A Study of Collembolan Populations Associated with Four Seral Stages Leading to the Beech-Maple Climax

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Abstract

Ninety-six litter samples of one square decimeter each were taken in April through July from an old field, oak and maple-oak dominated seral stages, and a beech-maple climax in Parke County, Indiana. The objective was to determine the relationship between Collembola and the seral stages.

From the 1821 Collembolans collected through modified Tullgren funnels, 59 species were found. The maple-oak had more species than any other area. This difference was highly significant. The oak area had a higher number of individuals per 100 cm^3 of litter than the other areas. This difference was highly significant. The oak area had the most individuals, the largest volume of litter, the highest total of prominence values of all species, and the greatest weekly average of individuals. In all attributes the field had the lowest value. *Isotobryoides ochracius* Maynard and *Onychiurus armatus* Tullberg were more frequent in the maple-oak area than in the other areas. The difference was highly significant. A three-dimensional ordination showed the similarity between the Collembola and the tree composition increased with each successive seral stage. The ordination indicated the collembolan populations of the wooded areas were more closely related to each other than to the Collembola in the field.

Introduction

Collembola are common inhabitants of the humus and upper soil layers in many ecological situations. The principal objective of this study was to determine the relationship of collembolan populations to plant seral stages. Leaf litter was collected from an old field, and the oak, maple-oak, and climax beech-maple areas of Allee Memorial Woods, which is located one and one-half miles northwest of Annapolis, Parke County, Indiana. The Collembola extricated from the litter were counted and identified.

Description of study area

Allee Woods is in the Tipton Till Plain close to the southern boundary of the Wisconsin glaciation (8). Soils are melanized podzolics with low fertility (7). The woods are severely dissected with 170 feet of relief. Three deep gorges are present along with a high bluff over Sugar Creek and numerous sloping ravines. All study sites were on the upland. Allee Woods was chosen for study because of the presence of numerous seral stages and a remnant of beech-maple dominated climax forest.

The beech-maple area represented the climax vegetation in the woods. There has been no cutting although windthrow has removed a few mature *Acer saccharum* Marsh. and *Fagus grandifolia* Ehrh. Beech and sugar maple are co-dominants with *Liriodendron tulipifera* L. an important associate. The understory consists primarily of sugar maple and beech saplings and *Cornus florida* L. The soil is silt loam and is

slightly acid. The litter depth averaged 3.83 centimeters. A slight southwestern slope was present.

The maple-oak probably represented an intermediate stage between the beech-maple climax and the oak stage as evidenced by the large number of sugar maple saplings. It was selectively cut about the turn of the century when some white oaks were removed. Quercus alba L., Quercus rubra L., and sugar maple are dominant species. The understory is mainly beech, sugar maple, and dogwood. The soil is slightly acid silt loam. The average litter depth is 4.41 centimeters. The letter is more uniformly spread over the ground in this area than in the others. The area slopes gently toward the west.

The oak area is predominantly white oak and red oak. Sugar maple, Asimina triloba (L.) Dunal., and Ostrya virginiana (Mill) K. Koch form the understory. The soil varies from acid to slightly acid loam. This area was completely cut over about fifty years ago and has remained undisturbed. The present evenly aged trees represent reproduction and sprouting stumps. This area had the highest average litter depth, 4.58 centimeters, consisting primarily of oak leaves. The area slopes slightly toward the south.

Tulip-poplar, Accr rubrum L., and Sassafras albidum (Nutt.) Nees are the trees most abundant in the old field. The soil is silt loam and is slightly acid. The field has a slightly western slope. This area had the least average amount of litter, 3.21 centimeters. The field was previously pastured and cultivated but has been abandoned for about thirty years. Several successful stages are present with parts of the field covered mainly by grasses while other sections have low shrubby vegetation or small to medium-sized trees.

Methods and Materials

A 100- by 200-foot tract, presumably representative of the vegetation in each of the four areas, was chosen. Within each tract, sample plots one decimeter square were selected at random before the actual sampling began. Each week for the 12 weeks from April 20 to July 5, 1968, two samples of leaf litter from each tract were taken by means of a trowel. The depth of the litter was measured to the nearest centimeter.

To prevent condensation on the sides of the funnel and the consequent loss of organisms, the litter was inverted and gently placed in a Tullgren funnel so that numerous air passages existed between the litter and funnel wall. A 15-watt bulb was suspended 3-4 inches above the sample for 24 hours. Insects were collected in 95 per cent ethanol to preserve coloration. The nomenclature followed that of Maynard (6). A species list is located in Table 1. Voucher specimens are on file in the Indiana State University entomological research collection. TABLE 1. A list of collembolan species of Allee Woods.

Entomobryidae

Entomobrua assuta Folsom Entomobrya atrocincta f. pseudoperpulchra Mills Entomobrua marginata Tullberg Entomobrya multifasciata Tullberg Entomobrya sp. A Entomobrya sp. B Isotobryoides ochracius Maynard Lepidocyrtus curvicollis Bourlet Lepidocyrtus unifasciatus James Lepidocyrtus sp. A Lepidocyrtus sp. B Lepidocyrtus sp. C Orchesella ainsliei Folsom Tomocerus elongatus Maynard Tomocerus flavescens Tullberg Tomocerus minor Lubbock Tomocerus vulgaris Tullberg Tomocerus sp. A Willowsia sp. A Willowsia sp. B

Isotomidae

Folsomia fimentaria L. Folsomia quadrioculata Tullberg Folsomia sp. A Isotoma eunotabilis Folsom Isotoma olivacea Tullberg Isotoma viridis Bourlet Isotoma sp. A Isotomurus palustris Muller Proisotoma immersa Folsom Proisotoma minuta Tullberg

Onychiuridae

Onychiurus armatus Tullberg

Poduridae

Anurida sp. A Hypogastrura tigrina Harvey Neanura barberi Handschin Pseudachorutes simplex Maynard Xenylla welchi Folsom Poduridae sp. A Poduridae sp. B Poduridae sp. C Sminthuridae

Arrhopalites binoculatus Borner Denisiella sp. A Folsom and Mills Dicyrtomina variabilis Maynard Katiannina macgillivrayi Banks Neelus albus Mavnard Neelus maculosus Maynard Neelus sp. A Neelus sp. B Phenothrix sp. A Sminthurides lepus Mills Sminthurides sp. A Sminthurides sp. B Sminthurides sp. C Sminthurinus radiculus Maynard Sminthurinus radiculus f. pictus Maynard Sminthurinus sp. A Sminthurinus sp. B Sminthuridae sp. A Sminthuridae sp. B Sminthuridae sp. C

Analysis of data

The ordination procedure (3, 1) is based on prominence values per species per community. From the prominence values, which are equal to the density times the square root of the frequency, a coefficient of community can be calculated. The inverse of the coefficient of two stands can be equated with linear distance and transformed into a threeaxis spatial pattern which will show a significant correlation between the actual, measured distances and the original coefficient of community between the two given stands. Collembola were ordinated in three dimensions by this method. The trees were ordinated in a slightly different manner. A full tally of all trees whose diameter, breast height, was greater than 2 inches was made for each area. The average of relative density and relative basal area for each species with dbh equal to 4.0 inches or more is called the importance value (5). Importance values were used instead of prominence values in the computations. Chisquare tests were used to test conclusions concerning relative density and frequency of species in each area.

Results and discussion

A total of 1821 individuals of Collembola was collected, including 59 species. The total amount of litter collected was 38,500 cubic centimeters. For all four tracts combined there was an average of 4.72 individuals per unit volume. A unit volume is defined as one-tenth of a cubic decimeter.

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Characteristics	Beech- Maple	Maple- Oak	Oak	Old Field	All Areas Combined
	<i>U</i> 0 7	C L T	0 2 2	0	
Average number of individuals per unit volume	4.00	4.10	0.00	1°20	4.(2
Fotal number of species	32.00	44.00	39.00	20.00	59.00
Fotal number of individuals	447.00	504.00	725.00	145.00	1821.00
Average depth of litter in cm.	3.83	4.41	4.58	3.21	4.02
Average volume of litter in cm^3 .	383.00	441.00	458.00	321.00	402.00
Fotal volume of litter in cm ³ .	9200.00	10,600.00	11,100.00	7700.00	38,500.00
rotal prominence value of all species	88.17	78.54	110.95	42.65	300.31
Range of number of individuals collected	1-57	3-65	2-163	0-29	0-163
Average number of individuals per week	37.20	41.90	60.30	12.10	152.00

ECOLOGY

235

There was an average depth of 4.02 centimeters of litter per sample. The lowest number of Collembola ever collected from a sample was 0.00 in one old field plot. The highest number was 163 from a plot in the oak area.

The oak area was unique in many ways (Table 2). It had (a) the highest average number of individuals (density) per unit volume; (b) the greatest number of individuals; (c) the highest average litter depth; (d) the highest total of prominence values of all species; and (e) the largest average number of individuals per week. In every attribute the old field had the lowest value. The beech-maple area was intermediate in value for every characteristic. Only once did the maple-oak area have the highest value; it had the greatest total number of species present per area.

The number of individuals per unit volume was greatest in the oak area followed by decreases in relative abundance in the beech-maple, maple-oak, and old field areas. This difference was highly significant $(X^2 = 213.96, 3df)$. The maple-oak area had more species present in the litter (44) than the other areas. The difference was significant $(X^2 = 9.60, 3df)$. A possible explanation is that the maple-oak area combines the features and hence Collembola of the oak and beech-maple areas. Although the old field had an average depth of 3.21 centimeters, some of this depth is a result of the cushioning and buoyant effect of the grasses in the litter. Hence the value cited is probably high.

Isotobryoides ochracius Maynard appeared in 71 per cent of all samples in the maple-oak area but in only eight per cent of the samples in the old field. This difference was highly significant ($X^a = 15.32$, 3df). Onychiurus armatus Tullberg was present in 83 per cent of the mapleoak samples but in only 12 per cent of the old field samples. The difference was highly significant ($X^2 = 10.48$, 3df). Table 3 lists the density per unit volume and prominence values for the ten most common species.

Some species could not be identified because of the absence of suitable taxonomic keys. More samples over a longer period of time might allow us to identify an increased number of the more difficult species. Some of the immature stages cannot be identified beyond family (2). Sminthuridae sp. A, which has occurred three times but only in the old field, may be an indicator species. Similarly, Sminthuridae sp. C has occurred only in the beech-maple area and could be an indicator species.

The most important species in terms of density, frequency, and prominence value is *Tomocerus minor* Lubbock. The second most important is *Onychiurus armatus*. The former was cosmopolitan in distribution while the latter is prevalent in the maple-oak area. The most important genus in terms of density, frequency, and prominence value is *Entomobrya* followed by *Tomocerus* and *Onychiurus*. The most important family by the same criteria is the Entomobryidae. However, both the Entomobryidae and Sminthuridae have 20 species represented.

Because trees are one of the primary constituents of a community and their leaves form the bulk of the litter, an ordination was made on

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	Beech-	Maple	Maple	e-Oak	õ	ak	Old	Field
	Density/	Promi-	Density/	Promi-	Density/	Promi-	Density/	Promi-
	Unit	nence	Unit	nence	Unit	nence	Volume	nence
Species	Volume	Value	Volume	Value	Volume	Value	Unit	Value
Inychiurus armatus	1.74	13.29	1.35	12.32	.64	4.71	.40	1.41
"omocerus minor	1.10	9.52	.81	7.57	1.34	11.60	.75	5.93
$rac{1}{2}ntomobrya$ assuta	1.23	8.32	.21	1.21	.29	1.96	.57	2.59
sotobryoides ochracius	1.09	6.67	.62	5.21	1.82	8.29	.40	1.15
Intomobrya multifasciata	.86	6.32	22.	7.23	1.50	12.25	.70	4.28
Intomobrya sp. A	.75	5.52	.59	3.54	1.79	13.17	.81	3.69
⁷ olsomia fimentaria	.83	3.39	.65	5.21	.44	2.37	.40	1.41
Kenylla welchi	.48	3.24	.30	1.62	.59	3.99	.74	4.52
Intomobrya marginata	.68	3.10	.26	1.30	.45	2.05	.22	4.98
sotoma olivacea	.44	2.20	.62	2.53	1.09	6.28	.76	3.46

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a full tally of the trees and on the Collembola of each area to determine if there is a relationship between the two populations. The data were plotted on the same set of axes (Figure 1). The interpoint distances were measured graphically from the trees of one stand to the Collembola of the same stand to determine the degree of similarity between the two populations. In lowest terms the distances are as follows: old field, 131 units; oak, 121 units; maple-oak, 42 units; and beech-maple, 34 units. There was a definite straight line relationship showing that the distance between the collembolan population and the tree composition, i.e., the



Legend

B = beech-maple. F = old field M = maple-oak O = oak c = Collembola t = trees

Figure 1. A two-dimensional ordination of the collembolan and tree populations of four seral stages.

ECOLOGY

dissimilarity between the two as measured by interpoint distance, decreases as the climax area is approached and stability is reached. In the more advanced seral stages, the maple-oak and beech-maple, the ordination results indicated equilibrium is approached between the woody vegetation and the collembolan population.

When the Collembola and trees were ordinated in the third dimension, the Collembola occurred in two main groups with respect to each other. The Collembola of the wooded areas were closely grouped together. Interpoint distances were beech-maple (BM) to maple-oak (MO) = 36.2; BM to oak (O) = 40.8; and MO to O = 48.0. When each wooded area was compared to the old field, another grouping occurred. Interpoint distances were BM to old field (OF) = 134.2; MO to OF = 146.2; and O to OF = 151.7. The obvious conclusion is that the collembolan population of the wooded areas are closely related to each other while the collembolan population of the old field is a separate group.

Summary

- 1. The largest numbers of Collembola per unit volume existed in the oak area and the smallest numbers in the old field.
- 2. The maple-oak area had the largest number of species (44) while the old field had the smallest (20).
- 3. Isotobryoides ochracius and Onychiurus armatus were present in the highest frequency in the maple-oak area.
- 4. The most important species in terms of density, frequency, and prominence value was *Tomocerus minor*. Second was *Onychiurus armatus*. The most important genera are *Entomobrya*, *Tomocerus*, and *Onychiurus*. The most important family was Entomobryidae.
- 5. Ordination showed that the similarity between the collembolan population and the tree composition in each area increased with each succeeding seral stage; the greatest similarity was found in the climax beech-maple area.
- 6. The Collembola in wooded areas were more similar to each other than to those in the old field.

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