; and on the south by small research plots of corn, alfalfa, soybeans, potatoes and apples (Fig. 1). Alfalfa in the study area was harvested for haylage or baled hay with a hay chopper on or about 21 May, 16 June, 29 July, and 29 August 1988. The alfalfa was irrigated with an overhead linear-move sprinkler at least weekly and often twice per week depending on drought conditions that prevailed during 1988. The field was plowed in early October.

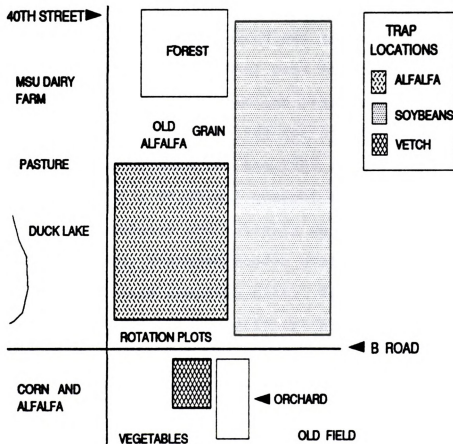


Figure 1. Study area, surrounding habitat, and trap locations.

Fifty-six sampling sites were established in a square grid throughout the field, however two sites were removed due to conflicts with other research projects. Sampling sites were located 50 m from each other, with a minimum of 25 m between field edges and the outer edge of the grid (Fig. 1). Each site was numbered and the locations assigned an (X,Y) coordinate on a digital base map using the state plane coordinate system. A similar trap grid system established in this field in 1987 for another project provided preliminary data for the 1988 study.

A 0.5 m X 0.5 m (0.25 m^2) quadrat sampler was used to sample beetle abundance and activity on the alfalfa at each site. In addition, T-shaped wooden standards were secured in the ground at each sampling site. To monitor ladybird beetle abundance and flight activity, a double-sided yellow sticky trap (22.5 cm X 14 cm, unbaited Pherocon^R, Zoecon, Palo Alto, CA) was secured to one arm of the "T", ca. 1.5 m above the ground. Preliminary observations in 1987 indicated that C7 could be captured by yellow sticky traps 1.5 m above the ground, therefore, it was decided to use these traps at this height for the 1988 study. A variety of sticky traps have been used to monitor ladybird beetles (Proffitt, in Taylor 1960; Ewert and Chiang 1966 a,b; Prokrym 1988), however the attractiveness of these traps to C7 has not been investigated.

Between 19 May and 5 October, traps were examined every 6-9 days and replaced every other sampling date. C7 adults

and other ladybird beetles were counted and removed from sticky traps on each sampling date. Captured beetles were transferred to 7.7 cm X 12.7 cm index cards for identification and sexing of C7 adults. A 0.25 m² quadrat sample was taken in an area randomly chosen in the alfalfa within 2 m of each trap site. Numbers of C7 adults, larvae, and pupae; number of aphids per 20 alfalfa stems; and 10 alfalfa stem heights were recorded for each quadrat sample. Aphids were not identified to species because it was assumed that the highly polyphagous C7 would consume any aphids encountered. Pea aphids, Acyrtosiphum pisum (Harris), and spotted alfalfa aphid, Therioaphis maculata (Buckton) were probably the most prevalent species observed.

Temperature, precipitation, solar radiation, wind speed and other weather variables were obtained from an automated weather station located approximately 75 m in from the southeastern corner of the field (Fig. 1). Degree-day accumulations were computed from daily minimum and maximum temperature data using a 12°C base temperature. This temperature is the developmental threshold for C7 (Obrycki and Tauber 1982).

Temporal distribution of C7 was characterized using data from quadrat samples and trap catches. Product-moment correlation analysis (Sokal and Rohlf 1981, Anonymous 1989) was used to determine the association between C7, aphids, plant height and weather factors over the season and between cuttings. Data from 31 May to 25 August 1988 were used for

correlations because this represented the most complete set of data for comparison, particularly for between-cutting correlations. Data obtained before 31 May were incomplete because sampling did not begin until the alfalfa had been growing for several weeks. Trap catch was standardized to a per day basis by dividing the total catch by the number of days the trap was exposed. Correlations involving C7 trap catch were calculated using these transformed values. Weather data were averaged over the sampling period for correlation with both trap and quadrat data. Data for each correlation test were checked for normality using the Wilk-Shapiro Rankits test (Shapiro and Wilk 1965, Anonymous 1989) (Table 2). Spearman's correlation coefficient (r_s) was calculated for data with a low rankits value. The product-moment correlation coefficient was compared with r_s to determine if using Spearman's correlation coefficient changed the outcome of the test. No substantial changes were found, so the product-moment correlations are reported. A t -test for significance of the correlation coefficient (r) was performed on the z -transformations of r , and P -values were obtained from the areas of the normal curve table as explained by Sokal and Rohlf (1981) for large sample sizes.

Spatial distribution of trap and quadrat data was analyzed with several methods. Taylor's Power Law (Taylor 1961) was calculated using Model II regression (Sokal and Rohlf 1981) over all dates between 31 May and 25 August 1988. This provided a rough estimate of the seasonal

Table 2. Wilk-Shapiro rankits test for normality.

All data	Variable	N	Rankit
	TC7	635	0.6796
	QC7	687	0.3333
	Aphids	687	0.4436
	Plant height	687	0.9775
	Rainfall	687	0.8533
	Temperature	687	0.9097
	Solar radiation	687	0.8809
	Wind speed	687	0.9308
21 May - 15 June			
	TC7	152	0.5410
	QC7	155	0.3339
	Aphids	155	0.3024
	Plant height	155	0.9434
	Rainfall	155	0.6070
	Temperature	155	0.6516
	Solar Radiation	155	0.8022
	Wind speed	155	0.7910
16 June - 28 July			
	TC7	238	0.8631
	QC7	320	0.4322
	Aphids	320	0.6033
	Plant height	320	0.9589
	Rainfall	322	0.8894
	Temperature	322	0.7600
	Solar Radiation	322	0.8978
	Windspeed	322	0.8774
29 July - 29 August			
	TC7	200	0.8160
	QC7	212	0.0898
	Aphids	212	0.3582
	Plant height	212	0.9218
	Rainfall	212	0.7750
	Temperature	212	0.7112
	Solar Radiation	212	0.7182
	Windspeed	212	0.7515

distribution of the population. The variance to mean ratio (s^2/x) (Southwood 1978) was calculated to estimate spatial distribution for each sampling date. Morisita's Index (I_g) (Southwood 1978) was calculated for each sampling date and tested with a Chi-Square goodness of fit test ($X^2 = (I_g * [n-1]) * N - n$, where n = total number of individuals in the sample and N = the total number of samples taken).

Morisita's Index was used to confirm or reject the spatial distribution estimated from the variance to mean ratio. Finally, each sampling date was analyzed with a Chi-Square goodness of fit test ($X^2 = (O-E)^2/E$) to the respective distribution (positive or negative binomial, or Poisson) verified by the Chi-square test of Morisita's Index. K of the negative binomial was calculated using the maximum likelihood estimate of Southwood (1978).

Methods of geostatistical analysis described by Journé and Huijbregts (1978) and Robertson (1987, 1988) were used to analyze the spatial variability of trap and quadrat data. Geostatistical Environmental Assessment Software (GEO-EAS) (Englund and Sparks 1988) was employed to calculate autocorrelation, and construct semivariograms and contour maps of spatial variability for C7, aphids, and plant height on each sampling date. A semivariogram is defined as "A plot of the variance (one-half the mean squared difference) of paired sample measurements as a function of the distance ... between samples" (Englund and Sparks 1988) and illustrates the degree of autocorrelation between samples.

Autocorrelation reflects the amount of spatial dependence of samples, and decreases with increasing distance between samples. Once a semivariogram is made, linear, spherical or exponential models are fit to the data by adjusting parameters called the sill, range, and nugget. The distance (x) at which the semivariogram levels off and becomes stable is identified as the "sill". This value represents the distance between sample sites at which there is a transition from spatial dependence (autocorrelation) to spatial independence (absence of correlation). Similarly, for some models, the "range" represents the distance at which the maximum or 95% of the maximum variance of the model occurs. The nugget, or nugget variance, is the y-intercept which theoretically equals zero (i.e., there is no variance between a sample point and itself). A non-zero nugget results from sampling error or from the presence of autocorrelation at distances smaller than the grid used, or a combination of the two (Robertson 1987). Nugget variance equal to the sill indicates an absence of correlation at any distance, and all samples are independent of each other.

Spatial variability between sample points was then calculated from the semivariogram, the model, and the spatial coordinates of each sample point by an interpolation method called "kriging". This "weighted-moving-average interpolation method" (Englund and Sparks 1988) provides unbiased interpolated values with known variance (Robertson 1987). Contour maps generated from kriging were compared

with results from traditional spatial analysis methods. Maps provided a visual aid for the description of the within-field distribution of C7 on traps and in quadrats, and aided in characterizing the correlations between C7, aphids, and plant height.

C7 caught on traps in the alfalfa were used for the study of sex ratios. Beetles were collected from an additional 74 traps in a soybean field to the east and a vetch field to the south of the alfalfa. A total of 33 sampling dates were used. Beetles also were collected by hand in these fields on 15 dates. Sex was determined under a dissecting microscope, using external morphological characters described by Baungaard (1980). Data from traps and field collections were analyzed separately for goodness of fit to a 1:1 sex ratio using a replicated G-test (Sokal and Rohlf 1981). Both overall and per date tests were performed.

Article 1

Description of the temporal distribution of the summer adults of Coccinella septempunctata L. (Coleoptera, Coccinellidae) in alfalfa using two sampling methods, and the interaction of prey, plant height and weather with its phenology and abundance.

The seven-spotted ladybird beetle, Coccinella septempunctata L. (referred to here as C7) is a Palearctic species brought to the United States from Eurasia between 1957 and 1973 (Angalet et al. 1979). This beetle was introduced for control of several aphid species, including the Russian wheat aphid, Diuraphis noxia (Mordvilko) (Angalet et al. 1979). The current distribution of the species includes 42 states (USDA 1988) and five Canadian provinces (Schaefer et al. 1987).

Although C7 has been established in the U.S. for at least 15 years, very little is known about its biology here. Studies conducted in the U.S. have been concerned mainly with release and recovery programs (Cartwright et al. 1979, Tedders and Angalet 1981, Obrycki et al. 1987). In Eurasia, studies indicate that C7 shows wide plasticity in voltinism (Bodenheimer 1943, Hodek 1967), prey preferences (Hodek 1973), and habitat selection (Honék 1982a, 1985b). This suggests that C7 has the ability to colonize diverse habitats and has the potential to become a major aphid predator in a variety of crop systems. However, its usefulness as a predator of a particular aphid species may be limited because of this plasticity. For example,

interest in C7 as a biocontrol agent of the Russian wheat aphid assumes that C7 will be prevalent in wheat. However, in Czechoslovakia, C7 prefers forage legumes (alfalfa and clover) and spring cereals (mainly barley) over other agricultural crops, including winter wheat (Honék 1982). In addition, many European strains of C7 are univoltine. Summer adults exhibit obligate reproductive diapause (Hodek 1966) and enter hibernation during late summer. These characteristics may limit the effectiveness of C7 as a late summer predator. Further assessment of C7 biology in the U.S. is needed before its potential for aphid control can be assessed.

The objectives of this study were to 1) describe the temporal distribution of C7 and aphids in alfalfa, 2) compare the two sampling methods used for C7, and 3) quantify the association between C7 and aphids, plant height, and weather factors.

MATERIALS AND METHODS

This study was conducted in a 400 m X 400 m, periodically irrigated, alfalfa field located on the Michigan State University Kellogg Biological Station (KBS), Hickory Corners, Mich. Alfalfa in the research plot was harvested for haylage or baled hay with a hay chopper on 21 May, 16 June, 29 July, and 29 August. The field was plowed during early October.

Fifty-four sampling sites were established in a square grid throughout the field. Sampling sites were located 50 m apart, with a minimum of 25 m between field edges and the outer edge of the grid. T-shaped wooden standards, approximately 1.5 m tall, were fixed in the ground at each sampling site. C7 abundance and flight activity was monitored with a double-sided yellow sticky trap (22.5 cm X 14 cm, unbaited Pherocon® , Zoecon, Palo Alto, CA) that was secured to one arm of the "T". Sampling was conducted every six to nine days from 19 May through 5 October, and traps were replaced every other sampling date. C7 adults were counted and removed from traps on each sampling date. In addition, at each site a 0.5 m X 0.5 m (0.25 m²) quadrat sampler was used to sample C7 and aphid abundance on the alfalfa plants. Quadrat samples were taken in an area haphazardly chosen in the alfalfa within 2 m of the trap standard. Numbers of C7 adults, larvae, and pupae; number of aphids per 20 alfalfa stems; and the height of 10 alfalfa stems were recorded in each quadrat sample. Aphids were not identified to species. It was assumed that the highly polyphagous C7 would consume any aphid species encountered. Pea aphids, Acyrtosiphum pisum (Harris), and spotted alfalfa aphids, Therioaphis maculata (Buckton) were probably the prevalent species.

Temperature, precipitation, solar radiation, and wind speed were obtained from an automated weather station located approximately 75 m in from the southeastern corner

of the field. Degree-day accumulations were computed from daily minimum and maximum temperature data and fitted to a sine curve using a 12°C base temperature (Baskerville and Emin 1969). This temperature is the developmental threshold for C7 (Obrycki and Tauber 1982).

Temporal distribution of C7 was characterized using data from quadrat samples and trap catch. Correlation analysis (Sokal and Rohlf 1981) was used to determine the association between C7, aphids, plant height and weather factors over the entire sampling period and between cuttings. A t-test for significance of the product-moment correlation coefficient (r) was performed on the z -transformations of r , and P -values were obtained from the areas of the normal curve table as explained by Sokal and Rohlf (1981) for large sample sizes. Data from 31 May to 25 August were used for correlations because this represented the most complete set of data for comparison, particularly for between-cutting correlations. Trap data from 22 June were not used in correlations because trap catch on this date was affected by cutting of the alfalfa, and was not representative of C7 activity. Because the number of days between sampling dates varied, trap data used in correlations were standardized to a per day basis by dividing the total catch by the number of days the trap was exposed. Weather data were averaged between sampling dates for correlation with trap and quadrat data.

RESULTS AND DISCUSSION

Phenology and abundance. Overwintered C7 adults were active in alfalfa as early as the second week of April 1988 (approx. 30 DD). Low numbers of overwintered adult beetles and a few larvae were observed during May and early June (Fig. 2, 3, 5). Obrycki and Tauber (1981) reported that the total development time of C7 based on thermal constants was 197 degree-days (base 12.1 C°). Extrapolating backward from the appearance of summer adults on 8 and 15 June (between 260 and 315 DD), overwintered C7 adults were probably laying eggs in this field ca. 6 May (63 DD) to 20 May (121 DD). Larvae would have developed between 19 May (113 DD) and 11 June (269 DD), and pupae from 1 June (216 DD) to 17 June (332 DD). Larvae and pupae were, in fact, observed in the field during this developmental window (Fig. 5).

The first summer adults were observed on 8 June, and the peak abundance on 15 June in both trap and quadrat samples (Fig. 2--3) consisted mostly of new adults. Newly emerged summer adults are easy to distinguish from overwintered adults because of their bright orange color and soft elytra (Tedders and Angalet 1981). Overwintered adults are a dull red color and have hardened elytra. Peak trap catch on 15 June was most likely due to the emigration of emerging summer adults from the field. Honék (1985a) reported that C7 activity increases when aphid density is low, so the scarcity of aphids in the field during late May

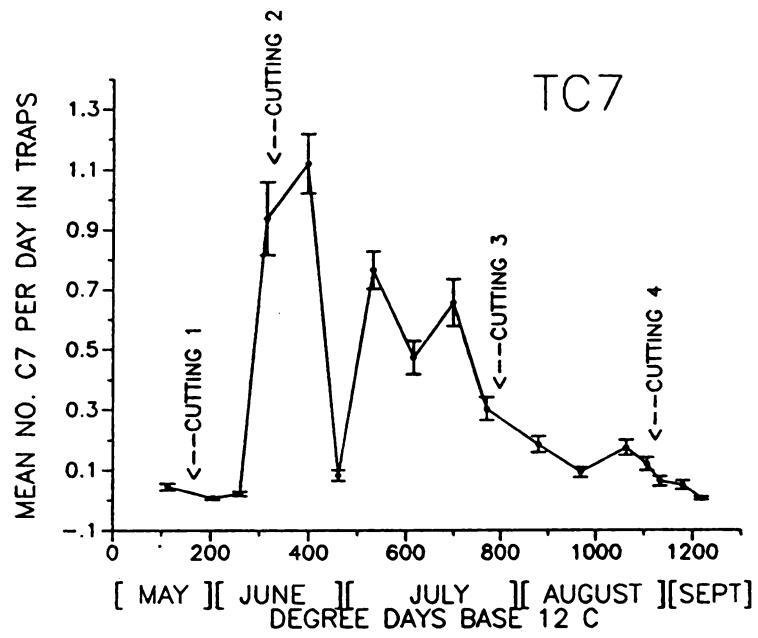


Figure 2. Mean number of C7 in traps, $\pm$ S.E.

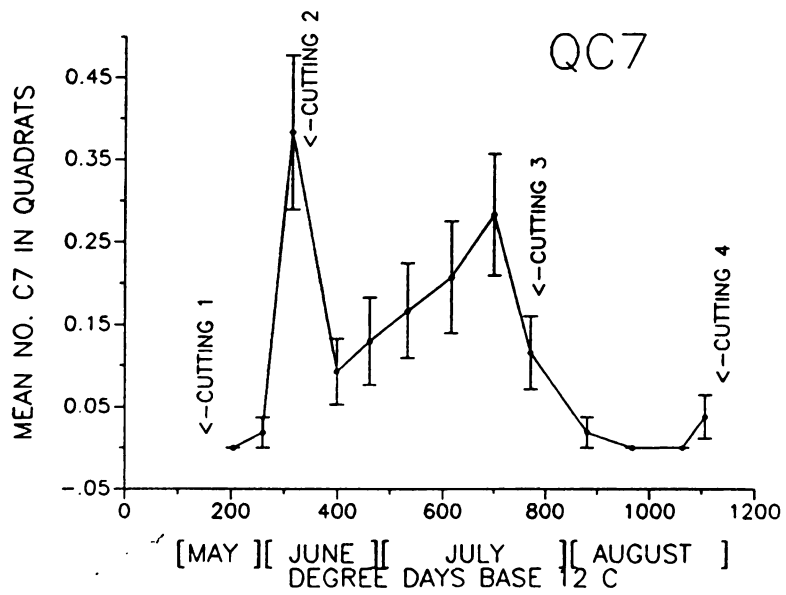


Figure 3. Mean number of C7 in quadrats, $\pm$ S.E.

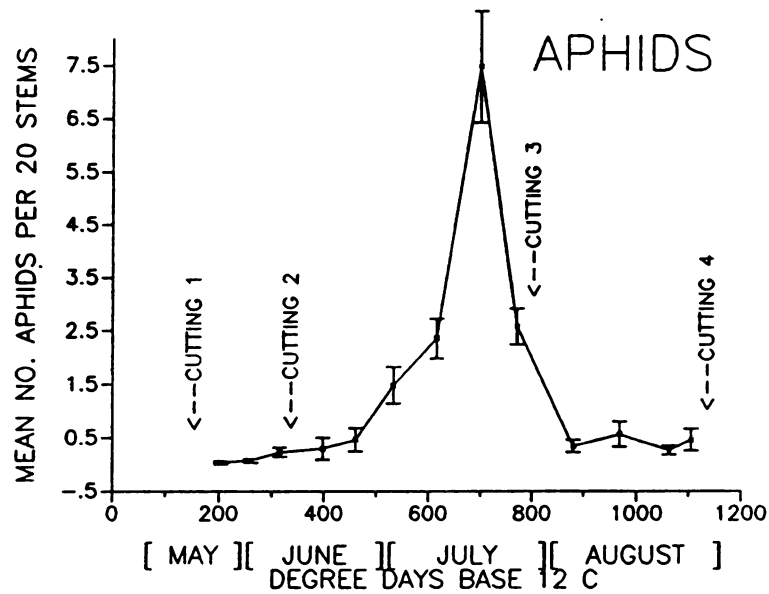


Figure 4. Mean number of aphids per 20 stems, $\pm$ S.E.

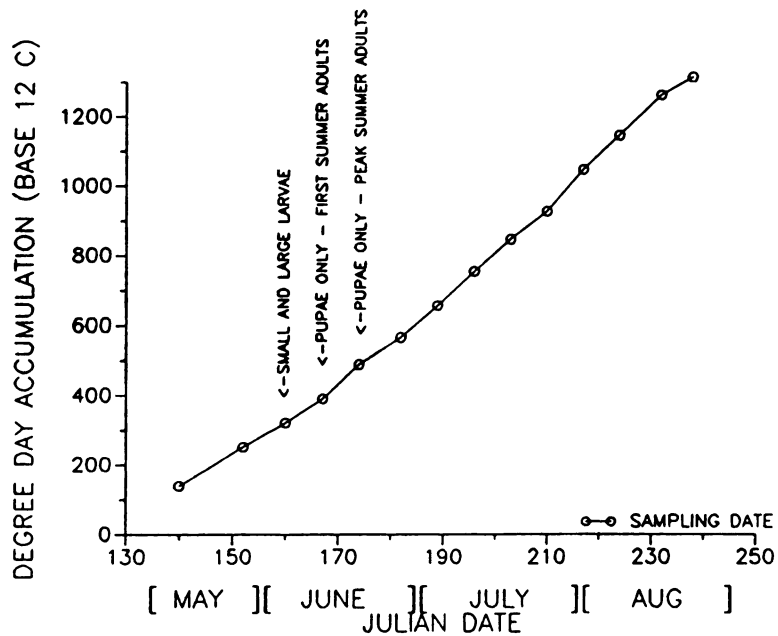


Figure 5. Occurrence of C7 larvae, pupae and summer adults, and degree day accumulation.

and June (Fig. 4) probably contributed to the high level of flight activity.

High trap catch on 22 June was probably due to the flight of C7 caused by cutting the alfalfa on 16 June. This cutting occurred near the end of pupation while summer adults were still emerging. Although some pupae may have been destroyed during cutting, the large number of beetles captured on 15 and 22 June suggests that the majority of summer adults had already emerged.

C7 and aphid numbers slowly increased and aphids peaked between 30 June and 28 July, reflecting recolonization of the alfalfa by these insects after the cutting on 16 June (Fig. 2--4). The increase in number of C7 observed in quadrat samples closely followed the build up of aphids during this period. Beetles caught in traps during this time were probably immigrants from nearby fields.

A pronounced and sustained drop in the number of C7 occurred after the third cutting on 29 July (Fig. 2--3). C7 may have been dispersing to hibernation sites during this time, which would concur with observations of C7 moving to hibernation sites in Delaware during late July and early August (Angalet et al. 1979). The decrease in aphids after the third cutting (Fig. 4) also may have affected C7 abundance. Occasional sweeps of the alfalfa in September showed a substantial increase in aphids, probably due to the continued absence of C7.

Comparison of sampling methods. Both trap and quadrat samples detected peak C7 activity and occurrence (e.g., emergence of summer adults, increased numbers during July) and cessation of activity in late summer. Although there was a significant correlation between trap catch (TC7) and quadrat counts (QC7) over the sampling period (Table 3), this association did not hold for correlations calculated between cuttings (Table 4). Traps and quadrats were significantly correlated only during early summer (21 May to 15 June) when both methods detected the peak emergence of summer adults. During the remainder of the summer the association was not significant. These differences may be explained in part by the methods themselves, and in part by the behavior of C7.

Quadrat samples can provide a fairly accurate measure of C7 abundance and density, but traps measure only relative activity and abundance. Traps are useful for identifying periods of flight activity, but should not be used to estimate population density unless the area of influence of a trap is determined. Also, because quadrat samples were taken during fair weather, they are not impacted as much by weather as traps.

The spatial and temporal aspects of each method are also dissimilar. Traps sample from an unknown amount of habitat over a long period of time, whereas quadrat observations represent a specific unit of habitat at a

Table 3. Correlation of trap and quadrat data over the sampling period.

	TC7 ^a		QC7		Aphids	
	r ^b	p ^c	r	P	r	P
QC7	0.2654	0.0000				
Aphids	0.2199	0.0000	0.1446	0.0000		
Plant height	0.2274	0.0000	0.1494	0.0000	0.3224	0.0000

a -- TC7 = trap catch; QC7 = quadrat samples

b -- r = Pearson's Product-Moment Correlation Coefficient

c -- P-value for $\alpha=0.05$

Table 4. Correlation of trap and quadrat data between cuttings.

	TC7 ^a		QC7		Aphids	
	r ^b	p ^c	r	P	r	P
21 May - 15 June						
QC7	0.4691	0.0000				
Aphids	0.1763	0.0150	0.2476	0.0009		
Plant Height	0.6171	0.0000	0.3857	0.0000	0.1627	0.0202
16 June - 28 July						
QC7	0.0292	0.3000				
Aphids	0.2211	0.0003	0.1267	0.0116		
Plant Height	0.1060	0.0516	0.1444	0.0049	0.4636	0.0000
29 July - 29 August						
QC7	-0.1075	0.0600				
Aphids	-0.0552	0.2206	-0.0395	0.2810		
Plant Height	-0.0879	0.1100	0.0648	0.1251	0.0053	0.4641

a -- TC7 = trap catch; QC7 = quadrat samples

b -- r = Pearson's Product-Moment Correlation Coefficient

c -- P-value for $\alpha=0.05$

discrete point in time. Furthermore, the size and timing of quadrat samples, which are determined by the researcher, may affect the observations. Although the area of influence of yellow sticky traps is unknown for C7, the large number of beetles caught on traps during the height of their flight activity suggests that a large area was being sampled.

Each method is also affected by the changing behavior of beetles in respect to prey abundance. The overwintered and summer adults searching plants for prey or feeding on prey would be observed in quadrats but not traps. When aphid density is high, C7 may rely on walking to search for prey and may not fly often, thereby appearing in quadrat samples but not traps. In fact, the number of C7 in quadrats closely followed the increase in aphids after the cutting on 16 June (Fig. 3--4) while trap catch fluctuated during this period (Fig. 2). Traps capture C7 that are "testing the environment" for prey, and their movement may be more haphazard than beetles that have settled on plants.

Association of C7 with aphids and plant height. Significant positive correlations were found between the number of C7 and aphids, and plant height over the entire sampling period (Table 3). These results concur with expectations of the association between predator and prey: C7 should be more abundant when aphids are more abundant, and vice versa. The positive association between aphids and plant height may be an indicator of preferred habitat, i.e., taller plants are

likely to be growing vigorously, providing aphids with a highly nutritious food source. Significant correlation between the number of C7 and plant height may indicate that C7 are able to find their prey by locating its preferred habitat. Further exploration into the association between C7 and plant height may elucidate the mechanism of prey-finding in C7.

Correlations calculated from data between cuttings (Table 4) reveal a few disparities from the seasonal correlations presented above. The significant positive correlations between the number of C7 and aphids, and plant height in early and mid-summer (21 May to 28 July) concur with seasonal results. In contrast, no correlations were significant during late summer (29 July to 29 August). During this period aphids were consistently low in number while the number of C7 fluctuated (Fig. 2--4), resulting in low, non-significant correlations. Disparity in the association between the number of C7 and aphids and plant height over the course of the summer can probably be contributed to phenological changes in C7. If C7 migrates to hibernation sites in late July and August, they may no longer be stimulated to find aphids or aphid habitat and, therefore, their response to hibernation "over rides" other stimuli.

Association of C7 with weather factors. Correlations between the number of C7 and aphids, and weather factors

were calculated to determine if any general trends could be identified that might warrant further investigation. No consistent trends were found in the association between weather variables and the number of C7 in traps or quadrats over the entire sampling period (Table 5). The negative association of rain with C7 was not unexpected because they probably do not fly during rain. Rain previous to quadrat sampling may also affect observation of C7 on plants. The positive correlation between solar radiation and C7 suggests that C7 is more active on sunny days. Adults bask on plants to increase body temperature (Honék 1985a), and would be more likely to be observed in quadrats on sunny days. Flight also increases during sunny days with temperatures above 20 °C (Honék 1985a), increasing the probability that beetles would be caught in traps. Wind speed had a significant negative correlation with the number of C7 in traps but not quadrats. Strong winds may inhibit C7 flight, but winds also disrupt traps, perhaps lowering their potential to capture beetles. Although the correlation between temperature and C7 was not significant, it is interesting to note that it was negative. There may be a temperature threshold for activity above which C7 avoids the heat by hiding in soil cracks or other remote places. These beetles would not be readily observed in quadrats, nor would they be flying into traps. This behavior could greatly influence sampling and affect the estimation of their number in the field. Conversely, basking may increase beetle

Table 5. Correlation of trap and quadrat data with weather variables.

	TC7 ^a		QC7	
	r^b	P^c	r	P
Rain	-0.2091	0.0000	-0.1143	0.0014
Temperature	-0.0398	0.1660	-0.0526	0.0838
Solar Rad.	0.2025	0.0000	0.0693	0.0351
Wind Speed	-0.1993	0.0000	-0.0053	0.4483

a -- TC7 = trap catch; QC7 = quadrat samples

b -- r = Pearson's Product-Moment Correlation Coefficient

c -- P-value for $\alpha=0.05$

activity on cool but sunny days. The interaction of solar radiation and temperature on C7 behavior and its impact on sampling should be investigated.

Cutting the alfalfa altered the habitat of C7, and the association between the number of C7 and weather factors between cuttings varied (Table 6). Rain was negatively correlated with the number of C7 in traps during early and mid- summer, but not late summer. Migration to hibernation sites during late summer probably affected trap catch more than rainfall. TC7 was associated with temperature and solar radiation in all three periods. The negative correlation with temperature during early summer may have been an artifact of the emergence of summer adults during fairly cool weather. Positive correlations during the rest of the summer may more accurately reflect the increase in C7 flight activity on warm sunny days. Wind was negatively correlated with TC7 in mid-summer (16 June to 28 July). An extremely windy week prior to 30 June may have adversely affected trap catch. However, other factors such as low aphid density may have been responsible for low trap catch on that date.

The number of C7 in quadrats was correlated with rain, temperature, and solar radiation during early summer, and there were no significant correlations the rest of the sampling period (Table 6). The only rain event during this period occurred before 8 June, but the low number of C7 at

Table 6. Correlation of trap and quadrat data and weather variables between cuttings.

	TC7 ^a		QC7	
	r ^b	p ^c	r	P
21 May - 15 June				
Rainfall	-0.3242	0.0000	-0.1907	0.0087
Temperature	-0.3638	0.0000	-0.2164	0.0034
Solar Radiation	0.5777	0.0000	0.3583	0.0000
Wind Speed	0.0054	0.2743	0.0194	0.4090
16 June - 28 July				
Rainfall	-0.2740	0.0000	-0.0579	0.1515
Temperature	0.2093	0.0006	0.0813	0.0749
Solar Radiation	0.1295	0.0228	-0.0837	0.0681
Wind Speed	-0.3547	0.0000	-0.0136	0.4013
29 July - 29 August				
Rainfall	-0.0881	0.1075	0.0141	0.4207
Temperature	0.1162	0.0505	-0.0976	0.0793
Solar Radiation	0.1869	0.0039	-0.0014	0.4900
Wind Speed	-0.0302	0.3372	0.0843	0.1131

a -- TC7 = trap catch; QC7 = quadrat samples

b -- r = Pearson's Product-Moment Correlation Coefficient

c -- P-value for $\alpha=0.05$

this time was most likely due to the dying off of overwintered adults rather than a negative association with rain or temperature. The absence of rain and high degree of solar radiation probably enhanced the activity of emerging summer adults on 15 June, and they were active on the plants regardless of cool temperatures.

Weather factors appear to have been less important for quadrat samples than traps. Extreme weather events, such as high winds and heavy rains, may interfere with the capture of beetles on traps. Quadrat samples, however, are probably affected by the weather at the time of sampling rather than weather occurring during the previous week. Since quadrats were taken during fair weather, the impact of weather was probably negligible. Phenology appears to be an important factor in both trap and quadrat samples, particularly during peak emergence of summer adults and migration to hibernation sites in late summer. The interaction of phenological events with weather factors, specifically temperature and solar radiation, warrants further investigation.

This study has provided baseline information on the temporal distribution of C7 in alfalfa. The results suggest that C7 ecology in alfalfa is determined by a complex combination of C7 and aphid phenology, plant characteristics, and weather factors. Farm managers wishing to utilize C7 for control of aphids or scientists wanting to use C7 for research should note the emergence of summer adults at approximately 300 DD base 12°C. At this time the

beetles are most abundant and could be collected and transported to areas of high aphid density, or collected for research projects. Additional research into the interaction between plant characteristics, aphid abundance and prey-finding by C7, and the interplay of weather factors and phenological events suggested by this study would greatly improve our knowledge of C7 ecology.

Article 2

Spatial distribution of the summer adults of Coccinella septempunctata L. (Coleoptera, Coccinellidae) in alfalfa.

INTRODUCTION

Coccinella septempunctata L. (C7) is a Palearctic coccinellid that was introduced to the U.S. for the biological control of aphids (Angalet et al. 1979). Although C7 has been studied extensively in Europe (Hodek 1966, 1973, Honék 1979, 1982b, 1985a,b), relatively little is known about the ecology of C7 in the U.S. Many reports from the U.S. have been concerned with the release and establishment of C7 (Cartwright, et al. 1979, Obrycki et al. 1987, Schaefer et al. 1987). Angalet, et al. (1979) characterized temporal distribution and identified hibernation sites and potential prey species of C7 in the Hackensack Meadowlands of New Jersey. The establishment of C7 as a predator in pecan orchards has been investigated (Teddars and Angalet 1981). Thermal development of C7 in New York has been determined by Obrycki and Tauber (1981).

One of the primary characteristics of the ecology of an organism is its spatial distribution (Andrewartha and Birch 1974, Taylor 1984). Spatial distribution can be used to explain behavioral characteristics such as territoriality; identify relationships with other organisms or physical attributes of the environment (Andrewartha and Birch 1974); and provide information for developing sampling programs (Taylor 1984). The focus of this study was to determine the

spatial distribution of Coccinella septempunctata L. in alfalfa, and investigate the influence of prey distribution and plant height on the distribution of this predator.

MATERIALS AND METHODS

Data used in the analysis of spatial distribution were collected during the summer of 1988 at the Michigan State University Kellogg Biological Station, Hickory Corners, Mich. A grid of 54 sampling sites spaced 50 m apart was established in a 40 ha alfalfa field. At each site, a yellow sticky trap (unbaited Pherocon^R, Zoecon, Palo Alto, CA) was secured to one arm of a 1.5 m tall T-shaped wooden standard. Sampling was conducted from 31 May to 25 August. A 0.25 m² quadrat sample was taken in the alfalfa near each trap and traps were monitored every six to nine days. C7 adults captured on traps were counted and removed. The number of C7 larvae and adults, number of aphids per 20 stems and height of 10 alfalfa stems were taken in each quadrat sample.

Spatial distribution of C7 in traps, and C7 and aphids in quadrats was analyzed using several methods. Taylor's Power Law (Taylor 1961) was solved using Model II regression (Sokal and Rohlf 1981) on the $\ln(x+1)$ transformed mean and variance for each date. A t-test was used to test if the calculated slope, b, was significantly different from one (1). If the slope is not significantly different from one, the distribution is random. A slope greater than one

reflects a clumped distribution, while a slope less than one indicates a regular distribution. The variance to mean ratio, s^2/x (Southwood 1978), for each sampling date was calculated to estimate spatial distribution by date. If this ratio is greater than one the distribution is clumped, if less than one it is regular, and if it is equal to one the distribution is random. Morisita's Index, I_{δ} , (Morisita 1962) was calculated for each date and tested for significance with a Chi-Square test ($X^2 = [I_{\delta} * (n-1)] * N - n$, where n = the total number of individuals observed on that date, and N = the number of samples taken). Decision rules for I_{δ} are the same as the variance to mean ratio. Finally, data from each sampling date were fit to the Poisson or negative binomial distributions using methods in Elliott (1971). Agreement with the Poisson distribution indicates a randomly distributed population. Similarly, data that fit the negative binomial distribution indicate a population with a clumped distribution. A maximum likelihood method was used to calculate k of the negative binomial (Southwood 1978). The Chi-Square goodness-of-fit test ($X^2 = (O-E)^2/E$) (Elliott 1971) was used to test the fit of the data to the distributions.

Distribution maps were generated from the mean number of C7 per trap and per quadrat, the mean number of aphids, and mean plant height at each trap site for 13 weekly observations. Geostatistical Environmental Assessment Software (GEO-EAS, Englund and Sparks 1988) was used to

construct distribution maps the of C7, aphids and plant height. Geostatistical techniques provide unbiased interpolation between sample points, calculated by a "weighted-moving-average" method called "kriging" (Englund and Sparks 1988). Kriging utilizes the amount of autocorrelation between sites to estimate values in unsampled areas between sites (Robertson 1987). Contour maps generated from kriged values were used to illustrate the spatial distribution of C7, aphids and plant height, and provide information for the biological interpretation of their spatial distribution.

RESULTS

Distribution of C7 in traps (TC7). The slope, b , of Taylor's Power Law for C7 in traps (TC7) was significantly greater than one, indicating a clumped distribution (Table 7). However, the variance to mean ratio calculated for each sampling date shows that the distribution of TC7 changed over the season, ranging from regular or near random (0.96) to clumped (3.62) (Table 8). According to Morisita's Index (I_g), TC7 were randomly distributed on 31 May, 8 June and all dates in August, but showed a clumped distribution on the remaining dates (Table 8). An I_g of 2.36 on 8 June did not fit a clumped distribution as expected, probably because of the low number of beetles captured ($n = 10$) and the high frequency of zero counts.

Table 7. Taylor's Power Law for C7 and aphids.

	N	b ^a	P	C.I.	Distr.
TC7 ^b	13	1.2557	0.0005	(1.1715, 1.3399)	Clumped
QC7	10 ^c	1.0351	0.1	(0.9839, 1.0862)	Random
Aphids	13	1.3808	0.005	(1.1740, 1.5876)	Clumped

a -- Model II Regression, Sokal and Rohlf 1981

b -- TC7 = C7 in traps; QC7 = C7 in quadrats

c -- three dates had zero beetles

Table 8. Spatial distribution of C7 in traps (TC7) by date.

Date	s^2/m	Morisita's Index			Poisson Distribution			Negative Binomial Distribution			
		I_5	P	Dist. ^a	χ^2	P	Dist.	k	χ^2	P	Dist.
31 May	0.96	0.00	0.300	Ra	0.10	0.3000	Ra	n.a. ^b	—	—	—
8 Jun	1.23	2.36	0.100	Ra	2.30	0.1000	Ra	0.66	0.86	0.3	Cl
15 Jun	3.62	1.38	0.001	Cl	69.36	0.0001	Not Ra	2.89	14.71	0.3	Cl
22 Jun	3.06	1.27	0.001	Cl	66.24	0.0001	Not Ra	3.51	6.52	0.3	Cl
30 Jun	1.58	1.91	0.005	Cl	11.76	0.0010	Not Ra	0.98	2.92	0.2	Cl
7 Jul	1.93	1.17	0.001	Cl	20.64	0.0250	Not Ra	5.70	9.39	0.3	Cl
14 Jul	2.02	1.28	0.001	Cl	14.35	0.0500	Not Ra	3.72	7.74	0.3	Cl
21 Jul	2.73	1.37	0.001	Cl	25.67	0.0010	Not Ra	2.72	6.74	0.3	Cl
28 Jul	1.71	1.32	0.005	Cl	6.47	0.2000	Ra	5.29	9.79	>0.05	Cl
4 Aug	1.22	1.18	0.100	Ra	2.62	0.3000	Ra	7.07	2.21	0.2	Cl
11 Aug	1.19	1.30	0.100	Ra	2.17	0.3000	Ra	3.24	0.38	0.3	Cl
19 Aug	1.36	1.26	0.060	Ra	2.76	0.3000	Ra	3.70	1.37	0.3	Cl
25 Aug	1.12	1.17	0.200	Ra	4.41	0.1000	Ra	7.00	3.33	>0.05	Cl

^a — Ra = random, Cl = clumped

^b — n.a. = not applicable, $s^2 < m$

All dates that resulted in a random distribution with Morisita's Index were not significantly different from random when fit to the Poisson distribution (Table 8). Dates with clumped distributions were significantly different from random, with the exception of 28 July. It is possible that non-randomness could not be detected for 28 July, as agreement with the Poisson does not necessarily prove randomness (Elliott 1971). The negative binomial fit all sampling dates to which it was applied (Table 8).

Distribution of C7 in quadrats. The slope, b , of Taylor's Power Law for C7 in quadrats (QC7) was not significantly different from random (Table 7). Variance to mean ratios for QC7 ranged from 0.90 -- 1.18, indicating a random or near random distribution for each date (Table 9). Results from Morisita's Index and the fit to the Poisson distribution were not significantly different from random for all dates tested (Table 9). Fit to the negative binomial was not performed on these data because of the strong evidence that all dates had randomly distributed populations.

Distribution of Aphids. The slope, b , of Taylor's Power Law for aphids was significantly greater than one, indicating a clumped distribution (Table 7). Variance to mean ratios for aphids by date ranged from near random (0.98) to clumped (7.73) (Table 10). Morisita's Index shows that aphids were

Table 9. Spatial distribution of C7 in quadrats (QC7) by date.

Date	s^2/m	Morisita's Index			Poisson Distribution		
		I_g	P	Dist.	χ^2	P	Dist.
31 May	n.a. ^a	--	--	--	--	--	--
8 Jun	1.00	0.00	0.3	Ra	0.01	0.3	Ra
15 Jun	1.08	1.41	0.3	Ra	1.94	0.3	Ra
22 Jun	0.92	0.00	0.3	Ra	0.26	0.3	Ra
30 Jun	1.18	2.35	0.2	Ra	1.04	0.3	Ra
7 Jul	1.08	1.50	0.3	Ra	0.21	0.3	Ra
14 Jul	1.18	1.93	0.1	Ra	1.46	0.3	Ra
21 Jul	1.00	1.01	0.3	Ra	0.04	0.3	Ra
28 Jul	0.90	0.00	0.3	Ra	0.40	0.3	Ra
4 Aug	1.00	0.00	0.3	Ra	0.01	0.3	Ra
11 Aug	n.a.	--	--	--	--	--	--
19 Aug	n.a.	--	--	--	--	--	--
25 Aug	0.98	0.00	0.3	Ra	0.04	0.3	Ra

a -- n.a. = not applicable, zero counts for date or $s^2 < m$

Table 10. Spatial distribution of aphids by date.

Date	s^2/m	Morisita's Index			Poisson Distribution			Neg. Binomial Distribution			
		I_2	P	Dist. ^a	χ^2	P	Dist.	k	χ^2	P	Dist.
31 May	0.98	0.00	0.300	Ra	0.04	0.300	Ra	n.a. ^b	—	—	—
8 Jun	0.94	0.00	0.300	Ra	0.16	0.300	Ra	n.a.	—	—	—
15 Jun	1.53	3.42	0.025	Cl	1.66	0.300	Ra	0.43	0.41	0.30	Cl
22 Jun	7.73	24.75	0.001	Cl	6.00	0.050	Not Ra	0.07	4.23	0.10	Cl
30 Jun	5.44	10.80	0.001	Cl	7.26	0.005	Not Ra	0.17	1.07	0.30	Cl
7 Jul	4.25	3.18	0.001	Cl	36.42	0.001	Not Ra	0.61	8.64	0.10	Cl
14 Jul	3.18	1.92	0.001	Cl	54.27	0.001	Not Ra	0.95	8.51	0.20	Cl
21 Jul	7.76	1.89	0.001	Cl	261.87	0.001	Not Ra	0.72	21.46	0.20	Cl
28 Jul	2.30	1.50	0.001	Cl	46.61	0.001	Not Ra	1.49	13.53	0.06	Cl
4 Aug	2.15	4.03	0.001	Cl	4.11	0.050	Not Ra	0.32	0.44	0.30	Cl
11 Aug	5.00	8.16	0.001	Cl	25.30	0.001	Not Ra	0.12	0.94	0.30	Cl
19 Aug	1.48	2.91	0.010	Cl	2.80	0.100	Ra	0.48	0.06	0.30	Cl
25 Aug	4.80	9.60	0.001	Cl	6.52	0.025	Not Ra	0.18	0.86	0.30	Cl

^a — Ra = random, Cl = clumped

^b — n.a. = not applicable, $s^2 < m$

randomly distributed on 31 May and 8 June, but were clumped on all other dates (Table 10). Aphid data fit the Poisson distribution on 31 May, 8 June, 15 June and 19 August, with all other dates significantly different from random (Table 10). Although aphids on 15 June and 19 August fit the Poisson distribution, results from Morisita's Index, the variance to mean ratio, and the fit to the negative binomial indicate that the distribution on these dates was actually clumped. It is possible that non-randomness could not be detected in these data (Elliott 1971). All dates tested fit the negative binomial, indicating that aphids were clumped in distribution.

The spatial variability of C7 and aphids in the field over the entire sampling period is shown in the contour maps (Fig. 6--8). The majority of C7 were observed in the western half and northern quarter of the field (Fig. 6--7). A patch of coinciding aphids and C7 occurred in a band traversing from the center of the field toward the southeast. The area of greatest aphid concentration, in the center of the field, slightly overlaps the "hot spot" of C7 in quadrats (Fig. 7--8). The south and eastern edges of the field had low numbers of both predator and prey over the sampling period. Plants were tallest in the western half of the field, and shortest in all corners but the northwestern corner (Fig. 9). A slight ridge of tall plants occurred transversely across the southeastern corner of the field.

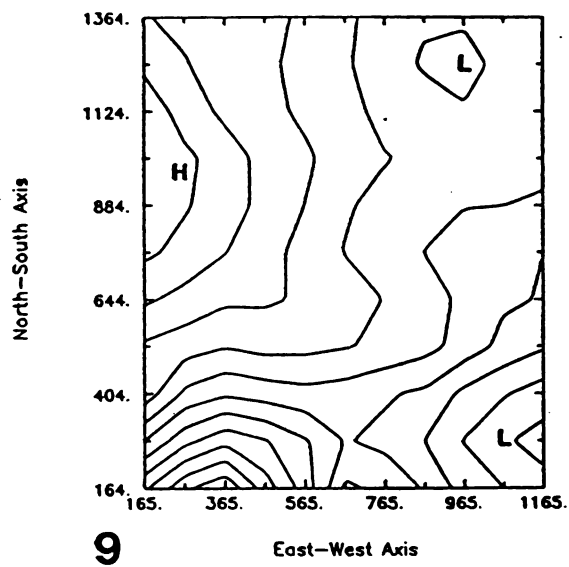
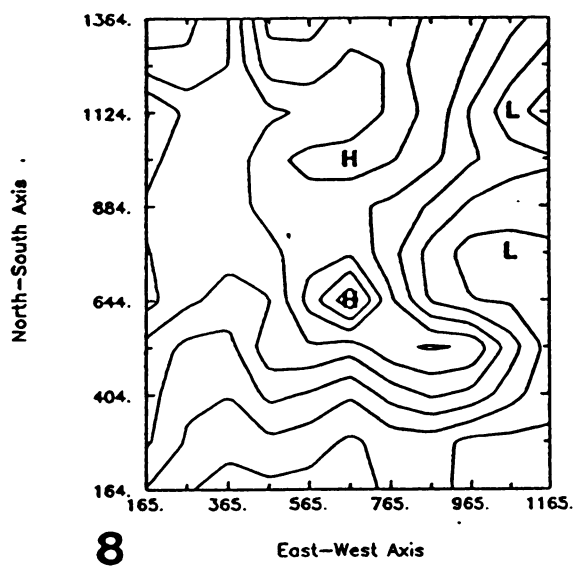
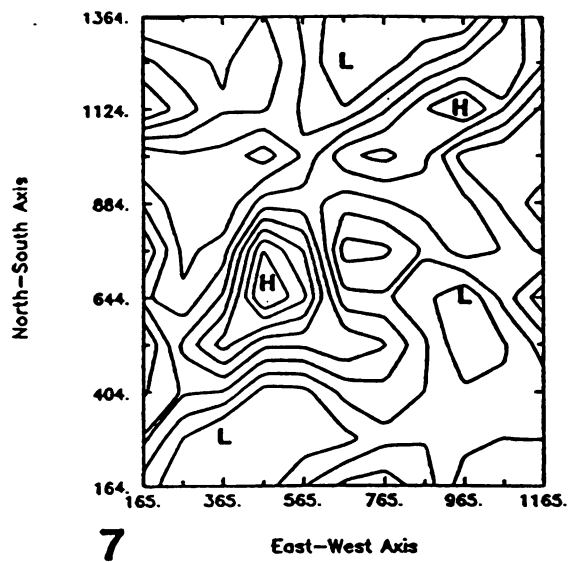
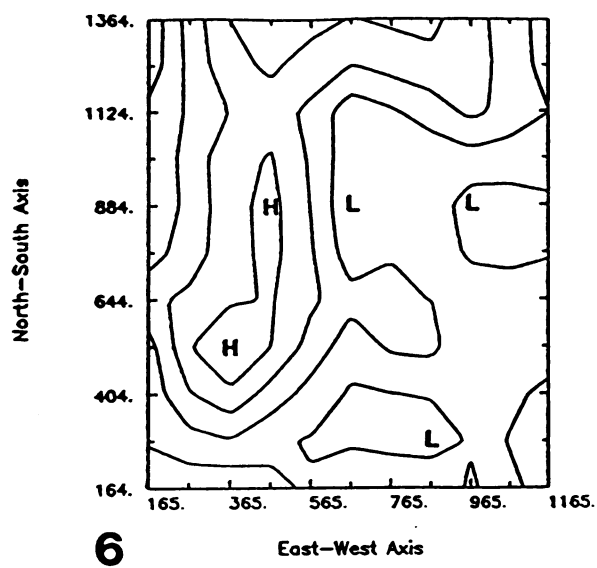


Figure 6--9. Contour maps of: 6, C7 distribution in traps;
7, C7 distribution in quadrats; 8, aphid distribution;
9, plant height distribution.

DISCUSSION

The variance to mean ratio and Morisita's Index show that the distribution of TC7 changed over the season from random to clumped and back to random. This change cannot be attributed to changes in abundance because clumped distributions were confirmed for dates with high (e.g. 15 June) as well as low trap catch (e.g. 30 June). Also, Morisita's Index is apparently resistant to changes in density (Myers 1978), providing an unbiased indicator of distribution. Although the variance to mean ratio is not resistant to changes in density, there was a consistency between variance to mean ratios and Morisita's Index for this data. Dates with a ratio below 1.36 resulted in a random distribution with Morisita's index, and those with a ratio above 1.53 were clumped. The negative binomial also may be affected by density (Myers 1978, Taylor 1984) which may explain the inconsistency between the variance to mean ratio, Morisita's Index and the fit to the negative binomial for 8 June and all dates in August. Since the biological interpretation of k as an index of aggregation has been questioned (Southwood 1978, Taylor 1984), and because as k gets larger, the negative binomial is indistinguishable from the Poisson (Elliott 1971), the usefulness of the negative binomial in determining the distribution of organisms is questionable.

The occurrence of a random distribution of TC7 has an interesting biological interpretation. Taylor (1984) claims

that organisms may be randomly distributed during the dispersal phases of their life cycle, but are otherwise clumped. The random distribution found for TC7 from 28 July to 25 August may be explained by the dispersal of C7 to hibernation sites during that period. The random distribution on 31 May and 8 June may be attributed to the solitary nature of the overwintered adults that were active at this time. These individuals have already mated so there is no reason for them to interact.

The clumped distribution of TC7 during the middle of summer is more difficult to interpret. A clumped distribution implies that the presence of one individual in a sample increases the probability of the occurrence of another individual (Elliott 1971). However, if the trap is attractive to beetles, it may have influenced the occurrence of more than one C7, rather than the beetles already on the trap. Furthermore, C7 does not locate prey visually and also may not be able to see other beetles on a trap. Traps, then, may be removing potential predators from the field, decreasing the population available to prey on aphids. It also seems unlikely that a predatory insect would tend to aggregate, as this might lead to competition for resources and/or aggression which would, in turn, result in avoidance. A clumped distribution, however, may have resulted if beetles were attracted to a localized area of high prey abundance in the alfalfa near the trap.

The fit of QC7 to a Poisson distribution was not unexpected. The majority of quadrat samples had zero or one C7, and only a few had two beetles, and as Taylor (1984) has commented "... one individual cannot aggregate...". The rarity of observing one beetle in a quadrat sample fits the theoretical definition of the Poisson as a distribution of rare events (Sokal and Rohlf 1981). Biologically, the Poisson distribution describes a situation in which "...the presence of one individual does not influence the presence of another" (Southwood 1978). It is generally accepted that organisms are not randomly distributed (Andrewartha and Birch 1974, Taylor 1984) because this implies that there is no interaction between individuals. A randomly distributed population, therefore, could not retain its viability as a species. However, C7 aggregates and mates during the fall and winter, so there is no reason for individuals to interact during the summer. Indeed, interaction between foraging predators is more likely to be repellant or competitive. Therefore, the random distribution of C7 found in quadrats in alfalfa is justified.

A clumped distribution was not unexpected for aphids, which are colonial organisms. A small value for k of the negative binomial indicates a higher degree of aggregation, and k is less than one for most of the dates tested (Table 10). Randomly distributed populations on 31 May and 8 June, shortly after the alfalfa was mowed on 21 May, may be due to the presence of individual alates that had not yet formed

colonies. All observations of aphids on 31 May and 8 June were solitary individuals.

The contour maps show that concentrations of C7 the field often, but not always, overlapped areas of high prey abundance (Fig. 6--9). Honek (1985b) reported that, although C7 is more prevalent in areas of high prey density, the relationship between high prey density and C7 occurrence is not strong. When the distribution of plant height is compared with that of C7 and aphids (Fig. 6,7,9), it is evident that both predator and prey were most abundant where plants were tall. C7 and aphids may be using a plant characteristic, such as plant height, to locate favorable habitat. The correlation between C7, aphids and plant height over the sampling period was highly significant (Sirota 1990). However, the correlation may be coincidental, and the key characteristic may be plant color or the density of plant cover.

Although mathematical indices and distributions specify the type of distribution a population exhibits, maps provide a visual characterization of the population in the physical environment. Visual analysis of maps of predators, prey and physical elements of the landscape can elucidate relationships that are not detectable with indices or mathematical distributions. Further research into the relationship of plant characteristics with C7 and aphids may provide insight into C7 host-finding behavior.

Article 3

The sex ratio of Coccinella septempunctata L. in hand-collected and yellow sticky trap samples.

INTRODUCTION

Sticky traps of various colors, sizes and shapes have been used to monitor ladybird beetles (e.g. Keickhefer and Olson 1974, Ives 1981, Dean 1982). However, no study has reported whether either sex of ladybird beetles are differentially attracted to sticky traps. Honék (1985a) observed that more male than female seven-spotted ladybird beetles, Coccinella septempunctata L., were active in the spring when males were searching for mates. These individuals would be more likely to be caught on traps. On the other hand, females searching for oviposition sites or new prey sources may fly more often and would have a greater chance of being captured on a trap. Therefore, the sex ratio of ladybird beetles caught in traps may change appreciably over time depending on the abundance of prey and behavior of the beetles.

This study examined the sex ratio of the Coccinella septempunctata (C7) in hand-collected samples and captured on yellow sticky traps. The objectives were 1) to determine if the sex ratio of hand-collected beetles was 1:1, 2) to test if traps captured both sexes of the population equally (1:1 ratio), and 3) to establish if the sex ratio from either method changed during the sampling period and investigate possible explanations if a change was detected.

MATERIALS AND METHODS

Unbaited yellow sticky traps (Pherocon^R) suspended from one arm of 1.5 m tall T-shaped wooden standards were set up in three fields at the Michigan State University Kellogg Biological Station, Hickory Corners, Mich. Sixteen traps were placed in a small vetch field, 54 traps in 40 ha alfalfa field, and 58 traps in approximately 35 ha of soybeans, for a total of 128 traps. Traps were monitored once per week from 12 May to 9 September 1988. The number of C7 on each trap was recorded, the beetles were removed from each trap and then attached to index cards with a dab of the sticky trap material. The index cards were stored in a freezer until the beetles could be cleaned and examined. Sixteen samples of C7 were taken in the fields using a sweep net or by picking beetles directly from plants or the soil surface. Hand collected beetles were collected into FAA (formalin, acetic acid and alcohol) and subsequently stored in 70% ethanol.

Beetles were removed from the index cards and placed in vials containing hexane for cleaning. The beetles soaked in hexane for 24-72 hrs with occasional agitation. After cleaning, the vials were drained and filled with 70% ethanol until the beetles could be examined. A dissecting microscope was used to sex C7 from both trap and hand-collected samples. Sex determination was based on morphological characteristics of the abdominal sternites as reported by Baungard (1980). The sixth visible abdominal

sternite of female C7 is similar to the fourth and fifth sternites. However, male C7 have a brush of hairs on the margin of a pit (fovea) on the sixth abdominal sternite. When this brush of hairs was destroyed in preparation, presence of a pit was adequate to identify a male.

The hand-collected and trap samples were analyzed separately with a replicated heterogeneity G -test (Sokal and Rohlf 1981) for goodness-of-fit to a 1:1 sex ratio. Each method was analyzed for heterogeneity by pooling the data (G_p) and using the dates as samples (G_H), and also for overall goodness-of-fit to the expected sex ratio (G_T). Where heterogeneity was found ($P \leq 0.01$), unplanned tests (Sokal and Rohlf 1981) were performed to determine which data contributed to the heterogeneity and which data formed homogeneous groups. First, sample dates were ranked by the proportion of males (p_i) in the sample. A "simultaneous test" for identifying heterogeneity in the data (Sokal and Rohlf 1981) was then performed by consecutively adding each sample date to the calculation until heterogeneity was attained. Heterogeneity occurred when the X^2 value calculated after a sample date was added became significant ($P \leq 0.1$). All sample dates in the calculation, except the last one added, were then identified as an homogeneous group. This test was performed on the ranked data starting first with female-dominated and then with male-dominated samples. Female-dominated or male-dominated samples that were found to be different from a 1:1 ratio were tested to

determine if they formed homogeneous groups. An α of 0.1 was used as the probability value because a high degree of confidence was not deemed necessary.

RESULTS AND DISCUSSION

Hand-collected samples of C7 did not differ significantly from a 1:1 sex ratio in any of the three G-tests performed (Table 11). Three dates did show a significant difference ($P \leq 0.1$) (Table 12, Figure 10), but did not deviate enough from 1:1 to cause heterogeneity in the G-tests. Therefore, the hypothesized sex ratio of 1:1 for this population of C7 was accepted.

Although the overall sex ratio was equal, Figure 10 shows a trend toward more females in May and June, and more males or more equal numbers in July and August. Females may be more active in searching for prey on plants during early summer to accumulate a maximum amount of resources for overwintering. Males may be more active during July if they are the first sex to move to hibernation sites. If behavioral differences affect the sex ratio of C7 in the field, the amount of aphids consumed may fluctuate as well. The impact of predation on aphids may be more intense in early summer when the activity of female C7 is higher, which could then influence pest management practices.

The sex ratio of C7 caught on traps was significantly different from 1:1 (Table 11). Results from calculation of G_H indicated that the data were heterogeneous. Because



Table 11. Homogeneity G-tests for Sex Ratio in C7.

	G-value	df	χ^2	P
Hand- collected				
G_H	16.81	13	22.362	> 0.1
G_P	2.47	13	22.362	>> 0.1
G_T	19.28	14	23.685	> 0.1
Trap catch				
G_H	70.82	32	46.194	< 0.001
G_P	1.04	32	46.194	>> 0.1
G_T	71.86	33	47.400	< 0.001

Table 12. Homogeneity G-Tests by Date for Sex Ratio
in Hand-collected C7.

Date	Crop*	M	F	Total	G-value	P
12 May	Alf	2	3	5	0.201	N.S.
17 May	Alf	5	12	17	2.970	0.10
8 Jun	Alf	3	10	13	3.977	0.05
15 Jun	Alf	23	20	43	0.210	N.S.
21 Jun	Vet	11	18	29	1.707	N.S.
22 Jun	Alf	10	12	22	0.182	N.S.
29 Jun	Soy	2	4	6	0.680	N.S.
30 Jun	Alf	5	12	17	2.970	0.10
5 Jul	Soy	7	3	10	1.646	N.S.
6 Jul	Vet	6	7	13	0.077	N.S.
7 Jul	Alf	17	9	26	2.502	N.S.
27 Jul	Alf	15	18	33	0.273	N.S.
27 Jul	Vet	4	4	8	0.000	N.S.
4 Aug	Alf	1	1	2	0.000	N.S.
25 Aug	Alf	3	5	8	0.505	N.S.
TOTALS		114	138	252		

*Alf = alfalfa, Vet = vetch, Soy = soybean

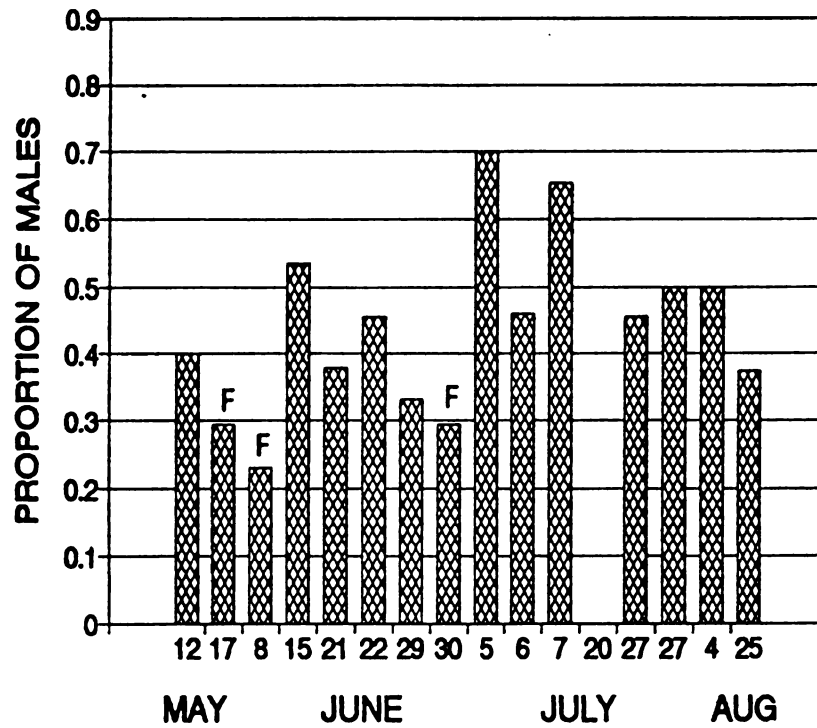


Figure 10. Proportion of males per hand-collected sample. Dates with an F have significantly more females ($P < 0.1$).

there were only 7 dates out of 33 that were significantly different from 1:1 (Table 13, Figure 11), the pooled data (G_p) did not deviate from a 1:1 sex ratio. This sometimes occurs with pooled data when samples that are not different from the expected ratio mask the few samples that are different (Sokal and Rohlf 1981). Results from the overall test (G_T), however, did not fit the expected ratio and further tests were performed to determine the source of heterogeneity.

The first two groups tested with the "simultaneous test" were samples with 1) a greater proportion of males ($p_i > 0.5$), and 2) a greater proportion females ($p_i < 0.5$) (Table 14). Sample dates with a 1:1 ratio ($p_i = 0.5$) and the lower ranking sample dates of the opposite sex group were included consecutively to each calculation until heterogeneity occurred. Results showed that the female-dominated samples formed a homogeneous group with the 1:1 ratio samples and three male-dominated samples ($p_i \leq 0.522$). Male-dominated samples were homogeneous with 1:1 ratio samples and three female-dominated samples ($p_i > 0.452$). While samples with 44% or fewer males can be considered "female-dominated" samples and those with 52% or more males are "male-dominated", samples in between cannot be determined to be dominated by either sex.

Female- and male-dominated samples that were significantly different from a 1:1 ratio were also tested with the simultaneous method (Table 15). Each test became

Table 13. Homogeneity G-Tests by date for C7 in traps.

Date	Crop*	M	F	Total	G-value	P
12 May	Alf	11	11	22	0.000	N.S.
19 May	Alf	10	5	15	1.699	N.S.
31 May	Alf	1	2	3	0.340	N.S.
8 Jun	Alf	4	6	10	0.403	N.S.
15 Jun	Alf	157	136	293	1.506	N.S.
21 Jun	Vet	40	54	94	2.093	N.S.
22 Jun	Alf	192	175	367	0.739	N.S.
30 Jun	Alf	12	21	33	2.486	N.S.
29 Jun	Vet	12	11	23	0.044	N.S.
5 Jul	Soy	287	295	582	0.110	N.S.
6 Jul	Vet	58	44	102	1.928	N.S.
7 Jul	Alf	127	163	290	4.481	0.05
11 Jul	Soy	238	221	459	0.630	N.S.
13 Jul	Vet	17	15	32	0.125	N.S.
14 Jul	Alf	72	62	134	0.747	N.S.
20 Jul	Vet	9	9	18	0.000	N.S.
21 Jul	Alf	129	60	189	25.782	0.001
27 Jul	Vet	2	5	7	1.328	N.S.
28 Jul	Alf	63	44	107	3.392	0.10
2 Aug	Soy	33	36	69	0.131	N.S.
3 Aug	Vet	17	4	21	8.662	0.01
4 Aug	Alf	28	34	62	0.582	N.S.
9 Aug	Soy	10	9	19	0.053	N.S.
10 Aug	Vet	5	1	6	2.910	0.10
11 Aug	Alf	12	22	34	2.985	0.10
16 Aug	Soy	7	11	18	0.896	N.S.
17 Aug	Vet	5	4	9	0.111	N.S.
19 Aug	Alf	23	39	62	4.176	0.05
24 Aug	Soy	3	4	7	0.143	N.S.
24 Aug	Vet	3	2	5	0.201	N.S.
25 Aug	Alf	14	22	36	1.793	N.S.
31 Aug	Alf	14	7	21	2.376	N.S.
9 Sep	Alf	4	4	8	0.000	N.S.
TOTALS		1619	1538	3157		

*Alf = alfalfa, Vet = vetch, Soy = soybean

Table 14. Simultaneous unplanned test for C7 in traps.

Date	M	F	Total	p_i^*	Test**
27 Jul	2	5	7	0.286	a
31 May	1	2	3	0.333	a
11 Aug	12	22	34	0.353 *	a
30 Jun	12	21	33	0.364	a
19 Aug	23	39	62	0.371 *	a
25 Aug	14	22	36	0.389	a
16 Aug	7	11	18	0.389	a
8 Jun	4	6	10	0.400	a
21 Jun	40	54	94	0.426	a
24 Aug	3	4	7	0.429	a
7 Jul	127	163	290	0.438 *	a
4 Aug	28	34	62	0.452	a,b
2 Aug	33	36	69	0.478	a,b
5 Jul	287	295	588	0.488	a,b
9 Sep	4	4	8	0.500	a,b
20 Jul	9	9	18	0.500	a,b
12 May	11	11	22	0.500	a,b
11 Jul	238	221	463	0.514	a,b
22 Jun	192	175	371	0.518	a,b
29 Jun	12	11	23	0.522	a,b
9 Aug	10	9	19	0.526	b
13 Jul	17	15	32	0.531	b
14 Jul	72	62	135	0.533	b
15 Jun	157	136	294	0.534	b
17 Aug	5	4	9	0.556	b
6 Jul	58	44	102	0.569	b
28 Jul	63	44	107	0.589 *	b
24 Aug	3	2	5	0.600	b
19 May	10	5	15	0.667	b
31 Aug	14	7	21	0.667	b
21 Jul	129	60	193	0.668 *	b
3 Aug	17	4	21	0.810 *	b
10 Aug	5	1	6	0.833 *	b

* -- $p(i)$ = proportion of males in sample, * next to number indicates samples significantly different from 1:1

** -- samples with same letter are in a homogenous group

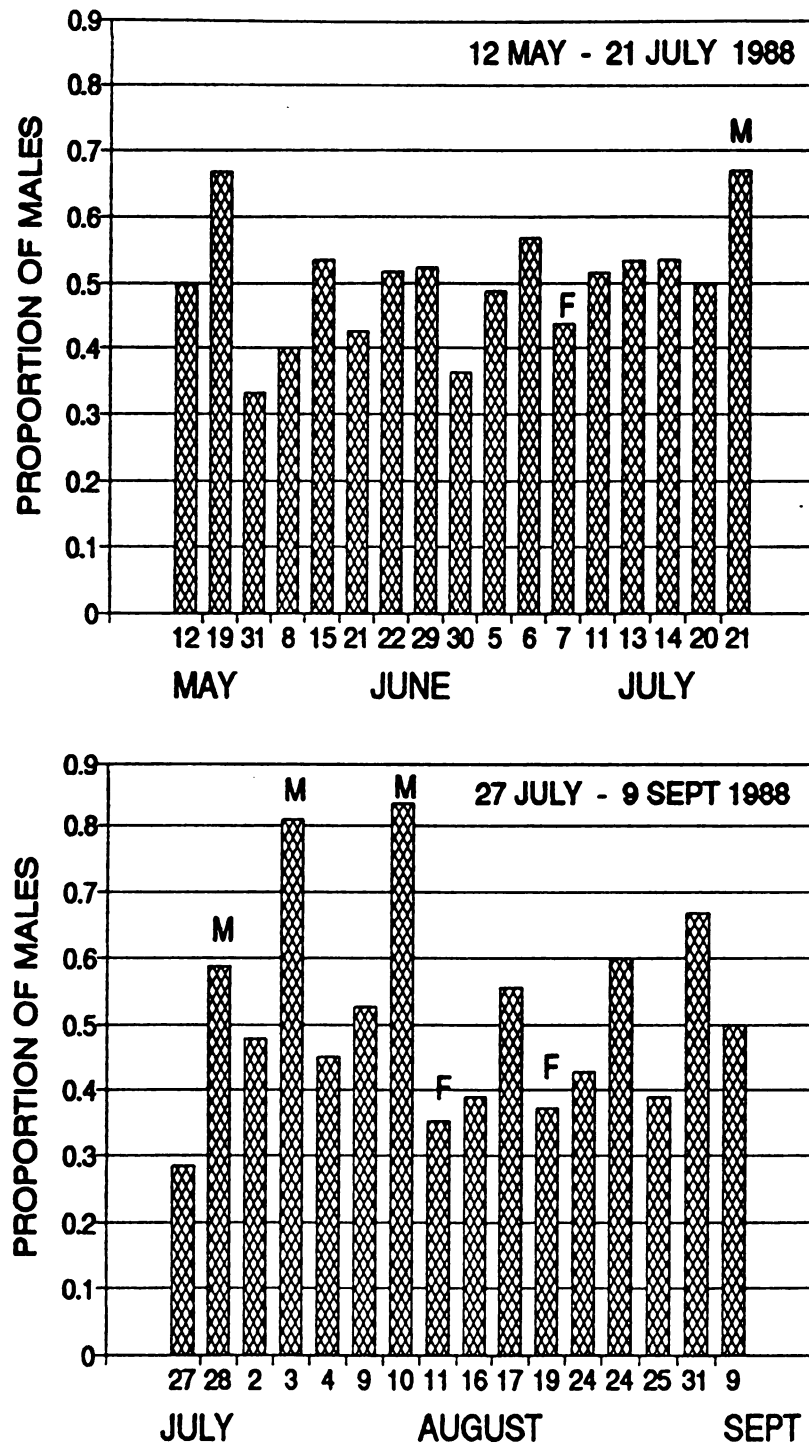


Figure 11. Proportion of males in traps. Dates with an F or M have significantly more females or males ($P < 0.1$).

Table 15. Unplanned tests for C7 in traps.

Test Group	G-value	N	df	χ^2	P*
Females	1.64	3	2	8.115	N.S.
Males	5.99	4	3	10.820	N.S.
Fem's + Males	167.03	7	6	17.604	<<0.01
Males + Fem's	37.44	7	6	17.604	<0.01

* Table 15, Sokal and Rohlf (1981)

heterogeneous when a sample from the opposite sex was added to the calculation, confirming that each group was definitely homogeneous. These samples, therefore, caused heterogeneity in G_T for beetles captured in traps. The trap catch on these dates may be due to behavioral differences between male and female C7 at over the season.

There was a slight trend in the temporal distribution of samples that were significantly different from a 1:1 ratio. Significantly more males occurred in traps on four dates from 27 July to 10 August, and significantly more females occurred in traps on one date before (7 July) and on two dates after (11 and 19 August) this time period (Fig. 11). A few dates with an excess of females occurred during late May and early June, and several dates from mid August to early September were female-dominated. The sex ratio was approximately equal during late June and most of July. In late July and early August there were several dates with an excess of males or an equal sex ratio and only one date with an excess of females (July 27).

This apparent temporal separation in flight activity between males and females may be explained by differences in the amount of prey finding activity and in migration to hibernation sites. Females may be flying more during early summer as they search for fields with abundant prey, and may reduce their flight activity by settling in these fields during mid summer. Females may also take longer to fulfil their nutritional requirements for overwintering, which

would inhibit flight activity until they are ready for migration to hibernation sites. Males may fulfill their nutritional requirements for overwintering earlier than females and migrate to hibernation sites during late July and early August. If this hypothesis can be supported by further testing, the proportion of females in a population could be used to determine the amount of aphid predation occurring in a field. This also may indicate that females are more important to summer-long aphid control than males. Further, if the sex ratio of C7 being reared for release could be altered in favor of females, biological control of aphids might be enhanced.

In summary, this study has shown that the sex ratio of C7 captured in the field was 1:1. The sex ratio of trapped beetles was relatively equal except in late May and early June, and late in the season when C7 may be moving to hibernation sites. The underlying reason for this difference in activity may be due differences in prey finding activity, or to different nutritional requirements for overwintering. Additional study is needed before a definitive answer can be given.

SUMMARY AND CONCLUSIONS

Phenology. Although this study was conducted during a single season, it has provided baseline information on the temporal and spatial distribution of C7 in alfalfa in Michigan. Prior to this study, no published accounts of C7 activity in Michigan were known to exist, so the timing and selection of field studies was difficult. Based on the results of this study, future research on overwintered adults must be started in mid to late March. Because summer adults will appear at approximately 300 DD base 12°C, close monitoring of their emergence will aid research concerning summer adult flight activity or abundance. Knowing that larvae are present prior to this will allow researchers to better time life cycle studies. Estimates of population size or density can also be conducted during the period of larval activity.

C7 appeared to have had only one generation in 1988, which is consistent with observations from the eastern U.S. and Europe. The possibility that a second or partial second generation occurred, however, should not be dismissed because close monitoring of larval late in the season was not performed in this study. The developmental rates presented by Obrycki and Tauber (1981) suggest that C7 is capable of producing more than one generation per year. It is not unlikely that some summer females in a population would mate and lay eggs, particularly when summers are unseasonably warm. Research involving the monitoring of

ovarian development of summer adults or caged mating studies could be conducted to test this hypothesis. If summer females do produce offspring, increasing the frequency of these facultatively diapausing females would increase the abundance of larvae late in the season. This would be beneficial to late-season aphid control in alfalfa. In this study, aphids increased tremendously during September as C7 became increasingly scarce in the field (personal observations). Therefore, unless larvae are produced by summer adults, C7 probably would not be an effective bio-control agent in crops where controlling aphids is necessary after mid-July.

The gradual decline of C7 in both traps and quadrats during late July and August, between 750 and 1200 DD, is most likely due to their movement to hibernation sites. C7 has been reported to enter hibernation sites during this time in New Jersey (Angalet et al. 1979). If hibernation sites could be found, factors influencing the movement of C7 between hibernation sites and cultivated habitats could be more precisely determined. The influence of degree-day accumulation, temperature, photoperiod, and solar radiation would be of particular interest, because these are factors that have been identified elsewhere as important to the dispersal of C7 from hibernation.

Sampling methods. Traps are a useful tool for determining the occurrence of important phenological events such as the emergence of summer adults and movement to

hibernation sites. Trap monitoring could become an important element in management of predator and prey populations. For example, if peak summer adult emergence can be predicted from trap catch and degree-day accumulations, harvesting and cultivation of crops could be timed to reduce larval and pupal mortality. Although the adults may disperse during cultivation activities, the local population would not be diminished and they may return to the field later. Also, decreases in trap catch may provide an early warning for future aphid problems.

Daily or hourly sampling of traps would have provided more accurate measurement of C7 activity. Traps set at various heights would have been useful for examining the pattern of C7 flight. However, these labor intensive methods were not possible with a two person sampling team.

Quadrat samples were consistent with trap catch in determining the temporal distribution of C7, but quadrat samples are time consuming and their efficiency may be affected by plant height and weather factors. The utility of quadrats is questionable with the recent development of time-efficient sequential sampling for estimation of C7 population density by Lapchin et al. (1987), and Ipert et al. (1988).

Correlations. The most interesting correlation in this study was between C7, aphids and plant height. C7 was found more often in areas where the alfalfa was tall. Plant characteristics such as height may be key components in C7

prey-finding. Since aphids were also associated with plant height, it is possible that C7 uses the same or similar cues for host finding as its prey. Further research on plant reflectance and amount of leaf cover may provide evidence that plant characteristics are the cues for prey-finding in C7. If C7 utilizes plant characteristics to find prey, crops with suitable characteristics could be used to enhance biological control programs for agriculture. For instance, C7 could be drawn into a field where "attractive" plants are strip cropped with a less attractive crop. Once in the general area, C7 probably would search for prey on both types of plants. Also, predictions might be made about the likelihood of aphid control by C7 in certain crops based on the attraction of the beetles to the crop.

Results from correlations between C7 and weather factors were inconsistent. In many cases, phenological events may have masked the association of C7 with weather factors. For example, no significant correlations occurred between C7 and weather factors during late summer when the beetles were probably moving to hibernation sites. This important phenological event may "over ride" the response of C7 to weather factors. Furthermore, although high temperatures have been cited as a principal component in C7 flight activity (Honék 1985b), adults emerging from pupae during this study were captured in traps during a relatively cool period. These individuals may have an innate drive to fly soon after emergence regardless of temperature, as long

as other weather conditions are not too limiting for flight. Further research is needed to determine the influence of weather factors C7 activity, and to what extent phenological events affect activity. In particular, temperature thresholds for activity, behavioral responses to rainfall, and the interplay of temperature and solar radiation should be explored because these elements have been implicated in C7 behavior (Honék 1985b). All of these factors may affect sampling and the management of C7 in biological control programs.

Comparison of weather factors and beetle activity between cuttings would have been useful, if the cuttings could have been controlled. Cutting on a regular basis would have enhanced the analyses in this study. However, harvesting was not under control of the researcher. Also, a plot of alfalfa that was left uncut would have provided information on C7 activity in an undisturbed habitat.

Spatial distribution. The spatial distribution of C7 was inconsistent between traps and quadrats. The clumped distribution of C7 in trap samples could have resulted from the attractiveness of traps rather than true aggregation behavior. Until the attractiveness of C7 to traps is quantified, the clumped distribution suggested in this spatial analysis cannot be fully accepted.

The random distribution that occurred in quadrat samples is more explainable, even though it is "common knowledge" that a species cannot be randomly distributed to

remain viable. C7 mate while aggregated at hibernation sites in the spring and late fall and, therefore, have no cause to interact (i.e., be aggregated or clumped) during the summer. In fact, interaction may lead to competition or aggression, especially near prey. Trap catch and quadrat observations did tend to be higher in areas of greater prey abundance, but C7 were never observed to be aggregated or clustered in an aphid colony. Therefore, it is not unreasonable to accept that C7 is randomly distributed during the summer. A random distribution may limit the density that this species can obtain in a particular crop, which would then influence the amount of prey consumed by the population.

Maps generated from geographic information system software appear to be useful for visualizing the spatial distribution of C7 and aphids, but have limitations. In the study site, beetles occurred more often in proximity to aphids and in areas where plants were tall, which concurred with the significant correlations found between these organisms. Mapping the characteristics of plants in a field may help identify areas susceptible to aphids or patterns of aphid colonization. However, it is difficult to determine the utility of these maps for mobile, primarily solitary insects like C7. Some flying beetles may be captured on traps strictly by chance, thereby falsely associating that capture with other characteristics of the field. The occurrence of one beetle in a sample does not necessarily

mean that other beetles are in the surrounding area, which is what a contour interval on a map indicates. In addition, many subjective decisions need to be made when constructing maps, such as the number and spacing of contour intervals, the model used to define the variogram, and the radius of the search area around a sample point. More information is needed to determine the effect of these decisions on the appearance and evaluation of maps.

Sex ratio study. A sex ratio of 1:1 was accepted for C7 in samples collected directly from the field, but C7 captured in traps differed from 1:1 on a few dates. These differences may be related to the movement of C7 to hibernation sites. Males were captured in traps more often in mid-July and early August, and females were more common in traps shortly after males. If this trend could be confirmed by further research, one hypothesis that could be tested is whether the amount of nutritional reserves needed for hibernation are higher in females than males. It is probable that females must accumulate more reserves during the summer for the development of ova the following spring. Females, therefore, would take longer to accumulate reserves than males, would feed on more aphids than males, and would enter hibernation sites later. Increasing the female to male ratio of C7 released for aphid control could have a positive impact on the success of the program.

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LIST OF REFERENCES

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APPENDIX A: ALFALFA DATA

Key to alfalfa data listing.

TRAP: Number of sampling site.
DATE: Sampling date.
TRC7: Total number of C7 on a trap at sampling.
C7: TRC7 divided by the number of days the trap was exposed.
QC7: Number of C7 observed in quadrat sample.
SLBLK: Number of small larvae, black, in quadrats.
SLGRY: Number of small larvae, gray, in quadrats.
LLBLK: Number of large larvae, black, in quadrats.
LLGRY: Number of large larvae, gray, in quadrats.
PUPA: Number of pupae in quadrats.
APHID: Number of aphids per 20 stems.
PLHT: Average height of 10 plants in the quadrat.
M: Missing observation.
--: Observation not taken.

APPENDIX A: ALFALFA DATA

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APPENDIX A: ALFALFA DATA

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TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
51	06/15	10.00	1.11	--	--	--	--	--	--	--	55.85
52	06/15	9.00	1.00	--	--	--	--	--	--	--	53.00
53	06/15	17.00	1.89	--	--	--	--	--	--	--	55.65
54	06/15	13.00	1.44	--	--	--	--	--	--	--	46.40
55	06/15	10.00	1.11	--	--	--	--	--	--	--	50.05
1	06/22	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.50
2	06/22	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.95
3	06/22	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.35
4	06/22	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.30
5	06/22	6.00	0.86	1.00	0.00	0.00	0.00	0.00	0.00	0.00	12.85
6	06/22	6.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.80
7	06/22	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.15
8	06/22	12.00	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.10
9	06/22	12.00	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.95
10	06/22	16.00	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.50
11	06/22	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	1.00	12.80
12	06/22	M	M	1.00	0.00	0.00	0.00	0.00	0.00	0.00	8.10
13	06/22	8.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.05
14	06/22	12.00	1.71	0.00	0.00	0.00	0.00	0.00	0.00	11.00	10.35
15	06/22	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.23
16	06/22	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.95
17	06/22	10.00	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.35
18	06/22	10.00	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.10
19	06/22	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.10
20	06/22	6.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.95
21	06/22	11.00	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.80
22	06/22	16.00	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.58
23	06/22	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.75
24	06/22	4.00	0.57	1.00	0.00	0.00	0.00	0.00	0.00	0.00	28.63
25	06/22	7.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	10.35
26	06/22	9.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.65
27	06/22	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.85
28	06/22	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.13
29	06/22	9.00	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30
30	06/22	7.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.30
31	06/22	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00
32	06/22	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.35
33	06/22	19.00	2.71	0.0							

APPENDIX A: ALFALFA DATA

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APPENDIX A: ALFALFA DATA

TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
42	07/07	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.90
43	07/07	6.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	3.00	42.10
44	07/07	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.15
45	07/07	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.00	25.80
46	07/07	15.00	2.14	0.00	0.00	0.00	0.00	0.00	0.00	1.00	32.85
47	07/07	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.05
48	07/07	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.30
49	07/07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	34.60
50	07/07	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	2.00	34.60
51	07/07	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.05
52	07/07	2.00	0.29	1.00	0.00	0.00	0.00	0.00	0.00	3.00	37.00
53	07/07	6.00	0.86	0.00	0.00	0.00	0.00	0.00	0.00	3.00	32.15
54	07/07	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.35
55	07/07	7.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	37.10
1	07/14	2.00	0.25	2.00	0.00	0.00	0.00	0.00	0.00	1.00	40.45
2	07/14	12.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.50
3	07/14	9.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.60
4	07/14	4.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.95
5	07/14	3.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.40
6	07/14	4.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	1.00	33.90
7	07/14	9.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	07/14	5.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	1.00	31.85
9	07/14	3.00	0.38	0.00	0.00	1.00	0.00	0.00	0.00	1.00	29.95
10	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.35
11	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	44.65
12	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.25
13	07/14	1.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.98
14	07/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	38.30
15	07/14	5.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.30
16	07/14	1.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.85
17	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	1.00	31.65
18	07/14	1.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	1.00	29.35
19	07/14	5.00	0.63	1.00	0.00	0.00	0.00	0.00	0.00	0.00	39.55
20	07/14	5.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	2.00	29.55
21	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	5.00	39.05
22	07/14	3.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	8.00	50.10
23	07/14	1.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.30
24	07/14	7.00	0.88	0.00	0.00	0.00	0.00	0.00	0.00	2.00	37.65
25	07/14	4.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.75
26	07/14	2.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.00	38.95
27	07/14	3.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	6.00	35.40
28	07/14	4.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	6.00	29.75
29	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	10.00	38.30
30	07/14	M	M	2.00	0.00	0.00	0.00	0.00	0.00	0.00	28.75
31	07/14	3.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.10
32	07/14	2.00	0.25	1.00	0.00	0.00	0.00	0.00	0.00	0.00	56.10
33	07/14	1.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	3.00	33.05
34	07/14	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	5.00	30.95
35	07/14	7.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	42.35
36	07/14	7.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.35
37	07/14	M	M	1.00	0.00	0.00	0.00	0.00	0.00	0.00	38.55

APPENDIX A: ALFALFA DATA

TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
38	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	48.65
39	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.25
41	07/14	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.05
42	07/14	2.00	0.29	1.00	0.00	0.00	0.00	0.00	0.00	1.00	30.80
43	07/14	4.00	0.57	1.00	0.00	0.00	0.00	0.00	0.00	3.00	61.65
44	07/14	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	4.00	34.00
45	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	1.00	40.05
46	07/14	M	M	1.00	0.00	0.00	0.00	0.00	0.00	2.00	29.00
47	07/14	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	2.00	23.70
48	07/14	M	M	M	M	M	M	M	M	M	M
49	07/14	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.35
50	07/14	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	6.00	46.80
51	07/14	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	5.00	35.50
52	07/14	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	3.00	47.15
53	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	5.00	51.85
54	07/14	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	25.20
55	07/14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	46.70
1	07/21	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.55
2	07/21	7.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.60
3	07/21	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	11.00	54.60
4	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	35.35
5	07/21	4.00	0.57	1.00	0.00	0.00	0.00	0.00	0.00	3.00	45.80
6	07/21	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	3.00	46.10
7	07/21	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.65
8	07/21	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.95
9	07/21	8.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	3.00	45.75
10	07/21	5.00	0.71	1.00	0.00	0.00	0.00	0.00	0.00	12.00	36.55
11	07/21	8.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	9.00	52.70
12	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.60
13	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	3.00	50.75
14	07/21	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	9.00	50.05
15	07/21	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.15
16	07/21	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.00	45.35
17	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	15.00	44.30
18	07/21	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	8.00	42.25
19	07/21	7.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	22.00	51.10
20	07/21	10.00	1.43	0.00	0.00	0.00	0.00	0.00	0.00	12.00	45.90
21	07/21	M	M	1.00	0.00	0.00	0.00	0.00	0.00	0.00	33.50
22	07/21	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	13.00	50.80
23	07/21	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.30
24	07/21	8.00	1.14	1.00	0.00	0.00	0.00	0.00	0.00	4.00	59.25
25	07/21	14.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00	46.50
26	07/21	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	13.00	40.80
27	07/21	3.00	0.43	1.00	0.00	0.00	0.00	0.00	0.00	16.00	55.90
28	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	10.00	52.15
29	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	33.00	59.20
30	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	4.00	54.90
31	07/21	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.80
32	07/21	5.00	0.71	1.00	1.00	0.00	0.00	0.00	0.00	0.00	61.85
33	07/21	3.00	0.43	0.00	0.00	0.00	0.00	1.00	0.00	26.00	57.65
34	07/21	2.00	0.29	1.00	0.00	0.00	0.00	0.00	0.00	7.00	46.65

TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
35	07/21	15.00	2.14	0.00	0.00	0.00	0.00	0.00	0.00	24.00	49.80
36	07/21	7.00	1.00	2.00	0.00	0.00	0.00	0.00	0.00	18.00	49.75
37	07/21	9.00	1.29	1.00	0.00	0.00	0.00	0.00	0.00	8.00	51.75
38	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	12.00	48.45
39	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.35
41	07/21	M	M	0.00	0.00	0.00	0.00	0.00	0.00	2.00	42.05
42	07/21	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	5.00	51.00
43	07/21	11.00	1.57	0.00	0.00	0.00	0.00	0.00	0.00	9.00	65.80
44	07/21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00	49.00
45	07/21	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	4.00	44.40
46	07/21	3.00	0.43	1.00	0.00	0.00	0.00	0.00	0.00	3.00	35.25
47	07/21	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.55
48	07/21	M	M	M	M	M	M	M	M	M	M
49	07/21	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.10
50	07/21	5.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	5.00	56.70
51	07/21	4.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	15.00	52.63
52	07/21	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	5.00	54.40
53	07/21	5.00	0.71	2.00	0.00	0.00	0.00	0.00	0.00	16.00	53.60
54	07/21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00	44.55
55	07/21	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	3.00	58.10
1	07/28	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	2.00	56.45
2	07/28	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.00	62.35
3	07/28	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	4.00	61.45
4	07/28	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	3.00	51.75
5	07/28	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	3.00	46.35
6	07/28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	61.30
7	07/28	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.70
8	07/28	2.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.85
9	07/28	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	6.00	47.05
10	07/28	3.00	0.43	1.00	0.00	0.00	0.00	0.00	0.00	2.00	45.55
11	07/28	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	2.00	70.15
12	07/28	2.00	0.29	1.00	0.00	0.00	0.00	0.00	0.00	1.00	48.75
13	07/28	1.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	1.00	50.20
14	07/28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.30
15	07/28	1.00	0.14	0.00	0.00	1.00	0.00	0.00	0.00	0.00	30.15
16	07/28	3.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.25
17	07/28	10.00	1.43	0.00							

APPENDIX A: ALFALFA DATA

[illegible]

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[illegible]

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[illegible]

APPENDIX A: ALFALFA DATA

[illegible]

APPENDIX A: ALFALFA DATA

TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
25	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.75
26	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.50
27	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.70
28	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.90
29	08/25	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	61.10
30	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	60.30
31	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.45
32	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.35
33	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.10
34	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	54.75
35	08/25	3.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.20
36	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	56.60
37	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	1.00	60.40
38	08/25	2.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	1.00	53.15
39	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	49.25
41	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.30
42	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	3.00	62.60
43	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.80
44	08/25	2.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	2.00	63.70
45	08/25	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	60.10
46	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.95
47	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	64.35
49	08/25	M	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	60.06
50	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	2.00	54.65
51	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	54.70
52	08/25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	55.60
53	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.50
54	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.70
55	08/25	1.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	1.00	58.40
1	08/31	1.00	0.17	--	--	--	--	--	--	--	--
2	08/31	1.00	0.17	--	--	--	--	--	--	--	--
3	08/31	0.00	0.00	--	--	--	--	--	--	--	--
4	08/31	0.00	0.00	--	--	--	--	--	--	--	--
5	08/31	1.00	0.17	--	--	--	--	--	--	--	--
6	08/31	0.00	0.00	--	--	--	--	--	--	--	--
7	08/31	1.00	0.17	--	--	--	--	--	--	--	--
8	08/31	0.00	0.00	--	--	--	--	--	--	--	--
9	08/31	0.00	0.00	--	--	--	--	--	--	--	--
10	08/31	0.00	0.00	--	--	--	--	--	--	--	--
11	08/31	0.00	0.00	--	--	--	--	--	--	--	--
12	08/31	0.00	0.00	--	--	--	--	--	--	--	--
13	08/31	0.00	0.00	--	--	--	--	--	--	--	--
14	08/31	0.00	0.00	--	--	--	--	--	--	--	--
15	08/31	0.00	0.00	--	--	--	--	--	--	--	--
16	08/31	M	M	--	--	--	--	--	--	--	--
17	08/31	0.00	0.00	--	--	--	--	--	--	--	--
18	08/31	1.00	0.17	--	--	--	--	--	--	--	--
19	08/31	1.00	0.17	--	--	--	--	--	--	--	--
20	08/31	M	M	--	--	--	--	--	--	--	--
21	08/31	0.00	0.00	--	--	--	--	--	--	--	--
22	08/31	1.00	0.17	--	--	--	--	--	--	--	--

APPENDIX A: ALFALFA DATA

TRAP	DATE	TRC7	C7	QC7	SLBLK	SLGRY	LLBLK	LLGRY	PUPA	APHID	PLHT
23	08/31	0.00	0.00	--	--	--	--	--	--	--	--
24	08/31	0.00	0.00	--	--	--	--	--	--	--	--
25	08/31	1.00	0.17	--	--	--	--	--	--	--	--
26	08/31	0.00	0.00	--	--	--	--	--	--	--	--
27	08/31	1.00	0.17	--	--	--	--	--	--	--	--
28	08/31	0.00	0.00	--	--	--	--	--	--	--	--
29	08/31	M	M	--	--	--	--	--	--	--	--
30	08/31	M	M	--	--	--	--	--	--	--	--
31	08/31	0.00	0.00	--	--	--	--	--	--	--	--
32	08/31	0.00	0.00	--	--	--	--	--	--	--	--
33	08/31	0.00	0.00	--	--	--	--	--	--	--	--
34	08/31	0.00	0.00	--	--	--	--	--	--	--	--
35	08/31	2.00	0.33	--	--	--	--	--	--	--	--
36	08/31	0.00	0.00	--	--	--	--	--	--	--	--
37	08/31	0.00	0.00	--	--	--	--	--	--	--	--
38	08/31	2.00	0.33	--	--	--	--	--	--	--	--
39	08/31	0.00	0.00	--	--	--	--	--	--	--	--
41	08/31	0.00	0.00	--	--	--	--	--	--	--	--
42	08/31	0.00	0.00	--	--	--	--	--	--	--	--
43	08/31	0.00	0.00	--	--	--	--	--	--	--	--
44	08/31	0.00	0.00	--	--	--	--	--	--	--	--
45	08/31	0.00	0.00	--	--	--	--	--	--	--	--
46	08/31	3.00	0.50	--	--	--	--	--	--	--	--
47	08/31	0.00	0.00	--	--	--	--	--	--	--	--
49	08/31	0.00	0.00	--	--	--	--	--	--	--	--
50	08/31	0.00	0.00	--	--	--	--	--	--	--	--
51	08/31	1.00	0.17	--	--	--	--	--	--	--	--
52	08/31	0.00	0.00	--	--	--	--	--	--	--	--
53	08/31	M	M	--	--	--	--	--	--	--	--
54	08/31	1.00	0.17	--	--	--	--	--	--	--	--
55	08/31	0.00	0.00	--	--	--	--	--	--	--	--
5	09/09	0.00	0.00	--	--	--	--	--	--	--	--
6	09/09	0.00	0.00	--	--	--	--	--	--	--	--
7	09/09	0.00	0.00	--	--	--	--	--	--	--	--
8	09/09	1.00	0.13	--	--	--	--	--	--	--	--
13	09/09	0.00	0.00	--	--	--	--	--	--	--	--
14	09/09	0.00	0.00	--	--	--	--	--	--	--	--
15	09/09	1.00	0.13	--	--	--	--	--	--	--	--
16	09/09	1.00	0.13	--	--	--	--	--	--	--	--
21	09/09	1.00	0.13	--	--	--	--	--	--	--	--
22	09/09	0.00	0.00	--	--	--	--	--	--	--	--
23	09/09	0.00	0.00	--	--	--	--	--	--	--	--
24	09/09	M	M	--	--	--	--	--	--	--	--
29	09/09	0.00	0.00	--	--	--	--	--	--	--	--
30	09/09	0.00	0.00	--	--	--	--	--	--	--	--
31	09/09	1.00	0.13	--	--	--	--	--	--	--	--
32	09/09	M	M	--	--	--	--	--	--	--	--
37	09/09	0.00	0.00	--	--	--	--	--	--	--	--
38	09/09	1.00	0.13	--	--	--	--	--	--	--	--
39	09/09	1.00	0.13	--	--	--	--	--	--	--	--
45	09/09	0.00	0.00	--	--	--	--	--	--	--	--

APPENDIX B: DEGREE-DAY DATA

Key to Degree-Day Data Listing.

DATE: Calendar date
JD: Julian date
DD12: daily degree-day above 12°C
ACCUM: Accumulated degree-days.

APPENDIX B: DEGREE-DAY DATA - 1988

DATE	JD	DD12	ACCUM	DATE	JD	DD12	ACCUM
3/05	65	0.0	0.0	4/26	117	1.4	40.4
3/06	66	0.0	0.0	4/27	118	0.0	40.4
3/07	67	0.0	0.0	4/28	119	0.2	40.5
3/08	68	0.4	0.4	4/29	120	1.1	41.7
3/09	69	0.0	0.4	4/30	121	2.9	44.6
3/10	70	0.0	0.4	5/01	122	3.0	47.5
3/11	71	0.0	0.4	5/02	123	3.6	51.2
3/12	72	0.0	0.4	5/03	124	1.6	52.8
3/13	73	0.0	0.4	5/04	125	1.6	54.4
3/14	74	0.0	0.4	5/05	126	3.4	57.8
3/15	75	0.0	0.4	5/06	127	5.0	62.7
3/16	76	0.0	0.4	5/07	128	5.1	67.8
3/17	77	0.0	0.4	5/08	129	7.8	75.6
3/18	78	0.0	0.4	5/09	130	3.0	78.7
3/19	79	0.0	0.4	5/10	131	0.9	79.6
3/20	80	0.0	0.4	5/11	132	2.7	82.3
3/21	81	0.0	0.4	5/12	133	4.7	87.0
3/22	82	0.0	0.4	5/13	134	2.5	89.5
3/23	83	2.7	3.1	5/14	135	3.1	92.6
3/24	84	1.2	4.3	5/15	136	6.7	99.3
3/25	85	1.2	5.5	5/16	137	2.9	102.1
3/26	86	0.0	5.5	5/17	138	2.9	105.0
3/27	87	0.0	5.5	5/18	139	3.9	108.9
3/28	88	0.0	5.5	5/19	140	4.4	113.3
3/29	89	0.0	5.6	5/20	141	8.1	121.4
3/30	90	0.0	5.6	5/21	142	8.5	129.9
3/31	91	0.0	5.6	5/22	143	9.6	139.6
4/01	92	0.1	5.7	5/23	144	5.9	145.5
4/02	93	0.7	6.4	5/24	145	3.2	148.7
4/03	94	2.8	9.1	5/25	146	1.9	150.7
4/04	95	1.2	10.4	5/26	147	4.3	154.9
4/05	96	6.1	16.5	5/27	148	7.8	162.7
4/06	97	3.1	19.6	5/28	149	8.7	171.4
4/07	98	2.0	21.5	5/29	150	11.4	182.9
4/08	99	0.5	22.0	5/30	151	10.6	193.5
4/09	100	1.3	23.3	5/31	152	10.4	204.0
4/10	101	3.2	26.5	6/01	153	11.5	215.5
4/11	102	1.6	28.1	6/02	154	2.6	218.1
4/12	103	1.6	29.7	6/03	155	3.2	221.3
4/13	104	4.1	33.9	6/04	156	4.4	225.7
4/14	105	0.3	34.2	6/05	157	7.6	233.3
4/15	106	0.0	34.2	6/06	158	11.4	244.7
4/16	107	0.0	34.2	6/07	159	10.8	255.5
4/17	108	2.6	36.8	6/08	160	4.0	259.5
4/18	109	0.0	36.8	6/09	161	2.3	261.8
4/19	110	0.0	36.8	6/10	162	2.9	264.7
4/20	111	0.0	36.8	6/11	163	4.6	269.3
4/21	112	0.0	36.8	6/12	164	8.6	278.0
4/22	113	0.4	37.2	6/13	165	11.1	289.1
4/23	114	0.7	37.9	6/14	166	13.1	302.2
4/24	115	0.0	37.9	6/15	167	12.5	314.7
4/25	116	1.0	39.0	6/16	168	8.9	323.6

APPENDIX B: DEGREE-DAY DATA - 1988

DATE	JD	DD12	ACCUM	DATE	JD	DD12	ACCUM
6/17	169	8.3	332.0	8/08	221	13.3	931.2
6/18	170	10.1	342.1	8/09	222	12.3	943.5
6/19	171	13.0	355.1	8/10	223	12.4	955.9
6/20	172	14.0	369.1	8/11	224	12.0	967.9
6/21	173	14.1	383.2	8/12	225	13.7	981.6
6/22	174	14.6	397.8	8/13	226	14.5	996.1
6/23	175	8.5	406.4	8/14	227	13.4	1009.5
6/24	176	9.2	415.6	8/15	228	13.7	1023.2
6/25	177	14.9	430.5	8/16	229	11.0	1034.3
6/26	178	6.8	437.3	8/17	230	15.7	1050.0
6/27	179	6.9	444.1	8/18	231	6.6	1056.6
6/28	180	6.2	450.4	8/19	232	6.7	1063.3
6/29	181	6.2	456.6	8/20	233	8.7	1072.0
6/30	182	4.4	461.0	8/21	234	7.0	1079.1
7/01	183	4.7	465.7	8/22	235	5.2	1084.3
7/02	184	6.3	472.0	8/23	236	6.9	1091.2
7/03	185	8.0	480.0	8/24	237	7.8	1099.0
7/04	186	9.8	489.8	8/25	238	7.1	1106.1
7/05	187	13.6	503.5	8/26	239	4.6	1110.8
7/06	188	14.5	518.0	8/27	240	3.7	1114.5
7/07	189	15.3	533.4	8/28	241	4.1	1118.6
7/08	190	14.4	547.8	8/29	242	3.2	1121.8
7/09	191	13.2	561.1	8/30	243	4.9	1126.7
7/10	192	12.2	573.3	8/31	244	7.3	1133.9
7/11	193	11.1	584.4	9/01	245	7.2	1141.2
7/12	194	9.4	593.8	9/02	246	9.0	1150.2
7/13	195	9.5	603.3	9/03	247	7.4	1157.7
7/14	196	12.8	616.2	9/04	248	5.6	1163.3
7/15	197	12.3	628.5	9/05	249	1.2	1164.5
7/16	198	15.4	644.0	9/06	250	1.8	1166.3
7/17	199	14.1	658.1	9/07	251	3.4	1169.7
7/18	200	10.6	668.8	9/08	252	4.8	1174.5
7/19	201	12.4	681.2	9/09	253	5.7	1180.2
7/20	202	8.6	689.8	9/10	254	6.2	1186.4
7/21	203	10.3	700.2	9/11	255	6.6	1193.0
7/22	204	9.5	709.7	9/12	256	9.5	1202.5
7/23	205	9.9	719.6	9/13	257	4.2	1206.7
7/24	206	9.0	728.6	9/14	258	4.9	1211.6
7/25	207	10.2	738.8	9/15	259	3.0	1214.7
7/26	208	9.0	747.9	9/16	260	4.4	1219.1
7/27	209	9.5	757.4	9/17	261	11.2	1230.3
7/28	210	14.0	771.4	9/18	262	9.6	1239.9
7/29	211	13.8	785.2	9/19	263	5.1	1245.0
7/30	212	13.1	798.3	9/20	264	1.4	1246.4
7/31	213	12.3	810.6	9/21	265	0.9	1247.4
8/01	214	17.3	828.0	9/22	266	3.5	1250.8
8/02	215	17.8	845.8	9/23	267	2.5	1253.4
8/03	216	17.5	863.3	9/24	268	2.8	1256.2
8/04	217	16.5	879.9	9/25	269	3.3	1259.5
8/05	218	13.4	893.3	9/26	270	4.0	1263.6
8/06	219	12.0	905.4	9/27	271	7.1	1270.7
8/07	220	12.5	917.9	9/28	272	1.0	1271.7

APPENDIX B: DEGREE-DAY DATA - 1988

DATE	JD	DD12	ACCUM	DATE	JD	DD12	ACCUM
9/29	273	5.1	1276.8	11/20	325	0.0	1308.7
9/30	274	5.8	1282.7	11/21	326	0.0	1308.7
10/01	275	6.5	1289.2	11/22	327	0.0	1308.7
10/02	276	1.5	1290.7	11/23	328	0.0	1308.7
10/03	277	0.8	1291.4	11/24	329	0.2	1308.9
10/04	278	0.0	1291.4	11/25	330	0.4	1309.3
10/05	279	0.0	1291.4	11/26	331	0.3	1309.6
10/06	280	0.1	1291.5	11/27	332	0.0	1309.6
10/07	281	0.3	1291.8	11/28	333	0.0	1309.6
10/08	282	1.2	1293.0	11/29	334	0.0	1309.6
10/09	283	1.4	1294.4	11/30	335	0.0	1309.6
10/10	284	1.2	1295.6	12/01	336	0.0	1309.6
10/11	285	0.0	1295.6	12/02	337	0.0	1309.6
10/12	286	0.0	1295.6	12/03	338	0.0	1309.6
10/13	287	0.0	1295.6	12/04	339	0.0	1309.6
10/14	288	2.0	1297.6	12/05	340	0.0	1309.6
10/15	289	3.9	1301.4	12/06	341	0.0	1309.6
10/16	290	1.7	1303.1	12/07	342	0.0	1309.6
10/17	291	0.6	1303.7	12/08	343	0.0	1309.6
10/18	292	0.2	1303.9	12/09	344	0.0	1309.6
10/19	293	0.0	1303.9	12/10	345	0.0	1309.6
10/20	294	0.0	1303.9	12/11	346	0.0	1309.6
10/21	295	0.0	1303.9	12/12	347	0.0	1309.6
10/22	296	0.0	1303.9	12/13	348	0.0	1309.6
10/23	297	0.0	1303.9	12/14	349	0.0	1309.6
10/24	298	0.0	1303.9	12/15	350	0.0	1309.6
10/25	299	0.0	1303.9	12/16	351	0.0	1309.6
10/26	300	0.0	1303.9	12/17	352	0.0	1309.6
10/27	301	0.0	1303.9	12/18	353	0.0	1309.6
10/28	302	0.0	1303.9	12/19	354	0.0	1309.6
10/29	303	0.0	1303.9	12/20	355	0.1	1309.7
10/30	304	0.0	1303.9	12/21	356	0.0	1309.7
10/31	305	0.0	1303.9	12/22	357	0.0	1309.7
11/01	306	0.0	1303.9	12/23	358	0.0	1309.7
11/02	307	0.0	1303.9	12/24	359	0.0	1309.7
11/03	308	0.8	1304.7	12/25	360	0.0	1309.7
11/04	309	1.3	1306.0	12/26	361	0.0	1309.7
11/05	310	0.0	1306.0	12/27	362	0.0	1309.7
11/06	311	0.0	1306.0	12/28	363	0.0	1309.7
11/07	312	0.0	1306.0	12/29	364	0.0	1309.7
11/08	313	0.0	1306.0	12/30	365	0.0	1309.7
11/09	314	0.0	1306.0	12/31	366	0.0	1309.7
11/10	315	0.0	1306.0				
11/11	316	0.0	1306.0				
11/12	317	0.0	1306.0				
11/13	318	0.0	1306.0				
11/14	319	0.2	1306.2				
11/15	320	1.4	1307.6				
11/16	321	1.2	1308.7				
11/17	322	0.0	1308.7				
11/18	323	0.0	1308.7				
11/19	324	0.0	1308.7				

APPENDIX C: WEATHER DATA

Key to Weather Data Listing.

DATE: Calendar date

JD: Julian date

RAIN: Rainfall in millimeters

AVGT: Average daily temperature in °C

TOTRAD: Total daily solar radiation in Millijoules/meter²

AVGWIND: Average daily wind speed in meters/second

DATE	JD	RAIN	AVGT	TOTRAD	AVGWIND
4/01	92		6.5	14.5	2.9
4/02	93	3.67	11.1	6.1	3.2
4/03	94	11.85	12.7	10.1	3.5
4/04	95		10.4	12.9	2.9
4/05	96		17.7	20.8	2.8
4/06	97	38.95	10.0	2.1	5.1
4/07	98	14.73	8.6	23.9	4.5
4/08	99		7.3	23.8	2.2
4/09	100		8.5	23.5	1.6
4/10	101		10.9	20.1	1.7
4/11	102		10.8	22.8	3.7
4/12	103		9.9	23.1	2.7
4/13	104		11.4	23.5	1.8
4/14	105	3.56	6.0	15.3	3.7
4/15	106		0.7	11.1	3.8
4/16	107		6.3	24.4	3.4
4/17	108	2.03	11.2	21.4	4.6
4/18	109		2.5	25.7	3.7
4/19	110		1.9	25.6	2.9
4/20	111	1.52	4.6	7.9	3.3
4/21	112		3.0	21.5	1.9
4/22	113	6.86	7.0	22.9	3.8
4/23	114	4.32	5.8	7.0	4.6
4/24	115		5.3	21.3	3.6
4/25	116		8.5	23.8	2.1
4/26	117		10.7	16.9	2.4
4/27	118	6.35	4.6	4.7	3.4
4/28	119		7.0	22.3	4.0
4/29	120		8.9	25.3	3.4
4/30	121		12.0	27.2	2.3
5/01	122		12.6	27.9	1.6
5/02	123		14.6	28.2	1.9
5/03	124		11.1	20.6	2.4
5/04	125		10.7	23.7	2.9
5/05	126		13.8	22.6	2.4
5/06	127		16.2	28.4	2.1
5/07	128		16.6	23.6	2.3
5/08	129	1.78	18.7	19.8	4.7
5/09	130	11.18	13.9	13.4	4.7
5/10	131		12.4	9.4	2.9
5/11	132		11.9	28.6	1.5
5/12	133		16.6	20.8	2.1
5/13	134	0.51	14.9	28.2	2.7
5/14	135		13.5	28.4	2.6
5/15	136	9.40	17.2	13.0	2.7
5/16	137	0.51	14.1	25.6	3.2
5/17	138		12.9	25.1	2.7
5/18	139		14.4	28.7	2.5
5/19	140		15.6	21.9	2.4
5/20	141		18.5	24.9	1.5
5/21	142		20.0	18.9	1.1
5/22	143		22.1	27.0	1.9

DATE	JD	RAIN	AVGT	TOTRAD	AVGWIND
5/23	144	8.51	17.6	5.6	2.2
5/24	145		14.5	28.2	3.6
5/25	146		10.0	30.5	2.5
5/26	147		15.3	29.9	2.4
5/27	148		19.9	29.3	2.7
5/28	149		21.1	23.6	1.7
5/29	150		23.1	28.6	1.7
5/30	151		23.0	28.3	1.6
5/31	152		23.1	29.3	1.8
6/01	153		23.8	29.1	2.6
6/02	154	7.37	12.8	11.7	3.2
6/03	155		13.4	29.1	3.2
6/04	156		15.5	30.6	1.5
6/05	157		20.6	29.2	2.6
6/06	158		23.4	29.2	2.4
6/07	159		23.2	29.9	2.6
6/08	160		14.9	26.8	3.9
6/09	161		12.3	30.8	3.4
6/10	162		13.7	30.5	1.9
6/11	163		16.7	29.2	1.9
6/12	164		21.3	30.3	1.9
6/13	165		23.6	29.3	1.8
6/14	166		25.2	28.3	1.9
6/15	167		24.2	27.0	2.4
6/16	168		20.4	26.9	1.8
6/17	169		20.1	26.7	1.8
6/18	170		22.2	30.6	1.4
6/19	171		25.2	26.2	2.6
6/20	172	7.37	25.7	24.8	2.7
6/21	173		26.5	27.4	2.0
6/22	174	4.57	26.5	15.5	3.0
6/23	175		20.7	30.9	2.4
6/24	176		21.7	24.8	2.6
6/25	177		27.9	27.9	3.9
6/26	178		18.1	25.0	2.9
6/27	179		18.8	29.9	1.9
6/28	180	2.03	17.2	8.6	1.2
6/29	181		17.8	31.7	2.3
6/30	182		16.5	28.6	2.4
7/01	183		16.8	27.3	1.9
7/02	184		18.5	29.3	1.5
7/03	185		20.4	30.6	1.2
7/04	186		23.1	30.1	1.3
7/05	187		26.1	28.3	1.0
7/06	188		26.8	27.8	1.3
7/07	189		27.2	23.7	1.3
7/08	190		26.7	27.5	1.6
7/09	191		25.9	26.1	1.6
7/10	192	2.29	22.6	13.5	2.7
7/11	193		22.7	28.0	2.3
7/12	194		21.0	27.6	1.4
7/13	195		23.1	26.5	2.4

DATE	JD	RAIN	AVGT	TOTRAD	AVGWIND
7/14	196		26.3	29.5	3.1
7/15	197	6.35	23.1	18.2	2.2
7/16	198	10.67	26.6	18.5	2.6
7/17	199		24.9	26.0	1.5
7/18	200	1.78	22.3	4.8	0.8
7/19	201		23.4	22.0	1.6
7/20	202	0.25	20.4	9.2	1.2
7/21	203		21.5	21.1	1.5
7/22	204	61.21	19.7	15.2	1.5
7/23	205	19.56	19.6	20.2	1.1
7/24	206		21.3	27.2	1.2
7/25	207	3.30	21.1	18.0	1.8
7/26	208		20.8	23.3	1.4
7/27	209		21.9	24.2	1.2
7/28	210		25.7	26.9	1.6
7/29	211		26.0	25.9	1.9
7/30	212	1.02	24.9	17.5	2.3
7/31	213		23.2	24.2	1.2
8/01	214		29.0	25.9	2.0
8/02	215		29.7	24.6	2.0
8/03	216	0.25	28.1	20.4	1.6
8/04	217		28.5	21.6	2.1
8/05	218	45.21	24.5	9.7	2.2
8/06	219	0.25	23.7	26.3	2.3
8/07	220		24.8	26.8	1.3
8/08	221		25.6	22.0	2.0
8/09	222	13.97	23.9	11.4	1.7
8/10	223	0.25	22.9	12.8	1.2
8/11	224		24.3	18.8	1.2
8/12	225		26.6	20.8	1.3
8/13	226		26.7	20.9	2.1
8/14	227	24.64	27.5	21.6	3.1
8/15	228		24.8	24.8	1.2
8/16	229		24.3	22.1	1.7
8/17	230		28.5	23.9	2.5
8/18	231	11.43	19.0	5.7	2.7
8/19	232		18.1	7.7	1.8
8/20	233		20.1	24.5	1.5
8/21	234		18.5	23.2	1.7
8/22	235		17.5	18.4	1.9
8/23	236	18.54	18.0	12.9	2.4
8/24	237		19.3	19.1	2.8
8/25	238		18.8	22.0	3.0
8/26	239		17.0	21.9	1.8
8/27	240	5.33	14.6	6.3	1.6
8/28	241		15.9	20.6	1.7
8/29	242		14.4	22.1	1.7
8/30	243	0.25	16.2	21.2	1.1
8/31	244		18.9	21.9	1.7
9/01	245		19.2	21.4	1.8
9/02	246		21.5	15.0	2.1
9/03	247	18.54	18.9	11.9	2.5



DATE	JD	RAIN	AVGT	TOTRAD	AVGWIND
9/04	248	8.13	16.2	12.2	2.4
9/05	249	0.25	11.8	17.6	3.3
9/06	250		11.2	18.0	1.6
9/07	251		13.3	22.0	1.9
9/08	252		16.4	19.6	2.8
9/09	253		18.5	21.1	2.1
9/10	254		17.2	18.2	0.9
9/11	255		18.3	17.8	1.7
9/12	256	6.35	20.8	9.5	2.0
9/13	257	0.25	16.4	18.4	2.6
9/14	258		15.7	20.1	2.4
9/15	259		13.6	19.8	2.0
9/16	260		15.8	13.8	2.1
9/17	261	0.76	22.3	11.2	2.6
9/18	262	12.70	19.7	6.3	2.0
9/19	263	51.31	17.7	3.4	3.5
9/20	264	0.25	13.4	2.6	4.0
9/21	265		12.8	5.6	2.1
9/22	266	62.99	14.3	4.8	2.3
9/23	267	2.03	14.8	17.7	2.8
9/24	268		11.6	17.3	0.9
9/25	269		12.9	17.9	1.0
9/26	270		14.6	17.4	1.6
9/27	271		18.2	14.4	2.7
9/28	272		12.5	7.2	3.5
9/29	273		15.1	14.1	2.1
9/30	274		17.0	9.3	1.2
10/01	275	4.57	17.9	5.9	2.7





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