STUDIES ON THE ORGANIZATION OF ORIBATID MITE COMMUNITIES IN THREE ECOLOGICALLY DIFFERENT GRASSLANDS

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PREFACE

Acarology, or the study of mites, has traditionally been unattractive to students in entomology, partly due to the minute size and the concealed existence of the mite. This is particularly true with terrestrial mites such as Oribatei. However, because this mite is important in the transmission of tapeworms among farm animals, more information about the way of life of the mite is necessary. An ecological approach was taken in the study reported here.

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CHAPTER I

INTRODUCTION

It has been said that the ultimate objective of science is to find formulas for explaining various phenomena of nature. Before such an explanation can be made, thorough knowledge about the phenomena must first be acquired. For that purpose a series of repeated systematic observations or experimentations must be undertaken. It can be said, therefore, that part of science is an accumulation and description of facts. With regard to an ecosystem, with all the complex interrelationships among its various components, direct or simple observations often become the major part of a scientific research.

In recent years many surveys have been made on the populations of oribatid mites, a group of free living, terrestrial mites. Formerly considered for taxonomic interest only, this group is now receiving attention from researchers of different scientific disciplines. The discovery by Stunkard (1937) of the life cycle of Moniezia expansa Rudolphi, the double-pored tapeworm of sheep, in which one species of oribatid mite was involved as an intermediate host, has made the group of special importance to parasitologists and zoologists. It is also generally agreed that, as soil inhabiting animals, the mites are important factors in promoting soil fertility through breaking down organic matter by digestion (Baker and Wharton, 1952). Moreover, the mites can be used by ecologists as biological indicators because they are sensitive to the changes in the conditions of their natural habitat.

Aware of the economic importance of oribatid mites, an increased amount of work has been done by the taxonomists. This mass of information now forms the bulk of the oribatid literature. However, because of the large size and the heterogeneity of the group, only an estimated seventy per cent of the described genera has been brought up to date taxonomically (Balogh, 1961).

While the taxonomy of oribatid mites has a long history, studies on their ecology are relatively recent. The ecological studies of the mites in pastures have been carried out primarily as a result of Stunkard's report. Such a study is indeed essential to fully understand the epidemiology or epizootiology of an arthropod-borne disease. To obtain effective control and prevention of such a disease, information on the distribution and habit of the vector or intermediate host is of great value.

Anoplocephalid cestodes are known to have a world wide distribution. The studies on the ecology and zoogeography of the intermediate hosts, however, are rather limited from the world standpoint. Despite the cosmopolitan occurrence of Moniezia, for example, the recent reports come mostly from East European countries. In the United States sources of citations are mainly the work of Krull (1939) in Beltsville, Maryland, Kates and Runkel (1948) in Beltsville and South Dakota, Edney and Kelley (1953), Wallwork and Rodriquez (1961), and Ibarra et al., (1965), all in Kentucky. The need for more documentation is still true now as it was twenty years ago when Kates and Runkel (1948) pointed out as follows:

> Although more information is now available on mite vectors of *Moniezia expansa* than on those other Anoplocephaline cestodes, the information is still decidedly fragmentary from a geographical point of view. So few studies have been made on mites concerned in natural transmission that it is impossible to predict what species are present on pastures widely separated geographically or even from pasture to pasture in the same locality.

In hope of making some contribution to such a need, a survey was made on two pastures and an ungrazed grassland near Stillwater. The objectives of the survey were:

1. to study the abundance of the known intermediate hosts;
2. to determine which of the local species may serve as natural intermediate host or hosts;
3. to study the organization of oribatid community on pastures;
4. to study the spatial distributions of oribatid mite populations;
5. to study the seasonal fluctuations of oribatid mite populations in the Stillwater area;
6. to study the effects of vegetation on oribatid populations.

CHAPTER II

REVIEW OF LITERATURE

The Taxonomy and Nomenclature of Oribatid Mite

According to the taxonomic system presently followed by the Acarology Laboratory at Wooster, Ohio, the oribatid mite is given a subordinal status, the suborder ORIBATEI. This is a large and heterogeneous taxon, consisting of usually dark colored mites which vary in size from 200 to 1,500 microns. Baker and Wharton (1952) summarized the characteristics of the group as follows:

> The gnathosoma is usually concealed within a camerostome, stigma and tracheae may be present, opening into porose areas. Pseudostigmatic organs are generally present on the propodosoma. The body is usually strongly sclerotized, dark in color, and when not thusly armored, the skin is leathery. The coxal apodemes are sunk beneath the skin but are still visible, although not as strongly so as in the Acaridiae. The tarsi have one to three claws and are without caruncles. The palpi usually have five movable segments. The two sexes are similar. Three pairs of genital suckers are present; the males do not possess adanal suckers; and both sexes generally have the genital and anal openings covered by lidlike shields.

As in the case of many other groups of organisms, there have been different opinions as to the taxonomic status and nomenclature of the oribatid mite. The taxonomic assignment of Oribatei cannot be traced without reviewing the different systems proposed in the higher classification of the Acari.

This classification is still the subject of disagreement and therefore is considered unstable. A brief review is presented here.

Linnaeus (1958) in his classification (Systema Naturae) included all the Acari in one genus, Acarus, in the order APTERA, class INSECTA. Subsequent classifications were based on ecological criteria or on simple morphological features. According to Evans, et al., (1961), modern classification schemes are structured after Kramer (Arch. Naturg. 2:215-247; 1877) who divided the Acari into two major divisions or suborders, i.e., TRACHEATA, adult mites with tracheae in some stage of development, and ATRACHEATA, adult mites without any trace of tracheae.

The name ORIBATEI was first created by Duges (1834) who considered the group as a family in the order ACARI. According to Evans, et al., (1961), Kramer in his classification placed the family ORIBATIDAE in the suborder TRACHEATA of the order ACARINA; this classification was later extended or modified successively by Canestrini (Atti Ist. Venete 38: 699-725; 1891), Berlese (Riv. Pat. Beg. 7:312-344), Reuter (Acta Soc. Sci. Fenn. 36:1-288; 1909), and Berlese (Acarotheca Italica. Firence; 1913). Canestrini regarded Acari as a class and gave Oribatei ordinal status with the name CRYPTOSTIGMATA. Berlese in 1899 added to this order a group of mites called Sarcoptina and reduced the rank of Oribatei to suborder. Reuter modified Berlese's system, he reduced the rank of the Acari back to an order and proposed new names for all suborders; the Oribatei was considered as a superfamily, ORIBATOIDEA, and was included in the suborder SARCOPTIFORMES. And finally, in 1913 Berlese separated the Sarcoptina from the Cryptostigmata, but considered the latter as a suborder.

A Dutch Acarologist, Oudemans (1906), elevated the Oribatei to a subclass, OCTOSTIGMATA, one of the five subdivisions of the class Acari. Later, however (1923), he changed his old classification, reducing the Acari to ordinal status with six suborders. In 1931, recognizing the close natural affinities among the suborders Sarcoptiformes, Trombidiformes, and Tetrapodili, he combined them into one suborder, Trombidi-Sarcoptiformes.

Grandjean (1935) divided the Acari into two major divisions based on the presence or absence of actinochitin in the setae, i.e., ACTINOCHITINOSI and ANACTINOCHITINOSI. Evans, et al., (1961) regarded these two divisions as superorders, and renamed them ACTINOCHAETA and ANACTINOCHAETA, respectively. According to these authors, Zachvatkin (Mag. Parasitol. 14:5-46; 1952) created the order ACARIFORMES for the Actinochitinosi and proposed the use of the ordinal name PARASITIFORMES Reuter, 1909, for Anactinochitinosi.

In the United States, Baker and Wharton (1952) and Baker, et al., (1958) considered the Acari as an order with five subdivisions, and placed the supercohort ORIBATEI in the suborder Sarcoptiformes. The Acarology Laboratory presently agrees with the ordinal designations of Acariformes and Parasitiformes, and considers the Oribatei as a suborder. Johnston (1964) of the Acarology Laboratory summarized the presently followed classification and synonyms as appear below:

subclass ACARI Leach, 1817
- Monomerosomata Leach, 1815
- Acarina Nitzsch, 1818
- Acaromorpha Dubinin, 1956

order ACARIFORMES Zachvatkin, 1952
- Trombidi-Saroptiformes Oudemans, 1931
- Actinochitinosi Grandjean, 1935
- Actinotrichida van der Hammen, 1960
- Actinochaeta Evans, Sheal, and McFarlane, 1961

suborder ORIBATEI Dugès, 1834
- Oribatidae Dugès, 1839
- Carabodides C. L. Koch, 1842
- Cryptostigmata G. Canestrini, 1891
- Octostigmata Oudemans, 1906
- Oribatoidea Reuter, 1909
- Stegasima Grandjean, 1932

In the subordinal classification, Grandjean (1953) attempted to group the oribatid mites through a phylogenetic system, considering the characteristics present during preimaginal stages. For practical purposes, however, oribatidologists generally follow the classification presented by Balogh (1961, 1963), in which only adult characteristics are used as criteria. In his classification the Oribatei is divided into three main groups, namely, ORIBATEI INFERIORES, PORONOTICAE, and PYCNONOTICAE, the last two being called ORIBATEI SUPERIORES. The first group is characterized by the presence of propodosoma which can be shut back like the blade of a penknife to the hysterosoma, or by the meeting together of the genital and anal plates which, combined, occupy the whole length of ventral side. For the second group, at least one of the following features is well apparent: on notogaster, either well developed, downward bending pteromorphae, or horizontal pteromorphae, hardly protruding from the outline of the body; on the notogaster, either areae porosae, sacculi, or pori are present. In the third group all the characteristics mentioned above are absent. In this classification Balogh recognized eighty-seven families which are grouped in twenty-five superfamilies.

The Ecology of Oribatid Mites

Most habitats rich in organic debris and with high humidity can support oribatid populations. Such places can range from cracks and crevices of a tree trunk, to the turf of the pasture floor, to the humus of the forest. Undoubtedly the most complex oribatid communities are those of forest soil where an amorphous mass of decomposed plant material is found in abundance. In Lithuanian (U.S.S.R.) forests, Eitminavichyute (1961) found not less than one hundred two species of Oribatei in a forest biotope with a heterogeneous vegetation, seventy-eight species in a deciduous forest, and sixty-eight species in a coniferous forest. In Ukraine Ovander (1963) found the highest concentration of Acari, of which 36.1 percent were oribatids, in the mixed forests. However, he observed that the greatest heterogeneity of species was found in broadleaf forests.

Although not as ideal as forest humus, the turf of the pasture floor is a good place for oribatid mites to live. This is especially true with permanent, natural pastures, which are known to support oribatid populations better than artificial pastures or arable lands, as reported by Zgardan (1963) and Eitminavichyute (1961). The latter worker found only five species of oribatids to occur on a biennially cultivated grazing cattle pasture, as compared to twenty-five species on perennial pasture.

The majority of the mites are found in the first inch of turf, consisting of the surface grass, humus, and grass roots with the included soil, according to Kates and Runkel (1947), later confirmed by Wallwork and Rodriquez (1961). At various times during the twenty-four hour period the mites wander upward to the grass stems and blades and then back to the floor. Krull (1939) suggested that this vertical movement was motivated by different factors such as food, moisture, light, and wind; he observed that mites were most abundant on grass after rains. Ibarra et al., (1965) reported that mite densities in the grass zone were slightly higher in the early morning but would decline somewhat during the day.

The vertical distribution of oribatid mites in the soil is generally governed by the physical conditions of the soil such as soil temperature, moisture, soil composition, and the amount of organic content. Subbotina (1963) stated that the most favorable conditions occur in the first four inches below the surface. This was confirmed by Nasarova (1964) who found ninety percent of the mites in the surface layers of the soil when the moisture content was the highest and the temperature mildest. On the other hand, Wafa et al., (1964) in Egypt found that the layer between six and eight inches below the surface contained more mites than any other layer. These workers also reported that the lower limit to which the mites could penetrate was twelve inches below the surface, while Subbotina (1963) still found isolated specimens at a depth of sixty to ninety centimeters. Apparently the character of locomotion and dwelling habit will influence the ability to penetrate into the soil. Krivolutskii (1965) noted three different groups of Oribatei with regard to these activities. The first group consisted of mites which move over the surface of the soil and are able to penetrate into the soil only along cracks considerably exceeding their body width; the second group was inhabitant of the soil and able to widen smaller pores; the third group consisted of nonspecific forms so classified with respect to their method of locomotion.

The moving behavior of oribatid mites, either vertically or horizontally, is actually far from simple and involves the interaction of several microclimatic factors. From laboratory studies on the humidity reaction of four species of oribatids, Madge (1964) discovered that the reaction could be very different with different species. For example, <u>Humerobates rostrolamellatus</u> Grandjean was more active in moist air than in dry air, while the opposite was true with Belba geniculosa Oudemans. He also observed that in general, the higher the temperature the greater the choice for the higher humidity, and also the faster the movement. In a later experiment (1966), he observed that H. rostrolamellatus clustered and was inactive during the exposure to dry air; the mites dispersed rapidly when a sharp rise of humidity occurred. Under natural conditions, the mobility of the oribatids was studied by Berthet (1964) using radio-isotope techniques. He reported that the average daily movement was generally of the order of a few centimeters and varied considerably with season and with the water content of the soil litter. In the cold season the movements were extremely limited and seemed to be independent of water content, or even negatively related to it. In the warmer season, on the other hand, certain species were able to move some tens of centimeters per day.

The seasonal distribution of oribatid mites, expectedly, follows the seasonal fluctuation of humidity and temperature. Generally population peaks occurred during the humid and mild period or periods of the year, which varies depending on the geography of the locality. In Moldavia (Romania) Zgardan (1963) observed two peaks occurring in May and October, while in Bulgaria Bankov (1965) found only one peak, which was in the November-December period, and the lowest population occurred during the period from July to September. While the warmer season is the favorable time for the mites to propagate, winter may not be detrimental to the whole population. Many species are not harmed when the soil temperature drops to below freezing (Nazarova, 1963), and in Kentucky Galumna virginiensis, an intermediate host of sheep tapeworm, may be found in considerable numbers throughout the winter (Edney and Kelley, 1953).

The spatial distribution of oribatid mites is usually not random. Statistical studies were done by Ibarra et al., (1965) on the distribution pattern of the mites on pastures and by Berthet and Gerard (1965) and Gerard and Berthet (1965) in forest communities. They all reported that the theoretical negative binomial distribution was the best fitted to the natural distribution of the mites. Berthet and Gerard (1965) also found that for a given species, when the density decreased, the heterogeneity of the distribution generally increased, probably the mites being clumped at the most favorable sites.

Oribatid Mite as the Intermediate Host of Tapeworms

The life cycle of tapeworms of the family Anoplocephalidae (Cestoda: Cyclophyllidea) remained a puzzle until the year 1936, when Stunkard (1937) discovered that the body of Galumna sp., an oribatid mite, was hospitable to the larva of Moniezia expansa Rudolphi, the double-pored sheep tapeworm. By feeding the worm's eggs to different species of soil mites, he succeeded in producing a larval infestation in the hemocoel of the oribatid mite. When the infested mite was fed to sheep, the adult tapeworm later occurred in the hemocoel of the oribatid mite. When the infested mite was fed to sheep, the adult tapeworm later occurred in the small intestine of the sheep. It was established, therefore, that an invertebrate intermediate host was required for the completion of the life cycle of this sheep tapeworm. Subsequent experiments by various workers, using the same tapeworm or other anoplocephalids, either confirmed the finding of Stunkard or provided evidence that the members of the family did require certain species of oribatid mites for their intermediate hosts (Stoll, 1938; Stunkard, 1940; Potemkina, 1941; Bashkivora, 1941; Stunkard, 1941).

Over fifty species of oribatid mites have hitherto been reported either as natural intermediate hosts or as experimental hosts. The species known to have connection with anoplocephalids of veterinary importance are listed in Table I. It can be seen from the table that there is practically no taxonomic specificity for the intermediate host. It appears that the abundance of the species on pastures, the size of the mites, and the habit of the mites, are the determining factors to qualify for being natural intermediate hosts, as pointed out by Baker and Wharton (1952).

TABLE I

LIST OF ORIBATID MITES REPORTED AS INTERMEDIATE HOSTS OF ANOPLOCEPHALID CESTODES OF VETERINARY IMPORTANCE

Oribatid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
GALUMNIDAE				
Galumna sp.	Stunkard, 1937	U.S.A.	*Moniezia expansa*	E
Galumna sp.	Stoll, 1938	U.S.A.	*Moniezia expansa*	E
Galumna sp.	Stunkard, 1940	Germany	*Bertiella studeri*	E
G. nigra (Ewing)	Stoll, 1938	U.S.A.	*M. expansa*	E
G. obvius (Berlese)	Potemkina, 1941	U.S.S.R.	*M. expansa*	E
G. obvius (Berlese)	Potemkina, 1944	U.S.S.R.	*M. benedeni*	E
G. obvius (Berlese)	Stunkard, 1941	Germany	*Cittotaenia ctenoides*	E
G. obvius (Berlese)	Bashkirova, 1941	U.S.S.R.	*Anoplocephala perfoliata*	E
G. obvius (Berlese)	Bashkirova, 1941	U.S.S.R.	*Paranoplocephala mamillana*	E
G. virginiensis (Jacot)	Kates & Runkel, 1947	U.S.A.	*M. expansa*	N
Pergalumna emarginatum (Banks)	Krull, 1939	U.S.A.	*M. expansa*	N
P. nervosus (Berlese)	Stunkard, 1941	Germany	*C. ctenoides*	E
P. nervosus (Berlese)	Bashkirova, 1941	U.S.S.R.	*A. perfoliata*	E
P. nervosus (Berlese)	Frank & Zivkovic, 1960	Yugoslavia	*M. expansa*	E
P. nervosus (Berlese)	Kassai & Mahunka, 1964	Hungary	*M. expansa*	N

Table I continued.

Oribatid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
GALUMNIDAE (contd.)				
P. formicarius (Berlese)	Kassai & Mahunka, 1964	Hungary	M. expansa	N
Galumna eliminatus (Koch)	Prokopic, 1963	Czechoslov.	M. benedeni	N
Allogalumna longipluma (Berlese)	Bashkirova, 1941	U.S.S.R.	P. mamillana	E
ORIBATULIDAE				
Scheloribates laevigatus (Koch)	Stunkard, 1940	Germany	B. studeri	E
Scheloribates laevigatus (Koch)	Stunkard, 1941	Germany	C. ctenoides; C. denticulata	E
Scheloribates laevigatus (Koch)	Potemkina, 1941	U.S.S.R.	M. expansa	E
Scheloribates laevigatus (Koch)	Kates & Runkel, 1947	U.S.A.	M. expansa	N
Scheloribates laevigatus (Koch)	Potemkina, 1944	U.S.S.R.	M. benedeni	E
Scheloribates laevigatus (Koch)	Prokopic, 1963	Czechoslov.	M. benedeni	N
Scheloribates laevigatus (Koch)	Bashkirova, 1941	U.S.S.R.	A. perfoliata; A. magna	E E
Scheloribates laevigatus (Koch)	Potemkina, 1944	U.S.S.R.	Thysaniezia giardi	E
S. latipes (Koch)	Bashkirova, 1941	U.S.S.R.	A. perfoliata; A. magna	E E
S. latipes (Koch)	Potemkina, 1944	U.S.S.R.	T. giardi	E
S. latipes (Koch)	Kassai & Mahunka, 1964	Hungary	M. expansa	N
S. seghettii (Runkel & Kates)	Kates & Runkel, 1947	U.S.A.	M. expansa	N

Table I continued.

Oribatid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
ORIBATULIDAE (contd.)				
S. pallidulus	Bankov, 1965	Bulgaria	*M. expansa*	E
S. perforatus	Graber & Gruvel, 1964	Chad	*Stilesia globipunctata*	E
S. parvus conglobatus	Graber & Gruvel, 1964	Chad	*Stilesia globipunctata*	E
Oribatula minuta (Ewing)	Kates & Runkel, 1947	U.S.A.	*M. expansa*	N
Liebstadia similis (Michael)	Stunkard, 1941	Germany	*C. ctenoides*	E
Zygoribatula longiporosa	Roberts, 1953	Australia	*M. benedeni*	N
Zygoribatula longiporosa	Sokol & Panin, 1960	U.S.S.R.	*M. benedeni*	N
Z. cognata	Svadzhyan, 1962	U.S.S.R.	*M. expansa*	E
Z. cognata	Sokolova & Panin, 1960	U.S.S.R.	*M. benedeni*	N
Z. friziae	Sokolova & Panin, 1960	U.S.S.R.	*M. benedeni*	N
Z. magna (Ramsay)	Ramsay, 1966	New Zealand	*M. expansa*	N
Z. exarata (Berlese)	Kassai & Mahunka, 1964	Hungary	*M. expansa*	N
Liebstadia similis (Michael)	Svadzhyan, 1962	U.S.S.R.	*M. benedeni*	E
Liebstadia sp.	Svadzhyan, 1962	U.S.S.R.	*M. expanasa*	E
Multoribates scheloribatoides (Ramsay)	Ramsay, 1966	New Zealand	*M. expanasa*	N

Table I continued.

Oribatid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
MYCOBATIDAE				
Punctoribates punctum (Koch)	Frank & Zivkovic, 1960	Yugoslavia	*M. expansa*	E
P. hexagonus	Sokolova & Panin, 1960	U.S.S.R.	*M. expansa*	N
HAPLOZETIDAE				
Peloribates curtipilus (Jacot)	Kates & Runkel, 1947	U.S.A.	*M. expansa*	N
Protoribates lophotrichus	Frank & Zivkovic, 1960	Yugoslavia	*M. benedeni*	E
CERATOZETIDAE				
Trichoribates incesellus (Kramer)	Stunkard, 1941	Germany	*C. ctenoides*	E
T. trimaculatus (Koch)	Prokopic, 1962	Czechoslov.	*M. expansa*	N
T. novus	Bankov, 1965	Bulgaria	*M. expansa*	E
Ceratozetes mediocris	Kassai & Mahunka, 1964	Hungary	*M. expansa*	N
LIACARIDAE				
Liacarus coracinus (Koch)	Stunkard, 1941	Germany	*C. ctenoides*; *C. denticulata*	E E
Liacarus coracinus (Koch)	Svadhyan, 1962	U.S.S.R.	*M. expansa*; *M. Benedeni*	E E
Adoristes ovatus (Koch)	Potemkina, 1946	U.S.S.R.	*Moniezia* sp.	?
Xenillus tegeocranus	Stunkard, 1941	Germany	*C. ctenoides*: *C. denticulata*	E

Table I continued.

Oribstid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
SCUTOVERTICIDAE				
Scutovertex minutus (Koch)	Stunkard, 1940	Germany	*B. studeri*	E
Scutovertex minutus (Koch)	Stunkard, 1941	Germany	*C. ctenoides*;	E
			C. denticulata	N
Scutovertex minutus (Koch)	Kassai & Mahunka, 1964	Hungary	*M. expansa*	N
ACHIPTERIIDAE				
Achipteria sp.	Bashkirova, 1941	U.S.S.R.	*A. perfoliata*	E
A. coleoptrata (Linn.)	Stunkard, 1940	Germany	*B. studeri*	E
A. coleoptrata (Linn.)	Prokopic, 1962	Czechoslov.	*M. benedeni*	N
NOTASPIDIDAE				
Notaspis punctatus	Frank & Zivkovic, 1960	Yugoslavia	*M. expansa*	E
PELOPIDAE				
Pelops tardus (Koch)	Stunkard, 1941	Germany	*C. ctenoides*	N
P. acromius (Hermna)	Stunkard, 1941	Germany	*C. ctenoides*	E
P. planicornis	Frank & Zivkovic, 1960	Yugoslavia	*M. expansa*	E
PHENOPELOPIDAE				
Peloptulus phaenotus (Koch)	Bankov, 1965	Bulgaria	*M. expansa*	E

Table I continued.

Oribatid Mite and Classification	Author and Date of Report	Region	Cestode	Note*
METRIOPPIIDAE				
Ceratoppia bipilis	Svadhyan, 1962	U.S.S.R.	*M. benedeni*	E
?				
Africacarus calcaratus	Graber & Gruvel, 1964	Chad	*Stilesia globipunctata*	N
CEPHEIDAE				
Cepheus cepheiformis (Nicolet)	Stunkard, 1941	Germany	*C. ctenoides*; *C. denticulata*	E E

*E = experimental; N = natural.

CHAPTER III

MATERIALS AND METHODS

The survey was started in the summer of 1965 in one cattle pasture with the main purpose to find oribatids with larval tapeworm infestation. The sampling procedure was oriented chiefly to collect mites in large numbers, to be sorted later according to species characteristics and then dissected for cysticercoid examination. Due to the negative finding of the infestation, beginning with the summer of 1967 the studies were directed mainly to the distributions and community organizations of the oribatid mites in pastures. Three grasslands of different natures and managements were investigated, these included: (1) Ward pasture (the cattle pasture mentioned above), approximately four miles northeast of Stillwater; (2) "Anaplasmosis" pasture, one and one half miles west of the Oklahoma State University main campus; and (3) a small field in the Lake Carl Blackwell area, about ten miles west of Stillwater. The cattle pasture is privately owned, while the other two are university lands. The survey was terminated in February of 1968; the survey period thus included three distinct seasons: summer, fall, and winter.

Description of Study Area

The Ward pasture is a thirty-acre land with a mixed vegetation. Although this range is not virgin or was once cultivated, it has been grazed by cattle in the last twenty-five years or longer. Various kinds of weeds occur in relatively large numbers. A moderate sized pond is situated at one corner and some erosions and land depressions are found in several places. This is an open land of moderate to low productivity, and is slightly sloped, the northern section being higher than the southern section. The soil is classified as the reddish brown colored prairie soil, and consists of three soil types: Zaneis loam in the southern section, Lucien-Vernon Complex in the northern section, and severely eroded loamy soils in the pond area.[1] It is practically a permanent pasture, in which the grass has never been cut or manipulated in any way. Figure 1 gives a general view of the area.

Among the grass species, the little bluestem (Andropogon scoparius Michx.) is predominant. Other species which were identified included the Japanese brome (Bromus japonicus Thumb.), Indian grass (Sorghastrum nutans L.), scribner panicum (Panicum scribnerianum Nash), arrow grass (Aristida purpurascens Poir.), windmill grass (Chloris verticillata Nutt.), Bermuda-grass (Cynodon dactylon L.), silver bluestem (Andropogon saccharoides Swartz), big bluestem (Andro-

[1]Information concerning soil types was obtained from the U.S.D.A. Soil Conservation Service, Payne County District Office, Stillwater.

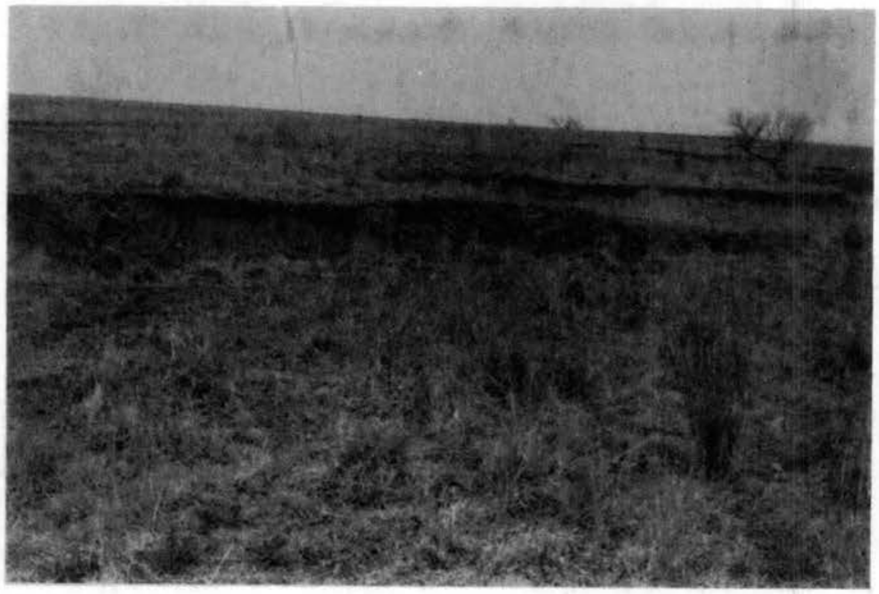

Fig. 1. Ward pasture in the early spring.

pogon gerardi), nodding wild-rye (Elymus canadensis L.), and prairie threeawn (Aristida oligantha Michx.). There are still other species of grass which were not identified because of their small numbers.

This pasture was originally selected for study because in previous times it produced moniezіasis in cattle. Prior to the survey, several fecal samples were collected and examined, and a small number of eggs of Moniezia benedeni (Moniez) were found by simple floatation technique.

The "Anaplasmosis" pasture is a grassland in the area of the Anaplasmosis Laboratory. It is approximately ten acres in size including barns and loading areas. This pasture is used to graze sheep at irregular times, usually prior to the slaughter of the animals for the University's Meat Laboratory. It is predominantly Bermuda-grass, but prairie threeawn has invaded some sections. Occasionally the dried, old grass is mowed or burned to promote rejuvenation. The field is not level but with two valley-like depressions which are heavily vegetated, and the grass can grow to over one foot high. There were no data about the soil, but in a 1916 soil map it was indicated that the soil type of the general area was Vernon very fine sandy loam. This pasture is again an open field with no woodland surrounding the area (Figure 2).

The study area near Lake Blackwell is approximately one acre in size. The field is a combination of a relict and a section of introduced grasses, bordered in part by trees and

Fig. 2. The pasture in the Anaplasmosis Laboratory area.

a small stream. It has been described as a well drained land which is subject to occasional flooding, a land of high productivity. The soil is of the port silt loam type, and classified as reddish brown colored, loamy bottomland soil. Although it is not entirely a secluded location, the area is relatively free from outside interference. In this area a number of pure grass colonies can be found, some of which were originally cultivated (Figure 3). For these two reasons the field was selected primarily to study the influence of different grass species on the oribatid populations.

Six grass species were chosen for the study, these were; (1) Indian grass, (2) sideoats gramma (*Bouteloua curtipendula*), (3) big bluestem, (4) broomsedge bluestem (*Andropogon virginicus* L.), (5) Bermuda-grass, and (6) prairie threeawn. The Indian grass and the sideoats gramma grow in rows, an indication that they were once planted. The big bluestem is found in stands, each of which form a separate colony. The broomsedge, bermuda grass, and the threeawn are found in isolated but continuous colonies.

Sampling Procedure

The sampling was done in a random fashion but it was attempted to collect the materials from all parts of the field. For this purpose the Ward pasture was divided into quadrats, "Anaplasmosis" pasture into thirty quadrats, while the area near Lake Blackwell was divided into six plots according to the grass colonies under study.

Fig. 3. The field near Lake Carl Blackwell, showing rows of sideoats gramma in the foreground and Indian grass in the background.

A total of seventy-eight subsamples were taken from Ward pasture during the entire survey period, from July 1967 through February 1968. Fifty-four subsamples were taken in July and August, twelve subsamples in November, and finally twelve more in February. In the summer one subsample was collected from every quadrat at random; in November and February, however, only twelve quadrats were sampled respectively, in which cases both the quadrats and the subsamples were taken randomly.

A total of ninety subsamples were obtained from "Anaplasmosis" pasture, thirty of which were collected during August, twenty-six in November, and twenty-four in January and February. Only one subsample was removed from each quadrat during any sampling season; however, not all quadrats were sampled in the fall and winter periods. As in Ward pasture, in fall and winter both the quadrats and the subsamples were selected at random.

The study of the effects of vegetation on oribatid populations in the Blackwell area were conducted in a factorial manner, the grass species and the date of sampling being the two factors. Each factor had six levels, which were six different grasses and six different dates, respectively. Two subsamples were observed for each treatment combination, to make a total of 6 x 6 x 2 or seventy-two subsamples, which were collected on these following dates: October 1, November 3, November 20, December 5, December 20, all of 1967, and January 16, 1968.

For each subsample in all three locations, the ground temperature and the relative humidity of the interspace approximately two inches above the ground surface were recorded. An air-sucking psychrometer was used to measure the dry bulb and the wet bulb temperatures. The air of the microenvironment was manually pumped into a chamber where a dry bulb and a wet bulb thermometers were fixed.

Collection and Extraction Methods

The unit of subsample consisted of four cores of sod, about two inches deep and two and one half inches in diameter each, plus the attached grass. The material was taken by a standard soil sampler for soil research. Four operations were executed to complete one subsample. After it was removed, the material was placed in a two-quart waxed paper container, brought to the laboratory and immediately put in an extraction funnel to recover the mites. The funnel was of Berlese-Tullgren type, involving a slow heating and drying of the sample material. A double wire mesh of 2 x 2 mm. hole size was placed at the base of the funnel to hold the material, which was laid with the sod side up whenever possible.

The funnel, made of aluminum, was 28.5 inches high from the lid to the outlet of the cone, and had an upper diameter of 11 inches. The cylindrical part was 13.5 inches high and the cone 15 inches. A 75-watt electric bulb was used as the heat source, and it was hung on the lid with the lower side of the bulb approximately 7.5 inches below the lid, or about 4 inches above the sod. This resulted in a slow heating and drying process on the sod material, to allow enough time for the slow moving mites to escape. The temperature in the lower part of the cylinder would rise to 128-132°F an hour after the start of the extraction; it would rise to 140-150°F after six hours; to 142-165°F after twelve hours, and after that time the temperature would remain constant. A mason jar partially filled with water was used to collect the mites. With this set up, the extraction lasted twenty-four hours.

Mite Identification

The mites were killed and preserved in 70% ethyl alcohol. Thereafter the handling of the mites for taxonomic purposes followed the recommendation suggested by Balogh (1963), who has provided a key to the genera of Oribatei of the world.

The specimens were cleared in a 50-50 mixture of full strength lactic acid and 90% ethyl alcohol and stored in open vials. The vials were then secured in a cigar box to keep away from dust. The alcohol eventually evaporated, leaving the specimens in the lactic acid. Using this technique the specimens were ready for microscopic studies in from two to eight weeks, depending on the degree of pigmentation. The clearing process, if so desired, may be accelerated by subjecting the material to moderate heat.

For some species with heavy pigmentation it was much preferred to find a young adult mite, which had a relatively transparent body but all the adult characteristics were present.

Due to the peculiar shape of the oribatid mites, the dorsum being highly convex in certain families, a temporary and open mount has been preferred over the conventional technique of permanent mount. This open technique was employed during the present study for all the specimens examined. A microscopic slide with a cavity was used in the preparation. A small drop of lactic acid was placed on one half side of the cavity, and then the cover slip was carefully placed upon the lactic acid in such a position that only one half of the cavity was covered by the slip. The free space of the cavity was then used to manipulate the specimens prior to the examination. Using a number 00 camel brush the mite was pushed from the free cavity into the medium underneath the cover slip. In this manner the position of the mite could be arranged as necessary, and the specimen could be examined from all aspects. This technique is particularly useful for seeing certain lateral characteristics which are difficult to view from above in some species. The position of the specimen can be altered from dorsal to ventral above without interupting the examination, simply by touching and sliding gently the cover glass.

Statistical Analysis

Before the data were subjected to an analysis of variance, it was necessary that the approximate form of the frequency distribution of the mites among the samples be determined. The assumption underlying the the theory upon which the practice of analysis of variance is based is that the population is normal or approaching normality. This type of population requires that, in its natural habitat, the individuals are distributed completely at random. Only when the individuals are randomly distributed will the analysis of variance be applicable to the data collected. In such a case the frequency distribution of the sample population will follow the Poisson series, in which the variance is equal to the mean. If the distribution follows a pattern other than Poisson, then the data have to be first transformed accordingly, in order that the normal procedures for the analysis become applicable.

As was expected the distribution of the oribatids in the present study does not agree with the Poisson series, the test for which is presented in Chapter IV. The transformation of the data therefore had to be done, according to the table of transformation made by Beal (1942). The table has been developed through the formula of equation:

$$x' = k^{-\frac{1}{2}} \sinh^{-1}(kx)^{\frac{1}{2}}$$

in which

x is the observed data,

x' is the transformed data, and

k is a constant, which can be estimated by $(Ss^2 - S\bar{x})/S\bar{x}^2$ or the sum of the sample variances minus the sum of the sample means divided by the sum of the squared sample means.

CHAPTER IV

RESULTS AND DISCUSSION

The information presented in this paper is the results of the investigations conducted during the period between June 1967 and March 1968. The quantitative values reported here are for the oribatids as a group and for two important host species. The classification and identification follows the key arranged by Balogh (1963), and the keys and descriptions by Jacot (1929, 1933, 1934, 1935). The identifications of the mites were carried out as far as the key permits except for some species which we were unable to identify.

In order to be able to make comparisons among the species regarding their respective significance in the oribatid fauna of a certain locality, these following values have been calculated for each species:

(1) the average number of mites per subsample;

(2) the frequency number (f) or the ratio between the number of samples containing the species and the total number of subsamples, expressed in percent;

(3) the species abundance (A) or the percentage of the individuals in the whole sample;

(4) the species dominance (D) or the product of A by f.

The average number of mites per subsample will give some idea on the density of the population. However, in a nonrandom distribution where individuals may be gregarious in nature, this kind of estimation can be misleading unless weighted by certain population indices such as frequency number and species abundance. Frequency number explains how the individuals disperse over the area; for example, a low value of *f* but with a high density would indicate that the individuals are clumped in some way, while a high value of *f* would show that the individuals are well distributed spatially regardless of density. Species abundance may be used as an indication of the role of a species in an ecosystem, specifically with regard to the balance of nature. Finally, the concept of dominance is being used here to denote the superiority of a species numerically and territorially.

Species Distribution and Abundance

A total of twenty-seven species, representing nine superfamilies, were collected during the studies on the three locations. These are listed in Table II. The superfamily Oribatuloidea is the best represented with twelve species, seven of which are members of the family Oribatulidae. Galumnoidea is second with five species, of which four belong to Galumnidae. Others include the superfamilies Oribatelloidea, two species, Ceratozetoidea, two species, and Pelopoidea, Oppioidea, Damaeoidea, Liacaroidea, and

Phthiracaroidea, all with one species each. Two of the species are Galumna virginiensis and Scheloribates laevigatus, which are important intermediate hosts of cestodes. The former is an intermediate host of Moniezia expansa in the United States, and the latter has been known to serve as a natural intermediate host for three tapeworms and is capable experimentally to host five more anoplocephalids.

The dominance of the species in each locality are compared in Tables III, IV, and V, along with the crude estimation of densities. It is worth noting that both intermediate host species mentioned above occur in significant numbers in the two pastures. Galumna virginiensis dominated the Ward pasture (hereafter called WARD) with an average of 10.2 mites per subsample, while Scheloribates laevigatus dominated the "Anaplasmosis" pasture (hereafter called ANA) with 28.7 average. Along with the fact that they dispersed well over the pasture (f = .86 and .96, respectively), undoubtedly these two species are the most potential intermediate hosts for this area. This potential, however, seems to vary with pastures or locations. As indicated in Tables III and IV, while G. virginiensis was the dominant species in WARD, it was only third in dominance in ANA with a very wide margin. On the other hand, S. laevigatus clearly was the single dominant oribatid in ANA but was below three other species in WARD. And in the plot near Lake Carl Blackwell (hereafter designated as BLACK) neither one was as numerous as Galumna sp., being second for

TABLE II

ORIBATID MITES COLLECTED FROM THREE LOCALITIES IN THE STILLWATER AREA

Spec. no.		Mite	Locality[1]
1	GALUMNOIDEA:	*Galumna virginiensis*	A, B, W
2		*Galumna* sp.	A, B, W
3		*Pergalumna curvum*	A, B, W
4		Galumnidae	W
5		*Parakalumna robusta*	A, B, W
	ORIBATULOIDEA:		
6		*Scheloribates laevigatus*	A, B, W
7		*Scheloribates* sp.	A, W
8		*Zygoribatula* sp.	A, B
9		*Zygoribatula* sp.	A, B, W
10		Oribatulidae	A, B, W
11		Oribatulidae	A, W
12		Oribatulidae	B
13		Oribatuloidea	A, B, W
14		Oribatuloidea	A
15		Oribatuloidea	W
16		*Peloribates* sp.	A, B, W
17		*Peloribates* sp.	A, B
18	ORIBATELLOIDEA:	*Anoribatella* sp.	A, B, W
19		*Tegoribates* sp.	W
20	OPPIOIDEA:	*Oppia* sp.	A, B, W
21		Oppiidae	A, B, W
22	CERATOZETIDAE:	*Ceratozetes* sp.	A
23		*Chamobates* sp.	A, B, W
24	PELOPOIDEA:	*Eupelops* sp.	A, W
25	DAMAEOIDEA:	*Epidamaeus* sp.	B, W
26	LIACAROIDEA:	*Furcoribula* sp.	A, B, W
27	PHTHIRACAROIDEA:	Phthiracaroidea	W

[1] A= "Anaplasmosis" pasture; B= Lake Blackwell area; W= Ward pasture.

TABLE III

THE DENSITIES AND DOMINANCE OF ORIBATID MITES IN WARD PASTURE(1)

Oribatid	Mites per Subsamp.	f	Species Abundance %	Species Dominance
Galumna virginiensis	10.2	.86	23.5	20.21
Galumna sp.	8.6	.80	20.0	16.00
Peloribates sp. (spec. 16)	10.0	.74	23.1	17.09
Scheloribates laevigatus	7.1	.78	16.5	12.87
Eupelops sp.	3.5	.70	8.0	5.60
Anoribatella sp.	1.6	.50	3.7	1.75
Chamobates sp.	0.9	.39	2.2	0.88
Scheloribates sp.	1.3	.27	3.1	0.84
Zygoribatula sp. (spec. 9)	0.5	.30	1.2	0.36
Pergalumna curvum	0.7	.19	1.6	0.30
Oppia sp.	0.4	.25	.9	0.225
Oppiidae	0.3	.20	.7	0.14
Epidamaeus sp.	0.3	.15	.7	0.105
Oribatuloidea (spec. 13)	0.16	.11	.35	0.04
Phthiracaroidea	0.16	.08	.35	0.03
Tegoribates sp.	0.08	.07	.18	0.013
Oribatulidae (spec. 10)	0.1	.04	.3	0.012
Parakalumna robusta	0.06	.06	.1	0.006
Furcoribula sp.	0.1	.03	.2	0.006
Oribatulidae (spec. 11)	0.02	.01	.04	0.0004
Galumnidae	0.02	.01	.04	0.0004
Oribatuloidea (spec. 15)	0.02	.01	.04	0.0004

(1) Data from 76 subsamples collected from July 1967 through February 1968.

TABLE IV

THE DENSITIES AND DOMINANCE OF ORIBATID MITES IN "ANAPLASMOSIS" PASTURE[1]

Oribatid	Mites per subsamp.	f	Species Abundance (%)	Species Dominance
Scheloribates laevigatus	28.7	.96	36.8	35.37
Pergalumna curvum	9.1	.60	11.7	7.02
Galumna virginiensis	6.2	.64	8.0	5.12
Galumna sp.	4.1	.62	5.2	3.22
Oribatulidae (spec. 10)	13.0	.14	16.7	2.34
Anoribatella sp.	3.0	.44	3.8	1.67
Ceratozetes sp.	2.8	.40	3.6	1.44
Chamobates sp.	2.4	.40	3.1	1.22
Peloribates sp. (spec. 17)	1.6	.23	2.0	0.46
Oppia sp.	.9	.41	1.1	0.45
Eupelops sp.	1.0	.31	1.3	0.40
Parakalumna robusta	1.1	.25	1.4	0.35
Scheloribates sp.	1.2	.20	1.6	0.32
Peloribates sp. (spec. 16)	1.0	.17	1.3	0.22
Oppiidae	.5	.26	.6	0.16
Zygoribatula sp. (spec. 9)	.8	.12	1.0	0.12
Furcoribula sp.	.7	.11	.85	0.09
Oribatulidae (spec. 11)	.3	.03	.3	0.009
Zygoribatula sp. (spec. 8)	.02	.02	.025	0.005
Oribatuloidea (spec. 13)	.01	.01	.01	0.0001

[1] Data from 80 subsamples collected from August 1967 through February 1968.

TABLE V

THE DENSITIES AND DOMINANCE OF ORIBATID MITES IN LAKE BLACKWELL PLOT[1]

Oribatid	Mites per subsamp.	f	Species Abundance (%)	Species Dominance
Galumna sp.	3.8	.74	21.2	15.7
Scheloribates laevigatus	5.1	.33	28.4	9.4
Zygoribatula sp. (spec. 8)	3.3	.36	18.4	6.6
Oppiidae	1.7	.41	9.4	3.85
Galumna virginiensis	1.6	.38	8.9	3.4
Zygoribatula sp. (spec. 9)	.95	.18	5.3	.95
Chamobates sp.	.4	.23	2.2	.51
Epidamaeus sp.	.36	.15	2.0	.30
Furcoribula sp.	.33	.10	1.8	.18
Anoribatella sp.	.2	.15	1.1	.16
Pergalumna curvum	.18	.15	1.0	.15
Oribatulidae (spec. 12	.5	.05	2.8	.14
Peloribates sp.	.13	.08	.7	.06
Oribatulidae (spec. 10)	.18	.05	1.0	.05
Parakalumna robusta	.1	.08	.5	.04
Oribatuliodea (spec. 13)	.05	.05	.03	.001

[1] Data from 72 subsamples collected from October 1967 through January 1968.

S. laevigatus and an insignificant fourth for G. virginiensis (Table V).

Considering the oribatid populations found in the three localities combined, S. laevigatus becomes the most dominant species for the Stillwater area. This species was also the dominant one in a sheep pasture in Kentucky (Ibarra, et al., 1965), but a previous investigation in the same pasture (Wallwork and Rodriquez, 1961) gave evidence that G. virginiensis was the dominant species and S. laevigatus was subdominant. In South Dakota, from a permanent sheep pasture two hundred twenty-one individuals of S. laevigatus were the average number of the mites per square foot, as reported by Kates and Runkel (1948). This figure, however, is difficult to be compared with the densities reported presently due to the difference of the size of the sampling units, and also of the details of the extraction techniques. These workers sampled 1-ft.^{2} areas of turf and recovered the mites through open funnels. The funnels had top diameters of 18 inches, and 200-watt electric light bulbs were used as the heat source.

It has been indicated earlier that the dominance of a certain species may vary from pasture to pasture. S. laevigatus, G. virginiensis, and Galumna sp. almost invariably dominated the areas, compared to the rest of the species. This was not the case with some other species, which were present in large numbers and dispersed widely only in one locality but not in the other two. For examples, Pergalumna *curvum* was significant only in ANA; *Peloribates* sp. was important among the oribatid community in WARD but very insignificant in ANA and absent in BLACK; *Eupelops* sp. was fairly common in WARD and *Zygoribatula* sp. in BLACK as compared to the other grass lands. Since the three localities are not too far apart geographically, but differ in the vegetation and management, it can be assumed that these factors play important roles in the abundance and the distribution of oribatids, and further, the composition of oribatid communities.

Community Comparison: Species Composition

Table II shows that about half of the species occurred in all three areas, and some mites were found only in one place. While the list of the species of one locality does not differ markedly from the others, the ranking in abundance does. This difference can be seen in Tables III, IV, and V, and the main elements which compose each community are compared in Figure 4. The abundance of the mites and the number of the species present in each locality are related in Figure 5.

It was common for all three communities that only a few species were represented by large numbers of individuals, the majority being found in much rarer occasions. Only two, out of twenty-one, species in ANA occurred with an average of ten or more individuals per subsample while thirteen

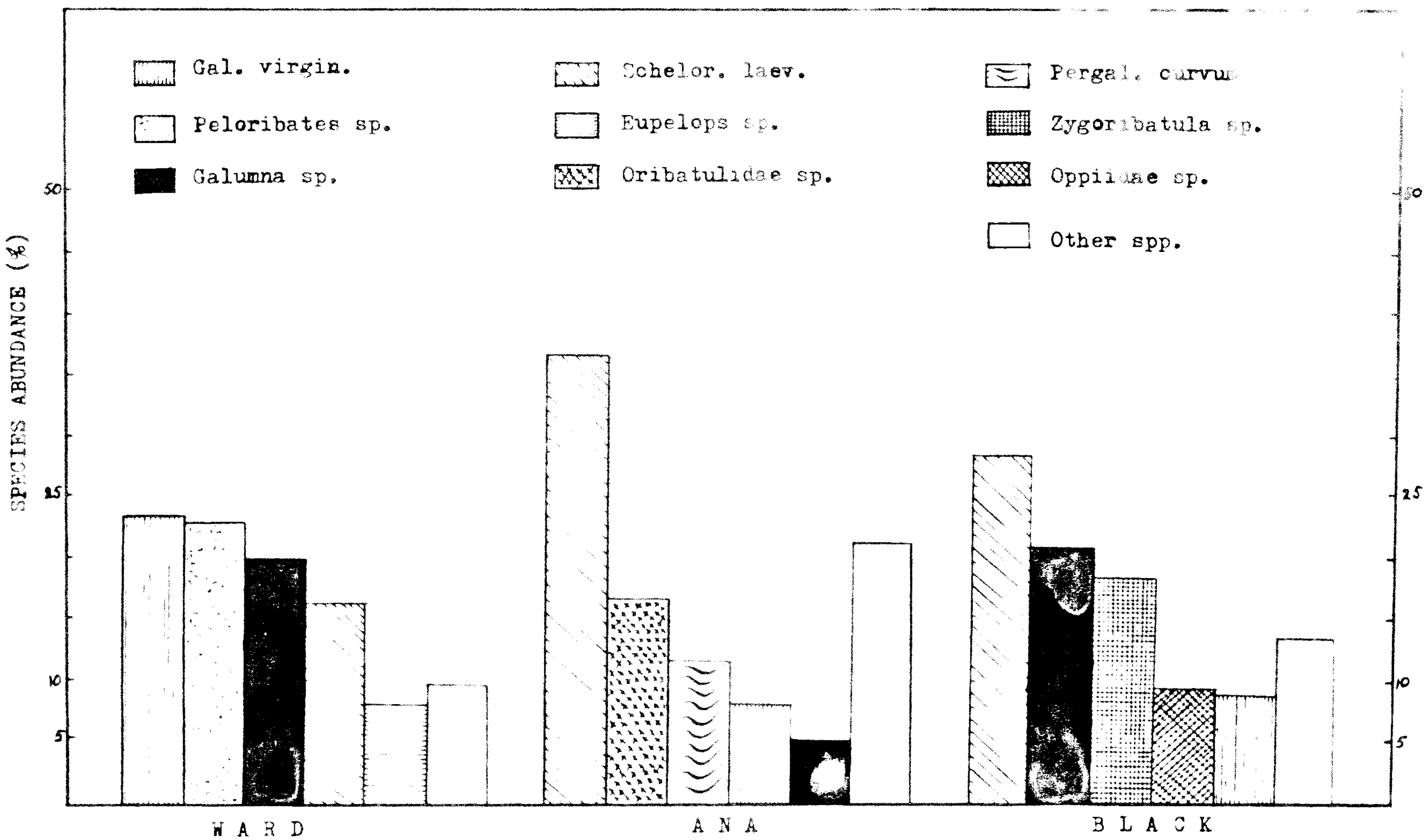

Fig. 4. The species compositions of three oribatid mite communities near Stillwater, Oklahoma.

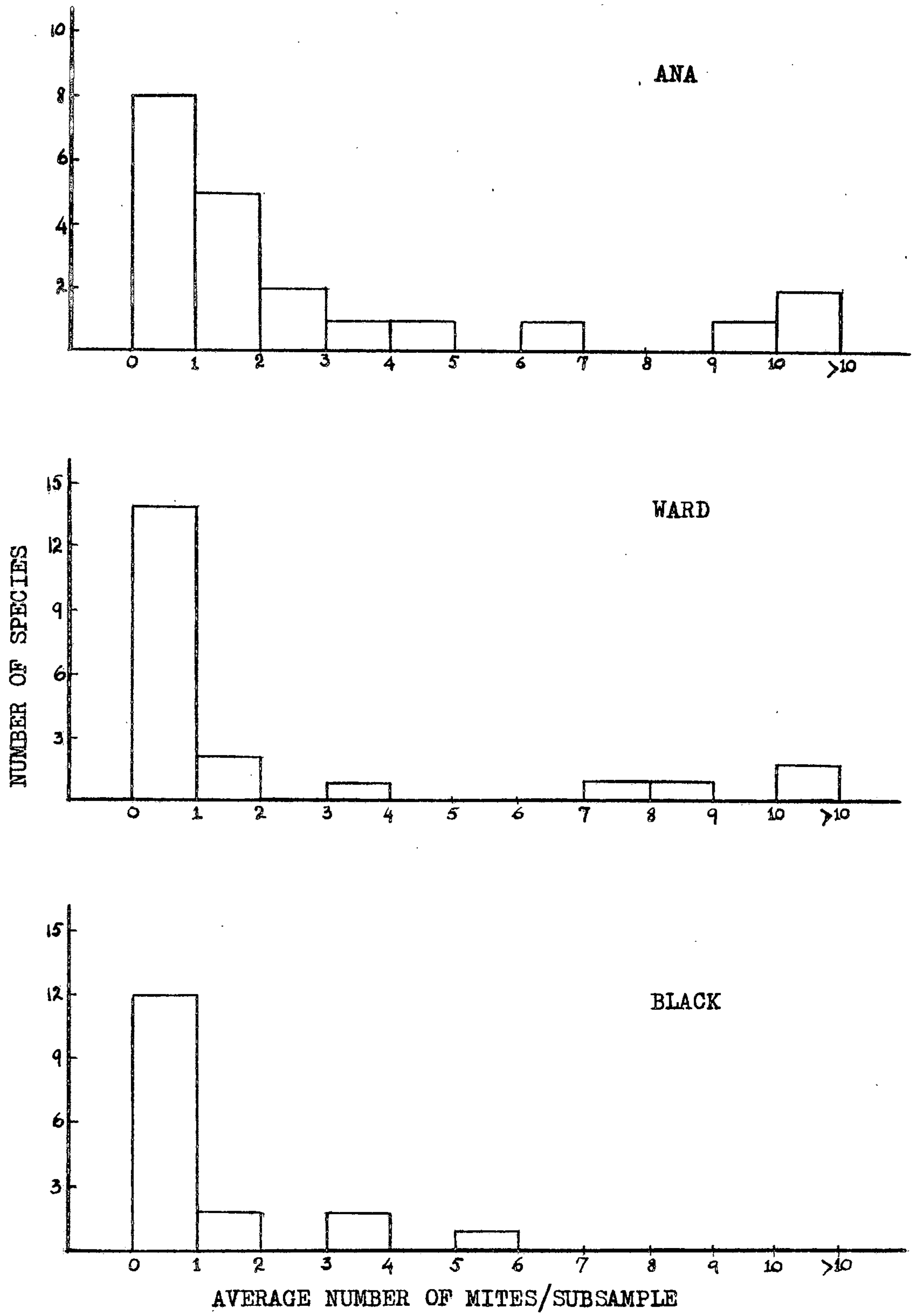

Fig. 5. The numbers of oribatid mite species occurring at certain densities.

species were found in less than two individuals per subsample. In WARD among the twenty-two species the ratio was 2 to 16, and in BLACK 12 out of 17 species had densities of less than one per subsample whereas only one species had more than five individuals per subsample.

In WARD, individuals of only five species together constituted over 90% of the total oribatid populations, while the remaining 17 species made up less than 10%. These five species were Galumna virginiensis (23.5%), Galumna sp. (20%), Peloribates sp. (23.1%), Scheloribates laevigatus (16.5%), and Eupelops sp. (8%). In ANA, S. laevigatus alone comprised 36.8% of the community, and this and four other species, i.e., Oribatulidae sp., Pergalumna curvum, G. virginiensis, and Galumna sp., contributed 78.4% of the whole oribatid population in this pasture. Here, however, the four species were far less abundant in comparison with S. laevigatus, the species abundance being 16.7%, 11.7%, 8%, and 5.2% respectively. In BLACK, 86.3% of the oribatid community was represented by five species, consisting of S. laevigatus (28.4%), Galumna sp. (21.2%), Zygoribatula sp. (18.4%), Oppiidae sp. (9.5%), and G. virginiensis (8.9%).

In recapitulation, the species compositions in WARD, ANA, and BLACK can be visually compared in Figure 4. In WARD and BLACK the bulk of the oribatid mites were roughly shared by three or four species, whereas in ANA S. laevigatus had a distinct plurality over other species. The WARD community was distinguished by Peloribates sp., that of ANA by

Oribatulidae sp. and <u>Pergalumna curvum</u>, while BLACK community was prominent in the population of <u>Zygoribatula</u> sp.

Community Comparison: Species Diversity

Species diversity is a measure of species spectrum in a certain community of living organisms. It relates the number of individuals in the community and the amount of species which are present; this relationship may be expressed in different ways according to different authors. Combined with the data on species abundance, they form a valuable means for interpreting the structure of an animal community.

Many workers have attempted to measure the value of the species diversity, as an index derived from the form of relationship between the number of species and the number of individuals. The mathematical approach of determining this relationship was first discussed by Fisher, Corbert, and Williams (1943), based on their studies of butterflies and moth populations. When the logarithmic number of individuals was plotted against the logarithmic number of species, they concluded that the relationship followed a logarithmic series. Based on this theory, they suggested the equation:

$$S = \mathrm{logn}\ (1 + \frac{N}{\ })$$

to estimate the number of species (S) expected to be found in a certain number of individuals (N) in a certain collection. In the above formula alpha is a constant which may be considered as a measure of richness in species or an expression of the diversity of species in relation to the total number of individuals. These workers stated that since the value of alpha was very much independent of the size of sample, it was a valuable index of the diversity of species in a natural community. One limitation to the application of this formula is that it requires more species of minimal abundance than any other category.

According to Hairston (1959), Margalef (Mem. Real Acad. Ciencias y Artes de Barcelona 32:373-449; 1957) proposed a simple index of diversity based on linear relationship between the number of species and the logarithm of the size of the sample, or of the total of individuals. Thus, according to Margalef, the index of diversity of species in a community is:

$$d = \frac{S - 1}{\text{logn } N}$$

In the present study the species diversities of the oribatid communities in the three grasslands are determined by both formulas, and the results are listed in Table VI. The solution for alpha of Fisher's formula is indirect. He has calculated a table from which, given the common logarithm of N/S, we may obtain the common logarithm of N/alpha. The value of alpha then can be found in the logarithm table, after the common logarithm of alpha is computed. To obtain the natural logarithm value (logn) in Margalef's formula, the common logarithm of N is to be multiplied by 2.3025851, which is the value of the natural logarithm of 10.

TABLE VI

THE DIVERSITIES OF SPECIES IN THREE ORIBATID COMMUNITIES

Local.	No. Indiv.	No. species		d
WARD(1)	3313	22	3.1632	2.590
ANA(2)	5928	21	2.7336	2.321
BLACK(3)	1300	17	2.7594	2.231

(1)Total collection made from July 1967 through February 1968.

(2)Total collection made from August 1967 through February 1968.

(3)Total collection made from October 1967 through January 1968.

The values of both alpha and d in Table VI indicate that the WARD community was the most diverse of the three communities. The values of alpha of ANA and BLACK, however, do not correspond to their respective d values. According to Fisher's formula, BLACK was richer in species than ANA, whereas through Margalef's index of diversity it was the opposite. Since both values are determined by formulas originally applied to explain the relationship of N and S, it is difficult to judge which one of the two indices is closer to reality. Judging merely from the ratio between N and S, it would seem logical to expect several additional species in BLACK if the sample size is enlarged to match the mite collection from ANA, thus giving a good chance to increase the index of diversity. Based on the sampling evidence, however, this may not be the case. The numbers of subsamples taken from ANA and from BLACK were almost equal, being 80 and 72, respectively, while the area in BLACK is less than one-tenth of that in ANA.

Due to the fact that many oribatids occur in such a low frequency, some species were even represented by a single individual during the survey, the extensiveness in sampling would seem to be a major factor in finding new species. This, however, did not always hold true during the investigation, as shown in Table VII. In ANA collection, the summer sampling with 30 sampling units yielded 21 species, 26 units in the fall produced only 17 species, and only 19 species were found from 24 subsamples collected during the winter. But in WARD, the same number of species were found in both summer collection with 54 subsamples and winter collection with only 12 subsamples.

It can be seen in Table VII that fewer species were collected in the fall from both pastures. However, nothing can be concluded from the present study whether or not weather variation has certain effects upon the species diversity. Meanwhile, the data prove that most, if not all oribatid mites in the Stillwater area overwinter as adults. The values of alpha and *d* in Table VII suggest that the oribatid populations in wintertime in ANA and in WARD were either more diverse or about as diverse as those during the summertime. It can be concluded that as many species were living in winter as in summer, but as the warm season arrived the reproduction rates were so much different among the different species that only a few species did actually make the big difference in the number of individuals.

TABLE VII

SPECIES DIVERSITIES OF ORIBATID COMMUNITIES IN THREE DIFFERENT SEASONS

Local./Season			No. Subsamp.	No. Mites	No. Species	α	d
ANA	Summer	1967	30	2223	21	3.2109	2.595
	Fall	1967	26	2347	17	2.4805	2.061
	Winter	1968	24	1358	19	3.1271	2.495
WARD	Summer	1967	54	2167	19	2.8660	2.343
	Fall	1967	12	844	15	2.5911	2.077
	Winter	1968	12	302	19	4.5018	3.152

Community Comparison: Population Density

As indicated in Table VI, the total numbers of mites collected were 5928 from ANA, 3313 from Ward, and 1300 from BLACK. These amounts were recovered from 80, 78, and 72 subsamples, respectively, to make densities of 70.4, 42.5, and 18.0 mites per subsample. Each subsample was a mass of turf material having a total area of approximately 19.6 square inches and about 2 inches deep. From these figures it can be seen that the average numbers of mites among the subsamples taken over a period of 4 to 8 months in three localities varied considerably.

Due to the unequal sizes of samples taken during a certain sampling period or season, statistical analysis was difficult to do. Only ANA and WARD were surveyed during all three seasons, while BLACK was studied only from October 1967 through January 1968. For this reason, in comparing the densities, statistical treatments were run only on those data obtained from ANA and WARD. As was discussed in Chapter III, the data had to be first transformed before the variance could be analysed, because the mites were not distributed according to Poisson series. In a Poisson distribution, there is an idea of uniform probability of the occurrence of some event, and the distribution is defined by a single parameter, the nean; the variance is equal to the mean (Snedecor, 1956). This definition can be used for a quick preliminary test upon the data as to the conformity with the distribution. The mean and variance of each collection are compared in Table VII, and the distributions of the mites among the subsamples are shown in Appendices A-F. It is clear that the variance in each collection sample was very much bigger than the mean. Beal (1942) proposed that in this non-random distribution the relationship between s^2 and $\bar{x}$ is curvilinear, expressed as $s^2 = \bar{x} - k\bar{x}^2$. This means that the larger the mean the larger the variance. From the previous equation $\underline{k}$ can be estimated by (sum of variance - sum of means)/sum of squared means. For the data above $\underline{k} = 1.218$, which was then used to transform all the raw data. These transformations are presented in Appendices A-F, and the means of the transformed values are listed in Table IX. It can be seen that the transformed mean is not always in proportion to the untransformed one. Thus, for example, the untransformed mean for ANA in fall 1967 was 90.3 and $\bar{x}' = 2.64$, while in summer 1967 $\bar{x}' = 2.69$ when the mean of the untransformed data was only 74.1. This was due to the difference in the distribution of the mites among the subsamples, the mites being more uniformly distributed in the summer collection than in the fall collection.

Since there were two factors simultaneously affecting the oribatid populations which were studied, i. e., the pasture and the season, the analysis of the variance was done factorially, the pasture with two levels and the season with three levels. However, because of the unequal numbers of subsamples, certain corrections had to be applied to the

TABLE VIII

THE MEANS AND VARIANCE OF ORIBATID MITE POPULATIONS IN TWO PASTURES AND THREE DIFFERENT SEASONS.

Pasture and Date	Number of Subsamples	Total Mites	$\bar{x}$	s^2
WARD				
Summer 1967	54	2167	40.1	1452.62
Fall 1967	12	844	70.3	1774.97
Winter 1968	12	302	25.2	661.97
ANA				
Summer 1967	30	2223	74.1	5336.86
Fall 1967	26	2347	90.3	19320.28
Winter 1968	24	1358	57.58	1247.12

TABLE IX

THE MEANS OF TRANSFORMED DATA FROM ORIBATID POPULATIONS IN TWO PASTURES AND THREE SEASONS.

Pasture and date	Total x'	$\bar{x}'$
WARD Summer 1967	125.69	2.34
Fall 1967	32.83	2.73
Winter 1968	25.70	2.14
ANA Summer 1967	80.81	2.69
Fall 1967	68.76	2.64
Winter 1968	57.69	2.40

season sum of squares, while the pasture sum of squares was obtained through a modified procedure, as advised by Snedecor (1956). The results of the analysis are summarized in Table X. It can be seen that the combined S.S. of pasture, season, pasture X season and error exceeds the total S.S. This is due to modification of the computation of the SS for pasture and season, while that for the error was done as usual. This way it gave a higher error M.S., so that the tests of significance would be unbiased. It turns out that values of the F-ratios are highly significant for the effects of pasture and of the season, while there was no indication of interacting effects of the two.

TABLE X

SUMMARY OF ANALYSIS OF VARIANCE OF THE TRANSFORMED DATA IN TABLE IX

Source of var.	d.f.	S.S.	M.S.	F-ratio
Total	157	45.261		
Pasture (weighted)	1	1.932	1.932	6.77*
Season (corrected)	2	4.333	2.166	7.60**
Pasture X Season	2	1.174	0.587	2.059
Error (original)	152	43.406	0.285	

*Significant at $\alpha = 0.025$

**Significant at $\alpha = 0.001$

It can be concluded, therefore, that the pasture in the Anaplasmosis Laboratory area, which is dominated by Bermuda-grass, supported more oribatid mites than the Ward pasture, which is dominated by the little blue stem but also has many other species of grasses as well as weeds. The oribatid populations would reach a peak in the November-December period . During the winter many oribatid mites survived although the reproductive activities were arrested. These overwintering mites included most if not all species, regardless of taxonomic alliance or size. Tables XI and XII show the weather conditions during the period of survey. While the summer months were hot, a considerable amount of precipitation was received to keep the turf moist enough for the mites to propagate. Although not much rain occurred during November, relatively wet weather occurred during the September-October period. January and February were dry compared with the preceding months, and subfreezing temperatures occurred frequently. It appears that the humidity is more critical than the ambient temperature in affecting the growth of oribatid populations.

Table XIII listed the abundance of the five most common species during each season. Scheloribates laevigatus contributed most to the whole oribatid population in ANA, and its relative abundance seemed to be consistent. In WARD this species was the most abundant one during the winter, but not in the summer or fall. It seems that Galumna virginiensis dominated the Ward pasture mainly during the

TABLE XI

THE AIR TEMPERATURE (F) IN STILLWATER, MAY 1967 - FEBRUARY 1968(1)

Month	Aver. max.	Aver. min.	Aver.	Highest	Lowest	No. of days 90 or above	No. of days 30 or below
1967							
May	78.4	52.8	65.6	93	35	4	0
June	86.1	66.1	76.1	95	53	6	0
July	89.1	66.0	77.6	101	52	15	0
August	90.5	64.2	77.4	101	49	18	0
September	81.0	59.4	70.2	88	37	0	0
October	75.8	49.2	62.5	88	33	0	0
November	60.1	35.6	47.9	76	24	0	8
December	51.5	29.1	40.3	70	14	0	19
1968							
January	47.3	28.3	37.8	70	0	0	20
February	51.6	25.7	38.7	72	19	0	24

(1) From: Climatological Data vol. 76 (1967), no. 5-12, and vol. 77 (1968) no. 1-2. U.S. Dept. Commerce, Envir. Sci. Serv. Adm. The data were recorded at 5 p.m. by the Oklahoma State University meteorologists at a station 2 miles west of Stillwater.

TABLE XII

INCHES OF PRECIPITATION IN STILLWATER, MAY 1967 - FEBRUARY 1968 [1]

Month	Total rain	Greatest day	No. days .10-1.0 in.	No. days 1.0 in. or more	Total snow	Max. Depth on ground
1967						
May	6.22	2.43	10	3	0	0
June	3.93	1.65	10	1	0	0
July	4.59	3.32	5	1	0	0
August	1.28	.63	4	0	0	0
September	4.60	.84	13	0	0	0
October	2.58	1.40	5	1	0	0
November	.72	.39	3	0	1	0
December	5.71	.27	3	0	T*	0
1968						
January	1.68	.90	5	0	T*	T
February	.25	.11	1	0	3	1

[1] From; Climatological Data vol. 76 (1967), no. 5-12, and vol. 77 (1968) no. 1-2. U.S. Dept. Commerce, Envir. Sci. Serv. Adm. The data were recorded at 5 p.m. by the Okla. State Univ. meteorologists at a station 2 miles west of Stillwater.

*Trace.

TABLE XIII

THE SEASONAL VARIATION IN RELATIVE ABUNDANCE OF FIVE COMMON ORIBATID MITES[1]

Oribatid	Summer 1967	Fall 1967	Winter 1968
WARD			
Scheloribates laevigatus	11.7	26.5	30.0
Galumna virginienses	23.2	10.1	10.6
Galumna sp.	22.3	16.2	12.5
Peloribates sp.	24.4	27.6	15.2
ANA			
Scheloribates laevigatus	47.6	45.6	47.4
Galumna virginiensis	8.2	9.0	11.4
Galumna sp.	4.1	7.0	8.1
Pergalumna curvum	14.4	17.2	7.3

(1) Relative abundance of a species or species abundance (SA) in per cent.

summer month, while in ANA it survived well during the winter, having relative abundance value higher than that in summer or fall. A similar trend was shown by Galumna sp. Peloribates sp. was the most abundant species during the fall season in WARD, and Pergalumna curvum also occurred most abundantly in the same season in ANA. Thus S. laevigatus, in addition to being the most common oribatid, also proved to be highly resistant to low temperatures, as were G. virginiensis and Galumna sp. Kates and Runkel (1948) found large numbers of G. virginiensis in turf after it was subjected to a long frost. Similar findings were also reported by Edney and Kelley (1953) in Kentucky.

Freeman (1952), studying the effect of temperature upon the development of Monocestus sp., anoplocephalid of porcupine, found out that a temperature of -5 degrees Celcius was not harmful to either the oribatid mite (Galumna sp.) or the tapeworm. Therefore one important aspect of the oribatid mite is the fact that it is capable of protecting the anoplocephalid larva from an adverse weather condition.

Distribution Pattern

It has been indicated earlier that the oribatid mites were not distributed at random; as shown in Table VIII the variance in each collection was much too large to be compared with the mean. For a closer look at the distribution pattern, the frequencies of occurrence of the mites among the subsamples are presented in Table XIV. Four collections are compared: from WARD in summer, from ANA in summer, fall, and winter. The numbers of mites per subsample range from 0 to over 150; one subsample from ANA contained 715 individuals (Appendix E).

It can be seen that among the subsamples taken from WARD many contained less than 20 mites and fewer numbers of them are listed in each of the successive categories of abundance. If the frequencies are plotted against the abundance, the curve resulting will be skewed to the left, which is closer to the curve of a negative binomial distribution. The frequency distributions in ANA, however, were less skewed, although the number of samples with 11-20 mites was larger than any other category. This may be due to the relatively small numbers of subsamples.

Table XV shows the distributions of two common and important species, G. virginiensis and S. laevigatus. In the case of the former species, a strikingly similar pattern was indicated in both WARD and ANA and in all seasons. The distribution of S. laevigatus in WARD differed from that in ANA, but again a rather similar pattern in all seasons was apparent. This similarity occurred despite the difference in the density or the average number of mites per subsample.

In attempting to interprete these non-random distributions, the statistic k, one of the two parameters of the negative binomial distribution, was estimated through the formula: $k = \bar{x}^2/s^2 - \bar{x}$, where, as usual, $\bar{x}$ is the sample mean and s^2 is the sample variance. As has been suggested

TABLE XIV

THE FREQUENCY DISTRIBUTIONS OF ORIBATID MITES AMONG SUBSAMPLES

Number of mites	Frequency[1]			
	WARD-S	ANA-W	ANA-S	ANA-F
0	1	0	0	0
1 - 10	6	3	1	2
11 - 20	10	6	6	4
21 - 30	8	2	1	2
31 - 40	8	3	1	3
41 - 50	4	1	2	2
51 - 60	4	2	2	2
61 - 70	4	1	2	1
71 - 80	1	0	3	2
81 - 90	3	0	2	2
91 - 100	1	1	4	0
101 - 110	1	1	1	1
111 - 120	0	0	0	0
121 - 130	0	1	1	0
131 - 140	0	1	1	0
141 - 150	1	0	1	1
151 or more	1	1	2	3
Total	54	24	30	26

[1] S = Summer; F = Fall; W = Winter.

TABLE XV

THE FREQUENCY DISTRIBUTIONS OF G. *virginiensis* AND S. *laevigatus* AMONG SUBSAMPLES

Number of mites	G. virgin.				S. laevig.			
	WARD S	ANA S	ANA F	ANA W	WARD S	ANA S	ANA F	ANA[1] W
0	10	11	11	8	16	0	1	2
1 - 10	27	12	11	11	32	9	9	8
12 - 20	12	4	2	3	2	4	2	3
21 - 30	3	1	-	1	2	2	1	5
31 - 40	1	1	-	-	1	4	2	2
41 - 50	1	1	1	1	-	4	3	1
51 - 60	-	-	-	-	1	2	2	-
61 - 70	-	-	-	-	-	1	2	1
71 - 80	-	-	-	-	-	-	2	-
81 - 90	1	-	-	-	-	2	-	1
91 -100	-	-	-	-	-	-	-	1
101 or more	-	-	1	-	-	2	2	-
Average[2]	9.1	6.0	8.4	5.6	5 1	35.0	40.9	23.3

[1] S = Summer; F = Fall; W = Winter.

[2] Mites per subsample.

by Berthet and Gerard (1965), the value of k may be used to measure the heterogeneity of the distribution. Stated differently, k is a measure of the degree of clumping (Hairston, 1959). The smaller the value of k, the more aggregated the individuals are. If the distribution tends toward Poisson, the difference between the mean and the variance becomes smaller and so k becomes larger.

In Table XVI the k values of the four distributions presented in Table XIV are compared. The largest k is that of the winter sample from ANA, the smallest is of the fall sample, also from ANA. It appeared as if there was an inverse relationship between k and the density, or the mites seemed to be more dispersed as the density was smaller. The real reason for the mites to come close together, however, may be different with different situations. Food is of course one factor, and water balance is another. The mites will undoubtedly gather in places where food materials are plentiful, or will prefer to stay wherever the moisture is sufficient to prevent them from desiccation.

The aggregations of G. virginiensis and of S. laevigatus are compared in Table XVII. It can be seen that the former was more distributed in clusters than was the latter. In WARD G. virginiensis seemed to be more dispersed than it did in ANA, while the opposite situation was the case of S. laevigatus. The tally of the frequencies in Table XV gives evidence for the preceding statement. Here again,

TABLE XVI

THE K VALUES OF FOUR ORIBATID DISTRIBUTIONS

Pasture and date	Number of subsample	Mean	k
WARD, Summer 1967	54	40.1	1.140
ANA, Summer 1967	30	74.1	1.043
ANA, Fall 1967	26	90.3	0.415
ANA, Winter 1968	24	57.6	2.787

TABLE XVII

THE K VALUES FOR THE DISTRIBUTIONS OF *G. virginiensis* AND *S. laevigatus*

Pasture and date	Number of subsample	G. virgin. Mean	G. virgin. k	S. laevig. Mean	S. laevig. k
WARD, Summer 1967	54	9.2	0.50	5.1	0.30
ANA, Summer 1967	30	6.0	0.35	35.0	1.15
ANA, Fall 1967	26	8.4	0.14	40.9	0.715
ANA, Winter 1968	24	5.6	0.31	23.3	1.10

both species appeared to be more clustered during the fall season in ANA.

To study the relation between microclimate and the spatial distribution of the oribatid mites, the temperature and relative humidity of each subsample were recorded prior to sampling. The data are listed in Appendices G-K. The relative humidity values of the subsamples and the numbers of mites collected during the summer of 1967 from WARD and ANA are plotted to each other in scattergrams in Fig. 6 and 7, and the ground temperatures and the numbers of mites in Fig. 8 and 9. Judging from the scattering of the dots, there were no correlations between the numbers of the mites and either the relative humidities or the temperatures of the subsamples. Large numbers of mites were found in both humid and dry places, and extreme temperatures of the ground did not seem to affect the mite populations. These facts show that microclimate is not the only limiting factor in the spatial distribution of the mites. A multitude of both biotic and abiotic factors may be responsible for either the aggregation or the spread of the individuals. This is especially true when a large taxonomic group such as Oribatei is the subject. There may be a marked difference in the biology or in the reaction to environment between one species and the others.

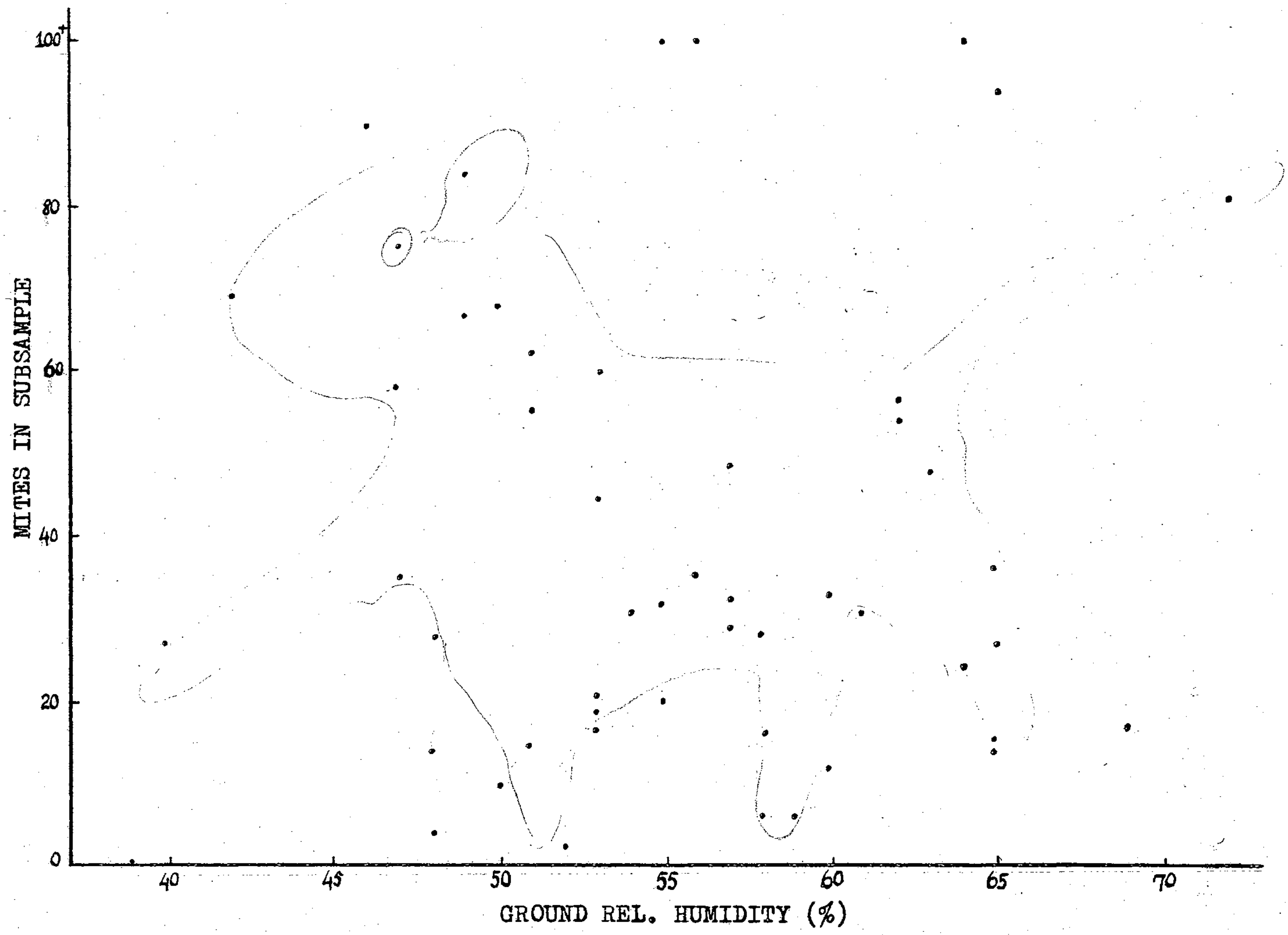

Fig. 6. The relation between the ground relative humidities and the numbers of mites in subsamples (WARD, summer 1967).

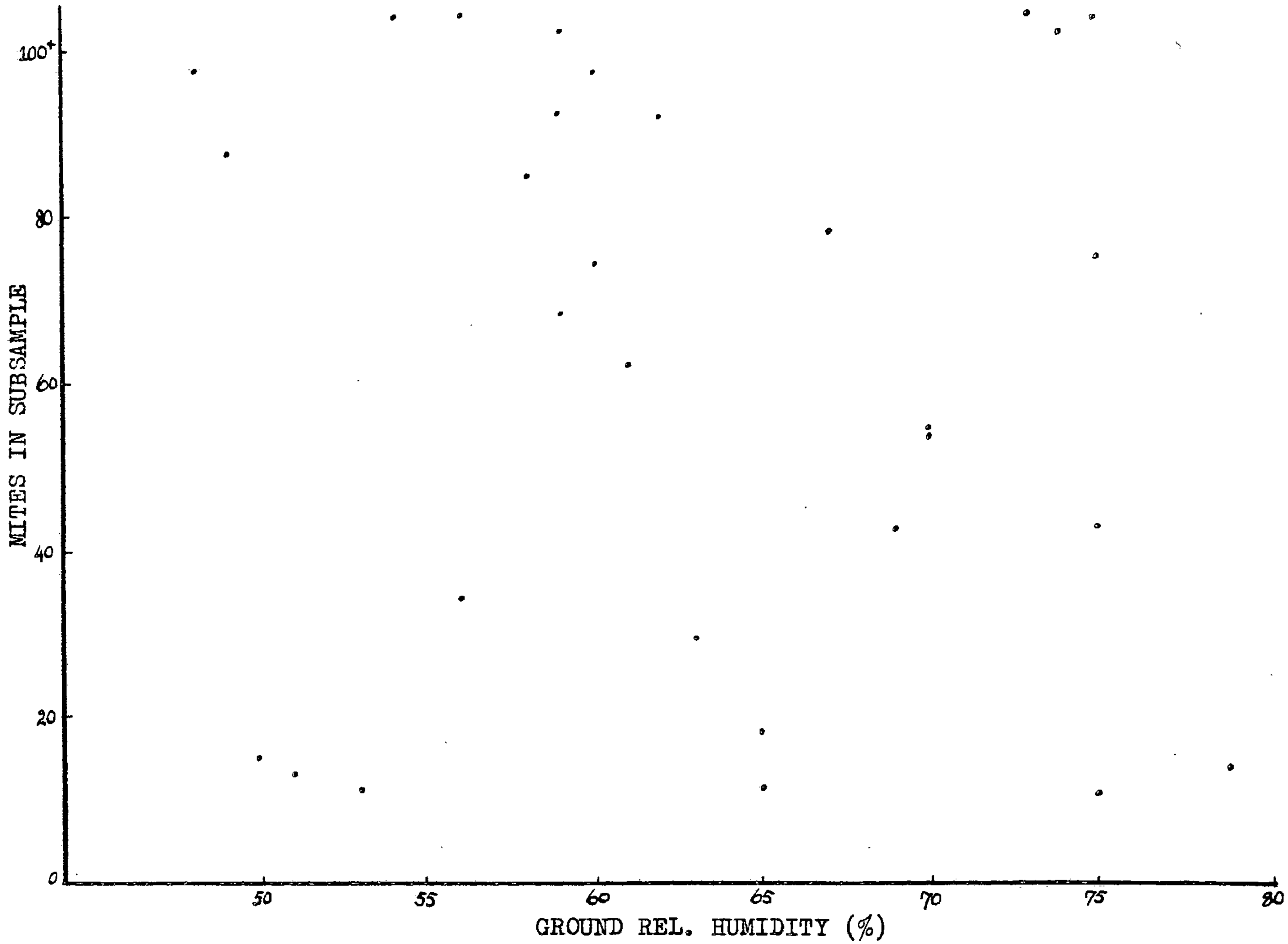

Fig. 7. The relation between the ground relative humidities and the numbers of mites in subsamples (ANA, summer 1967).

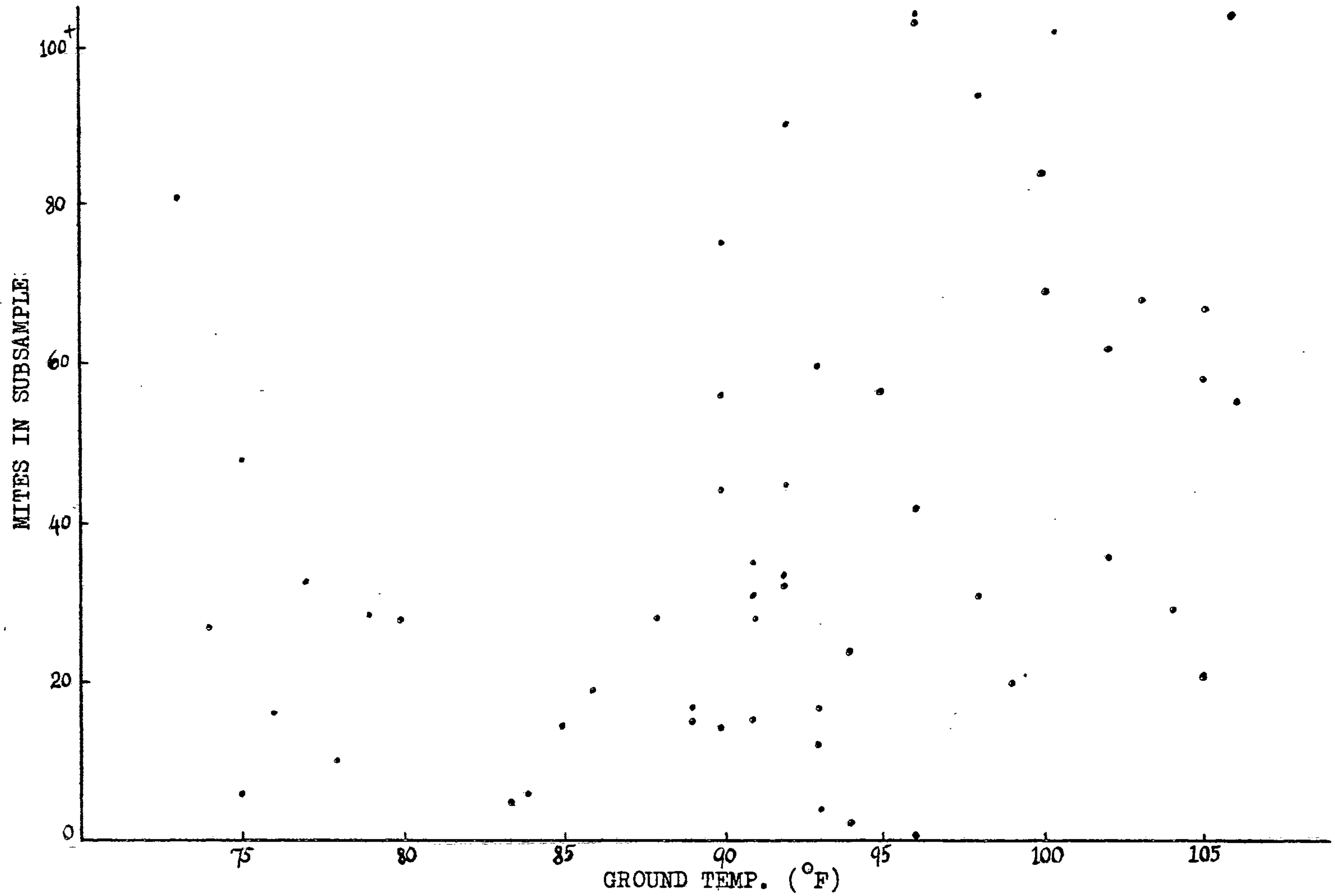

Fig. 8. The relation between the ground temperatures of subsamples and the numbers of mites (WARD, summer 1967).

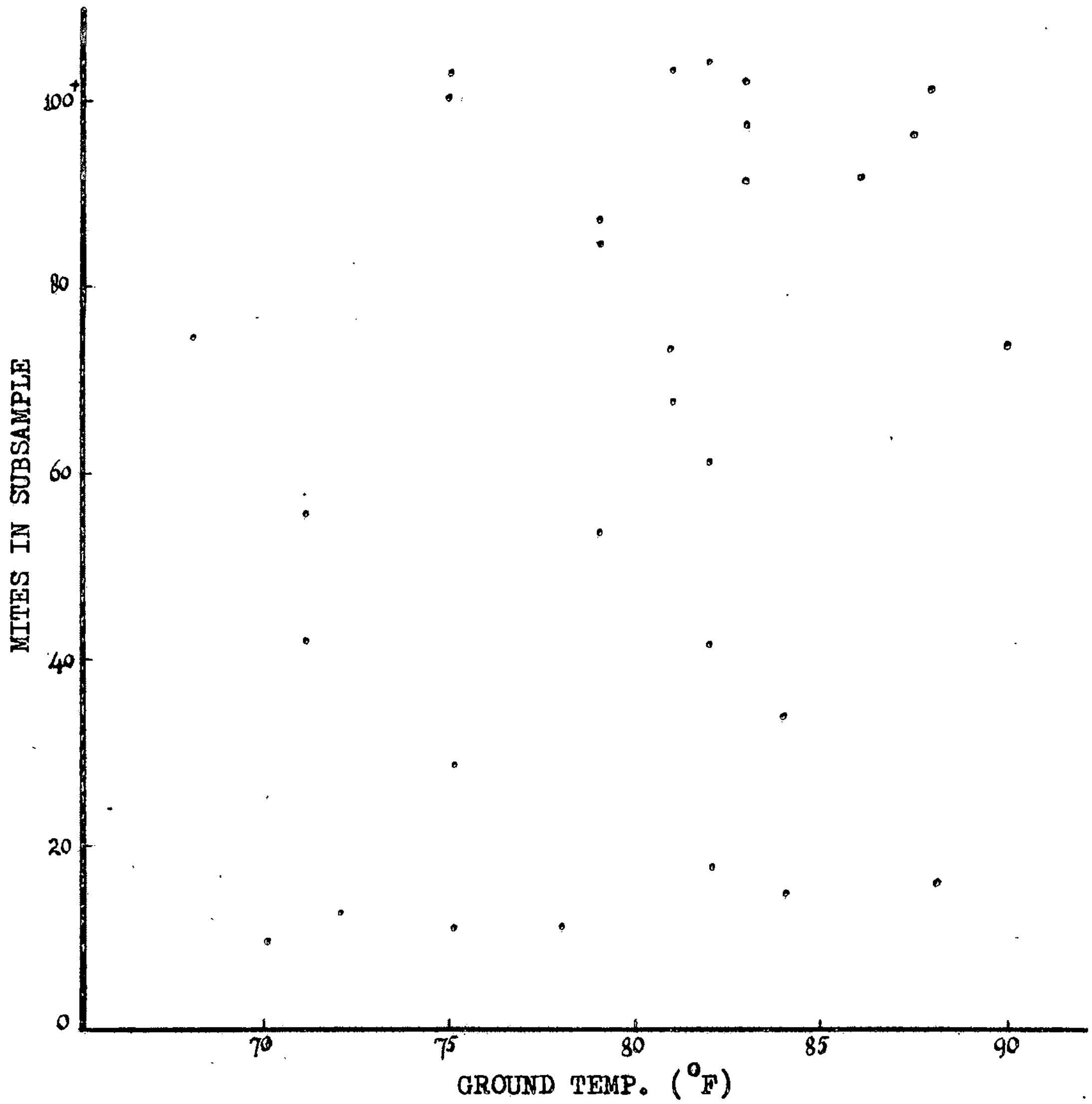

Fig. 9. The relation between the ground temperatures of subsamples and the numbers of mites (ANA, summer 1967).

The significance of the distribution pattern of the oribatid mites lies in the effect upon the method of estimating the density. Unless the specific pattern of distribution is known for a certain pasture, it would be impossible to estimate the size of the population. For an example, one species of Oribatulidae in ANA has an overall average of 13.0 per subsample because of a single occurrence of the mite in a large number, which was above 500, whereas the rest of the subsamples were mostly empty of this species or it occurred in low numbers. It is clear, therefore, that a single cluster can effect a lot of difference in the density.

The Effects of Vegetation on Oribatid Populations

The study on this subject was carried out exclusively in the small plot near Lake Carl Blackwell. The populations of the oribatid mites in six pure stands or colonies of grasses were compared with regards to the abundance, species composition, and species diversity. The results of the mite collections are presented in a two-way table (Grass X Date), Table XVIII. As with the previous data, transformations were performed using $k = 0.04$, and the transformed values are presented in Appendix L. The results of the analysis of variance are presented in Table XIX.

The results indicate that there were significant differences in the numbers of mites found in different grasses. Bermuda grass and the prairie threeawn supported more mites

TABLE XVIII

THE NUMBERS OF ORIBATID MITES COLLECTED FROM SIX GRASS SPECIES DURING OCTOBER 1967 TO JANUARY 1968 IN BLACKWELL PLOT

Grass	Date of sampling						Aver.
	Oct. 1	Nov. 3	Nov. 20	Dec. 5	Dec. 20	Jan. 16	
Broomsedge	6 11	5 9	41 20	8 30	12 22	10 4	15.4
Indian	15 30	1 7	9 3	14 12	5 15	19 29	12.4
Sideoat grm.	19 5	13 7	4 9	23 50	8 11	20 13	15.1
Big bluestem	16 17	0 5	14 27	2 4	7 3	3 6	8.7
Bermuda	69 37	25 36	43 34	16 9	14 19	26 11	29.1
Pr. threeawn	4 11	20 25	74 90	12 5	4 5	51 37	28.1
Average	20.0	12.7	30.7	15.4	10.4	19.0	

TABLE XIX

THE ANALYSIS OF VARIANCE OF THE DATA IN TABLE XVIII AND APPENDIX M

Source of var.	d.f.	S.S.	M.S.	F-ratio
Total	71	116.567		
Date	5	16.108	3.221	2.155
Grass	5	35.022	7.004	4.685**
Date X Grass	25	11.615	0.464	0.310
Error	36	53.822	1.495	

**Significant at α = 0.005

TABLE XX

THE SPECIES DIVERSITIES OF THE ORIBATID COMMUNITIES IN SIX DIFFERENT GRASS SPECIES

Grass	Total mites	Total species	α	d
Broomsedge	178	11	2.588	1.927
Indian	149	8	2.375	1.374
Sideoat grm.	182	15	3.881	2.687
Big bluestem	104	7	1.330	1.282
Bermuda	349	14	2.970	2.243
Pr. threeawn	338	13	2.725	2.056

than the others, the average numbers in these two species were about the same, being 29.1 in Bermuda and 28.1 in threeawn. The broomsedge bluestem was third in the oribatid mite abundance, sideoat gramma fourth, the Indian grass fifth, and the big bluestem was last. The F test indicated in Table XIX is significant at $\alpha = 0.005$.

On the other hand, the variation due to the date of sampling was not significant. About as many mites were found in January as in October, with some fluctuations in between. The statistical test also indicates that there was no interaction between grass species and date.

It has been said previously that only 17 species of oribatids were found in BLACK as compared with 21 in ANA and 22 in WARD. Fifteen of these species were found in the sideoat gramma, to make the community in this grass the most diverse. Table XX compares the diversities among the oribatid communities in the six grasses. It shows that after the sideoat gramma, Bermuda-grass was also rich in oribatids with 14 species, followed by prairie threeawn with 13 species, while the broomsedge, Indian grass, and big bluestem had 11, 8, and 7 species, respectively.

The species compositions in different grasses gave an interesting picture. With the exceptions of the communities in Bermuda-grass and in big bluestem, all had one species which was far more abundant than the others. In the broomsedge community, *Galumna* sp. made up 56.2% of the total oribatids, while *Zygoribatula* sp., the second most abundant, was only 19.0%. In the Indian grass it was Zygoribatula sp. which constituted 50.5% of the community, followed distantly by Galumna sp. and Scheloribates laevigatus, each with 17.0%. In the sideoat gramma again Galumna sp. dominated the population with 46.2%, Zygoribatula sp. contributed 22%, and Oppiidae sp. 10%, the remaining 21.8% comprised 12 other species. And finally in the prairie threeawn, Scheloribates laevigatus formed the bulk of the oribatid community with 58.5%, while Zygoribatula sp. made up only 12.4%. Oppiidae sp. 7.5%, G. virginiensis 6.4%, and Galumna sp. 6.0%. The compositions in big bluestem and Bermuda-grass were less extreme. Zygoribatula sp. was the most abundant in the former grass with 38.3%, Galumna sp. was second with 25.7%, and G. virginiensis third with 20.2%. in the latter, G. virginiensis headed the list with 25.7% followed by Oppiidae sp. with 17.5%, S. laevigatus with 16.9%, Galumna sp. with 13.0%, and Zygoribatula sp. with 8.5%, while 9 other species made up the remaining 18.4%.

The differences in the abundance and structure of oribatid populations in these six different grasses can be partially explained by the differences in the morphological features of the grasses, which in turn determine the physical nature of the habitat of the mites. Bermuda grass and prairie threeawn are both primarily creeping species and, particularly bermuda, sod forming. The stems and blades will densely cover the ground so that the floor of the turf will be rich in organic matter which is essential for the existence of the mites. Such species as broomsedge and big bluestems are standing, tall grasses. These kinds of grasses spread in clones which are usually separated from each other. Besides relatively low humus accumulation, the microenvironment will be less exclusive to be an ideal niche.

More precise explanations require information concerning both the chemical compositions of the grasses and the nutrient requirements of the mites. The difference in mineral content in the part of the habitat, for example, may affect the extent of an oribatid population. There have been no studies in this problem done on oribatid mites. The fact that those six different grass species support different amounts and species of oribatids should create some interest for the study in that direction.

CHAPTER V

SUMMARY AND CONCLUSIONS

A survey was made in two pastures and an ungrazed grassland in Stillwater, Oklahoma, and vicinity to study the structure of oribatid mite community, with special reference to the distribution and abundance of two species, *Galumna virginiensis* Jacot and *Scheloribates laevigatus* Koch, which are important intermediate hosts of anoplocephalid tapeworms of cattle and sheep.

The grasslands selected for the study represent three different ecological conditions; the three areas differ in size, vegetation, management, and utilization, as well as locality. The Ward pasture, located four miles northeast of Stillwater, is a thirty-acre permanent pasture which has been grazed by cattle for more than twenty-five years. Many species of grasses and weeds occur in this land, but little bluestem is predominant in most sections. The second study area, the pasture surrounding the Anaplasmosis Laboratory at the Oklahoma State University's campus, is about ten acres in size and predominantly Bermuda-grass, but prairie three-awn has invaded several parts. Sheep are brought in to graze at irregular times every year, and mowing or grass burning is done periodically. The third study area is located near Lake Carl Blackwell, nine miles west of Stillwater. It is a one-half-acre abandoned field with rows and stands of once cultivated grasses. The place is partially bordered by woodland and a small stream.

A total of 230 sampling units, each consisting of four cores of turf approximately 2 inches deep and 2½ inches in diameter, were collected during the period from July 1967 through February 1968. Of these units, 80 were taken from the pasture near the Anaplasmosis lab, 76 were obtained from the Ward pasture, and 72 from the plot near Lake Blackwell. The materials were processed through Berlese-Tullgren extracting funnels to recover the mites.

A total of 27 species, representing 9 superfamilies of the oribatid mites were found from all three areas. Twenty-two species were collected from Ward pasture (designated as WARD), 21 species from the "Anaplasmosis" pasture (designated as ANA), and 17 species from the small abandoned plot at the lake (designated as BLACK). Among these mites, Schelorbates laevigatus was the most common and occurred in large numbers. This mite contributed 36.8% of the total oribatids in ANA, 16.5% of that in WARD, and 28.4% in BLACK, Two other species which were abundant included Galumna virginiensis and Galumna sp. G. virginiensis which was the most dominant oribatid occurring in WARD, constituted 23.5% of the oribatid fauna in this pasture. Galumna sp. was second with 20% in WARD, but this mite was dominant in BLACK with a species abundance of 21.2%.

The main elements of the community differed with locality. In ANA, in addition to *S. laevigatus*, three other species, *Pergalumna curvum*, *G. virginiensis* and Oribatulidae sp. were also abundant. The WARD community was dominated by the two species of *Galumna* mentioned earlier and also by *S. laevigatus* and *Peloribates* sp. In fact this last species was the second most abundant in this community. In addition to these, *Eupelops* sp. was found substantially (8%). In BLACK the main elements were *Galumna* sp., *S. laevigatus*, and *Zygoribatula* sp. These different pictures clearly illustrate how the structure of oribatid community may be easily dictated by the conditions of the environment.

The number of mites and the number of species can be related in the concept of species diversity. An index of diversity is a measure of richness in species of a certain community relative to the total number of individuals. It was found that the Ward pasture, a thirty-acre area with a relatively varied vegetation, was the most diverse with respect to its oribatid community, whereas the "Anaplasmosis" area, a ten-acre grassland with Bermuda-grass and prairie threeawn, was the least diverse. However, the difference in species diversity was not too great. The value of Fisher's diversity index (α) was 3.16 for WARD, 2.76 for BLACK and 2.73 for ANA.

It is difficult at this point to single out the factor or factors which caused the difference in the species composition and species diversity. A complex interaction among factors, both biotic and abiotic, are certainly responsible in causing either the survival or the elimination of a species.

Statistical analysis indicates that there were significant differences in the abundance of the oribatid mites among pastures and among seasons. Thus, the pasture near the Anaplasmosis laboratory, which was poorer in species variety, harbored more mite individuals than the WARD pasture. The mild fall weather conditions effected a better situation upon the microenvironment of the mites than did those of summer or winter; more mites were collected during the fall than in other seasons studied. It appeared that a peak was reached during the November-December period. Judging from the data of the climatological cycle in this geographical area, it is likely that another peak can be reached during the May-June period.

The fact that the oribatid mites survived the winter as adults for most, if not all species, stresses the significance of the mites in serving as intermediate hosts for tapeworms. With a life span of over a year for either *G. virginiensis* or *S. laevigatus*, the tapeworm larvae are protected from the adversities of the environment within the bodies of the mites, securing better chances to complete their life cycle and to perpetuate.

Spatially the mites were not distributed at random. Various degrees of clumping were observed from all the collections. An index of heterogeneity (k) was determined to compare the population distributions. The value of k indicated that the mites as a group were more clustered during the fall, and that G. virginiensis was more aggregated than S. laevigatus. There were no indications that the microclimate was the major factor affecting the spatial distribution of the mites. Other factors such as food and the limited ability of maintaining the water balance of the mites will indeed determine the dispersion or the clustering of the oribatids. This patchiness in the distribution points out the difficulty encountered if the population density of the mites is to be estimated.

The study in the small plot at Lake Blackwell showed that there were significant differences in the oribatid populations occurring in different species of grass. Among the six species studied, Bermuda-grass and prairie threeawn provided the best habitat for the oribatids. Sideoats gramma carried a larger variety of species than either of the two, with 15 species, as compared with 14 in Bermuda and 13 in the threeawn. Tall and erect grasses such as the Indian grass, broomsedge, and the big bluestem proved to be a poor habitat for the oribatid mites, the last mentioned grass being the poorest. It is suggested that the morphological structures of the grasses have some influence on the nature of the habitat from the physical standpoints. An accurate explanation for the oribatid-grass relationship must require detailed information concerning both the chemical constituents of the grass and the nutrient requirements of the mites. This problem should make an interesting topic for future study.

BIBLIOGRAPHY

Balogh, J. 1961. Identification keys of world oribatid (Acari) families and genera. Acta Zool. Acad, Sci. Hung. 7:243-344.

Balogh, J. 1963. Identification keys of Holarctic oribatid mite (Acari) families and genera. Acta Zool. Acad. Sci. Hung. 9:1-60.

Baker, E. W., and G. W. Wharton. 1952. An introduction to Acarology. McMillan, New York. 465p.

Baker, E. W., J. H. Camin, F. Cunliffe, T. A. Wooley, and C. E. Yunker. 1958. Guide to the families of mites. Univ. Md., College Park, Md. 242 p.

Bankov, D. 1965. The Biology of Moniezia and the epidemiology of monieziosis in Bulgaria /in Bulgarian 7. Vet. Med, Nauki, Sof. 283-294. (Abstr. in Vet. Bull. 36:30; 1966).

Bashkirova, E. J. 1941. Contribution to the study of the biology of the tapeworm Anoplocephala perfoliata (Goeze, 1972), parasitic in the horse. Compt. Rend. (Doklady) Acad, Sci. U.R.S.S. 30:576-578.

Beal, G. 1942. The transformation of data from entomological field experiments so that the analysis of of variance becomes applicable. Biometrika 32:243-262.

Berthet, P. 1964. Field study of the mobility of Oribatei (Acari) using radioactive agging. J. Anim. Ecol. 33: 443-449.

Berthet, P., and G. Gerard. 1965. A statistical study microdistribution of Oribatei (Acari). Part I: The Distribution Pattern. Oikos 16:214-227.

Duges, A. 1834. Recherches sur l'ordre des Acariens en general et la famille des Trombidies en particulier. Ann. Sci. Nat. Tome 1 (Zool):5-46.

Edney, J. M., and G. W. Kelley, Jr. 1953. Some studies on Galumna virginiensis and Moniezia expansa (Acarina: Oribatoidea; Cestoda: Anoplocephalidae). J. Tenn. Acad. Sci. 28:297-296.

Eitminavichyute, I. 1961. The distribution of oribatid mites in the Lithuanian S.S.R./in Russian/. Akad. Nauk Latviisk S.S.R. (Riga), 271-274. (Abstr. in Biol. Abstr. 44 no. 25659; 1963)

Evans, G. O., J. G. Sheals, and D. MacFarlane. 1961. The terrestrial Acari of the British Isles. British Museum, London. 219 p.

Fisher, R. A., A. S. Corbert, and C. B. Williams, 1943. The relation between the number of species and the number of individuals in a random sample from an animal population. J. Anim. Ecol. 12:463-481.

Frank, F., and V. Zivkovic. 1960. Oribatid mites as intermediate hosts of anoplocephalids /in Serbian, German summary/. Acta Veterinaria 10:39-53. (Abstr. in Helminthol. Abstr. 33:947; 1964)

Freeman, R. S. 1952. Temperature as a factor affecting the development of Monococestus (Cestoda: Anoplocephalidae) in Oribatid Mites. J. Exp. Parasitol. 1:256-262.

Gerard, G., and P. Berthet. 1966. A statistical study of microdistribution of Oribatei (Acari). Part II: The Transformation of the Data. Oikos 17:142-149.

Graber, M., and J. Gruvel. 1964. Preliminary note on the transmission of Stilesia globipunctata (Rivolta, 1874) of sheep by various oribatid mites. Revue Elev. Med. Vet. Pays Trop. 17:467-476. (Abstr. in Vet. Bull. 35:643; 1965)

Grandjean, F. 1932. Au sujet des Palaeacariformes Tragardh. Bull. Paris Mus. d'Hist. Nat. ser. 2, 4:411-426.

Grandjean, F. 1935. Observations sur les Acariens (1 ere serie). Bull. Paris Mus. d'Hist. Nat. ser. 2, 7:119-126.

Grandjean, F. 1953. Essai de classification des Oribates. Bull. Soc. Zool. France 78:421-446.

Hairston, N. G. 1959. Species abundance and community organization. Ecology 40:404-416.

Ibarra, E. L., J. A. Wallwork, and J. G. Rodriguez. 1965. Ecological studies of mites found in sheep and cattle pastures. I. Distribution patterns of oribatid mites. Ann. Entomol. Soc. Amer. 58:153-159.

Jacot, A. P. 1929. American oribatid mites of the subfamily Galumninae. Bull. Harvard Mus. Compar. Zool. 69:1-37.

Jacot, A. P. 1933. The primitive Galumninae (Oribatoidea, Acarina) of the Middle West. Amer. Midland Nat. 14:680-703.

Jacot, A. P. 1934. The Galumnas (Oribatoidea, Acarina) of the Northeastern United States. J. N. Y. Entomol. Soc. 42:87-125.

Jacot, A. P. 1935. The large-winged mites of Florida. Florida Entomol. 19:1-55, 17-31. 43-47.

Johnston, D. E. 1964. A classification of the orders and suborders of Acari. Loose leaf, n. p. In: Acarology Laboratory Work Book. The Institute of Acarology, Ohio Agr. Res. Devel. Center and the Ohio State University, Wooster, Ohio.

Kassai, T., and S. Mahunka. 1964. Vectors of Moniezia [in Hungarian]. Magy. Allatorv. Lap. 19:531-538. (Abstr. in Vet. Bull. 35:705; 1965)

Kates, K. C., and L. E. Runkel. 1948. Observations on oribatid mites, vectors of Moniezia expansa on pastures, with a report on several new vectors from the United States. Helminthol. Soc. Wash., Proc. 15:10-33.

Krivolutskii, D. A. 1965. Morphological-ecological types of Oribatei mites (Acariformes)[in Russian]. Zool. Zh. 44:1176-1189. (Abstr. in Biol. Abstr. 47, no. 54773; 1966)

Krull, W. H. 1939a. On the life history of Moniezia expansa and Cittotaenia sp. (Cestoda: Anoplocephalidae). Helminthol. Soc. Wash., Proc. 6:10-11.

Krull, W. H. 1939b. Observations on the distribution and ecology of the oribatid mites. J. Wash. Acad. Sci. 29:519-528.

Linnaeus, C. 1758. Systema Naturae. Tomus I: Regnum Animale. 10th ed. Holmiae.

Madge. D. S. 1964. The Humidity reactions of oribatid mites. Acarologia 6:566-591.

Madge, D. S. 1966. The significance of the sensory physiology of oribatid mites in their natural environment. Acarologia 8:155-160.

Nazarova, S. A. 1963. Vertical migrations of Oribatidae, intermediate hosts of Anoplocephala. In: Data from the scientific conference of the All-Union Society of Helminthologists. pt. 2. Moscow, 18-20[in Russian]. (Abstr. in Biol. Abstr. 45, no. 106749; 1964).

Oudemans, A. C. 1906. Nieuwe classificatie der Acari. Entomol. Ber. 2:43-46.

Oudemans, A. C. 1923. Studie over de sedert 1877 ontworpen systemen der Acari; Nieuwe classificatie; Phylogenetische beschouwingen. Tijdschr. Entomol. 66:49-85.

Oudemans, A. C. 1931. Acarologische aanteekeningen CXI. Entomol. Ber. 8:312-331.

Ovander, E. N. 1963. Notes on the distribution by stations of the central forest steppe of the Ukrainian S.S.R. /in Russian/. In: Problemy Paraxitologii. Akad. Nauk Ukrainsk. S.S.R., Kiev. 496-499. (Abstr. in Biol. Abstr. 45, no. 84634; 1964)

Petomkina, V. A. 1941. Contribution to the biology of Moniezia expansa (Rudolphi, 1810), a tapeworm parasitic in sheep and goats. Compt. Rend. (Doklady) Acad. Sci. U.R.S.S. 30:474-476.

Potemkina, V. A. 1944. On the decipherment of the biological cycle in Moniezia benedeni (Moniex, 1879), tapeworm parasitic in cattle and other domestic animals. Compt. Rend. (Doklady) Acad. Sci. U.R.S.S. 42:146-148.

Prokopic, J. 1962. Sezonni dynamika vyskytu tasemnic z rodu Moniezia a otazky vyvojovch cyklu techte tasemnic v pastvinarske oblasti Sumavy. Ceskoslovenska Parasitologie 9:355-364. (Abstr. in Helminthol. Abstr. 34: 187; 1965)

Ramsay, G. W. 1966. Two mew oribatid mites (Acari) from a New Zealand pasture. New Zeal. J. Sci. 9:416-425.

Roberts, F. H. S. 1953. Zygoribatula longiporosa Hammer (Oribatei: Acarina), an intermediate host of Moniezia benedeni (Moniez) (Anoplocephalidae: Cestoda) in Australia. Austral. J. Zool. 1:239-241.

Snedecor, G. W. 1956. Statistical Methods. The Iowa State Univ. Press, Ames, Iowa. 534 p.

Sokolova, I. B., and V. Y. Panin. 1960. The intermediate hosts of Moniezia, Thysaniezia and Avitellina in Kazakhstan /in Russian/. Akad, Nauk Kazakhskoi S.S.R. 12:145-149. (Abstr. in Helminthol. Abstr. 30:516; 1961)

Stoll, N. R. 1938. Tapeworm studies. VII. Variation in pasture infestation with M. expansa. J. Parasitol. 24:527-545.

Stunkard, H. W. 1937. The life cycle of anoplocephaline cestodes. J. Parasitol. 23:569.

Stunkard, H. W. 1940. The morphology and life history of the Cestode, Bertiella studeri. Amer. J. Trop. Med. 20:305-333

Stunkard, H. W. 1941. Studies on the life history of the anoplocephaline cestodes of hares and rabbits. J. Parasitol. 27:299-325

Subbotina, I. A. 1963. The problem of the vertical distribution of oribatid mites in winter in the loamy trongly podsolized soils of the environs of the town of Gor'kii. In: Notes on the scientific conference of the All-Union Society of Helminthologists. pt. 2, 100-111 /In Russian 7. (Abstr. in Biol. Abstr. 45, no. 84636; 1964)

Svadzhyan, P. K. 1962. Species composition of oribatid mites, intermediate hosts of Moniezia, their distribution and natural infection in Armenian S.S.R. /In Russian 7. Zoologicheski Sbornik. Akademya Nauk S.S.R. 12:163-178. (Abstr. in Helminthol. Abstr. 32:22; 1963)

Wafa, A. K., A. H. El-Kifil, and M. S. Tadros. 1964. Ecology and microdistribution of soil mites: ecological studies on oribatids in Giza region (Egypt). Acarologia 6:183-186.

Wallwork, J. A., and J. G. Rodriquez. 1961. Ecological studies on oribatid mites with particular reference to their role as intermediate hosts of anoplocephalid cestodes. J. Econ. Entomol. 54:701-705.

Zgardan, E. S. 1962. Oribatid mites and their seasonal dynamics in natural and artificial pastures in Moldavia /In Russian 7. Byul. Manchu. Tekh. Inform. Moldask., Manchu.-Issled. Inst. Zhivotnovodstvo i Vet., 143-152. (Abstr. in Biol. Abstr. 44, no. 1914; 1963)

APPENDIX A

THE NUMBERS OF MITES COLLECTED FROM WARD PASTURE IN SUMMER 1967 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'(1)	Quadrat	X	X'(1)
1	109	3.05	28	28	2.37
2	32	2.43	29	28	2.37
3	45	2.69	30	10	1.87
4	84	2.92	31	17	2.12
5	49	2.64	32	5	1.54
6	28	2.37	33	31	2.42
7	94	2.97	34	33	2.45
8	191	3.32	35	15	2.06
9	57	2.72	36	6	1.63
10	31	2.42	37	35	2.48
11	42	2.57	38	141	3.17
12	31	2.42	39	55	2.70
13	58	2.73	40	67	2.80
14	29	2.39	41	21	2.23
15	69	2.82	42	68	2.81
16	75	2.86	43	17	2.12
17	20	2.20	44	60	2.74
18	62	2.76	45	33	2.45
19	81	2.89	46	90	2.95
20	48	2.63	47	0	0.00
21	6	1.63	48	36	2.49
22	16	2.09	49	14	2.03
23	27	2.35	50	4	1.44
24	29	2.39	51	15	2.06
25	19	2.18	52	54	2.69
26	2	1.15	53	24	2.29
27	14	2.03	54	12	1.96

(1) $x^1 = k^{-\frac{1}{2}} \sinh^{-1}(kx)^{\frac{1}{2}}$; $k = 1.218$

APPENDIX B

THE NUMBERS OF MITES COLLECTED FROM WARD PASTURE IN FALL 1967 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'(1)	Quadrat	X	X'(1)
5	168	3.25	27	63	2.77
11	76	2.86	30	101	3.00
16	55	2.70	36	41	2.56
19	33	2.45	42	24	2.29
23	88	2.94	44	106	3.03
24	18	2.15	50	71	2.83

(1) See Appendix A.

APPENDIX C

THE NUMBERS OF MITES COLLECTED FROM WARD PASTURE IN WINTER 1968 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'(1)
1	32	2.43
7	5	1.54
10	16	2.09
16	11	1.91
24	17	2.12
29	6	1.63
32	13	1.97
35	15	2.06
40	12	1.96
45	92	2.96
48	60	2.74
52	23	2.27

APPENDIX D

THE NUMBERS OF MITES COLLECTED FROM ANA IN SUMMER 1967 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'[(1)]	Quadrat	X	X'[(1)]
1	42	2.57	16	75	2.86
2	78	2.88	17	129	3.13
3	219	3.39	18	92	2.96
4	11	1.91	19	146	3.19
5	88	2.94	20	98	2.99
6	10	1.87	21	337	3.60[(2)]
7	97	2.98	22	131	3.13
8	62	2.76	23	16	2.09
9	54	2.69	24	103	3.02
10	92	2.96	25	15	2.06
11	29	2.39	26	68	2.80
12	18	2.15	27	85	2.92
13	74	2.85	28	54	2.69
14	13	1.99	29	34	2.46
15	11	1.91	30	42	2.57

[(1)] See Appendix A.

[(2)] Calculated through $x' = k^{-\frac{1}{2}} \log_e((kx)^{\frac{1}{2}} - (1 - kx)^{\frac{1}{2}})$

APPENDIX E

THE NUMBERS OF MITES COLLECTED FROM ANA IN FALL 1967 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'[1]	Quadrat	X	X'[1]
1	8	1.76	14	12	1.96
2	52	2.65	15	18	2.15
3	256	3.46	16	33	2.45
4	77	2.87	17	74	2.85
5	15	2.06	18	86	2.92
6	30	2.40	19	20	2.20
7	2	1.15	20	154	3.21
8	51	2.65	21	103	3.02
9	32	2.43	22	148	3.19
10	164	3.24	23	49	2.64
11	45	2.60	24	24	2.29
12	62	2.75	25	81	2.89
13	715	4.55[2]	26	36	2.49

[1] See Appendix A.

[2] Calculated through $x' = k^{-\frac{1}{2}} \log_e \left((kx)^{\frac{1}{2}} - (1 - kx)^{\frac{1}{2}} \right)$

APPENDIX F

THE NUMBERS OF MITES COLLECTED FROM ANA IN WINTER 1968 AND THE CORRESPONDING TRANSFORMATIONS

Quadrat	X	X'[1]	Quadrat	X	X'[1]
1	14	2.03	13	19	2.18
2	55	2.70	14	4	1.44
3	133	3.15	15	2	1.15
4	31	2.42	17	13	1.99
5	48	2.63	18	100	3.00
6	6	1.63	19	38	2.52
7	18	2.15	20	26	2.33
8	55	2.70	21	123	3.11
9	106	3.03	22	162	3.24
10	35	2.48	23	11	1.91
12	67	2.80	24	64	2.77
25	23	2.27	26	15	2.06

[1] See Appendix A.

APPENDIX G

THE GROUND TEMPERATURES AND RELATIVE HUMIDITIES OF THE SUBSAMPLES FROM WARD TAKEN IN SUMMER 1967

Quadrat	t (F)	RH (%)	Quadrat	t	RH (%)
1	96	55	28	88	48
2	92	55	29	80	53
3	90	53	70	78	50
4	100	49	31	89	53
5	92	57	32	83	57
6	91	48	33	91	54
7	98	66	34	77	60
8	96	64	35	91	51
9	95	62	36	84	59
10	98	61	37	91	47
11	96	62	38	106	56
12	98	55	39	106	57
13	106	47	40	105	49
14	104	40	41	105	53
15	100	42	42	103	50
16	90	47	43	93	69
17	99	55	44	93	53
18	102	57	45	92	60
19	73	58	46	92	46
20	75	63	47	96	39
21	75	58	48	102	65
22	76	58	49	90	65
23	74	56	50	93	48
24	78	57	51	89	65
25	86	53	52	90	62
26	94	52	53	94	64
27	85	48	54	93	60

APPENDIX H

THE GROUND TEMPERATURES AND RELATIVE HUMIDITIES OF THE SUBSAMPLES FROM ANA TAKEN IN SUMMER 1967

Quadrat	t (^{o}F)	RH (%)	Quadrat	t (^{o}F)	RH (%)
1	71	80	16	68	80
2	90	72	17	88	64
3	81	78	18	86	64
4	78	70	19	75	80
5	79	54	20	82	53
6	70	80	21	82	61
7	88	65	22	83	59
8	82	66	23	88	56
9	79	75	24	75	79
10	83	67	25	84	55
11	75	68	26	82	64
12	82	70	27	79	63
13	81	65	28	71	75
14	72	84	29	84	61
15	75	58	30	82	74

APPENDIX I

THE GROUND TEMPERATURES AND RELATIVE HUMIDITIES OF THE SUB-SAMPLES FROM WARD TAKEN IN FALL 1967 AND WINTER 1968

Fall			Winter		
Quadrat	t (^{o}F)	RH (%)	Quadrat	t (^{o}F)	RH (%)
5	62	59	1	53	73
11	68	68	7	54	70
16	67	63	10	55	73
19	67	70	16	51	67
23	64	74	24	52	74
24	66	62	29	49	76
27	69	70	32	52	74
30	70	66	35	50	76
36	68	65	40	48	72
42	71	70	45	51	68
44	69	74	48	54	71
50	70	72	52	52	75

APPENDIX J

THE GROUND TEMPERATURES AND RELATIVE HUMIDITIES OF THE SUBSAMPLES FROM ANA TAKEN IN FALL 1967

Quadrat	t (°F)	RH (%)	Quadrat	t (°F)	RH (%)
1	52	69	14	64	62
2	51	63	15	63	76
3	55	76	16	51	56
44	55	74	17	54	68
5	64	64	18	54	84
6	50	81	19	54	86
7	51	73	20	71	73
8	54	82	21	60	75
9	55	73	22	57	78
10	58	70	23	60	76
11	62	84	24	65	77
12	53	72	25	59	72
13	55	78	26	56	72

APPENDIX K

THE GROUND TEMPERATURES AND RELATIVE HUMIDITIES OF THE SUBSAMPLES TAKEN FROM ANA IN WINTER 1968

Quadrat	t (^oF)	RH (%)	Quadrat	t (^oF)	RH (%)
1	54	71	14	57	76
2	60	67	15	45	90
3	60	68	17	62	71
4	46	87	18	60	76
5	46	78	19	54	80
6	53	71	20	47	87
7	55	72	21	44	85
8	61	72	22	44	80
9	47	87	23	47	80
10	47	80	24	53	83
12	58	63	25	48	84
13	63	72	26	45	82

APPENDIX L

TOTALS OF TRANSFORMED VALUES OF PAIRS OF DATA PRESENTED IN TABLE XVIII[1]

Grass	Date of Sampling					
	Oct. 1	Nov. 3	Nov. 20	Dec. 5	Dec. 20	Jan. 16
Broomsedge	5.47	5.01	9.35	7.44	7.41	4.93
Indian	8.30	3.53	4.54	6.69	5.73	8.61
S. gramma	6.36	5.89	4.79	9.99	5.81	7.37
Big bluestem	7.42	2.17	8.00	3.35	4.24	4.06
Bermuda	11.63	9.49	10.40	6.50	7.40	7.59
Pr. threeawn	5.06	8.43	13.56	5.40	4.12	10.86

(1) $k = 0.04$

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