FINAL REPORT

I. TITLE: CYCLING AND EFFECTS OF ^{36}Cl LABELED DDT ON SOIL INVERTEBRATES

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DISCLAIMER

II. INTRODUCTION

On June 10, 1969 a single application of ^{36}Cl DDT was made on a 4 ha (10 A) old field herbaceous community in west central Ohio (Champaign, Co.). The radiolabeled insecticide was applied at the rate of 1.12 kg/ha (1 lb/A) with a total activity of 10.2 mc over the entire site. Approximately 2 ppm DDT were present in the uppermost 4 cm of soil. Both the 4 ha treated (T) site and the control or untreated (UT) site were located within an inactivated state wildlife area of 207 ha (518 A) near Urbana, Ohio. During the 1940's the area was used for pheasant rearing, and prior to this project no known pesticide applications were made on the site.

The research reported here was conducted in cooperation with colleagues at Ohio State University. Their aspect of the total project was reported by Bandy and Peterle (1972).

Original objectives of the soil ecological research were as follows:

1. To determine the cycling of ^{36}Cl DDT residues, the possibility of storage quilibrium, and the magnification of residues in soil microcommunities.

2. To describe the presence of DDT residues and metabolites in soil invertebrates.

3. To determine alterations in the invertebrate food-web relationships in litter and soil of an old field herbaceous community.

4. To determine the qualitative (including species diversity) and quantitative population density changes in invertebrate fauna of litter and soil resulting from the application of technical DDT.

5. To determine the time-related changes in invertebrates over at least a three-year period after insecticide application.

III. METHODS

A. Sampling Scheme

Over the three year field collection period (January 1969 to January 1972) of this project a total of 1500 soil samples were taken. These were collected monthly from both the T and UT research sites following a stratified random sampling design (Peterson and Calvin 1965). Each soil core (5.4 cm in diameter) was divided into two sections: 1) an upper 3 cm (73.6 cc) sample including the litter and most of the organic matter, and 2) the lower 1 cm (18.4 cc) section composed mainly of mineral soil.

B. Laboratory Procedures

Various physical-chemical factors, radioisotopic assays, microbial respiration analyses and invertebrate extractions were carried out on each soil section individually. The minute size of these non-target soil invertebrates, their small spatial range of activity, their contagious distribution along with natural, broad population variations necessitated this separate microhabit-microcommunity approach and analysis. Dealing with this enormous bulk of samples and more than 450,000 invertebrates resulting from the extractions, laboratory analyses were not completed until June 1976. Although a massive analysis of community structural changes due to DDT has been conducted to date (1978), much more information will be forthcoming for a number of years, due to the comprehensive nature of the study. This is evidenced by the manuscripts with the appendix of this report.

Specific procedures and methods were as follows:

1. Physical-chemical factors:

   a. Soil moisture assay.

      Direct oven drying method after Gardner (1965)

   b. Soil texture analysis.

      1) Standardized seiving procedure

      2) Clay fraction-hydrometer method both methods after Day (1965)

   c. Soil pH.

      Wet analyses using Orion pH probe after Peech (1965)

   d. Isotopic assay methods.

      1) Ring labeled ^{36}Cl DDT

      2) Liquid scintillation preparation and assay methods as used by Dindal (1970) and Dindal and Wurzinger (1971)

2. Biological and ecological factors:

   a. Microbial respiration.

      24 hr incubation method after Stotzky (1965)

   b. Modified Tullgren funnel extraction method.

c. Community structural evaluations.

1) Shannon-Weiner species diversity ($\bar{H}=H'$)

$\bar{H} = C/N\ (N \log_{10} N - \ \ n \log_{10} n)$

(Lloyd, Zar and Karr 1968)

and

$H' = \sum p_i \log_{10} p_i$

(Shannon and Weaver 1963)

2) Bray-Curtis ordination (Bray and Curtis 1957)

3) Interspecific association (Cole 1949)

IV. RESULTS AND DISCUSSION

A. Physical and Biological Site Characteristics

The dominant soils in both treated and untreated areas were gray-brown podzolics, specifically Crosby Silt Loam. According to the Seventh Approximation Classification this soil is considered an Alfisol and sub-classified as an Aeric Ochraqualf.

The top 4 cm of soil had an average pH of 6.45 ± 0.08 and an organic matter prercent of 5.1. An average textural evaluation was 8.8% sand, 74.1% silt, 17.1% clay and the bulk density of 1.31 gm/cc. Generally this soil was imperfectly drained having an optimum moisture percentage of 16.8.

Considering these physical factors separately, there were no significant correlations between any of them and the population dynamics or community structural characteristics observed. Furthermore, considering the lower 1 cm sample, no significant differences were found between physical factors or the faunal characteristics in the T and UT sites. Therefore, the remainder of the report deals with observations of the upper most 3 cm sample where significant faunal differences did exist.

Plant communities on the research sites were determined using the line intercept method. The dominant plants were as follows: Kentucky bluegrass (*Poa pratensis*), quackgrass (*Agropyron repens*), orchard grass (*Dactylis glomerata*), wild parsnip (*Pestinaca sativa*), wild carrot (*Damcus carota*), goldenrod (*Solidagao* spp.), ragweed (*Ambrosia artemisiifolia*) and ironweed (*Veronica* spp.).

B. Cycling of ^{36}Cl DDT Residues

Evidence collected in this study indicated that there were no residues, cycling, storage or magnification of radiolabeled DDT within the microarthropods collected. Laborious investigations testing all types of microarthopods with liquid scintillation spectrometry involving 100 min counts yielded no activity above background. It, therefore, can be concluded that if DDT residues were present in the soil microarthropods, they were there in concentrations much lower than the detectable limits.

Bandy and Peterle (1972) reported detectable residue concentrations in terrestrial macroarthropods such as millipedes (2-7 ppm), carabid beetles (1-2 ppm), ants (1 ppm) and crickets (0.7 ppm). These organisms were collected at the same time from the same sites as our collections, and assay methods were identical. These macroarthropods are all much larger organisms than the soil microfauna of this specific project. Also, carabid beetles and ants are predaceous and scavengers within the soil litter system and are at the top of food chains where maximum biological magnification should be exhibited. Concentration levels within these top consumers should, therefore, be very high relative to levels to be expected within most of the microarthropods which are first and second level decomposers (many of them fungivores). This fact was considered to be the reason no detectable levels were found in microfauna of the soil.

C. DDT Residues in Specific Soil Invertebrates

Stimulated by the negative findings given above and by those positive data presented by Bandy and Peterle (1972) we embarked on a laboratory project to determine the comparative rates of accumulation and excretion of ^{36}Cl DDT in two species of terrestrial snails *Cepaea hortensis* (Muller) and *Otala lactea* (Muller). These species represent common decomposers found in many communities including old field sites. Positive results from this objective were presented by Dindal and Wurzinger (1971) and Wurzinger and Dindal (1975); copies of both reprints are attached in Appendix A.

D. Soil Invertebrate Food Web Relationships

1. Potential microbial interactions: Since the energy source for so many microarthropods is fungi, the microbial respiration for each sample was assayed to see if any relationships existed with DDT and/or soil faunal dynamics. For example, some pesticides produced and tested by Niagara Chemical Co.[1] have shown definite stimulation of certain common soil fungi, namely *Trichoderma* (K.J. Ensing, pers. comm.). Data from this research suggested the same possibility in that after an initial 1 mo suppression period, microbial respiration of T soil was increased one to three fold over that of the UT soil samples. (Details are given in Appendix B in Dindal, Folts and Norton [1975]). Unfortunately, this method does not permit the determination of just what microorganisms (be they bacteria, fungi, actinomycetes or protozoa) may have been mainly responsible for the observed results. In any case, C.A. Edwards (pers. comm.) of Rothamsted Experiment Station, also stimulated by our findings, found the same type of microbial respiration inhancement when he tested many types of pesticides. This is a fertile area for future research.

Finally, no soil faunal population or community structural patterns followed directly those trends observed in the microbial respiration.

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[1] FMC Corp., Middleport, NY

2. Collembola and mesostigmatid mites: Population from the first 2 yr indicated fluctuations and predator-prey interactions caused indirectly by the DDT application. Mesostigmatid mite predator populations were reduced by 2/3 to 1/2 in the T sites (compared to the UT site) for 4 mo following application. Even though the prey species (Collembola) were also suppressed initially for 2 mo, within 6 mo after application their numbers increased to twice those on the UT site. This was apparently the result of reduced predation. A year later, mesostigmatid populations on the T site doubled over the UT area, and as a result collembolan populations were reduced to almost zero (Figures 1 and 2, Appendix C).

E. Populations and Community Structural Alterations Resulting from the DDT Application

1. Total microarthropod community: More than 200 different species of microarthropods were collected and identified from the study sites (see survey list in Appendix D). Among these there were approximately 50 new or undetermined species; this taxonomic condition within soil invertebrate populations is not uncommon and will take years to remedy.

An initial 2 mo suppression of soil microarthropod members occurred in the upper 3 cm immediately following treatment (Figure 3, Appendix D). A 2 mo lag period followed. Then the populations were stimulated for the months of October and November. Non-significant differences were observed for all months until the autumn of the following year when again significant differences appeared.

Specific details on all microarthropods are presented in Dindal, Folts and Norton (1975) (Appendix B).

2. Oribatid mite community structure: As fungivores, oribatid mites are important decomposer organisms in litter of all vegetative communities. In general, they appear to show a positive response to the indirect or direct effects of DDT. Details of these responses are presented in Dindal, Folts and Norton (1975) in Appendix B and Folts (1972) in Appendix E. Also, responses to DDT as a selection pressure on oribatids are compared with the effects of other human impacts on these mites (Dindal 1977, Appendix F).

3. Prostigmatid mite community structure: Numerous representatives of this diverse mite group were collected from the study areas; during the autumn of each year on the T site total population numbers were highly significantly different from those on the UT area (Figure 4, Appendix G). Although some differences in species diversity existed due to treatment (bracketed months in Figure 5, Appendix G), differences were not so dramatic as those seen among oribatid mites. Many more years of careful analyses must be undertaken before the complete species-treatment interactions will be known.

Responses of the soil Prostigmata to DDT as a selection pressure have been compared with influences of other human activities (Dindal and Norton 1979, Appendix H).

F. Time Related Changes in Populations Related to DDT Treatment

1. Oribatid mites: There appeared to be two definite increases in species diversity annually, one in the spring and another in the fall on the T area.

Also, using the Bray-Curtis ordination method for graphic analyses of community similarity, it was observed that DDT treatment did cause time related changes among oribatid populations. Figure 6 (Appendix I) represents the preliminary results of a very complicated and time-consuming analysis which accounts for its lack of completeness. However, the obvious trends are that treatment tends to increase the level of similarity of the oribatid communities over that observed in the UT site. As detailed in Folts (1972) (Appendix E), certain species populations were selected for by DDT treatment. Some of these organisms are new colonizing species common only to the T site. This positive selection response and commonality of species tends to bring the communities more closely together.

2. Prostigmatid mites: As already mentioned total numbers of the soil Prostigmata on the T site were increased yearly during autumn. The specific reason for this is not known and requires further detailed study.

V. CONCLUSIONS

Considering the data accumulated from 450,000 invertebrates over three years of collecting, there remains much yet to be analysed and complied; therefore, the following list of conclusions and those in the manuscripts are but the beginning of the information that is yet to come from this specific research project.

1. DDT, radiolabeled with ^{36}Cl (total activity of 10.2 mc) and applied in the field at the rate of 1.12 kg/ha, cannot be detected within decomposer microarthropods using liquid scintillation spectrometry.

2. Soil microarthropods exhibit both positive and negative responses to direct and indirect effects of DDT.

3. Faunal simplification (decreased diversity) resulting from pesticide application as reported by many others does not apply to the oribatid and prostigmatid mites of the old field.

4. New colonization is possible by some species of Acari as a result of DDT application.

5. The following oribatid mite taxon can be considered DDT sensitive and, therefore, should be useful as impact indicator species:

   Brachychthonius spp.
   Oppiella nova
   Ceratozetes mediocris
   Oppia minus
   Quadroppia spp.
   Nothrus spp.

6. The following soil prostigmatid mite taxa can be considered DDT sensitive and, therefore, should be useful as impact indicator species:

   Scutacarus spp.
   Eupodes spp.
   Microdispus spp.
   Cocceupodes spp.

7. Soil microbial respiration is enhanced by a single DDT application of 1 kg/ha.

8. No apparent relationships exist between the increased microbial respiration and soil microarthropod population dynamics in this DDT treated old field.

9. No apparent relationships exist between soil pH, moisture levels, texture and soil microarthropod population dynamics.

10. Microarthropod community structure (species diversity and richness, interspecific relationships and similarity) are definitely affected by a single application of DDT.

11. The Prostigmata are the most numerous mites in the soil of an old field in central Ohio.

12. After a single feeding a storage equilibrium of DDT occurs in the digestive tract and hepatopancreas of the terrestrial snails Cepaea hortensis and Otala lactea.

13. In entire specimens of Cepaea hortensis, a body burden equilibrium of 11 ppm DDT was reached after a single feeding.

14. After a single feeding of DDT, two separate maximum residue concentration levels exist in the reproductive organs of Cepaea hortensis and Otala lactea.

15. Vertebrate predators feeding on terrestrial snails may be subjected to magnified concentrations of DDT residues.

16. Coprophagic decomposer organisms feeding on snail feces will be subject to much larger DDT concentrations.

17. Terrestrial snails represented by Cepaea and Otala are not killed by acute oral doses of DDT.

18. Within a three year period after a single application of DDT no effects on the soil faunal populations were seen below 3 cm of soil.

IV. INFORMATION DISSEMINATION

In addition to the five published manuscripts and one thesis, a number of papers originating from these data were given as seminars or as contributed papers at national scientific meetings as follows:

March 1971	Research progress report, New York State Workshop for Insect Pest Control Technicians, SUNY CESF.
May 1971	Invited Seminar, "Effects of DDT on soil invertebrates," Biology Department, University of Hartford, W. Hartford, CT.
Aug 1971	Contributed paper, "Effects of DDT on soil invertebrates," Soil Sci. Soc. Am. Annual Meetings, New York City. (Abst in 1971 Agron. Abst. p. 117. SSSA, Madison, Wisc.)
Aug 1972	Contributed paper, "Effects of DDT on soil microcommunity structure", AIBS and Ecol. Soc. Am. Meetings, Univ. Minn. (Abst in 1972, Bull. Ecol. Soc. Am. 53(2):28).
Sept 1973	Contributed paper, "Effects of DDT on microcommunity structure of oribatid mites". Vth International Colloquium on Soil Zoology, Prague, Czechoslovakia.
Oct 1975	Invited paper, "Influence of human activities on oribatid mite communities". Entomol. Soc. Am. Meeting, Philadelphia, PA.
Aug 1978	Invited paper, "Influence of human activities on soil Prostigmata mite communities". Vth International Congress of Acarology, Mich. State Univ., E. Lansing, MI.

VII. LITERATURE CITED

(Literature citations given here are only those referred to in the text of this report. Each published manuscript in the appendix also possesses its' separate, specific reference section.)

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Shannon, W.E. and W. Weaver. 1963. The mathematical theory of communication. Univ. Ill. Press, Urbana, Ill.

Stotzky, G. 1965. Microbial respiration. Pages 1550-1558 in C.A. Black (ed). Methods of Soil Analysis. Pt. 2. Am. Soc. Agron. Madison.

Wurzinger, K-H. and D.L. Dindal. 1975. Dynamics of DDT in the terrestrial snail Otala lactea (Stylommatophora: Helicidae). Malocological Rev. 8:65-80.

APPENDIX C

Relationships of Collembola (Figure 1) and

Mesostigmata (Figure 2) populations

FIGURE 1:

COLLEMBOLAN POPULATIONS IN DDT TREATED AND UNTREATED OLD FIELD HERBACEOUS COMMUNITY

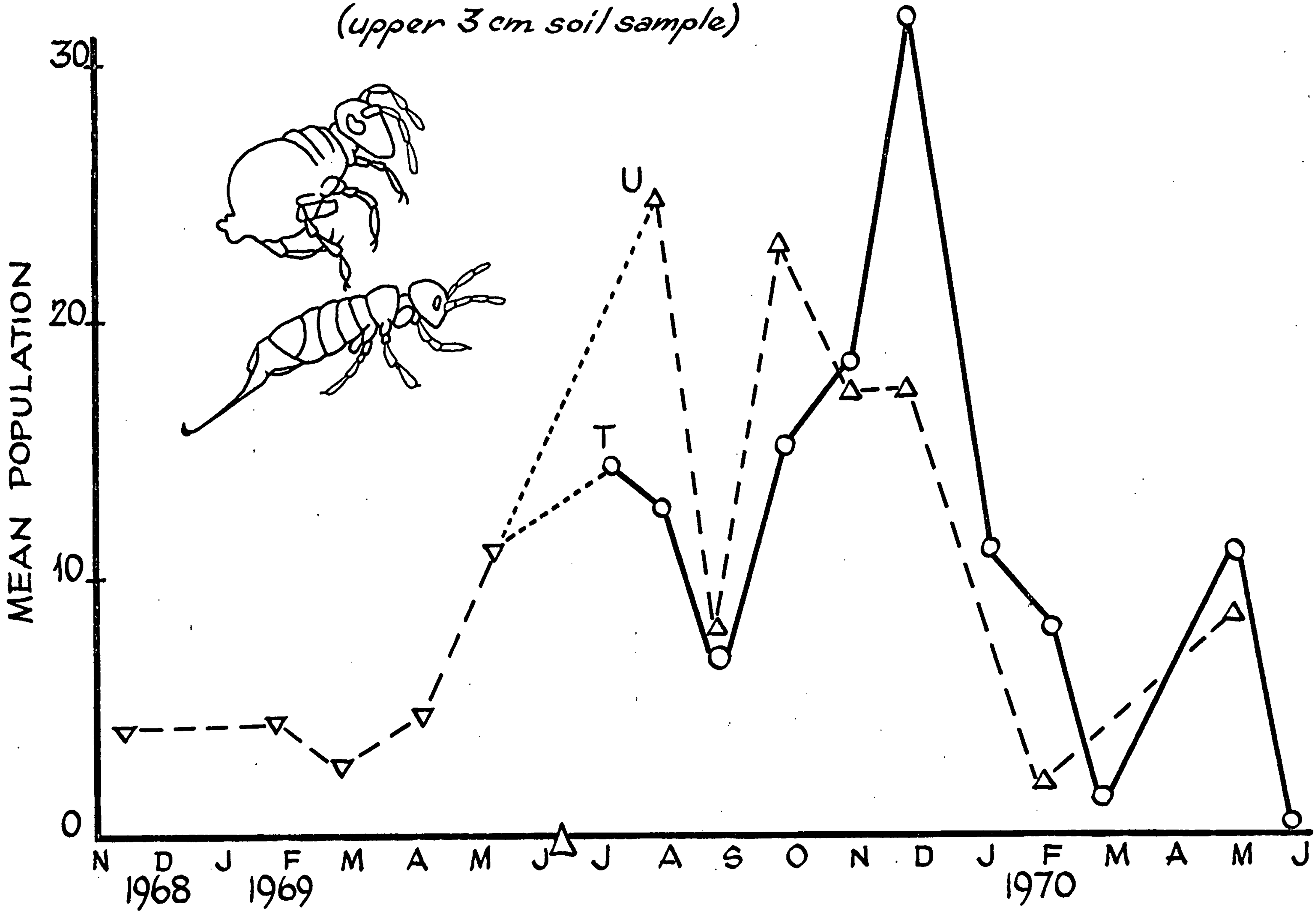
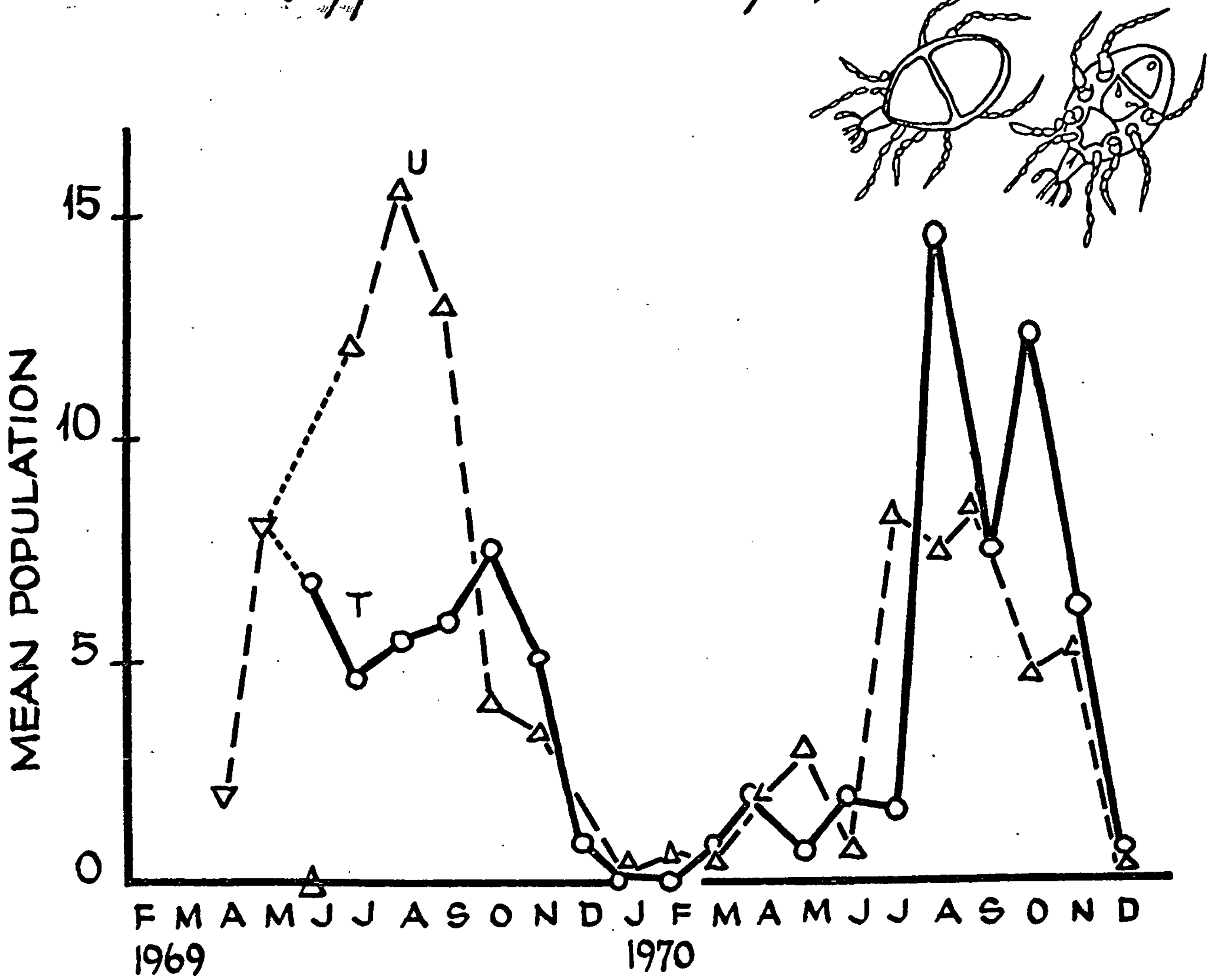


FIGURE 1:

FIGURE 2:

MESOSTIGMATID MITE POPULATIONS IN DDT TREATED & UNTREATED OLD FIELD COMMUNITY

(Upper 3 cm soil sample)



APPENDIX D

Survey lists of soil invertebrate taxa collected from old field study sites, Urbana, Champaign Co. Ohio

Figure 3: Dynamics of total microarthropod populations as influenced by a single DDT application

SURVEY LIST OF LITTER AND SOIL INVERTEBRATES FROM OLD FIELD HERBACEOUS COMMUNITIES
Urbana, Champaign Co., Ohio

Phylum ANNELIDA
    Order Oligochaeta
        ENCHYTRAEIDAE

Phylum MOLLUSCA
  Class Gastropoda
    Order Stylommatophora
        PUPILLIDAE

Phylum ARTHROPODA
  ClassArachnida
    Order Araneae
        GNAPHOSIDAE
            Drassyllus sp.
        DICTYNIDAE
        LYCOSIDAE
        MICRYPHANTIDAE
    Order Phalangida (1 sp.)
    Order Pseudoscorpionida
        NEOBISIIDAE
            Microbisium _confusum_ Hoff

    Order Acarina
      Suborder Mesostigmata (49 spp, 17 families)
        VEIGAIIDAE
            Veigaia _mitis_ (Berlese)
            Veigaia _planicola_ (Berlese) = _V_. _serrata_ _Willmann_
            Veigaia _pusilla_ (Berlese)
            Veigaia sp. A

        PARASITIDAE
            Parasitus sp. A
            Parasitus sp. B
            Pergamasus sp. X
            Pergamasus _crassipes_ (Linnaeus)

        NEOPARASITIDAE sp.

        PARHOLASPIDAE
            Holaspina _pulchella_ Berlese = _Neoparholaspulus_ _hurlbutti_ Krantz
            Neparholaspis _zwartae_ Marshall
            Calholaspis sp.

        MACROCHELIDAE
            Macrocheles sp.

        PODOCINIDAE
            Podocinum _pacificum_ Berlese

RHODACARIDAE

Rhodacarus sp.
Rhodacarus sp. X (possibly a *Rhodacarellus*)
Rhodacarellus silesiacus Willmann

ASCIDAE

Asca aphidioides (Linnaeus)
Asca garmani Hurlbutt
Asca ? nesoica
Arctoseius sp. nr. *ornatus* Evans
Gamasellodes sp. nr. *bicolor*
Lasioseius sp. A (may be listed just as *Lasioseius* sp.)
Lasioseius sp. B
Protogamasellus primitivus Karg

LAELAPIDAE

Hypoaspis sp. A
Hypoaspis sp. B
Hypoaspis sp. C
Cosmolaelaps sp. nr. *claviger* Berlese
Cosmolaelaps sp. B
Ololaelaps sp.
4 unknown species, Laelapidae A, B, C, D

PHYTOSEIIDAE

Amblyseius sp. A
Amblyseius sp. B
Amblyseius sp. C
Amblyseius sp. D

AMEROSEIIDAE

Ameroseius sp.

DIGAMASELLIDAE

Digamasellus sp.

ZERCONIDAE

Zercon sp.

PACHYLAELAPIDAE

Pachylaelaps sp.

EVIPHIDIDAE

Alliphis sp. nr. *chirophorus* Willmann
"*Eviphidid* sp." - unknown genus, only DNs available

EROPODIDAE

3 species, labeled uropodid A, B and C

TRACHYTIDAE

Dithinozercon sp.

Suborder Prostigmata (140 spp, 23 families)

1. Tarsonemini

TARSONEMIDAE (5 spp)

PYEMOTIDAE

Neopygmephorus (12 spp)
Pseudopygmephorus (1 sp)
Pygmephorus (1 sp)
Siteroptes (5 spp)
Microdispus (2 spp)
Pediculaster (1 sp)

SCUTACARIDAE

Scutacarus (26 spp)
Imparipes (8 spp)
Pygmodispus calcaratus (1 sp)

2. Eleutherengona

EUPODIDAE

Eupodes (5 spp)
Cocceupodes (2 spp)
Linopodes (1 sp)
Protereunetes (5 spp)

PENTHALEIDAE

Penthaleus (1 sp)

RHAGIDIIDAE

Rhagidia (8 spp)
Coccorhagidia (2 spp)

EREYNETIDAE (2 spp)

TYDEIDAE

Tydeus (3 spp)
Microtydeus (2 spp)
Tydaeolus tenuiclaviger (1 sp)
Coccotydeus (1 sp)
Paralorryia (1 sp)
Lorryia (4 spp)

TETRANYCHIDAE

Bryobia praetiosa (1 sp)
unknown larva (1 sp)

CHEYLETIDAE (1 sp)

TENUIPALPIDAE

Brevipalpus (1 sp)

RAPHIGNATHIDAE

Raphignathus (1 sp)

CUNAXIDAE

Cunaxoides (2 spp)
Cunaxa (1 sp)

BDELLIDAE (5 spp)
    Bdella longicornis
    Thoribdella
    Spinibdella tenuirostris
    Biscirus sylvaticus
    Cyta latirostris

STIGMAEIDAE
    Stigmaeus (2 spp)
    Cheylostigmaeus pannonicus (1 sp)
    Ledermuelleria clavata (1 sp)
    L. pectinata (1 sp)
    L. segnis (1 sp)
    Stigmalychus (1 sp)

3. Endeostigmata

LORDALYCHIDAE
    Lordalychus (1 sp)

NANORCHESTIDAE
    Nanorchestes arboriger (1 sp)
    Speleorchestes (1 sp)

PACHYGNATHIDAE
    Pachygnathus (2 spp)
    P. villosus (1 sp)
    P. sp nr *ornithorhynchus* (1 sp)
    Bimichaelia (1 sp)

ALICORHAGIDAE
    Alicorhagia (2 spp)

4. Parasitengona

TROMBIDIIDAE
    Dinothrombium (1 sp)
    Microtrombidium (1 sp)
    unknown larva (4 spp)

ERYTHRAEIDAE
    Leptus (Leptinae) (1 sp)
    ? genus (Callidosomatinae) (1 sp)

SMARIDIIDAE (1 sp)

5. Tetrapodili
ERIOPHYIDAE (1 sp)

Suborder Oribatei (= Cryptostigmata) (57 spp, 26 families)

Supercohort Oribatei Inferiores

PALAEACARIDAE (1 sp)
    Palacecarus hystricinus

HYPOCHTHONIIDAE (1 sp)
- *Hypochthonius rufulus*

BRACHYCHTHONIIDAE (10 spp)
- *Brachychthonius bimaculatus*
- *B. erosus*
- *B. italicus*
- *B. rostratus*
- *B. semiornatus*
- *Brachychthonius* spp
- *Liochthonius evansi*
- *L. scalaris*
- *L. fimbriatissma*

PHTHIRACARIDAE (2 spp)
- *Phthiracarus olivaceum*
- *Steganacarus diaphanum*

EUPHTHIRACARIDAE (2 spp)
- *Euphthiracarus* sp.
- *Rhysotritia ardua*

EPILOHMANNIDAE (1 sp)
- *Epilohmannia elongata*

LOHMANNIDAE (1 sp)
- *Lohmannia brevipes*

PERLOHMANNIIDAE (1 sp)
- *Perlohmannia*

NOTHRIDAE (2 spp)
- *Nothrus biciliatus*
- *Platynothrus* sp

NANHERMANNIIDAE (1 sp)
- *Masthermannia mamillaris*

Supercohort Oribatei Superiores

HERMANNIELLIDAE (1 sp)
- *Hermanniella subnigra*

DAMAEIDAE (2 spp)
- *Epidamaeus* spp

CEPHEIDAE (1 sp)
- *Oribatodes* sp.

GUSTAVIIDAE (1 sp)
- *Gustavia* sp

EREMOBELBIDAE (3 spp)
- *Eremobelba* sp.
- *Eremulus* sp.
- *Fosseremus* sp.

ASTEGISTIDAE (1 sp)
- *Cultroribula juncta*

TECTOCEPHIDAE (1 sp)
Tectocepheus velatus

OPPIIDAE (5 spp)
Oppiella (Oppia) nova
Oppia minus
Oppia sp
O. carolinae
Quadroppia ferrumequina

SUCTOBELBIDAE (1 sp)
Suctobelba laxtoni

PELOPIDAE (1 sp)
Peloptulus sp.

ACHIPTERIIDAE (2 spp)
Anachipteria achipteroides milleri
Anoribatella

ORIBATELLIDAE (1 sp)
Oribatella brevicornuta

CERTATOZETIDAE (5 spp)
Ceratozetes mediocris
C. gracilis
Ceratozates sp.
Chamobates sp
Trichoribatos sp.

GALUMNIDAE (5 spp)
Galumna lanceatum
Galumna spp
Pergalumna spp

ORIBATULIDAE (3 spp)
Scheloribates milleri
S. laevigatus
Oribatula sp

HAPLOZETIDAE (2 spp)
Haplozetes sp
Xylobates lophotricus

Class Pauropoda

PAUROPODIDAE
Pauropus sp.

Class Diplopoda
  Order Polydesmida (2 spp.)
    POLYDESMIDAE
      Scytonotus granulatus (Say)
      1 unknown sp.
  Order Julida (2 spp.)*

Class Symphyla (1 sp.)

Class Chilopoda
  Order Geophilomorpha
      Strigamia sp. nr. *branneri*
  Order Lithobiomorpha
      Nadabius sp.

Class Insecta
 Subclass Apterygota
  Order Protura
    EOSENTIOMIDAE
      Eosentomon (2 spp.)
    ACERENTOMIDAE
      Amerentulus americanus (Ewing)
  Order Thysanura
   Suborder Diplura
    Japygidae (1 sp.)
    Campodeidae (1 sp.)

  Order Collembola (23 spp)
      Friesia ?claviseta Axelton
      Neanura muscorum Templeton
      Micranurida furcifera Mills
      Pseudachorutes ?simplex Maynard
      Pseudachorutes aureofasciatus millsi Maynard
      Tullbergia clavata Mills
      Tullbergia granulata Mills
      Protaphorura sp.
      Onychiurus subtenius Folsom
      Onychiurus fimetarius L.
      Onychiurus armatus Tullberg
      Willowsia buski Lubbock
      Orchesella ainslisi Folsom
      Lepidocyrtus cyaneus Tullberg
      Pseudosinella violenta (Folsom)
      Folsomia elongata (MacGillivary)
      Folsomia diplophthalma Axelson
      Folsomia fimetaria L.
      Folsomia fimetaria coldaria Axelson
      Spinisotoma sp.
      Isotoma eunotabilis Folsom
      Isotomurus palustris (Muller)
      Sminthurinus quadrimaculatus Ryder

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* JULIDAE
      Ophyiulus pilosus (Newport)
      1 unknown sp.

Subclass Pterygota
- Order Orthoptera
  - TETTIGONIIDAE
- Order Psocoptera
  - LIPOSCELIDAE
    - *Liposceles* (1 sp.)
- Order Thysanoptera (4 spp.)
  - THRIPIDAE
    - *Thrips tabaci* Lindeman
  - PHLAEOTHRIPIDAE
    - *Eurythrips hindsi* Morgan
    - *Nesothrips bicolor* (Heeger)
    - *Glyptothrips flavescens* Hood

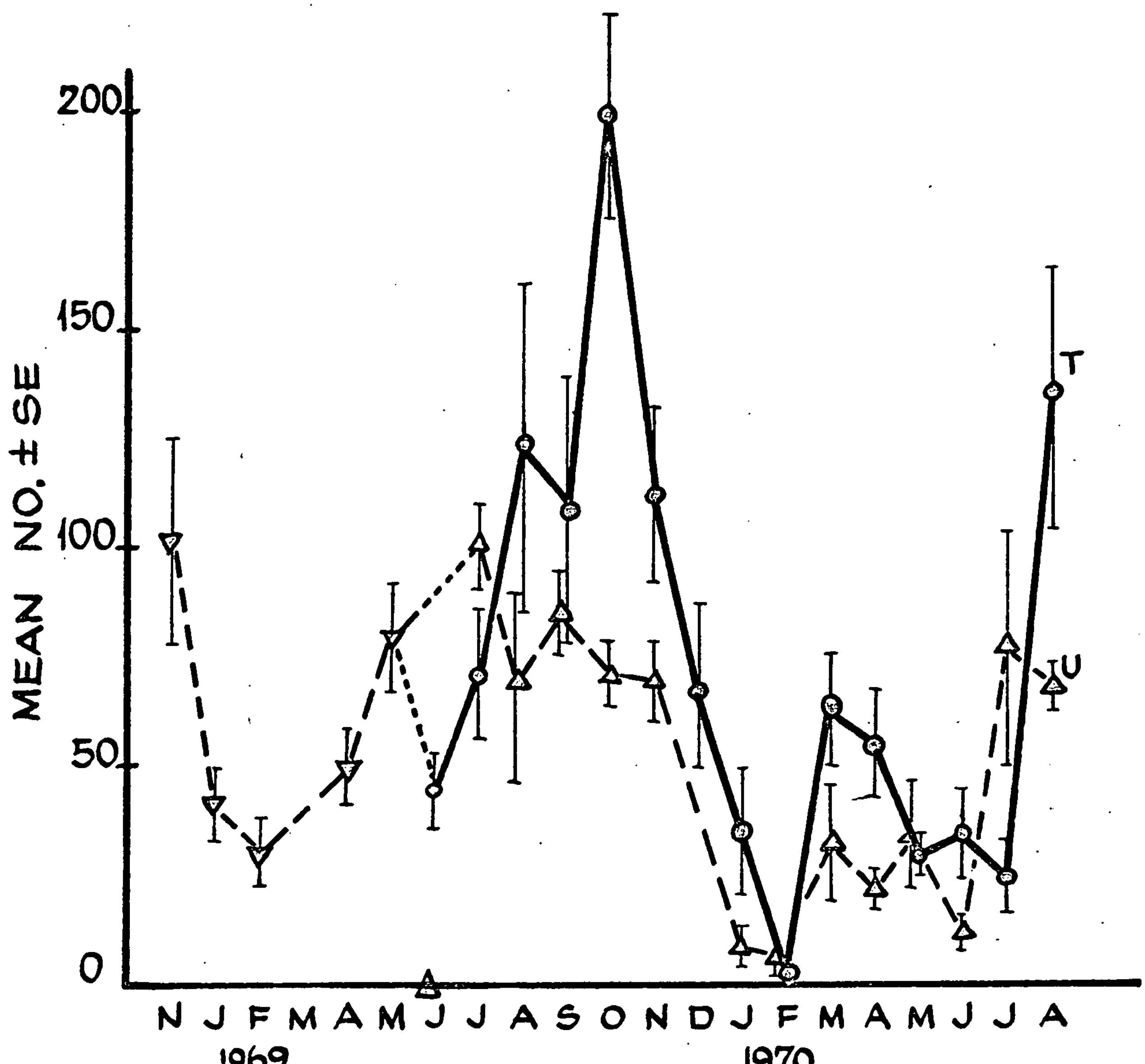
- Order Hemiptera (nymphs and adults)
- Order Homoptera (nymphs and adults)
  - CICADELLIDAE
  - CERCOPIDAE
  - PSYLLIDAE
  - APHIDIDAE
  - PSEUDOCODDICAE several spp. including
  - ERIOCOCCIDAE *Chnaurococcus trifolii* (Forbes)

- Order Coleoptera (larvae and adults)
- Order Diptera (larvae and adults)
- Order Hymenoptera
  - Suborder Apocrita (mostly Formicidae)

FIGURE 3:

TOTAL SOIL MICROARTHROPODS *from* DDT TREATED & UNTREATED OLD FIELD COMMUNITY

(upper 3 cm soil sample)



APPENDIX E

Effects of DDT on oribatid mite community

(unpubl. MS thesis)