STUDIES ON SEASONAL ABUNDANCE AND ECOLOGY OF MICHIGAN OPILIONES

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George E. Klee

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ABSTRACT

STUDIES ON SEASONAL ABUNDANCE AND ECOLOGY
OF MICHIGAN OPILIONES

by George E. Klee

Seasonal abundance and ecology of Opiliones in Monroe County, Wexford County and at several sites in the central part of Michigan were analyzed using several collecting techniques. Most of the work utilized a pit-fall trap collection method. This yielded large numbers of several species over the summer collecting season and showed definite population curves for these species over the sample periods.

Simultaneous collections with aerial insect traps in Monroe County showed large numbers of an arboreal species, Leiobunum vittatum. The occurrence of this species, rarely collected in pit traps, and a minute litter form, Crosbycus dasycnemus collected only by Berlese extraction hinted that the pit traps were biased toward collecting litter surface active forms. This should be taken into account in any pit trap work.

Preliminary data from Monroe County material showed larger numbers of Opiliones in insecticide treated areas. More detailed analysis of the vegetation of the treated and untreated plots revealed community differences that may have had a larger influence on numbers than the insecticide.

George E. Klee

Pit trap transect collections across central Michigan woodlot edges showed large differences in species collected in the mature woodlot and in adjacent old field situations. Large numbers of a litter species, Hadrobunus maculosus were collected in the old field areas. This species, previously reported from only scattered locations in the state, is apparently a dominant form. It has been collected from the majority of areas in which pit traps have been used. Its diurnal inactivity may explain previous sparse records.

Adults of several species have been maintained under laboratory conditions. Phalangium opilio has been maintained through all its life stages and a rearing and maintenance technique is presented. Eclosion and the initial molt of a species of Leiobunum is described in detail.

STUDIES ON SEASONAL ABUNDANCE AND ECOLOGY

OF MICHIGAN OPILIONES

By

George E. Klee

A THESIS

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INTRODUCTION

The author became interested in Opiliones after examining a great number of specimens of the order that were obtained in a 1965 monitoring study done by several members of the MSU Entomology Department. The large differences between a series of treated and untreated plots indicated possible effects of an insecticide.

Thus, a review of literature on the order was begun. It was soon found that numerous workers in Europe have done much in both the taxonomic and biological aspects, both in the past and recently. However, in the last twenty years very few North American researchers have worked on Opiliones. Clarence and Marie Goodnight have done a vast amount of work on the order in Central America and the Southwestern United States, and have written numerous articles since 1942 on material from these areas and on other collections from scattered parts of the world. They are considered the living authorities on Taxonomy of Opiliones in the Western Hemisphere. Sherman Bishop was active from 1924, initially with Crosby, another taxonomist, until 1949; when he published a paper on the Opiliones of New York. This included a useful key and excellent illustrations of most of the species. Arlan Edgar did a very comprehensive study on the biology and distribution of the order in Michigan for his Ph.D. dissertation (1960). He included a key to Michigan species in this work and has recently published a good key for all species of the Great Lakes

(1966). He has continued active work on the order in the United States, and is currently in the process of doing additional taxonomic revision.

Other than the foregoing, however, there has been surprisingly little detailed work done on the order beyond the taxonomic aspect. This seemed rather unusual for such a conspicuous member of the arachnid fauna. Edgar reported only 19 species for the order in Michigan in his 1966 paper; this relatively small number of species plus the limited amount of research on biology invited an ecological study of the order.

The Goodnights and Edgar were contacted and were very willing to be of assistance. The proximity of the authorities was also a very favorable factor. Dr. Goodnight is Head of the Biology Department at Western Michigan University in Kalamazoo, 80 miles southeast of East Lansing, while Dr. Edgar is a Professor of Biology at Alma College in Alma, 50 miles north. These factors, combined with the availability of the large amount of material collected over an entire summer from Monroe County (3100 specimens), a smaller seasonal collection from Wexford County in the northern part of the State (596 specimens), and approximately 1000 specimens in the Michigan State University Entomology Museum (50% determined) led the author into a detailed ecological study on selected species of the order in Michigan.

The project was designed to satisfy the following major objectives:

(I) To acquire a familiarity with taxonomy of Michigan representatives of the order, so that most of the large numbers of specimens involved could be identified by the author.

(II) To identify the Monroe Co. and Wexford Co. series collected in the summer of 1965. Seasonal abundance curves were to be made for the species with sizeable numbers. Most previous collecting had been done at irregular intervals in different parts of the state, with virtually no systematic or quantitative collections over an entire season. Such collections might give a better idea of when different species were present and when they were most abundant; possibly some information could be gained about the appearance of immature forms in these long series. Finally, comparisons of the insecticide treated and untreated woodlots were to be made.

(III) To make field observations and collections of live material in as wide a range of local habitats as possible for trial maintenance of different species in laboratory rearing chambers. Several collecting methods were to be used in order to get as many species as possible.

(IV) To determine effective methods for sampling Opilione species, and ascertain the horizontal range of the dominant species across vegetation margins. The margins in this case were forest edges. Sampling transects were to be established from the mature section of a forest through the edge to a relatively open old field situation nearby. Five major woodlot types would be sampled for comparison.

(V) To rear selected species through all of their life stages in the laboratory, recording length and number of instars, per cent survival, egg production and other pertinent life cycle information, and the optimal environmental conditions for the species.

(VI) To develop an efficient rearing technique, and subject the selected species to chlorinated hydrocarbon insecticides in its water supply and by direct application.

The author found, much as did Edgar (1960) with his broad research objectives, that several of the foregoing aspects could easily have been enlarged into separate research projects in themselves. Thus, a conscious effort has been made to work on several aspects Edgar did not cover in detail, using his thesis research as a basis for further work. The systematic, regular collecting over an entire season in several areas provides information on the life histories of dominant species, and use of different collecting techniques. These aspects and the rearing information will hopefully be a useful complement to previous work.

TAXONOMIC RESUME

Edgar (1966) listed 19 species records for Michigan; these are contained in 8 genera and 3 families, all of the suborder Palpatores (Table 1). Eleven other species are reported from adjoining Great Lakes states and the Canadian province of Ontario, and some of these may eventually be collected in the state; one species which was reported as new in the state was collected during the course of this study.

460 collections which included every Michigan county were made by Edgar and distribution maps for all species were illustrated (1960). He also listed approximately 100 previous collection records for the state by species and county, and these are included on the distribution maps. These distribution maps are the only available county check list for the order.

Nineteen species did not appear to be too large a taxonomic task, particularly when one considered that all but two of these were in the same family. Edgar's key was invaluable for the area, but in some cases it was necessary to use determined specimens for comparisons. Several of the genera are monospecific, and these usually vary enough so that separation of them from the remainder is not too difficult, once a grasp of the morphology is gained. But the largest genus, *Leiobunum*, and a closely related one, *Hadrobunus*, are extremely difficult. First, there is a great amount of sexual dimorphism, yet

TABLE 1

SYNOPSIS OF GENERA AND SPECIES OF MICHIGAN OPILIONES (Modified from Edgar, 1966)

Suborder Cyphophthalmi--No representatives
Suborder Laniatores--No representatives
Suborder Palpatores
  Tribe Dyspnoi
    Family Nemastomatidae
        Genus *Crosbycus*
          C. dasycnemus (Crosby) 1911
    Family Ischyropsalidae
        Genus *Sabacon*
          S. crassipalpi (L. Koch) 1879
  Tribe Eupnoi
    Family Phalangiidae
      Subfamily Phalangiinae
        Genus *Opilio*
          O. parietinus (DeGeer) 1778
        Genus *Phalangium*
          P. opilio L. 1761
      Subfamily Oligolophinae
        Genus *Caddo*
          C. agilis Banks 1891
          C. boöpis Crosby 1904 (New from state)
        Genus *Odiellus*
          O. pictus (Wood) 1870
            subsp. *pictus argentus* Edgar 1966
            subsp. *pictus pictus* (Wood) 1870
      Subfamily Leiobuninae
        Genus *Hadrobunus*
          H. maculosus (Wood) 1870
        Genus *Leiobunum*
          L. calcar (Wood) 1870
          L. cretatum Crosby & Bishop 1924
          L. flavum Banks 1894
          L. lineatum Edgar 1962
          L. longipes Weed 1887
          L. nigripes Weed 1887
          L. nigropalpi (Wood) 1870
          L. politum Weed 1890
          L. serratipalpi Roewer 1910
          L. ventricosum (Wood) 1870
          L. verrucosum (Wood) 1870
          L. vittatum (Say) 1821

most characters used in the key are only those of the male. The shape of the protrusible penis is a very important differentiating character, but unfortunately few good taxonomic characters have been found on the ovipositor. Size, shape, and coloration of the females vary markedly also, and in some species it almost becomes a matter of identifying them by association with males of the species to which they belong. Color, although used extensively by earlier taxonomists, is an extremely unreliable character for either male or female. Immatures sometimes lack the adult color pattern; adults often are lighter when freshly molted than later on in the season, and often specimens collected in moist areas appear to have more melanic forms of the same species than do those collected in comparatively dry areas. The type of preservative can have an effect on the color. Specimens preserved in 95% alcohol tend to yellow with age, but if more than a very small percentage of glycerin for softening is added, an opposite bleaching effect has been observed.

Variation within a species is also great, especially among the tropical forms. It is very difficult to fathom just how much variation there is, particularly for someone who has worked primarily with insect taxonomy. All aspiring Opiliones systematists should read the well documented and rather sobering paper by the Goodnights on recognition of individual variation in species of Opiliones (1953). Color variation, color patterns, dorsal spination, leg spination, number of tarsal segments and shape of eye tubercle have all been used for separating Opilione genera and species, but exceptions to each of these characters are noted for several southern U. S. and Central

American species. Such considerations emphasize the importance of having available a good series for each species in order to ascertain individual variation. As examples of the results of more critical taxonomic analysis, these authors cite two very striking reductions made in the course of their own work, in two different groups. The number of phalangodid genera in Mexico and nearby central America was reduced from approximately 50 to eight, while the 64 ill-defined genera of cosmetids for the same area were contained in three well defined genera. While the temperate species of the Great Lakes region do not illustrate these extremes, the lists of synonomies with many species here attest to their considerable variation. It is probably one of the reasons the order has often been bypassed for more well defined groups. Goodnight has expressed the opinion that there are probably several species complexes in the genus Leiobunum in the U. S. (pers. comm.).

Species recognition eventually becomes a kind of "gestalt," or form thing. The shape of the body, combined with the relative length of legs, banding of legs, general color, etc. are all amalgamated into a kind of picture by which both male and female are recognized. The complexity of this picture, best formed by seeing numerous different specimens, is not truly grasped until one tries to explain some of the subtle differences between species to a biologist unacquainted with the group.

After a review of much of the North American taxonomic literature on the group, working with the determined material in the museum collection and on scattered collections made by the author; tentatively identified specimens of available species were sent to either Goodnight or Edgar for verification. This was necessary before proceeding to the Monroe Co. material and subsequent research on the order. Every species mentioned in this study has had one or more verifications by either Goodnight or Edgar, on both male and female when both were available.

In the entire course of the study over 7400 specimens have been examined, from Michigan and numerous other areas in the Eastern United States and a few widely scattered western localities.

One species is reported for Michigan for the first time: Caddo boöpis Crosby, from Montmorency Co. in the second week of August, 1967, recovered from moss and very moist leaf litter by Berlese extraction.

In another uncommon species, Leiobunum serratipalpi Roewer, the female has been reported for the first time. It has never been described in the literature before, but was found in close association with the males of the species and Edgar has given a preliminary confirmation of the determination.

FIELD WORK

Monroe County Phase

The initial interest of the author in the group began in April, 1966, when data were being analyzed from a monitoring study done in Monroe County, in the extreme southeastern corner of Michigan by the Michigan State University Department of Entomology. Two aerial applications of a granular cyclodiene insecticide (at the rate of two pounds/acre of aldrin in 1960 and two pounds/acre of dieldrin in 1962) had been applied over the southern section of the county in an attempt to control an outbreak of the Japanese beetle (*Popillia japonica* Newman) which was moving into the state from the south. Samples of soil, milk, and alfalfa were taken at monthly intervals during the growing season from 1962 to 1965 for insecticide residue analysis. In the 1965 sampling, a program was initiated to assess possible effects on non-target terrestrial arthropods in the area.

Six farm woodlots were selected for this study, three in the treated area and three in the untreated area north of it. Figure 1 shows aerial views of the woodlots showing their size and giving their exact location, with the "X" indicating the sampling sites. As can be seen, most of the surrounding area is under cultivation, and thus woodlots were selected for sampling because they represented the only natural areas that could possibly maintain a stable arthropod community. The particular woodlots chosen were selected for the apparent

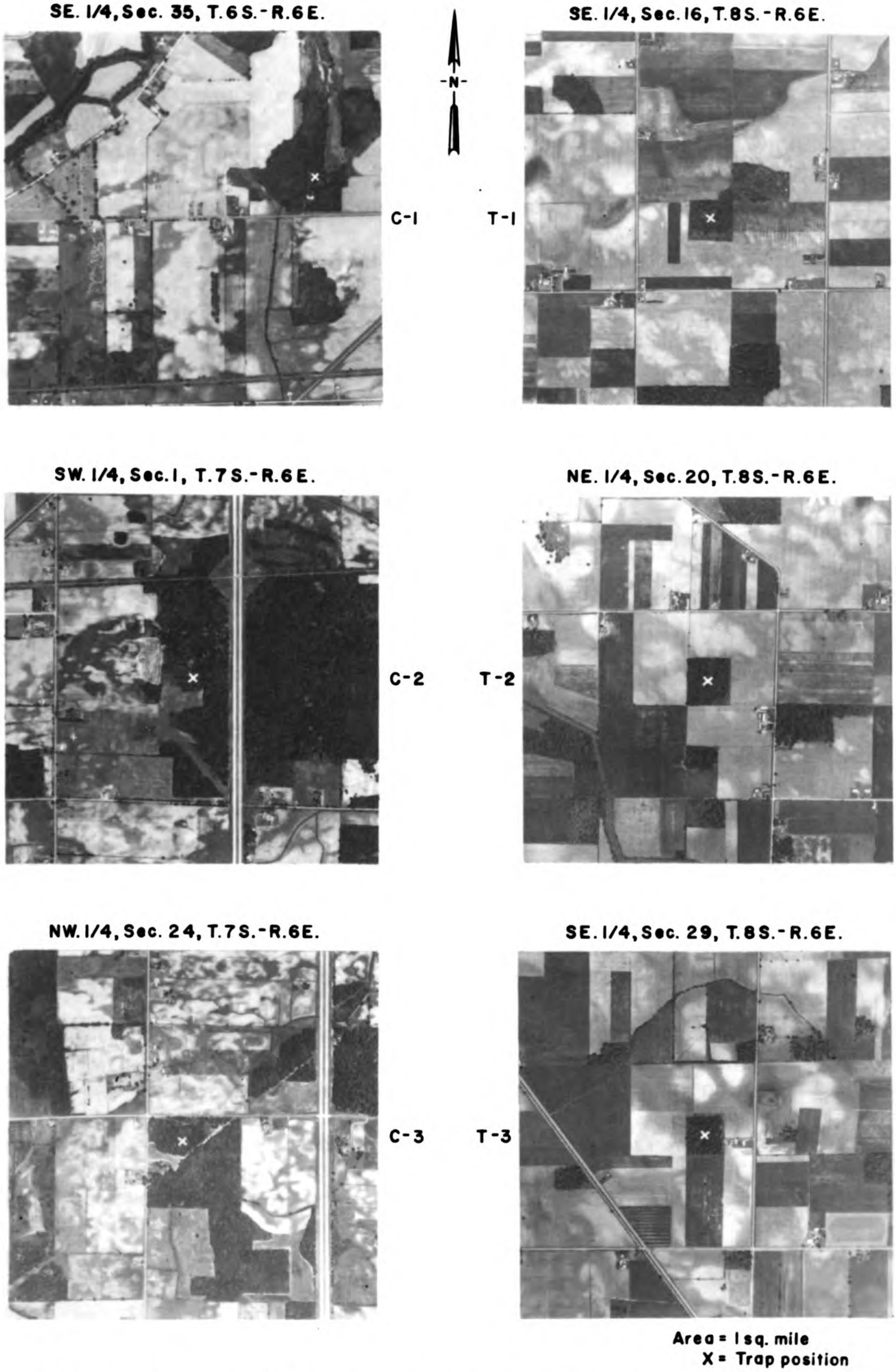

Figure 1. Location of sample woodlots in Monroe County, Michigan (from Truchan, 1966).

similarity of vegetation and also for availability. The number and variety or arthropods collected were used as a basis for comparison between woodlots within and outside the treated area (Truchan, 1966).

Three sampling techniques were employed in an effort to get as representative a community as possible. Crawling forms were sampled with a series of pit-fall traps; deep litter and soil forms were sampled with four inch diameter soil cores of the top fifteen cm. of the soil, and aerial, forms were collected with a tent-like Malaize trap. Samples were taken at regular intervals with each of these methods from June 10 to Sept. 27, 1965. A tremendous variety and number of arthropods were collected over this period, but we will be here concerned primarily with the order Opiliones.

The pit-fall trap sampling in each woodlot consisted of 25 meter transects in which six pit traps (white plastic cartons) were placed approximately 5 meters apart and sunk into the ground so that their tops were flush or slightly below the surface. The cartons were 11 cm. in diameter and 8 cm. deep. 2-3 cm. of ethylene glycol was placed in the bottom for trapping and preserving anything that fell in. These traps were very similar to the one pound cottage cheese cartons that commercial dairies use; they were inexpensive, almost unbreakable, could be tightly sealed for transport back to the laboratory, and could be easily set in holes made with a turf sampler of a similar diameter. All 36 traps were collected at 6 day intervals, and traps with fresh ethylene glycol were put back in their places.

Collections in the pit traps showed a great deal of species diversity of Opiliones, representing a total of 10 species and 4 genera. A surprisingly large number, 2464, were collected for the whole season. Six of these species were present in sufficient numbers to analyze separately. They also were chosen because all but the first stages of the immatures could be determined with some accuracy. In these six, total numbers for the three treated woodlots and for the three control woodlots were lumped for each sampling period, this information is portrayed graphically in Figures 2-5.

Figure 2-A shows the relative abundances of Hadrobunus maculosus (Wood). In the treated plots it reached 19 specimens on June 17 but oscillated somewhat below this most of the summer, with the last specimens collected on Aug. 28. The control plots show more striking peaks, however, with 65 specimens collected on June 29 and another peak of 46 in the middle of August. This species appeared to be reduced in numbers in the treated woodlots. The remaining five species show opposite results. In fact, in each case there were so few specimens in the control plots that they could not be shown in a meaningful way. Consequently the graphs show population curves for treated woodlots only. The sparse collections in the control areas are shown in Appendix I.

Figure 2-B shows that Leiobunum calcar (Wood) is predominently an early summer species. There was a peak of 72 specimens on June 17, but it had completely disappeared by the end of July.

Figure 3-A shows a somewhat similar pattern with a peak for Leiobunum nigripes Weed. The peak collection of 47 specimens was made on July 5, with a smaller peak later in the month. The last specimen was collected on Aug. 4.

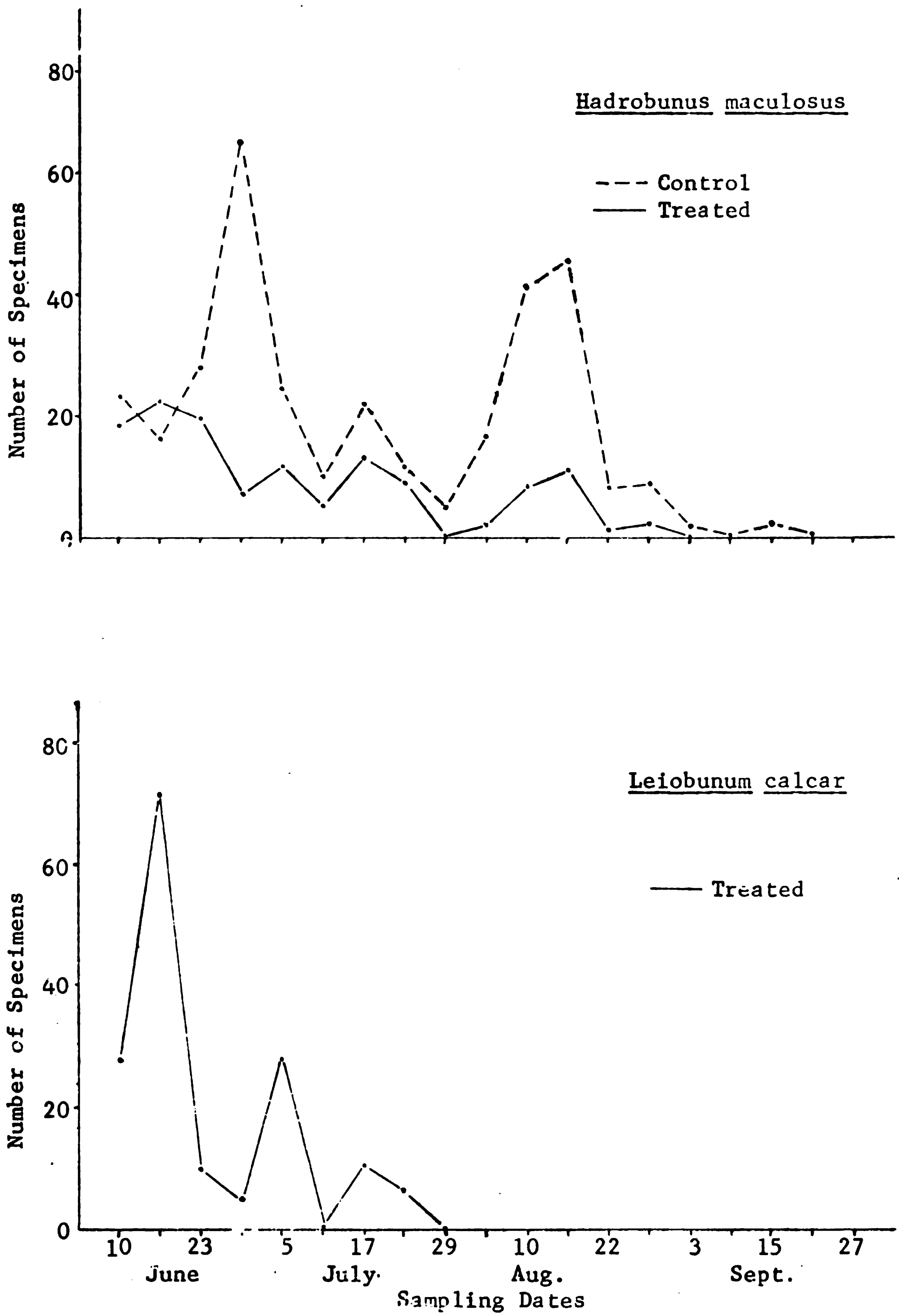

Figure 2. Seasonal abundance curves for H. maculosus and L. calcar, based on Monroe Co. pit trap collections.

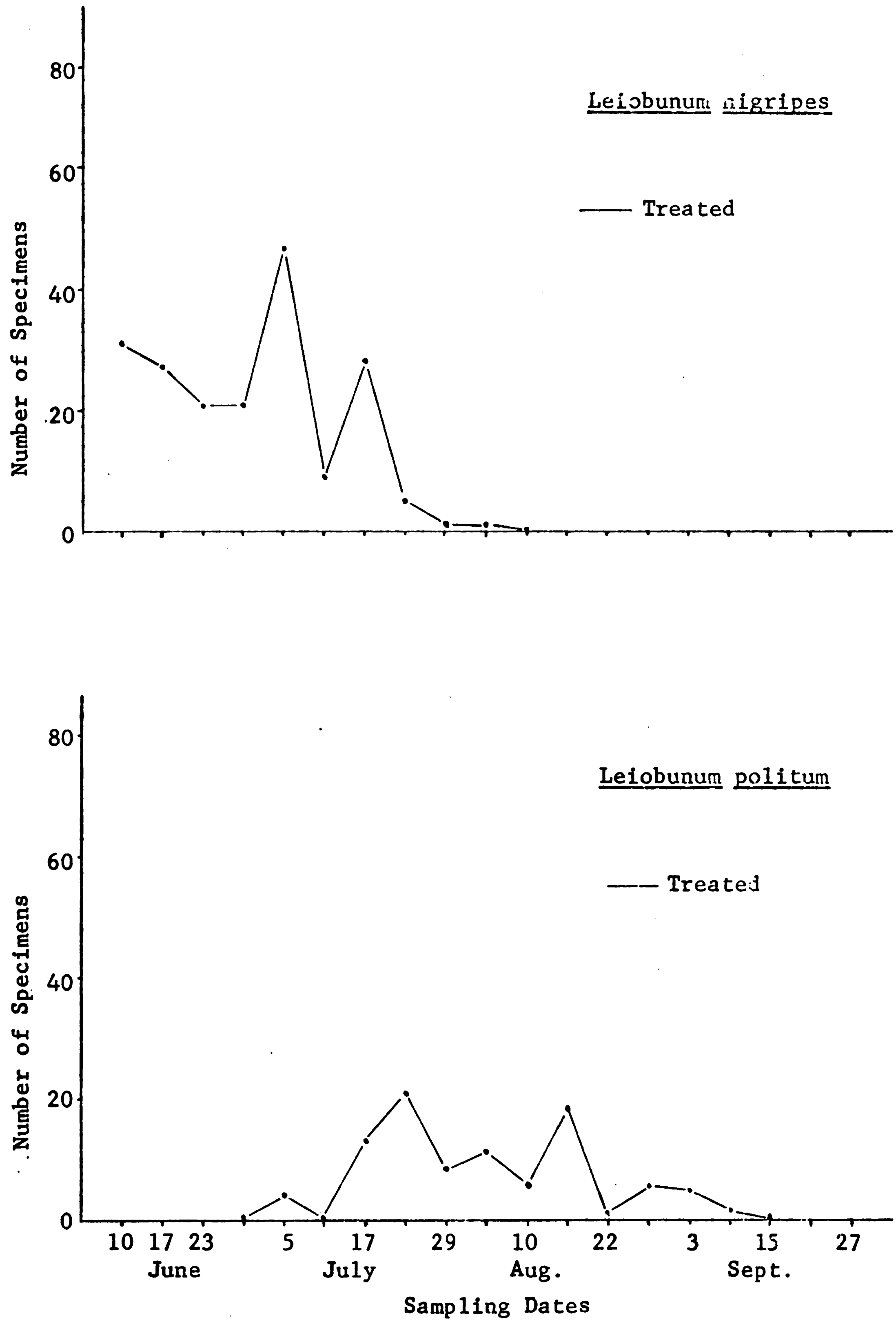

Figure 3. Seasonal abundance curves for L. nigripes and L. politum, based on Monroe Co. pit trap collections.

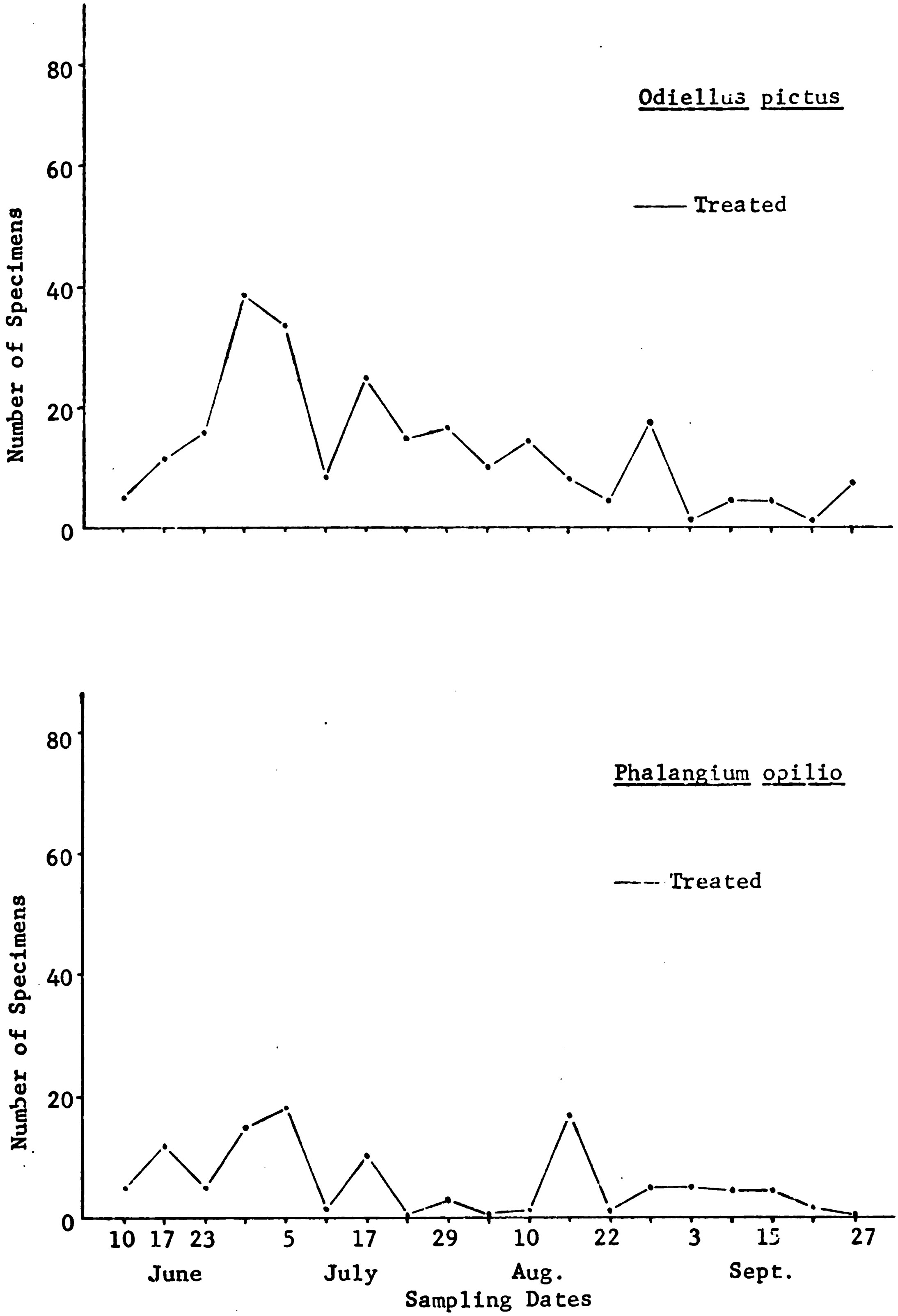

Figure 4. Seasonal abundance curves for O. pictus pictus and P. opilio, based on Monroe Co. pit trap collections.

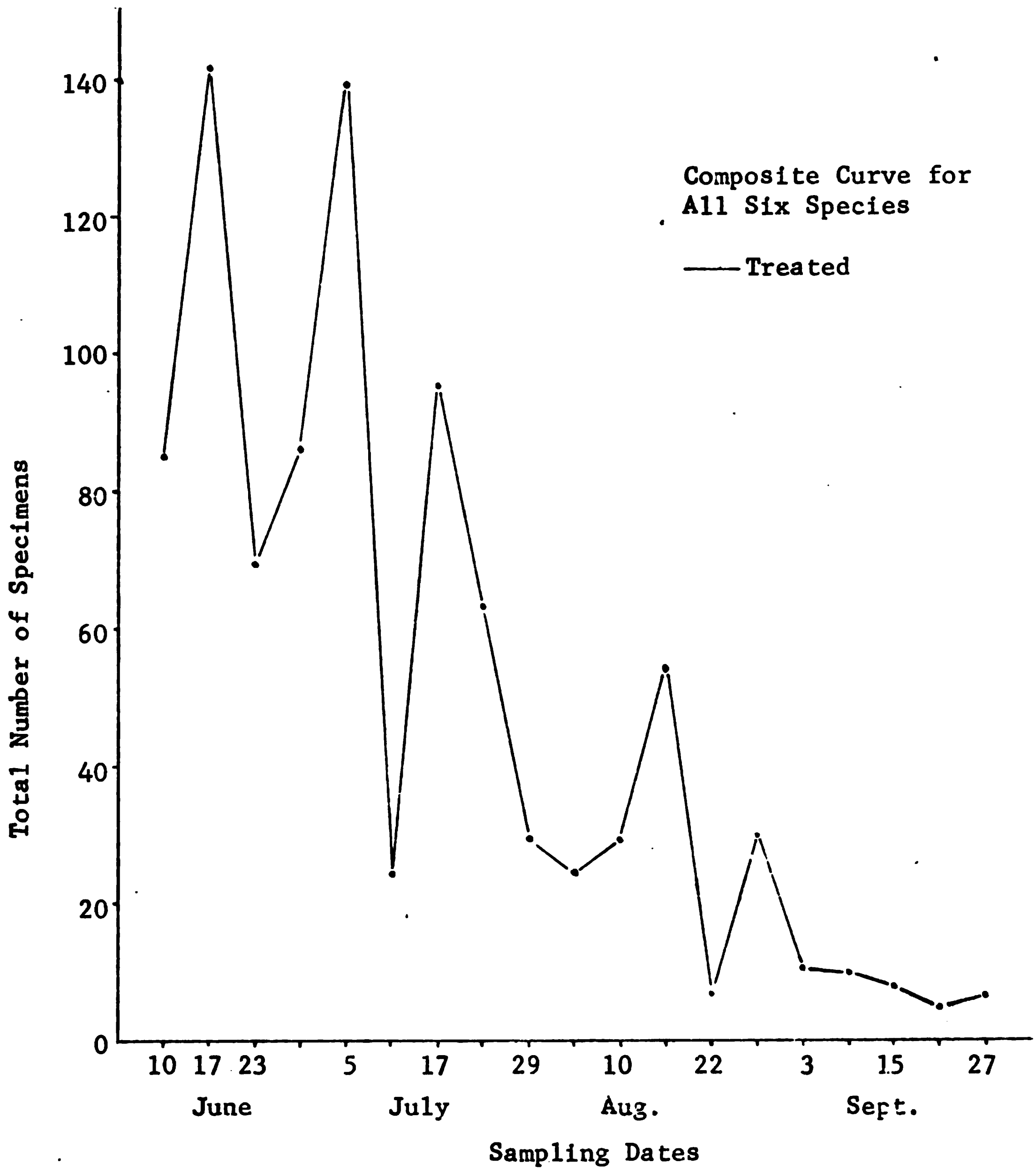

Figure 5. Composite abundance curve for the six dominant species collected in pit traps in the Monroe Co. woodlots.

Leiobunum politum Weed shows a definite midsummer peak (Figure 3-B). It was never very abundant, but lasted over a longer period of time, with a peak population of 21 on July 23, another smaller peak of 18 on Aug. 16. It completely disappeared by Sept. 15.

Odiellus pictus (Wood) shows the longest seasonal collecting record of any species in the study. Specimens were collected in every sampling period from June through September (Figure 4-A). As in the foregoing species, early collections showed only immatures, but the development over the summer was more gradual until a few specimens of the adult appeared in early September.

Phalangium opilio Linn. was collected in relatively small numbers during most of the sampling periods (Figure 4-B). Collections of this species suggested the possibility of a different life history than the five previously discussed species, however. Both adults and immatures were present early in the summer and late in the fall. Adults were collected at irregular intervals over the entire summer, along with various immature stages.

A composite curve of totals for all six species in the treated woodlots makes it possible to almost label each respective peak in population (Figure 5). The first peak is largely due to L. calcar and H. maculosus; the second peak to L. nigripes and O. pictus; and the third peak to L. politum and O. pictus.

Deep litter and soil forms were sampled with the same turf sampler used to set the pit traps. Twelve 10 cm. X 15 cm. cylindrical soil cores were taken every 12 days on each plot. Four were taken from leaf litter, four from near the bases of large trees and four from relatively grassy areas in the woodlots near the pit trap transects. These cores were extracted immediately in the lab with a Berlese apparatus.

Only a few immature Opiliones were obtained, but among these were two mature specimens of Crosbycus dascynemus (Crosby), each from a different plot. This is an extremely small species (1 mm. in length when mature) and had been collected by Edgar only once before in the state. He also collected his specimen by Berlese extraction, and apparently it is almost impossible to collect by other means. His specimen was from Cheboygan County, in the northern part of the state. This indicates a more widespread distribution than is evidenced by the present sparse collections.

Malaize traps were used to sample aerial insects. This device was a ten foot high, tent-like structure with a cross pattern baffle running from the center to each corner, which funneled insects upwards from all directions (Figure 6-A). The actual collection apparatus consisted of an inverted screen funnel leading through the side of an upright plastic funnel, with a plexiglass sheet across the top. At the bottom of the plastic funnel was an interchangeable pint bottle half filled with ethyl alcohol, which collected and preserved the specimens after they tired of flying up against the transparent cover (Figure 6-B). Townes (1962), who developed it, and Truchan (1966) explain the construction and use of this trap in detail.

Two traps were used for the study, one in the control and one in the treated woodlots. Each trap was moved from one woodlot to the next every six days; viz., C-1 to C-2 and T-1 to T-2, etc. Within

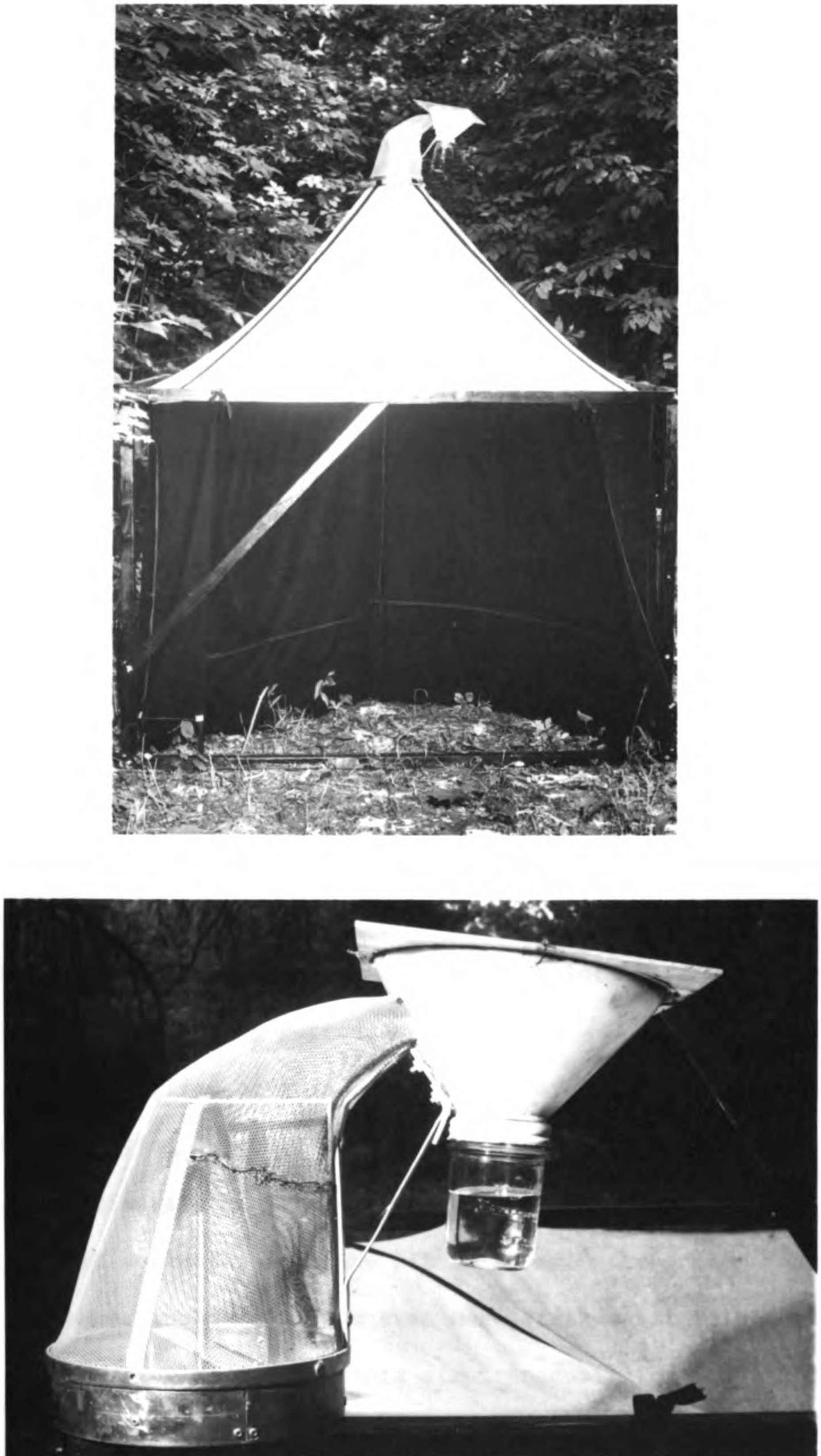

Figure 6. Malaize trap in operation, and detail of collecting apparatus (from Truchan, 1966).

each woodlot the six day period was further divided by removing the collections after three days and again on the sixth, when the traps were moved. Thus, capture totals for any one period of sampling represented only one woodlot each time.

The majority of the material collected has previously been analyzed by Truchan (1966) to the family level, with several dominant species being removed for further analysis. We are concerned here only with the large number of Opiliones that were collected in the trap. One species, Leiobunum vittatum (Say) was clearly dominant in this material. It was chosen for further analysis for this reason and also because it could be identified in almost all developmental stages.

Figure 7 shows the relative abundance of L. vittatum from the Malaize traps, for both the treated and the control woodlots. This shows a life history much like O. pictus (Figure 4-A) with many immatures and peak abundance in early summer while dropping down to a few adults by early September. The treated plots yielded more specimens in every collecting period.

The collection of this large number of Opiliones was not expected in a flying insect trap. It gave good evidence that this species is primarily an arboreal one, for only 15 specimens of L. vittatum were collected from the pit traps over the entire season. The differences would have been even more striking if Malaize traps had been operating in all woodlots simultaneously for the entire summer, instead of one trap rotating in both the control and treated woodlots.

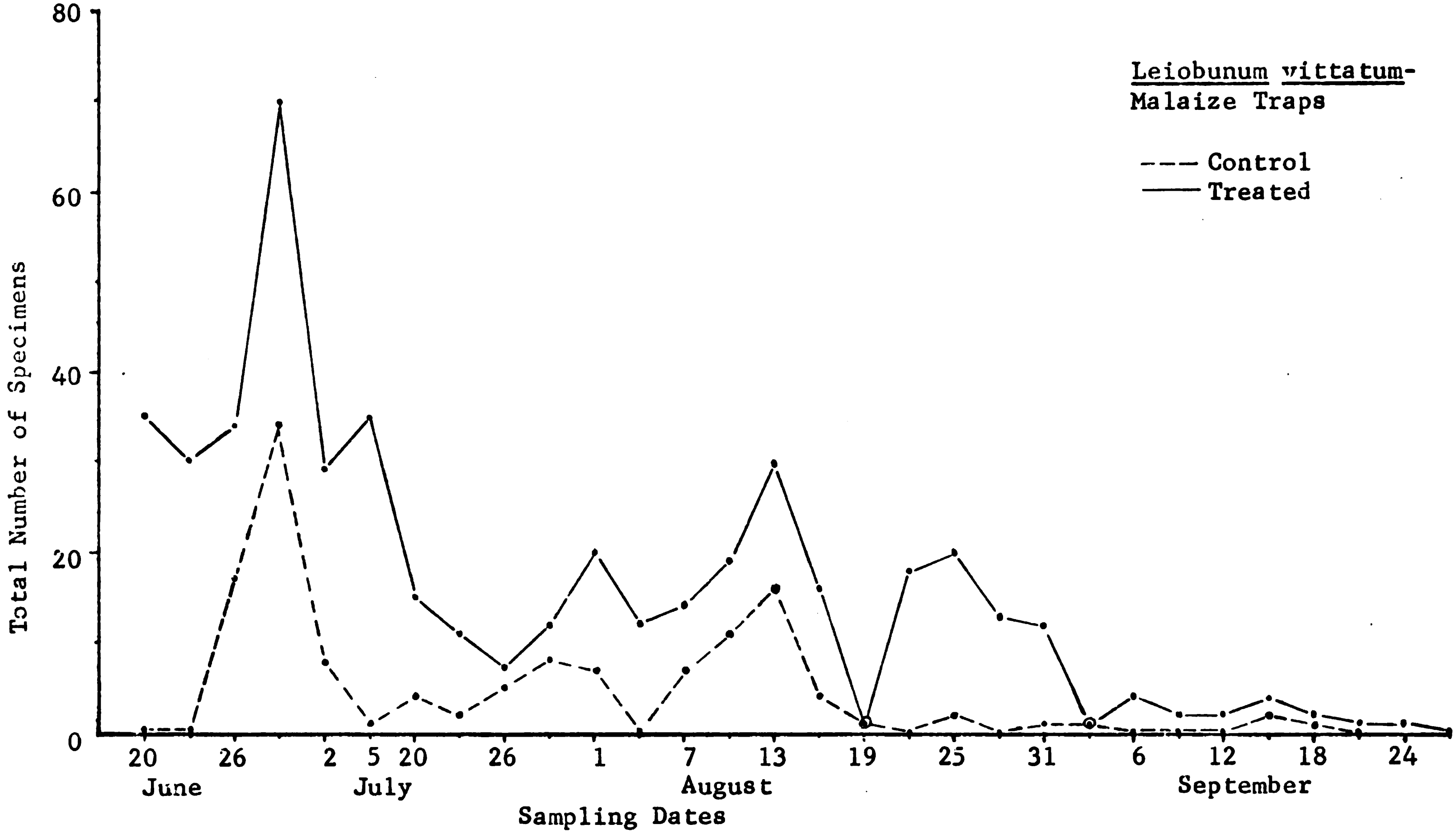

Figure 7. Relative seasonal abundance of _L. vittatum_ from Malaize traps in the treated and in the control woodlots.

This large seasonal series of L. vittatum may have shed some light on a taxonomic problem associated with this species, also. In the initial determinations of the Malaize trap material several specimens collected toward the end of the season were called Leiobunum crassipalpi Banks, a closely related species. There has been some argument as to whether L. crassipalpi occurs in the state at all. Edgar (1960) has thought that Michigan specimens previously reported were actually L. vittatum, collected in late autumn when body proportions and coloration change somewhat. Edgar determined the Monroe Co. L. crassipalpi specimens as L. vittatum, and the long series of L. vittatum (602 specimens) support this, and Edgar's previous opinion. It is unlikely that L. crassipalpi would be evident for only a few weeks at the end of the season when L. vittatum had been the primary species collected for three months before that time in the same area.

The unexpected collections of L. vittatum gave an additional benefit; they showed that not all species of Opiliones were adequately collected with the pit traps. Based on pit trap data, L. vittatum would be considered a very minor species in the woodlots, but the Malaize traps showed that this was far from the case. The finding of a species not collected by either of these methods, by Berlese extraction from the soil cores, further illustrates the point that a group as varied ecologically as the Opiliones can not be sampled adequately with one method. One must know something about each species microhabitat to know how to collect it. These three sampling methods have given valuable insight into the ecology of the various species.

Large differences in numbers collected between treated and control woodlots could have been due to pretreatment plant community differences as well as a possible insecticide influence. This could easily mask any insecticide effects. Truchan (1966) made a vegetation analysis of the areas and found that all of the control woodlots were negatively correlated in terms of tree species abundance with the treated woodlots. Soil testing data gave part of the explanation. Soil from the control woodlots was low in nitrogen and calcium and had a lower pH; it was of rather poor quality. Soil from the treated areas had a much greater supply of essential plant nutrients. The area treated for Japanese beetle included mostly good agricultural land. The poorer soil to the north of it was untreated. Vegetation reflected this soil difference. The treated woodlots were second growth sugar maple-basswood-red oak upland and the control woodlots were species-poor second growth oak upland and swamp forest. The treated woodlots had a much higher canopy and a moister litter layer and this would create a higher relative humidity and more moderate moisture fluctuations in the woodlots. Most Opiliones are very desiccation prone and must spend much of their time in areas of high relative humidity. Moisture in all of its forms is probably the most important environmental factor for the order. The only species more abundant in the control woodlots, H. maculosus, is reported by Edgar (1960) to be found in a variety of habitats and associated with many other species of Opiliones. It has a large, strongly chitinized body, short legs and could be a more desiccation resistant form. Later work with H. maculosus supported this hypothesis.

The gross difference in numbers of Opiliones points out the difficulties of finding untreated plots strictly comparable with those in the insecticide treated area. When, as in this instance, insecticide has been introduced into the system, areas had to be located that were similar in respect to the parameters being examined. As was demonstrated here, the apparently similar woodlots which were selected for comparison with the treated woodlots were, unfortunately, dissimilar in important respects. Ideally, any zoological comparisons between two areas should be prefaced by a comprehensive soil and vegetational analysis before proceeding into actual field work. This was not possible in the areas described here, where monitoring was actually begun 2-4 years after treatment. Furthermore field monitoring studies are not established as research areas and necessarily suffer from inadequate experimental design. Population depressions of any organism cannot be attributed entirely to insecticide effects; other aspects of the environment must be considered.

Wexford County Phase

Another arthropod study using similar sampling methods was conducted during the same time period in Wexford County, in the Northern part of the lower Peninsula of Michigan. The sites were approximately 225 miles northeast of those in Monroe County. The plots were established on pine plantations to measure diversity of litter and aerial arthropods between three different types of pine stands; planted jack pine (*Pinus banksiana* Lamb), naturally seeded jack pine and planted Scotch pine (*Pinus sylvestris* Linn.). (Scotch pine rarely seeds itself naturally.) All stands were about 15 years old and soil testing done at the time of the sampling showed little differences in quality between the three types. Thus, the variables were more adequately controlled in this work.

Malaize traps of the same design as that used in the Monroe Co. study were run for seven day intervals every other week. The same type of pit traps were also used, and operated every second week, on a similar schedule to that of the Malaize traps. The pit traps were set out in a slightly modified distribution pattern in an attempt to compensate for the effect of tree rows. All traps were paired, with one trap in the middle of a row and one under a tree. The sampling was more intensive, with one pair every 20 yards and 8 pairs per replication. Three plantations of each type were chosen as a better basis for statistical analysis. Each replicate thus had 16 traps.

Only 2 species had large enough numbers to permit seasonal graphing, and because of this the three replicates were added together for each collection period. In the case of planted jack pine few specimens (only 30 for the entire summer) were found. Consequently the data for this vegetation type is not graphed. 596 specimens were collected in all.

Seasonal abundance trends can still be shown in this way, but allowance must be made for the fact that these totals are based on 48 pit traps over a seven day period, instead of the totals for 18 traps over six day period on which all the Monroe Co. curves are based.

Figure 8 shows the abundance of H. maculosus and P. opilio on the naturally seeded jack pine sites over the season. P. opilio is almost completely absent, but the curve for H. maculosus shows approximately the same trend as the Monroe Co. material did with the highest peak in late June. They also had completely disappeared by the end of August.

Planted Scotch pine showed a different relationship. Figure 8 also shows the curves for the same two species in this type of plantation, but here P. opilio was the most numerous and H. maculosus was only half as abundant as it was in the natural jack pine stands. This could be in part an effect of disturbance. P. opilio is found around human habitation and often in agricultural situations (Edgar, 1960) and might be able to tolerate the planted habitat better.

In checking the histories of all the plots another unexpected variable was found; the planted Scotch pine plots had all previously been treated with DDT, a chlorinated hydrocarbon insecticide of the same type as dieldrin. Neither of the other plots had been treated. The two to one ratio of H. maculosus between untreated and treated areas very closely resembles the two to one ratio of this species between untreated and treated woodlots in Monroe Co. This may demonstrate an insecticide effect; it showed up very similarly in two widely separate and different environments.

The Malaize traps yielded only about 25 specimens for the entire season in the pine plantations. However, they again were almost all L. vittatum.

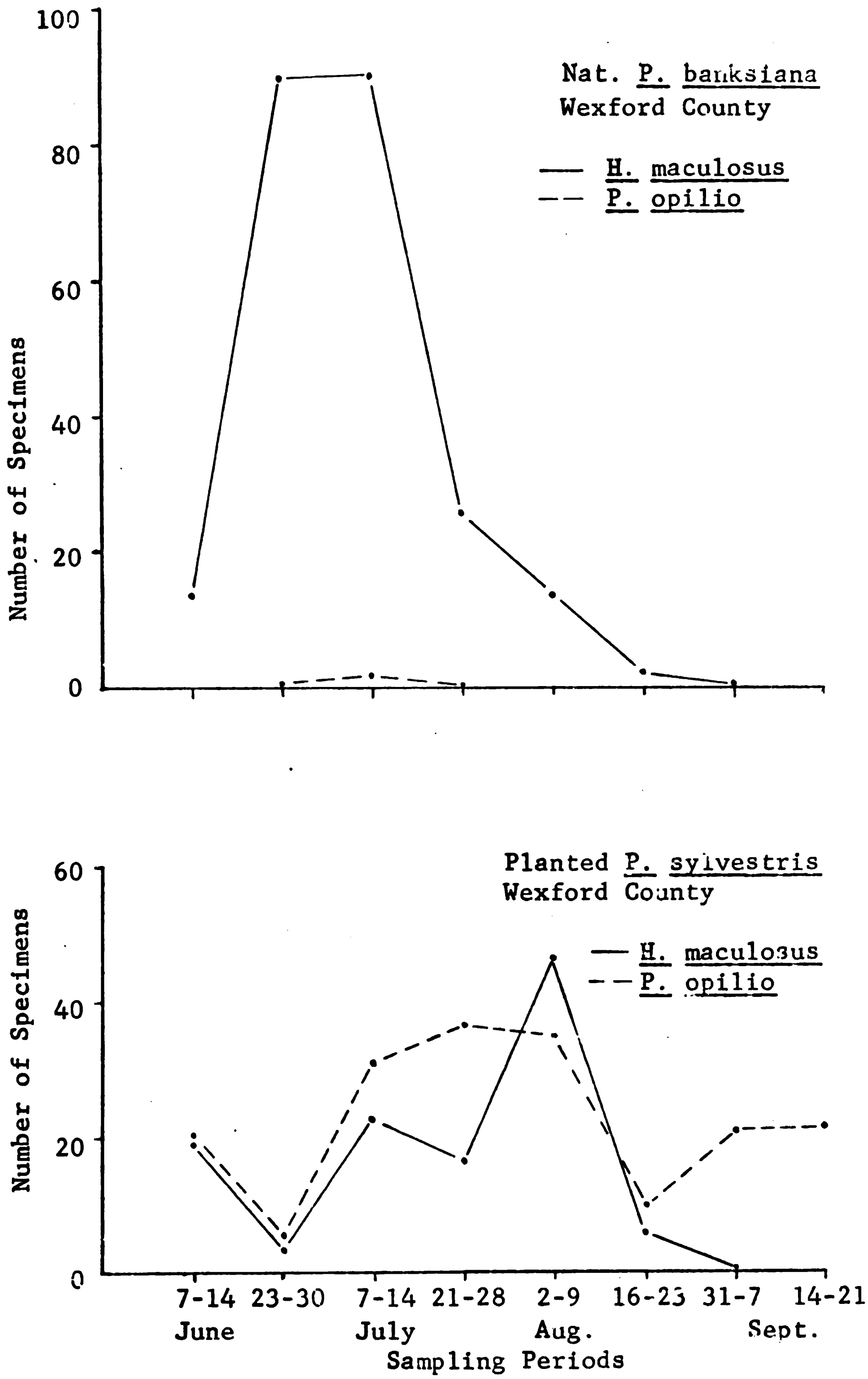

Figure 8. Relative seasonal abundance of P. opilio and H. maculosus in two different types of Wexford Co. pine plantations.

The small species diversity of these 3 types of plantations undoubtedly reflects the sparsity of vegetation. After only 15 years scant litter had accumulated and there undoubtedly are large fluctuations in temperature and relative humidity in such stands. This would tend to limit all but a few hardy species like *P. opilio* and *H. maculosus*.

Local Forest Edges Phase

Interim Biological Work

Numerous field observations and collections of live material were made during the time the author was gaining a taxonomic knowledge of the group and determining the Monroe Co. and Wexford Co. series. The collections were made by both the author and several of his associates, over a wide range of locations from Keweenaw Co. in the extreme northern part of the Upper Peninsula of Michigan, to Mammoth Cave National Park in Central Kentucky. However, most were confined to the south central part of Lower Michigan, with emphasis on several woodlots within a 10 mile radius of the MSU East Lansing campus.

After some searching, Toumey woodlot, a 15 acre tract of virgin beech-maple south of campus was tentatively selected as a site for intensive collecting for the following reasons: (1) It was a relatively undisturbed woodlot with an extensive upper canopy in most areas. (2) It contained some open grassy areas and a vernal pond on the east end. (3) There were openings in the canopy caused by windthrown trees and there were also some evergreen windbreaks along three of the borders. Thus it appeared that a large variety of habitats could be sampled within a comparatively small area. (4) Lastly, it was quite close to the laboratory (two miles south of campus) and accessible, but yet was far enough away so that there were not very many casual campus visitors disturbing it. Live specimens could be brought back to the laboratory with ease and nocturnal collecting and observations were possible.

The project was explained to Dr. James, Chairman of the Department of Forestry at MSU, and permission was granted to make preliminary collections from the woodlot, provided it was left relatively undisturbed. The Department of Forestry has a continuous ecological study of the woodlot in progress and did not want the flora to be disturbed to any marked degree. Thus only a small series of pit traps were set up at each end of the woodlot and hand picking collections were made at different points during various times of the day, to determine what species were present.

At the initiation of the project, little was known about the ecological requirements of any species, so all live material was brought back to the laboratory for screening to find some that would survive controlled conditions well. Growth chamber conditions were the same as those used by Fowler and Goodnight (1966). Temperature was maintained at 25^{o}C. with a light-dark cycle as close as possible to that existing in the field at that time of year. A saturated solution of rock salt was put in a container in the bottom of the chamber to keep the relative humidity between 65% and 75% (O'Brien, 1948). Small plastic and glass containers were used with open water and some bacon added for food. The containers were covered with clear plastic lids. The same conditions were used for specimens collected from all other areas also. Soon there were a number of species in the chamber.

Unfortunately, few of the species survived. In spite of different food experiments and relative humidity tests very few specimens lived longer than a month in the laboratory and most died within a week. From the appearance of many of the animals, the problem seemed to be one of moisture. Some specimens dried out very rapidly, while others actually molded.

An intensive review of previous ecological and biological work was undertaken to help solve the maintenance problem.

Previous Ecological and Biological Work on Opiliones

As is the case with so many of the Arachnida and of soil zoology in general, the majority of papers have been taxonomic in nature. The earliest biological and anatomical work was done by several German and French workers in the last half of the 19th century (Menge 1850, DeGraff, 1882, Henking, 1888). Additional German researchers and workers of various other areas did a great amount of work in the first part of the 20th century on almost every aspect of the group. The most extensive taxonomic treatment was done by C. F. Roewer, culminating in his 1923 tome, Die Weberknechte der Erde. This compendious volume and its later supplements treated all the known species of the world at that time (approximately 2200) and certainly is the most complete taxonomic work of the order on a world-wide scope. The text was written in very abbreviated German and keys are hard to use, however. This is further complicated by the fact that the morphological terms are not too clearly defined. Distribution data is included, but there is little biological information of any consequence. The size of the publication (1116 pp.) probably limited this.

Kästner, in his Opiliones article (1929) in Dahl's Die Tierwelt Deutschlands series on the various zoological orders found in Germany, gave much useful information in addition to keys for all the German species. The work was a kind of a review of the work done on German forms to that time, and is written in very readable, straightforward German. Morphological terms are generally excellently illustrated and explained, and the keys are very well illustrated. In a short but very useful preliminary section he gave many valuable hints on collecting techniques, type of preservative needed, the importance of determining whether or not a specimen is an adult, and a precautionary note concerning the use of color or coloration patterns in determination. Kästner also includes seasonal abundance data with the distribution notes for most species, and there is a general discussion of the biology of each family. In his literature review he gives short summaries of the work cited, and this is also very helpful.

Kästner did more original work on Opiliones and other Arachnids in the first half of the 1930's, publishing several papers. Most of this work is included in a much more extensive type of review, Kükenthal & Krumbach's Handbuch der Zoologie. This series was designed to give a general biological treatment of all Phyla of the animal kingdom on a world-wide basis, with a short taxonomic resumé included at the end of each group.

Kästner reviewed almost every biological aspect in his very lucid style, with particular emphasis on external and internal anatomy of several widespread species. Almost every system of *Phalangium opilio* Linn. is well described and illustrated, and since this species is common in both Europe and North America this could be of general use to many workers. His literature list appears to cover almost work done prior to 1935 and is quite valuable. Some of the early articles are quite hard to obtain now, so Kästner's review of their contents for this reason is even more valuable.

Ecological observations on Opiliones are more common. In Europe and England there have been several quite detailed ecological studies reported since 1945. Bristowe (1949) made some detailed observations on food, enemies and methods of escape of British Opiliones; his notes on food include identification to genus and species of the prey in some cases. Most observations were nocturnal, using artificial light. He also reported the distribution records of 21 species by county in England, Wales, Scotland, and Ireland, and his records are probably quite complete as they included those of Savory, Todd, Sankey and other workers. Todd (1949) in an excellent paper reported the results of a detailed study of several British species. She correlated the occurrence of different species with different habitat types, and did some successful rearing experiments in the laboratory. She determined their reactions and tolerances to several environmental factors, and then attempted to relate field and laboratory conditions. Sankey (1949) reported on many scattered field observations. He briefly noted the vertical distribution of many of the English species, as well as adding some new distribution records to those of Bristowe. Phillipson (1959) worked with ten species of Opiliones in an area near that of Todds', in Southern England. His life history data largely corraborated those of Todd's, but his measure of the number of eggs laid by the different species was entirely new information. Juberthie (1965) did an extensive study on the ecology, reproduction and development of the Opiliones of France and Central Europe. It covered many embryological and anatomical aspects of the genital system never before investigated, and his ecological investigations on several species also were completely new.

Unfortunately, little ecological work has been done on the order in North America. As Savory (1964) points out;

> The biology of the European species has been well studied, but there are certain to be surprises from those that live in remoter places.

The remoter places referred to include almost everywhere but Europe; most of the early workers here made only brief mention of chance observations they happened to make while collecting.

A concise synopsis of reactions and general habits was included by Bishop (1949) in his paper on the New York species. The most comprehensive biological work to date on North American forms was Edgar's Ph.D. Thesis (1960, unpublished) on the order in Michigan. He has continued to work actively on the group both taxonomically and ecologically, and recently completed a key (1966) to the Great Lakes forms, with brief species descriptions and distribution data. In addition to Edgar, the author found only three other people in the country currently working on the group: D. Fowler, on the staff at

Western Michigan University now and working with Goodnight on various histological and hormonal aspects; D. Husted, a graduate student working on life cycles of two plains species in Kansas, and an individual (not specified) working in the Applachian region on the genus Leiobunum (Edgar, pers. comm.). Thus, laboratory maintenance of animals through the entire life cycle was a relatively unexplored facet of the order in N. America. The only information in the literature was based on European species, but since two European species and several genera are also found in North America, an attempt was made to use some of their techniques.

Materials and Methods

Todd's 1949 paper was the most complete work on the ecology of the entire Opilione fauna of a relatively limited area. Her successful rearing and other laboratory work was prefaced by intensive meter quadrat collections in a wide variety of habitats over a one year period in Southern England. In order to gain the additional ecological information needed to determine what the natural environments of different species were, it was decided that a series of 5 separate collection transects would be set out in five different woodlot types through the summer of 1967.

Previous work in Toumey yielded the largest number of species of any woodlot in the area, so it was selected for the most detailed work and instrumentation. The virgin beech-maple appeared to be the optimal habitat for Opiliones in general in the area. It also has been intensively studied for almost 30 years by the Forestry Department, and Schneider (1966) characterized it very completely in the third of a continuing series of vegetational analyses being done on the woodlot every ten years; 1940, 1950, and 1960. Since the woodlot had been one of the most intensively studied plots in the vicinity, it was thought that any data on animal ecology would be a contribution to the extensive plant ecological information already obtained. Conversely, the available plant ecology might make it easier to interpret the Opilione relationships.

Preliminary collections from the eastern end of the woodlot had revealed a gradual change in species, from the forest canopy through the conifer windbreak to an old field situation on the eastern margin. Edgar (1960) found in his habitat characterizations of the different species in the state that the largest percentages of many species taken were made in areas with moderately dense upper canopy and some understory. Almost none were collected in areas with no canopy, yet the optimum was not a complete cover. Most seemed to be found in intermediate amounts of cover protection. This apparent "edge effect," or tendency for increased variety and density at community junctions (as defined by Odum, 1959) seemed to correspond with a change in moisture conditions between the grassland and the forest. Thus, the edge, or the transition area at the forest margin was chosen as the midpoint for a sampling transect. To show the species change across the edge the transect was set up over the gradient from a relatively moist area under the beech-maple canopy to a relatively dry segment in the grassy area. This covered 182 meters, with ten pit traps placed along the gradient at 18 meter intervals.

A hygrothermograph in a standard Weather Bureau shelter was placed near the moistest point on the ground on the transect in order to measure the relative humidity and temperature in the layer near the soil surface where Opiliones were most often found. Another was placed in a shelter on the ground at the dry end of the transect, to obtain continuous readings for comparisons.

Edgar (1960) also reported that, while the various species of maple were dominants where most Opiliones were found, there were some species most commonly found in other forest types. Therefore, similar transects were set up in four other woodlot types in the vicinity. They were selected on the bases of previous study in the area which revealed them to be good examples of their ecological type and because of the existence of a fairly well defined margin and an old field type nearby.

The additional sites were; (1) Acid bog margin-flood plain forest at Bear Lake Bog (Ingham Co., T4N, R2W, S. 35); (2) flood plain forest (Shiawassee Co., T5N, R1E, S. 28); (3) Oak-hickory upland forest (Clinton Co., T5N, R1W, S. 14); and (4) a white pine stand, for comparison of numbers and species in conifers (Ingham Co. T4N, R1W, S. 17).

All climatological data from these sites was taken with a portable thermistor psychrometer ("Hygrophil", No. 3300, Cole-Parmer Instrument & Equipment Co., Chicago). This utilizes a very small amount of air pulled by a motor and fan through a barrel which contains two minute thermistors mounted inside. One thermistor gives the actual temperature of the air. The other is covered with a thin cotton wick which dips into the water container machined in the lucite block of the pistol; this gives readings corresponding to the wet bulb reading of a standard sling psychrometer (Fig. 9). Three different temperature scales are given on the indicating meter, including a range from 7 to 198 degrees F. Three sets of trigger buttons are on the pistol handle, one for each of the scales. First the dry bulb button is pushed to obtain the actual air temperature, and then the other button of each pair is depressed to give a wet bulb reading. These two readings are recorded in the field and taken back to the laboratory for conversion to relative humidity later.

The hygrophil was chosen for use in preference to a standard sling psychrometer because readings at each point were to be taken both at the standard four foot height and at two inches above the soil surface. This showed the difference between standard weather bureau meteorological observations and the actual microhabitat near the soil surface where Opiliones spend most of their time. In addition, the device made readings considerably faster than a sling psychrometer (one minute instead of three or four) and was very light and compact (approximately 1 kilogram). This made a real difference in the time involved in the taking of some 400 readings over the course of the season.

The readings were taken at weekly intervals at the same time pit trap collections were made at three points on each transect; one near the pit trap at each end and one at the pit trap nearest the center of the edge area. Collections were started early in the afternoon, so most relative humidities recorded would be taken at the

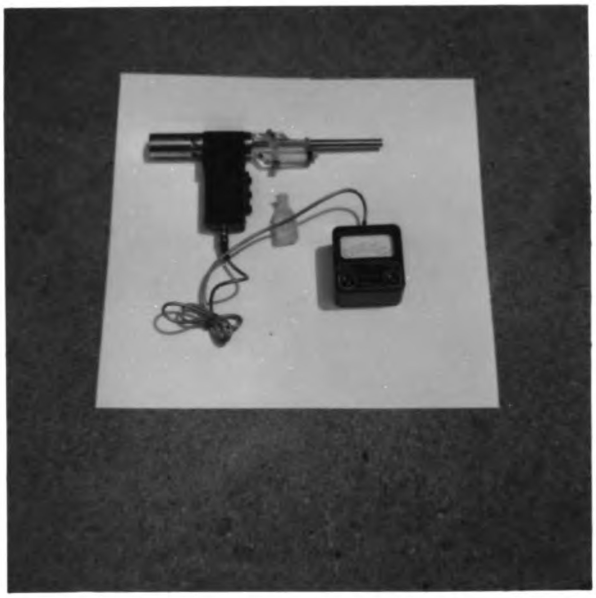

Figure 9. "Hygrophil" thermistor psychrometer, with indicating meter and distilled water reservoir.

minimum relative humidity for each habitat. To be sure that the device remained accurate it was calibrated each week in the field with a standard sling psychrometer before collections started. The hygrothermographs were also calibrated weekly with this instrument. Readings were taken each day from July 18 to Oct. 3, 1967. On days when it was raining the Hygrophil was not used; the relative humidity was assumed to be 100%.

Pit trapping in all five woodlots started on June 29 and was continued until Oct. 18 when leaf fall and the opening of small game season in the area made collecting very difficult and rather hazardous. The traps were changed every seven days over this period and new ones with clean ethylene glycol were put in their place. The pit traps were brought back to the laboratory and all arthropods were separated from the debris and preserved in 75% ethyl alcohol. All sorting and determinations of the 1991 specimens of Opiliones was personally done by the author to avoid any bias an additional technician might cause in sorting.

Descriptions of the Habitat Vegetation

Before and during this study the vegetation and cover in the edge and at both end points of each of the five transects were characterized. Although it was beyond the scope of this study to attempt a quantitative analysis of plant cover at each of these points, the vegetation and amount of cover were shown by two methods; (1) a series of three pictures were taken at the three points along each transect, and (2) the vegetation was identified in a five meter quadrat with a pit trap at the center of each of these points. All identifications were made or checked by competent botanists. Identifications were all made in May and all nomenclature follows Gleason and Cronquist (1963).

Figures 10 through 14 each show a series for one of the five transects. All pictures were taken in early afternoon on a cloudless day, so they represent the maximum amount of light penetration into each habitat during the growing season. The pictures are arranged with the mature forest habitat first in each case and are coded in this way; "M" for the mature forest areas, "E" for the edge habitats, and "O" for the old field or open habitats. The plant species are also arranged under this same code designation, and it will be used in all subsequent Opilione habitat and abundance discussions for each transect.

Figure 10 shows the 3 habitat types along the beech-maple transect. The mature locality had complete beech canopy cover over it and was on relatively high ground. The edge habitat was a low area near a small vernal pond in the woodlot. It was always a very moist, productive area because it was protected by the bulk of the woodlot to the west and a high morainic bluff to the east, on which the conifer windbreak was planted. The open habitat is located over the bluff from this in a very unprotected grassy area.

Acer saccharum Marsh. was dominant in the mature habitat understory (6-15 feet) while the field layer was dominated by *Claytonia virginica* L. and *Dentaria laciniata* Muhl. Other species present were *Arisaema triphyllum* (L.) Schott, *Erythronium americanum* Ker., *Fagus*

M

E

O

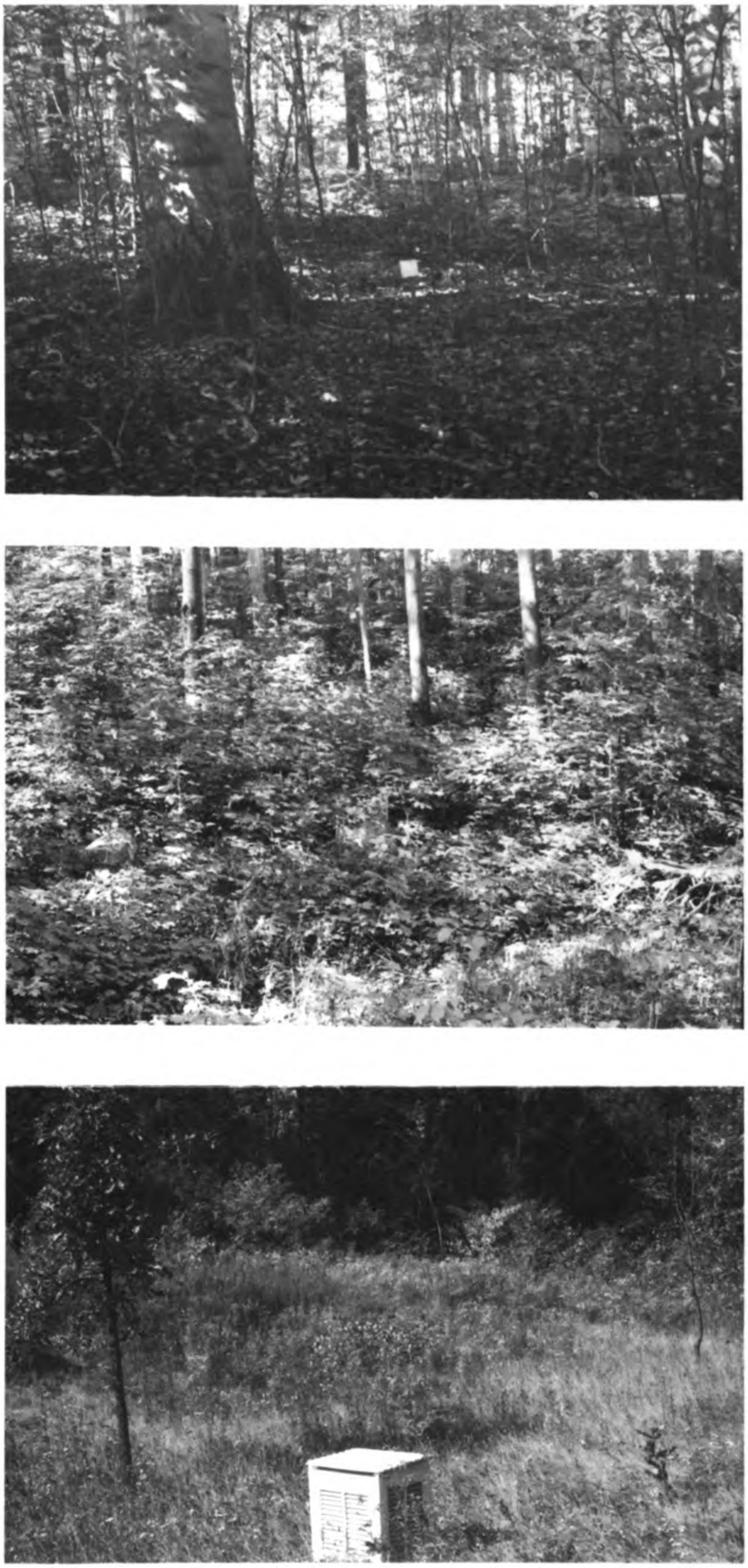

Figure 10. Habitat types on the Beech-maple transect.

grandifolia Ehrh. (seedling), Sambucus pubens Michx. and Viola pubescens Ait.

The edge habitat also had Acer saccharum dominant in the understory but the canopy was more open. Much light was coming in through spaces left in the canopy by elms killed by the Dutch elm disease. There was about an 80% leaf litter cover with the following species present: Euonymus obovatus Nutt., Carex sp. Circaea quadrisulcata (Maxim.) Franch. & Sav., Dentaria laciniata, Erythronium americanum, Fagus grandifolia, Fraxinus americana L., Geum sp., Parthenocissus quinquefolia (L.) Planch., Prunus serotina Ehrh., Quercus sp. and Tilia americana L.

The old field habitat had about a 40% dead grass and other layer, and Fragaria virginiana Duchesne was quite common though not dominant. Other species occurring in the plot were Acer saccharum, Achillea millefolium L., Antennaria plantaginafolia (L.) Richards, Aster laterifloris (L.) Britt., A. macrophyllus L., Carex sp. Celtis occidentalis L., Equisetum arvense L., Fraxinus americana L., Linaria vulgaris Hill, Panicum sp., Plantago lanceolata L., Populus tremuloides Michx., Prunella vulgaris L., Prunus serotina, Quercus sp., Scrophularia marilandica L., Solidago canadensis L., and Taraxacum officinale Weber.

Figure 11 shows the 3 habitat types along the acid bog margin transect. The mature locality was on the bog mat itself; this is evidenced by the species present. Most of the litter layer was a mat of deep Sphagnum spp.; there was another moss also, Polytrichum sp. Scattered Carex sp. and Rumex acetosella L. completed the ground layer.

M

E

O

Figure 11. Habitat types on the bog margin transect.

Included in trees and high shrubs were Amelanchier sp., Betula pumila L., Populus tremuloides and Vaccinium corymbosum L.

The edge habitat was in a flood plain forest surrounding the bog. There was a wide variety of species present here. The tree layer (above 6 feet) was dominated by Prunus serotina and Nyssa sylvatica Marsh. In the shrub layer were Crataegus spp., Hamamelis virginiana L., Quercus velutina Lamarck, and Rhus typhina L. Species in the field layer included Acer saccharum, Atrichum angustatum (Brid.) BSG, Asparagus officinalis L., Carex sp., Carya ovata (Mill.) K. Koch, Fragaria virginiana, Galium spp., Poa sp., Potentilla sp., Pteridium aquilinum (L.) Kuhn, Rumex crispus L., Solidago canadensis, Taraxacum officinale, Viola pubescens, V. rostrata Pursh., and V. sororia Willd.

The old field habitat is shown in the picture as a relatively open field near the forest. Unfortunately before the area could be characterized it was completely destroyed by road construction. A nearby old field area had Achillea millefolium L., Agropyron repens (L.), Beauv., Solidago canadensis and Rubus sp., but this is intended only as an approximation of the habitat.

Figure 12 illustrates the 3 habitat types of the flood-plain forest. The mature habitat here was so moist, that the collecting transect had to be terminated at the eighth pit trap, and even with this the last trap was sometimes floating, and occasional gerrids and saldids were collected in it. It also had the largest mosquito population the author has ever encountered in the state. Much of the Ulmus canopy has been killed by the Dutch elm disease. The field cover dominants were Symplocarpus foetidus (L.) Nutt. and Thalictrum sp.

M

E

O

Figure 12. Habitat types on the flood plain transect.

(these were replaced later in the season by Impatiens biflora Walt. and Laportea canadensis (L. Wedd.). Other vascular plants present were Acer rubrum L., Arisaema triphyllum, Maianthemum canadense Desf., Carex spp., Fraxinus nigra Marsh., Galium sp., Geum sp., Lysimachia ciliata, Mitella diphylla, Parthenocissus quinquefolia, Poa sp., Polygonum sp., Prunus pensylvanica L., Quercus sp., Rhus radicans L., Sambucus canadensis L., Saxifraga pensylvanica L., Smilacina stellata (L.) Desf., Trillium gfandiflorum (Michx.) Salisb., Ulmus americana L. and Veronica sp. Two ferns were also present, Onoclea sensibilis L. and Osmunda cinnamonea L. One bryophyte, Conocephalum conicum (L.) Dum. covered scattered areas of the soil surface beneath other plants.

The edge habitat was dominated by Populus tremuloides in the tree layer; the field layer was dominated by bracken fern Pteridium aquilinum (L.) Kuhn. Other species represented were Acer rubrum, Carex sp., Celtis occidentalis, Cornus alternifolia L. f., C. racemosa Lam., Fragaria virginiana, Fraxinus pensylvanicus Marsh., Galium sp., Hepatica americana (DC.) Ker., Luzula parviflora (Ehrh.) Desv., Onoclea sensibilis, Polygonatum pubescens (Willd.) Pursh., Smilacina racemosa (L.) Desf., Spiraea alba, Thalictrum sp., and Ulmus americana.

As can be seen from the old field habitat picture, this area was very open with no high shrubs. A few scattered cornstalks and a furrowed appearance indicated it had once been crop land. It was almost entirely Agropyron repens with a few scattered other species: Equisetum arvense, Lychnis alba L., Rubus sp., Rumex acetosella, Saponaria officinalis L., Verbascum thapsus L., Vicia sp. and Vitis sp.

Figure 13 shows the Oak-hickory forest habitat types. The mature site was on a rocky slope with a 50% leaf cover. Two high shrubs in the area were Prunus serotina and P. pensylvanica; the canopy was predominantly Quercus velutina. Other species present were Aster macrophyllum, Carex sp., Crataegus sp., Euonymus obovatus, Galium sp., Geranium maculatum, Osmorhiza longistylus (Torr.) DC., Parthenocussus quinquefolia, Prenanthes sp., Rosa sp., Sassafras albidum, Thalictrum dioicum L. and Viola sororia.

The edge habitat had one specimen of Carya ovata and one of Prunus serotina in the canopy. The field layer was dominated by Carex pensylvanica Lam.: other species occurring in the quadrat were Acer rubrum, Aster macrophylla, Cornus alternafolia, Crataegus sp., Galium sp., Geranium maculatum, Osmorhiza longistylis, Poa compressa, Polygonatum sp., Thalictrum sp., Trillium grandiflorum and Viola sororia.

The old field habitat was not very open but was the only grassy area that could be found nearby. There were Crataegus sp. individuals in the shrub layer, and the field layer dominant was Achillea millefolium. Other species present were Antennaria plantaginifolia, Aster laterifloria, Cerastium vulgatum L., Cornus racemosa Lam., Daucus carota L., Lactuca serriola L., Monarda fistulosa L., Parthenocissus quinquefolia, Plantago rugelii Decne., Poa compressa L., Quercus alba L., Ranunculus sp., Rumex acetosella, Solidago sp., Taraxacum officinale, Trifolium hybridum L. and T. repens L.

Figure 14 shows the final series of the habitats in a white pine forest. A conifer forest with a high, well developed canopy was

M

E

O

Figure 13. Habitat types on the Oak-hickory transect.

M

E

O

Figure 14. Habitat types on the Pinetum transect.

desired as a comparison of similar aged confier and deciduous forests, but the only forest of this type in the vicinity was the MSU Pinetum, a grove of 60 year old white pines. The only area available for trapping adjacent to it was a few acres of flood plain forest. Thus in this transect the margin between the conifer and deciduous forest was designated as the edge with the mature area in the flood plain forest and the old field area in the most open area of the pine forest. Thus all the points have upper canopy but the ground cover varies considerably as can be seen in the series of pictures.

In the mature area, Tilia americana made up most of the canopy layer, while Aster lateriflorus and Rhus radicans were the dominants in the field layer. Other species present in the quadrat included Arisaema triphyllum, Clematis virginiana, Equisetum hymenale L., Eupatorium fistulosum Barrett, Fraxinus americana, Geum sp., Lysimachia nummularia L., Minispermum canadense L., Panicum sp., Parthencissus quiquefolia, Plantago rugelii, Polygonum sp., Smilicina stellata, Solidago canadensis, Thalictrum sp., Viburnum dentatum, Viola sororia, and Vitus sp.

The edge habitat showed the influence of both forest types; there was a 70% pine needle cover, which reflected the Pinus strobus L. canopy above. Acer saccharum was the dominant in the shrub layer, but there were no actual dominants in the field layer. Other species in the area include Asarum canadense, Aster macrophylla, Circaea quadrisulcata, Claytonia virginica, Erythronium americanum, Euonymus obovatus, Geranium maculatum, Galium spp., Impatiens biflora, Lonicera sp., Nepeta cataria L., Parthenocissus quinquefolia, Pinus strobus, Polygonum sp., Prunus serotina, Rubus sp., Similicina stellata, Thalictrum dioicum, Tilia americana and Viola pubescens. This area had many of the species that the beech-maple edge contained.

As can be seen by the picture of the point, the old field area had no shrub layer and little vegetation in the field layer. It was thickly covered with a 90% cover of pine needles. There was a complete Pinus strobus canopy at this point. There were a few scattered specimens of the following species; Acer saccharum, Ambrosia trifida L., Arctium minus Schk., Aster macrophyllus, Berteroa incana (L) DC., Carex spp., Chenopodium album L., Impatiens biflora, Leonurus cardiaca L., Nepeta cataria, Oxalis sp., Panicum sp., Smilax herbacea L., Solanum nigrum L., Cynanchyum nigrum, Taraxacum officinale, Xanthoxylum americanum, and Viola sororia.

The preceding species lists and pictures for each habitat on the transects give a more detailed idea of the transects than simply saying they each cross a different type of forest margin.

Temperature and Relative Humidity Fluctuations

The temperature and relative humidity reading for the same four week periods as abundance data are shown in Appendices II and III. The mean of each 4 week period for both heights at each location was taken for each value shown.

The temperature data shows few differences either between the heights or between habitats. No consistent trends other than the expected lowering of all temperatures as fall approached were shown.

The relative humidity data are more informative, however. Although the mean differences are not as evident as the primary readings that had been taken to set up the transects, there is still a trend towards a higher relative humidity on the mature ends and also a higher relative humidity at 2" than at 4'. The Bog is a notable exception. It was found that the mature point on the bog transect was actually consistently drier than the same point in the flood plain forest adjacent to it. This was probably because the mesic point in the bog was more open with very little canopy, yet was a long distance from the bog lake itself.

Differences were undoubtedly lessened by the high percentage of rainy periods on sample days. This would tend to make both temperature and relative humidity similar at both the 2 inch and 4' heights and also along the transects, and would mask the very low humitities that occur in mid-afternoon on a clear summer day. Also, it was not always possible to make all collections at exactly the same time each week and it was sometimes dusk before the last readings were taken, especially during the shorter fall days. This would also tend to lessen differences, as the cooler temperatures in the evening usually bring the relative humidity up to the dew point before morning.

These diurnal changes were better demonstrated by records from the two continuously recording hygrothermographs in operation in Toumey. One station was placed in the old field area while the other was set up in the interior of the woodlot. Only one hygrothermograph and shelter was available until September, so the readings are shown for the period between Sept. 12 and October 11. This one month period encompassed a great variety of weather, from 85°F., dry summer days to some very cold rainy days late in the period when the temperature fell to 32°F. Thus a good sample of comparative conditions was obtained.

Figure 15 shows maximum and minimum temperatures in both the old field area and the interior of the woodlot. Figure 16 shows maximum and minimum relative humidities for the same two areas over the identical period of time. A comparison of the two areas shows that there are much greater extremes in the dry area than under the canopy, particularly in respect to relative humidity. Daily ranges of 70% were not uncommon in the old field area, reaching 100% at some time during each day recorded. In the woodlot the relative humidity never drops as rapidly or as low. The daily temperature differences often reached 30 degrees in the old field, while the range in the woodlot was 10 to 15 degrees on most days.

It can be added further, on the basis of standard Weather Bureau climatological summaries for the time period involved, that the early part of the record manifests consequences of one of the driest Septembers on record for the area. The first rain that fell in the period was on Sept. 21, when 1.07 inches were recorded at the U. S. Weather Bureau's E. Lansing station (located approximately 300 yards west of the woodlot). Smaller amounts were reported on several other days during the remainder of the month which was generally stormy. There was no rain in the first week of October, but near the end of the observation period (Oct. 9, 10, 11) there was some precipitation. The effects of these storms on temperature and relative humidity is quite marked, as can be seen in the figures.

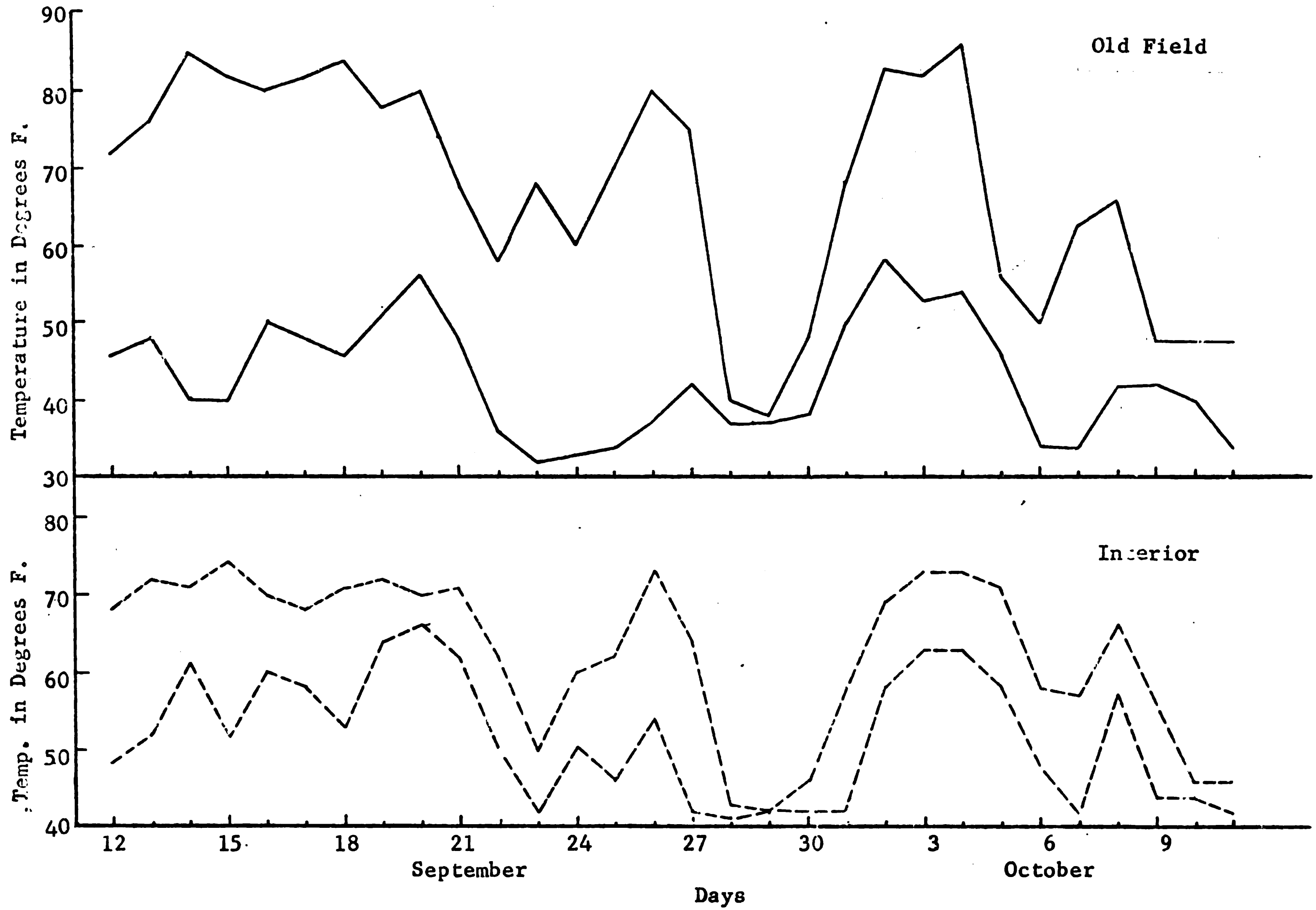

Figure 15. Daily maximum and minimum temperatures in the interior and in the old field area of Toumey woodlot, Sept. 12-Oct. 11, 1967.

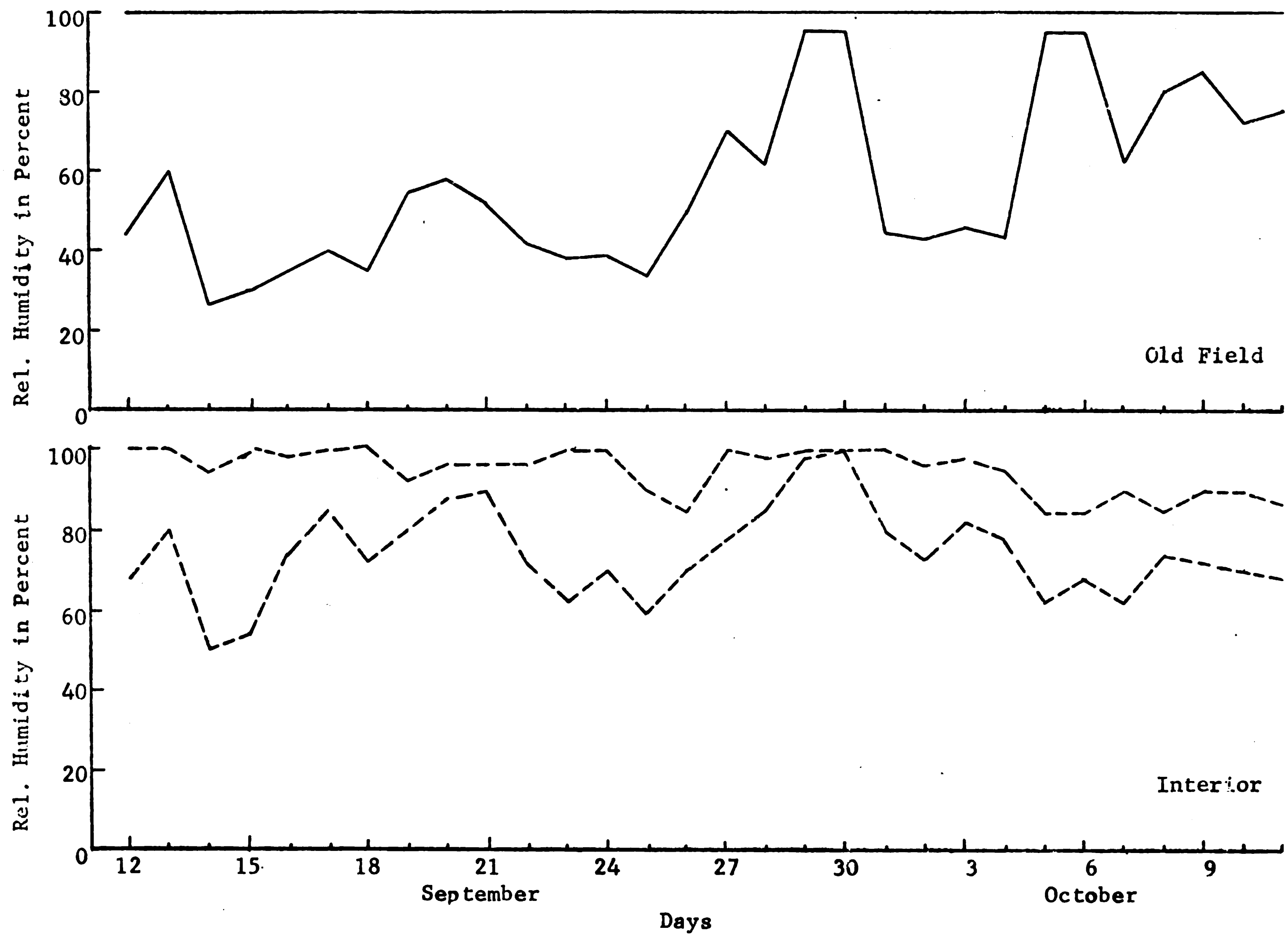

Figure 16. Daily relative humidity extremes in the interior and in the old field area of Toumey woodlot, Sept. 12-Oct. 11, 1967.

A more detailed picture of the diurnal pattern is shown in Figure 17. Weekly charts were used for most of the records but daily charts were installed for the week of Sept. 13-19. The graph shows the temperature and relative humidity at four times each day; 4 A.M., 10 A.M., 4 P.M. and 10 P.M. These are reported with the standard Weather Bureau notation of 24 hour days (4, 10, 16, 22), illustrating the maximum diurnal range in each area. There was no rain during this period or for the previous two weeks, so these recordings should show high moisture stress conditions for the areas.

The moderating effects of the forest canopy are apparent. Not only is there a larger range of temperature and relative humidity in the dry area, but the changes are much more rapid too; a jump from 60 to 90% relative humidity in 30 minutes was not uncommon. The changes under the canopy were more gradual as well as being over a narrower range. Such gradual changes could allow Opiliones to move out of an unfavorable environment more easily than would the very rapid changes outside the woodlot.

A perusal of the Weather Bureau records for this same period show a different situation than did either of the stations. This investigation is another chapter in the rapidly expanding story of microclimatic differences in a very small area, and emphasizes the fact that Standard Weather Bureau data taken at a distance from an experimental site must be used with discretion. A field experimenter may not be able to take readings as accurately as the weather bureau stations do, but his experimental error will in all probability be less than the differences between the station and his experimental plots.

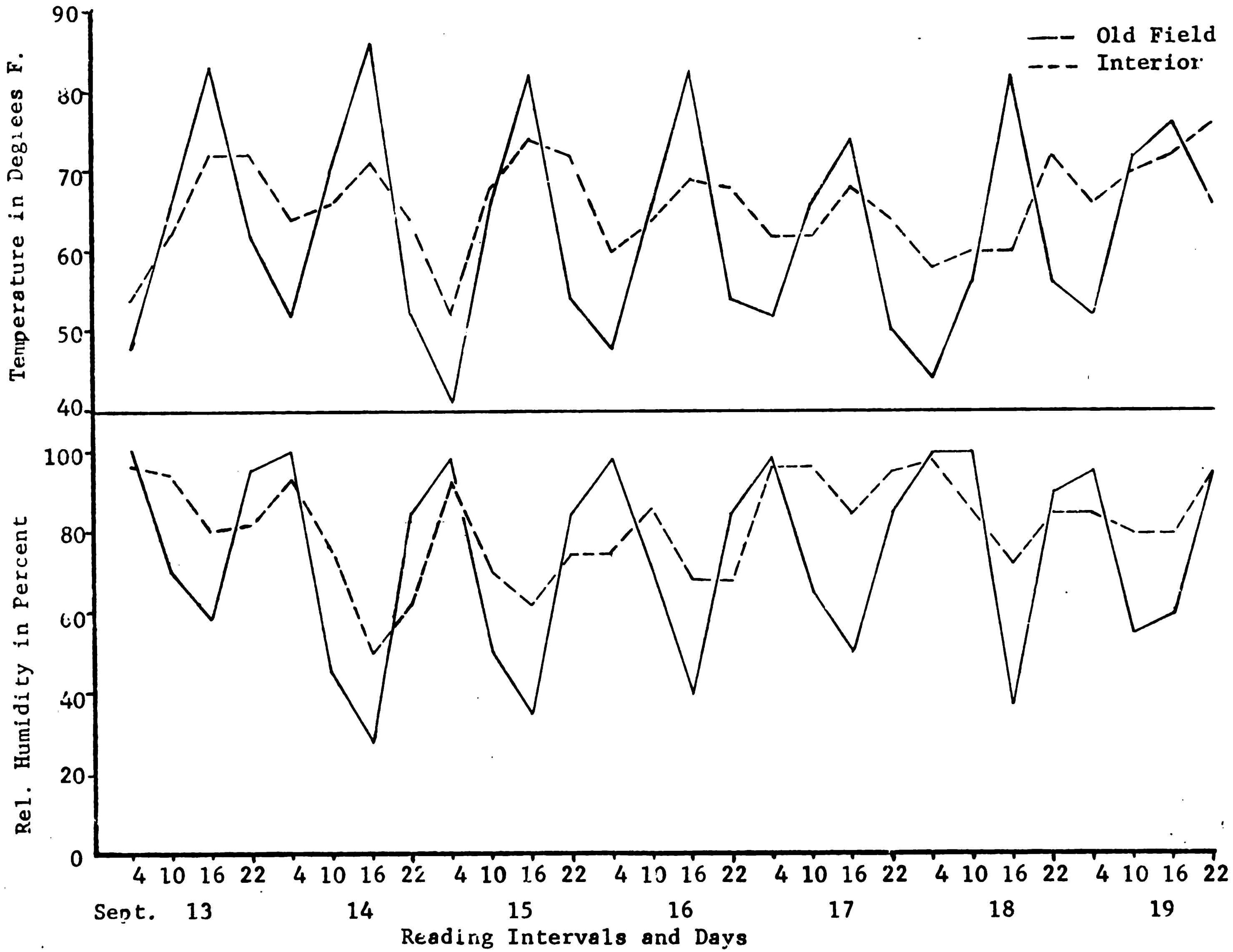

Figure 17. Comparative temperature and relative humidity readings between the interior and the old field area of Toumey woodlot, Sept. 13-19, 1967.

Results and Discussion

Table 2 gives a list of all species of Opiliones collected in the pit traps for the edges aspect of the study. The same code designations for habitats have also been applied here; "M" for the total for the three pit traps in the mature areas, "E" for four pit traps in the edge areas and "O" for totals for the remaining three pit traps in the open areas. Occurrence in each habitat as well as total numbers of each species collected in the respective habitats are shown.

From the table it is evident that L. calcar, L. longipes, L. nigropalpi, L. vittatum, O. pictus argentus and O. pictus pictus were collected in very small numbers and thus little can be said about these species. The consistency of the habitats in which these limited numbers of specimens were collected should be noted in passing, however. L. calcar was found only in edge areas, mostly in the Beech-maple edge. Edgar (1960) characterized this species as one found "not far from the edge of a clearing of some sort". He reported that it was not very abundant in an area with a dense upper canopy or one that was completely open. L. longipes, on the other hand, was described as occurring in an area with a relatively dense upper canopy and lush, undisturbed ground cover in a situation protected from the drying effects of the sun. This is not shown very well here, but this species was very abundant in the mesic area and over much of the woodlot. As many as 35 specimens of L. longipes have been collected in less than an hour of hand picking in areas adjacent to the transect in the beech-maple woodlot at dusk. L. nigropalpi occurred in

TABLE 2

HABITAT OCCURRENCE AND SEASON TOTALS OF LOCAL OPILIONES

	Beech-Maple			Bog			Flood Plain			Oak-Hickory			Pinetum		
	M	E	O	M	E	O	M	E	O	M	E	O	M	E	O
H. maculosus	-	1	72	12	12	6	8	52	185	14	26	49	-	-	-
L. calcar	-	9	-	-	-	-	-	-	-	-	-	-	-	1	-
L. longipes	1	5	-	-	-	-	-	-	-	1	-	-	1	1	-
L. nigripes	5	10	1	-	9	3	4	4	-	1	1	-	3	-	2
L. nigropalpi	2	2	-	-	-	-	-	1	-	4	2	1	1	-	-
L. politum	6	8	-	-	1	3	1	10	-	2	2	2	10	1	1
L. serratipalpi	-	-	-	-	-	-	-	-	-	3	2	16	-	1	-
L. vittatum	1	-	1	-	-	-	-	-	-	-	-	-	3	3	2
O. pictus argentus	-	-	-	-	-	-	2	2	-	-	-	-	1	2	-
O. pictus pictus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
P. opilio	-	9	177	-	-	-	-	-	3	-	-	-	13	167	189

habitats similar to L. longipes, but its presence in the oak-hickory woodlot indicated a tolerance for somewhat drier conditions. L. vittatum is also found in very limited numbers and with little regularity. It has been rather strikingly shown by the Monroe Co. malaize trap data that this species is not taken very well by pit traps. This species and also the previous mentioned species of Leiobunum all have very long legs and are probably more arboreal than other species. The long legs might also enable them to escape pit traps even if they did tumble in (this has been observed by the author for L. longipes).

The paucity of the subspecies of O. pictus is another matter, however. Over 200 specimens of O. pictus pictus were collected in Monroe Co.; this short-legged compact form appeared to be collected well in pit traps there. Its scarcity in pit trap studies probably gives a true indication of a low population. It had not previously been reported for either Clinton or Ingham Co. (although both subspecies are reported for an adjacent Co., Livingston) and the author has never been able to collect it alive in the area, although an extensive search was conducted during the summer of 1966 for this species as a laboratory subject for rearing work. This is not the northern limits of its range, either; Edgar (1960) collected it in several Upper Peninsula counties and there is a series from Isle Royale in the MSU Entomology Museum collected during an ecological study of the spiders on the island. Bixler (1967) used both pit traps and hand sampling methods to collect the spiders, yet most Opiliones from this work are listed from pit traps. Furthermore, the vast majority of specimens collected were O. pictus pictus, in the middle of August.

Undoubtedly there were other species of the order in the area, but this adds weight to the validity of pit trap sampling of this species.

Collection data for the five most abundant species will be examined in more detail. Figure 18 shows numbers of these species in each of the habitats for the four months in which samples were taken. Each time interval is actually a four week period to divide the 16 week sampling schedule into equal parts for comparison. Each value represents the total collection for the three pit traps in each habitat for a four week period. To make the 4 pit trap edge figures more equivalent, collection data for one of the pit traps in each edge was randomly chosen and discarded.

L. politum was the most widespread species, occurring in 12 of the 15 habitats, and at some point in each woodlot. It was not collected in large numbers, here or in Monroe Co. This wide range corresponds to Edgar's information on the species (1960). He collected it more often than any other species in the state and mentioned that it was found in association with almost all other species of Opiliones. Though it was most abundant in areas where the ground vegetation was very thick, he mentioned it was often found far from its favored habitat, in yards, fence rows near woods, or in the interior of forests.

H. maculosus is the next most widely distributed species occurring in 11 of the habitats. This species occurred in extremely large numbers in some areas, as many as 20 specimens in a single pit trap at times. It was the most widespread species in the Monroe Co. woodlots, occurring in some numbers in every one. It was the only

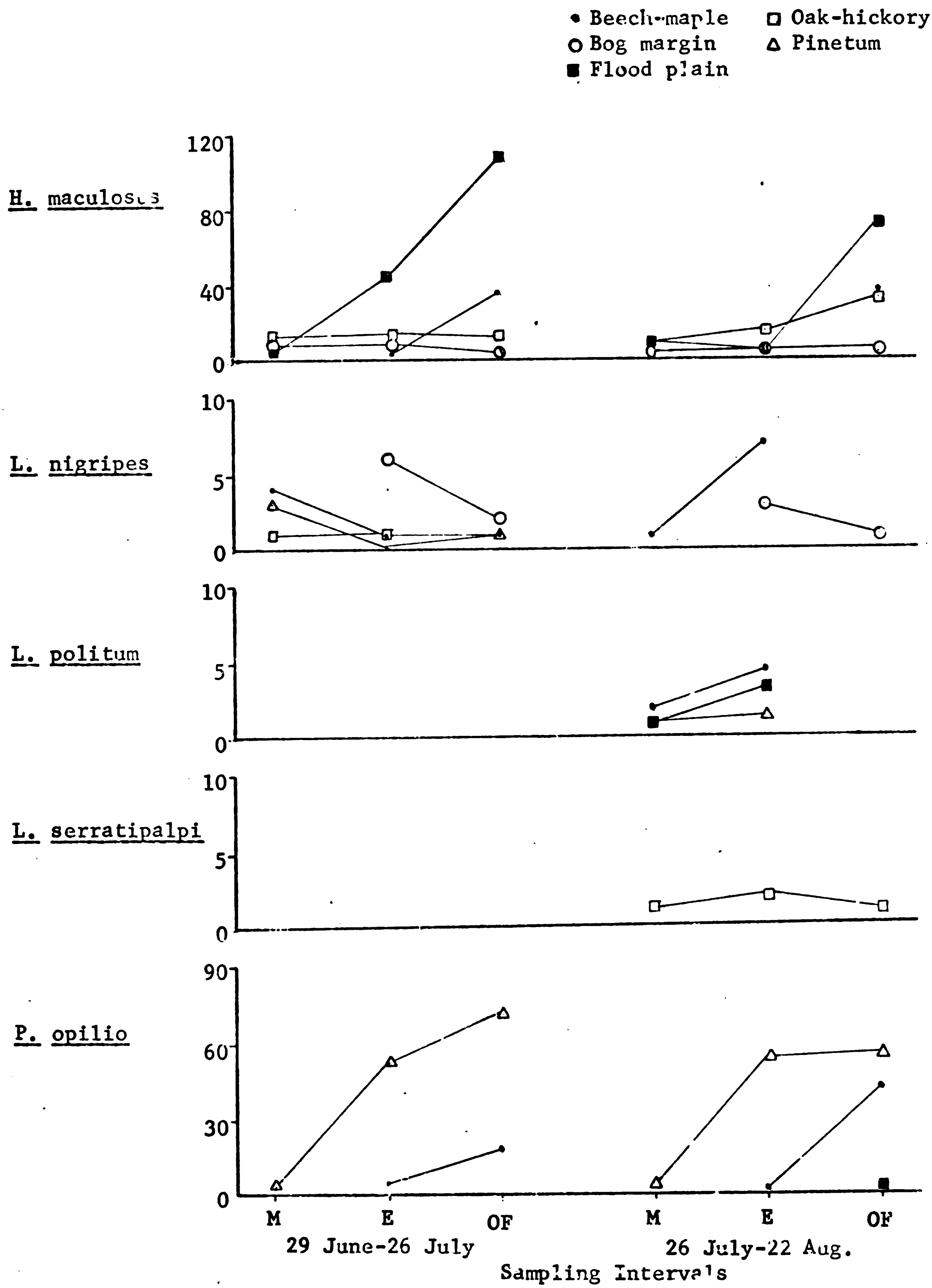

Figure 18. Comparative abundance of the five dominant species by monthly intervals along each transect.

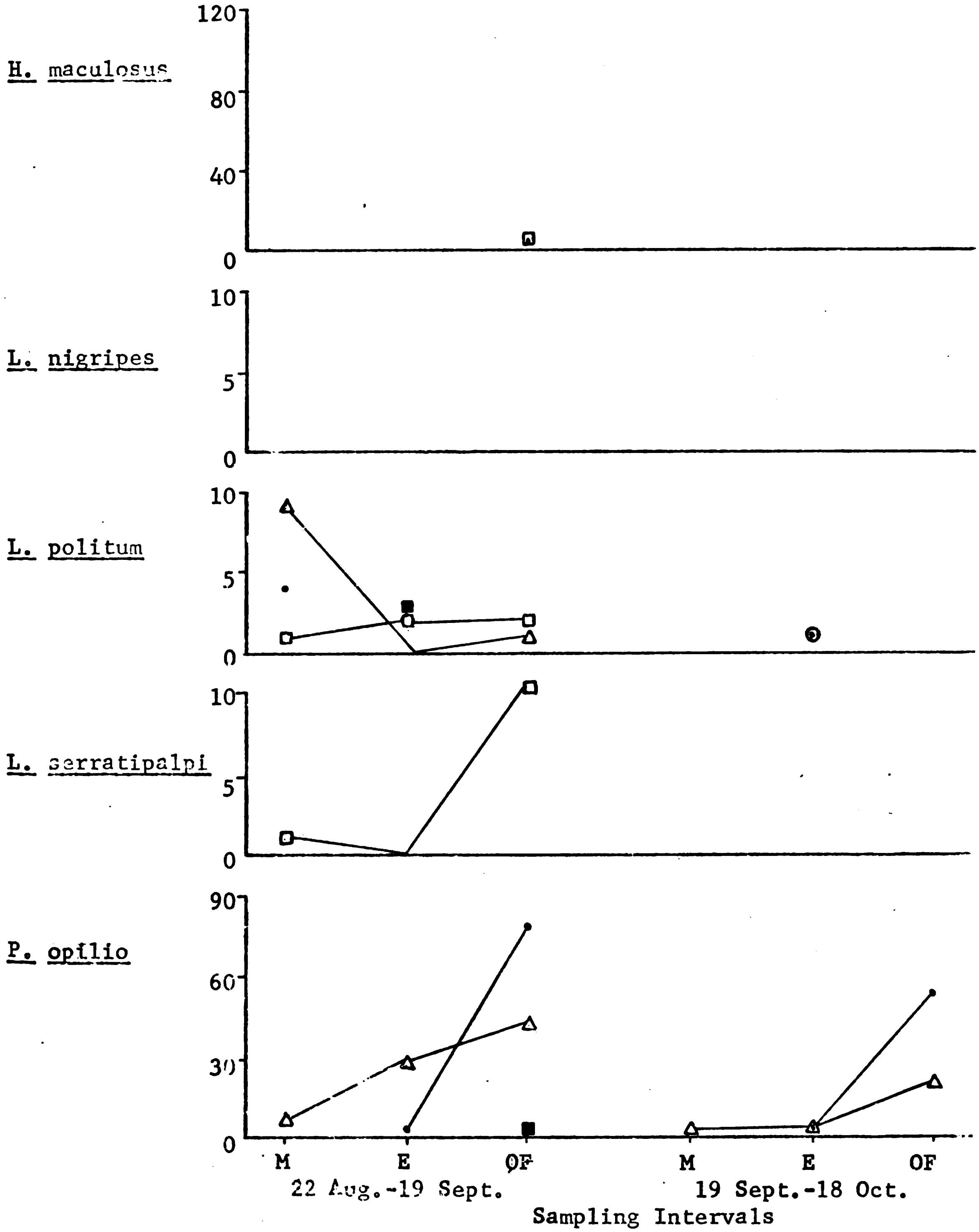

Figure 18--Continued

species to occur in greater numbers in the untreated woodlots there. Collections from the local transects helped explain this. Fig. 18 shows clearly that H. maculosus predominently inhabits open areas, although it is found in smaller numbers in the edge and mature habitats. The control areas in Monroe Co. had poorer soil and thus less luxuriant tree canopy and vegetation. This could allow more openings and penetration of light. The points where the species is missing in local transects are as significant as are the high populations. The species was not collected at any point on the Pinetum transect or at the mature point under the heavy beech-maple canopy. The absence at the two mature points is more understandable than is the complete absence in the edge and open areas in the Pinetum. However, these two points each have a complete canopy of white pine. While they are comparatively dry, they are not open. Also, the Pinetum has been sprayed aerially with DDT for mosquito control in the past.

Edgar (1960) reported H. maculosus from dry areas with stands of grass and often goldenrod. This is strongly supported by the above data. He reported it from only eight collection sites, however, and indicated it probably was more widely distributed than his records showed. Based on all pit trap collecting done by the author this is certainly true. The species has been one of the dominants in almost every area where the traps have been used, from Monroe Co. to Wexford Co. Yet, only two specimens of this species were in the MSU collection when this study began (part of the Dreisbach collection, from which Edgar made some of his records). It is seldom brought in by casual collectors for identification, and the author has seen less than a dozen live specimens.

How harsh an environment this species can survive and possibly how it manages was very graphically demonstrated during a reconissance trip for possible collecting sites. The automobile had been left near the top of a sandy rise while a boggy area nearby was explored for a possible edge transect. Twenty minutes later, in the process of leaving, the back tires quickly buried themselves in the almost dunelike, sparsely vegetated sandy ridge. During strenuous efforts to extricate the vehicle a specimen of H. maculosus was flushed from the space underneath the frame. Fortunately the author was not so angry at the time as to neglect collecting the specimen, and the double import of this occurrence did not escape him. First, the species must be able to survive in extremely exposed habitats in which one would not ordinarily look for any species of Opiliones, and second, that it probably does so by remaining inactive during the day. It is a very large bodied, relatively short legged species and probably seldom leaves the ground layer. It is a rather drab brown form with scattered light spots on the dorsum. This combined with the short legs would make it easy for this species to work its way into tufts of grass and small soil crevices to escape the harsh daytime conditions. Nocturnal activity limited to the ground surface and the short legs make H. maculosus very susceptible to pit trapping. Thus the traps have revealed a dominant species that has been collected only at scattered localities in the state before.

L. serratipalpi was included for analysis despite its low numbers because it too is a rarely collected species. Edgar reported it from only four areas in Michigan. Based on these limited collections the most abundant canopy species associated with it was oak. It was collected in this study only on the oak-hickory transect and mostly in the dry area. Its late occurrence of adults, mid-August to mid-September, may be part of the reason Edgar did not collect it more often since most of his collecting was done before September. It still must be relatively uncommon, however, because only two specimens have been collected by the author at any other localities in the state (one in Monroe Co. and one in The Pinetum edge).

Phalangium opilio was the most numerous species collected. Over 700 individuals were taken and the occurrence resembled the data for H. maculosus; few or none taken in the mesic areas and large numbers taken in the old field areas. The distribution was much more limited however. They were taken on three of the transects and in significant numbers on only two, the Beech-maple and the Pinetum. The large number collected on the open site in the Pinetum is even more surprising when one looks at the picture of this area (Figure 14-0); there is almost a complete cover of white pine needles; the surface of the soil is very dry, and there is very little vegetation. Edgar (1960) reported this species was one of few common around human habitation and man-made disturbances. This area has a large number of casual campus visitors moving through several parts of it and is changed from what an undisturbed conifer forest floor would be. However this human disturbance factor does not explain the large number found in the dry area of Toumey, as few people get that far away from campus and the Department of Forestry has kept it as undisturbed as possible. The species has been collected in small numbers from other undisturbed areas but never as plentifully as in the Toumey vicinity.

As in the Monroe Co. collections of this species, both adults and young were collected in varying proportions throughout the entire collection period. This and biological work lend support to the hypothesis that in this species there is more than one generation a year.

LABORATORY BIOLOGICAL WORK

Preliminary Species Survey

Edgar (1960) has done detailed field work on the biology of several Michigan species, particularly *L. calcar*, *L. longipes*, *L. politum* and *L. vittatum*. His excellent reports on instar size and time interval, feeding, mating and numerous other biological aspects of these species give a fairly complete picture of Opilione life cycles.

The biological work in this study has been directed towards a relatively unexplored facet, laboratory rearing of selected species in large numbers for experimental work. Although progress has been made with one species, mass rearing has not been perfected to the point where insecticide work can be done. Thus, the initial objective has met with limited success. The completed research will be reported as a basis for further study.

Initial work consisted mainly of collecting as many live species as possible and bringing them back to the laboratory for trial maintenance. Several different relative humidities and types of food were tried at different times over the summer of 1966, based on information in the literature.

Only three species survived longer than one week in the rearing chambers; *H. maculosus*, *L. vittatum* and *Phalangium opilio*.

All other Michigan species either have not been collected alive or died within a week of their introduction into the chamber. The three species are all open area types commonly found in exposed habitats. Also, all are easily identified in the field and observations could be made without disturbing or killing them for determination. Moreover, the three species were all abundant in Toumey and in other nearby collecting areas, so a supply of material for laboratory work was available.

L. vittatum is primarily an arboreal form and seldom comes to the ground except along forest margins and when mating or ovipositing. For maintenance, a terrarium with two square feet of litter surface in the bottom was prepared. An effort was made to remove this material from Toumey without rearranging its structure. It was then placed in the terrarium at the site. Several small branches were added to simulate an arboreal habitat. The chamber was maintained at a temperature of 60 degrees F. and 75% relative humidity. A food source of yeast and corn meal (suggested by Fowler, pers. comm.) was placed in a bottle cap recessed into the soil and open water was placed nearby in a glass container. A glass cover placed over the top prevented the relative humidity from dropping when the growth chamber door was opened.

L. vittatum and associated woodland species were placed in the terrarium. In a few days the other species all died and only L. vittatum remained. It survived for four or five weeks, but no mating or oviposition was observed. Experiments with different sizes of containers yielded no additional information. Perhaps L. vittatum preferred a complete tree to move around on, but since this was rather difficult to reproduce in the laboratory, attention was focused on the other two species.

H. maculosus survived in the lab but did not adapt well to controlled conditions. Only a few specimens were collected and these ate very little. They were generally very lethargic and made few movements. This may reflect their natural behavior in light. No mating was observed and no eggs were obtained from these species. Thus, although its field habitat requirements appeared to be very broad, this species also lacked some critical factor in the controlled environment. It was eventually bypassed for the species showing the most promise in rearing work; Phalangium opilio.

Many specimens of P. opilio were collected. It was commonly found around building foundations, in cropland and near other man made disturbances. Todd (1949) characterized them as a cornfield species and collected them in southern England only in cropland, grassland and gardens. Edgar (1960) also collected the species in Michigan in these habitats and in addition found them in shrubs and hedges and near the foundations of building. The field data presented for P. opilio in this study generally supports these characterizations, although it has also been collected in woodlots. Edgar (1960) found that this species was able to survive longer periods of dry atmosphere without food or water than any other species except L. vittatum.

Rearing of Phalangium opilio

The laboratory rearing of P. opilio and the development of an artificial substrate for oviposition has been described previously (Klee & Butcher, 1968). The procedure will be summarized only briefly here. A more detailed description of the collecting habitat and further work done with the species will be discussed.

Adults survived well in styrene containers at 65 degrees F. and 75-90% relative humidity. Numerous pairs were brought into the lab but no oviposition was observed. They were given the yeast-corn meal mixture (1:5 proportion) and also some dried bacon for food. They sometimes ate moribund specimens of other species of Opiliones in the same container. They also ate members of their own species, so only three or four were kept in each container.

All eggs collected during the 1966 and 1967 phases of the rearing study were collected in a very limited microhabitat. They were all found along the edge of a dairy barn foundation in soil and under stones. The foundation of this barn, located on the River Bend Dairy Farm in Shiawassee Co. (T5N R2E Sect. 35), was the richest P. opilio habitat ever encountered by the author. Explorations of numerous other cement foundations at other locations have failed to yield eggs, even though the adults were often present. Each time the site was visited over the two seasons many specimens of adults and immatures were easily collected. Almost a thousand eggs have been taken from the area under the edges of rocks or dispersed in moist soil. Surprisingly there were also large numbers under blobs of mortar, which had been dropped on the foundation when the cement block wall was laid. The area is not very old; the section of the barn along which the eggs were found was constructed in 1957.

Figure 19 shows a view of the microhabitat. The grassy margin is dominated by Bromus inermis Leyss. with some Chenopodium album L. and Amaranthus retroflexis L. This exposed area at the base of the west wall of the building appeared to be a very unprotected place for overwintering of eggs. When this was mentioned to the owner, however, he said that the area was probably relatively warm compared to the surrounding soil. This was due to the heat given off by a large herd of dairy cows during the winter months when they are kept inside. This would help explain the extremely high population near the dairy barn as compared to the few found around adjacent buildings.

Large numbers of eggs have been obtained from this area and through use of the artificial substrate. Over 95% hatch has usually been observed from natural sites with lower percentages from the artifical substrate. However, although most of the immatures went through the first two molts, none of the hundreds of specimens obtained in fall collections ever made the third molt. Some invisible barrier stopped every specimen at that point.

During this time the author began corresponding with D. Husted, a researcher at Ft. Hays State College in Kansas working on the rearing of two plains species of Opiliones. He wrote of similar problems encountered in rearing. He had had little success with growth chambers and sterile containers or plaster-charcoal bases to keep the humidity high. The young always died in the early instars. Husted

Figure 19. Natural oviposition site of Phalangium opilio, in cement crevices and under rocks at base of barn foundation.

was finally able to rear some specimens past this stage by a very simple method. He filled the bottoms of large desiccator jars with soil and then forced glass tubes down into it. Water was added to the substrate through the glass tubes. This kept the surface moist but not wet. A glass dish with a wet sponge was used as a water source. The desiccators were placed on a window ledge in his office. Relative humidity was controlled by a very primitive method; the top was taken off during the day and replaced during the evening hours. He also found that the young had to be handled with extreme care when they were transferred to a different container. Forceps apparently damage the legs and make the next molt impossible.

A large number of eggs of undetermined species were collected in a sandy area on April 15, 1968. Most hatched in from one to two weeks after they were put into the chamber at 60 degrees F. The young were divided into several smaller groups of about 35 specimens with some of the original substrate in each one. Each group was given brewers yeast and live Collembola from a large Folsomia fimetaria (L.) culture maintained in the MSU Soil Zoology Laboratory. The Collembola were taken very rapidly by the immature Opiliones, although they were of comparable size. If a collembola would stop jumping and start twisting back and forth, close observation usually revealed that it was grasped in the chelicerae of an opilione. This probably helped to reduce the extensive cannibalism observed initially.

Two groups were put into aquaria with moist sand on the bottom and half dram shell vials with distilled water and a sponge in the open end for a water supply. The aquaria were left on a bookcase and were covered during the evening and uncovered in the morning. The other groups were left in the growth chamber under the same conditions that had been used previously. Within ten days all specimens in the growth chamber had died, while most specimens in the aquaria were surviving well and many had molted.

At the time of this writing 18 specimens are still alive and some have reached the 5th instar. They are now identifiable as *P. opilio*. There has been some cannibalism but they have fed mostly on dried June beetles made available to them. Cannibalism is actually not a problem if large numbers of specimens are collected; it merely provides a good food source.

Based on this information the oscillation of relative humidity was a critical factor in survival. Molting is adversely affected by humidity extremes in either direction. Edgar (1960) described the difficulties encountered in molting in both cases. If relative humidity is too low the long legs dry out before they can be completely extricated from the molt exuvia. Then the animal dies with its legs tangled beneath it. If the relative humidity is too high, the chitin of the freshly molted legs can not dry properly. When weight is placed on them they are twisted out of their normal shape. The latter was probably the case in previous rearing work with continuous high humidity. An animal with twisted legs would live through the next instar but would never be able to molt again; thus it would die. The possibility of an obligatory diapause for the fall specimens can not be ruled out, even though experiments on chilling the eggs have been unsuccessful. However, a diurnal humidity cycle is normal in the field.

Eclosion and First Molt of *Leiobunum* sp.

Two groups of Opilione eggs were collected under very tight bark of dead elm trees on January 23 and 24, 1968. The position of the eggs, under tight bark and about 3 feet off the ground, suggested that the eggs were one of the species of the predominently arboreal genus *Leiobunum*, although of course no adult animals of any type were observed at that time of the winter.

The eggs were left as undisturbed as possible on their respective pieces of bark, and were put into small opaque metal containers with some moist cotton, in an attempt to simulate the environment under the bark as closely as possible. The cannisters were placed in 60^{o} F. constant temperature growth chambers, and the eggs were checked periodically for signs of development.

Within a week a dark area began to appear which later proved to be the eye tubercle. Mold began to develop to a limited degree on some areas of the bark around the eggs, but remained conspicuously absent from the egg masses themselves. They gradually changed from a very pale white to a more yellowish color, until a few days before hatching, when the grayish-white embryo became easily visible. On February 9, 17 days after they were obtained in the field, the eggs hatched. A few young were noted on that day's inspection of one container, so the container was taken from the growth chamber for more detailed observation under a binocular microscope. Only normal room illumination was used in order to prevent desiccation of the newly hatched immatures.

The timing of the observation proved to be very fortuitous, as during the course of the next hour the remainder of one large group of eggs hatched, and the entire process of eclosion and the shedding of the first molt was observed in various stages for 15-20 individuals. Stages and their duration were recorded and averaged over several specimens. Later molts of two North American species of *Leiobunum* have been excellently described and portrayed by Edgar (*Leiobunum longipes* Weed and *L. vittatum* (Say), 1960) and also in somewhat less detail by Stipperger (1928) for a European species, *L. limbatum*. To the author's knowledge, eclosion and the almost immediate first molt, though briefly mentioned by several researchers, has not been reported in detail and because of this it will be treated in its entirety here. Specimens were removed and preserved at different stages for later illustration.

A few minutes prior to hatching, movement was observed in the egg. The abdomen contracted in a wave-like motion along the longitudinal axis and caused the cephalothorax to move gradually up and down. This seems to cause the small hatching tooth on the anterior margin of the cephalothorax to "score" the egg membrane, as the break appears to move both ventrally and dorsally from this point. Edgar (1960) briefly described the position of the embryo of *L. longipes* in the egg just prior to hatching. This species of *Leiobunum* seems to correspond closely to his account. A dorsal view shows the two black eyes in the eye tubercle and the distal ends of the second pair of legs coiling up over the dorsum of the abdomen. The remainder of the legs are folded underneath the animal. The egg tooth is minute and difficult to see in this species. A ventral view shows the folding of the appendages under the body. The palpi, as well as the first and second pairs of legs cross each other against the ventral side of the body. The long second legs then coil up over the other side and back over the dorsum. Leg pairs three and four extend posteriorly a short distance and then make a 180 degree turn after which they run anteriorly, parallel to the long axis of the body, almost up to the chelicerae. From a ventral view they cover parts of the palpi and the first two pairs of legs. None of the tarsi of the legs appear to be divided into many segments at this time. Later stages have many more segments on the tarsi.

The chelicerae are the first appendages to emerge from the egg membrane, but once they were out the rest of the body and finally the legs emerged quite rapidly, usually in one minute or less.

The first instar moved around somewhat but very slowly. The whole body was covered with a sticky, translucent white layer. Few tubercles were present on the first instar integuments; only some dark setae on the legs and particularly on the palpi. The eye tubercle is pressed down into the dorsum of the cephalothorax at this point and protruded very little; this was a very characteristic feature of the first instar.

Within 15 minutes after eclosion the first molt began. This is probably one of the reasons it has been so seldom observed. One of the first signs that the molt was about to take place was the spreading out of the legs to a very flat position, before the body started its spasmodic contractions. This may have assisted the molt, and made the legs quite linear so that they could be more easily withdrawn. A molting fluid was present that helped lubricate all their elements, also. The molting break point appeared to be at the anterior margin of the cephalothorax, as the chelicerae were the first things to appear. The skin was then pulled back over the eye tubercule and body, leaving the legs protruding posteriorly and remaining in the exuvium. Then the palpi and the first pair of legs appeared and next the third and fourth pair; the second pair, longest of all, were the last to be withdrawn. The cheliceral claws were quite dark and apparently well chitinized at this time. They appeared to be used to grasp the legs and assist in pulling them out of the old exuvia. There were lobes on the first two segments of the palpi covered with setae, that appeared to be used to help clean the legs as they were withdrawn. They have been observed in later instars also, but are rarely present in adult forms. This would further support the hypothesis of their use, as they would no longer be needed for molting cleanup in the adult stage.

After all legs were extracted, the animals sat motionless on the tips of the abdomens for several minutes. Then they slowly began moving the legs about, as if drying them, and then put all except the second pair of the legs down on the substrate. They then pulled themselves off the tripod like remains of the first exuvium and immediately started to drink from the central area of it. This probably was some sort of water retention device. One spent 10 minutes at this, another spent 7 minutes. Afterwards, they moved away quite rapidly from the site of the molt; particularly if they were disturbed at all.

The cast exuviae of the first instar were left in stellate patterns fastened to the substrate. They dried out quickly and no segmentation was visible afterward, but the characteristic pattern remained, and the dried out white exuviae were quite visible at different places in the container.

Table 3 shows the duration of the different stages of eclosion and the first molt.

TABLE 3

STAGES AND THEIR DURATION IN ECLOSION AND FIRST MOLT OF LEIOBUNUM SP.

Stage	Time Duration
Break of egg membrane	0 min.
Animal out of egg	1-2
Length of first instar	12-14
Legs spread out, break appears	3
Body and legs pulled out	7
Drying period	3
Legs put down, release of abdominal connection from molt	1
Drinking at molt case	7-10

SUMMARY AND CONCLUSIONS

The purposes of this investigation were:

(a) to acquire a familiarity with the taxonomy of Michigan Opiliones to permit accurate identification of large numbers of specimens.

(b) to determine collections of Opiliones from Monroe and Wexford Counties, which were collected in the summer of 1965. Hopefully, systematic collecting in these two areas over an entire season would give a more precise picture of when different species were present and when they were most abundant.

(c) to make field observations and collect live material in as wide a range of habitats as possible for trial maintenance of different species in laboratory rearing chambers.

(d) to determine the horizontal ranges of dominant species across forest edges. By setting up pit trap transects five woodlot types in central Michigan were sampled for comparison over a four month period in the summer and fall of 1967.

(e) to develop an efficient laboratory rearing technique for selected species. When this had been accomplished the species were to be exposed to DDT and Dieldrin by several methods.

In the entire course of the study over 7400 specimens have been examined. The bulk of these were from Michigan but numerous other areas in the Eastern United States and a few widely scattered Western localities are represented. Representative determinations of all Michigan species collected were verified by either Dr. Edgar or Dr. Goodnight. Major findings included the following:

1. One species, Caddo boöpis, is a record for Michigan. The female of Leiobunum serratipalpi, never described in the literature before, was found.

2. Seasonal abundance curves were made for the most numerous species in the Monroe and Wexford Co. series. There were several successive abundance peaks for different species in the pit trap collections.

3. Preliminary data from Monroe Co. material showed larger numbers of Opiliones in insecticide treated woodlots. Detailed analysis of the vegetation in the treated and untreated plots revealed community differences that may have had a greater influence on numbers than did the insecticide.

4. Information on development of several species was obtained from the Monroe Co. material. Successive immature instars collected early in the season were compared with adults of the same species collected later in the same areas.

5. Weekly pit trap transect collections across five central Michigan forest edges showed large differences in species and numbers collected in the mature forest and in adjacent old field situations. Temperatures and relative humidity readings were taken along these transects at the same time as collections were made. Vegetation descriptions

at the end points and in the forest edge along each transect were made to further illustrate the types of habitats.

6. Pit trap collections in the three widely separated study areas revealed seasonal abundance trends and habitat preferences of the following species:

(a) *Hadrobunus maculosus* was collected in very large numbers in old field situations and in relatively open woodlots. This species, previously reported from only scattered locations in the state, is apparently one of the dominant forms. It has been taken in the majority of areas in which pit traps have been used. The fact that it is inactive during the day may explain why it was rarely collected. This habit may also permit it to survive in old field situations with large relative humidity and temperature fluctuations. It was found from May to early September. Its early appearance indicates that it may overwinter as an immature, but the succession of instars over a season show only one generation a year.

(b) *Leiobunum calcar* and *L. nigripes* were collected in areas near the edges of woodlots. The early appearance and complete disappearance of these species by the end of July indicates that they also overwinter as immatures. This is almost certainly true for *L. nigripes*.

(c) *Leiobunum politum* and *L. serratipalpi* were collected in small numbers in a range of habitats. Their occurrence from late July through September indicates that these species probably overwinter as eggs. They evidently mature by the latter part of the summer.

(d) Odiellus pictus pictus was collected in large numbers only in the treated Monroe Co. woodlots in areas of second growth sugar maple-basswood-red oak forest, although it has been reported from a range of habitats. Virtually a complete developmental series has been obtained for this species. Early instars were collected in the first part of June and development was gradual until the middle and latter part of September, when adults were found.

(e) Phalangium opilio was often collected in the vicinity of human habitations and disturbances. It was also taken in old field areas and open woodlots in association with H. maculosus. It was collected throughout the growing season, but its life history appears to be different from any other species of Michigan Opilione studied. Adults and various stages of immatures were collected in varying proportions throughout the entire season. This suggests that there may be more than one generation a year.

7. Simultaneous collections with Malaize aerial insect traps in Monroe Co. yielded large numbers of an arboreal species, Leiobunum vittatum. This species and several other very long legged forms were rarely collected in pit traps. A minute litter form, Crosbycus dasycnemus, has been collected only by Berlese extraction. These collections and some others made by hand picking suggested that the pit traps were biased toward collecting predominantly surface

frequenting forms. This fact should be taken into account in any further pit trap work.

8. Adults of several species were maintained under laboratory conditions. Phalangium opilio has been maintained in all of its life stages and a rearing technique is presented. Mass rearing was not perfected to the point where insecticide work could be done, however. Two critical factors in rearing this species were a satisfactory food supply and maintenance of daily relative humidity fluctuations. A detailed description of the eclosion and first molt of a species of Leiobunum is given.

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APPENDIX I

Monroe County pit trap collection totals for each sampling period, for the dominant species represented.

	June				July					August					September				
	10	17	23	29	5	11	17	23	29	4	10	16	22	28	3	9	15	21	27
H. maculosus																			
Control	23	16	28	65	21	10	22	12	5	16	41	46	8	9	2		2		
Treated	16	19	17	7	12	5	13	9		2	8	11	1	2					
L. calcar																			
Control						1													
Treated	28	72	10	5	28		11	7											
L. nigripes																			
Control				3			3		2										
Treated	31	27	21	21	47	9	25	5	1	1									
L. politum																			
Control						1													
Treated					4		13	21	8	11	6	18	1	6	5	2			
O. pictus																			
Control							1			1				1			2	1	2
Treated	5	12	16	38	30	8	24	15	17	10	14	8	4	17	1	4	4	1	7
P. opilio																			
Control		1										23			1		1		
Treated	5	12	5	15	18	2	10		3		1	17	1	5	5	4	4	2	

APPENDIX II

Mean temperature in degrees F. over each sampling interval at 5 and 120 cm. heights in the different habitat types.

	4-25 July		1-22 August		22 Aug.-19 Sept.		19 Sept.-18 Oct.	
	5	120	5	120	5	120	5	120
Habitat Types								
Beech-maple								
M	72	--	70	70	71	70	59	58
E	72	--	70	69	69	67	58	57
O	71	--	72	71	69	69	59	58
Bog Margin								
M	73	--	71	69	72	70	62	63
E	73	--	69	70	70	70	61	60
O	73	--	69	70	70	70	58	60
Flood Plain								
M	58	--	69	68	67	67	57	56
E	59	--	71	71	67	66	58	58
O	61	--	72	71	67	67	58	58
Oak-hickory								
M	58	--	72	71	70	69	59	56
E	59	--	72	71	69	69	59	59
O	60	--	72	71	67	67	58	58
Pinetum								
M	66	--	71	71	68	69	57	59
E	66	--	71	71	69	68	59	58
O	65	--	72	73	70	69	58	58

APPENDIX III

Mean relative humidity in percent over each sampling interval at 5 and 120 cm. heights in the different habitat types.

	4-25 July		1-22 August		22 Aug.-19 Sept.		19 Sept.-18 Oct.	
	5	120	5	120	5	120	5	120
Habitat Types								
Beech-maple								
M	90	--	78	74	87	90	93	86
E	90	--	82	79	98	95	95	86
O	84	--	76	72	90	88	80	67
Bog Margin								
M	89	--	78	66	87	89	85	79
E	85	--	89	76	93	89	85	80
O	83	--	80	71	95	92	97	79
Flood Plain								
M	100	--	100	92	100	100	100	100
E	97	--	90	82	98	95	100	91
O	92	--	79	78	95	95	95	91
Oak-hickory								
M	100	--	78	71	95	92	100	100
E	100	--	78	75	93	89	100	93
O	96	--	81	75	95	92	100	95
Pinetum								
M	92	--	91	83	98	93	97	88
E	95	--	84	76	98	95	95	93
O	92	--	79	69	96	94	95	89