

## Diversity and Abundance of Springtails (Insecta: Collembola) in Native and Restored Tallgrass Prairies

RAYMOND H. BRAND AND CHRISTOPHER P. DUNN

*The Morton Arboretum, 4100 Illinois Route 53, Lisle, Illinois 60532-1293*

ABSTRACT.—This study suggests that heterotrophic components of prairie ecosystems can be used with autotrophic components to assess the degree to which a restored prairie approaches the biotic complexity of a native prairie. Springtails (Collembola) were collected from prairie vegetation and litter samples from 13 prairie sites (seven native and six restored) located in southwestern Michigan and northeastern Illinois. The diversity and abundance of these insects and the plant and litter biomass were compared. There were 27 different taxa of springtails in the 225 samples collected. Native prairies had the greatest species richness with 26 species. The oldest restored prairie had 17 species. Three common species were *Hypogastrura boletivora*, *Isotoma viridis*, and *Lepidocyrtus pallidus*. *Neanura muscorum*, *Xenylla grisea*, and *Pseudosinella rolfsi* were rare. *Tomocerus flavescens* was found primarily in native prairies with only one occurrence in the oldest restored prairie in this study. Native prairies and restored prairies of 17 and 24 yr did not differ significantly in numbers of springtails.

Differences in springtail numbers did occur, however, between restored prairies of <6 yr and native prairies, and between younger (<6 yr) and older (17 and 26 yr) restored prairies. An analysis of plant and litter biomass indicated significant differences among the prairie sites sampled. These results suggest that all components of the prairie ecosystem are useful for making restoration management decisions.

### INTRODUCTION

Before European settlement in the 1800s, much of the midwestern landscape was dominated by native tallgrass prairies. The northern and central sections of Illinois were approximately 60% prairie (Transeau, 1935). In more recent times, industrialization, transportation routes, agriculture and increasing human populations have decreased the amount of Illinois prairie to less than 0.01% of its original expanse (Iverson, 1988). One response to the disappearance of prairie communities has been an effort to re-establish these communities in protected areas. Both professional ecologists and volunteer prairie enthusiasts have attempted restorations in many parts of the Midwest (Curtis, 1959; Schulenberg, 1970; Betz, 1986). One of the largest Illinois efforts (over 400 acres) began in 1975 inside the high energy particle accelerator ring at the Fermi National Accelerator Laboratory (Fermilab), Batavia, Illinois (Betz, 1986). An earlier, smaller restoration of 32 acres, known as the Schulenberg prairie at the nearby Morton Arboretum, Lisle, Illinois, was initiated in 1962 (Schulenberg, 1970).

Most effort expended on restoration of prairies has concentrated on establishment of prairie grasses and forbs to form a matrix for the development of a complex community (Betz, 1986). Although natural communities consist of both floristic and faunistic elements, the latter have not generally been emphasized in evaluating restoration success.

This paper presents the results of a 5-yr ecological study of the epigeic springtail insects (Collembola) occurring in 13 native and restored prairie communities in northeastern Illinois and southwestern Michigan (Chapman and Pleznac, 1982). Seven of these sites were native prairie remnants ranging in size from 1 to over 40 ha. Six of the sites were located in two restored prairies; *i.e.*, Fermilab and The Morton Arboretum.

Springtails are primarily herbivores or detritivores. Only a few species, such as *Proisotoma*

*grandiceps*, are known to be carnivores (Christiansen, 1964, 1992). Rarely have any species become agricultural pests, but their important ecological role (Christiansen, 1964), along with other microarthropods in preparing organic material for later decomposition processes, is widely recognized (Zinkler and Stecken, 1985). Collembola also eat moss protonema (Varga, 1992), transport fungus spores, and consume bacterial plant pathogens (Christiansen, 1964; Wiggins and Curl, 1979). Their dispersal rates may be much slower than winged insects (Christiansen and Bellinger, 1980). However, their small size and minimal mass contribute to their dispersal by wind and other animals and they are found in almost all ecosystems throughout the world (Christiansen and Bellinger, 1995). A thin, chitinous exoskeleton limits their distribution within ecosystems to sites with adequate moisture (Christiansen, 1992). Ascertaining which springtail taxa are native and which are introduced can be difficult because documented zoogeographic information is lacking for many Nearctic species (Christiansen and Bellinger, 1994). However, some information on geographic origin is available for many species in the most complete taxonomic publication on North American Collembola (Christiansen and Bellinger, 1998).

The specific purpose of this study was to compare the species richness and abundance of springtails present in native prairies to those in various stages of restored prairies, and to ascertain if any species or the diversity of species might serve as indicators of well-established prairie conditions. As Kremen (1992) notes, no single taxon is sufficient to serve as an indicator of "naturalness" because soil conditions, diversity of plant species and other heterotrophic components of the community must also be considered in natural area monitoring. That a correlation exists between plant and insect species diversity has been shown for homopteran insects and old-field communities (Murdoch *et al.*, 1972).

#### METHODS

*Study sites.*—The seven native prairies included in this study contain a rich diversity of plant and animal species. For example, over 500 native flowering plant species have been identified on the West Chicago Prairie in DuPage County, Illinois, and soil samples have provided no evidence of past agricultural or soil disturbance (Kelsey and Hootman, 1992). On the Dayton Prairie in Berrien County, Michigan, the number of flowering plant species has not been documented but over 200 insect species have been identified (Ewert, 1989). The remaining five native prairies are smaller remnants that have not received intensive study but are floristically similar to the larger native prairies in a general field survey of the areas (Chapman and Pleznac, 1982).

The six restored prairie sites in DuPage County are in various stages of restoration. The Fermilab restoration began in 1976 and had 115 species of native flowering plants within 10 yr. (Betz, 1986). Samples from the Fermilab site were collected from three site age classes, Ra = 2 to 5 yr (younger), Rb = 6 to 11 yr (intermediate), and Rc = 14 to 19 yr (older). In the case of the sites at The Morton Arboretum, the prairie restoration project began in 1962 and had over 200 native plant species by 1968 (Schulenberg, 1970). Since then, species lists indicate 303 native species (Wilhelm and Masters, 1994). The three age classes available for sampling at The Morton Arboretum were as follows: Rd = 17 yr, Re = 19 yr, and Rf = 24 yr. For the remainder of this paper in both text and tables, the older restored prairies refer to Fermilab Rc and to all Morton Arboretum sites (Rd, Re, and Rf; Table 1), all more than 16 yr old. Management regimes for all prairie sites involved burning on a regular, often annual, basis but accurate records were not available for all sites. At the Fermilab site annual burning did not commence until after the 3rd growing season in 1979.

*Data collection and analysis.*—Samples of 0.2 m<sup>2</sup> of plants and surface litter were collected each year over the 5-yr period from 1987 to 1991 during the middle of the growing season

TABLE 1.—Study sites, number of samples (N), plant biomass g mean  $\pm$  SE, springtail numbers/m<sup>2</sup> mean  $\pm$  SE, number of springtail species (Sp), and Simpson diversity index (D)

Location	Site	N	Biomass	Springtails	Sp	D
Native prairies						
Newaygo, Mich.	Na	09	427.7 $\pm$ 54.7	9.57 $\pm$ 20.6	04	NA
Markham, Ill.	Nb	18	573.2 $\pm$ 45.6	22.4 $\pm$ 30.6	07	2.7
Lawton, Mich.	Nc	09	1016.0 $\pm$ 136.8	36.5 $\pm$ 45.4	07	NA
Bakertown, Mich.	Nd	09	1757.4 $\pm$ 159.0	188.9 $\pm$ 101.1	14	NA
Buchanan, Mich.	Ne	18	1186.1 $\pm$ 116.8	273.9 $\pm$ 204.1	17	6.6
West Chicago, Ill. (A)	Nf	18	874.3 $\pm$ 62	498.3 $\pm$ 142.5	17	7.5
West Chicago, Ill. (B)	Ng	18	850.7 $\pm$ 72.4	422.9 $\pm$ 358.4	17	3.5
Restored prairies						
Batavia, Ill. (A)	Ra	24	485.9 $\pm$ 29.9	46.1 $\pm$ 88.1	09	5.6
Batavia, Ill. (B)	Rb	24	820.6 $\pm$ 104.8	27.2 $\pm$ 47.8	12	6.3
Batavia, Ill. (C)	Rc	24	1295.9 $\pm$ 118.8	171.8 $\pm$ 252.5	13	5.7
Lisle, Ill. (A)	Rd	18	703.8 $\pm$ 66.7	34.6 $\pm$ 36.7	08	2.6
Lisle, Ill. (B)	Re	18	984.3 $\pm$ 98.2	361.8 $\pm$ 340.5	10	3.5
Lisle, Ill. (C)	Rf	18	1378.8 $\pm$ 109.8	80.1 $\pm$ 82.9	12	5.8

(June or early July) by clipping all growing and dead plants at ground level. This material was placed in plastic bags in ice-cooled, insulated, polyethylene chests for transport to the laboratory. A total of 225 randomly selected samples were obtained from the 13 sites ranging from 9 to 24 samples per site. Modified Tullgren funnels were used to extract the organisms from the field samples of vegetation by placing the samples on cheese-cloth covered screens inside the funnels. Springtails and other invertebrates were collected over a 4-day period (starting on the day the field samples were obtained) in bottles of Van Torne's preservative (Christiansen and Bellinger, 1980) placed at the base of the funnels. A gradient of humidity was established by placing pans of water on the floor between the funnels to facilitate the downward migration of invertebrate organisms to higher humidity levels. Light bulbs of 60 and then 40 watts were turned on for 2 days each in the reflectors at the top of the funnels to create a temperature gradient to attract the organism to the cooler temperature near the floor. Springtails were presorted into different kinds—under a low power binocular microscope—into small vials of 99% isopropyl alcohol. Identification to genus or species was made using higher magnifications of either an Olympus research microscope or a Nikon phase contrast microscope. A scanning electron microscope was also used to photograph particular morphological features necessary for the identification of some species. Permanent voucher slides for representative specimens are stored at The Morton Arboretum. Some taxa could only be identified to genus, but these are known to be different species from the congeneric species listed in that genus.

Following the funnel extraction process for obtaining the invertebrates, each sample of dried plants and litter was weighed to the nearest gram. Data were analyzed statistically using the software program, Statistix Version 4.1 (Analytical Software, 1994). Preliminary analysis indicated that the data were not normally distributed and the variances were heterogeneous. As these results did not meet the assumptions of a standard parametric ANOVA, data were analyzed with a Kruskal-Wallis one-way nonparametric method appropriate for non-normal distributions. For any result in which a null hypothesis was rejected, a parametric ANOVA was applied to ranked data for multi-group comparisons (Zar, 1984). Data

TABLE 2.—Species occurrence distribution<sup>a</sup>

Taxon	Native sites							Restored sites						Springtail abundance
	Na	Nb	Nc	Nd	Ne	Nf	Ng	Ra	Rb	Rc	Rd	Re	Rf	
Hypogastruridae														
<i>Hypogastrura boletivora</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	c
<i>H. sp. 2</i>		x	x	x	x	x	x				x	x	x	c
<i>Xenylla grisea</i>						x	x							r
<i>Neanura muscorum</i>				x	x									r
Onychiuridae														
<i>Tullbergia granulata</i>					x	x		x	x	x	x	x		c
<i>Onychiuris sp. 2</i>						x		x	x					i
Isotomidae														
<i>Isotoma viridis</i>	x	x		x	x	x	x	x	x	x	x	x	x	c
<i>I. sp. 2</i>			x	x	x	x	x			x	x			i
<i>I. sp. 3</i>			x	x		x						x		i
<i>Folsomides americanus</i>						x	x	x	x					i
<i>Folsomia sp.</i>		x		x	x	x	x					x	x	c
<i>Proisotoma sp.</i>										x				r
Entomobryidae														
<i>Lepidocyrtus pallidus</i>	x	x	x	x	x	x	x	x	x	x	x	x	x	c
<i>L. paradoxus</i>				x	x	x	x							i
<i>L. violaceus</i>	x		x					x						i
<i>Entomobrya quadrilineata</i>		x	x					x						i
<i>E. purpurascens</i>							x	x						r
<i>E. sp. 3</i>		x		x	x		x	x			x	x		c
<i>Orchesella hexfasciata</i>							x				x	x	x	i
<i>Pseudosinella rolfsi</i>			x									x	x	r
<i>Tomocerus flavescens</i>				x	x	x	x			x				i
Sminthuridae														
<i>Sminthurides pumilis</i>				x	x		x							i
<i>S. sp. 2</i>					x	x	x						x	i
<i>Sminthurinus henshawi</i>					x	x	x			x				i
<i>S. sp. 2</i>				x		x								r
<i>Bourletiella sp. 2</i>			x		x	x	x	x			x	x	x	c
<i>Arrhopalites amarus</i>					x									r
Number of species	4	7	7	14	17	15	18	5	11	11	7	10	10	

<sup>a</sup> Abbreviations for native and restored sites defined in text; for abundance, c = common (taxon occurs in 7 or more sites), i = intermediate (3 to 6 sites), r = rare (fewer than 3 sites)

from the Newaygo, Michigan, prairie site were omitted from the statistical analysis since only two of nine samples contained springtails. Simpson's diversity index was calculated for sites with 18 or more samples (Simpson, 1949).

## RESULTS

*Springtails*.—Twenty-seven springtail taxa were identified from all sites. Six taxa obtained from native prairies did not occur on restored prairies, and only one taxon, *Proisotoma sp.*, was found exclusively on restored prairies (Table 2). Three species were common at most

sites: *Hypogastrura boletivora* (Packard), *Isotoma viridis* (Bourlet), and *Lepidocyrtus pallidus* (Router). Three other species were rarely encountered, being taken at only two of the 13 sites: *Neanura muscorum* (Templeton), *Xenylla grisea* (Axelson), *Pseudosinella rolfsia* (Mills). Of these latter species, *N. muscorum* and *X. grisea* were taken only at native prairies. Two other species, *Lepidocyrtus paradoxus* (Uzel) and *Tomocerus flavescens* (Tullberg) were mainly restricted to native prairies, although *T. flavescens* was also taken at the oldest restored Fermilab site (Rc). The remaining 18 species have no apparent affinity or restriction to the native or restored prairies studied.

No clear trends were found in Simpson's index of diversity for each site (Table 1). A scale of presence of each species was based on their occurrence at the study sites according to the following criteria: rare (r) = found at fewer than three sites; intermediate (i) = found at three to six sites; and common (c) = found at seven or more sites (Table 2). Furthermore, a null hypothesis of no difference in springtail numbers among the sites was rejected using the Kruskal-Wallis nonparametric analysis ( $H = 74.85$ ,  $df = 11$ ,  $P < 0.001$ ). Ranked data, analyzed with ANOVA, indicated a significant difference for the multigroup comparison ( $F = 22.43$ ,  $df = 3$ ,  $P < 0.001$ ), with the number of springtails being greater in native vs. all restored prairie sites ( $F = 7.59$ ,  $df = 1$ ,  $P < 0.006$ ) and in younger vs. older restored prairie sites ( $F = 23.49$ ,  $df = 1$ ,  $P < 0.001$ ); but not significantly different in native vs. older restored prairie sites ( $F = 0.12$ ,  $df = 1$ ,  $P > 0.732$ ).

*Plant and litter biomass.*—Plant plus litter mean dry weights of the prairie sites sampled were significantly different using the Kruskal-Wallis test ( $H = 83.63$ ,  $df = 12$ ,  $P < 0.001$ ; Table 1). The two oldest restored prairie sites, Fermilab Rc and The Morton Arboretum Rf, differed significantly in plant and litter biomass analyzed with ANOVA from the most productive and diverse native prairies, Dayton and West Chicago ( $F = 37.76$ ,  $df = 1$ ,  $P < 0.001$ ). Younger restored prairies also differed significantly in plant plus litter biomass from older restored and native prairies ( $F = 16.09$ ,  $df = 1$ ,  $P < 0.001$ ). Plant and litter biomass increases steadily from younger to older restored prairie sites at both Fermilab and The Morton Arboretum prairies (Table 1).

#### DISCUSSION

The 27 epigeic springtail taxa encountered in the vegetation and litter are fewer than might be expected considering that in 1996, Waltz and Hart reported 216 species for the state of Indiana (Waltz and Hart, 1997). In an earlier study of arthropods in three northeastern Illinois prairies, 21 or 23 species of springtails were present (Hamilton and Stathakis, 1987). However, the majority of soil-dwelling forms, except for a rare litter emigrant, were not included in this study, whereas all habitats were included in the Waltz and Hart study, and pit traps rather than Berlese funnels were used in the Hamilton study. In the present study, *Lepidocyrtus paradoxus*, although originally from Europe (Gisin, 1960) and apparently introduced into northeastern United States about 1950 (pers. comm., Peter Bellinger, 1990), was collected only from native prairie sites. *Tomocerus flavescens* was found on four of the native prairie sites but not on restored sites except the oldest restored Fermilab prairie. This latter species was also collected during previous studies of old field habitats that had not been used agriculturally for over 60 yr (Brand, 1989). These results suggest that these two species could be considered as indicator species of native prairie conditions. However, other studies show that these species occur in a variety of other habitats (Zinkler and Stecken, 1985; Christiansen, 1964). Like *T. flavescens*, two other taxa (*Hypogastrura* sp. 2, and *Folsomia* sp.) were found only in native prairies and the older restored prairies (Table 2). Of all the springtail species identified in the study, only six species were not found in restored prairie samples. Apparently, many springtail species can survive the transition pro-

cess from an agricultural field to restored prairie, or they can disperse from nearby old fields or native prairies within a relatively short time. In at least one other study, the species richness of the collembolan community in rehabilitated forested areas is positively correlated with plot age (Greenslade and Majer, 1993).

A number of ecological differences occur between native and restored prairies (*e.g.*, soil conditions, microclimate, plant cover), but perhaps one of the most critical for springtails is the amount of moisture. In this study, the dense summer growth of grasses and forbs in both native and restored prairies provided high humidities during at least some of the periods of the day when samples were collected. In an earlier study of springtail populations, time of sampling was shown to be important, with optimum sampling times being in the early mornings and 1 or 2 days after substantial rains (Brand, 1979). Following periods of prolonged drought, any surviving epigeic forms apparently remain in the top, loose soil surface or in the tangled mat of vegetation and litter close to the soil surface. Early stages of restored prairies have less dense plant growth with many patches of bare ground. With time, plants fill in these spaces, humidity increases, and available food sources become more abundant for springtail immigration and survival (Jastrow, 1987). Thus, in later stages of restored prairies the environmental conditions become increasingly similar to native prairies. In addition to humidity, the vertical migration of some springtails (*e.g.*, *Onychiurus subtenuis*; Bauer and Christian, 1993) within the litter layer is partly dependent on the presence of palatable microorganisms and is not simply a reaction to moistening and desiccation (Bauer and Christian, 1993).

*Management implications.*—The difference in numbers of springtails between the native and restored prairies shown is of interest in evaluating prairie restoration. Despite high variability in the sample numbers from restored and native prairies, there was a significant difference in numbers of springtails between native and all restored prairies, and between younger and older restored prairies. No difference, however, could be shown between native prairies and the subset of oldest restored prairies (*i.e.*, those older than 16 yr). This result, along with the increasing diversity of plant species described by others (Betz, 1986; Wilhelm and Masters, 1994) and the increased soil aggregates in older restored prairies (Jastrow, 1987) are indications that the efforts to restore native conditions have had some measure of success.

Biomass of plant and litter samples was variable and showed patterns similar to the springtail numbers for native and restored prairies. Thus, for plant and litter biomass, there were significant differences between native and all restored prairies. It is also of interest that the average gain in plant plus litter weight for the two oldest restorations at Fermilab and The Morton Arboretum over the same interval in years is remarkably similar despite the difference in location and management methods. This suggests that the methods employed in collecting plant and litter samples were appropriate for the purposes of the study. As information accumulates about the process of prairie restoration and management, it is hoped that the results of this study will encourage others to focus on the invertebrate animal component in conjunction with present emphases on plants. Another study has already demonstrated that a species-rich collembolan fauna is positively correlated with plant species richness and diversity (Greenslade and Majer, 1993). Such results provide direction for those involved in assessing the degree of prairie restoration achieved.

*Acknowledgments.*—The authors thank Wayne Lampa of the Forest Preserve District of DuPage County, Illinois, for permitting sampling at the West Chicago Prairie, and Fermi National Accelerator Laboratory and The Morton Arboretum for allowing sampling in restored prairies. Kenneth Christiansen provided assistance in the identification of specimens. Support for field work during the early part of the study was provided by the Illinois Department of Conservation, Division of Natural Heritage.

## LITERATURE CITED

- ANALYTICAL SOFTWARE. 1994. Statistix Version 4.1. Analytical Software, Tallahassee, Florida.
- BAUER, R. AND E. CHRISTIAN. 1993. Adaptation of three springtail species to granite boulder habitats (Collembola). *Pedobiologica*, **37**:280–290.
- BETZ, R. F. 1986. One decade of research in prairie restoration at the Fermi National Accelerator Laboratory (Fermilab), Batavia, Illinois, p 179–185. *In*: G. K. Clambey and R. H. Pemble (eds.). Proceedings of the 9th North American Prairie Conference. Tri-College University Center for Environmental Studies. North Dakota State University, Fargo.
- BRAND, R. H. 1979. Effect of sampling time on estimates of soil arthropod populations. *Rev. Ecol. Biol. Sol.*, **16**:499–515.
- . 1989. Diversity of epigeic springtails in grasslands of Midwestern United States, p. 206–215. *In*: P. Stahle (ed.). Proceedings of the 5th Australasian Conference on Grassland Invertebrate Ecology. D&D Printing, Victoria, Australia.
- CHAPMAN, K. A. AND R. J. PLEZNAC. 1982. Public prairies of Michigan. The Michiana Prairie Society, Kalamazoo, Michigan. 14 p.
- CHRISTIANSEN, K. 1964. Bionomics of Collembola. *Annu. Rev. Entomol.*, **9**:147–178.
- . 1992. Springtails. *Kans. School Nat.*, **39**:1–16.
- AND P. BELLINGER. 1998. The Collembola of North America north of the Rio Grande. Grinnell College, Grinnell, Iowa. 1518 p.
- AND ———. 1995. The biogeography of Collembola. *Bull. Entomol. Pologne*, **64**:279–294.
- COOK, B. D., J. D. JASTROW AND R. M. MILLER. 1988. Root and mycorrhizal endophyte development in a chronosequence of restored tallgrass prairie. *New Phytol.*, **110**:355–362.
- CURTIS, J. T. 1959. The vegetation of Wisconsin. University of Wisconsin Press, Madison. 657 p.
- EWERT, D. 1989. Biotic communities at Dayton Wet Prairie. The Nature Conservancy, East Lansing, Michigan. 18 p.
- GISIN, H. 1960. Collembolenfauna Europas. Museum D'Histoire Naturelle. Geneva, Switzerland. 240 p.
- GREENSLADE, P. AND J. D. MAJER. 1993. Recolonization by Collembola of rehabilitated bauxite mines in Western Australia. *Austr. J. Ecol.*, **18**:385–394.
- HAMILTON, R. W. AND D. G. STATHAKIS. 1987. Arthropod species diversity, composition, and trophic structure at the soil level biotope of three northeastern Illinois prairie remnants. *Trans. Ill. State Acad. Sci.*, **80**:273–298.
- IVERSON, L. R. 1988. Land-use changes in Illinois, USA: the influence of landscape attributes on current and historic land use. *Landscape Ecol.*, **2**:45–61.
- JASTROW, J. D. 1987. Changes in soil aggregation associated with tallgrass prairie restoration. *Am. J. Bot.*, **74**:1656–1664.
- KELSEY, P. D. AND R. G. HOOTMAN. 1992. Relationships between water tables, plant communities, and hydric soils, West Chicago Prairie, West Chicago, Illinois. *Soil Surv. Horiz.*, **33**:53–74.
- KREMEN, C. 1992. Assessing the indicator properties of species assemblages for natural area monitoring. *Ecolog. Appl.*, **2**:203–217.
- MURDOCH, W. W., F. C. EVANS AND C. H. PETERSEN. 1972. Diversity and pattern in plants and insects. *Ecology*, **53**:819–828.
- SCHULENBERG, R. 1967. Prairie in a post-prairie era. *Morton Arbor. Quart.*, **3**:17–27.
- . 1970. Summary of Morton Arboretum prairie restoration work, 1963–1968, p. 45–56. *In*: P. Schramm (ed.). Proceedings of Symposium on Prairie and Prairie Restoration. Knox College, Galesburg, Illinois.
- SIMPSON, E. H. 1949. Measurement of diversity. *Nature*, **163**:688.
- TRANSEAU, E. N. 1935. The prairie peninsula. *Ecology*, **16**:423–437.
- VARGA, J. 1992. Analysis of the fauna of protected moss species. *Biol. Conserv.*, **59**:171–173.
- WALTZ, R. D. AND J. W. HART. 1997. Checklist of the Indiana Collembola. *Proc. Indiana Acad. Sci.*, **105**:29–41.
- WIGGINS, E. A. AND E. A. CURL. 1979. Interaction of Collembola and microflora of cotton rhizosphere. *Phytopathology*, **69**:244–249.

- WILHELM, G. AND L. MASTERS. 1994. Species list for the Schulenberg Prairie. The Morton Arboretum, Lisle, Illinois. 3 p.
- ZAR, J. H. 1984. Biostatistical analysis. Prentice Hall, Englewood Cliffs, New Jersey, 718 p.
- ZINKLER, D. AND R. STECKEN. 1987. Digestion of leaf litter by the springtail *Tomocerus flavescens* (Insecta, Collembola), p. 730–734. *In*: B. R. Striganova (ed.). Soil fauna and soil fertility. Nauka, Moscow.

SUBMITTED 27 AUGUST 1996

ACCEPTED 1 JULY 1997