THE EFFECTS OF ALDRIN AND DIELDRIN APPLICATION ON WINGED INSECT POPULATIONS IN FARM WOODLOTS

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ABSTRACT

THE EFFECTS OF ALDRIN AND DIELDRIN APPLICATION ON WINGED INSECT POPULATIONS IN FARM WOODLOTS

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The long-term effects of dieldrin and aldrin applications on flying insect populations, were analyzed. Farm woodlots located within the treated area were compared to untreated woodlots outside the area. Yield, diversity and herbivore-predator ratios were calculated for the flying insect communities from the woodlots in each area. No significant difference was found in the total number of insects collected for the season from the woodlots in each area. However by breaking the yield up at the ordinal level differences were found. Three abundant species were identified, and the complete absence of one of these species, Brachyrhinus ovatus, from the treated area suggests a possible insecticide effect. Analysis of the diversity and herbivore-predator ratios, showed the untreated woodlots with a low diversity and high H/P ratio. The treated woodlots however had a higher diversity with a stable H/P ratio. It was found that these results could have been caused by pretreatment community differences instead of insecticide effects.

Analysis for the reliability of the Malaise trap sampling device was also carried out. A significant amount of the day-to-day variation

found in insect yield was attributed to temperature, evaporation and wind differences. Temperature differences explained a significant amount of the variability in yield; correction at least for this factor should be made if results independent of weather are desired.

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By

James G. Truchan

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INTRODUCTION

Historically man has accepted the contamination of his environment as an inevitable penalty for creating a highly industrialized society. His complex social structure is possible only so far as he can control or change the so called "natural balance" of nature. Control is a key word in this interpretation, because an "imbalance" is considered only insofar as it is detrimental to his goals. Of the numerous tools he has used to control nature for his own needs, his recently acquired knowledge of chemistry is perhaps the most important. Initially, one use of this tool was simply the spreading of inorganic compounds found in his environment which were lethal to competing species. The cumulation of his efforts are now represented by his vast knowledge of chemistry and the chemical industry. The effect of these weapons, coupled with man's innate ability to contaminate his own environment, is so great that they can no longer be used indiscriminately. In using chemical toxicants to suppress individual species competing for common resources, the homeostasis of the environment is frequently affected, creating new problems which in turn prevent him from attaining his goal.

Public interest in environmental contaminents, as associated with public health problems, and the demonstrated need to know the total effect of toxicants on the ecosystem, were the basic factors which motivated the innovation of this study. The basic question asked at the onset of this program, which this thesis is a part of is: What is the effect of pesticides on non-target organisms and the environment in general?

Following an outbreak of the Japanese beetle (Popillia japonica Newman) in the southeastern corner of Michigan, the State and Federal authorities initiated a chemical control program with granulated chlorinated hydrocarbons (a 1962 dieldrin application at 2 lbs. actual/ acre, on top of a 1960 aldrin application at 2 lbs./acre). This study is concerned primarily with the long-term effects of this program on the non-target insects.

The insecticides used in this control program are ideal for long term study, as both remain active in the soil for many years. Woodlots were selected for study because they represented the only natural areas that could possibly maintain a stable insect community from one year to the next, in this area of intense agriculture. The number and variety of insects were used as a basis for comparison between farm woodlots located within and outside the treated area. The soil and winged insect communities were both sampled, but this study includes only the analysis of the winged forms.

Samples from the winged insect community were obtained with a Malaise trap. This trap is selective in that the more active insects are collected most efficiently. The trap is simple, inexpensive and can be left unattended for several days. These attributes are evaluated in relation to the trap's reliability in sampling an insect community.

During the summer of 1965, two malaise traps caught 21,404 specimens representing 129 families and 13 order of insects.

Harvestmen, of the order Phalangida, were also included in the total count of specimens. Spiders (Araneae), mites (Acarina), Collembola and various insect larvae were also collected on occasion, but are not considered in this presentation.

LITERATURE REVIEW

Side-effects

Application of insecticides frequently causes catastrophic changes in arthropod density. These changes may be expressed immediately in the numerical increase or decrease of certain species due to changes in predator and competitor species density. This influence may be expressed as a superabundance of a previous minor component of the community. The initial and dramatic change in relative abundance is usually a short-term effect, that is of a temporary nature. This study is concerned with the long-term consequence, or shift in relative abundance, due to a repeated insecticide application. These changes are more subtle and slower than the short-term effects (Ripper, 1956).

These subtle effects are often reflected by changes in the relative densities of various species and a shift in trophic structure toward lower levels. In addition, many predators and parasites are eliminated and there is a general decrease in population size and variety (Ripper, 1956). Menhinick (1962) demonstrated these changes in his study on soil and litter arthropods in relation to long-term pesticide usage. The importance of predator-prey relationships to insect population dynamics has been reported by Holling (1959). Lord (1962) demonstrated these relationships in his study of the fauna from apple orchards. He found that repeated DDT applications caused a less diverse fauna and a change in the herbivore-predator ratio. The net result was a trophic shift toward the herbivorous species. Published literature suggests that pesticide induced changes in the segment of the community sampled should reveal themselves in an analysis of the herbivore-predator ratios and relative densities of the winged insects sampled in untreated and treated woodlots, even though all insects will not be equally affected by the treatment.

Indices of Diversity

The structure and dynamics of the community system are based on the successful evolution of plants and animals together in a habitat. Diversity of species and complexity of associations among species are considered essential to the stability and balance of the community system (Pimentel, 1961). The simplest index of diversity is the total number of species inhabiting a particular area. Since this index does not take into account differing abundances of species, more sophisticated measures have been proposed which weight the contribution of each species according to its abundance. The resulting indices are of two general types; those that assume the natural distribution of species fit a mathematical expression, and those that do not assume an underlying statistical distribution.

Williams (1944) noted that if a sample of a number of individuals was taken from a mixed population, the distribution of individuals per species would be best represented by Fishers' et al. (1943) logarithmic series. This mathematical relationship between species and individuals is termed "alpha" and called the Index of Diversity of the population. A high "alpha" indicates more species and conversely a low "alpha" indicates fewer species for the same number of individuals. Calculation of diversity by the above method is simple and rapid with the tables presented by Fisher et al. (1943).

Another method for comparing the similarity in community diversity is Kendall's "tau" (Ghent, 1963). This is a nonparametric test that utilizes differences in rank order abundance of the various species. The method makes no assumptions for distribution, however a certain amount of information is lost in ranking the species. This method can only be used for determining the similarity in abundances between the two areas being compared, this is done by the calculation of a correlation coefficient. Values cannot be obtained for a single community.

William's (1944) "alpha" has been found by Menhinick (1964) to vary with sample size, when applied to samples of field insects. Looman et al. (1960) concluded, after testing several indices of diversity on prairie vegetation, that William's index was limited to detecting the existance of heterogeneity. Kendall's "tau" (Ghent, 1963) was found to be awkward to calculate but permitted the estimation of error. MacFadyen (1963) criticizes the above models for being too theoretical and utilizing parameters which have no biological meaning. He suggests MacArthur's (1957) "broken stick" model, as modified by Hairston (1959), as a more realistic approach to the problem.

A more promising index of diversity is the information theory proposed by Margalef (1957). This index also assumes no underlying distribution, with the calculation being made directly from the number of individuals per species as given in the following formula:

Diversity = $- \Sigma p_i \log_e p_i$, in which p_i is the proportion of all of the individuals which belong to the i^{th} species. This method is relatively easy to calculate, with higher values indicating greater diversity. Satisfactory use of this method has already been made by MacArthur and MacArthur (1961), Margalef (1957) and many others.

Preston, (1962) has proposed still another method for calculating diversity, based on what he terms a "canonical" distribution. This canonical distribution is based on a relationship between the log-normal fit of assignments for individuals to species and the abundance curve for the species. Preston uses this method for predicting the patterns of species diversity that occur in isolated areas such as on islands.

The choice of the index used in any particular investigation depends on several factors, the more important being the difficulty in appraisal of species abundance and shifts in the relative abundance during the study (Pianka, 1966). Another prime consideration is the determination of species. In studies of this nature, where large samples of insects are taken continuously throughout the summer, the problem of species identification is very great. To avoid this problem, identification in this study was only done to the family level. To calculate familial diversity, William's "alpha" was used. It has been suggested that this index would be satisfactory for this type of data (D. P. Pielou, personal communication). The log-series distribution fit required for the index, was found to be satisfied by the data at the family level.

Sampling Method

Ecological studies involving the sampling of insect populations fall into two general categories. First single-species populations and second, community studies where a mixed population is sampled. Morris (1960) and MacFadyen (1963) present excellent reviews of the methods and procedures involved in sampling single-species populations. Some of these same procedures apply to this study which is concerned with sampling mixed populations of winged insects, e.g. abundance or insect density. In addition, however, such parameters as diversity, and herbivore-predator ratios were also estimated. The accuracy of these estimates is equally a function of sample size and variance but are not so easily interpreted or estimated as are population parameters. Fortunately the nature of the problem is different in community studies and precision is not as important in these studies as in problems of population dynamics. Selection of an adequate sampling method is important and it is absolutely essential that its efficiency remains unchanged for similar species in different habitats.

The devices used to sample insect fauna are generally of two types, either a mechanical device which captures insects or a behavioral type, where the insect is caught by its own movements (MacFadyen, 1963). Maki (1965) analyzed two mechanical sampling devices, a sweep net and a vacuum collecting net and found that neither one was adequate for sampling an entire fauna. The Malaise trap presently under consideration is a behavioral device which insects fly into and are trapped as they move upward into a collecting apparatus. Consideration of the data presented by Marston (1965) on the insect catch from a Malaise trap, showed that this type of device would provide adequate samples for the present study even though all species are not trapped with equal efficiency. Although the Malaise trap does not measure population density it is objective and can be standardized for comparisons of yield between areas or from one part of the season to another (Townes, 1962). Designs for the trap were presented by Townes (1962) and a modified version by Marston (1965) from which our traps design was made.

MATERIALS AND METHODS

Six woodlots, located in the southern portion of Monroe County, Michigan, were selected for this study. The three located within the treated area were coded T1, T2, and T3. These were arbitrarily paired with the three control woodlots designated C1, C2, and C3. The area between the pairs of woodlots was primarily farmland with many of the fields under cultivation. Figure 1, is an aerial view of the woodlots giving their size and location, with the "X" indicating a sampling site. Selection of these areas was based on availability, accessibility and vegetational uniformity. Samples of the soil were taken for determination of nutrients and dieldrin residues (aldrin breaks down into dieldrin) by the Soil Lab and Pesticide Research Center at Michigan State University.

The Malaise traps (Figure 2) used as sampling devices for this study were constructed from plans presented by Townes (1962) and Marston (1965). Black cotton was used for the baffles and light gauge white canvas for the top. The screen collecting apparatus was constructed entirely of aluminum, with a polyethylene funnel and transparent plexiglass top (Marston, 1965) forming the killing chamber (Figure 3). Attachment of the pint jar, to hold killing fluid, was accomplished by cutting off the lower portion of the funnel and heating the edge. While the edge was still hot a metal jar ring was inserted above the heated area so the plastic flowed inside it forming a permanent mount.

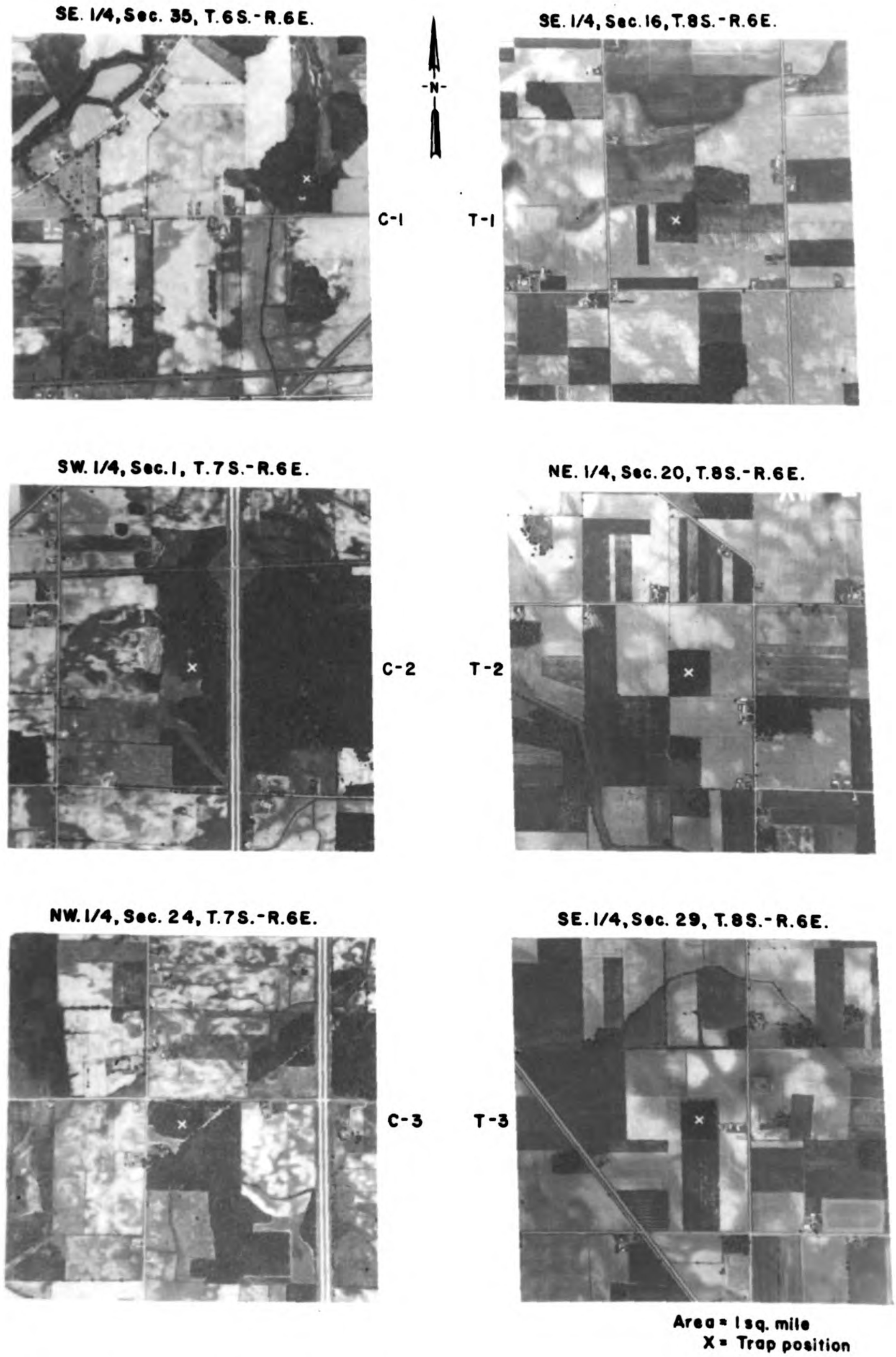

Fig. 1.--Location of sample woodlots in Monroe Co., Michigan

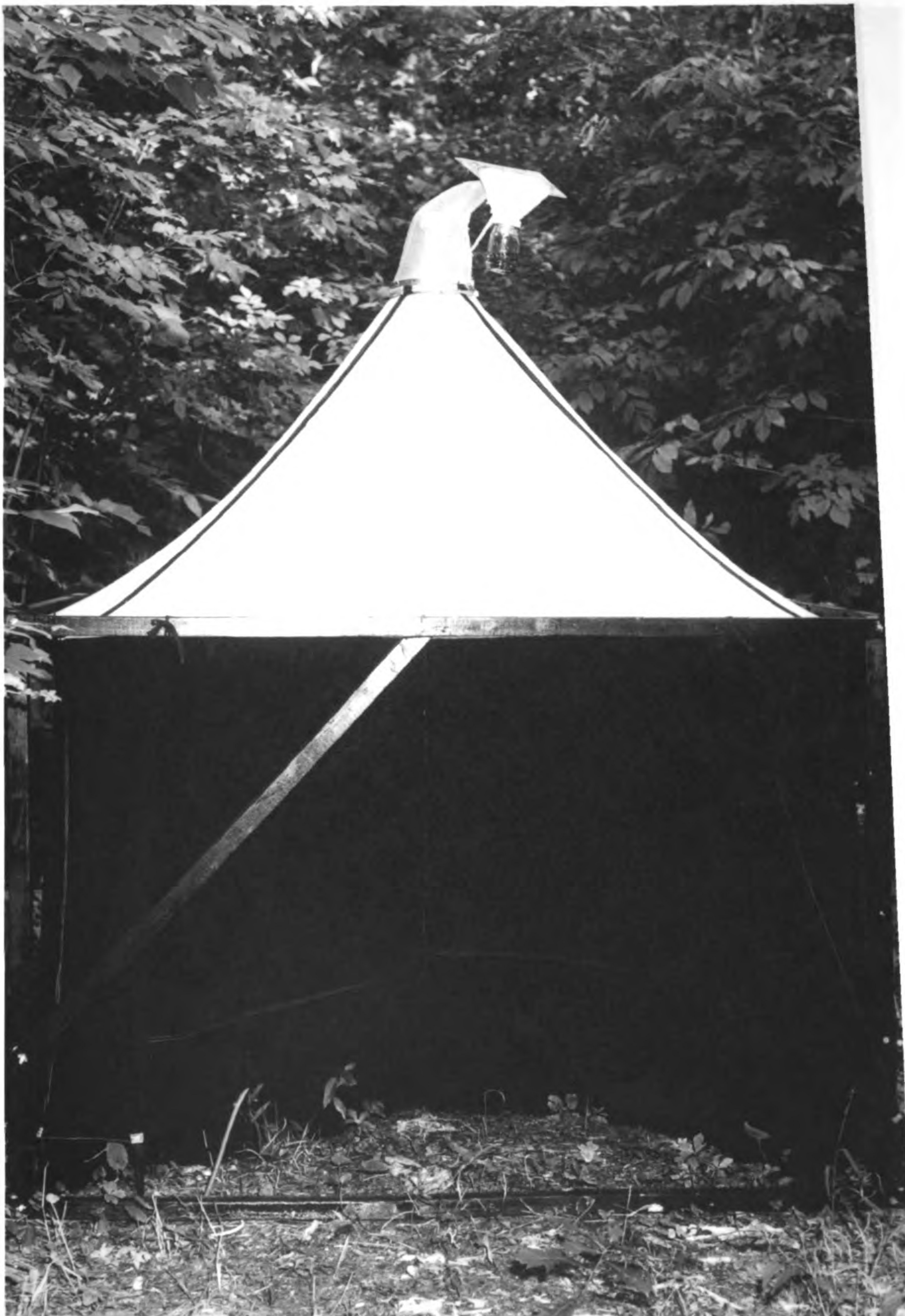

Fig. 2.--Malaise trap in operation

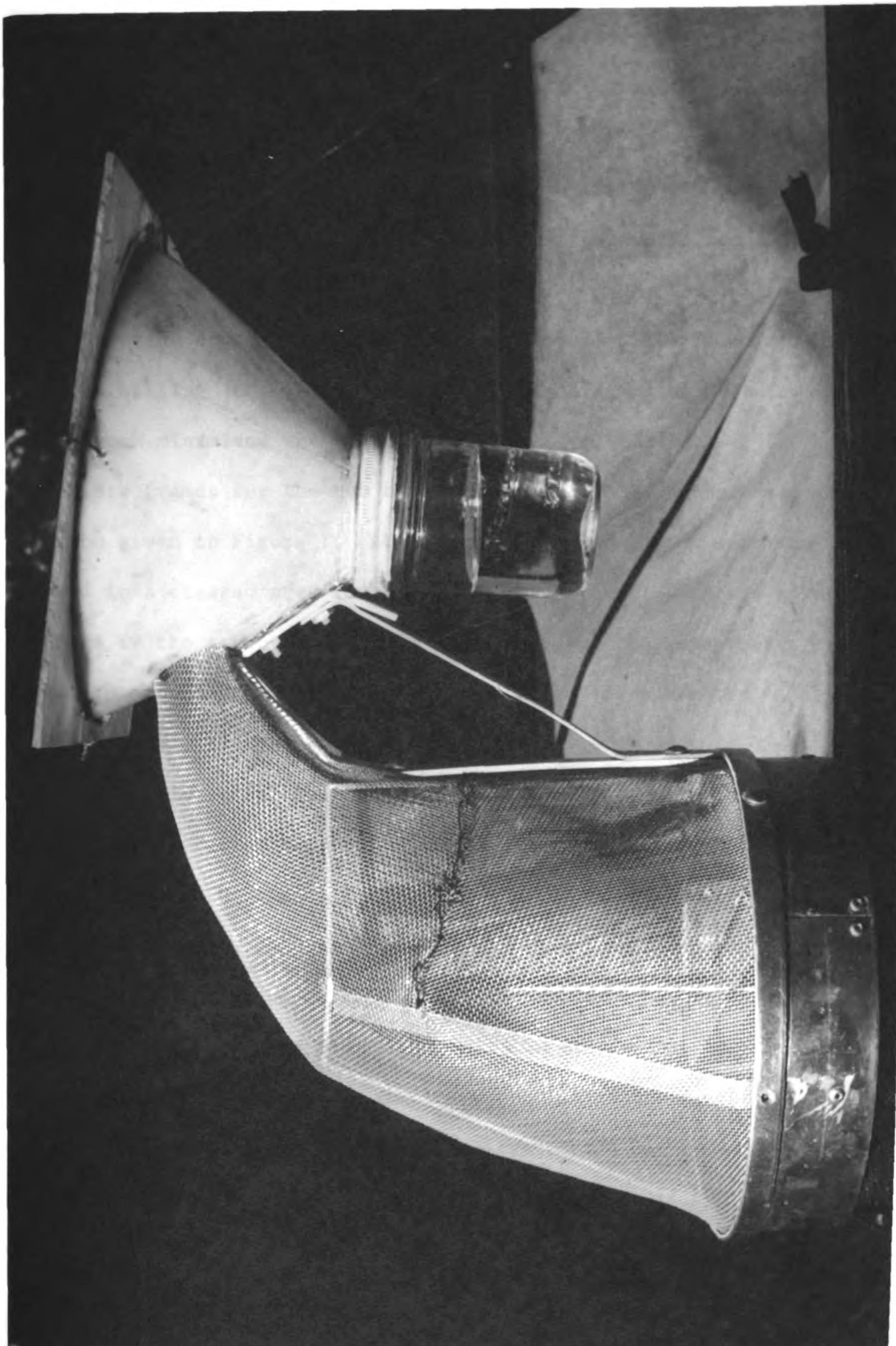

Fig. 3.--Collecting apparatus

Several problems with the trap were found during the study. Rodents chewed the cotton tie strings off, so they were replaced with nylon straps which the rodents did not chew. The epoxy glue holding the plexiglass to the funnel also gave way, allowing the plexiglass to fall off. Holes were drilled through the funnel and top and the two were wired together. Spiders spun their webs in the bottom of the collecting apparatus and prevented trapped insects from moving up into the killing jar. Removal of the spiders, along with their webs, once a week minimized their effect on insect yield.

Six frames for the two traps were built, one for each sample location given in Figure 1. At each sample location the trap was located in a cleared area with the collecting funnel directed toward openings in the canopy. Sunlight coming through the canopy openings helped to bring the insects up into the collecting apparatus. Only the center pole, with trap attached, was moved from plot to plot (Figure 4). Two traps were used in the study, one for the treated and one for the untreated woodlots. At six-day intervals both traps were moved e.g., from C1 and T1 to C2 and T2, and after six-days at C2 and T2 to C3 and T3. Within each woodlot the six-day period was further divided by removing the collection after three days and again on the sixth day. This allowed 2 collections to be made within each woodlot for one six-day period. From the third plot in each area the traps were moved back to the first and the 18-day series was repeated. Five consecutive 18-day series were run during the summer of 1965. Sampling dates within each series are presented in Appendix I.

The pint jars on the traps were filled halfway with 95% ethyl alcohol for killing and preserving the trapped specimens. Specimens

Fig. 4.--Trap in transporting position

were brought into the laboratory for counting and identification. Most of the adult insects were identified to the family level using the keys and terminology in Borror and Delong (1963). Chalcid wasps were determined to Chalcidoidea, and fulgorids were taken to Fulgoroidea. Lepidoptera had to be dried out before identification was possible and microlepidoptera were only identified to suborder.

RESULTS

Vegetation and Soil Analysis

Determining the disruptive effect of a pollutant in a biological system can be accomplished by measuring the differential response of selected parameters to the influence of the pollutant. If this measurement is done after the pollutant has been introduced, then areas have to be located that were identical as to the parameters in question before the pollutant was introduced. Locating identical or at least similar areas is an inherent weakness in field problems of this type. This problem of finding comparable control and treated woodlots is well documented in the following analysis for vegetation and soil uniformity.

Vegetational uniformity was checked by obtaining the relative abundance of tree species in each of the six woodlots. Although the entire flora was not sampled, the abundance of tree species will give an indication as to the type of vegetational community present (Oosting, 1956). Sampling of the trees was accomplished by using the Random Pairs survey method. This method was designed primarily to sample trees for forest surveys. Although not as accurate as the standard Quadrat method, it does allow a larger area to be sampled in less time (Cottam *et al.*, 1949, 1955). Sample size, time involved, and ease with which this method can be applied, make it an ideal sampling method for use in this study.

To analyze the differences in abundance for the various tree species, correlation coefficients were calculated. Kendall's "tau" was used to analyze the differences, between areas and pairs of woodlots. This test measures the differences in rank order abundance for the various species. A perfect correlation (+1) is obtained when the orders of abundance are identical. Perfect negative correlations occur when the order of abundance is reversed, e.g., the most abundant species in one area are the least abundant in the other area. Results of the analysis are given in Table 1.

Results for the analysis between pairs of woodlots, shows that they are all negatively correlated in terms of tree species abundance. The woodlots within the control and treated areas show both positive and negative correlations to each other. The treated woodlots are all positively correlated, while in the control area, C3 is negatively correlated to C1 and C2. The most important differences are those between the treated and untreated pairs of woodlots. These indicate that the control and treated areas are different, at least in vegetation.

A partial explanation for the differences noted above is given by the soil data presented in Table 2. Soil from the control woodlots is of poor quality. It is low in nitrogen and calcium, two nutrients essential for good plant growth. Also, the low pH prevents phosphorus and potassium from being readily available (Miller, 1950). Soil from the treated area is rich in available nutrients for good plant growth. The area treated for Japanese beetle control included most of this good agricultural land, leaving the poorer soil untreated. This soil difference is shown in the vegetation; the treated woodlots being

TABLE 1

CORRELATION* OF TREE SPECIES ABUNDANCE
BETWEEN CONTROL AND TREATED AREAS

a) Between Pairs		b) Control Woodlots		c) Treated Woodlots	
C1 & T1	-.29	C1 & C2	.05	T1 & T2	.07
C2 & T2	-.25	C1 & C3	-.07	T1 & T3	.04
C3 & T3	-.42	C2 & C3	-.22	T2 & T3	.23

*-1 = perfect negative correlation

0 = no correlation

+1 = perfect positive correlation

TABLE 2
RESULTS OF SOIL ANALYSIS FOR EACH WOODLOT IN LBS./ACRE

	pH	N	K	Ca	Mg	Mn	Na	Cl	K Value		Dieldrin**
C1	5.4	T	10	140	T	45	4	50	225	14	T
C2	4.6	3	7	132	T	20	T	60	200	17	T
C3	5.8	T	10	140	0	48	14	64	200	12	T
T1	6.7	45	6	128	T	40	T	54	200	18	6.9
T2	6.9	70	17	152	700	45	0	54	T	22	2.3
T3	6.9	70	12	116	850	40	0	68	160	25	3.1

T = trace

**Dieldrin given in ppm

second-growth sugar maple-basswood-red oak upland, and the control woodlots being species-poor, second-growth oak-upland and swamp forest (John Cantlon, personal communication). A considerable amount of dieldrin still remained in the soil of the treated woodlots (Table 2).

Comparison of Yield between Areas

To determine if the insecticide caused any gross difference, the total number of insects collected from each area was calculated. The control plots gave 10,831 individuals while the treated plots yielded 10,573, for the entire summer. Yield in the control plots was greater by only 258 individuals. Assuming that insect mobility was equal in both areas, then this difference indicates the areas were similar at least in total yield. Although the two areas were similar in total yield, a more detailed analysis was performed on the abundance of insect families. All families with at least 10 individuals collected from one or both areas for the season were used in the analysis. The families collected from both the control and treated areas were first ranked separately in order of decreasing abundance. The rank of each family from the treated area was then placed under the rank for the same family in the control area. Kendall's "tau" was used to calculate a correlation coefficient, between the two areas by comparing the differences in rank order for all the families. A positive "tau" value of .206 was obtained which gave a "z" value (Seigel, 1956) of 2.327 showing significance at the 1% level. This high correlation shows that the order of relative abundance for families of insects was the same in both areas. If the insecticide was influencing yield of insects from the treated area, we would expect a much lower degree of correlation.

Although the above analysis did not indicate any reduction in total yield or family abundance, a more detailed breakdown of the data showed a number of discrepancies. At the ordinal level, consistent differences in yield were found to exist. A histogram was constructed of total yield in each area for the orders examined (Figure 5). The difference in total yield for the orders with an asterisk was maintained throughout the sampling program. Yield for the following three groups was found to be different for each sampling period. Arthropod yield in the miscellaneous category, which includes minor orders of insects and harvestmen, was consistently higher in the treated area. Coleoptera yield however, was just the opposite, with the control area producing higher numbers. The Homoptera also showed a large discrepancy, with yield from the treated area always being larger than from the control. Diptera yield, although not consistently different, showed a large total difference. The yield varied from area to area with each sampling date, e.g., the treated may have been higher for one sample period, but then the control area was higher in the next period sampled.

Three abundant species, one from each consistently different group, explained the differences shown above. The identification is tentative, pending expert verification. The number of each species was counted and the total subtracted from the yield data for each control and treated woodlot. If the resulting yields at each sampling date were in close agreement then the species removed caused the previously observed difference. A harvestman, Leiobunum vittatum, an arboreal species, accounted for most of the differences in the "Misc."

Total Yield (x1000)

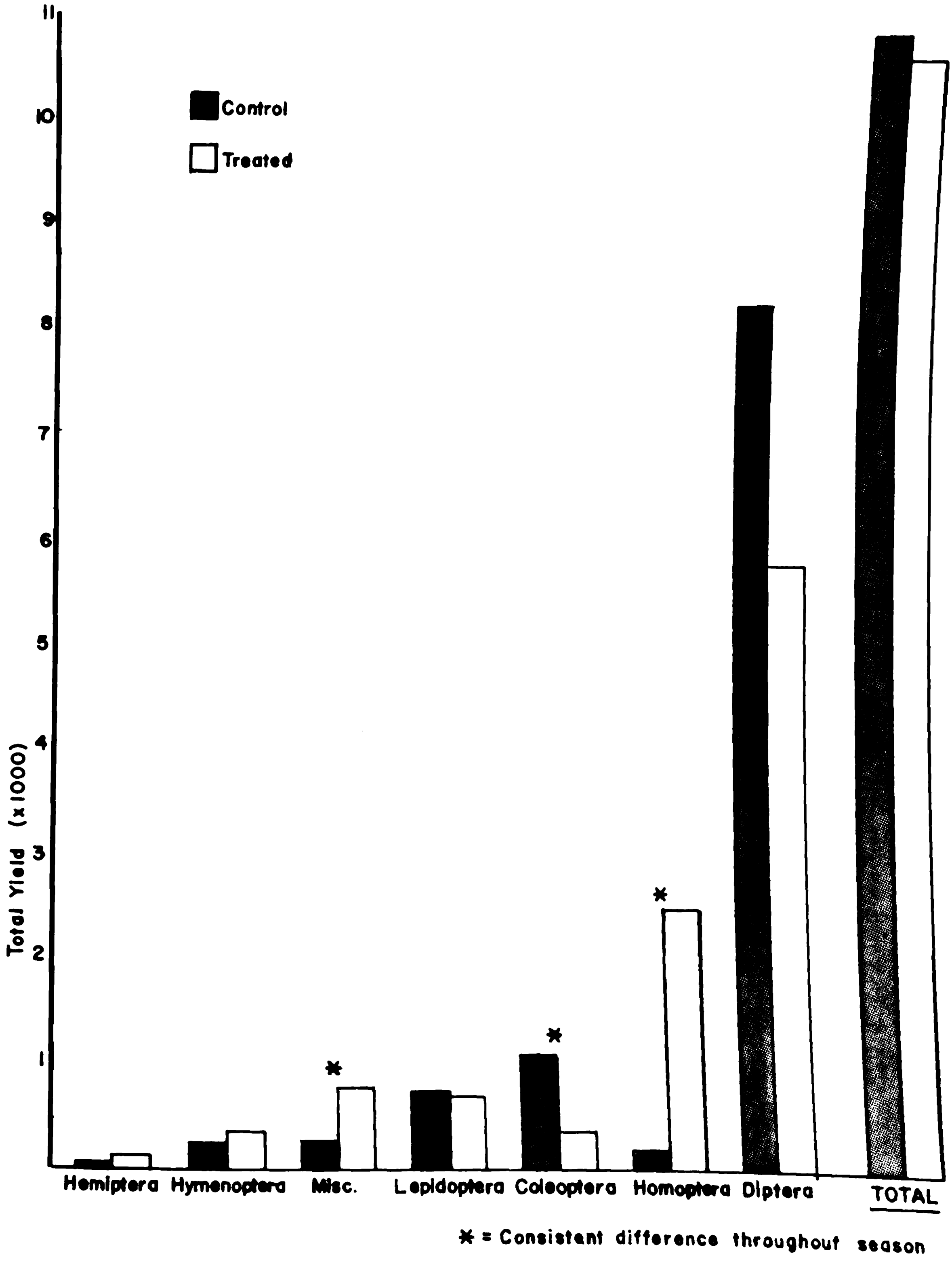

Fig. 5.--Total yield of arthropod taxa, for the entire season, from the control and dieldrin treated woodlots.

category. Removal of this species made the yield differences negligable between areas (Figure 6). The strawberry root weevil, Brachyrhinus ovatus, the larvae of which live in the soil and feed on plant roots, caused the difference in Coleoptera. No specimens were collected from the treated area. Removal of this species from the check data brought the yields of both areas into close agreement (Figure 7). The third species identified was Empoasca fabae, the potato leaf hopper. This homopteran feeds on a variety of plant hosts (including alfalfa) and is a possible migrant into Michigan from the southern states. Figure 8 shows this species to be very abundant in the treated area. Removing it from the data brought the yields into closer agreement, but the treated area still remained slightly higher than the check.

Comparison of Community Structure

The index of diversity proposed by Williams (1944) was used to obtain the diversity for the five 18-day series run in the control and treated areas. Assumptions for use of the indices are random samples and the log-series distribution. Although the samples were not obtained at random, the original selection of sites was done at random. Any error introduced by not strictly meeting this assumption is constant for both areas so the comparison is not affected. The number of individuals per family collected was arranged in the following order: number of families with one individual, number with two individuals, number with three . . . to number of families with the largest number of individuals. The decrease in the number of families in each group was geometric, i.e., the number of families

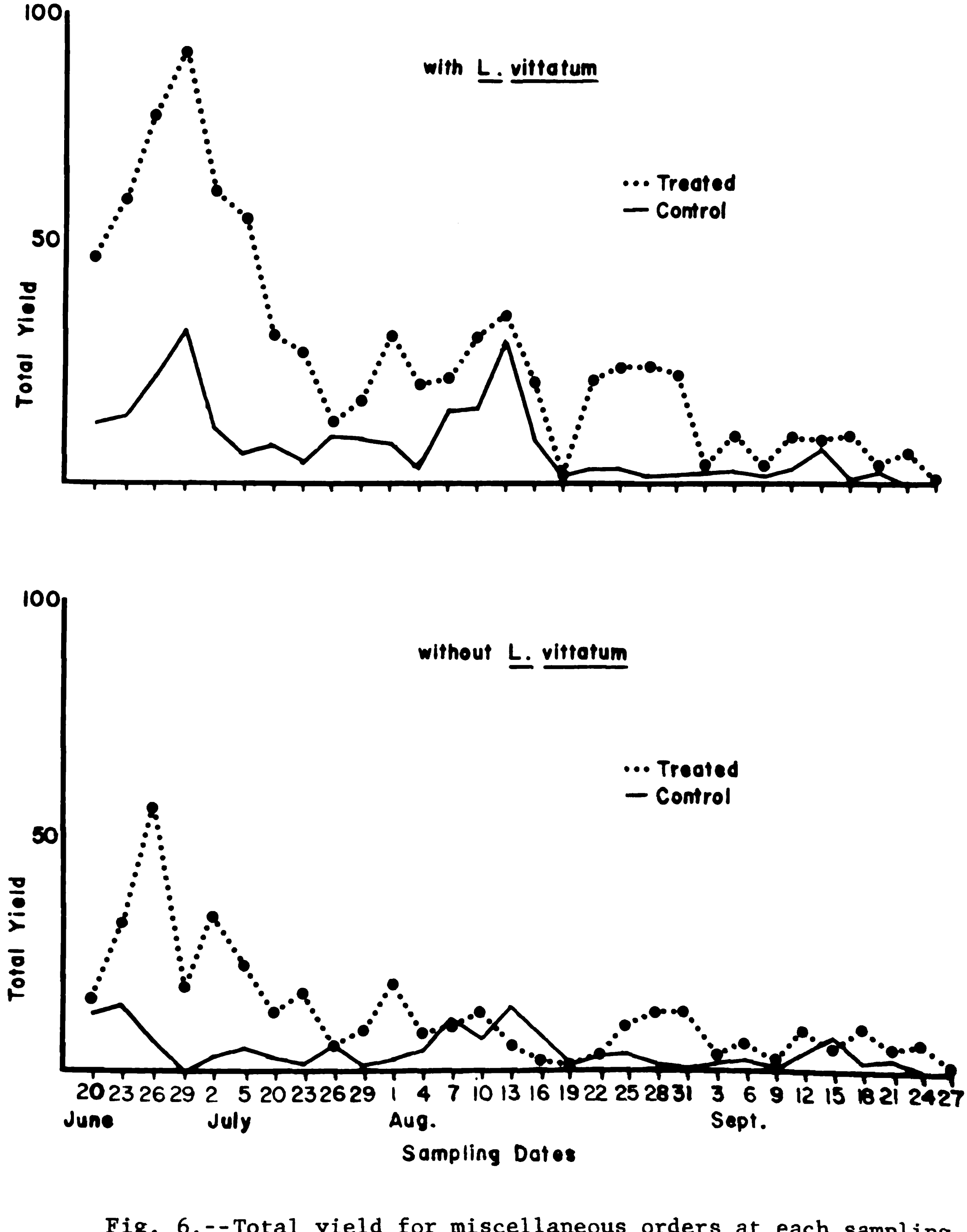

Fig. 6.--Total yield for miscellaneous orders at each sampling date between the control and treated woodlots, with and without *L. vittatum*.

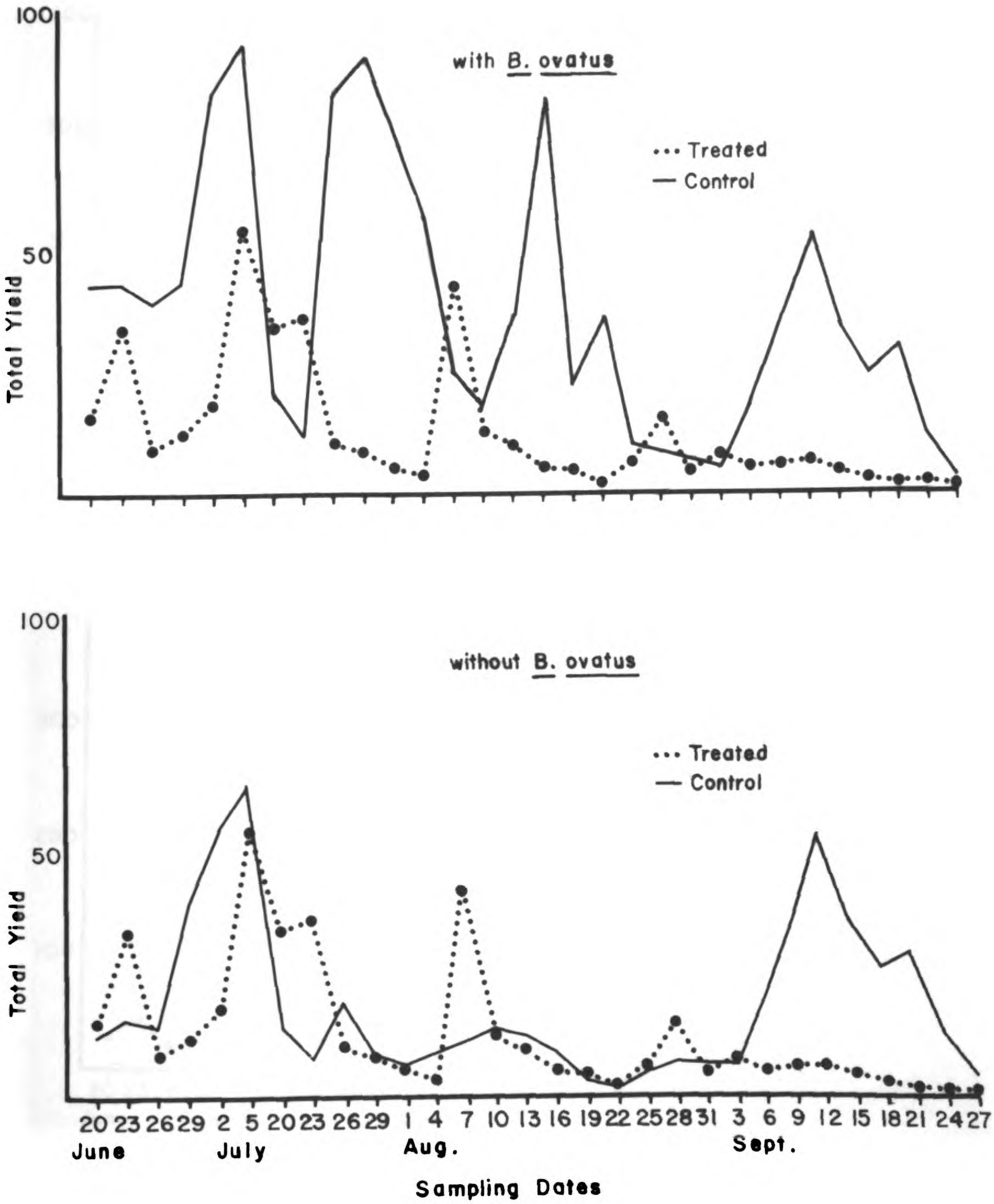

Fig. 7.--Total yield for Coleoptera at each sampling date between the control and treated woodlots, with and without B. ovatus.

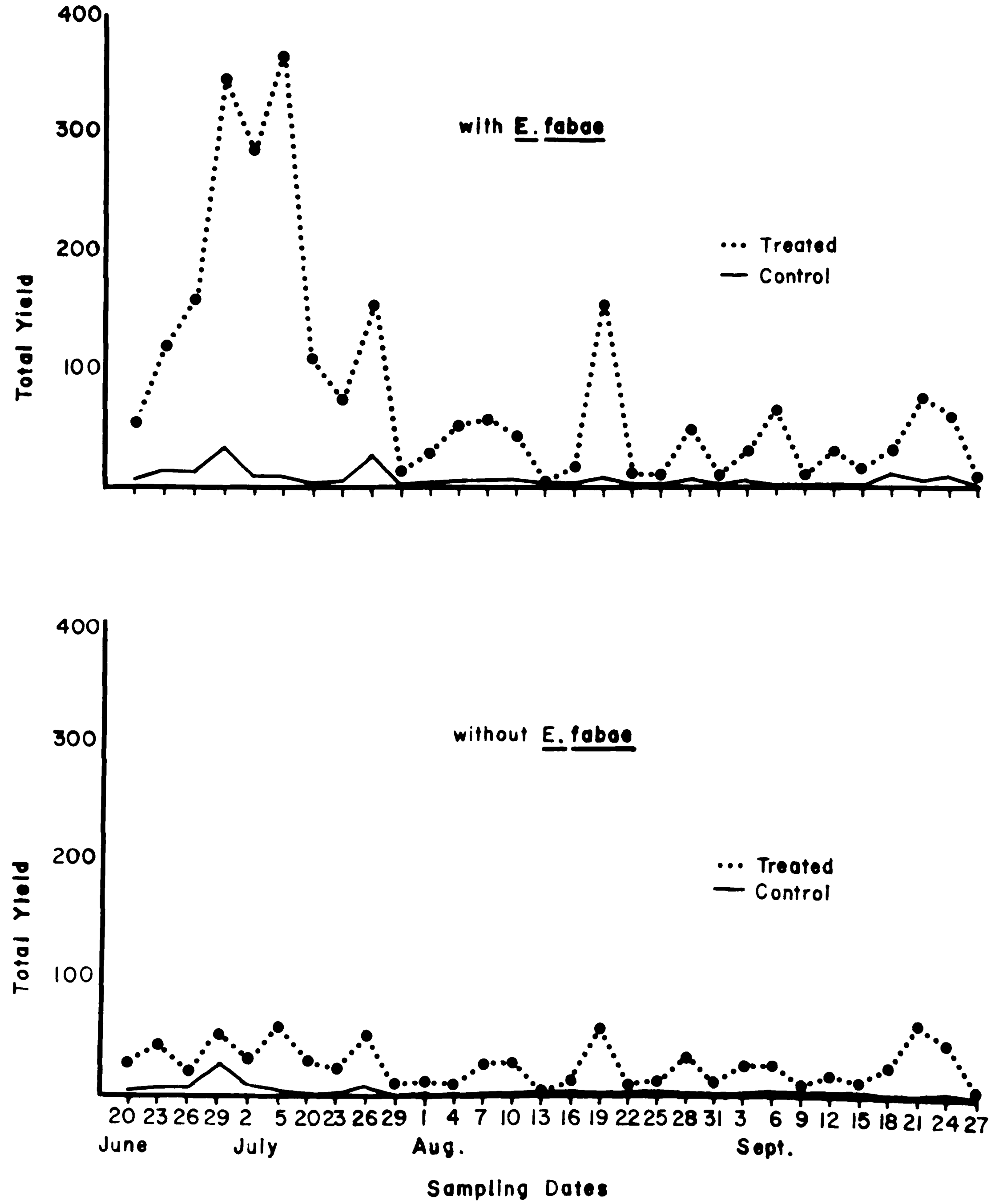

Fig. 8.--Total yield for Homoptera at each sampling date between the control and treated woodlots, with and without E. fabae.

represented by one individual was large, the number of families represented by two individuals was about half the number represented by one, the number with three individuals was about one-third of the number represented by one, and so on. This geometric decrease satisfies the requirement for a log-series distribution.

All individuals and families collected were used to calculate the diversity of families within each area. The results are presented graphically in Figure 9. Diversity was also calculated without *E. fabae* and very little difference was found between the estimates, demonstrating that one super-abundant group has little effect on this index. The graph shows that the diversity in both areas declined with time at an equal rate, being high in the spring and lower in the fall. However, the elevation of the lines is distinctly different; the treated fauna was more diverse throughout the season than the untreated control fauna.

The effect of the treatment on trophic structure was measured by calculating a herbivore/predator ratio (H/P) for each series in both areas. Trophic designations made for entire insect families were based on the feeding habits of the adults. Several problems are involved when trophic assignments are made at the family level. Different species within the same family may be in different trophic levels; also, immature stages may feed on a different level than the adults. For the above reasons, the ratios given are not representative of the entire community, but they do represent the segment sampled. The trophic designations made for each family are presented in the first column of Appendix II. Ratios calculated from these designations are presented in Figure 10. The change in the ratio for each area

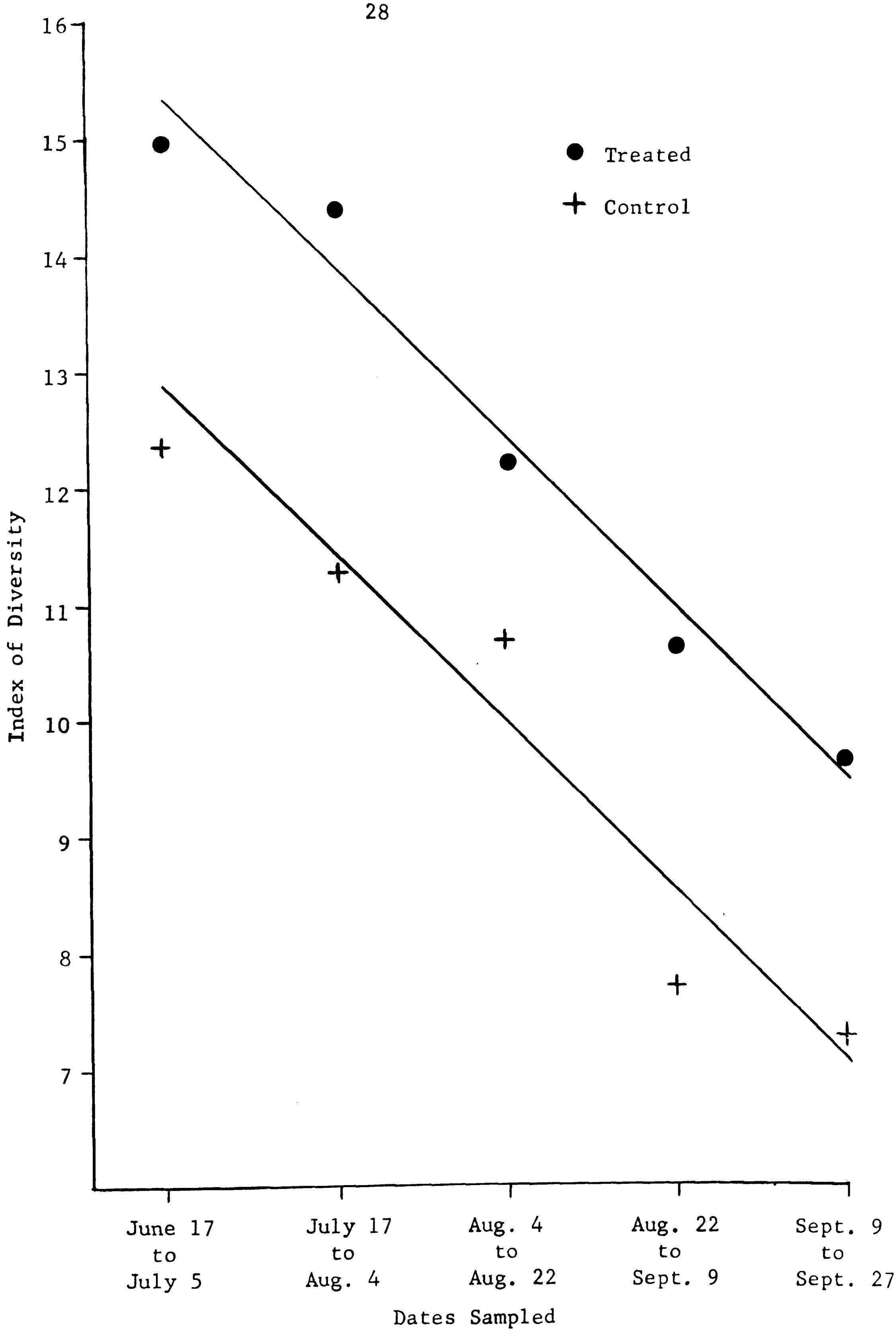

Fig. 9.--Familial diversity for the control and treated areas, as related to time.

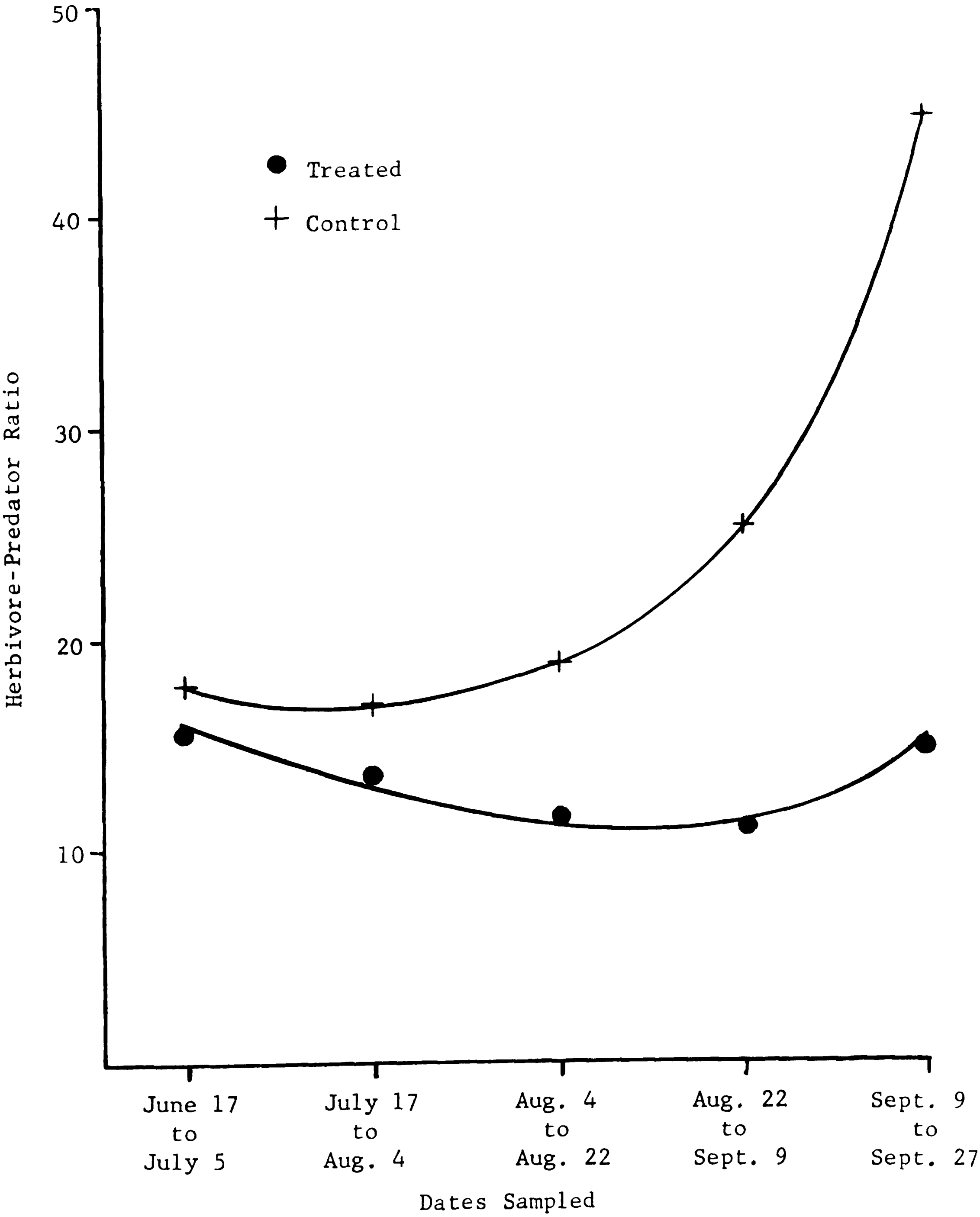

Fig. 10. Family herbivore-predator ratio for the control and treated areas, as related to time.

appears to be curvilinear, with the control area showing a consistent increase with time, while the treated area remained almost constant.

The relationship between family diversity and H/P ratio has biological significance at the community level. Diversity and complexity between herbivores and predators are essential to the stability and balance of the community system (Pimentel, 1961). Therefore, communities with a diverse fauna should be resistant to large fluctuations in the H/P ratio. Insecticides, because they are general poisons, tend to reduce the diversity of the fauna and permit large fluctuations to occur (Ripper, 1956). By examination of Figures 9 and 10 it can be seen that both areas have a diverse fauna with the diversity of both areas decreasing at an equal rate with time. Examination of the H/P ratio from the treated area shows the stabilizing influence of higher diversity, as the ratio remains almost constant throughout the season. However, the control area was just the opposite; with lower diversity the H/P ratio increased greatly with time.

To determine if there was any difference in yield between the two areas, related to time, a comparison was made. Differences in yield, either + (control) or - (treated) were analyzed in relation to time. A linear relationship was obtained and a correlation coefficient calculated (Figure 11). The "r" value of .61 showed that time of year accounts for $(.61^2)$ or 34% of the variability in yield difference. The treated area yielded more insects in the spring and the control more in the fall. Relating this difference in yield back to the fall increase in H/P ratio, it was found that a greater percentage of the increased yield in the control area was comprised of

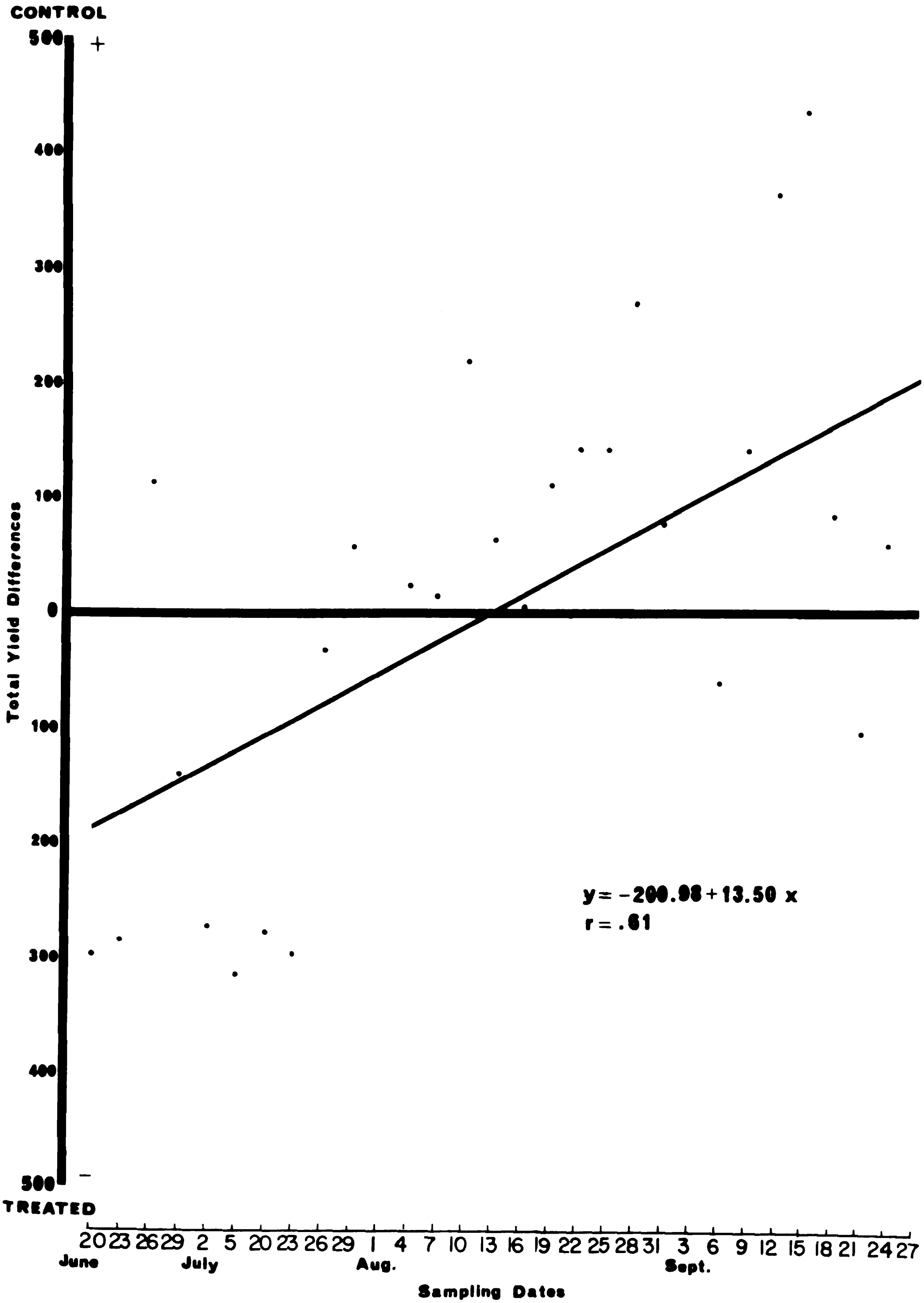

Fig. 11.--Effect of time on total yield differences between the control and treated areas.

herbivores. These herbivores were primarily Diptera belonging to the family Cecidomyiidae (gall midges). This increase in the yield of herbivores from the control area is possibly a reflection of natural instability as indicated by the lower diversity or it could be due to the presence of plant types conducive to gall midge development.

Analysis of Malaise Trap

For the Malaise trap to be reliable in a sampling program, the variation in number of insects collected within one woodlot should be reasonably constant. The best estimate of this variance would be obtained if two or more traps were run simultaneously. In this study, however, it was not possible, so the variance in insect yield obtained between the first and second 3-day samples for a given woodlot was used. Although one of the 3-day sample periods may show a greater yield, the difference could be due to insect emergence. This difference would not be constant in time, but would vary with the seasonal abundance of the insect.

Two woodlots from the control and treated areas were selected on the basis of vegetational uniformity and time. Twelve days was the total time interval for sampling any two consecutive woodlots. Woodlots chosen were T2 and T3 from the treated area, with C1 and C2 selected from the check area. More insects were collected in the spring, so the data for Series I were used. A two-way analysis of variance (Li, 1964), using families as treatments and 3-day intervals as replications, was used to compare the mean number of insects per family collected within and between woodlots. The mean yield of insects per family for T2 and T3 was significantly different at the 5%

level. No significant difference was found in the control woodlots (Table 3). The means from the treated woodlots were not separated, because insect emergence within the 12-day sampling period could be causing the difference. A more detailed analysis was performed to determine if seasonal abundance of insects could be causing differences in yield between the two 3-day sample periods.

TABLE 3

ANALYSIS OF VARIANCE RESULTS FROM WOODLOTS T2 AND T3

Source	df.	SS	MSS	F
Replications	3	2053.50	684.50	3.022*
Treatments	43	316150.637	7352.34	32.460**
Error	129	29222.50	226.531	
Total	175	347426.637		

* significant at 5% level

** significant at 1% level

To determine the influence of insect emergence on yield, the two 3-day samples from each woodlot were paired, and the differences in abundance for individual families were calculated. These differences were then ranked in order of increasing magnitude without regard to sign. The ranks were then assigned the sign of the difference. If there was no difference in family abundance, then the sum of the positive ranks should be close to the sum of the negative ranks. Discrepancies in the sum of the ranks were analyzed with the Wilcoxon, non-parametric, test for paired comparisons (Siegel, 1956). This test measures the magnitude as well as the direction of any observed differences. To reduce the error involved when large numbers of these tests are performed, and still obtain results representative of the entire sampling season, only differences within woodlots for Series I, III, and V were analyzed. Results of the analysis are presented in Table 4. The significant differences for Series I show the second 3-day sample to be more productive. Series III shows significant differences for the first and second 3-day samples. The fifth series shows two highly significant differences with the first 3-day samples being more productive. The seasonal pattern of these yield differences suggests the influence of a variable factor, possibly weather. Series I seems to be in the center of peak spring emergence, with the last samples in Series V encompassing the fall die-off period.

TABLE 4

COMPARISON OF TOTAL ARTHROPOD YIELD, BETWEEN THE FIRST (a) AND SECOND (b) 3-DAY SAMPLES WITHIN WOODLOTS, FOR SERIES I, III AND V

	Series I		Series III		Series V	
	a	b	a	b	a	b
C1	456	915*	307	458	547	680
T1	724	1156*	298	248	166	247
C2	564	578	164	255	232	151
T2	454	725*	100	261**	141	249
C3	438	524	468	289	378	50**
T3	733	868	362	151*	324	55**

* significant 5% level

** significant 1% level

To determine the influence of weather on yield, weather records for the area were obtained from the U.S. Weather Bureau at East Lansing, Michigan. Three weather factors, temperature, evaporation and wind were selected for analysis of effect on yield. Temperature was recorded about 25 miles from the study area at the Monroe sewage disposal plant. Maximum and minimum temperatures were given for each 24 hour period. Wind and evaporation data had to be taken from the East Lansing Horticultural Farm Station. Complete records could not be obtained from a station closer to the study area. Wind was measured in total miles over 24 hours. Evaporation was recorded as inches per 24 hours from a standard weather bureau 4-foot diameter pan.

To obtain the correct relationship between the above weather parameters and difference in insect yield, the following procedure was used. The mean of each weather factor for the first 3-day sample was arbitrarily assigned (+) and the mean for the second 3-day sample was assigned (-). The two means were then subtracted to obtain a positive or negative difference. Thus, the magnitude as well as direction of the differences was shown. Yield of insects was handled in much the same way except that differences between the 3-day samples from the control and treated areas were added together and the sum divided by two. This procedure gave a difference in mean insect yield to work with. The individual relationships obtained for temperature, evaporation, and wind on insect yield are presented graphically in Figures 12, 13 and 14.

Analysis for the effect of each factor, individually and together, on the difference in yield, was accomplished with a multiple correlation analysis (Steel _et al._, 1960). The multiple regression

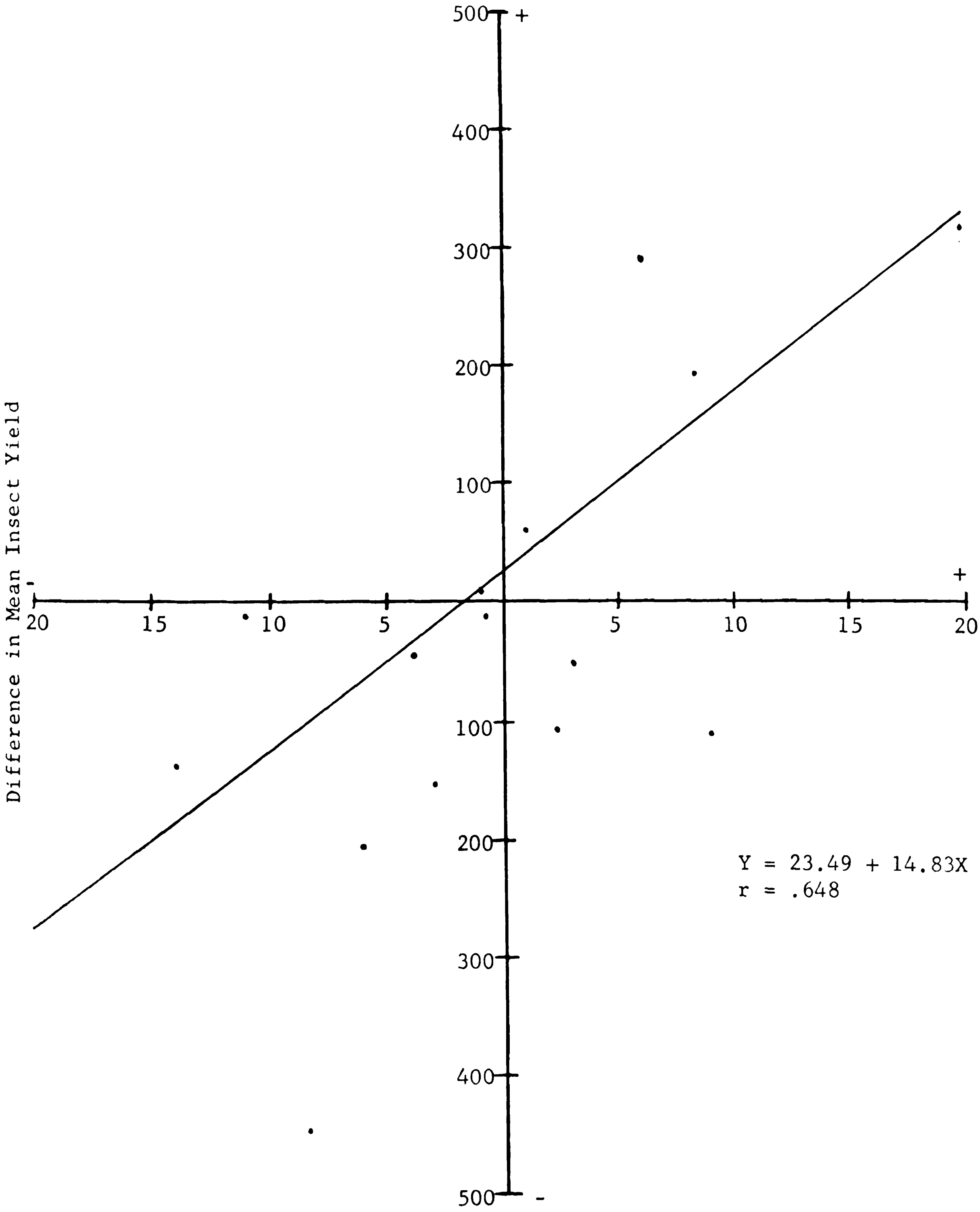

Fig. 12.--Relationship between mean temperature differences and mean insect yield differences, between the two 3-day sample periods within each woodlot, for the entire season.

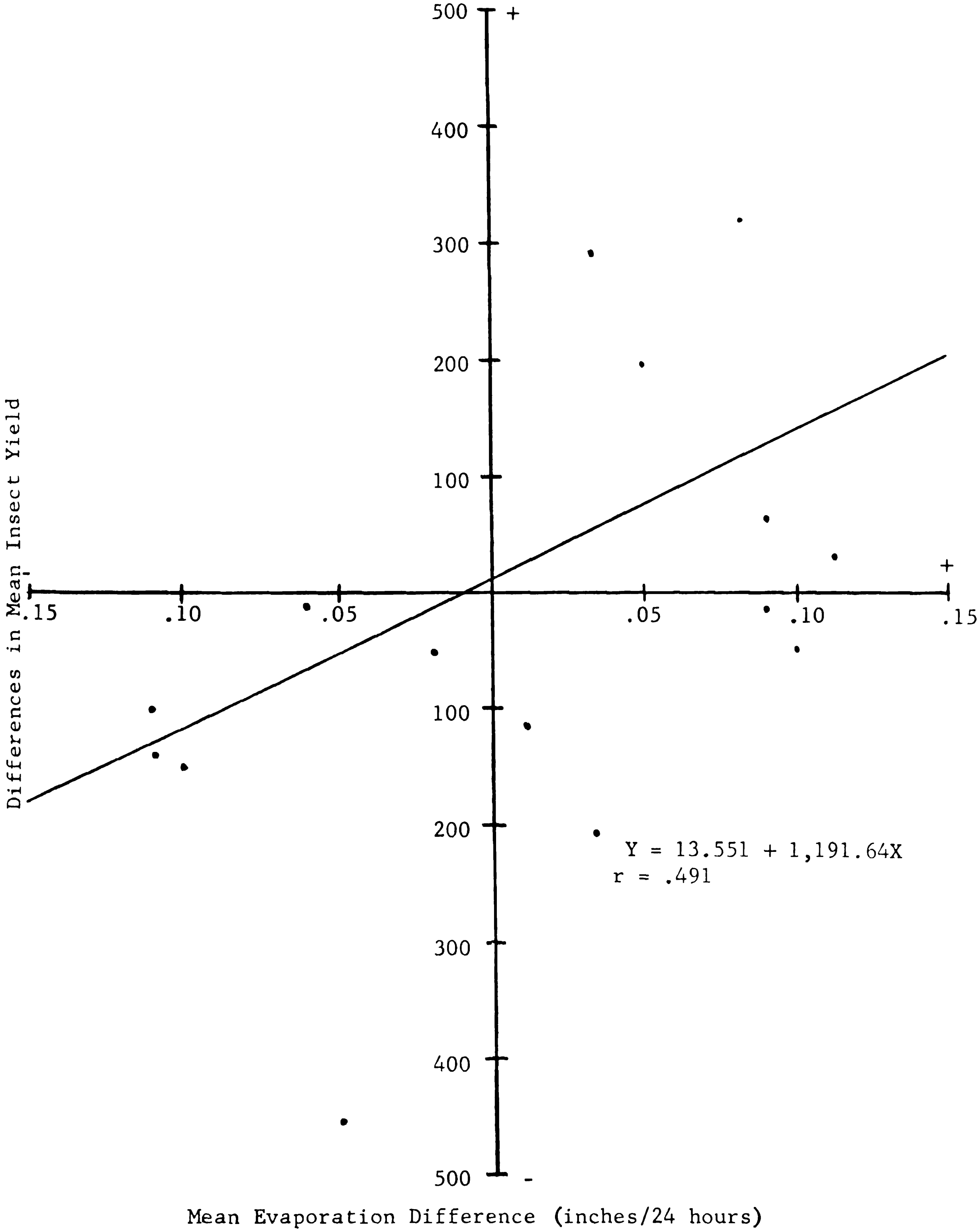

Fig. 13.--Relationship between mean evaporation differences and mean insect yield differences, between the two 3-day sample periods within each woodlot, for the entire season.

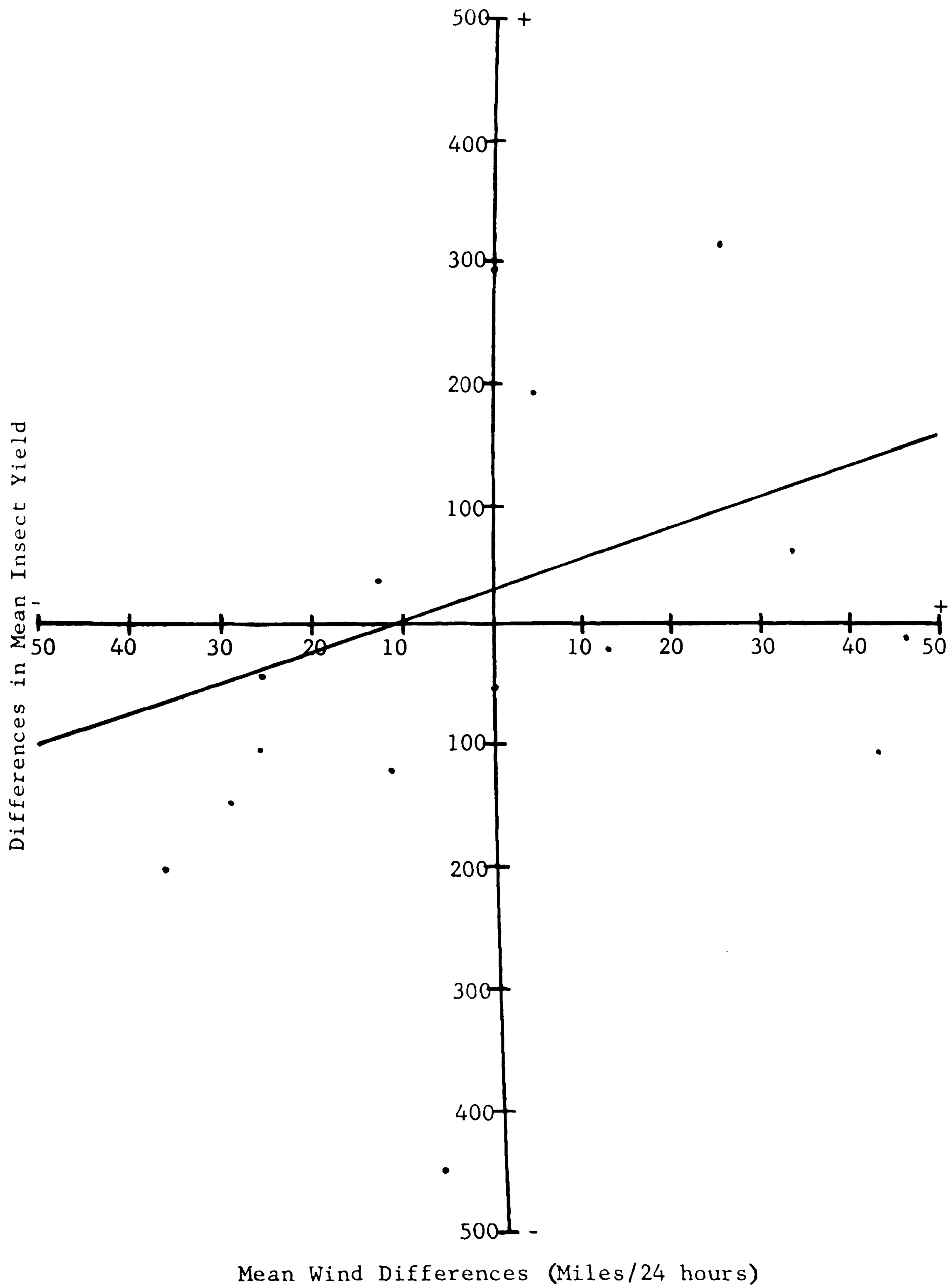

Fig. 14.--Relationship between mean wind differences and mean insect yield differences, between the two 3-day sample periods within each woodlot, for the entire season.

coefficient $Ry.x_1x_2x_3$ equaled .701, where y = yield, x_1 = temperature, x_2 = evaporation and x_3 = wind. It can be stated that $(.701)^2$ or 49.2% of the variation in yield could be accounted for by the parameters x_1, x_2 and x_3. The coefficient was just significant at the 5% level, indicating that the regression slope was different from zero. To determine what effect each individual factor had on the yield, with the others held constant, partial regression coefficients were calculated. The effect of temperature on yield with evaporation and wind held constant, was calculated by $byx_1.x_2x_3 = 42.319$. One unit change in temperature causes a 42.319 unit change in yield. One unit change in evaporation, $byx_2.x_1x_3 = 602.347$, will cause a 602.347 unit change in yield. This relationship is made clearer when the unit for evaporation, one inch in 24 hours, is related to actual Weather Bureau measurements of hundredths of an inch in 24 hours. Wind had the least effect on yield of the three factors analyzed. The wind $byx_3.x_1x_2 = 1.049$ is almost a one to one unit change.

The only factor that approached significance at the 5% level, was temperature. To single out one factor as affecting yield the greatest, is in a sense unrealistic, because all three factors are closely interrelated. However, temperature is affected the least by evaporation and wind, and contributes the most to the observed differences in yield. Therefore, by correcting the Malaise trap for temperature, more reliable results could be obtained. Results in this study were not corrected for temperature. The differences analyzed were mainly between the control and treated areas, where the influence of weather was assumed to be constant at any given date.

However, correction should be made for weather if the traps were being used for comparison of insect yield between widely separated areas on a given date or for different dates.

SUMMARY AND CONCLUSIONS

Measurement of soil nutrients and frequency of tree species within each woodlot revealed that pretreatment differences existed between the control and dieldrin treated woodlots. Although these differences in soil fertility and vegetation are apparent, their relationship to the insect fauna could not be determined. Interpretation of the differences obtained for community size and structure between areas is limited. Many of the differences could result from either the inherent community dissimilarity or dieldrin treatment.

The large difference in yield between areas shown for the potato leaf hopper can possibly be explained by considering the size of the woodlots (Figure 1) and the intensity of agriculture in the treated area. It was noted that this insect is commonly found on alfalfa, where large populations build up during the summer. The treated area is intensely farmed with large fields of alfalfa adjacent to the woodlots. The large number of leafhoppers collected in this area could have been trapped as they moved into the woods from high populations in adjacent alfalfa fields. The harvestmen *L. vittatum* were also more abundant in the treated area. Greater diversity in vegetation may have provided a more suitable habitat. The third species under consideration is the strawberry root weevil. This species was completely absent in the treated woodlots. It is sometimes a pest in nursery beds, where it feeds on the roots of seedlings. Recommended control procedures for the nursery are soil applications of aldrin or dieldrin. Therefore, the presence of dieldrin in the soil from the treated areas most likely explains this species absence.

The analysis of community structure showed the control and treated areas to be different in terms of diversity and H/P ratio. If we assume that the estimates obtained for the above parameters are reliable within each area, then the observed differences are representative of the two communities, regardless of the presence of absence of dieldrin. The decrease in diversity with time is shown for both areas. Here the similarity ends. The relationship between H/P ratio and diversity are not consistent. This inconsistency can be explained if the check woodlots are more unstable communities. Low soil fertility and low faunal diversity show this to be the case. Thus, the large increase in the H/P ratio is possibly a reflection of this instability. Any gross side-effects of the dieldrin application in the treated area are not evident in the faunal diversity or H/P ratio for the segment of the insect community sampled.

The analysis for reliability of the Malaise trap showed that a significant portion of the day-to-day differences in yield could be accounted for by temperature, evaporation and wind. A certain amount of error was introduced into the analysis because the measurement of the above factors was not carried out in the woodlots. Forest areas generally tend to moderate the effect of weather factors. Temperature is lower because much of the radiant energy from the sun is absorbed by the canopy. Evaporation is also reduced because of higher relative humidity and less air movement (Geiger, 1959). More accurate measurement of these weather factors would probably help to explain more of the observed variability in yield. Since temperature differences alone explain a large amount of the variability in yield, correction at least for this factor should be made if results independent of weather are desired.

In studies of this type where information on the yield of mobile insects is required, the Malaise trap seems to be a reliable and efficient sampling device. Continuous sampling (24 hours a day), along with trash-free samples reduce the time and money required to operate a sampling program with this trap.

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APPENDIX I

SAMPLING DATES FOR THE ENTIRE TRAPPING PERIOD

The (a) and (b) designate the first and second 3-day sampling periods within each woodlot. The traps were moved and changed about noon on the dates indicated. The 12-day lapse in sampling between Series I and Series II was due to trap malfunction.

	C1 and T1		C2 and T2		C3 and T3	
Series	a	b	a	b	a	b
I	June 17-20	June 20-23	June 23-26	June 26-29	June 29-July 2	July 2-5
II	July 17-20	July 20-23	July 23-26	July 26-29	July 29-Aug. 1	Aug. 1-4
III	Aug. 4-7	Aug. 7-10	Aug. 10-13	Aug. 13-16	Aug. 16-19	Aug. 19-22
IV	Aug. 22-25	Aug. 25-28	Aug. 28-31	Aug. 31-Sept. 3	Sept. 3-6	Sept. 6-9
V	Sept. 9-12	Sept. 12-15	Sept. 15-18	Sept. 18-21	Sept. 21-24	Sept. 24-27

APPENDIX II

SEASONAL ABUNDANCE FOR THE INSECT FAMILIES COLLECTED DURING THE STUDY AND HERBIVORE OR PREDATOR DESIGNATIONS FOR EACH FAMILY

Seasonal abundance for each family and species considered in this study is presented. The mean number of individuals trapped per 3-day period within each woodlot, for the entire season, was calculated. The date given at the top of each column is the first day of the 6-day period each trap was left in a woodlot. Means were calculated by adding the number of individuals from the two consecutive 3-day samples from the control and the two consecutive 3-day samples from the treated woodlots, and dividing by four. Means greater than 2 are rounded off to the nearest unit. The first column indicates whether the family was considered herbiverous (H) or predacous (P). Families marked with a dash (-) were not considered, because of small numbers or difficulty in making an accurate trophic designation.

	H or P	6/17	6/23	6/29	7/17	7/23
THYSANURA						
Machilidae	-					
ORTHOPTERA						
Cyrtacanthacridinae	-					
Phaneropterinae	-					
Pseudophyllinae	-					
Oecanthinae	-					
Phasmidae	-			.25		.25
Blattidae	-	4		.75		
PSOCOPTERA						
--		1		.25	.25	
THYSANOPTERA						
Phloeothripidae	-	.50	.75	1.50	.25	.75
HEMIPTERA						
Anthocoridae	P		.25			
Miridae	H	9	5	6	1.25	1.50
Reduviidae	P		.50	.75		
Nabidae	P			.75		
Tingidae	H				.25	
Piesmidae	H	.25				
Lygaeidae	H					
Coreidae	H					.25
Coriscidae	H	.50				
Aradidae	P			.25		
Pentatomidae	P		.25	.25	.25	
HOMOPTERA						
Membracidae	H	5	1.75	3	.50	
Cicadellidae	H	40	128	159	43	42
<u>Empoasca fabae</u>	H	27	108	138	32	29
Cercopidae	H	1.50	.75	1.50	1.75	1.25
Fulgoroidea	H		4	.25	5	.25
Psyllidae	H	.50	.25	1		
Aphididae	H	1	1.25	.50		
NEUROPTERA						
Hemerobiidae	-	.75			.25	
Chrysopidae	-	.75		.25	.25	
COLEOPTERA						
Cupesidae	H			.25		.25
Carabidae	P	.50	.50	.50	1.50	1.25
Ptiliidae	H					
Leiodidae	H				.25	
Staphylinidae	P	.25		1.75		
Cantharidae	H	6	4	1	.75	.75
Lampyridae	H	5	.25	4	1	.25
Lycidae	H					.25
Ostomidae	H			.25		
Cleridae	P	.50	.25	.50	.25	1
Elateridae	H	3	1.50	1.75	.75	.75
Buprestidae	H					

7/29	8/4	8/10	8/16	8/22	8/28	9/3	9/9	9/15	9/21
			.25						
	.25								
				.25					
						.25			
				1.25			1.25		
.25						.25			
	.75	1	.50	1	.25	.50	1.25	.75	.25
.25	1.50					.25	.75		
							.25		
.75	1.50	1.25	1.25	1.75	1	.25	1.50	1	1
		.25			.25				
			.25						
	.25								
	.25								
		.25		.25		.25			
		.25		.25					
20	25	4	46	14	3	17	9	27	18
14	27	6	46	5	2	12	4	5	5
1.25	2	.25		.50	.50				
	.75	1.25	1.25	4	10	4	4	4	2
	.25								
.25	.50	.50	.75	.25					
			.25		.50		.25		.25
	.25						.25		
	.25								
1.25	1.75	.25	.25	.75	.25	.75	.25	1.25	
	.25								
				.25	.25		.25		
	1	.75	.25	.50			.50		.50
		.25							
	.50			.25			.50		
				.50		.25			.25
.25	.25	1		.50	.50				.25
1.25	1.25	.75		1		7	19	8	.75
				.25					

	H or P	6/17	6/23	6/29	7/17	7/23
COLEOPTERA (Continued)						
Ptilodactylidae	H			1.25		
Helodidae	H		.75			
Rhizophagidae	H					
Cryptophagidae	H	.50	.75	.25		
Erotylidae	H					
Nitidulidae	H		.25			.25
Endomychidae	H					
Coccinellidae	P	.50	.50	.25		.75
Anthicidae	H		.25	.25		
Euglenidae	H		.25			
Pyrochroidae	H				.25	
Pedilidae	H			.75		
Mordellidae	H	1.50	1.25	5	12	2
Alleculidae	H		.50	18	.50	.25
Melandryidae	H	.25	.25	.50		.75
Anobiidae	H		.50		.50	
Cerambycidae	h	6	3	10	3	.75
Chrysomelidae	H		.50	.50	.50	.25
Anthribidae	H		.25			
Curculionidae	H	9	11	16	1.50	36
<u>Brachyrhinus ovatus</u>	H	7	5	13	1.25	36
Scolytidae	H				.25	1
MECOPTERA						
Panorpidae	-					.50
TRICHOPTERA						
Hydroptilidae	-	.25		.75	2	.25
Limnephilidae	-				.25	
LEPIDOPTERA						
Satyridae	H	.50	.50	3	1.25	
Nymphalidae	H	.50	.25			
Hesperiidae	H	.75			.50	.25
Arctiidae	H	.25				
Noctuidae	H	2	3	8	10	12
Thyatiridae	H	.25				
Geometridae	H		1.25	.75	.50	.25
Pyralidae	H	.25	.50		.75	
Aegeriidae	H					
Microlepidoptera	H	61	44	29	20	15
DIPTERA						
Tipulidae	H	4	1.25	1	.25	1.75
Psychodidae	-	2	2	.75	1.50	.25
Culicidae	-	5	3	3	1.75	1
Ceratopogonidae	P	12	4	1	.50	.50
Chironomidae	H	47	44	13	45	36
Anisopodidae	H		.25	.25	.25	
Bibionidae	H				1	.75
Mycetophilidae	H	34	17	15	12	14

7/29	8/4	8/10	8/16	8/22	8/28	9/3	9/9	9/15	9/21
.25									
						.25			
		.50						.50	
.25		.50							
					.25				
.25	.75		.25	.25					
	.25								
.75	8	.25	.50	.75		.50	.25	.25	
	.25								
.25	1	1			.25	.25		.50	
1	3	.25	.50	1					
			.50	.25		.25		1.25	
30	5	25	12	3	1.50	7	3	3	3
30	4	25	12	1	.25	4	1.25	1	1
	.75	.50		1		.25			.25
.25									
								.25	
4	5	5	4	1.75	1.50	2	2	.50	
	.25	.50							
	.25								
14	31	23	9	17	5	4	4	3	3
	.75	.25	1.25	2	.50	3	1.50	.75	1.25
.25	.25	.25	1	.75		.25	.50	1	3
.50	1	1.25	.75	1.75	1.50	1.25	1.25	3	5
	.25	.50	.25	.50				.75	1.75
4	8	3	1.25	10	4	3	6	7	.75
				.25					.25
7	8	10	15	8	8	42	25	42	44

	H or P	6/17	6/23	6/29	7/17	7/23
DIPTERA (Continued)						
Sciaridae	H	24	26	70	3	8
Cecidomyiidae	H	203	138	131	67	93
Xylophagidae	H			4	.25	
Xylomyidae	-	1.25	4	.50	1	.25
Stratiomyidae	H	2	2	1.50	.75	.50
Tabanidae	P	.25	.25			
Rhagionidae	P	1.25				
Therevidae	H	.25		.25	.25	.25
Asilidae	P	1.50	1.25	3	.75	2
Empididae	P	10	2	3	1.50	.75
Dolichopodidae	P	9	6	5	5	2
Phoridae	H	3	4	7	5	1.50
Platypezidae	H	.25		.75	.25	
Pipunculidae	P	1.25	.25	6	3	.50
Syrphidae	H	2	1	3	.75	
Psilidae	-	6	3	5		
Otitidae	H	.75		.50	1	
Tephritidae	H	5		.25	1.25	
Helcomyzidae	H					
Sciomyzidae	P	.25	.25			
Lauxaniidae	H	4	1.75	2		.50
Lonchaeidae	H	23	4	5	4	
Milichiidae	H	.75	.75		.25	
Drosophilidae	H	3	1.75	2	.25	1
Chloropidae	H	1.25	1	3	.25	.75
Agromyzidae	H	3	.50	5	1.75	
Clusiodidae	-	12	7	11	7	4
Anthomyiidae	H	91	9	7	7	1
Muscidae	H	23	14	17	7	1.75
Calliphoridae	H	.75	.75	1	.75	.50
Sarcophagidae	H	82	6	17	15	5
Tachinidae	P	3	.25	.25	1	.50
Micropezidae	-	.50	.25	1	.25	
HYMENOPTERA						
Pamphiliidae	H					
Braconidae	P	.75	3	3	1.75	1.25
Ichneumonidae	P	5	3	6	3	3
Chalcidoidea	P	.50	.75	.50	.50	.75
Cynipidae	H	.50	.50			.50
Chrysididae	P	.75				
Tiphiidae	P					
Sapygidae	P	.25				
Formicidae	H	5	7	8	1	7
Vespidae	P	.25	.25			
Sphecidae	P	1.25	3	5	3	1.25
Andrenidae	H	.75				
Halictidae	H	.50			.25	
Megachilidae	H	.25				

6/29	8/4	8/10	8/16	8/22	8/28	9/3	9/9	9/15	9/21
3	14	3	7	8	5	33	122	15	39
51	135	68	191	212	52	106	185	60	55
.75	.50		.25						
.50	.50			.25					
.25	.75	.25							
.50	.25	.25	.25	1.25					.25
.75	1.50	.25	.75	1.25	.50	.50	1	.25	.25
1.50	5	1	1.25	6	4	5	8	.50	1.25
1	4	.75	4	.25	.25	.75	1.50	.75	9
				.25			.50		.25
1	5		3	5	.25		3		1
.50	.25	.75	.25	.75	.25	.50	1	.25	
	.25							.25	1
.25									.25
.25		.25						.25	
				.25	.25				
.25		.50		.25			.25		.50
.75							.25		
1.50	.25	.25	1.75	1	.25	3	4	1	5
.50	.25								
				.25			.25	.50	
4	5	.75	2	2	.25	1.25	.50	.25	.75
2	1.25	3	.25	2	.50		.75	.25	.25
2	1.25	.75	1.50	4	.50	.25	1.25	4	4
	.50		.25	.25			1	.75	
3	1.75	1.25	.25	.50		.25	1	1	.50
	.25						.50		
1.50		.25							
	5	.50							
1.75	5	3	3	1	.50	1.50	1.25		1.75
2	1.75	2	1.75	1.75	.75	1	.75	.25	.50
.50	1.50	1.25		.50	.50	1.25	1.75	1	1
.50	.50	.25		.25			.50		
			.50						
			.25						
4	1.50	3	.75	1	3	4		5	1
.25		.25	.50		.25				
1.25	1.75	.25	.50	.25			.25		

	H or P	6/17	6/23	6/29	7/17	7/23
HYMENOPTERA (Continued)						
Apidae	H	.25				
PHALANGIDA						
--	-	26	54	31	14	11
Leiobunum vittatum		16	36	18	9	8

7/29	8/4	8/10	8/16	8/22	8/28	9/3	9/9	9/15	9/21
							.25		
15	19	22	6	11	7	3	4	2	1
5	13	17	5	7	4	3	3	.75	.25