



124
698
THS

SOIL ARTHROPODS IN RELATION TO AGE OF
RED PINE STANDS AND CONCOMITANT
MEASURABLE CHANGES IN THE ENVIRONMENT

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
Hugh Oliver Schooley
1964



ABSTRACT

SOIL ARTHROPODS IN RELATION TO AGE OF RED PINE STANDS AND CONCOMITANT MEASURABLE CHANGES IN THE ENVIRONMENT

by Hugh Oliver Schooley

During the summer of 1963, a project was undertaken to sample the soil arthropod fauna present in three closely associated areas of Kellogg Forest, in Kalamazoo County of southwestern Michigan. The areas sampled included an abandoned field, a 15-year-old planted red pine stand, and a 32-year-old planted red pine stand. Seven times during the summer, core samples were taken in each area. Berlese collections from these cores showed the following trends:-

1. Numerically, the number of arthropods taken in the abandoned area and between the trees in the 15-year-old stand was the same. Greater numbers were collected from beneath these 15-year-old trees while the highest numbers were taken beside the stems of the trees. Similar high numbers were taken beside the trees in the 32-year-old stand. Collections of Collembola and to a lesser extent, Oribatid mites, were responsible for these increases.

2. The range of the number of individuals taken during the summer throughout the abandoned area remained stable. In the plantations, however, the range varied both with the date of sampling and the sampling position in the stand.

3. Physical division of the core samples into litter and soil components prior to extraction of arthropods showed

by Hugh Oliver Schooley

a much higher number constantly present in the soil than in the litter of the abandoned area. In the plantations, however, higher numbers were picked up in the soil only after an extended period of low rainfall. As rainfall increased larger numbers were present in the litter.

The three study areas were characterized (1.) historically (2.) by soil analysis and (3.) by ground vegetation. Observations were made on depth of litter accumulation and the seasonal fluctuation of soil moisture. More intensive studies were made in the 32-year-old plantation. Distribution of litter fall and rainfall, in relation to time and distance from the trees, were examined and correlated with crown density. Synoptic measurements of temperature and light intensity were also taken.

SOIL ARTHROPODS IN RELATION TO AGE OF RED
PINE STANDS AND CONCOMITANT MEASURABLE
CHANGES IN THE ENVIRONMENT

By

Hugh Oliver Schooley

A THESIS

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

MASTER OF SCIENCE
DEPARTMENT OF ENTOMOLOGY

1964

629586
2112162

ACKNOWLEDGMENTS

My grateful acknowledgment is made to Dr. Gordon Guyer, head of the Department of Entomology, who made this study possible. I wish to express my appreciation to Dr. James Butcher, under whose supervision and faithful guidance this study was made. I also wish to thank Doctors Angus Howitt, and Victor Rudolph for serving on my committee. I am indebted to both Dr. Butcher and Dr. Rudolph for their critical reading of the manuscript of this thesis.

Sincere thanks is extended to Mr. Walter A. Lemmien, resident forester at the University's Kellogg Forest, for providing valuable assistance in getting this project underway; and to Dr. Walter Morofsky, Director, of the Kellogg Biological Station, for providing laboratory and other working space while the field work for this project was being conducted.

My deepest thanks and appreciation is offered to my wife Jill. Her invaluable encouragement and technical help, both in the field and in the preparation of this thesis, has prompted me to dedicate this presentation to her.

Sincerely:

Hugh Oliver Schooley.

TABLE of CONTENTS

INTRODUCTION	1
CHARACTERIZATION of the AREAS	
History of the areas:	2
Nature of the substrate	3
Vegetation of the study areas:	5
MEASUREMENT of FACTORS CONTRIBUTEING to the SOIL ENVIRONMENT	
Measurement of litter fall and accumulation:	8
-The layer of accumulated litter.	8
-Seasonal pattern of litter fall.	12
Soil moisture:	20
Measurement of rainfall distribution:	22
Soil temperature:	28
MEASUREMENT of the FAUNA	
Plot size and location:	31
Sampling procedure:	32
THE SOIL ARTHROPOD FAUNA	
Area distribution of arthropods: the theory.	36
Area distribution of arthropods: the data.	37
Seasonal distribution of arthropods:	40
Vertical distribution of arthropods:	47
SUMMARY of FINDINGS	51
LITERATURE CITED	53

LIST OF TABLES

TABLE	PAGE
1: Soil characteristics:	4
2: List of plant species collected:	6
3: Distribution of litter fall at different distances from the trees:	17
4: Seasonal pattern of litter fall:	18

LIST of FIGURES

FIGURE	PAGE
1: Accumulated litter layer beneath a tree in the 15-year-old plantation.	10
2: Accumulated litter layer beneath a tree in the 32-year-old plantation.	10
3: Litter collecting mat being unrolled in laboratory.	13
4: Litter is removed from center of mat.	13
5: Apparatus used in making crown density measurements.	23
6: Wedge shaped rain gauge beside a tree.	23
7: Rain gauges radiating from a central tree.	23
8: Relationship between crown density and the amount of rainfall collected.	26
9: Changes in the amount of rainfall collected because of branches above the rain gauges.	27
10: Ejected core sample.	33
11: Modified Tullgren extractor.	33
12: Extractor with the doors closed.	33
13: Area distribution of arthropods	38
14: Seasonal distribution of arthropods in the abandoned area.	41
15: Seasonal distribution of arthropods in the 15-year-old plantation.	42
16: Seasonal distribution of arthropods in the 32-year-old plantation.	43
17: Vertical distribution of arthropods.	48

INTRODUCTION

This study was undertaken by the author to introduce himself to the techniques and problems of soil zoology, an aspect of entomology in which he had no experience but had developed some interest through the enthusiasm of different authors in this field of study. A secondary interest in some of the problems of growing plantation trees, dictated that the study should involve plantations. Inspection of the University's Kellogg Forest showed that a suitable work area was available for such a study---so work was started.

During the summer of 1963, samples of the soil fauna present in three closely associated areas in Kellogg Forest, Kalamazoo County of southwestern Michigan, were collected and studied. The areas sampled included an abandoned field, a 15-year-old red pine plantation, and a 32-year-old red pine plantation. At the same time, measurements of factors such as litter fall, litter accumulation, rainfall, soil moisture, and soil temperature, that are contributing to the soil environment were also made.

Kevan's textbook, "Soil Animals" (1962), has been a tremendous help in the preparation and carrying out of the studies reported here. The introduction and references of his book introduced most of the major authors working with the soil fauna. Also of enormous value for locating literature and outlining the different aspects of soil zoology was a review, "Soil-Inhabiting Arthropoda", by Kühnelt, (1963).

Considerable reference was also made to the books "Soil Zoology", (ed. Kevan, 1955) and "Soil Organisms", (ed. Doensen and van der Drift, 1963). Both these are proceedings of colloquia on soil fauna. The latter source was extremely useful in clarifying the interrelationships of soil fauna and microflora.

CHARACTERIZATION of the AREAS

History of the areas:

The following history of the 32-year-old red pine stand is taken from Ilnytzky, (1962). The stand, as a whole, consists of about six acres of red pine, (Pinus resinosa Ait.), furrow planted in the fall of 1932 with a 6 x 6-foot spacing. The stand had shaded out the ground cover by 1942, and by the fall of 1946 all branches on the lower half of the trees were dead. At this time the stand had reached a basal area of 110 to 116 square feet per acre, and was beginning to show the effects of competition. In the winter of 1946-47, the stand was thinned and pruned. Approximately two cords of pulpwood per acre were removed. In the fall of 1954, the stand was thinned again by removing 4.8 cords of pulpwood per acre. In January 1963, a third thinning was performed in a portion of the stand not included within the limits of this study.

The younger plantation consists of about 10 acres of red pine, furrow planted in the fall of 1949 with a 10x 10-foot spacing. The stand has received no cultural treatment other than the removal of undesired hardwood ingrowth. Tree heights

varied between 10 and 18 feet at the time of the study. The crown density over the largest portion of the stand is such that closure between trees is nearly complete, although no serious competition between trees is yet apparent. The major basal branches on most trees are still living and no pruning is planned for the immediate future of the stand.

The history of the abandoned area is similar to that of the young plantation. Both areas were given similar preplanting treatment and were furrow planted at the same time. The present day abandoned condition occurs because the exotic species of tree planted failed to become established in the areas. Existing vegetation is discussed later under another heading.

Nature of the substrate:

Perhaps the greatest possible source of variability in the soil environment was avoided by choosing areas close together and all with the same soil type. The soil of the study areas is Oshtemo sandy loam, (described in the "Review for Series File", Soil Science Department, Michigan State University). Samples of the upper three inches of soil in each area were given a standard agricultural soil analysis by the Soil Testing Laboratory, (M.S.U.) . The results of these tests (TABLE 1: p.4), demonstrate that some differences are present in the soil of the three study areas, apparently as a result of the vegetation.

TABLE 1: Soil characteristics:

Characteristic	Abandoned Area		15-year-old Stand		32-year-old Stand	
	1	2	1	2	1	2
Soil pH	5.6	5.7	5.1	5.3	4.8	4.8
lbs./acre phosphorus	10	14	112	23	18	14
" potassium	200	104	35	64	80	80
" calcium	728	600	192	408	408	416
" magnesium	80	64	11	32	46	46
Exchange capacity	6.3	7.8	4.4	5.1	11.2	12.2
Percent saturation						
-of potassium	3.9	1.6	0.9	1.5	0.8	0.8
-of calcium	28.5	19.2	9.0	19.6	8.9	8.1
- of magnesium	4.7	2.5	0.0	1.9	0.9	0.8
Percent base saturation	36.5	23.0	9.0	21.5	10.7	9.8

Vegetation of the study areas:

The natural vegetation of the study areas, based on soil type, is deciduous forest; principally oak, hickory and sugar maple. Development to this end would certainly be restricted by the red pine trees in the plantations, but the abandoned area already has the expected species of trees established on it. More than 80 percent of the ground surface in the 32-year-old stand lacked vegetation. The ground immediately beneath the trees in the young plantation was characterized by a similar lack of vegetation. Between the trees in the young stand, particularly where closure was incomplete, ground vegetation was similar to that present in the abandoned area. Sample plots in the abandoned area were chosen for homogeneity of vegetation. Encroaching on these plot locations from the northwest was a developing stand of trembling aspen, (Populus tremuloides L.), from the west a dense growth of cornus, (Cornus canadensis), and sumac, (Rhus typhina L.), and from the south a strong ingrowth of hawthorne, (Crataegus sp.), and red oak, (Quercus rubra L.).

In an effort to characterize the ground vegetation, all the physically identifiable plants, (excluding mosses), along two 35-foot transects, (each taken diagonally across a sample plot), in each study area were collected. This was done on August 28, and only species of plants found at that time of the summer are represented. A list of the plants collected and the areas in which they were found is presented in TABLE 2:(p.6 & 7).

TABLE 2: List of plant species collected:

Plant	Abandoned Area		15-year-old Stand		32-year-old Stand	
	1	2	1	2	1	2
<i>Pteridium aguilinum</i>	-	-	-	-	X	-
<i>Panicum dichotomiflorum</i>	-	X	-	X	-	-
<i>Muhlenbergia schreberi</i>	-	-	-	X	-	-
<i>Elymus canadensis</i>	X	X	-	X	-	-
<i>Carex arctato</i>	-	-	-	-	X	-
<i>Juncus tenuis</i>	-	X	-	-	-	-
<i>Asparagus officinalis</i>	X	-	-	-	-	-
<i>Smilax</i> sp.	-	-	-	-	-	X
<i>Populus tremuloides</i>	X	-	-	-	-	-
<i>Carya ovata</i>	-	-	X	X	X	-
<i>Celtis occidentalis</i>	-	-	-	-	-	X
<i>Quercus rubra</i>	X	X	X	X	X	-
<i>Urtica procera</i>	X	-	-	-	-	-
<i>Rumex acetosella</i>	-	-	-	X	-	-
<i>Chenopodium album</i>	X	X	X	X	-	-
<i>Phytolacca americana</i>	-	-	-	-	X	X
<i>Sassafras albidum</i>	X	-	X	X	X	X
<i>Berberis vulgaris</i>	-	-	-	-	X	X
<i>Ribes strigosus</i>	-	X	-	-	-	-
<i>Ribes cynosbati</i>	X	X	X	X	-	-
<i>Rubus hispidus</i>	X	-	-	-	-	-
<i>Potentilla recta</i>	X	-	X	X	-	-
<i>Fragaria virginiana</i>	-	-	-	X	-	-
<i>Crataegus</i> sp.	X	X	X	-	-	-
<i>Malus</i> sp.	X	-	-	-	X	-
<i>Prunus pensylvanica</i>	X	X	X	X	-	-
<i>Prunus serotina</i>	X	-	-	-	-	-
<i>Trifolium procumbens</i>	X	X	X	-	-	-
<i>Trifolium arvense</i>	-	-	X	-	-	-
<i>Medicago lupulina</i>	-	-	X	X	-	-
<i>Desmodium</i> sp.	-	X	-	-	-	-
<i>Euphorbia corollata</i>	-	-	X	X	-	-
<i>Rhus radicans</i>	X	-	-	-	-	-
<i>Rhus typhina</i>	X	X	-	-	-	-
<i>Acer spicatum</i>	-	-	X	X	X	-
<i>Vitis aestivalis</i>	-	X	X	X	-	-
<i>Parthenocissus quinquefolia</i>	-	X	-	-	-	-
<i>Hypericum perforatum</i>	-	-	X	X	-	-
<i>Daucus carota</i>	X	X	X	-	X	X
<i>Cornus canadensis</i>	X	-	-	-	-	-
<i>Lysimachia terrestris</i>	X	X	-	-	-	-
<i>Asclepias</i> sp.	-	-	-	X	X	-
<i>Apocynum cannabinum</i>	-	X	-	-	X	-

TABLE 2: List of plant species collected: (continued)

Plant	Abandoned Area		15-year-old Stand		32-year-old Stand	
<i>Cynoglossum officinal</i>	X	X	X	-	-	-
<i>Solanum dulcamara</i>	-	-	-	-	X	X
<i>Solanum nigrum</i>	-	-	-	X	-	X
<i>Verbascum thapsus</i>	-	-	-	-	X	X
<i>Plantago lanceolata</i>	-	-	X	X	-	-
<i>Plantago major</i>	X	-	-	X	-	-
<i>Sambucus pubens</i>	-	-	-	-	-	X
<i>Sambucus canadensis</i>	-	-	-	-	-	X
<i>Lactuca scariola</i>	-	X	X	-	X	-
<i>Taraxacum officinale</i>	X	-	X	-	X	-
<i>Ambrosia elatior</i>	X	X	-	-	-	-
<i>Hieracium aurantiacum</i>	-	-	-	X	X	-
<i>Solidago nemoralis</i>	X	X	X	-	X	-
<i>Solidago hispida</i>	-	X	X	X	X	-
<i>Solidago graminifolia</i>	X	X	-	-	X	-
<i>Antennaria plantaginifolia</i>	X	-	X	-	-	-
<i>Gnaphalium obtusifolium</i>	X	X	-	X	-	-
<i>Bidens fondosa</i>	-	-	-	X	-	-
<i>Achillea millefolium</i>	X	X	X	-	-	-
<i>Cirsium arvense</i>	-	-	-	-	X	-
<i>Senecis sp.</i>	-	-	-	-	X	-
Total number of species in each area.	37		35		27	
Number present in one area but not in the others.	14		10		10	
Number present in both plantations.					<u>12</u>	
Number present in both the 15-year-old plantation and the abandoned area.	<u>20</u>					
Number present in both the 32-year-old plantation and the abandoned area.					<u>10</u>	
Number present in all three areas.					(7)	
Total number of different species collected.					(64)	

MEASUREMENT of FACTORS CONTRIBUTING
to the SOIL ENVIRONMENT

Measurement of litter fall and accumulation:

Comparative distribution studies of soil surface arthropods has brought about recognition of the importance of litter fall and accumulation to the fauna. In the three study areas the soil arthropod population that had developed was apparently strongly related to the depth and decay condition of the litter present. The project discussed here was carried out (1) to make observations on the layer of accumulated litter, (2) to examine the seasonal pattern of litter fall, and (3) to measure the distribution of this litter fall beneath the trees.

The layer of accumulated litter. The areas studied offered an opportunity to make some interesting observations as to the way litter accumulates on the ground. Pine litter is very slow to decompose; retaining its exterior shape and volume for a number of years. This characteristic has brought about the accumulation of a layer of litter in various stages of decomposition (yet still recognizable as to its origin) in the two study plantations. The possibility of non-pine litter confusing this pattern of accumulation, particularly in the younger plantation, is slight. A check of soil profiles in the abandoned field adjacent to the 15-year-old plantation revealed that decomposition of non-pine litter is such that there is virtually no accumulation of more than one or possibly two years of this litter type.

The main source of interference to uniform accumulation of litter in the study areas is the planting furrows. Specifically, a shallow double furrow was turned over in the young plantation and a single deep furrow was used in the old plantation. The resulting furrows and mounds of earth have and are continuing to strongly influence the lateral movement of the litter that has fallen on or near them. The furrows very rapidly fill up with litter, (FIGURE 1 and 2, p.10). Most of the material apparently moved from the adjacent mounds where it has fallen. After only a few years' needle fall, the ground contours of the young plantation already show no outward indication that the trees were furrow planted. If, however, the litter layer is cleared away, the ground still shows the outlines of ploughing. The permanence of this surface disturbance is shown in the older plantation where the furrows and mounds still persist. Here the movement of litter off the mounds has generally continued. Only recently have the furrows become filled in enough to allow accumulation on the mounds.

The structure of the trees themselves offers some interference to litter fall. In both plantations it was common to see dead needles hung up on bark scales and branch crotches. A large portion of the recent litter fall in the young plantation was found to be supported above the ground by the lowest branches of the trees.

The natural accumulation of litter in the study stands is also disturbed by the activity of animals. The tunnels of unidentified rodents are commonly found along the surface of the



FIGURE 1: Accumulated litter layer beneath a tree in the 15-year-old plantation. Note the planting furrow full of litter.



FIGURE 2: Accumulated litter layer beneath a tree in the 32-year-old plantation.

mineral soil beneath the layer of litter. This activity undoubtedly prolongs the period required to decompose the litter layer because it puts much of it out of the reach of soil moisture. The reverse of this activity was observed in several locations in the older stand. Squirrels burrowing into the ground covered fairly large areas of litter with soil. Here the litter layer would be held down in contact with the ground and it would be reasonable to expect decomposition to be hastened. The cultural treatments applied to the older plantation are responsible for much disturbance to the uniform accumulation of litter. Not only was there mechanical disturbance by the forestry operations carried out, but there was also abnormal depositing of litter in the form of slash, sawchips and bark.

Observations of the undisturbed layer of litter that has built up in the two plantations has revealed a difference in the pattern of accumulation. In the trees of the young plantation, natural mortality of needles (because of age), progresses upward and outward from the base of the trees with the passage of time. The area from which needle fall has occurred, therefore, roughly takes the shape of an inverted steep-sided cone. This has led to the formation of a layer of litter that is also, although very shallow, in the rough shape of an inverted cone. This development of accumulation is easily understood. When the older plantation was examined however, this pattern of accumulation was entirely absent. At some time between the ages of 15 and 30 years the pattern of litter fall changes and the

accumulation of more recent litter tends to even out the thickness beneath the whole stand.

Seasonal pattern of litter fall. Distribution litter collections were made within the older plantation between April 10, and November 26, 1963. Mats of a rough rug textured material, (30 inches wide by 10 feet long), were placed on the ground stretching from the base of two randomly selected trees at right angles to the rows of trees. The rugs were pinned down to prevent movement. Exposed mats were replaced with clean ones about once a month. To do this a piece of light canvas was placed on top of each mat to sandwich the fallen litter between the layers of material. This allowed each mat to be rolled up and brought into the laboratory where it was unrolled on a long table and the canvas cover was removed, (FIGURE 3: p. 13). Beginning at the point that had been occupied by the tree, the length of each mat was divided into one-foot quadrats for a distance of nine feet. The central one foot of each of these quadrats was located and each was divided into left and right halves by a line drawn from the tree position to the other end of the mat. Each of these six-inch by one-foot half blocks in turn, was outlined by a wood frame and the litter therein was cut free from the adjacent blocks, collected by vacuum suction and placed in separate identified envelopes, (FIGURE 4: p.13). The envelopes and their contents were oven dried at 60°C. to a constant weight for three successive weighings; then given four or five days to come to equilibrium with moisture present



FIGURE 3: Litter collecting mat being unrolled in laboratory.



FIGURE 4: Litter is removed from center of mat.

in the laboratory air. Following this, the collections were sorted for their content; needles, bark bud scales, etc., and the different components were weighed.

Crown density measurements were made above the mats using three degrees of density; (1) closed (no sky visible), (2) semi-closed (sky visible through the foliage), (3) and open (no foliage). Measurements were made by looking through a prism mounted in a tube, and drawing the crown on cross-section paper as it appeared through a grid supported at the end of the tube, (FIGURE 5: p.23). The observed limitations of each degree of density was drawn using a different coloured pencil. No absolute measurements of crown area were calculated but the design of the apparatus used was such that as the height of the above the prism increased so did the area of the crown being measured, (grid size was 2 X 2-inches and measured an area 4 X 4-feet at a height of 10 feet above the prism). The total number of crown density units for any location was assessed by accumulating the number of squares on the cross-section paper occupied by each density degree and treating them as follows;-

$$\text{Crown density} = 4(\text{area CD}) + 2(\text{area SCD}) - \text{area OD},$$

where the number of squares occupied by closed density = area CD, the number of squares occupied by the semi-closed = area SCD, and the number of squares occupied by open density = area OD. Recordings of crown density less than the maximum units possible correspond proportionally to a decrease in actual crown density.

Crown density measurements were made above each one-foot interval along the centerline of each of the "distribution" litter fall collecting mats. Drawings were divided into left and right halves (as were the mats themselves), and crown density units for each half were added together, then averaged to get a final total of crown density units for the intervals. This procedure allowed a maximum total of 800 crown density units for each position measured. Measurement of litter fall distribution at locations above which the crown density was determined are summarized in TABLES 3 and 4:(p.17 and 18).

Total litter fall was less to the one-foot of ground adjacent to the trees than to any other one-foot section up to a distance of nine feet from the trees. In both study locations the total litter fall increased to a high level between two and three feet from the trees, then between three and five feet it was somewhat less. Weights were high again between five and seven feet, much less between seven and eight feet, and then fairly high again between eight and nine feet, (TABLE 3:). The distribution pattern of litter fall is more or less the same for both mat locations, and similar reasoning can be used to interpret distribution at both sites. It is here suggested that the pattern of litter fall necessary to produce the shallow inverted cone type of accumulation described for the young plantation still exists in the old plantation. Currently, however, the trees not only prevent accumulation in the point of the cones but also interfere with accumulation at a distance of up to two feet from the trees. The region of

high accumulation observed next to the trees in the young plantation is presently being found between two and three feet away from the trees in the older plantation. Some explanation of the reason for this can be obtained by considering the measurements of crown density.

Although the recorded crown density is highest next to the trees in both locations, these density values alone do not mean much. Measurements of crown density are nearly as high at greater distances from the trees. What these density figures lack is a supplementary measurement of the "crown area" occupied by branches. In a related study, (distribution of rainfall), measurements of the crown density showed that the area occupied by branches was up to two and one-half times as great next to the trees as it was several feet from the tree; yet both areas were assigned the same number of crown density units as a measure of the foliage present. In this related study, the measurements of branch area were consistently high next to the trees if the measurements of crown density were also high. The interference of these branches to litter fall is probably the reason why the weight of litter collected between two and three feet from the trees is higher than it is next to the trees.

The high weights of litter collected between five and seven feet from the base of the trees at both mat locations can be explained. The planting furrow for the row of trees adjacent to those containing the base trees crossed beneath both mats between five and one-half and six and one-half feet from the base trees. The furrow location was still evident as a slight

**TABLE 3: Distribution of litter fall at different distances
from the trees.**

Percent of the total measurements	Distance from the trees, (feet).								
	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
Weight of collections									
June 19 to Nov. 29.	6.37	9.11	14.5	12.1	11.8	11.8	12.2	9.86	12.4
Weight of needles									
June 19 to Nov. 29.	6.13	8.58	14.4	12.3	12.4	11.9	12.7	9.36	12.3
Weight of male flowers									
April 10 to Sept. 21.	4.00	7.29	21.9	19.6	9.47	27.2	6.88	1.12	2.59
Weight of insect frass									
June 19 to Sept. 21.	4.34	11.5	18.1	13.5	12.4	17.5	2.40	6.59	13.6
Weight of bud scales									
June 19 to Sept. 21.	3.51	8.53	16.7	10.7	7.86	24.8	8.36	5.02	14.7
Crown density units									
	15.1	14.1	15.0	11.1	7.92	8.55	10.8	8.57	8.95

1/-some of the litter components were found in easily measured quantities only part of the study period.

TABLE 4: Seasonal pattern of litter fall.

Litter component	Average weight collected in grams per square foot.					
	April 10 to June 19	June 19 to July 22	July 22 to Aug. 15	Aug. 15 to Sept. 21	Sept. 21 to Oct. 15	Oct. 15 to Nov. 29
Total ^{1/} litter	6.37	1.26	1.30	5.19	9.07	11.87
Needles	3.59	0.47	0.46	4.68	8.68	10.69
Male flowers	.287	.080	.020	.010	-	-
Insect frass	-	.074	-	.189	-	-
Bud scales	-	.073	.025	.036	-	-

Other interesting determinations

Average needle weight in grams	.093	.072	.108	.093	.085
Number of needles collected per square foot.	5.89	7.22	31.50	93.28	125.89

1/ Wind-blown sand found settling in the plantation throughout the whole summer contained particles large enough to be retained by a 40-mesh screen, (particles were larger than 0.420 mm. and smaller than 0.595 mm. in diameter).

depression where mat one was placed. More important than this, however, was the presences of a very steep grade moving upward to the top of the furrow slice. Here the recorded litter collected was quite low. It is suggested that there has been movement of litter along the surface of the mats down the steep sides of these furrow slices to accumulate where the higher weights of collected litter were obtained. The strongest indication of this movement is given by the frass and male flower weight percentages, (TABLE 3:). Because of their shape, these components of the litter certainly could "roll" down hill.

Litter fall was quite heavy in May, but decreased considerably in June. Throughout the remainder of the summer until the period when red pine begins to shed its needles naturally, the weight of litter fall remained low. From early September to mid-November, litter fall was much heavier. Between November 29, and December 15, the amount of litter that reached the ground was very small, (TABLE 4:).

It is interesting to discover that the weights of the average needle reaching the ground are different at different times of the year. All collections were treated the same and similar results were obtained from both locations, so it is reasonable to assume that this change in weight is the result of some physical makeup within the needles themselves. Although many of the needles collected in the spring were small, those collected throughout the summer and later appeared to be of a normal size. Needles collected in the early summer weighed

more than those collected in the late summer but less than those collected throughout the early autumn at the beginning of the natural shedding period of these trees. Needles collected during the peak of the shedding period in mid-autumn weighed about the same as those collected in the early summer, but more than those collected at the end of the shedding period. No explanation for this difference in needle weight is offered here.

The total litter collected was divided, by hand sorting, into its component parts; needles, bark, sand particles, male flowers, bud scales, and the frass from insect feeding, (almost entirely by the sawfly Diprion frutetorum). To be of any value, measurements of litter components should be made on a more frequent schedule than was applied in this exercise. Nevertheless some interesting results were obtained. These are outlined in TABLES 3 and 4.

Soil moisture:

Soil moisture can be a limiting factor. It is the most significant factor in controlling the abundance and migration of soil micro-arthropods, (Wallwork, 1958). Kevan, (1962, p.130), points out that the smallest arthropods are the least drought resistant, many of the smaller, little pigmented groups being dependent on a high humidity for survival. These same groups apparently suffer the most from extreme moisture conditions and are immobilized or killed by the surface tension of soil water.

Unfortunately there is no inexpensive, easily used method of taking soil moisture measurements that does not involve

some degree of disturbance of the soil profile. Rather than completely omit examination of the soil moisture from this study, a very limited approach was made. Use was made of Bouyocos moisture blocks^{1/}, according to the following procedure. Cores of earth four-inches in diameter and five inches deep were removed from the ground and retained in an undisturbed condition. Blocks were placed in a shallow groove at the bottom of each hole and the cores were replaced. Three blocks, one each beneath the furrow, the furrow slice and midway between furrow positions were set out at two locations in each of the three study areas.

Readings were taken with a soil moisture meter^{2/} beginning on July 5, at irregular intervals throughout the summer. In general terms, comparison of the different study areas yielded the following results. During the driest period the 32-year-old stand recorded the least soil moisture with readings of 2 to 12 percent. At the same time, the 15-year-old stand recorded 3 to 17 percent and the abandoned area 8 to 24 percent. Recordings taken a few hours after a heavy rain storm showed this same arrangement of areas; each with increased moisture content; 67 to 83, 63 to 91, and 80 to 100 percent respectively. After rain storms, proportionally less soil moisture was usually recorded where the accumulation of litter above the blocks

1/ (plaster of paris blocks 1x2x $\frac{1}{2}$ -inches, containing uniformly placed electrodes) (Bouyoucos, 1937)

2/ Bouyoucos Moisture Meter, Industrial Instrument, Cedar Grove, Essex County, New Jersey.

increased. This pattern reversed during dry periods, with more moisture being recorded where the accumulated litter was deepest.

The furrow, furrow slice and a position midway between furrows were chosen for the moisture blocks not only because these were the positions where arthropod samples were taken, but also because they offered an easy way to measure different soil depths. Locations for the blocks were selected so that the furrows were all about three inches lower and the furrow slices two inches higher than the nearby undisturbed areas. It was hoped that the horizontal movement of moisture in the soil would indicate the moisture conditions at 8, 3, and 5-inches deep in the soil for the furrow, furrow slice, and midway positions respectively. However, the variable depth of the litter layer above the moisture blocks distorted comparisons of the influence of depth in the soil for all but the abandoned area. Here, several hours after a heavy rain storm, soil moisture was uniformly high at all depths. Differentiation of moisture content at different depths occurred as the soil dried out. On the driest days, the moisture readings showed 19 and 24 percent at the "eight-inch" depth, 16 percent at the "five-inch" depth and 8 to 10 percent at the "two-inch" depth.

Measurement of rainfall distribution:

It is well understood that trees greatly disturb the distribution and quantity of rainfall reaching the ground beneath them. Since rainfall is by far the most important source of soil moisture in the study areas, 36 rain gauges



FIGURE 5: Apparatus used in making crown density measurements.

FIGURE 6: Wedge shaped rain gauge in position beside a tree.



FIGURE 7: Rain gauges radiating from a central tree to neighbouring trees.

were set out in the 32-year-old stand to examine the disturbance. The gauges used were the common home garden, wedge-shaped, plastic type with a capacity of five inches, (FIGURE 6: p.23)^{1/}

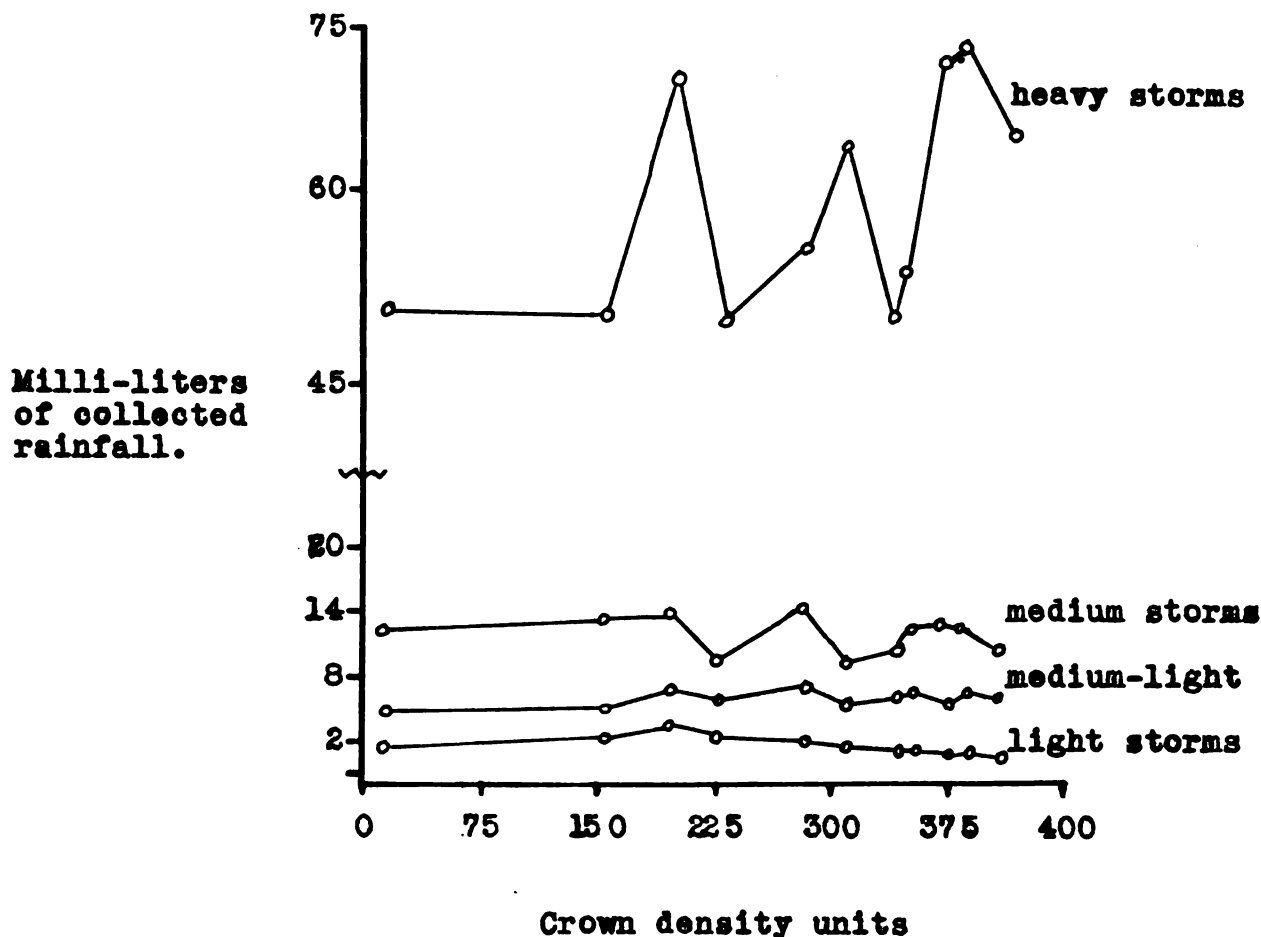
Support stakes for the gauges were placed so that rain was trapped at a height of 12-inches above the ground and along lines radiating from the bases of two randomly chosen trees to the bases of neighbouring trees, (FIGURE 7: p.23). Five tree-to-tree lines were used. Individual collecting points were between 2.5 and 5.5 inches from the tree trunks and spaced at intervals of between 16 and 18 inches along each line. Rather than use the measurement scale figured on each gauge, collected rainfall was poured into a graduated cylinder and recorded as milliliters of rainfall collected. Crown density measurements were made above each gauge position using the procedure already described. The record of crown density units above each gauge was supplemented by a measure of the area occupied by major branches in the crown. Only the center one-quarter of the area represented in each drawing was considered in obtaining a final measure of crown density units, (an area 4x4-feet at a height of twenty feet). Installation of the gauges in the field was completed on June 21, but the first measurable storm did not occur until July 17. Between then and September 21, rainfall from 16 storms was recorded. These were arranged according to their intensity into four storm classes;- light, medium-light, medium, and heavy.

1/ Rain gauges, model R7, Thermometer Corp. of America, Springfield 99, Ohio.

A major problem usually confronted in studies of rainfall is the measurement of water that flows down the surface of the tree stems. No such problem occurred in this study. The bark on the boles of study trees is characterized by a curl type shedding. Scales of bark curl outward from their ends to take on a "C-shaped" appearance. Because of this, virtually no water can move down the stem. Instead, it drips from the bottom of the scales and reaches the ground at varying distances from the trees. The rain gauges beside the trees may then be said to include measurement of water that is directed within the trees towards the stem.

The foliage of pine trees intercepts and holds a large volume of rain water. In red pine, this holding capacity is mainly a result of capillarity. Water collects between the paired needles of each sheath. This feature would suggest that rainfall measurements should be lower within the stand than they are in the open. Also, proportionally less rain should reach the ground where the crown density is higher. This suggested pattern was observed but only during light storms. For more intense storms, the records show a complete reversal of the expected pattern. During more intense storms, the gauges with the least crown cover commonly collected the lowest amount of rain. From these low levels, there was a general increase in the amount of rain recovered from gauges with increasingly higher measurements of crown density. These relationships are shown in FIGURE 8:p.26. Without exception, measurements of crown density increased by moving from the outer margins of

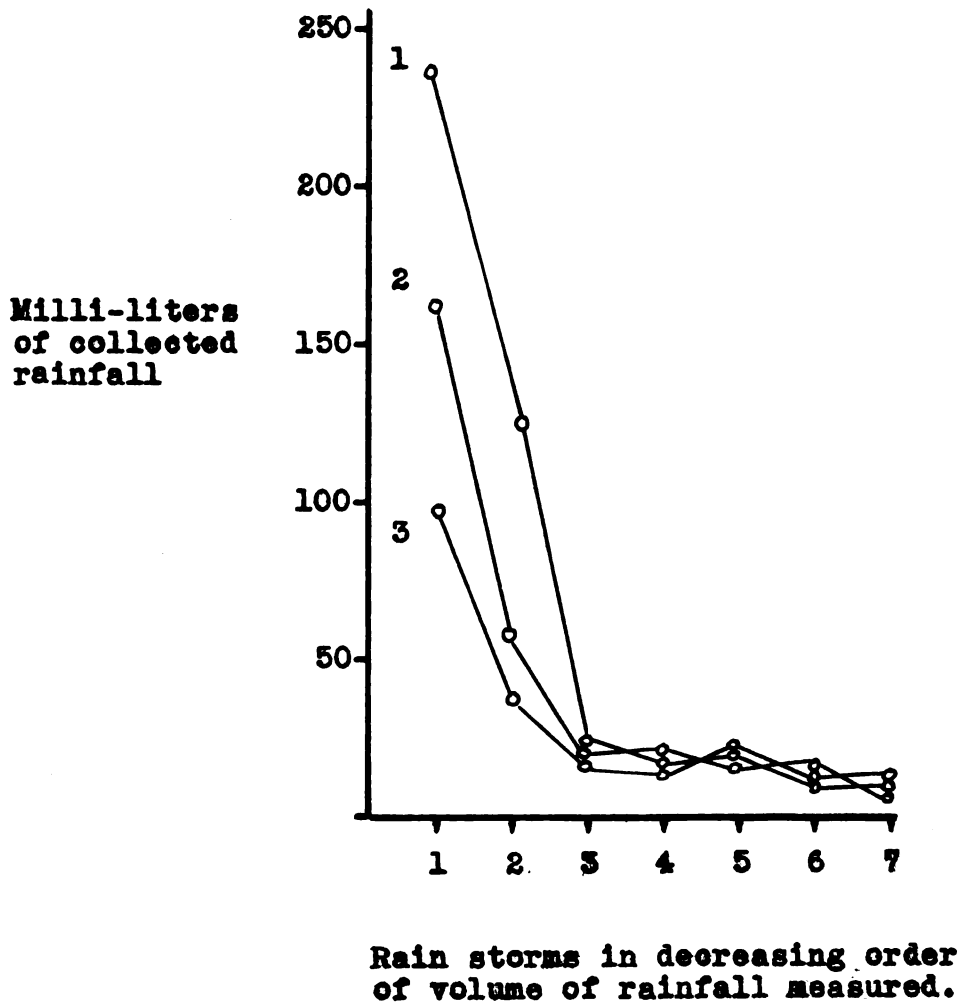
FIGURE 8: Relationship between crown density and the amount of rainfall collected.



Note: Each point on the curves represents the average amount of rainfall falling into each of 11 rain gauges selected because of the absence of major branches in the tree crown above them.

FIGURE 9: Change in the amount of rainfall collected because of branches above the rain gauges.

raingauge number	crown density units for foliage + branches	
	1	2
1	400	66
2	400	48
3	400	25



the tree crowns towards the stem.

The reasons for this increase in recorded rainfall with an increase of crown density are not understood. It can, however, be demonstrated that this effect is strongly compounded by the presence of branches in the tree crown. The movement of water down the branches to the main stem that is common in most deciduous trees is limited in red pine because the branches are only slightly upturned. FIGURE 9: (p.27), particularly for the heavy storms, shows the importance of branches in determining rainfall patterns. Each curve represents the rain collected in a gauge above which the crown density is the maximum, measurable for foliage; but greatly variable with respect to branches. They show that more water may be expected to reach the ground where there is a greater density of branches. The relationships between crown density and the amount of rain collected do not show this compounding, (FIGURE 8:). The 11 gauges represented in these curves were selected because they had few branches above them.

Soil temperature:

There is undoubtedly a relationship between the various life processes of arthropods and the temperature of their habitat. Study of this relationship needs consideration of the many factors that influence temperature. The temperature of the soil surface and the subsoil is by no means uniform, but varies irregularly with depth, soil type, and the depth of litter accumulated on the surface.

Synoptic soil temperature measurements over a 24-hour period were made at a chosen location within the older plantation on July 2-3, July 24-25 and August 19-20. Field use was made of a multiple point recording potentiometer^{1/} suitably encased and powered by a light-weight alternator. This machine has a capacity for recording temperature from 24 points, with a time interval of 12 minutes between successive recordings of the same point. Points were selected on the surface, at the interface between the accumulated layer of litter and the soil and two inches beneath the interface, in each of the furrow, furrow slice and between furrow positions. Records were taken for six one-hour periods with a three-hour interval between each period. For continuity, it was proposed that periods of recording begin at one, five, and nine o'clock. This schedule was maintained except for the dawn and dusk recordings. The dawn and dusk recording times respectively, for July 2-3, and August 19-20, were started one-half hour earlier; the respective dusk and dawn periods were started one-half hour later.

The maximum daily temperature at the surface of the ground and beneath the litter was reached during or shortly after the 1:00 p.m. recordings. Two inches deep in the mineral soil the maximum was not reached until after the 5:00 p.m. readings were recorded. A delay in reaching the minimum temperature was also noted but it was not as long. The minimum temperature

1/ Type 153 Universal "Elektronik" Multipoint recording potentiometer . Minneapolis-Honeywell Regulation Co., Philadelphia 44, Pa., U.S.A.

recorded two inches deep in the mineral soil was the same regardless of the depth of litter above the point of measurement. The maximum, on the other hand, was always about 3°F lower beneath the deep accumulation of litter in the planting furrows. There was also a strong indication that the minimum temperature reached was 2-or-3°F higher beneath this same deep accumulation than it was beneath the litter layers of the furrow slice or between furrow positions.

The ground surface in the plantation is shaded from direct exposure to sunlight almost continually. Where sunlight does reach the ground it results in temperature changes. To test this change, light was recorded^{1/} above each surface point at the same time that temperature was being recorded. At 12:45 p.m., August 20, the light was noted to increase from the shaded reading of 220 foot-candles to 2600 foot-candles and the surface temperature increased from 77.5 to 86.5°F. No change in temperature was recorded at this time in the lower levels of the soil. Twelve minutes later, the light recording had dropped to 420 foot-candles and the surface temperature to 80°F. Then, however, the recording point at the interface between the litter and soil showed an increase from 59.5 to 77°F. The temperature 24 minutes after the exposure to sunlight was 80.5°F. at the surface and 60°F. at the interface. Throughout the whole period the temperature measured two inches deep in the mineral soil remained the same; 60°F. This same light-temperature

1/ Weston (Quartz Filter), Illumination Meter, Model 756.
Weston Elect. Inst. Corp., Newart 5, N.J. U.S.A.

relationship was visible to a lesser degree at other times with lower increases of light intensity.

The deeper levels of the soil are less sensitive to the day-to-day fluctuations in air temperature than are the surface and interface between the litter and the soil. Although this suggests that a more stable environment is present two inches deep in the soil, moisture, not temperature is the limiting factor. The extremes of temperature recorded at all levels are well within the range that can be tolerated by the fauna. Temperature is important for its affect on soil moisture but not for a direct influence on the soil arthropod population.

MEASUREMENT of the FAUNA

Plot size and location:

Two plots were selected for sampling within each of the three study areas. Plots were chosen for; (1) uniformity of slope (preferably level), (2) homogeneity of ground vegetation and (3) uniformity of tree cover, (in the plantations). Rather than use a uniform plot size, plot limits were defined as that area occupied by six adjacent rows of trees, five trees long. In the abandoned area, the trees were simulated by stakes located according to the spacing present in the young plantation. Plots in the plantations were chosen far enough within the stand to avoid edge effect from adjoining areas. Use of these methods of plot location and size determination was justified

by the fact that this study was set up to test the influence of the red pine trees on the fauna.

Sampling procedure:

Similar locations in each plot were sampled on each sample date. Locations were selected from a table of random numbers. A piston ejector, type, core extractor^{1/} was used to remove paired core samples from beside the tree in the planting furrow, from the top of the furrow slice and from a position mid-way between the planting furrows. Cores, four inches in diameter and deep enough to include the complete layer of accumulated litter and a minimum of two inches of mineral soil were taken, (FIGURE 10: p.33). They were ejected directly into ice-cream cartons^{2/}, capped, and transported to the laboratory. At the laboratory, the bottom of each carton was cut away and the carton lid was replaced with a screen, (1/8-inch mesh). The containers and their contents were inverted and placed in a modified "Tullgren" extractor as described below.

The apparatus used for extracting soil arthropods from the core samples, (illustrated in FIGURES 11 and 12: p.33), can be described briefly as follows. Inverted with their containers, individual core samples were placed on a cross of narrow gauge wire supported on a frame above a plastic coated, steep sided, paper funnel. A vial containing 95 percent ethyl alcohol and an

1/ A cup-cutting tool used to make the holes on golf greens, figured in Cohen, (1955).

2/ "Squat quart plastic kans," cylindrical plastic lined cardboard containers manufactured by Seal-rite.



FIGURE 10: Ejected core sample.

FIGURE 11: Modified Tullgren extractor.

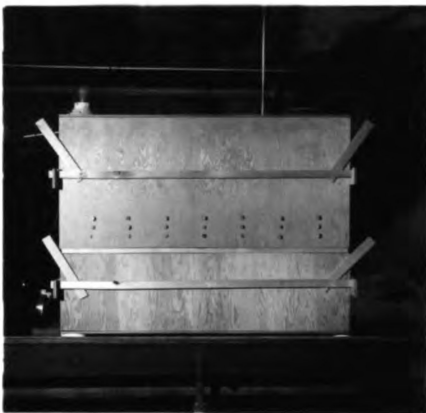


FIGURE 12: Extractor with the doors closed.

identification label were put beneath the funnel exit to collect the arthropods falling from the sample. A 25-watt light bulb fixed to the inside bottom of a can (six inches wide and seven inches deep), and inverted above the sample provided a source of light and heat, (thermostatically controlled to maintain about 120°F.).

A bank of 14 of these individual extractors, (two rows of seven each) was contained and supported within a plywood box, (three feet high, four feet wide and 14 inches deep). The front of the box could be removed in two sections; an upper door allowed the placement or removal of sample containers and height adjustment of the source of light and heat; a lower door allowed access to the collecting vials beneath each funnel. Four of these boxes with a total capacity of 56 samples were used during the summer^{1/}.

Extraction of arthropods was allowed to proceed for 5-8 days. Samples with moderate moisture content were extracted in the closed boxes with the light-heat source a maximum distance of eight inches away from the sample for the first day. For the remainder of the period the light was lowered to two inches above the samples. Wet samples were exposed with the light high during the first three days of extraction and during the first day the boxes were not closed. It was necessary to allow wet samples to dry out to a moderate level, before they were heated.

1/ An extensive discussion of the different methods of extracting soil arthropods is given by Macfadyen, (1955 and 61).

This avoided condensation of moisture on the outside of the cores within the containers.

There was one distinct advantage in extracting soil arthropods from core samples that have been retained in their natural state and turned upside-down for exposure in the funnels. It not only facilitates the movement of the fauna out of the litter, (where the greater part of the population was usually present), but it also prevented the fall of debris into the collecting vials. No samples had to be discarded because of an excess of debris.

Counting of arthropods was done under a binocular dissecting microscope. Only a few test samples had been examined when it was realized that it was going to be very difficult to maintain a consistent counting technique. Silt size soil particles and very small organisms were very difficult to distinguish one from the other. It was decided to rid the samples of silt even at the risk of losing some of the smallest arthropods. All the samples were washed in a 100-mesh screen, (screen opening 0.149 millimeters), with 95 percent alcohol. Since this procedure was applied to all samples it was decided not to give any consideration to the arthropods that may have been lost.

The arthropods were counted and recorded to the smallest readily recognized group; to order or family for the insects, and to Class or morphological group for the other arthropods. When the count was completed for a sample, the Collembola were sorted out and removed to a separate identified vial. These are

currently being determined to species by Richard J. Snider, a student at Michigan State University, who has done considerable work with Michigan Collembola. The Acarina collections are scheduled to be taken to the Institute of Acarology, Ohio State University, for at least partial determination during the 1964 summer session.

SOIL ARTHROPOD FAUNA

Area distribution of arthropods: the theory.

It is very difficult to make definite statements on the distribution and density of the soil arthropod fauna without being able to refer to collections on a species level. The major taxonomic groups of the fauna are cosmopolitan at the level of determination outlined in this study. Despite this, however, some important area comparisons are possible with the use of total numbers of the different groups taken. These figures are at least indicative of the degree of favorability of each location for the fauna present. This is of course, dependent on the assumption that groups which find the environment favorable, have the capacity to take advantage of it and hence become more numerous than they otherwise would be.

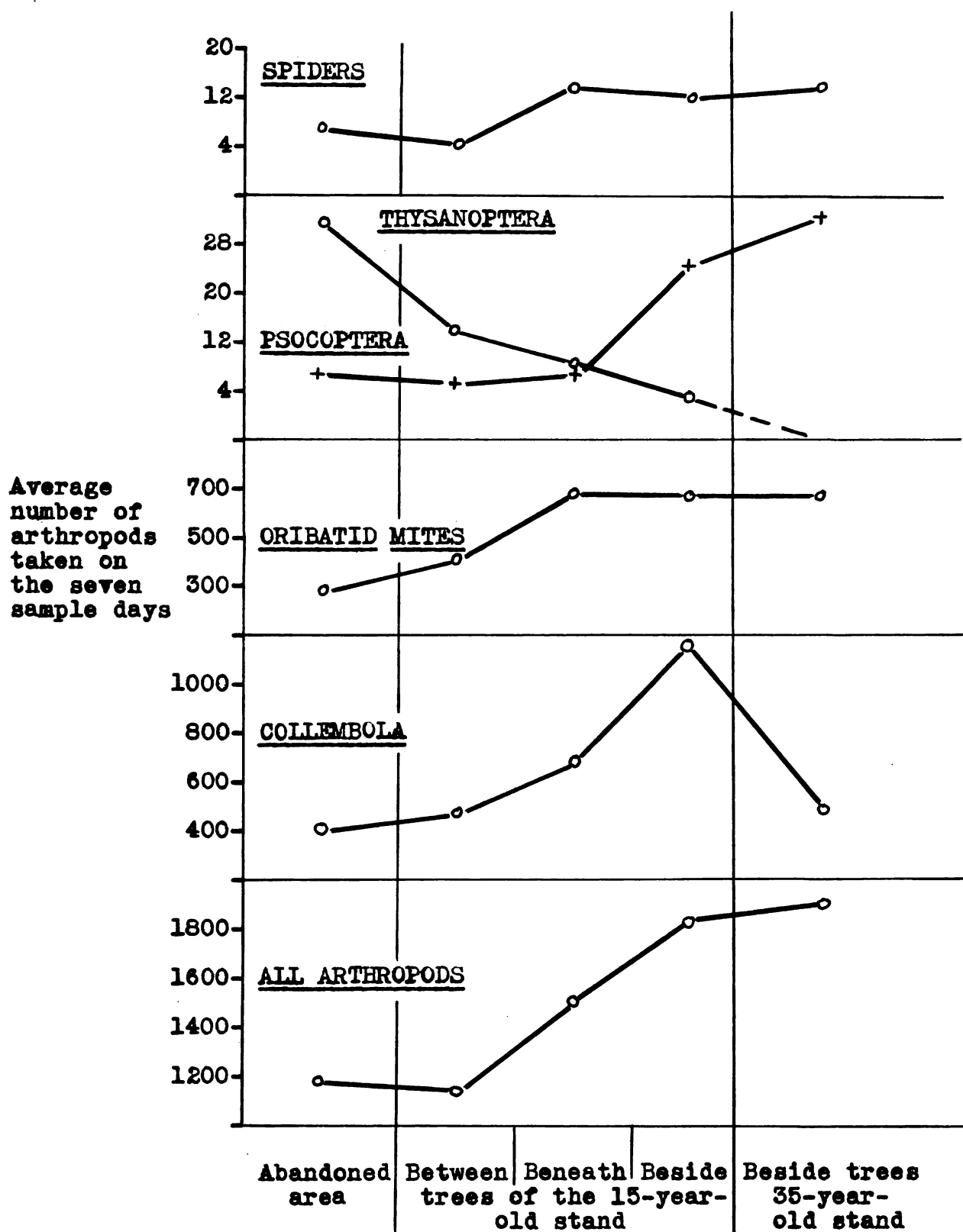
Such an assumption demands recognition of the fact that some irregularity of occurrence is to be expected in any area. Most researchers are in agreement that soil organisms are not distributed at random, but rather show an aggregated pattern, (Kevan, 1962, Murphy, 1955). The variation in thickness of the layer of litter in the plantations, for example, is reason

enough to question the possibility of uniformity of distribution within these areas. It is generally recognized that a thicker layer of litter offers a more favorable environment, particularly for the avoidance of desiccation during dry periods. Collection records even suggest a possible migration of arthropods, capable of such movement, to areas of deeper litter accumulation when moisture conditions are unfavorable elsewhere. Murphy, (1953), has suggested that an accumulation of conifer needles provides very suitable environmental conditions; whilst the more readily decomposed, deciduous, leaf litter is more suitable as food. Present conditions beneath the trees in the young plantation are such that both these litter types are available to the fauna; pine needles from the trees are present in a layer up to four inches deep beside the trees, herbaceous growth between the trees is adequate to supply a reasonable quantity of deciduous litter. Murphy's reasoning appears to be sound for a part of the fauna; at least the Collembola collections were consistently higher here.

Area distribution of arthropods: the data.

FIGURE 13: (p.38), illustrates the numbers of arthropods collected in (1) the abandoned area; (2) between, beneath, and beside the trees in the young plantation; and (3) beside the trees in the old plantation. The curve for the total number of arthropods shows an interesting pattern of increase from one area to the next. Parallelling this increase in numbers of arthropods is an increase in the accumulation and stage of

FIGURE 13: Area distribution of arthropods.



decomposition of red pine litter. The importance of litter accumulation is well illustrated by the above relationship. The contribution of the different taxonomic groups to this relationship is very interesting.

Both in respect to numbers of individuals and numbers of species, the Acarina and Collembola are the most abundant soil arthropods. As would be expected, these groups are primarily responsible for the variation in the area distribution of arthropods. The record of Oribatid mites collected, very closely follows the pattern of increase outlined above for total arthropods; the Collembola, on the other hand, do not. It has already been mentioned that the greatest numbers of Collembola were recorded from beside the trees in the 15-year-old stand. A considerable drop in these numbers was recorded in the 32-year-old plantation. The reason for this, as outlined earlier, is probably a lack of deciduous litter. As far as total numbers of arthropods are concerned, this decrease is compensated for by a sizable increase in the number of non-Oribatid mites, (of the order Cryptostigmata).

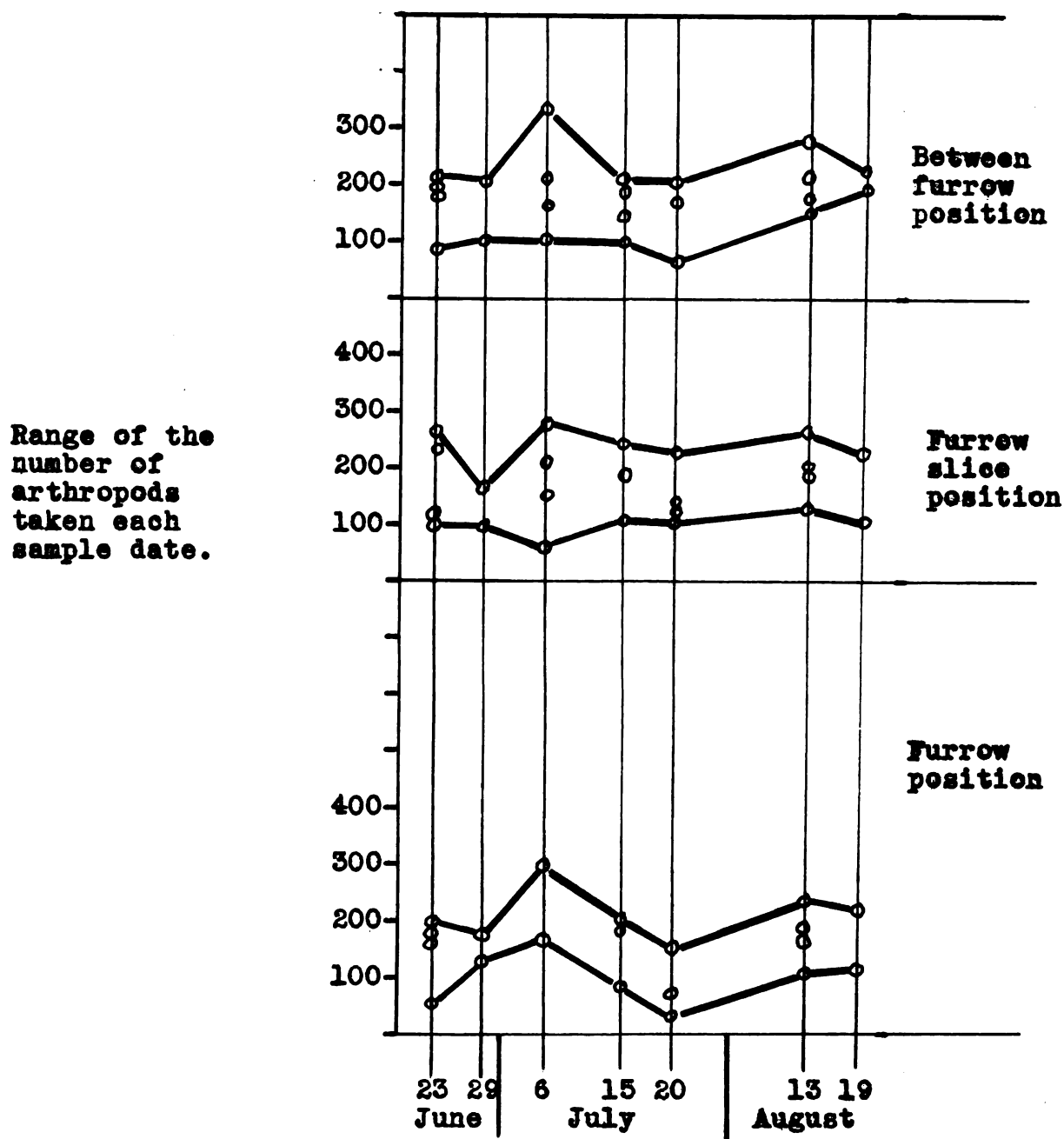
The less numerous taxonomic groups recorded show some pronounced variation from one location to another. The number of spiders collected was lowest where the ground vegetation was most dense, (probably because most of the spiders were removed with the ground vegetation when it was eliminated before core samples were taken). Collections of Thysanoptera decreased from a few in the abandoned area to none in the old plantation while at the same time the Psocoptera showed the reversal of this

pattern. All the above relationships have been illustrated in FIGURE 13:. Additional information is available on other groups. The Homoptera (mainly Cercopidae and Aphididae) are numerous in the abandoned area; they are fewer between the trees in the young plantation and almost absent in the other areas. Collections of Formicidae, Chalcidoidea, Thysanura, (Japigidae and Campodeidae), Centipedes and Isopods were absent or present in very low numbers in all but the abandoned area. Collections of Pseudoscorpions and Diptera larvae were more numerous throughout the young plantation than in the other areas. Lepidoptera and Coleoptera larvae were picked up irregularly in all areas.

Seasonal distribution of arthropods:

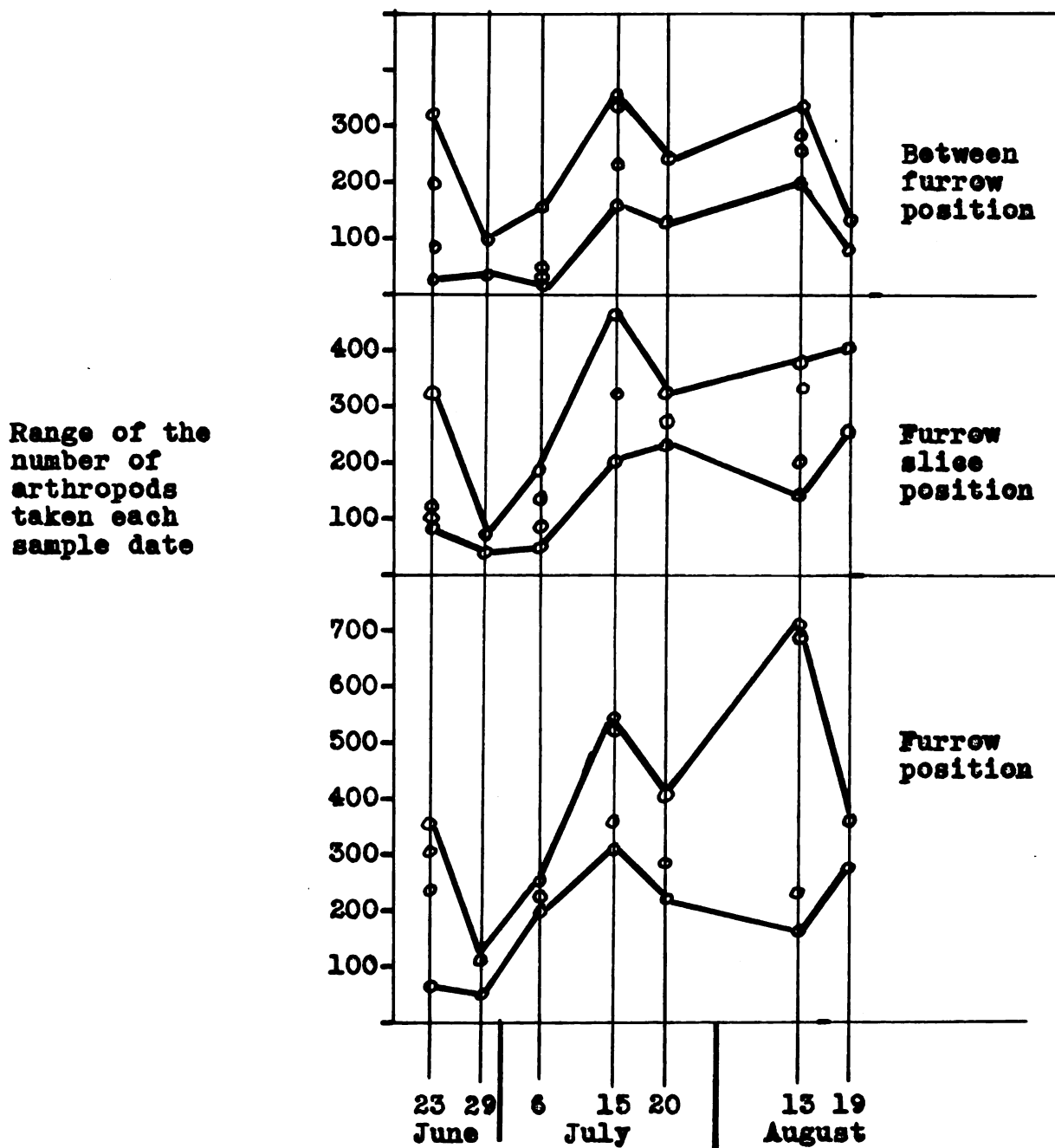
The seasonal distribution of arthropods, together with the range of numbers taken per core sample, are illustrated by sample dates in FIGURES 14, 15 and 16: (p.41, 42, and 43), representing the abandoned area, the young plantation and the old plantation respectively. In general terms it may be said that these curves show the degree of stability and uniformity of the arthropod population throughout the summer at each sample position. Contrasting examples of this stability and uniformity are illustrated when the furrow position of FIGURE 14: (where the range in numbers collected was small and about the same number were picked up throughout the summer) is compared to the furrow position of FIGURE 16: (where there was extreme irregularity in the number picked up, both on a

FIGURE 14: Seasonal distribution of arthropods in the Abandoned area.



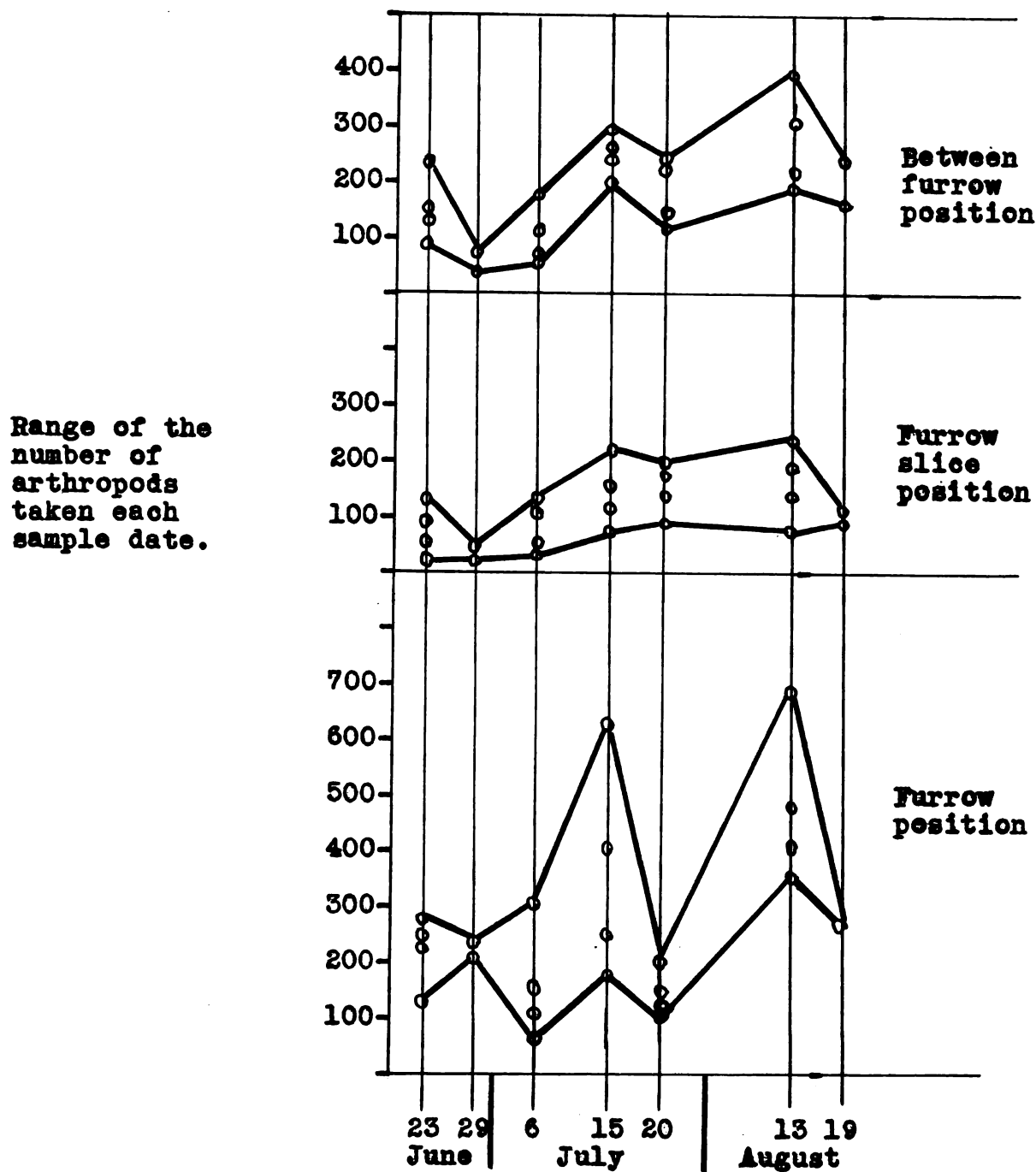
Note- Points on the curves represent the number of arthropods taken per core sample.

FIGURE 15: Seasonal distribution of arthropods in the 15-year-old plantation.



Note- Points on the curves represent the number of arthropods taken per core sample.

FIGURE 16: Seasonal distribution of arthropods in the 32-year-old plantation.



Note- Points on the curves represent the number of arthropods taken per core sample.

given date and throughout the summer). It may be recalled that two core samples were taken in each position, in two plots, in each sample area. A wide range in the number collected in one position on a given date may on occasion be the result of two plots being sampled; but this study was attempting to characterize the three areas sampled, rather than each plot in the areas.

It is interesting to look at the three sets of curves (FIGURES 14, 15 and 16:), and observe that the lines outlining the extremes of the range of collections follow a similar pattern in all the positions and areas. This suggests that some major factor of the environment may be influencing the soil fauna. Simultaneous changes in local weather conditions, mainly rainfall, and the soil arthropod population can be related to each other.

The first collecting date, June 23, was preceded by 12 days with relatively little rain; nine of which had clear weather and unseasonably high temperatures. The second collecting date, June 29, followed five additional clear days of high temperatures. The maximum number of arthropods collected on the latter date was less in all locations. The minimum taken, however, was higher in the furrow positions. This suggests that although the total population was declining in numbers, some of the decline may not be due to the death of the organisms. Both the Oribatid mites and Collembola show an increase in the furrow position of the abandoned and old plantation areas, perhaps as the result of migration to these areas.

The dry hot weather continued to the third collecting date, July 6. The period without a reasonable rain storm had lasted 26 days. Of these 21 were clear and seasonably hot. Although there was some indication that the migration to the furrow locations had continued, a more interesting increase in the maximum numbers collected was recorded in all sample positions. This increase was probably the result of reduced predation by non-Oribatid mites. These mites showed a pronounced decline in all areas on the previous collecting date and the population had not recovered. Some core samples appear to have yielded abnormally high numbers of arthropods. This was indeed true for the most numerous collections from the between furrow, and furrow slice positions of the abandoned area. Both these cores included a portion of an ant nest and the ants collected more than doubled the number of arthropods taken.

The fourth collection of core samples was taken, July 15, the day after a heavy rain storm (more than one inch of rainfall), that ended the 33-day dry period. Certainly the fauna would not have had time to take full advantage of this increase in available moisture. The decrease in the population that occurred throughout the abandoned area, was what would be expected to occur in all areas. Instead of this decrease, however, both plantations showed a very strong increase in population. The increase occurred by a multiplication of the number of Collembola, (as a result of an egg hatch), and a lesser increase of the Oribatid mites taken in the young plantation. In the old plantation, the increase was a result of the multiplication of

the first of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The second of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The third of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The fourth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The fifth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The sixth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The seventh of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The eighth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The ninth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The tenth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The eleventh of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The twelfth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The thirteenth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

The fourteenth of these is the fact that the system is not a simple one, and that the results of the experiments are not in agreement with the theoretical predictions.

the number of non-Oribatid mites taken. The number of predaceous mites in the young plantation showed only a slight increase and this undoubtedly favoured the Collembola and the Oribatids.

The fifth collecting date, July 20, followed six days of very wet weather. There were five days with rain. Two heavy storms, one of 1.03 inches, another of 1.73 inches, (measured in the open), appear to have been unfavourable to the soil fauna. There was a general decrease in the numbers of all taxonomic groups in all the areas sampled. The greatest decrease occurred in the furrows of the old plantation. Here the non-Oribatid mites that had consisted of a high number of almost entirely young individuals on the previous collecting date, were almost completely gone. In the discussion of rainfall distribution in the old plantation it was pointed out that the amount of rain reaching the ground beside the trees (in the furrow position sampled) during heavy storms was about three times as great as it was in the open. This means the soil fauna in the furrows beside the trees was exposed to upwards of seven inches of rainfall.

Intermittent rainy and clear weather such as that which occurred prior to the sixth sample date, August 13, is most favourable for the development of the soil population. The collections were highest on this date and all arthropod groups were well represented. The seventh collection date, August 19, was preceded by nine days with little rain and the population was generally less numerous than on the sixth date. In locations

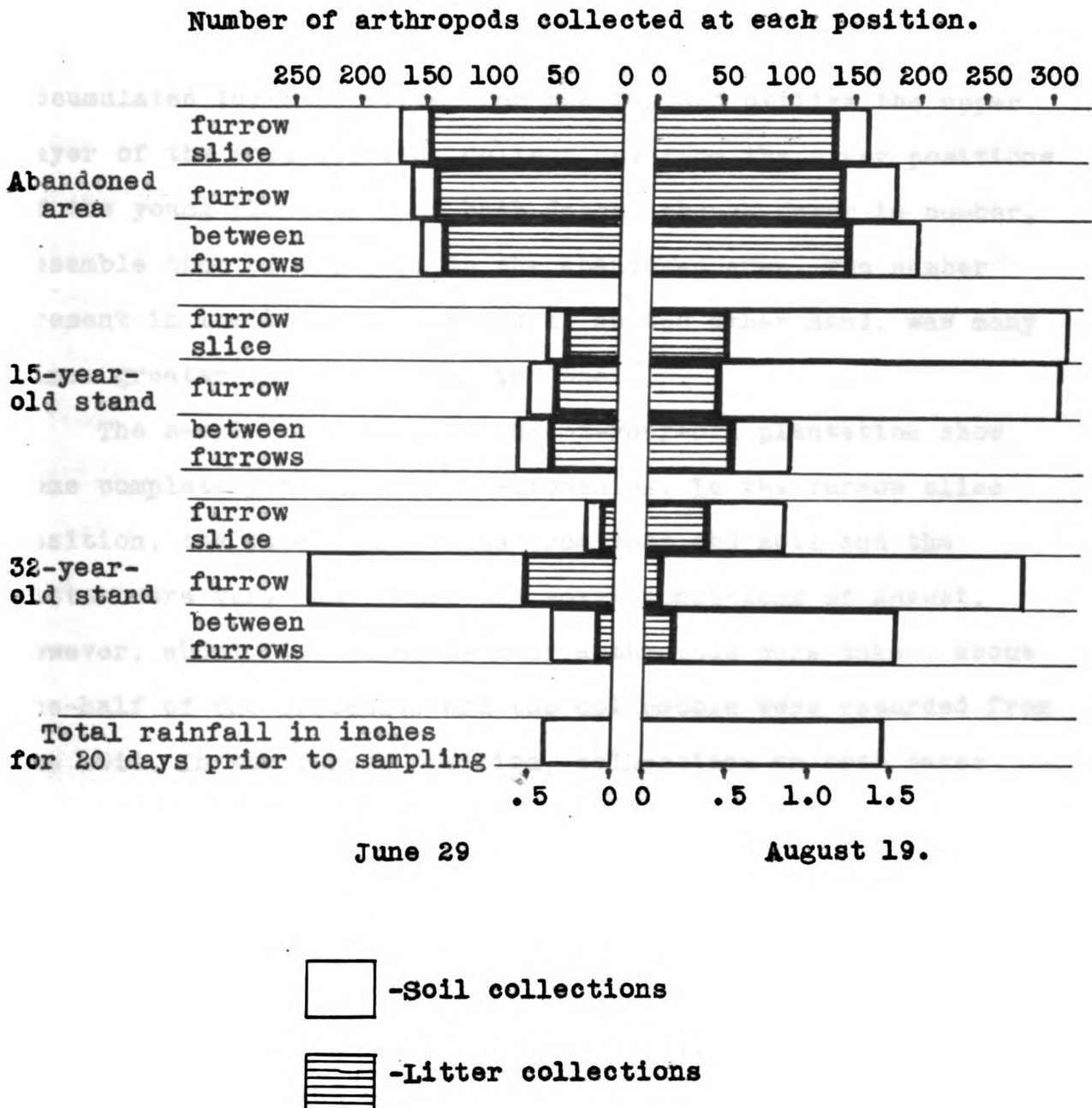
where large decreases occurred, the decline was predominantly in the Collembola. A situation much like that which preceded the first and second collecting dates appears to be developing. The population may be decreasing to compensate for less available moisture.

Vertical distribution of arthropods:

The vertical distribution of arthropods was tested on two collecting dates, June 29, and August 19. Core samples were collected and transported to the laboratory in the usual way. Prior to extraction the cores were physically divided into their soil and litter components and each was treated separately. The depth of penetration into the soil was not demonstrated but certainly, most of the arthropods recorded from the soil could have been, and probably were present, in only the upper most layer of the soil. The records of collected arthropods correlated with the amount of moisture that has been made available as rainfall to the fauna shows the relationships figured in FIGURE 17: (p.48).

For a period of 20 days prior to taking the June 29, core samples, rainfall totaled only 0.43 inches. For August 19, the total was 1.47 inches, more than three times as much as the June 29, total. The fauna, responding to the more favourable moisture conditions, was much more numerous in the August collection. In the abandoned area, collections on the two dates, at each of the three sample positions, were nearly the same; both in the number collected and in the proportions

FIGURE 17: Vertical distribution of arthropods.



of the total occupying the soil and litter components of the substrate. These same relationships apply to the between furrow position in the young plantation. The Collembola and Acarina, present in about equal numbers, do not have an accumulated layer of litter for shelter and utilize the upper layer of the soil instead. Collections from the other positions of the young plantation on both dates, though fewer in number, resemble that of the soil in the abandoned area. The number present in the litter collections, on the other hand, was many times greater in August than in June.

The sample positions in the 32-year-old plantation show some completely different relationships. In the furrow slice position, the June collections from both the soil and the litter were very low. Under the moist conditions of August, however, about five times as many arthropods were taken; about one-half of the Oribatids and the Collembola were recorded from the soil. In the furrow position, collections on both dates were more numerous. The June collections here showed that about half the Oribatids and only a few Collembola were present in the soil. In the August collections, almost all the arthropods were taken from the litter. The between furrow position harboured a small population when the June collection was made; a few Collembola and about one-quarter of the mites collected were taken from the soil. The August record shows little change in the number from the soil but the litter collections were many times greater.

In summary, the vertical distribution of arthropods is dependent on three factors; (1) the availability of a layer of litter for shelter, (2) the amount of moisture available to the fauna, and (3) the ability of the arthropods to move into the soil. Where a layer of litter is not present, the fauna inhabits the upper layer of the soil and is only slightly affected by changes in moisture conditions. Where a layer of litter is present, the fauna utilizes it only when moisture is favourable. A deep accumulation of litter is less sensitive to drying conditions and retains a higher population number. Movement of a part of the population into the soil to avoid adverse conditions was only apparent beneath the deep layers of litter. Here the Oribatid mites appeared to be able to move into the soil beneath the litter.

A SUMMARY of FINDINGS

The study areas, an abandoned field, a 15-year-old red pine plantation and a 32-year-old red pine plantation, were characterized by their history, soil characteristics and ground vegetation.

Attempts made to measure factors contributing to the soil environment demonstrated that such measurements are feasible. The volumes of both rain and litter that fall to the ground beneath the trees are greater in positions where the measured crown density is higher. Major branches radiating from the trees increase the volume of rain falling beneath them but decrease the amount of litter fall. Movement of litter down inclines in the forest floor is important for filling up the planting furrows with a deep layer of litter. The weight of litter components changes during the summer. Deeper levels of the soil are less sensitive to fluctuations in air temperature than the soil surface and the interface between soil and litter.

The study areas supported different soil arthropod populations. Unfortunately, time did not allow collections to be determined to a species level. Higher taxonomic groupings showed that the 15-year-old plantation had a fauna that was intermediate between that of the abandoned area and the 32-year-old plantation. The soil population is favoured, first, by a deep accumulation of litter and second by moderately moist conditions in the soil. Collections had fewer individuals

where litter accumulation was absent and where moisture conditions were too wet or too dry. There was a strong correlation between population size and rainfall but the effects of this relationship had been compounded by what may be normal fluctuation in the soil population. Of the major taxonomic groups collected, the non-Oribatid mites were most sensitive to adverse conditions; the Collembola intermediate in sensitivity; and the Oribatid mites least sensitive. The fauna inhabiting the upper layers of soil in the abandoned area was less affected by dry periods than the populations of the soil and litter of the other study areas. Movement from the litter into the soil to avoid unfavourable conditions was evident only in the furrow position of the 32-year-old plantation.

2a

3b

3c

3d

3e

3f

3g

3h

3i

3j

3k

3l

3m

LITERATURE CITED

General sources:

Soil Animals.

1962. by D.K.McE. Kevan. H.F.&G. Witherby, Ltd., London, pp.237.

Soil Organisms.

1963. (ed. J.Doeksen and J. van der Drift), Proceedings of the Colloquium on soil organisms, Oosterbeek, The Netherlands, 1962. North-Holland Pub. Co., Amsterdam.

Soil Zoology.

1955. (ed. D.K.McE. Kevan), Proceedings of the University of Nottingham Second Easter School in Agricultural Science, 1955. Butterworths Scientific Pub., N.Y.

Specific sources:

Bellinger, Peter F.

1954. Studies of soil fauna with special reference to the Collembola. The Conn. Agric. Exp. Sta. Bul.583. pp.67.

Cohen, M.

1955. Soil sampling in the National Agricultural Advisory Service. (see Soil Zoology, 347-50).

Iltnitzky, Steven.

1962. Red pine borer biology as inferred from trap log data. M.S. Thesis, Dept. of Ent., Mich. State Univ., Mich.

Kevan, D.K.McE.

1962. Soil Animals. H.F.&G. Witherby, Ltd., London, 237 pp.

Kühnelt, Wilhelm.

1963. Soil-inhabiting Arthropoda. Ann. Rev. of Ent. 8:115-36.

Macfadyen, A.

1955. A comparison of methods for extracting soil arthropods. (see Soil Zoology, 315-32).

1961. Improved funnel-type extractors for soil arthropods. J. Anim. Ecol., 30: 171-84.

Murphy, P.W.

1953. The biology of forest soils with special reference to the mesofauna or meiofauna. J. Soil Sci. 4: 155-93.

Murphy, D.H.

1955. Long-term changes in Collembolan populations with reference to moorland soils. (see Soil Zoology, 157-66).

Wallwork, J.A.

1959. The distribution and dynamics of some forest soil mites. *Ecology*, 40: 557-63.

ROOM USE ONLY

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03169 5236