DIVERSITY OF SPRINGTAIL INSECTS
IN RESTORED PRAIRIE

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Introduction

Prior to human settlement by European Immigrants, much of the mid-western landscape of the United States was dominated by native tall grass prairies. The state of Illinois was approximately eighty-five percent prairie according to a vegetation map of the prairie peninsula (Transeau, 1935). In recent times, industrialization, transportation routes, agriculture, and an ever expanding human population has now decreased the amount of Illinois prairie to less than five percent (Anderson, 1970).

One response to the disappearance of prairie communities has been the effort to re-establish some of them in protected areas. Both professional ecologists and volunteer, amateur prairie enthusiasts have attempted restorations in many parts of the midwest. One of the largest efforts (over 440 acres) has taken place inside the high energy accelerator ring at the Fermi National Laboratory (Fermilab) in Batavia, Illinois (Betz, 1984).

This paper presents the results of a study on the epigeic springtail insects of the Fermilab restored prairie communities. Some reference to similar continuing studies at nearby native prairies and other restored prairies will also be included (Brand, 1989). One of the advantages of the Fermilab site is the opportunity to sample a number of adjacent restored prairies in a chronosequence extending over sixteen years within the general context of similar environmental conditions of climate, soil, and fire management regimes. It is thus possible to obtain information about the changes in species diversity with time and to assess the present establishment success of individual species.

In addition to vegetation and other studies in progress at the Fermilab site, soil analyses have shown an increase in soil aggregates with time since restoration began (Jastrow, 1987).

Springtail insects are mainly herbivores or detritivores with only a few species recognized as carnivores. Only rarely have any species become agricultural pests, but their important ecological role in decomposition processes along with other microarthropods is generally recognized. Compared to winged insects their dispersal rates are much slower. However, their small size and minimal weight contribute to dispersal by wind and they are found in almost all environments throughout the world.

Most effort expended on restoration of prairies has concentrated on the establishment of prairie grasses and forbs. However, the animal components of these prairie communities are also important for understanding the complex nature of the ecosystem interactions. In this study, I have attempted to identify the species of springtail insects present at various stages of prairie restoration, relate their population numbers to the age of restoration, and ascertain if any particular species might serve as indicators of well-established prairie conditions. A relatively recent comprehensive treatment of the taxonomy of Collembola in North America, including keys to genera and species, was a particularly useful reference tool (Christiansen, 1980). The distinction between native and recently introduced taxa is difficult to ascertain in many cases since documented zoogeographic information is lacking for many Nearctic species.

Materials and Methods

Field collections of vegetation and litter were made by clipping growing plants near the ground with large-bladed hedge shears. Randomly selected quadrant samples of two square feet in area were obtained from recent, middle-aged and older restored prairies. Ground litter and cut vegetation were placed in plastic bags in ice-cooled, insulated, polyethylene chests for transport to the laboratory.

Samples were placed on cheese-cloth covered screens in modified Tullgren funnels and specimens collected in bottles of van Torne's medium (primarily isopropyl alcohol). The different kinds of springtails were pre-sorted using a 7 x 30x magnification stereoscopic binocular microscope. Specimens were placed in small vials of 99 percent isopropyl alcohol until further taxonomic study was completed. All small vials from one sample were placed in a tightly capped jar of alcohol. Further details about field and laboratory methods used are contained in a previous publication (Brand, 1979). Upon completion of the funnel extraction process which normally required four days, the dried vegetation and litter was weighed to the nearest gram. Permanent reference voucher specimen slides were prepared for representative specimens identified to Genus or species.

Data was analyzed by various statistical techniques including regression, chi-square analysis, and the analysis of variance (ANOVA) using formulas and critical value tables (Zar, 1984). Graphs of regression results were plotted through the use of a Sigma Plot computer program. Values in all tables and graphs are converted to square meter units for ease of comparison with published literature.

Pre-sorted specimens were observed at higher magnifications including an oil immersion lens (100 x) with either an Olympus research microscope or a Nikon phase-contrast microscope. A scanning electron microscope was also used to photograph particular morphological features useful in identification of species.

Specimens were compared to the author's reference collection of permanent slides identified to Genus (some to species) by Kenneth Christiansen or Peter Bellinger and were also keyed down as far as possible using keys (Christiansen, 1980: Gisin, 1960; Stach, 1947, and Scott, 1961),

Results

A total of 72 randomly selected samples was collected at the Fermilab site comprising an equal number (24) from each of three age classes of restored prairie (R = Recent, 2 to 5 years; M = Middle-aged, 6-12 years; and 0 = Oldest, 13-16 years). Table 1 presents a summary of the number of individuals and species of springtails and weight of dry vegetation/litter for these three age categories. In general agreement with successional trends the greatest number of springtail species occurs in the oldest restoration. The oldest restoration also has from four to six times as many total springtails as the recent and middle-aged restorations, respectively. This pattern is repeated in the mean number of springtails per sample and further reflected, in part, by the weight of the litter. For the litter mean weights, the oldest restoration is almost three times that of the recent restoration and more than one-half greater than the middle-aged restoration.

Statistical analysis of the data for springtails and litter was performed using several methods. Each approach and the results obtained are explained separately with the interpretation and conclusions presented in the later discussion section of the paper.

Age of Plot	No. of Samples	No. of Species	No. of Individuals	$\bar{x}$ of Ind.*	$\bar{x}$ Wt. in Gms. of Litter
Recent (2-5 Years)	24	13	925	38.5	486.0
Middle-Aged (6-12 years)	24	12	613	25.5	820.5
Oldest (13-16 years)	24	17	3687	153.6	1296.0

* = Per Square Meter

TABLE-1 Summary of springtails and vegetation/litter for restored prairies of various age classes.

Springtails

The null hypothesis that there is no difference in the number of springtails collected in the three age classes of restored prairies was rejected ($X^2 = 296$ with 2 df, $p < .01$ **) using chi-square analysis. Based on the assumption that the springtails collected in randomly selected samples were distributed in an approximately normal distribution and their sample variances for each of the three restoration age classes were homogeneous, the null hypothesis of no difference in within and among group variance was rejected ($F = 2382$ with 2 df, $p < .01$ **) ANOVA. A further analysis using the Tukey test for comparison among means resulted in significant differences for all three comparisons (Oldest vs. Recent, Oldest vs Middle-aged, and Recent vs Middle-aged with q values of 264.17; 297.78; and 33.61 respectively, at $p < .05$*). The possibility that a relationship existed between the numbers of springtails and the growth of vegetation was tested using regression analysis. Graphs of the results are presented in Figures 1, 2, 3. In no case was a statistically significant result obtained. However, in the oldest restored prairie (labeled Established on the graph) the slope of the line shows a tendency in the direction of a positive relationship (greater vegetation growth has higher springtail numbers).

<u>Vegetation/Litter</u>

With respect to the growth of vegetation and accumulation of ground litter, the null hypothesis that there is no difference in the total dry weight of vegetation/litter in the three age classes of restoration was rejected ($X^2 = 9647.71$ with 2 df an $p < .001$**) using chi-square analysis.

Using assumptions similar to those for the distribution of springtails, the null hypothesis of no difference in within and among group variance for the randomly selected samples of vegetation/litter in the three/age classes was rejected ($F = 2381$ with 2 df, $p < .01$ **) ANOVA. The Tukey test for comparison among means also resulted in statistically significant differences (q values of 365.6, 623.1, and 257.5 with $p < .01$ **).

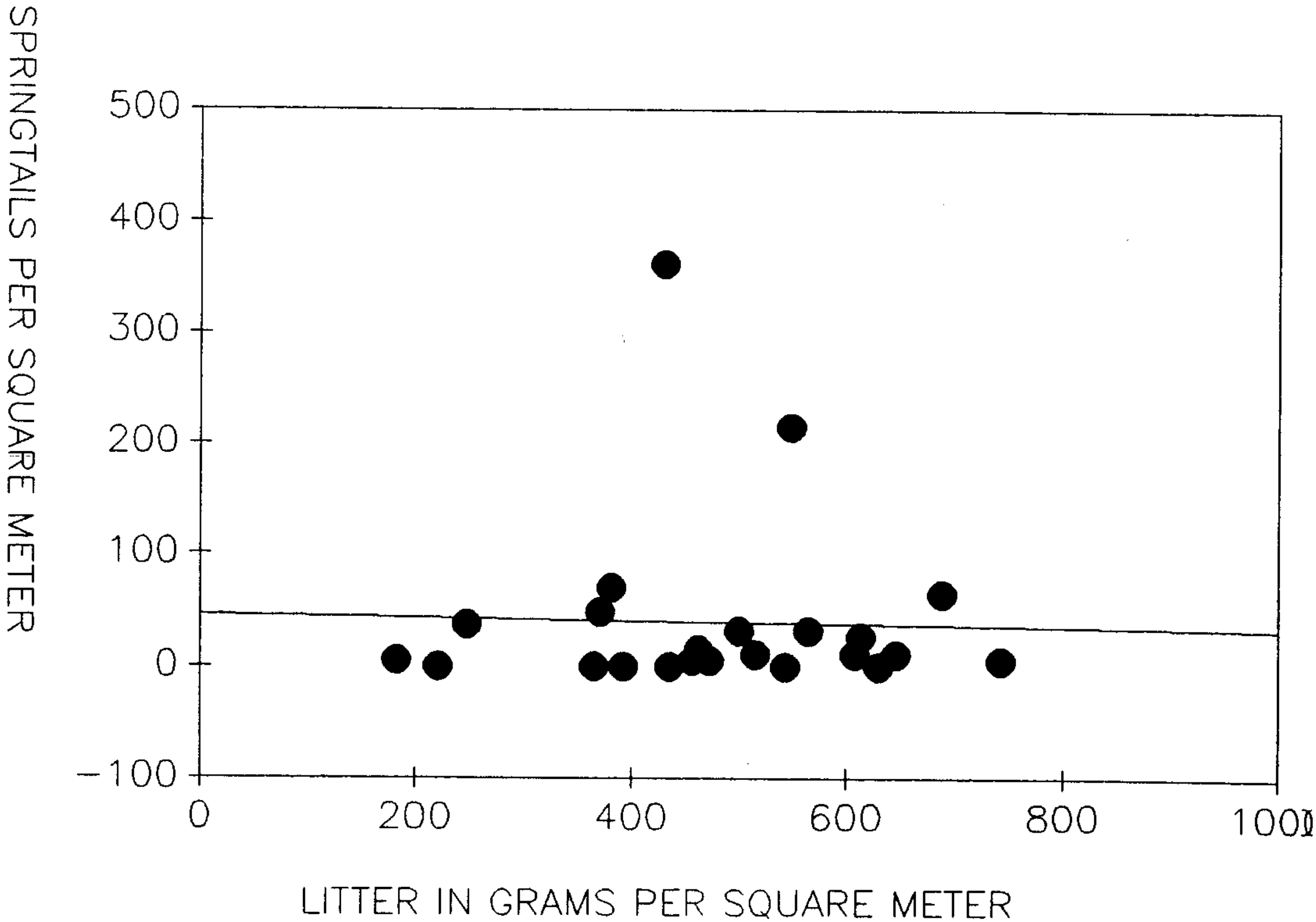

FIGURE 1 — FERMILAB PIONEER STAGE

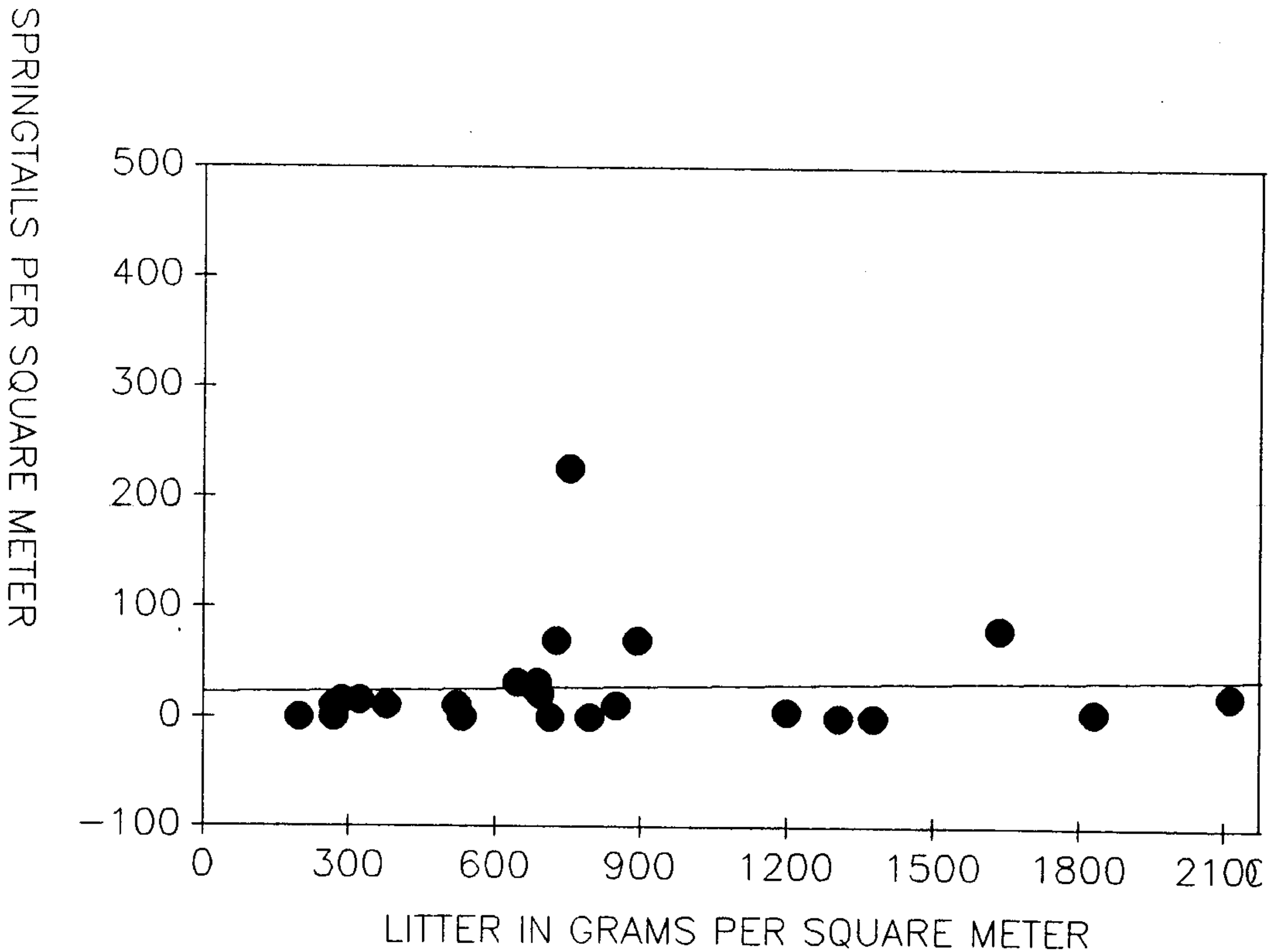

FIGURE 2 — FERMILAB INTERMEDIATE STAGE

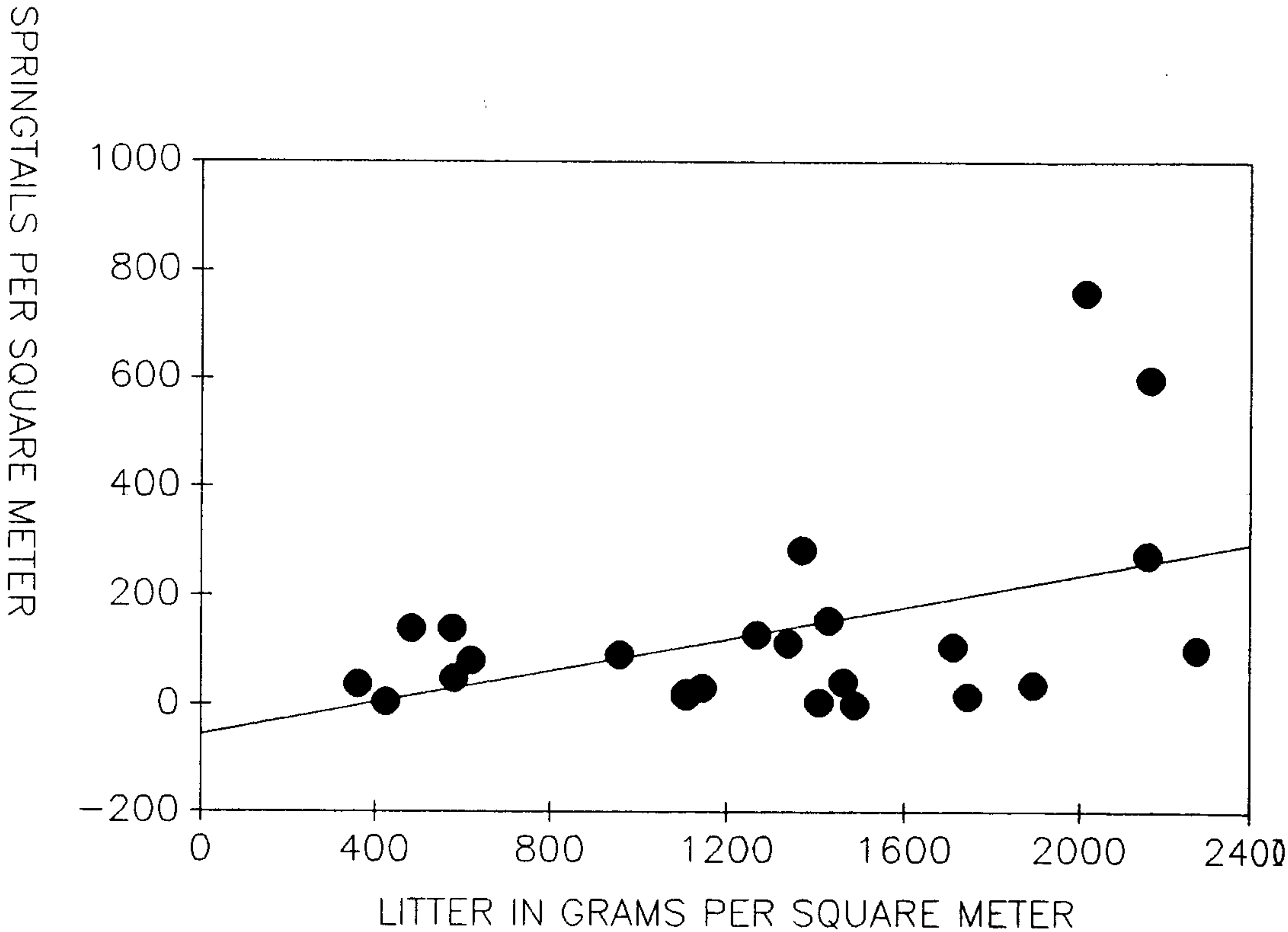

FIGURE 3 – FERMILAB ESTABLISHED STAGE

Precipitation Records

The total precipitation amounts in inches were collected at the weather station of the Morton Arboretum which is located about sixteen kilometers almost directly east of the Fermilab site. These results are recorded here for the total amount of precipitation in that year to the day prior to the sample collection date for that year (1988 = 14.1 inches, 1989 = 6.8 inches, 1990 = 23.0 inches, and 1991 - 18.3 inches). As might be expected there is a general relationship of more vegetation/litter in most years with higher precipitation but extreme variation in sample total weight (1988 = 18,436 gms., 1989 = 7,169 gms., 1990 = 17181 gms., and 1991 = 19,672 gms.) made statistical comparisons meaningless. Similarly, the number of total springtails collected (1988 = 1,841, 1989 = 1,238, 1990 = 1,098, and 1991 = 415) was unrelated to either total precipitation or total vegetation/litter. Probably of more significance is the time lapse between the last measurable rainfall and the time of collection to be discussed later.

Species Composition

Nineteen different species of springtails were collected during this study. Of these, twelve were able to be identified to species level and seven to Genus level. A list of these including Family categories and arranged from most common to infrequent is presented in Table 2. All species except two (Sminthurinus elegans and Entomobrya sp.2) were found in the oldest restoration plot. Middle-aged restoration plots contained twelve species and the recent restoration plot thirteen species. Of considerable interest is the result that three species (Tomocerus flavescens, Sminthurides pumilis, and Pseudosinella sp.) were found only in the oldest plot. Sminthurinus elegans was found only in the most recent plot.

Simpson's measure of diversity (D) was calculated for each of the age class restoration plots with the following result: Recent = D = 3.39, Middle-aged = D = 6.99. and Oldest = D = 8.39. This measure accounts for the abundance of individuals in each species as well as the overall richness of the number of species.

TABLE-2 List of all springtail species collected.

Common (25-50 individuals/sample)

Family	Genus or species
Hypogastruridae	Xenylla grisea
Isotomidae	Isotoma viridis
Entomobryidae	Lepidocyrtus pallidus

Intermediate (10-25 individuals/sample)

Onychiuridae	Tullbergia granulata
	Onychiurus sp.
Isotomidae	Folsomides americanus
Entomobryidae	Lepidocyrtus paradoxus
	Lepidocyrtus violaceus

Infrequent (1-10 individuals/sample)

Isotomidae	Proisotoma sp.
	Isotoma sp.
Entomobryidae	Tomocerus flavescens
	Pseudosinella sp.
	Sinella sp.
	Entomobrya purpurascens
	Entomobrya sp.
Sminthuridae	Sminthurides pumilis
	Sminthurinus elegans
	Sminthurinus henshawi
	Bourletiella sp.

Discussion

Several results contribute to the conclusion that the oldest restoration plot is measurably different from the recent and middle-aged plots. It has the highest population numbers of springtails, the greatest amount of vegetation/litter, the largest diversity measure for springtail species, and the most springtail species. Other published studies, indicate that a prairie matrix of tall grass species, prairie forbs, and larger soil aggregates characterize the older restoration plots at this site (Betz, 1986 and Jastrow, 1987). The latter reference also makes comparisons with the nearby native West Chicago prairie and includes lists of common vascular plant species. Further confirmation of the progress of this oldest restoration plot toward a native prairie condition is provided by a comparison of the springtail diversity measure of 8.39 with that for the West Chicago prairie of 7.55 obtained in a previous study (Brand, 1989). This study also listed a total of 17 species of springtails in the native prairie which compares well with the 19 listed in this study for the oldest restoration plot. (It should be noted that only 18 total samples were analyzed from the native prairie compared to 72 for the restored prairie.) Obviously, the oldest restoration plot has not yet reached the complexity of a native prairie but the above several indicators suggest it has made good progress in that direction.

The exceptional drop in total vegetation/litter weight in 1989 (7,169 gms.) is perhaps the result of the sustained drought in the previous year of 1988. Although native prairie plants are generally adapted to wet winters and dry summers, this particular drought had severe effects through many parts of the United States. It is also possible that a previous fire burned accumulated litter prior to that year's sampling. Details of fire history are limited for this site as discussed later in this section.

The total number of springtails declined each year of the study from a high of 1,841 to a low of 415. Such annual fluctuation may be spurious since the behavior of epigeic springtails is closely correlated with the relative humidity and the presence of water droplets on the vegetation. During the 1988 sampling, rain occurred before the collecting procedure was completed. Nine samples were taken before the rain and nine after with total springtails collected tallying 38 and 1803, respectively. Not only is the time of sampling critical on a daily basis as shown previously (Brand, 1979), but population estimates may be strongly influenced by the number of days that have elapsed since the last rain occurred prior to sampling.

As natural communities change over time through successional stages, there is generally an increase in the number of species. The restored Fermilab prairies are also subject to many anthropogenic influences including the initial sowing of native prairie plant seed, setting of annual fires, and other more subtle influences from the daily activities on the site. A residual number of springtail species from previous pasture or agricultural crops form the basic minimal component. Additional species gain entrance through storms and wind dispersal from nearby areas, from animal transport by mainly birds and mammals, and from man-made transport of vehicles and other shipped commodities.

Despite the availability of the taxonomic resources listed earlier, the identification of all specimens was subject to a number of limitations. Usually several specimens are required in order to view key characters (e.g. - apical bulbs on the antennae, presence of spines on the dens, or number of tubercles on the post-antennal organ) which often are located in different planes on the body structure. For heavily pigmented species the decolorization technique using potassium hydroxide can result in specimen damage if left in this solution too long. All too often the infrequent species (note that 11 out of the 19 listed in Table 2 are in this category) is only present in a sample as a single individual. The number of species listed thus represents a minimum and several more might have been added if these limitations had been overcome.

Of the species that only occurred in the oldest restored plot, Tomocerus flavescens is one of the largest springtails (up to 9 mm.) on record. It is thus more likely to be noticed in general insect sweep samples and is one of the more easily identified forms. At this point it is a candidate for a possible indicator of "good" restored prairie conditions or the high quality of native prairie remnants. However, the ecological amplitude of this species and many other Collembolen species needs further refinement before an indicator status can be assigned.

The relatively high number of species in the recent restoration plot (13-see Table-1) may be the result of its proximity to a deciduous, mixed hardwood woods which forms the eastern boundary of the plot. It is also bounded on the north and west by successional old fields and recently used land for agricultural row crops. The other plots studied were all located inside the accelerator ring. Some scattered trees are located along the southern boundary of the oldest restoration, whereas the middle-aged plots are some distance from any accumulation of trees.

Fire management of restored prairies has led to loss of insect species according to some entomologists and animal ecologists who have advocated that unburned islands be preserved or that only one-half of a given prairie be burned each year. The effect of fire in this study has not been evaluated as accurate records for all the restoration plots were not readily available. A number of recent publications have been investigating this important component (Dunwiddie, 1991; Anderson, 1989; and Warren, 1987).

Summary

Although native prairie remnants have almost vanished from Illinois landscapes, a number of prairie restorations have been attempted. This study reports on the kinds and numbers of springtail insects (Order Collembola) collected in 72 samples over a four year period from a prairie restoration site at the Fermi National Laboratory in Batavia, Illinois.

Restoration plots of known age in a chronosequence extending over sixteen years were classified in three categories as recent, middle-aged, and oldest. Field samples of vegetation and litter were collected and placed in modified Tullgren funnels for the extraction of arthropods. Springtails were sorted, enumerated, classified, and preserved in isopropyl alcohol.

Despite variation in both springtail numbers and litter weight, clear differences were demonstrated. The oldest restoration plot had the highest springtail species diversity, the greatest number of springtails, and the heaviest weight of vegetation and litter. Rainfall prior to sample collection resulted in greater numbers of springtails than in the same areas sampled before the rain.

Species identification of all specimens was not always possible but at least nineteen species were known to be present on the oldest restoration plot. Recent and middle-aged plots had thirteen and twelve species, respectively.

Although indicator springtail species of mature prairie conditions have not been unequivocally confirmed, the results of this study indicate a general preference of these small, wingless arthropods for grassland habitats that have become established over longer time periods than for recently disturbed areas.

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