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INSECTS AND OTHER MAJOR ARTHROPODS OF A TALLGRASS PRAIRIE

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ABSTRACT

Rangeland offers ideal habitats where populations of insects can multiply almost unnoticed. Ecological data are generally not available for insect herbivores, with the exception of some species of Acrididae.

Invertebrate data were obtained at the IBP Comprehensive Osage Site, Foraker, Oklahoma for 1970-1971. Eighteen collections were taken between July 3, 1970 and November 7, 1971 in grazed and ungrazed treatments. Each treatment consisted of two replications of five quadrats each. All biomass figures (g/m^2) and numbers (mean number/m^2) were obtained using a modified quick trap, vacuum collector combination.

Major groups of insects for the grazed and ungrazed treatments were Formicidae, Thysanoptera, and Entomobryidae, respectively. Secondary contributors were Sminthuridae, Coccoidea, Nitidulidae and Cicadellidae. Major groups of insects according to biomass were Formicidae, Cicadellidae, and Curculionidae, respectively. Secondary contributors were Gryllidae, Chrysomelidae, Acrididae, and immature Lepidoptera.

Total number of insects (mean number/m^2) were larger in 1971 than in 1970. Numbers were low in April and May but increased until July followed by a decline in August and September, moderate increases in October, and a decline in November. Trends of total invertebrate numbers were close to those of total insect numbers.

Biomass in the ungrazed area decreased in August while that of the grazed increased during both seasons. Peaks of biomass occurred

in the latter part of August in both 1970-71 in the grazed and ungrazed areas. Biomass declined in September, stayed approximately the same in October, then tapered off in November.

Araneida numbers were lower than other invertebrates but biomass exceeded .01 g/m^2 in several collections. Biomass was found to be highest when numbers were lowest, in April, May, June, and August on the ungrazed treatment. Biomass in the grazed area generally followed the mean $number/m^2$.

Acarina numbers were generally higher in the grazed than the ungrazed treatment. The grazed treatment supported greater biomass than the ungrazed in both 1970 and 1971.

For 1971, it was estimated that an average of 59 per cent of the total invertebrate biomass in the ungrazed and 66 per cent in the grazed treatment was composed of herbivores.

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INTRODUCTION

Although some progress has been made in understanding the function and interaction of invertebrate fauna in a community, studies of this type are largely in an infant stage of development (Elton and Miller 1954).

Ahring and Howell (1968) stated that the gradual development and lack of uniform maturity, characteristic of most forage grasses offer ideal habitats where populations of small insects can multiply almost unnoticed; they are so abundant that no doubt they are important in the ecology of Oklahoma grasslands.

This study involves investigation of a grassland ecosystem located at the International Biological Program Grasslands Biome Osage Comprehensive Site near Foraker, Oklahoma. The Analysis of Ecosystems program is designed to supply basic information through a comparative study of six major biomes: Grassland, Deciduous Forest, Coniferous Forest, Desert, Tundra, and Tropical Forest. The objectives for each biome are: (1) to elucidate productivity, nutrient cycling, energy flow, and other characteristics of ecosystems in a set of distinct environments; (2) to determine the driving forces, the processes causing transfers of matter and energy among components, and the controlling variables in each biome; (3) to determine the ecosystem response to the natural and man-induced stress appropriate to each biome; (4) to understand the land-water interactions characteristic of each biome; and (5) to synthesize the results of these and previous studies into predictive models of temporal variation, effects of pollutants and of exploitation, stability, and other ecosystem characteristics necessary for resource management in each biome (IBP Newsletter 1971).

Questions about the actual impact of insects in grasslands occur as more materials are removed from this ecosystem for products of human consumption. Will grass species composition change, bringing a change in insect fauna? Do grasslands now house a latent supply of insect species which would become major pests of grassland if production were intensified? Will new pests invade a changed ecosystem? These and other questions stress the need for basic research to develop better methods of collecting, handling and interpreting biological data so that resulting principles can be used in population regulation if and when necessary.

The objectives of this study were: (1) to determine the trophic level of each group of invertebrates; (2) to provide information on the role of certain major groups of invertebrates in the grasslands; (3) to obtain estimates of the numbers and biomass of above-ground invertebrates, and (4) to check the accuracy of the collecting methods employed. A survey of this type is necessary before deciding which species are herbivores or detrimental and which need concentrated study.

Hanson and Vorhies (1938) observed that most insect pests in grassland regions are native species and that efficient control must be based on knowledge of interrelationships, behavior, life history and protection in the natural environment. Morris (1965) notes that many elements in a life system affect natality or mortality, but a few critical influences may largely determine population trends.

Smith (1940) indicated that in overgrazed mixed-grass prairie in Oklahoma the total population of insects was about four times as large as normal and that the basic problem in grasslands is overgrazing. Evans and Murdoch (1968) on Michigan old field grassland found that the feeding relationships imposed on the insect community persist in spite of a continual seasonal replacement of species.

Pepper (1955) stated that until quantitative data are made available for insect species, management of insect populations will have to come from principles developed through studies on other animals.

Ideally, this study will provide some of the much-needed information on the role of insects in tallgrass prairie.

LITERATURE REVIEW

Fundamental quantitative research on grassland invertebrates has been very limited. Many early investigations have been concerned with grazing capacity of an area or the control of undesirable species. Control of certain insects has been attempted often without knowledge of its overall effect on the grassland ecosystem.

In the past only short studies have covered such fundamental topics as the quantitative composition of the insect fauna and its variability in relation to season, the influence of climatic and soil conditions on the fauna, and the interrelations of plant and insect fauna (Hanson and Vorhies 1938). They state that grassland investigation of a quantitative nature, continued over many years in one location, is absolutely essential to furnish the fundamental facts and biological concepts of the grassland ecosystem. Price (1971) states that plot techniques have been invaluable in obtaining good estimates of insect populations and their change in time. By sampling insects flying from a plot Dempster (1968) found a density-dependent dispersal by herbivores and explained much of the sudden drop in insect numbers within a plot this way.

Insect studies in grassland have concentrated mostly on overt injurious species; therefore, most work is focused on Acrididae. It has become apparent, however, that many herbivorous insects reduce primary productivity either by reducing total biomass or lengthening the period of attainment of total biomass.

Sampling Apparatus (sampling enclosure)

Difficulties involved in quantitative invertebrate sampling include construction of traps of a known surface area which do not disturb the fauna, removing specimens from the enclosure, and processing them in the laboratory.

Hills (1933) used a cylindrical cage mounted on a 136.8 cm pitchfork handle. The cage was covered with cloth; the lower edge of the metal was ground to a knife edge so it would easily sink into the soil. A hole 15 cm in diameter was cut in the side of the cage opposite the handle and was fitted with a sleeve to allow entrance into the cage. Insects were removed by a battery-powered vacuum collector; the blower fan was that of an automobile heater.

Smalley (1960) used a one meter square cage covered on the sides and top with fine mesh copper screening to sample grasshoppers in a salt marsh. The cage was held by two men who ran over the marsh, and at a signal, placed the cage sharply down on the ground. Grasshoppers were removed by hand.

Smith and Stewart (1946) designed a screen cage which could be tossed ten to fifteen feet; after landing a tray was worked under the cage. This method worked satisfactorily for all grasshopper instars in pasture land and for light stands of alfalfa and ragweed.

Beall (1935) used a metal drum 42.8 cm in diameter and 30.4 cm in height to sample herbage. An anaesthetic was poured in a hole in the top of the drum after it was placed over the vegetation. After soil was removed from around the drum, the drum was lifted, and the column of soil remaining was removed.

Wiegert (1961) designed a screen-covered cylindrical cage with a Mason jar lid soldered to the tip of a metal cone. The jar acted as a collecting device when the cage was turned over and proved to be adequate for the collection of adult spittlebugs which he could approach to within a few feet without inducing flight.

Turnbull and Nicholls (1966) constructed a spring-operated trap for area sampling of arthropods in grass communities. It was designed to drop quickly on the area to be sampled when triggered from a distance, thus not disturbing insects in the area to be sampled. The trap consisted of a folding tripod within which a screened cage was suspended. A main feature of the trap was the use of tension springs attached to the cage to allow a sudden release when the tripping mechanism was released. The trap was erected at least 24 hours before it was sprung to permit the fauna to redistribute over the area disturbed by erecting the trap. The diffuse shadow cast on part of the sample area did not seem to produce any measurable bias in the distribution of arthropods. The quick trap sampled a $1/2m^2$ area. Arthropods were removed from the cage by a vacuum collector.

Sampling Apparatus (vacuum collectors)

A number of vacuum collectors have been constructed. The most widely used was devised by Dietrick (1961).

Johnson et al. (1955) developed a portable electric-powered vacuum collector that took almost a complete sample from various types of grassland. The greatest extraction was of Collembola, Thysanoptera, Auchenorhyncha, Aphidoidea, Heteroptera, Diptera adults, and parasitic Hymenoptera, and the lowest extraction was of Coleoptera larvae, Chilopoda and Diplopoda. Kennard and Spencer (1955) described a similar, but smaller machine for sampling fauna of mango flowers at heights up to 20 feet. Remane (1958) briefly mentioned quantitative sampling of Homoptera (Auchenorrhyncha) by a type of vacuum cleaner driven by a 500 cc gasoline engine.

Dietrick et al. (1959) have described a gasoline engine with a motor fan adapted to suck arthropods, along with trash, from square-foot areas of an alfalfa field into a collecting bag without damage. Living organisms were immediately refrigerated to retard predation and general exhaustive activity. They did not measure the efficiency of their machine, but they were able to gather all possible organisms by manually clearing the habitat. Dietrick (1961) produced a small motorized sampler that could be carried strapped on the operator's back. This apparatus was modified and used in gathering of samples for this study.

Southwood and Pleasance (1962) devised an inexpensive hand-operated vacuum collector. It was constructed from a gear-box, fan, and casing of a hand-dusting machine, with a metal cylindrical suction chamber and a suction hose fixed to the intake which provided the vacuum. Efficiency was low for larvae of Coleoptera and Diptera, but the Homoptera (Auchenorrhyncha), Heteroptera, adult Diptera and surface-dwelling Collembola the extraction rate was over 95 per cent.

Heikinheimo and Raatikainen (1962) state that the advantages of the vacuum method are as follows: (1) samples are obtained from well-defined areas; (2) arthropods of the different vertical layers in the field stratum and even of the ground will be equally and well represented in the samples; (3) the representatives of most arthropod groups are caught more quantitatively by this method than by a netting method; (4) samples can be taken from plots without plant cover or covered by low vegetation; (5) the errors introduced by weather components, time of day, type, density and height of vegetation, and sampler are less than in a netting method. They found that the efficiency of their vacuum collector, using Calligypona pellucida (F.) as an experimental subject, revealed a highly significant difference between the capture of adults and nymphs (87.5 and 74.8 per cent efficiency, respectively).

Turnbull (1966) provided an efficiency test on a vacuum collector modified from the one designed by Dietrick. Modified Berlese funnels were used to extract the arthropods, and 96.2 per cent were removed by the vacuum collector; 12.1 per cent of the homopterans, 12.5 per cent of Hemiptera larvae, 6.9 per cent of coleopterans, and 10.0 per cent of the dipterous larvae were missed. All Araneida, Lepidoptera, hemipteran adults, Thysanoptera, Orthoptera and 97.7 per cent of the Acarina and 96.2 per cent of the Collembola were picked up. Whittaker (1965) obtained an extraction rate of 87 per cent for Auchenorrhyncha

(Cercopidae) using a vacuum collector. Kauri et al. (1969) found the vacuum collector effective for Aphidoidea and Cicadoidea. Only a small portion of Collembola and Acari, 16 per cent and 13 per cent, respectively, were taken with only one suction and no clipping. They obtained best extraction results by vacuuming the vegetation, then clipping and removing the plant material for extraction in Tullgern funnels, and then vacuuming again. After the first vacuuming, 71.4 per cent of the individuals were left in the sample plot. They reported 23 per cent of the Coccoidea were taken by a vacuum collector before vegetation was removed.

Sampling Apparatus (sweep net)

Grassland communities are commonly sampled with a sweep net even though faults and biases of this method have been known and demonstrated (DeLong 1932, Southwood and Pleasance 1962, Carpenter and Ford 1936, Dietrick et al. 1959, Hughes 1955, Rommey 1945). The sweep net fails to give a true or consistent census of the area sampled and data are biased (Turnbull and Nicholls 1966).

Heikinheimo and Raatikainer (1962) state that the disadvantages of the netting method are: (1) the samples can not be referred to clearly defined areas; (2) the samples are better representative of the fauna in the upper part of the plant cover than of the lower strata; (3) the errors caused by type, height and density of vegetation and by time of sampling are higher than with a vacuum method; (4) the greater part of the arthropods evade capture. The netting method may be more efficient than the suction method in sampling work with the Thysanoptera and Diptera, and probably with adult Lepidoptera.

Hughes (1955) found the behavior of females of *Meromyza variegata* (Chloropidae) under different weather conditions is reflected in sweep net catches more than the behavior of the male of the same species. Wind speed seems likely to be the major weather factor affecting smaller insects, but extremes of any factor may also substantially alter the number caught. DeLong (1932) and Rommey (1945) have shown that the weather will affect the sweep net catches of insects other than *M. variegata*. Green (1969) found that Cicadellidae are not particularly active in temperatures below 14.5 C. Lower temperatures forced them close to the soil surface where they were difficult to collect with a sweep net. Wind also caused leafhoppers to remain within the protection of the host plant.

Beall (1935) felt that a different conversion factor should be used for each species for the calculation of populations. Between 6 and 9 6.3 meter strokes indicate the population of one square meter. Menhinick (1963) found that jumping insects such as Membracidae, Cicadellidae, Fulgoridae, Gryllidae, and Acrididae were less easily captured by a sweep net than other families in a stand of *Lespedeza cuneata*. The number of sweep-strokes equivalent to one m^2 varied from 2.3 to 10.8 depending on the species and weather conditions.

Menhinick (1967) calculated the equivalent number of sweep-strokes required to capture the insects present on one m^2. Results showed 17.5 sweeps for adult Tettigoniidae, Acrididae, Odonata, and butterflies, 3.2 for Curculionidae, 4.5 for Formicidae, 2.7 for Asilidae, 3.2 for Lygaeidae, 7.7 for Membracidae, and 6.5 for other Homoptera were necessary.

Rommey (1945) found that the percentage of beet leafhoppers caught by a brisk-sweep method was similar for adults as compared to a cylinder method but much lower for nymphs. Turnbull and Nicholls (1966) stated that sweep nets miss large proportions of every group, especially Collembola and mites. This method is more accurate for grasshoppers, Heteroptera, Hymenoptera, and Diptera.

Sampling Apparatus (pitfall traps)

Pitfall traps are useful collecting devices. With caution they may be used to study daily rhythm, seasonal trends, and dispersion of a single species in one type of vegetation (Southwood 1966). Grüm (1959) found invertebrates to be influenced by changes in activity due to weather conditions and variation in their life stages. Greenslade (1964) reported pitfall traps as disadvantagous because catches are dependent both on the density of the population and the activity of individuals in the population. A jar sunk in the soil with the lip level with the soil surface, within a 60 cm diameter area from which vegetation was removed, resulted in high catches of Carabidae. He found baited traps had no effect on the catch.

Doane (1961) collected Tettigoniidae, Acrididae, Ichneumonidae, Formicidae, Carabidae, Tenebrionidae, Silphidae, Chrysomelidae, Curculionidae, Cicindelidae, Scarabaeidae, and Arachnoidea with a funnel pitfall trap in a continuously cropped wheat field. Duffey (1962) used jam jars as traps for spiders. In windy weather, however, a grass stalk or leaf could blow in and provide an escape route, or rain could erode away soil around the jar rim and prevent the trap from operating efficiently.

Southwood (1966) noted that large species of arthropods can damage or consume smaller ones before the traps are emptied. Williams (1958) produced a trap to separate the catch into six periods of activity during a day; however, this trap underestimated numbers of oribatid mites and parasitic Hymenoptera. In comparing glycerine in Stictite as a holding agent, 1.5 times more Collembola, and 2.5 times more parasitic Hymenoptera were collected in glycerine. Boyd (1957) used 10 cc of strong formalin in each trap to prevent decay of the catch if rainwater collected. Small mammals, Lumbricoids, Insects, and Arachnids were obtained during the trapping period. Turnbull and Nicholls (1966) found that pitfall traps captured 21 species of spiders that were not taken by the quick trap method.

Sample Extraction (Berlese funnels)

Haarlov (1947) used a Tullgren apparatus to obtain Collembola and Acarina from soil samples and found that greatest emigration occurred during the first hour. Sources of error could result from dew formation on the inner side of the funnel or the sudden change of temperature acting as a "temperature shock" to specimens. The maximum temperature in the sample should not rise above that of the localities investigated. Raw (1956) reported that the use of a modified Berlese funnel appeared to be more suitable for litter than soil samples in the extraction of Protura.

Clark et al. (1959) found that pink bollworm larvae could be driven from cottonseed by using 43 C temperature for 30 to 60 minutes on three consecutive days in a Berlese funnel. Larvae could not withstand temperatures above 115 F. The larvae of a phorid fly and other saprophagous flies and boll weevils also were driven out of cracked green bolls. A grid-type heating system was used which provided a more even heat distribution.

Turnbull (1966) reported that loss of invertebrates in litter processed by Berlese funnels is minor. Of 21 animals recovered, 12 were mites, 3 were Thysanoptera, 5 were Homoptera nymphs, and 1 was a spider. Huddleston et al. (1969) reported incomplete extraction of insects from litter in Berlese funnels; extraction was least efficient for Collembola and leafhopper and planthopper nymphs.

Dondale et al. (1971) chilled and treated samples with CO_2 while still in collecting bags before transferring them to a Berlese-Tullgren funnel. Ventilator screens were used to permit escape of moisture from litter which could condense on the walls of the funnel and trap descending arthropods. Staphylinidae are killed in litter if a high temperature is applied at the onset. Grasshoppers become active at high temperatures causing more litter to descend into the collecting container. Temperatures of 40 C or less will not clear litter of mites, spiders, and many beetles.

Dietrick et al. (1959) placed a 75-watt spotlight directed upward from below the alcohol jar attached to a Berlese funnel which resulted in a positive phototropic gradient toward the alcohol trap. Trash should be kept to a minimum and dispersed enough to allow the light from below to shine to the top.

One advantage of the Berlese method is the excellent conditions of specimens preserved in alcohol. The sample can be counted at a future time. Edwards and Fletcher (in press) stated that when funnels are kept in a well-ventilated constant temperature room their efficiency is increased. Picric acid or 70 per cent ethyl alcohol with 5 per cent glycerol are better collecting fluids than distilled water.

Literature on the role of invertebrates in tallgrass prairie is found in the appendix.

MATERIALS AND METHODS

The Study Area

The site is located on the K. S. Adams Ranch. It is a functional beef ranch now operating under the direction of Mr. Dick Whetsell, Foraker, Oklahoma and is located in Osage county in the northeast corner of Oklahoma. Elevation is 1250 feet on mostly rolling topography. Average January temperature is 2.4 C and the average July temperature is 27 C. Average annual precipitation is 36.6 inches with 25.0 inches during the April to September warm season. The growing season is 205 days. The soil is a Brunizem of the Labette-Summit-Sogn association. These are dark colored soils mostly with clayey subsoils developed on shales, sandstones, and limestones under tallgrass (Risser 1970).

The experimental design utilized two areas. The ungrazed control was a 12.6 acre (150 by 330 meters) rectangle which had been ungrazed (but probably mowed) for approximately fifteen years. The grazed area was adjacent to the control area. It was lightly to moderately winter-grazed from mid-October to mid-May. No grazing occurred during the invertebrate collecting season.

Both the grazed and ungrazed treatments had not been burned or subjected to other major disturbance for a number of years. Each treatment had a 15 to 20 acre pond within 1,200 to 1,300 feet of the collecting areas which accounted for the presence of aquatic fauna.

The major grass species in both treatments were *Andropogon scoparius* (little bluestem) and *Panicum virgatum* (switchgrass). followed in importance by *Sporobolus asper* (tall dropseed), *Sorghastrum nutans* (Indiangrass), *Andropogon gerardi* (big bluestem), *Bromus japonicus* (brome grass) and *Poa pratensis* (Kentucky bluegrass). Table 1 lists the plant species and frequency data for 1971.

Collections

Collections were made from July 3, 1970 through November 7, 1971. The months of December 1970 and January-March 1971 were excluded due to low insect numbers and overall inactivity. Collections were taken biweekly from June through August and monthly in April, May, September, October, and November. Collecting methods corresponded closely to the methods in IBP Technical Report No. 85 (French 1971). Samples were taken between 10 A.M. and 4 P.M. using a modified Turnbull and Nicholls quick trap. The traps were developed at the IBP Pantex Comprehensive Site. Traps were further modified by the author to reduce sources of error in the collections. A total of ten samples per treatment was taken on all collection dates (Table 2).

The experimental design allowed the quick traps and the vacuum collector to be moved through the treatments keeping undisturbed rangeland available for sampling throughout the collecting season. Each treatment area (grazed and ungrazed) was placed on a grid system which allowed a predestined position for each quadrat to be sampled. Each treatment had two replicates with five quadrats per replicate. The grid was approximately 150 by 330 meters. The quadrats were approximately 15 meters apart. For the 1970 collections the traps were kept on a lengthwise transect by an alphabetical designation (A-J) across the width of the treatment. In 1971 the quick traps were shifted approximately 15 meters from the 1970 positions. This allowed areas not sampled in the 1970 season to be sampled in 1971. By proceeding in this manner an overall survey of each treatment was taken with a reduction of the possibility of excluding a portion of the insect fauna because of an unknown distribution pattern.

Each season quick traps were placed at the edge of the grid on the first transect designated (A). The transects were approximately 10 meters apart. With an A-J designation ten collections could be taken per season. If more collections were desired, the traps could be moved to the opposite side of the grid and shifted left or right to provide an undisturbed sampling area several meters from the original quadrats.

The sampling method allowed quantitative estimates of invertebrate numbers and biomass. Modifications consisted of using the gravitational method of dropping rather than the original spring-type apparatus. The tripod which provided the height and support for the cage enclosure was constructed of 2.5 cm aluminum poles 3.5 m in height.

To reduce tipping in strong winds which occur on tallgrass prairie of Oklahoma, a hole was bored in the bottom flat base on the middle support pole of the tripod. A 21.6 cm bridge nail was driven through the hole after the tripod was placed in position (Fig. 1). The direct pull of the cord which held the cage was opposite the middle supports. A bridge nail secured the quick trap and eliminated problems resulting from the suspended cage swaying in a strong wind.

The poles were flattened at both ends to allow attachment at the top and a resting surface at the bottom. Two holes were bored at the distal end of all three poles. The flattened distal portion of two poles was bent to a 45 degree angle; hence, when all poles were bolted together with stove bolts, a stable tripod structure was formed (Fig. 2). A forked piece of metal was welded to the middle support pole, and an eyebolt was bolted in the fork structure providing a simple suspension mechanism for the cage (Fig. 2). This allowed the nylon cord which held the cage to glide through the structure freely when released.

The nylon cord used to suspend the cage was knotted on one end and placed through a flat washer welded to the cage frame. The opposite end was fastened with a slip knot to a 21.6 cm bridge nail. The nail, when driven into the soil, adequately held the cage in its suspended position. This method worked favorably in both dry and moist soil. The lower edge of the cage was approximately one meter from the soil surface when the trap was in position.

Cages (Fig. 4) were constructed of two cm metal strips; the circular enclosure was $1/2m^2$. Each was covered with 16 mesh wire screen. A strip of parachute cloth sewn to the bottom of the screen enabled it to be fastened, without tearing, by placing a second metal strip at the bottom and attaching with stove bolts. A circle was cut in the top

EXPLANATION OF FIG. 1

A 21.6 cm bridge nail was used to anchor the tripod; this prevented overturning of the quick trap in strong winds.

EXPLANATION OF FIG. 2

The drop mechanism of the quick trap was constructed of a forked metal structure with an eyebolt securely fastened; the distal end of the poles was flattened and bolted.

Fig. 1

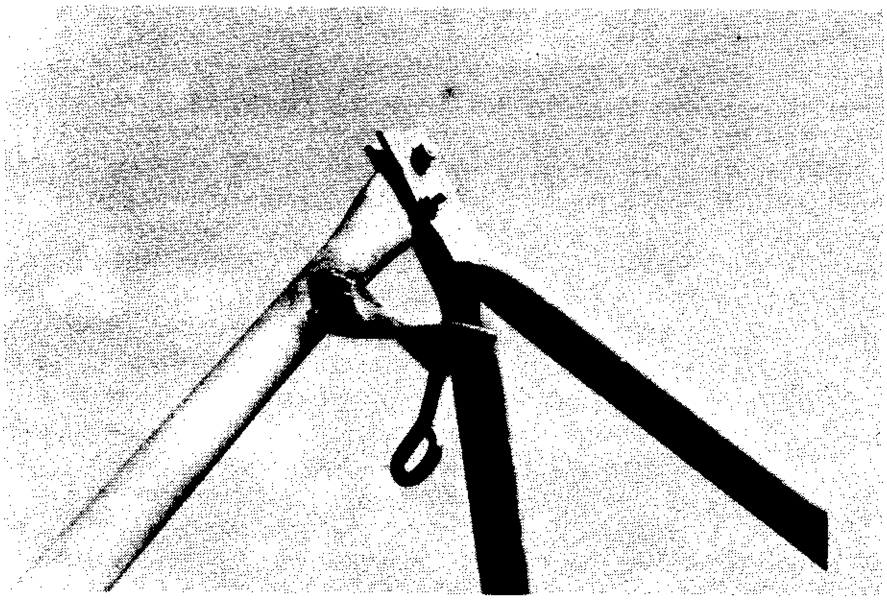


Fig. 2

of the screen for a cloth sock which gave entrance to the cage. The sock could be easily knotted and untied.

Total cage height was 81 cm (Fig. 4) to accommodate the height the grasses attained during a normal growing season. The weight of the cage allowed it to drop quickly, and the cage was light enough for suspension from the tripod and easy handling by field workers.

Removal of Samples From Quick Traps

Arthropods were removed from the cage with a commercial vacuum collector manufactured by the D-vac Company, Riverside, California. Modifications were made for better application to the quick traps and for transporting the engine from quadrat to quadrat in the two treatments. To make extraction feasible, a tin reducing cone was attached to the fiberglass cylinder (Fig. 3). The cone reduced the diameter of the inlet tube from 36 to 12 cm. In 1971, a plastic dryer-ducting hose, obtained at a Sears outlet, was used to replace the canvas tubing on the reducer cone. The plastic hose permitted free movement of moist soil and litter and prevented clogging which often occurred with the canvas tubing. Plastic hose does not work well during cold or freezing weather; therefore, a spare canvas hose was kept on hand for the fall collecting periods. The dryer-ducting hose was 3.1 meters in length, 12 cm in diameter, and was taped to the reducing cone elbow joint (Fig. 3). The elbow joint was a commercial stove pipe neck 12 cm in diameter with one end tapered so the fit into the reducing cone was secure. The joint helped reduce clogging at the point where the litter entered the cone. A tin cylinder 12 cm in diameter and 12 cm in length

EXPLANATION OF FIG. 3

Vacuum collector and associated collecting apparatus; the plastic collecting hose, the reducer cone and elbow joint, the cooling chest, and the collecting cart.

EXPLANATION OF FIG. 4

Modified Turnbull and Nicholls quick-trap; suspension of the cage by nylon cord, parachute material fastened to the bottom of the wire screen, and the overall height of the trap.

Fig. 3

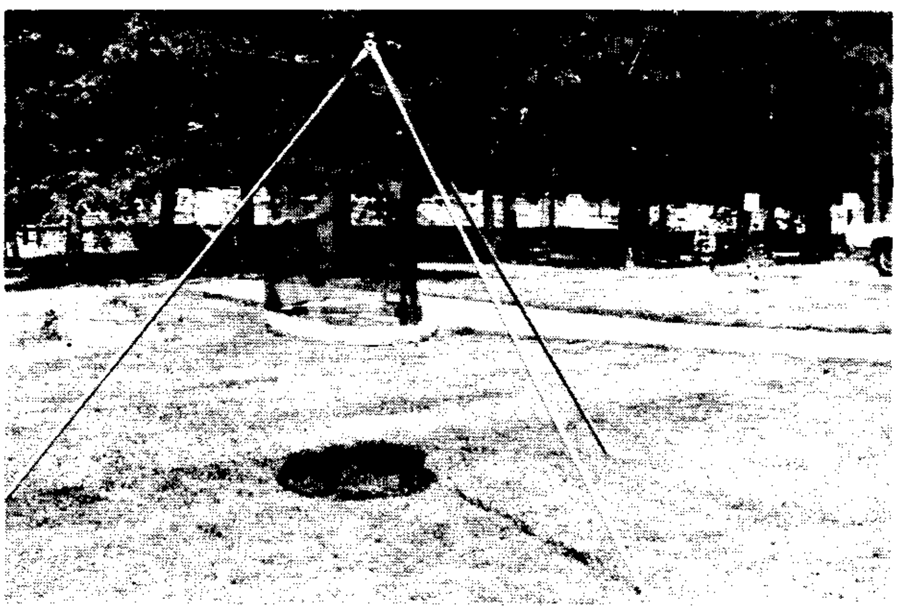


Fig. 4

was placed inside the distal end of the ducting hose. Five cm were left exposed and the connection was taped. This provided a rigid structure to apply to the soil surface and bunch grasses during the vacuuming process. The primary function of the adapter hose was to increase air velocity, and hence suction power, in order to obtain all the plant material and litter. The air chamber behind the hose inside the reducing cone acted as a reducing chamber which kept the increased suction from injuring organisms as they were picked up with the litter.

A second modification removed the D-vac engine from the original back-pack and mounted it on a three wheel cart (Fig. 3). The cart, using 48 cm diameter bicycle wheels for ample clearance of the vegetation when pulled from quadrat to quadrat, made transporting of the vacuum collector within the treatments less time consuming and reduced the disturbance of the surrounding environment. The only resulting disruptions of the environment were the imprints left by the tires of the cart and the field workers.

Another advantage of the cart was that an ice chest could be carried. The samples were placed in the chest and cooled after being removed from the vacuum collector; this helped reduce predation rates by slowing arthropod activity.

After the first collection (July 3, 1970) it was obvious, due to large amounts of vegetation, that the quadrats would have to be clipped near ground level to provide better assessment of the invertebrate population. After the cages were dropped, the quadrats were clipped using hand-powered grass clippers, and clippings were placed in commercial paper sacks and saved for extraction.

Starting with the June 19, 1971 collection, Sunbeam electric clippers with a Stewart-Shearmaster nine point comb cutting head were used. The comb was 0.8 cm between points allowing large forbs to be clipped as well as grass. Power for the clippers was supplied by a portable Tecumseh 3 HP four cycle engine-generator complex mounted on a two wheeled moving cart. Electric clippers gave an even, closer cut of vegetation allowing better extraction by the suction apparatus.

After clipping and removing of the vegetation, the quadrats were vacuumed. The pattern of movement of the adapter hose and nozzle was the same on each quadrat to insure consistency. The nozzle was held approximately 1.5 cm above the soil surface and moved from side to side in the cage until the total area was covered. The nozzle then was placed firmly on the soil, and the area was again covered in the same manner. The top and sides of the screen were then vacuumed to collect any flying insects. The average vacuuming time per quadrat was five minutes.

Invertebrates and litter were collected in nylon D-vac bags. The vacuum collector was left running to keep a constant vacuum on the sample while it was being removed from the fiberglass collecting chamber. This procedure prevented flying insects from escaping when the adapter cone and the collecting bag were removed. Identification labels giving treatment, replicate, and quadrat were placed in each sample. Bags were knotted and placed in a large Coleman ice chest lined with industrial plastic bags which prevented samples from becoming damp as the ice melted. A 25 pound block of ice adequately cooled each ice chest.

Processing of the Samples

Samples were returned to the laboratory and placed in modified Berlese funnels for 48 hours. The invertebrates were collected in 70 per cent isopropyl alcohol, and the litter was then removed from the funnels and saved for hand-sorting. Grass clippings were likewise processed; however, since only one specimen was recovered from the hand-sorted grass clippings of the July 3 and 16, 1970 collections, this procedure was discontinued.

The vacuum samples were hand-sorted by placing the sample in a 30 x 48 cm dissecting tray and examining with a 2X hand lens. Specimens found were recorded by number and weighed with the rest of the sample. Sorting was done under a stereoscopic microscope at 10X with the samples in petri dishes.

Identification of adults was to family in most cases, whereas immatures were identified only to order. Families were kept separate in four dram vials so they could be weighed by replicate; weighing per quadrat would not have been feasible due to small amounts of biomass. Numbers of families were recorded by quadrat.

Specimens were oven-dried at 60 C for 24 hours and weighed on a Mettler balance to ten-thousandths gram accuracy.

Construction of Berlese Funnels

Berlese funnels were constructed to accommodate the large quantities of grass in both the clipping and vacuum samples.

The modified funnels (Fig. 5 and 7) were constructed from galvanized cans 30 cm in height with the bottom removed. A tin reducing cone was

EXPLANATION OF FIG. 5

Modified Berlese extractors showing general construction and method of suspension; four such units were used, thus twenty samples could be processed at once.

EXPLANATION OF FIG. 6

The generator complex and clippers used to clip the plots after the cage of the quick trap had been dropped.

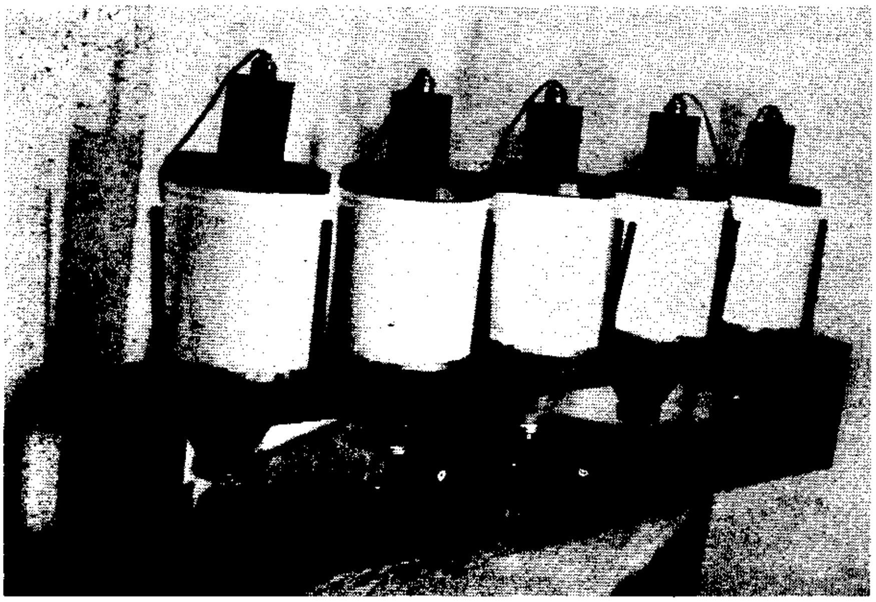


Fig. 5

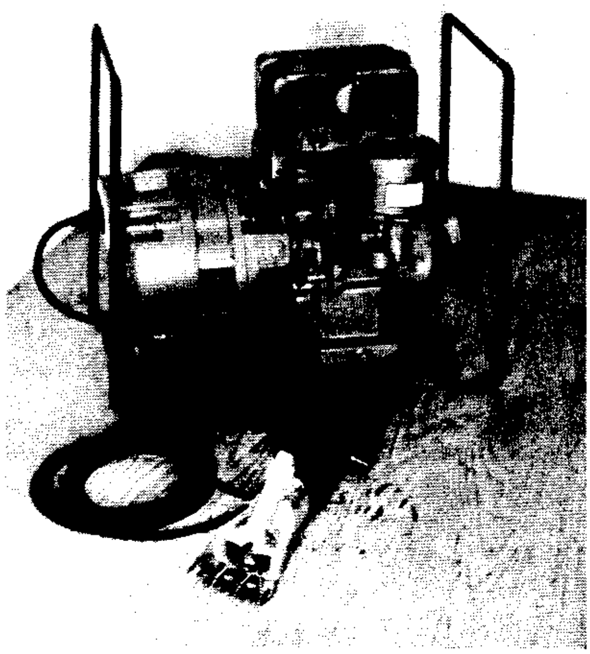


Fig. 6

EXPLANATION OF FIG. 7

A three mesh wire screen held the bulk of the sample 23.5 cm from the top of the cylinder; diameter of the cylinder was 26 cm.

EXPLANATION OF FIG. 8

Modified Berlese extractor showing collecting jar attachment, height of the cylinder, light fixture, and reducing cone.

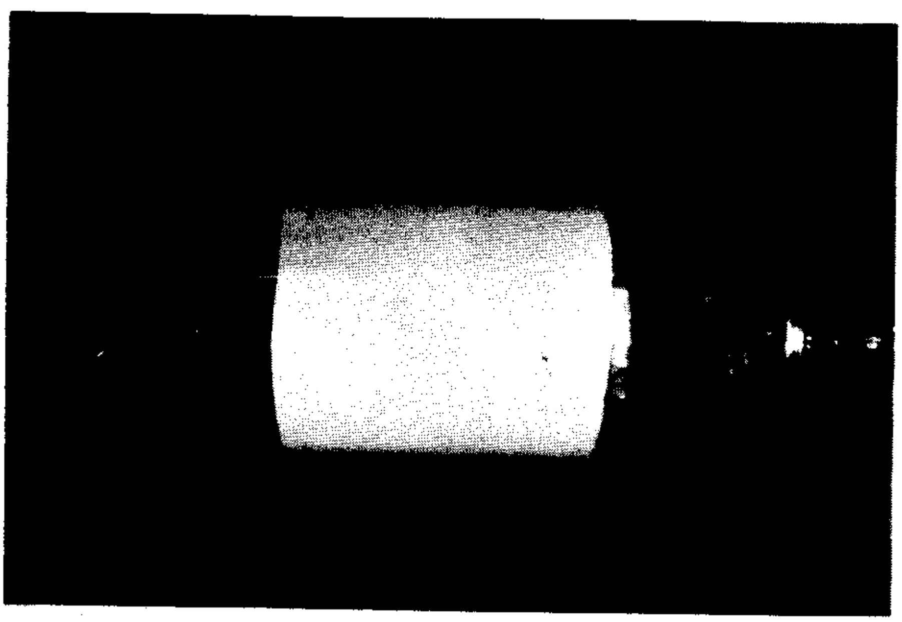


Fig. 7

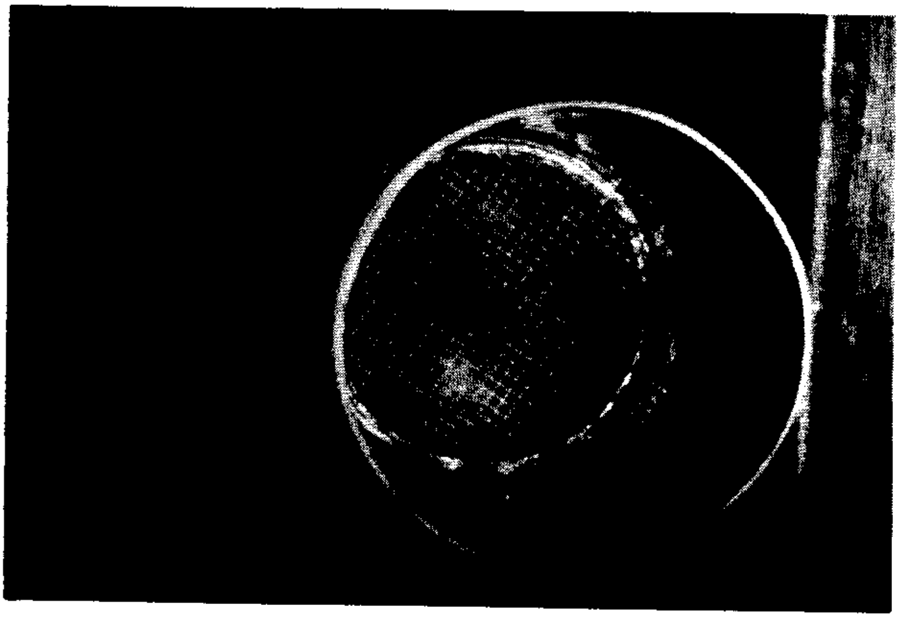


Fig. 8

soldered to the bottom of the cylinder. A pint Mason jar lid was soldered to the apex of the reducing cone so that jars could be attached and removed quickly. The inside diameter of the cylinder was 26 cm.

The lid was converted into the heat source by cutting a circle in the center and soldering an oil can to the top of the lid (Fig. 5 and 7). A circle was then cut in the top of the oil can, and a light fixture was soldered in the opening. A 60 watt bulb was used to supply the heat. Holes 0.6 cm were bored in the tops of the oil cans around the outer edge, thus preventing heat build-up and possible combustion of the grass samples.

Two wire screens of 3 and 16 mesh hardware cloth were used in the cylinder to trap grass and large soil particles. The top screen could be removed to clean the second screen or for removing the samples. The sides of the bottom screen were soldered to the bottom of the cylinder, and a small opening was cut in the center to allow invertebrates to escape. Twenty funnels were used, and all samples could be processed concurrently. Funnels were set in wooden frames that held five funnels each (Fig. 5).

Other Sampling Methods Used as Efficiency Checks

Sweep net samples were taken with a standard 15" diameter net on both grazed and ungrazed treatments. One sweep per meter for 100 meters was taken. This material was placed in gallon ethyl acetate kill jars which kept the insects in a relaxed condition. After identification, material was pinned for a representative collection of the Osage Site species.

Pitfall traps were placed in both grazed and ungrazed treatments; these were pint jars, placed with the top lip even with the soil surface. A 1.5 cm layer of glycerine was added to each trap because the viscosity is such that invertebrates were held once they came in contact with the fluid. The evaporation rate of glycerine is small, and traps can be left in the field for long periods of time. Six traps were placed in each treatment on a transect covering the length of the treatment. They were removed at approximately two-week intervals and taken to the laboratory for processing.

Specimens were removed by placing a teaspoon of kerosene in the jar, then adding 250 ml of tap water. The contents were then stirred vigorously and allowed to settle. Specimens held in kerosene were removed and placed in a petri dish of 70 per cent isopropyl alcohol for examination.

Efficiency Check of the Vacuum Collector

To obtain an estimation of the efficiency of extraction with the suction apparatus, a quick trap was placed in the grazed treatment and left for four hours to let the insect fauna stabilize. The trap was dropped, and the vegetation was clipped and removed. The enclosure was then vacuumed for one minute in the standard manner, and the collecting bag was then removed and labeled. This procedure was repeated five times, and the samples were returned to the laboratory for extraction. This was done on July 25, August 6, and August 20, 1971.

Efficiency Check of the Berlese Funnel

Berlese funnel extraction efficiency was checked to determine if all invertebrates were being removed. A flotation method was used on several samples after they had been in the funnels for 48 hours. These samples were taken from the material which was usually hand-sorted. A sample was placed in a 4000 ml flask with 2000 ml of tap water. The flask was heated under 25 lbs of vacuum and allowed to boil for five minutes to remove gasses from the plant material. The flask was then removed, and the contents were placed in a 6000 ml beaker. After cooling, a teaspoon of kerosene was added and mixed for 2 to 3 minutes. When most of the plant material had settled to the bottom of the beaker, the kerosene phase containing the invertebrates was removed and placed in a petri dish containing 70 per cent isopropyl alcohol for examination.

RESULTS AND DISCUSSION

To this point, 16 orders and 108 families have been identified (Table 3). Specialists have determined 26 genera and 39 species of leafhoppers (Table 4), 14 genera and 15 species of Curculionidae, 5 genera and 7 species of Formicidae, and 8 genera and 13 species of Acrididae (Table 5). All biomass figures (g/m^2) and numbers (mean number/m^2) of the reported groups were obtained using the modified quick trap, vacuum collector combination. Trophic levels of many groups are incomplete due to problems of classifying some insects and the absence of information of others. Many of the immature forms were classified only to order.

Major groups of insects according to numbers and biomass (Tables 6 and 7) were determined for 1970 and 1971. Major groups according to numbers in 1971 were Formicidae, Thysanoptera, and Entomobryidae, respectively. Other groups commonly found in high numbers were Smithuridae, Coccoidea, Nitidulidae, Cicadellidae, Delphacidae, Lygaeidae, and Carabidae. These groups were similar to those found in high numbers in 1970 except for the higher numbers of Carabidae and Delphacidae. Major groups by numbers for the ungrazed area in 1971 were Formicidae, Thysanoptera, Entomobryidae and Sminthuridae, respectively, and for the grazed area, Thysanoptera, Formicidae, Entomobryidae, and Sminthuridae, respectively. Morris (1971) found immature and adult Cicadellidae and Delphacidae were more numerous on ungrazed plots than grazed; the difference was greater for immatures. He reported that many other groups of invertebrates had more species and individuals on ungrazed grassland than on grazed. Smith (1940) reported Homoptera, Orthoptera and Lepidoptera showed a preference for overgrazed mixed-grass prairie in Oklahoma.

Formicidae ranked as the most numerous family overall, but on April 24, 1971, there was in the ungrazed area a mean number of $9.8/m^2$ as compared to 258.4 Entomobryidae/m^2. Only $2.6/m^2$ of Formicidae were found on the November 7, 1971 ungrazed treatment. There was a wide fluctuation in populations during a season.

Major groups of insects according to biomass were Formicidae, Cicadellidae, and Curculionidae, respectively. Secondary contributors were Gryllidae, Chrysomelidae, Acrididae, immature Lepidoptera, and Carabidae. Major groups by biomass for the ungrazed area in 1971 were

Formicidae, Acrididae, Curculionidae, Cicadellidae, and Scutelleridae, respectively, and for the grazed area were Formicidae, Cicadellidae, immature Lepidoptera, Gryllidae, and Curculionidae, respectively. All of these groups, with the exception of Formicidae, are almost entirely herbivorous. Evans and Murdoch (1968) noted that Lepidoptera, Hemiptera, Homoptera, and Orthoptera represented the bulk of the biomass in a grassland community.

Studies of Cicadellidae during 1970-71 indicated that an index of leafhopper numbers is not always a good predictor of biomass. Both biomass and numbers data are necessary because of the wide variation in weight between species, sexes of the same species, and size of life stages (Blocker et al. 1971).

Total numbers of insects (mean number/m^2) and biomass (g/m^2) are shown in Table 8 and Fig. 9-11. Figure 9 indicates that the total insect numbers in 1971 were larger than in 1970. Environmental conditions could well be responsible for this difference since there was more rainfall and cooler temperatures in 1971. Macnamara (1924) reported Collembola to decrease in abundance in drier habitats and to increase under moist conditions. Numbers of insects for the two years seem to show population trends. Low numbers were present in April and May with an increase until July followed by a decline in August. Populations increased again in the latter part of August and September with moderate increases in October followed by a decline in November. Evans and Murdoch (1968) found that in the course of an annual season of insect activity there was a gradual progression in diversity to a peak in mid-summer and a gradual decline towards autumn.

EXPLANATION OF FIG. 9

Insect numbers collected from grazed and ungrazed treatments, Osage Site, Oklahoma.

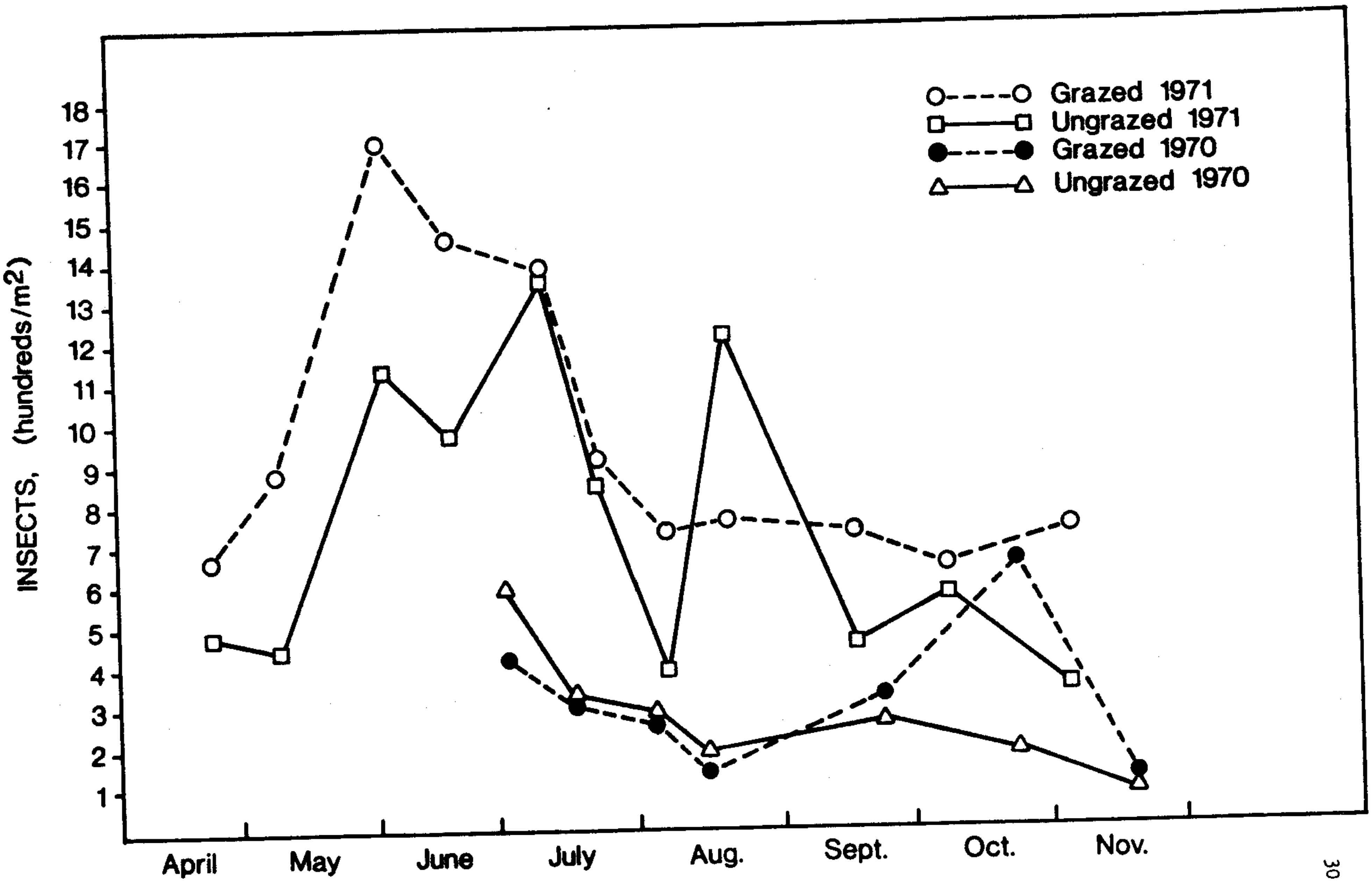

Grazed 1971
Ungrazed 1971
Grazed 1970
Ungrazed 1970
INSECTS, (hundreds/m2)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 9

EXPLANATION OF FIG. 10

Insect biomass collected from the grazed treatment, Osage Site, Oklahoma.

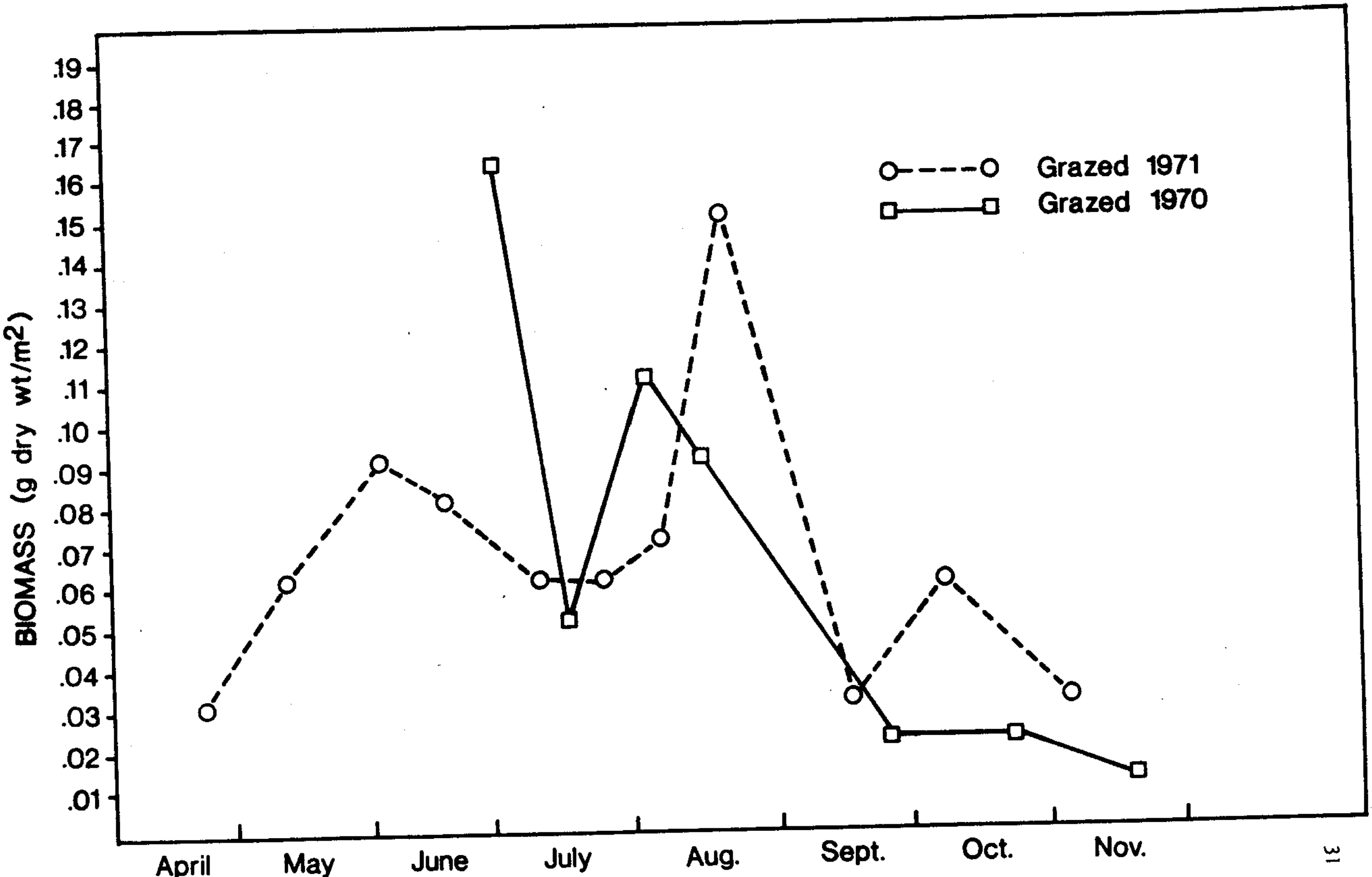

Grazed 1971
Grazed 1970
BIOMASS (g dry wt/m2)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 10

EXPLANATION OF FIG. 11

Insect biomass collected from the ungrazed treatment, Osage Site, Oklahoma.

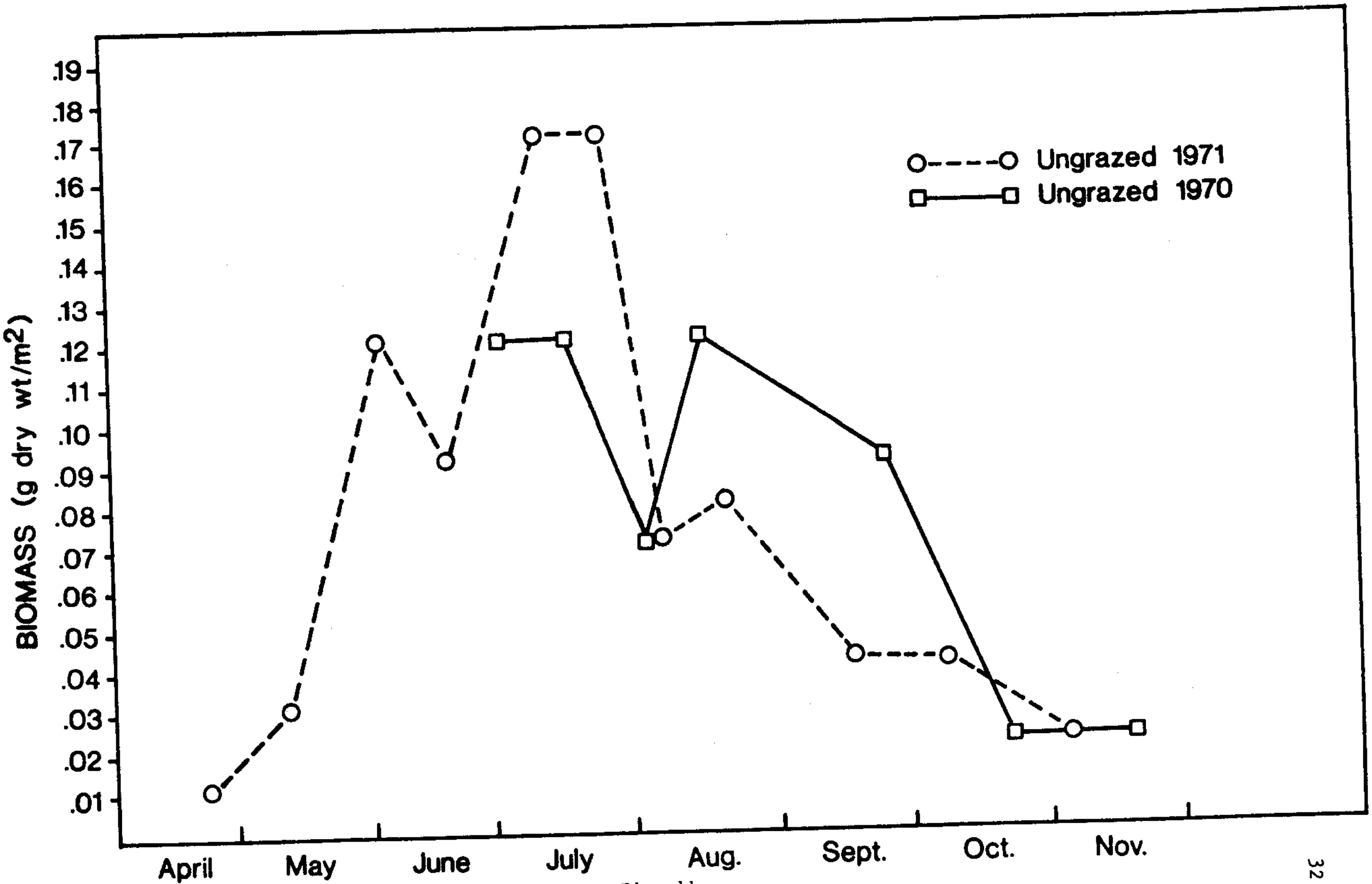

Ungrazed 1971
Ungrazed 1970
BIOMASS (g dry wt/m2)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 11

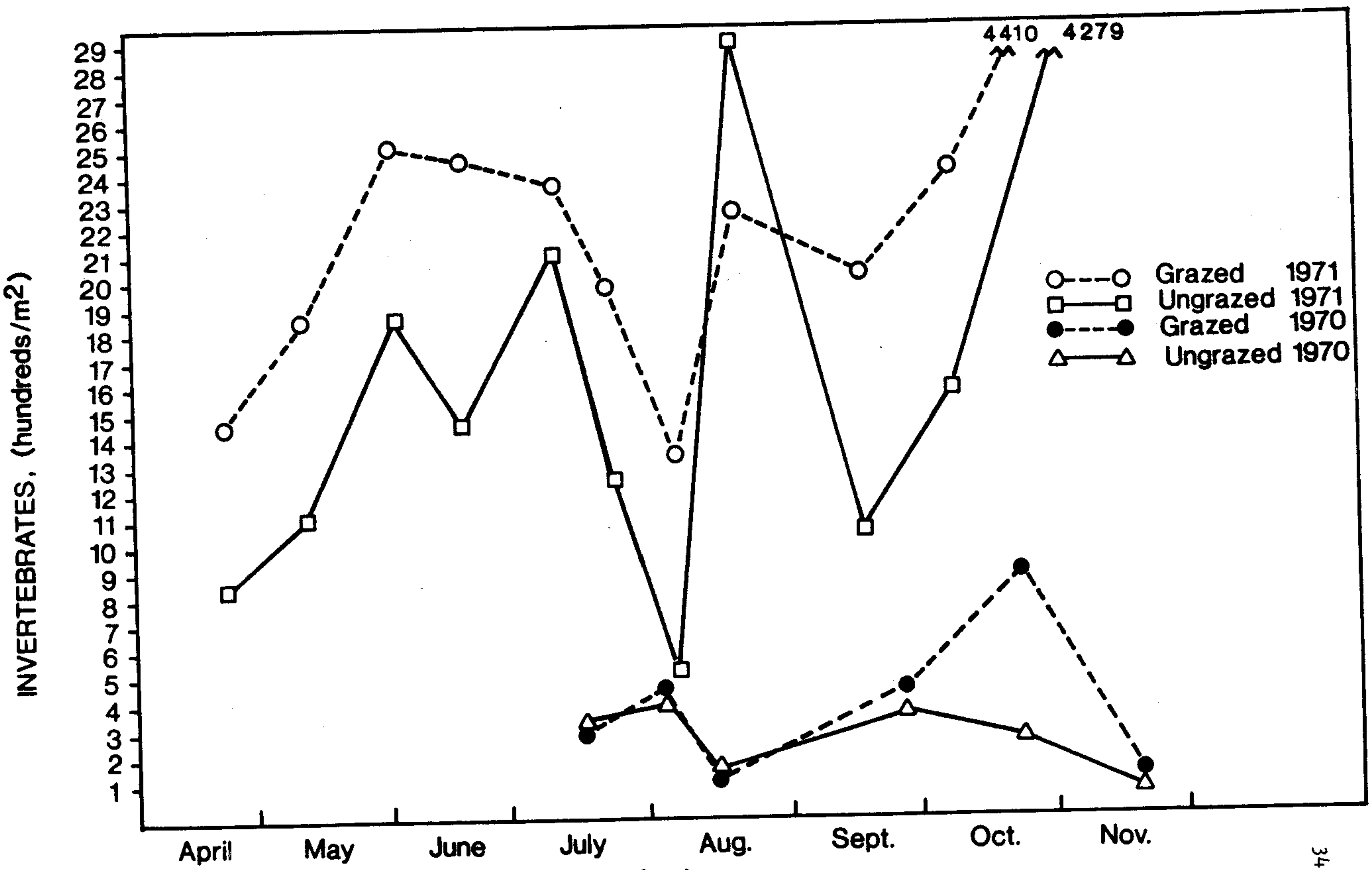
The peak coincided approximately with the maximum standing crop of plant biomass. Biomass in the ungrazed treatment decreased in August compared to an increase in the grazed treatment. This also occurred in 1970 (Fig. 10-11). Peaks of biomass occurred in the latter part of August in both 1970-71 in the grazed and ungrazed treatment; it then declined in September, showed moderate increases in October, then tapered off in November. Huddleston et al. (1969) showed that a general reduction in most taxa occurred two weeks after the first killing frost. Exceptions were Formicidae, adult Chrysomelidae, Elateridae, and adult Cicadellidae. This indicated that fairly large insect biomass may remain in late autumn.

Trends of total invertebrate numbers for 1970 and 1971 (Fig. 12) were close to those of the total insect numbers with the exception of the latter part of August and the November collection in 1971. Invertebrate numbers declined in the latter part of August in 1970 while in 1971 there were peak numbers. This was primarily the result of high numbers of Formicidae, Coccoidea, Thysanoptera, and Acarina. The November collection showed large populations of Acarina in 1971 which accounted for the high invertebrate numbers for that month. Total invertebrate biomass and numbers for 1971 are shown in Table 9 and Fig. 13 and 14. Invertebrates collected at Osage but not recorded as numbers or biomass were Diplopoda, Chilopoda, Isopoda, and Phalangida.

Data on spiders (Order Araneida) are given in Table 10. Compared to other invertebrates, the numbers are lower but the biomass exceeds

EXPLANATION OF FIG. 12

Invertebrate numbers collected from the grazed and ungrazed treatments, Osage Site, Oklahoma.

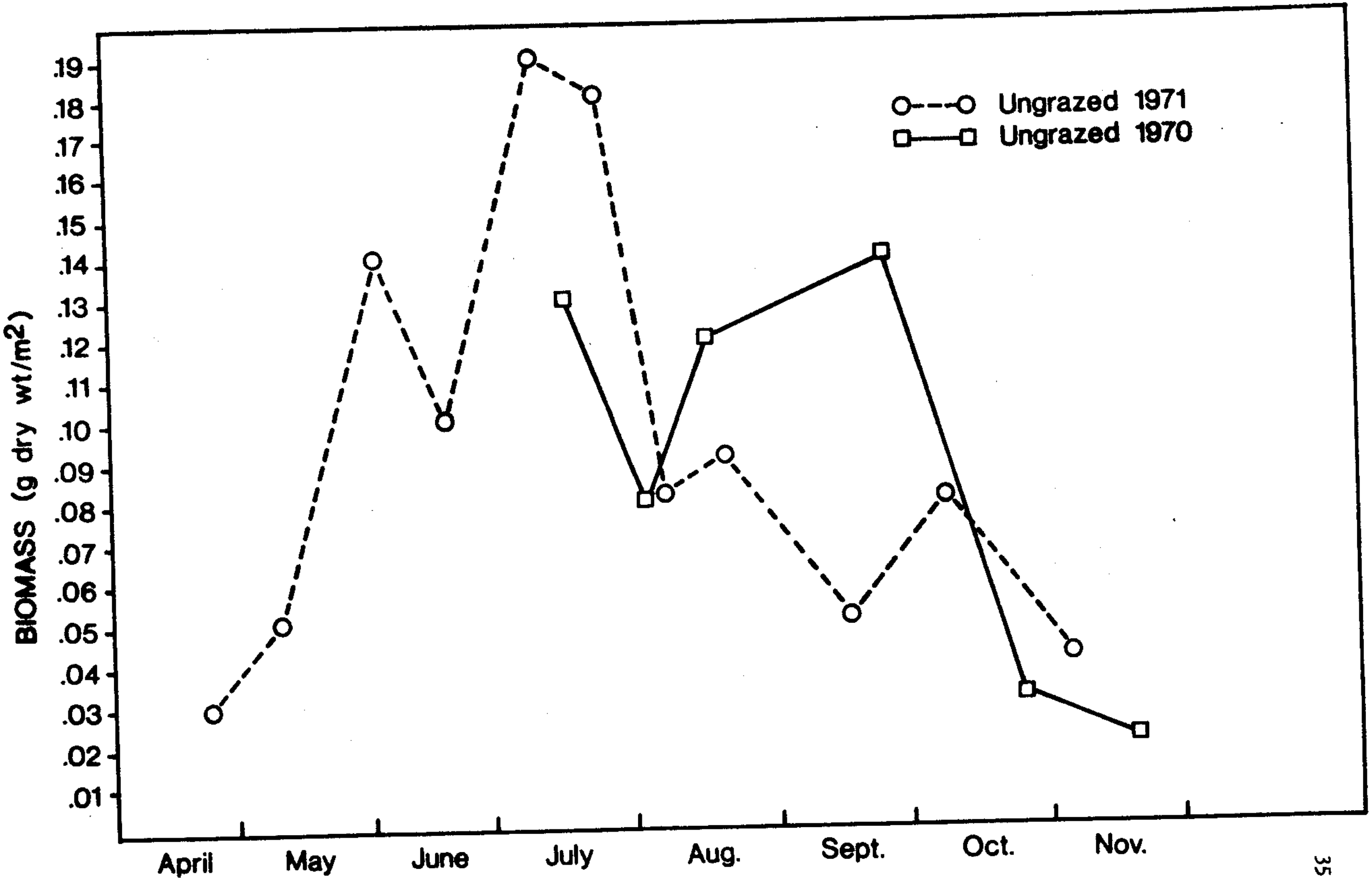


INVERTEBRATES, (hundreds/m²)
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
4410
4279
Grazed 1971
Ungrazed 1971
Grazed 1970
Ungrazed 1970
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 12

EXPLANATION OF FIG. 13

Total invertebrate biomass collected from the ungrazed treatment, Osage Site, Oklahoma.



Ungrazed 1971
Ungrazed 1970
BIOMASS (g dry wt/m²)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 13

EXPLANATION OF FIG. 14

Total invertebrate biomass collected from the grazed treatment, Osage Site, Oklahoma.

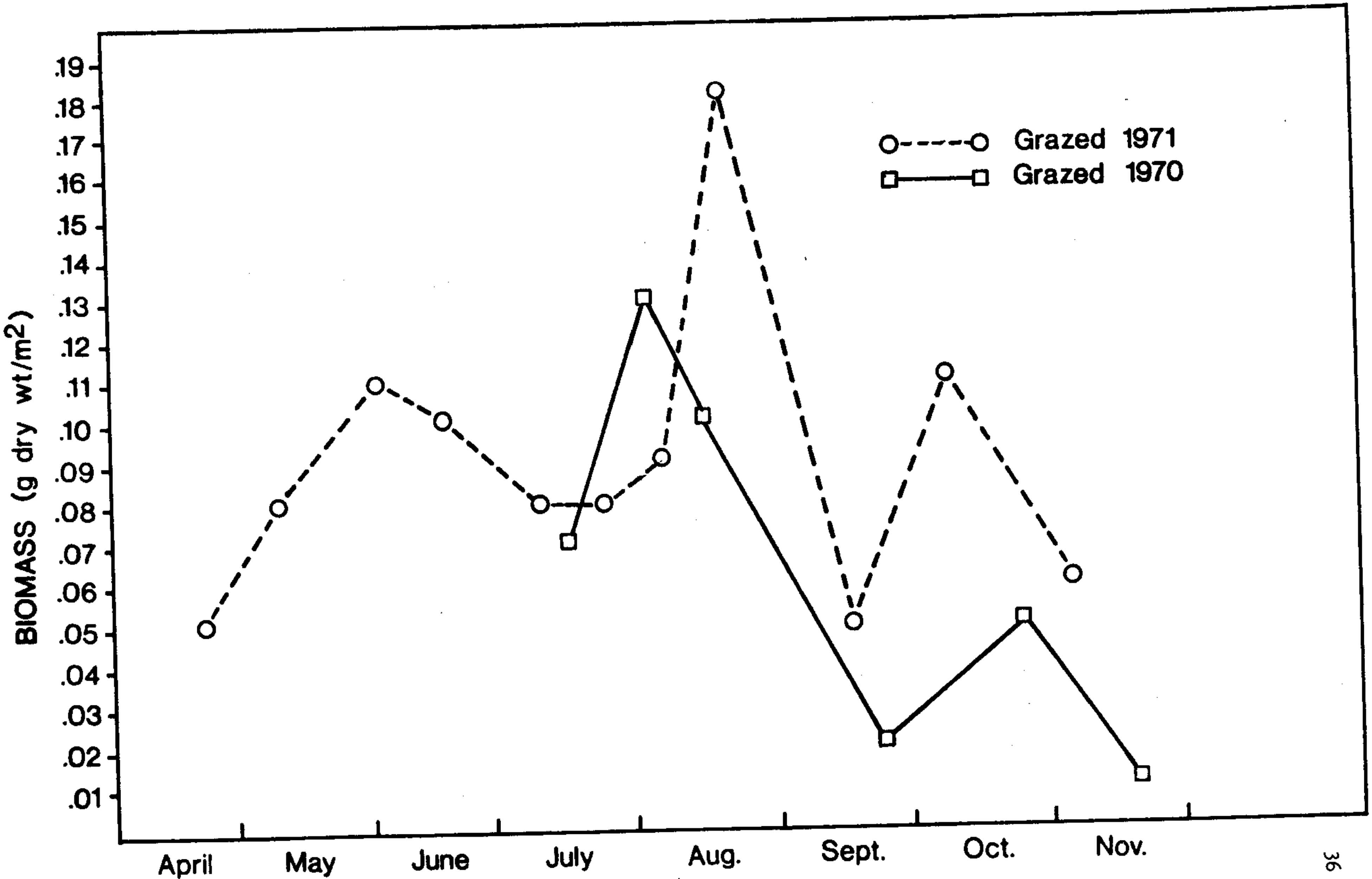

Grazed 1971
Grazed 1970
BIOMASS (g dry wt/m2)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.

Fig. 14

.01g/m^2 in several collections. In 1971, numbers were high in April and May, declined in June, peaked again in July and declined in August. Numbers rose moderately in the latter part of August then declined in September. A large peak occurred in October followed by a sharp decline in November. These data follow somewhat the work of Duffey (1962) in limestone grassland where numbers were high in April, May and June. Declines were noted in July and August with increases in late August and September and peaks were recorded in October with a decline in November.

The 1970 Araneida data in the grazed area were similar to 1971 except for an increase in numbers during September. The 1970 ungrazed data also showed an increase in numbers in September as compared to a decrease in 1971; otherwise, 1970 data were similar to 1971. The ungrazed treatment had high numbers in April through early June, July, early August and early October. The grazed treatment had higher numbers in early July, late August and the early part of October. In the ungrazed treatment biomass was highest when the numbers were lowest in April, May, June and August; numbers stayed the same in late August, but biomass declined. These data agree with Turnbull (1966) who found that of 42 species of spiders, two were responsible for 80 per cent of the biomass. Numbers and biomass appeared to be related in September, October and November. Biomass in the grazed treatment generally followed the same pattern as the mean number/m^2. Araneida numbers in both grazed and ungrazed treatments for 1971 exceeded the numbers in 1970 except in September, 1970, where numbers in the ungrazed treatment were higher. Boyd (1960) noted that certain species of _Lycosa_ sp. were abundant on ungrazed and almost absent from the grazed areas. Certain species of Xysticus were more common on grazed areas.

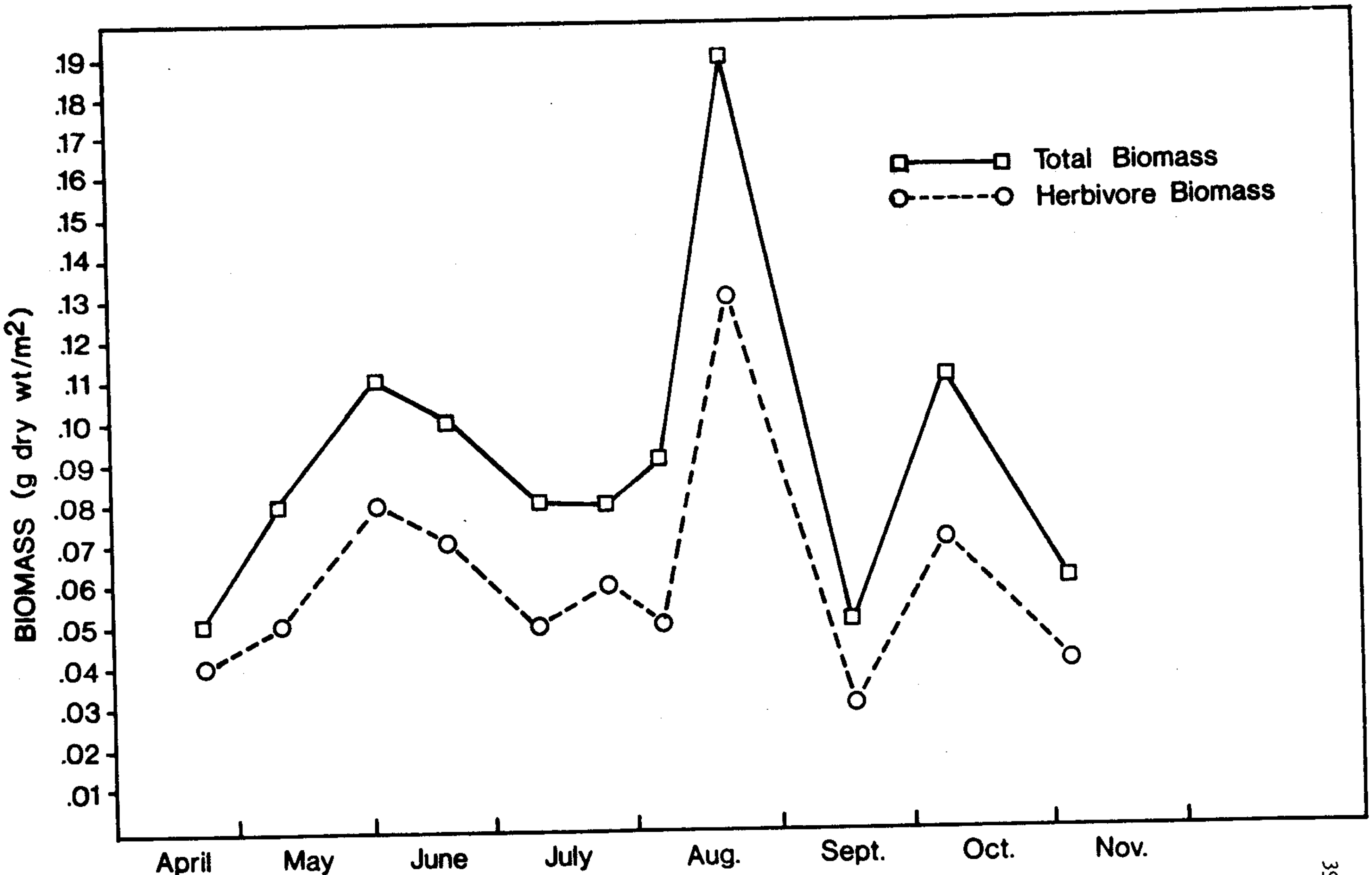
The 1970 biomass of Araneida in the grazed treatment exceeded the 1971 biomass only once, in mid-July. The 1970 biomass was greater in ungrazed areas in mid-July, mid-August and mid-September.

Mite (Order Acarina) data are shown in Table 11. Numbers were quite high in 1971. Biomass in the grazed treatment exceeded .01 g/m^2 on several occasions and seemed to follow numbers in increases and decreases except in mid-May and June when numbers increased, but biomass decreased. In November large numbers were recorded and biomass declined. The grazed treatment had greatest biomass than the ungrazed for both years. The 1971 grazed treatment had larger numbers except in mid-August and November. The 1970 grazed area population was higher except in mid-July and mid-August. The higher 1971 populations could well be due to above-average rainfall and color temperatures.

A comparison of herbivore to total invertebrate biomass in 1971 is shown in Table 12 and Fig. 15 and 16. Herbivore biomass followed total invertebrate biomass to varying degrees throughout the collecting season in both treatments. Table 12 shows estimates of the per cent herbivores compared to total invertebrates; the ungrazed treatment had a variation of 45 per cent on August 6, 1971 to 73 per cent on August 20, 1971. This gave an annual average of 59 per cent. The grazed treatment ranged from 48 per cent on September 19, 1971 to 81 per cent on July 25, 1971, with an annual average of 66 per cent. The 1970 herbivore estimate was a 65 per cent annual average for both treatments. This consistency from season to season was also found by

EXPLANATION OF FIG. 15

Total invertebrate and herbivore biomass for the grazed treatment, Osage Site, Oklahoma for 1971.



BIOMASS (g dry wt/m²)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Total Biomass
Herbivore Biomass

Fig. 15

EXPLANATION OF FIG. 16

Total invertebrate and herbivore biomass for the ungrazed treatment, Osage Site, Oklahoma, for 1971.

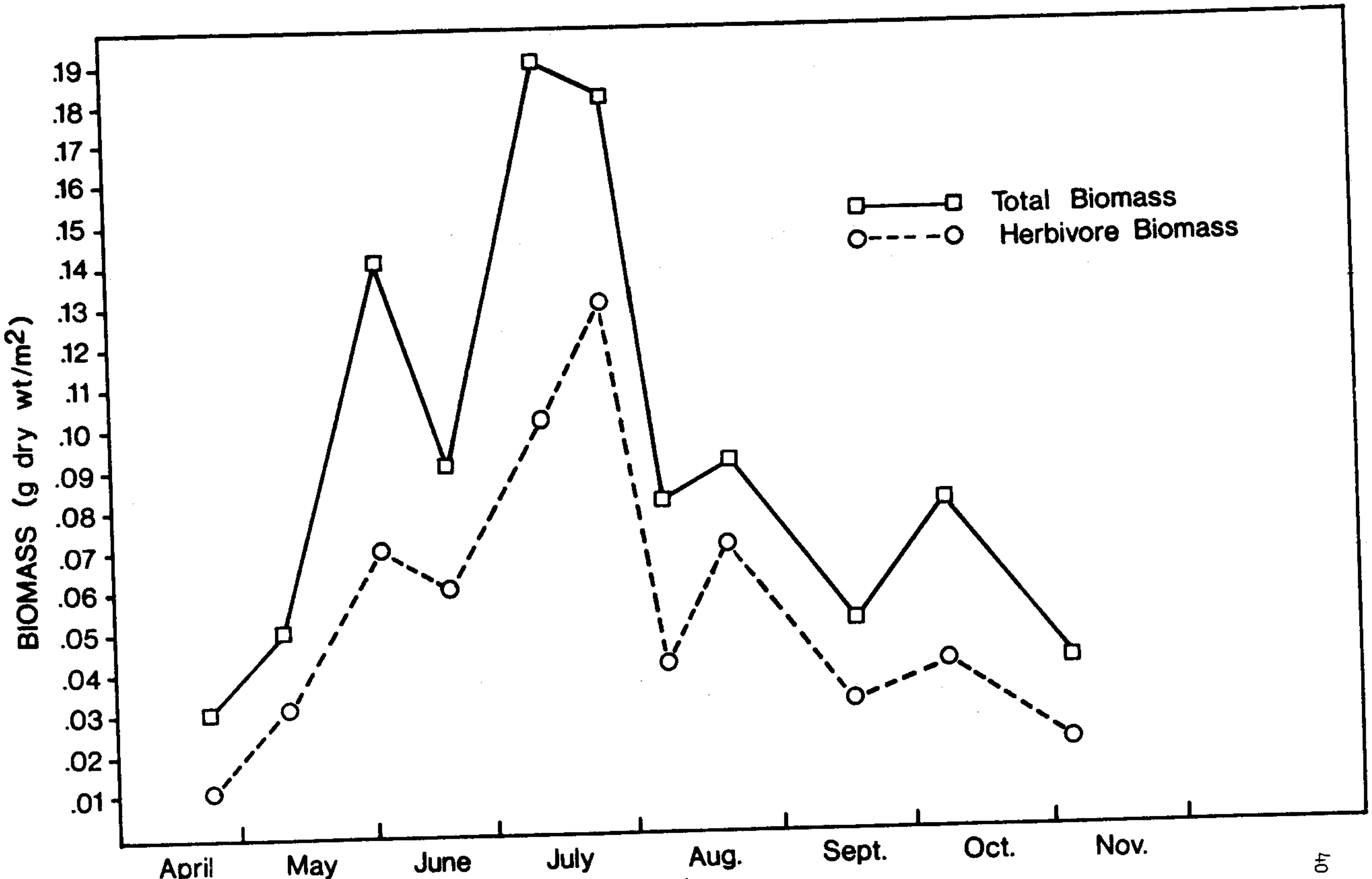

BIOMASS (g dry wt/m²)
.19
.18
.17
.16
.15
.14
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Total Biomass
Herbivore Biomass

Fig. 16

Evans and Murdoch (1968). They found that 85 per cent of the insect species in a grassland community were herbivorous as adults but only 41 per cent of the larvae, mainly Lepidoptera, Hemiptera, Homoptera, and Coleoptera. They did not, however, include apterygotes or other arthropods.

More species and a higher frequency of forbs were recorded in the grazed area. Clenton Owensby, Kansas State University (personal communication), reported frequency of forbs highest in tallgrass prairie in the early part of the growing season (May and June) and the latter part (September and October). Generally invertebrate numbers appeared to have an association with forbs. The higher frequency of forbs on the grazed area could account for certain groups of invertebrates being present in large numbers (e.g., Thysanoptera). The per cent of herbivores was also found to be highest when forbs would be most abundant in the grazed treatment. The ungrazed area had a higher frequency of the major grass species except for Sporobolus asper. A vegetative difference between the two treatments probably accounted directly for the difference in invertebrate numbers and indirectly for biomass. It also appeared to account for the number of herbivores present in a grassland community.

A list of orders and families found in sweep net collections is shown in Table 13, quick trap collections in Table 14, and pitfall trap collections in Table 15. A total of 11 orders and 70 families was obtained by sweep net, 11 orders and 56 families by pitfall traps, and 13 orders and 75 families by the quick trap. Turnbull and Nicholls (1966) determined that the quick trap coupled with a vacuum collector is the best way to census the total arthropod population of a grassland. Table 16 shows orders and families that are unique to a given type of collecting method. It should be noted that the quick trap obtained more parasitic Hymenoptera and litter dwellers than the pitfall or sweep net method. The pitfall traps were unique in their collection of large active individuals. Pitfall traps could also function as bait traps. Once an organism was trapped and died, its decomposition served as an attractant to certain groups of insects. This accounted for the reasonably large numbers of Silphidae. More families of Diptera were captured by the sweep net method. Beall (1935) also obtained more Diptera from grassland using a sweep net than a cylinder method. Gray and Treloar (1933) obtained larger numbers of Hemiptera and Diptera than other orders using a sweep net in an alfalfa stand. Moderate numbers of Phasmidae were collected by sweep net, yet none in the quick trap; movement away from the area during disturbance by field workers positioning the trap could be responsible since they tended to be slow in their dispersal back into the area. Only one Gryllidae (subfamily Oecanthinae) was collected, and it was captured by a sweep net in the ungrazed area. Table 16 also shows the insect families observed in the field but never captured by any of the trapping methods.

The extraction of invertebrates by the vacuum collector is shown in Table 17. Assuming that virtually 100 per cent was removed at the end of five minutes, extraction was high for Homoptera, Hemiptera, Coleoptera, Orthoptera, Hymenoptera, Diptera, Thysanoptera and Araneida. Johnson et al. (1955) showed results of efficiency of the vacuum collector which correspond to those shown in Table 17 except for lower extraction of immature Diptera and Coleoptera. Turnbull (1966) found a D-vac sampler missed 12.1 per cent of the homopterans, 12.5 per cent of the immature Hemiptera, 6.9 per cent of the coleopterans, and 10.0 per cent of the dipterous larvae. All spiders, Lepidoptera, Hemiptera adults, Thysanoptera, Orthoptera, 97.7 per cent of the mites, and 96.2 per cent of the Collembola were picked up. Problems with the vacuum collector resulted because certain groups (Formicidae and Acarina) would probably be recovered from the soil regardless of the amount of vacuuming time. To obtain only above ground invertebrates, vacuuming should be terminated after the litter is removed; however, certain invertebrate groups that might burrow into the soil at certain time periods of the day would be excluded.

Relatively high numbers of immature Hemiptera, Homoptera, and Coleoptera were collected by the quick trap-suction method. The high numbers were in no way proportional to the small number of adults which were collected (e.g., Fulgoridae in 1970, Delphacidae in 1971). There is the possibility that some of these insects leave the grassland community at certain stages of their life cycle and spend the adult stage in other communities such as field crops. There is also the possibility of a high mortality rate in immatures. This same trend was noted during 1970.

Table 18 depicts the per cent of specimens recovered by the various sorting techniques for 1970 and 1971. Handsorting the D-vac litter was necessary to obtain specimens of Orthoptera, Homoptera, Lepidoptera, Coleoptera, and Hymenoptera which remained trapped in the Berlese funnels or were injured during collection and therefore were unable to crawl out. Berlese extraction of the grass clippings yielded many Psocoptera, Thysanoptera, Hymenoptera, Homoptera, Hemiptera, Acarina, and Diptera. Most of the Homoptera and Hemiptera were immatures. It is noted that in 1970 large numbers of immature Miridae were recovered from grass clippings, although large numbers of adults were never found. The Berlese method for D-vac material showed best results recovering Formicidae, Cicadellidae, Delphacidae, Coleoptera, Collembola, Lygaeidae, and Araneida.

The D-vac litter was removed from the Berlese funnels and checked with a kerosene flotation method on six samples (Table 19). Extraction was lower than 75 per cent for immature Cicadellidae, Coleoptera, Lygaeidae, and adult Eulophidae and Aphididae. Large differences between extraction efficiency for certain groups was probably due to the amount of vegetation in the funnel, the larger the quantity of vegetation, the lower the extraction efficiency.

SUMMARY AND CONCLUSIONS

Invertebrate data were collected at the IBP Comprehensive Osage Site, Foraker, Oklahoma in 1970-1971. Eighteen collections were taken between July 3, 1970 and November 7, 1971, in grazed and ungrazed treatments. Each treatment consisted of two replications of five quadrats each.

Samples were obtained using a modified Turnbull and Nicholls quick trap (0.5 m^2 area), and a D-vac vacuum collector. Modified Berlese funnels were used to extract the invertebrates from the sample litter.

Although immatures were classified only to order, most insects were sorted to family, dried at 60 C for 24 hr and weighed. Sixteen orders and 108 families were identified.

Major groups of insects for the grazed and ungrazed treatments were Formicidae, Thysanoptera and Entomobryidae, respectively. Secondary contributors were Smithuridae, Coccoidea, Nitidulidae and Cicadellidae. Major groups of insects according to biomass were Formicidae, Cicadellidae, and Curculionidae, respectively. Secondary contributors were Gryllidae, Chrysomelidae, Acrididae and immature Lepidoptera.

Total numbers of insects (mean number/m^2) were larger in 1971 than in 1970. Numbers were low in April and May but increased until July followed by a decline in August. Numbers increased again in the latter part of August and September with moderate increases in October followed by a decline in November. Trends of total invertebrate numbers were close to those of total insect numbers.

Biomass in the ungrazed area decreased in August but increased in the grazed area during both seasons. Peaks of biomass occurred in the latter part of August, 1970-71, in the grazed and ungrazed area. Biomass declined in September, stayed approximately the same in October, then tapered off in November.

Araneida numbers were lower than other invertebrates but biomass exceeded .01 g/m^2 in several collections. Biomass was found to be highest when numbers were lowest, in April, May, June and August on the ungrazed treatment. Biomass in the grazed area generally followed the mean number/m^2.

Acarina numbers were generally higher in the grazed than the ungrazed treatment. The grazed treatment supported greater biomass than the ungrazed during both seasons.

A comparison of herbivore to total invertebrate biomass in 1971 showed that herbivore biomass followed total invertebrate biomass to varying degrees throughout the collecting season in both grazed and ungrazed treatments. For 1971, it was estimated that an average of 59 per cent of the total invertebrate biomass in the ungrazed and 66 per cent in the grazed treatment was composed of herbivores.

For both 1970-71 the grazed area supported larger numbers of total invertebrates than the ungrazed; however, the ungrazed treatment supported greater biomass in both 1970-71 than the grazed. This was probably due to the larger number of herbivores found in the grazed area. These groups were high in numbers but tended to be low in biomass on an individual basis (e.g., immature Homoptera and Lepidoptera). The ungrazed contained a smaller number of invertebrates which generally were greater in biomass per individual.

A vegetative difference between the grazed and ungrazed areas probably accounted directly for the difference in invertebrate numbers, and indirectly for biomass. It also appeared to account for the number of herbivores present in a grassland community.

Efficiency checks on the Berlese funnels showed extraction to be below 75 per cent for immature Cicadellidae, Coleoptera, Lygaeidae, and adult Eulophidae and Aphididae. These and other specimens remaining in the funnels were extracted by hand-sorting.

Samples were taken to evaluate the efficiency of the quick-trap, sweep netting and pitfall trap. The sweep net samples yielded 12 families that were not collected by the quick traps and the pitfalls six. Seven families were observed in the field but were not captured by any of the three methods. The quick trap proved to be the most comprehensive method of trapping in tallgrass prairie.

An efficiency check of the vacuum collector showed most invertebrates were removed at the end of five minutes of vacuuming. Certain groups such as Formicidae, Acarina, and immature Coleoptera would probably be obtained if vacuuming were continued for a longer period of time.

It appeared that a reasonably good evaluation of relationships between populations of above-ground invertebrates was made with the methods employed. It was evident that high numbers of invertebrates do not necessarily reflect the amount of biomass; numbers in 1971 were much higher than in 1970, but biomass differences were not so great.

It is probable that certain life stages of Hemiptera, Homoptera and perhaps Coleoptera left the grassland communities or had a high mortality rate, or both. The small numbers of adults collected compared to immatures was evidence that numbers were out of proportion.

Insect competition with livestock at the Osage site was probably small primarily due to good range conditions. Visual inspection of heavily grazed pastures in the same vicinity suggested a higher population of certain insect groups (e.g., grasshoppers and leafhoppers).

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APPENDIX I

Table 1. Species list* and frequency data of vegetation for 1971, Osage Site. **

Species name	Grazed	Ungrazed
Andropogon scoparius Michx.	74	100
Panicum scribnerianum Nash.	70	100
Sorghastrum nutans (L.) Nash	30	40
Sporobolus asper (Michx.) Kunth	76	38
Panicum virgatum L.	62	36
Carex spp.	2	32
Psoralea tenuiflora Pursh	4	32
Bouteloua curtipendula (Michx.) Torr.	4	28
Bromus japonicus Thumb.	90	26
Leptoloma cognatum (Schult.) Chase	44	24
Agrostis hiemalis (Walt.) B.S.P.	10	22
Vernonia baldwini Torr.	4	22
Ruellia humilis Nutt.	30	22
Andropogon gerardi Vitman	20	20
Aster ericoides L.	0	18
Salvia azurea Lam.	0	14
Oxalis stricta L.	16	14
Croton capitatus Michx.	18	12
Strophostyles leiosperma (T. & G.) Piper	10	8
Amorpha canescens Pursh	2	8
Schrankia nuttallii (DC.) Standl.	0	4
Poa pratensis L.	14	4
Ambrosia psilostachya DC.	50	4
Coreopsis grandiflora Hogg	0	4
Achillea lanulosa Nutt.	18	4
Solidago missouriensis Nutt.	0	2
Euphorbia supina Raf.	20	2
Galium texense	0	2
Physalis pumila Nutt.	0	2
Bouteloua gracilis (H.B.K.) Lay exstevd.	0	2
Nemastylis geminiflora Nutt.	0	0
Baptisia leucophaea Nutt.	0	0
Lespedeza stipulacea Maxim.	26	0
Aristida oligantha Michx.	24	0
Setaria viridis (L.) Beauv.	12	0
Desmodium illinoiense Gray	6	0
Medicago lupulina L.	2	0
Euphorbia corollata L.	4	0
Andropogon virginicus L.	2	0
Andropogon saccharoides Swartz	2	0

Table 1 (concluded)

Species name	Grazed	Ungrazed
Lactuca ludoviciana (Nutt.) DC.	2	0
Elymus canadensis L.	2	0
Gutierrezia dracunculoides (DC.) Blake	4	0
Triden flavus (L.) Hitchc.	6	0
Muhlenbergia sobolifera (Muhl.) Trin.	2	0
Petalostemum purpureum (Vent.) Rydb.	2	0

* Represents 90-95% of the species present.

** Data supplied by Dr. Paul G. Risser, University of Oklahoma.

Table 2. Insect samples taken at the Osage Site, 1970 and 1971.[a, b]

1970		1971	
July	3	April	24
July	16	May	13
August	3	June	3
August	17	June	19
September	27	July	11
October	25	July	25
November	23	August	6
		August	20
		September	19
		October	11
		November	7

[a] Treatments were ungrazed and grazed with 2 replicates each, 5 quadrats per replicate.

[b] Invertebrate data collected in 1970 on the Osage Site is Grassland Biome data set A2U3009.

Table 3. List of families determined from Osage Comprehensive Site from July 3, 1970 through November 7, 1971.[a, b]

Order	Family	Trophic level
Thysanura	Japygidae	Unknown
Collembola	Entomobryidae	Herbivore, Omnivore
	Poduridae	Herbivore, Omnivore
	Sminthuridae	Herbivore
Orthoptera	Acrididae	Herbivore, Scavenger
	Blattidae	Omnivore
	Mantidae	Predator
	Gryllidae	Herbivore, Omnivore
	Phasmidae	Herbivore
	Tettigoniidae	Herbivore
Homoptera	Cicadellidae	Herbivore
	Coccoidea	Herbivore
	Issidae	Herbivore
	Aphididae	Herbivore
	Cercopidae	Herbivore
	Fulgoridae	Herbivore
	Delphacidae	Herbivore
	Membracidae	Herbivore
	Psyllidae	Herbivore
	Cixiidae	Herbivore
	Dictyopharidae	Herbivore
Hemiptera	Ploiariidae	Predator
	Lygaeidae	Herbivore
	Miridae	Herbivore
	Corimelaenidae	Herbivore
	Pentatomidae	Herbivore
	Tingidae	Herbivore
	Neididae	Herbivore
	Coreidae	Herbivore, Predator
	Reduviidae	Predator
	Scutelleridae	Herbivore
	Gerridae	Predator
Coleoptera	Cicindelidae	Predator
	Nitidulidae	Herbivore
	Lathridiidae	Scavenger
	Phalacridae	Herbivore
	Cerambycidae	Herbivore
	Curculionidae	Herbivore
	Staphylinidae	Predator

Table 3 (cont'd).

Order	Family	Trophic level
Coleoptera (cont'd)	Chrysomelidae	Herbivore
	Pselaphidae	Herbivore
	Malachiidae	Predator
	Ptilidae	Herbivore
	Cisidae	Herbivore
	Scydmaenidae	Unknown
	Scaphidiidae	Herbivore
	Elateridae	Herbivore
	Meloidae	Herbivore, Predator
	Carabidae	Predator
	Coccinellidae	Predator
	Throscidae	Herbivore
	Dermestidae	Scavenger
	Euenemidae	Herbivore
	Silphidae	Scavenger
	Histeridae	Predator
	Cantharidae	Herbivore
	Mordellidae	Herbivore
	Cleridae	Predator
	Scarabaeidae	Herbivore
	Erotylidae	Herbivore
Lepidoptera	Nymphalidae*	Herbivore
	Danaidae*	Herbivore
	Noctuidae	Herbivore
	Pyralidae	Herbivore
	Satyridae*	Herbivore
Diptera	Tabanidae	Herbivore, Predator
	Tachinidae	Parasite
	Sarcophagidae	Scavenger
	Asilidae	Predator
	Chloropidae	Omnivore, Herbivore
	Cecidomyiidae	Herbivore
	Sciaridae	Herbivore
	Mycetophilidae	Herbivore
	Sciomyzidae	Unknown
	Pyrgotidae	Parasite
	Rhagionidae	Predator
	Piophilidae	Scavenger
	Syrphidae	Herbivore
	Pipunculidae	Parasite
	Scatopsidae	Scavenger
	Acroceridae*	Herbivore, Parasite
	Culicidae	Parasite

Table 3 (concluded).

Order	Family	Trophic level
Diptera (cont'd)	Chironomidae	Scavenger
	Ceratopogonidae	Parasite, Predator
	Tipulidae	Herbivore
	Otitidae	Unknown
Hymenoptera	Formicidae	Omnivore
	Trichogrammatidae	Parasite
	Encyrtidae	Parasite
	Thysanidae	Parasite
	Eulophidae	Parasite
	Dryinidae	Parasite
	Tenthredinidae	Herbivore
	Halictidae	Unknown
	Figitidae	Parasite
	Pteromalidae	Parasite
	Ichneumonidae	Parasite
	Tiphiidae	Parasite
	Sierolomorphidae	Unknown
	Vespidae*	Herbivore
	Scelionidae	Parasite
	Mutillidae	Parasite
	Braconidae	Parasite
Psocoptera		Scavenger
Thysanoptera		Herbivore, Predator Omnivore
Odonata	Libellulidae*	Predator
	Coenagrionidae*	Predator
Neuroptera	Chrysopidae	Predator
	Hemerobiidae	Predator
	Myrmeleontidae	Predator
Dermaptera		Scavenger, Herbivore
Strepsiptera		Parasite
Ephemeroptera		Non-feeding

* Families observed in the field but never captured.

[a] All orders were not determined to family (e.g., Thysanoptera, some Lepidoptera, etc.).

[b] All immatures were not determined to family.

Table 4. Cicadellidae collected at the Osage Site from July 3, 1970 through August 20, 1971.

Taxon	Sweep net	Quick trap
Subfamily Ledrinae		
Xerophloea majesta (Lawson)	G*	G
Xerophloea peltata (Uhler)		
Subfamily Hecalinae		
Parabolocratus curtus (Shaw)	UG*	UG
Parabolocratus grandis (Shaw)	G, UG	G, UG
Subfamily Agallinae		
Aceratagallia uhleri (Van Duzee)	G, UG	UG
Aceratagallia sp.		UG
Subfamily Iassinae		
Prairiana sp.	UG	G, UG
Gyponana angula (DeLong)	G, UG	
Subfamily Xestocephalinae		
Xestocephalus pulicarius (Van Duzee)		G, UG
Subfamily Cicadellinae		
Draeculacephala mollipes (Say)	G, UG	
Subfamily Typhlocybinae		
Empoasca sp.	UG	
Erythroneura sp.	UG	
Subfamily Deltocephalinae		
Kansendria kansiensis (Tuthill)		G, UG
Athysanella emarginata (Osborn)	G	
Athysanella texana (Osborn)	G	G
Balclutha incisa (Matsumura)	UG	
Balclutha neglecta (DeLong and Davidson)	G, UG	
Chlorotettis spatulatus (Osborn and Ball)	G, UG	UG
Chlorotettis viridius (Van Duzee)	G	
Comellus comma (Van Duzee)	G	
Endria inimica (Say)	G, UG	G, UG
Exitianus exitiosus (Uhler)	G, UG	G, UG
Extrusanus ovatus (Sanders and DeLong)	G, UG	G, UG
Flexamia atlantica (DeLong)	G	
Flexamia graminea (DeLong)	G, UG	UG
Flexamia inflata (Osborn and Ball)	G, UG	
Flexamia picta (Osborn)	G, UG	G
Flexamia prairiana (DeLong)	G, UG	G, UG
Flexamia reflexa (Osborn and Ball)	UG	

Table 4 (concluded).

Taxon	Sweep net	Quick trap
Subfamily Deltocephalinae (cont'd)		
Gillettiella atropunctata (Gillette)	G	
Graminella mohri (DeLong)	G, UG	UG
Laevicephalus unicoloratus (Gillette and Baker)	G, UG	
Limotettix sp.		
Macrosteles fascifrons (Stal)	G, UG	
Paraphlepsius lobatus (Osborn)	UG	G, UG
Paraphlepsius solidaginis (Walker)		G
Polyamia caperata (Ball)	UG	G, UG
Polyamia sp.	G, UG	UG
Scaphytopius sp.	UG	
Stirellus bicolor (Van Duzee)	G, UG	UG

* The treatments were G (Grazed) and UG (Ungrazed).

Table 5. Species of Acrididae, Curculionidae, and Formicidae collected from July 3, 1970 through July 11, 1971.

Taxon
Family Acrididae
Subfamily Oedipodinae
Arphia simplex (Scudder)
Chortophaga viridifasciata (DeGeer)
Hadrotettix trifasciatus (Say)
Subfamily Cyrtacanthacridinae
Hesperotettix viridis pratensis (Thomas)
Melanoplus admirabilis (Uhler)
Melanoplus bivittatus (Say)
Melanoplus differentialis (Thomas)
Melanoplus femurrubrum femurrubrum (DeGeer)
Melanoplus sp.
Phoetaliotes nebrascensis (Thomas)
Subfamily Acridinae
Orphulella speciosa (Scudder)
Syrbula admirabilis (Uhler)
Family Curculionidae
Subfamily Curculioninae
Anacentrinus longipennis (Linell)
Aulobaris dux
Baris sp.
Centrinaspis sp.
Ceutorhynchus erysimi (Fab.)
Ceutorhynchus sp.
Chalcodermus aeneus (Boh.)
Curculio sp.
Hypera meles (Fab.)
Hypera punctata (Fab.)
Macrorhoptus hispidus (Dietz)
Odontocorynus sp.
Sphenophorus aermavi (Horn)
Sphenophorus coesifrons (Gyll.)
Sitona cylindricallis (Fahr.)
Sitona hispidula (Fab.)
Stethobaris incompta (Csy.)
Stictobaris cribrata (LeC.)

Table 5 (concluded).

Taxon
Family Curculionidae (cont'd)
Subfamily Apioninae
Apion sp.
Subfamily Otiorhynchinae
Epicaerus imbricatus (Say)
Pantomorus pallidus (Horn)
Family Formicidae
Crematogaster lineolata subopaca (Emery)
Formica pallidefulva (Latreille)
Formica neogagates (Emery)
Formica sp.
Leptothorax pergandei (Emery)
Momomorium viridum peninsulatum (Gregg)
Tapinoma sessile (Say)

Table 6. Major groups of insects by number, Osage Site, July 3, 1970, through November 7, 1971 (mean number/m^2).

Date	Treatment	Order	Family	Number
July 3, 1970	Ungrazed	Hymenoptera	Formicidae	253.4
		Thysanoptera		78.6
		Collembola		49.2
		Hemiptera	Lygaeidae	31.4
		Homoptera	Cicadellidae	29.6
		Coleoptera	Nitidulidae	25.6
		Homoptera	Fulgoridae	10.4
		Hymenoptera	Tiphiidae	5.4
		Coleoptera	Phalacridae	4.4
	Grazed	Hymenoptera	Formicidae	162.6
		Collembola		67.4
		Thysanoptera		48.2
		Homoptera	Cicadellidae	35.2
		Coleoptera	Nitidulidae	24.2
		Homoptera	Fulgoridae	10.2
		Hemiptera	Miridae	5.6
		Hemiptera	Lygaeidae	4.2
July 16	Ungrazed	Hymenoptera	Formicidae	178.8
		Thysanoptera		29.6
		Collembola		24.2
		Hemiptera	Lygaeidae	19.4
		Homoptera	Cicadellidae	11.6
		Coleoptera	Nitidulidae	7.0
		Homoptera	Coccoidea	6.2
		Homoptera	Fulgoridae	5.4
		Hymenoptera	Encyrtidae	4.2
		Coleoptera	Lathridiidae	3.0
		Hymenoptera	Thysanidae	2.0
	Grazed	Hymenoptera	Formicidae	111.8
		Hemiptera	Miridae	47.4
		Collembola		33.8
		Thysanoptera		24.4
		Homoptera	Cicadellidae	23.0
		Coleoptera	Nitidulidae	13.8
		Homoptera	Fulgoridae	10.4
		Homoptera	Coccoidea	4.2
		Hemiptera	Lygaeidae	3.0

Table 6 (cont'd).

Date	Treatment	Order	Family	Number
August 3	Ungrazed	Hymenoptera	Formicidae	82.4
		Hemiptera	Miridae	53.8
		Collembola		46.2
		Thysanoptera		30.4
		Hemiptera	Lygaeidae	25.2
		Coleoptera	Nitidulidae	11.0
		Hymenoptera	Encyrtidae	6.0
		Homoptera	Cicadellidae	5.4
		Homoptera	Fulgoridae	5.2
	Grazed	Hymenoptera	Formicidae	108.4
		Hemiptera	Miridae	49.6
		Thysanoptera		37.0
		Collembola		35.2
		Coleoptera	Nitidulidae	21.8
		Homoptera	Fulgoridae	5.8
		Homoptera	Cicadellidae	3.0
		Hemiptera	Lygaeidae	3.0
August 17	Ungrazed	Hymenoptera	Formicidae	64.8
		Homoptera	Coccoidea	22.2
		Collembola		19.2
		Hemiptera	Lygaeidae	15.8
		Thysanoptera		8.4
		Hemiptera	Miridae	7.6
		Coleoptera	Nitidulidae	3.2
	Grazed	Homoptera	Coccoidea	46.0
		Collembola		32.8
		Thysanoptera		19.6
		Hymenoptera	Formicidae	13.8
		Hemiptera	Lygaeidae	1.6
		Coleoptera	Nitidulidae	1.6
		Orthoptera	Tettigoniidae	1.6
September 27	Ungrazed	Thysanoptera		72.6
		Collembola		66.2
		Hymenoptera	Formicidae	48.2
		Homoptera	Coccoidea	26.6
		Diptera		4.6
		Coleoptera	Nitidulidae	4.4
	Grazed	Thysanoptera		127.4
		Collembola		91.8
		Hymenoptera	Formicidae	42.6
		Homoptera	Coccoidea	26.0
		Coleoptera	Nitidulidae	4.6
		Diptera	Cecidomyiidae	3.6

Table 6 (cont'd).

Date	Treatment	Order	Family	Number
October 25	Ungrazed	Collembola		72.0
		Thysanoptera		44.4
		Hymenoptera	Formicidae	14.2
		Homoptera	Coccoidea	12.0
		Hemiptera	Lygaeidae	5.8
		Coleoptera	Lathridiidae	5.6
	Grazed	Collembola		381.4
		Thysanoptera		134.8
		Hymenoptera	Formicidae	42.6
		Coleoptera	Nitidulidae	22.2
		Homoptera	Coccoidea	11.0
		Homoptera	Cicadellidae	10.2
		Coleoptera	Lathridiidae	5.2
November 23	Ungrazed	Collembola		11.2
		Hemiptera	Lygaeidae	10.8
		Homoptera	Coccoidea	9.0
		Thysanoptera		6.2
		Coleoptera	Nitidulidae	2.6
		Diptera		1.4
	Grazed	Homoptera	Coccoidea	25.4
		Collembola		17.0
		Thysanoptera		14.4
		Coleoptera	Nitidulidae	5.4
		Coleoptera (imm)		2.8
		Homoptera	Cicadellidae	2.0
April 24, 1971	Ungrazed	Collembola	Entomobryidae	258.4
		Collembola	Poduridae	68.6
		Thysanoptera		44.6
		Collembola	Sminthuridae	24.0
		Homoptera	Coccoidea	12.6
		Hymenoptera	Formicidae	9.8
		Coleoptera	Carabidae	8.8
		Coleoptera	Nitidulidae	8.2
	Grazed	Thysanoptera		237.0
		Collembola	Entomobryidae	154.0
		Hymenoptera	Formicidae	89.0
		Collembola	Poduridae	70.8
		Coleoptera	Nitidulidae	46.4
		Homoptera	Coccoidea	37.8
		Homoptera	Cicadellidae	13.0
		Collembola	Sminthuridae	4.4

Table 6 (cont'd).

Date	Treatment	Order	Family	Number
May 13	Ungrazed	Collembola	Entomobryidae	138.0
		Collembola	Sminthuridae	98.8
		Hymenoptera	Formicidae	68.4
		Thysanoptera		53.0
		Collembola	Poduridae	27.6
		Coleoptera	Carabidae	16.2
		Homoptera	Coccoidea	14.8
		Homoptera	Cicadellidae	11.8
	Grazed	Hymenoptera	Formicidae	348.6
		Thysanoptera		322.0
		Coleoptera	Nitidulidae	48.2
		Homoptera	Coccoidea	42.0
		Collembola	Entomobryidae	33.6
		Collembola	Sminthuridae	25.4
		Coleoptera (imm)		20.8
		Homoptera	Cicadellidae	16.2
June 3	Ungrazed	Hymenoptera	Formicidae	491.2
		Collembola	Entomobryidae	246.2
		Collembola	Sminthuridae	101.8
		Thysanoptera		80.8
		Collembola	Poduridae	38.8
		Homoptera	Cicadellidae	33.0
		Coleoptera	Carabidae	29.0
		Homoptera	Coccoidea	24.2
	Grazed	Hymenoptera	Formicidae	652.0
		Thysanoptera		553.4
		Collembola	Entomobryidae	142.6
		Coleoptera (imm)		89.0
		Homoptera	Coccoidea	46.0
		Diptera (imm)		43.6
		Collembola	Poduridae	42.2
		Collembola	Sminthuridae	40.6
June 19	Ungrazed	Collembola	Entomobryidae	169.2
		Hymenoptera	Formicidae	161.8
		Collembola	Sminthuridae	153.8
		Thysanoptera		146.2
		Hemiptera	Lygaeidae	81.0
		Homoptera	Delphacidae	45.4
		Diptera (imm)		37.0
		Coleoptera (imm)		34.4

Table 6 (cont'd).

Date	Treatment	Order	Family	Number
	Grazed	Thysanoptera		472.6
		Hymenoptera	Formicidae	379.4
		Collembola	Entomobryidae	176.6
		Homoptera	Cicadellidae	98.2
		Collembola	Sminthuridae	83.2
		Coleoptera (imm)		76.8
		Homoptera	Coccoidea	65.6
		Homoptera	Delphacidae	26.4
July 11	Ungrazed	Hymenoptera	Formicidae	434.4
		Collembola	Entomobryidae	374.0
		Collembola	Sminthuridae	140.8
		Thysanoptera		140.2
		Diptera (imm)		41.2
		Homoptera	Cicadellidae	36.0
		Hemiptera	Lygaeidae	35.2
		Coleoptera (imm)		32.0
	Grazed	Thysanoptera		306.6
		Hymenoptera	Formicidae	301.2
		Collembola	Entomobryidae	271.2
		Collembola	Sminthuridae	175.4
		Diptera (imm)		60.8
		Homoptera	Delphacidae	48.6
		Coleoptera (imm)		35.2
		Homoptera	Cicadellidae	28.6
July 25	Ungrazed	Hymenoptera	Formicidae	345.4
		Thysanoptera		217.8
		Hemiptera	Lygaeidae	49.4
		Homoptera	Coccoidea	35.0
		Diptera (imm)		32.0
		Homoptera	Cicadellidae	25.2
		Collembola	Entomobryidae	22.6
		Coleoptera (imm)		22.4
		Homoptera	Delphacidae	22.4
	Grazed	Thysanoptera		247.8
		Hymenoptera	Formicidae	237.6
		Homoptera	Coccoidea	86.0
		Collembola	Sminthuridae	63.6
		Homoptera	Delphacidae	51.4
		Coleoptera (imm)		46.2
		Collembola	Entomobryidae	42.8
		Coleoptera	Nitidulidae	22.8

Table 6 (cont'd).

Date	Treatment	Order	Family	Number
August 6	Ungrazed	Hymenoptera	Formicidae	168.0
		Homoptera	Coccoidea	78.2
		Thysanoptera		42.8
		Hemiptera	Lygaeidae	16.0
		Collembola	Sminthuridae	11.2
		Coleoptera (imm)		8.6
		Diptera (imm)		7.0
		Hymenoptera	Scelionidae	5.6
	Grazed	Hymenoptera	Formicidae	256.2
		Thysanoptera		211.0
		Coleoptera (imm)		98.6
		Homoptera	Coccoidea	88.6
		Collembola	Sminthuridae	19.6
		Hemiptera	Lygaeidae	15.8
		Coleoptera	Nitidulidae	9.2
		Diptera (imm)		7.0
August 20	Ungrazed	Hymenoptera	Formicidae	441.8
		Thysanoptera		238.2
		Homoptera	Coccoidea	120.4
		Collembola	Entomobryidae	102.4
		Homoptera	Delphacidae	55.0
		Homoptera	Cicadellidae	47.2
		Hemiptera	Lygaeidae	47.2
		Diptera (imm)		21.2
	Grazed	Hymenoptera	Formicidae	262.4
		Thysanoptera		143.0
		Collembola	Entomobryidae	75.2
		Homoptera	Delphacidae	49.4
		Collembola	Sminthuridae	47.4
		Homoptera	Coccoidea	40.4
		Coleoptera (imm)		33.6
		Coleoptera	Nitidulidae	15.4
		Homoptera	Cicadellidae	15.2
September 19	Ungrazed	Collembola	Sminthuridae	109.0
		Collembola	Entomobryidae	101.2
		Hymenoptera	Formicidae	57.8
		Diptera (imm)		39.2
		Thysanoptera		34.0
		Homoptera	Coccoidea	14.6
		Homoptera	Delphacidae	10.0
		Coleoptera (imm)		9.8
		Homoptera	Cicadellidae	9.6

Table 6 (concluded).

Date	Treatment	Order	Family	Number
	Grazed	Collembola	Entomobryidae	240.0
		Collembola	Sminthuridae	213.2
		Hymenoptera	Formicidae	80.6
		Thysanoptera		56.8
		Homoptera	Coccoidea	18.8
		Diptera (imm)		16.6
		Homoptera	Delphacidae	14.0
		Homoptera	Cicadellidae	13.4
October 11	Ungrazed	Collembola	Entomobryidae	192.2
		Thysanoptera		92.8
		Hymenoptera	Formicidae	79.0
		Homoptera	Delphacidae	45.2
		Hemiptera	Lygaeidae	38.2
		Collembola	Sminthuridae	38.2
		Coleoptera	Carabidae	11.2
		Homoptera	Coccoidea	10.8
	Grazed	Thysanoptera		223.2
		Hymenoptera	Formicidae	151.0
		Coleoptera	Nitidulidae	43.8
		Homoptera	Delphacidae	35.4
		Collembola	Entomobryidae	29.0
		Collembola	Sminthuridae	24.8
		Homoptera	Coccoidea	19.8
		Coleoptera	Staphylinidae	13.2
November 7	Ungrazed	Collembola	Entomobryidae	119.8
		Collembola	Sminthuridae	46.4
		Diptera (imm)		41.2
		Homoptera	Delphacidae	36.2
		Thysanoptera		29.0
		Homoptera	Coccoidea	20.6
		Hemiptera	Lygaeidae	10.2
		Coleoptera	Carabidae	4.8
	Grazed	Collembola	Sminthuridae	239.0
		Collembola	Entomobryidae	192.6
		Thysanoptera		108.2
		Homoptera	Delphacidae	42.4
		Homoptera	Coccoidea	36.4
		Diptera (imm)		28.2
		Coleoptera	Nitidulidae	17.2
		Homoptera	Cicadellidae	15.0

imm = immature life stage.

Table 7. Major groups of insects by biomass, Osage Site, July 3, 1970 through November 7, 1971 (g/m^2).

Date	Treatment	Order	Family	Weight
July 3, 1970	Ungrazed	Hymenoptera	Formicidae	.020
		Orthoptera	Tettigoniidae	.019
		Diptera	Tabanidae	.009
		Coleoptera	Nitidulidae	.006
		Homoptera	Cicadellidae	.005
	Grazed	Orthoptera	Tettigoniidae	.122
		Hymenoptera	Formicidae	.012
		Homoptera	Cicadellidae	.007
		Homoptera	Fulgoridae	.003
		Orthoptera	Acrididae	.003
		Coleoptera	Chrysomelidae	.003
July 16	Ungrazed	Orthoptera	Acrididae	.053
		Hymenoptera	Formicidae	.026
		Orthoptera	Tettigoniidae	.012
		Homoptera	Cicadellidae	.005
		Coleoptera	Chrysomelidae	.002
		Hemiptera	Lygaeidae	.002
	Grazed	Hymenoptera	Formicidae	.017
		Orthoptera	Acrididae	.011
		Homoptera	Cercopidae	.004
		Homoptera	Cicadellidae	.003
		Orthoptera	Tettigoniidae	.003
		Hemiptera	Lygaeidae	.001
		Coleoptera	Coccinellidae	.001
August 3	Ungrazed	Hymenoptera	Formicidae	.050
		Orthoptera	Acrididae	.006
		Hemiptera	Lygaeidae	.003
		Homoptera	Fulgoridae	.002
		Homoptera	Cicadellidae	.001
		Homoptera	Membracidae	.001
	Grazed	Orthoptera	Acrididae	.048
		Orthoptera	Tettigoniidae	.039
		Hymenoptera	Formicidae	.014
		Homoptera	Cicadellidae	.001
		Homoptera	Fulgoridae	.001
		Homoptera	Membracidae	.001

Table 7 (cont'd).

Date	Treatment	Order	Family	Weight
August 17	Ungrazed	Orthoptera	Acrididae	.073
		Hymenoptera	Formicidae	.028
		Lepidoptera	Noctuidae	.004
		Hemiptera	Lygaeidae	.002
		Diptera	Tachinidae	.000
		Hemiptera	Pentatomidae	.000
	Grazed	Orthoptera	Acrididae	.036
		Orthoptera	Tettigoniidae	.021
		Coleoptera	Chrysomelidae	.007
		Hymenoptera	Formicidae	.003
		Hymenoptera	Halictidae	.001
		Diptera	Sarcophagidae	.000
September 27	Ungrazed	Orthoptera	Gryllidae	.047
		Lepidoptera		.010
		Hymenoptera	Formicidae	.006
		Hemiptera	Lygaeidae	.003
		Hemiptera	Scutelleridae	.002
		Collembola		.002
	Grazed	Hymenoptera	Formicidae	.003
		Thysanoptera		.002
		Collembola		.001
		Lepidoptera		.001
		Coleoptera	Cerambycidae	.001
		Diptera	Tachinidae	.000
October 25	Ungrazed	Hymenoptera	Formicidae	.003
		Coleoptera	Carabidae	.002
		Hemiptera	Lygaeidae	.002
		Homoptera	Cercopidae	.002
		Collembola		.001
		Thysanoptera		.001
	Grazed	Collembola		.005
		Hemiptera	Lygaeidae	.003
		Hymenoptera	Formicidae	.002
		Thysanoptera		.002
		Coleoptera	Lathridiidae	.001
		Homoptera	Membracidae	.000
		Coleoptera	Nitidulidae	.000

Table 7 (cont'd).

Date	Treatment	Order	Family	Weight
November 23	Ungrazed	Lepidoptera		.005
		Hemiptera	Lygaeidae	.003
		Coleoptera	Carabidae	.002
		Coleoptera		.000
		Homoptera	Cercopidae	.000
		Coleoptera	Curculionidae	.000
	Grazed	Collembola		.002
		Coleoptera	Carabidae	.002
		Coleoptera	Curculionidae	.001
		Coleoptera		.000
		Hemiptera	Lygaeidae	.000
		Homoptera	Cicadellidae	.000
April 24, 1971	Ungrazed	Hymenoptera	Formicidae	.004
		Hemiptera	Lygaeidae	.002
		Homoptera	Cicadellidae	.001
		Homoptera	Fulgoridae	.001
		Homoptera	Coccoidea	.001
		Hemiptera	Scutelleridae	.001
	Grazed	Coleoptera	Chrysomelidae	.008
		Hymenoptera	Formicidae	.006
		Homoptera	Cicadellidae	.005
		Coleoptera	Nitidulidae	.002
		Thysanoptera		.002
		Coleoptera	Staphylinidae	.001
		Coleoptera	Lathridiidae	.001
		Homoptera	Fulgoridae	.001
May 13	Ungrazed	Hymenoptera	Formicidae	.017
		Hemiptera	Scutelleridae	.003
		Coleoptera	Chrysomelidae	.002
		Coleoptera	Curculionidae	.002
		Hemiptera	Lygaeidae	.002
		Coleoptera	Carabidae	.002
		Homoptera	Cicadellidae	.001
		Coleoptera	Elateridae	.001
	Grazed	Hymenoptera	Formicidae	.023
		Homoptera	Cicadellidae	.009
		Coleoptera	Nitidulidae	.007
		Orthoptera	Blattidae	.003
		Thysanoptera		.002
		Coleoptera	Chrysomelidae	.002
		Lepidoptera (imm)		.002
		Coleoptera	Elateridae	.001

Table 7 (cont'd).

Date	Treatment	Order	Family	Weight
June 3	Ungrazed	Hymenoptera	Formicidae	.100
		Coleoptera	Elateridae	.003
		Homoptera	Cicadellidae	.002
		Hemiptera	Lygaeidae	.002
		Coleoptera	Carabidae	.002
		Coleoptera	Curculionidae	.001
		Homoptera	Fulgoridae	.001
		Hemiptera	Scutelleridae	.001
	Grazed	Hymenoptera	Formicidae	.029
		Orthoptera	Gryllidae	.023
		Lepidoptera	Noctuidae	.022
		Thysanoptera		.004
		Coleoptera	Carabidae	.002
		Coleoptera	Elateridae	.002
		Coleoptera	Nitidulidae	.001
		Homoptera	Cicadellidae	.001
June 19	Ungrazed	Hymenoptera	Formicidae	.022
		Homoptera	Cicadellidae	.014
		Coleoptera	Curculionidae	.011
		Coleoptera	Scarababaeidae	.009
		Lepidoptera (imm)		.009
		Coleoptera	Chrysomelidae	.006
		Homoptera	Delphacidae	.003
		Hemiptera	Lygaeidae	.002
	Grazed	Hymenoptera	Formicidae	.028
		Homoptera	Cicadellidae	.010
		Coleoptera	Curculionidae	.009
		Thysanoptera		.005
		Lepidoptera	Pyralidae	.005
		Lepidoptera	Noctuidae	.003
		Homoptera	Delphacidae	.002
		Hemiptera	Scutelleridae	.001
July 11	Ungrazed	Hymenoptera	Formicidae	.142
		Coleoptera	Curculionidae	.009
		Coleoptera	Chrysomelidae	.003
		Homoptera	Delphacidae	.002
		Homoptera	Cicadellidae	.002
		Orthoptera	Gryllidae	.002
		Coleoptera	Carabidae	.002
		Diptera (imm)		.002

Table 7 (cont'd).

Date	Treatment	Order	Family	Weight
	Grazed	Hymenoptera	Formicidae	.020
		Orthoptera	Gryllidae	.014
		Homoptera	Cicadellidae	.006
		Coleoptera	Curculionidae	.004
		Hemiptera	Lygaeidae	.003
		Homoptera	Delphacidae	.002
		Thysanoptera		.002
		Orthoptera	Acrididae	.002
July 25	Ungrazed	Orthoptera	Acrididae	.064
		Hymenoptera	Formicidae	.034
		Hymenoptera	Aphidae	.015
		Lepidoptera (imm)		.013
		Coleoptera	Curculionidae	.008
		Homoptera	Cicadellidae	.008
		Orthoptera	Gryllidae	.007
		Hemiptera	Reduviidae	.005
	Grazed	Hymenoptera	Formicidae	.022
		Lepidoptera (imm)		.012
		Homoptera	Cicadellidae	.009
		Coleoptera	Curculionidae	.004
		Hemiptera	Reduviidae	.003
		Homoptera	Delphacidae	.002
		Hymenoptera	Ichneumonidae	.002
		Coleoptera	Carabidae	.001
August 6	Ungrazed	Hymenoptera	Formicidae	.027
		Diptera	Tabanidae	.012
		Coleoptera	Carabidae	.010
		Coleoptera	Curculionidae	.005
		Hemiptera	Scutelleridae	.004
		Lepidoptera	Noctuidae	.004
		Hemiptera	Lygaeidae	.003
		Homoptera	Cicadellidae	.001
	Grazed	Hymenoptera	Formicidae	.030
		Coleoptera	Curculionidae	.014
		Coleoptera	Carabidae	.009
		Homoptera	Cicadellidae	.004
		Coleoptera	Chrysomelidae	.003
		Hemiptera	Reduviidae	.003
		Thysanoptera		.002
		Coleoptera (imm)		.002

Table 7 (cont'd).

Date	Treatment	Order	Family	Weight
August 20	Ungrazed	Hymenoptera	Formicidae	.035
		Coleoptera	Curculionidae	.007
		Hemiptera	Scutelleridae	.007
		Orthoptera	Acrididae	.006
		Homoptera	Cicadellidae	.006
		Hemiptera	Lygaeidae	.004
		Thysanoptera		.003
		Homoptera	Delphacidae	.002
	Grazed	Lepidoptera (imm)		.037
		Hymenoptera	Formicidae	.034
		Orthoptera	Gryllidae	.020
		Orthoptera	Tettigoniidae	.013
		Homoptera	Cicadellidae	.010
		Orthoptera	Acrididae	.007
		Coleoptera	Carabidae	.006
		Hemiptera	Lygaeidae	.005
September 19	Ungrazed	Coleoptera	Curculionidae	.008
		Coleoptera	Carabidae	.007
		Hemiptera	Scutelleridae	.005
		Hymenoptera	Formicidae	.005
		Coleoptera	Staphylinidae	.002
		Homoptera	Cicadellidae	.002
		Coleoptera	Chrysomelidae	.002
		Hemiptera	Lygaeidae	.002
	Grazed	Hymenoptera	Formicidae	.007
		Homoptera	Cicadellidae	.003
		Hymenoptera	Ichneumonidae	.002
		Orthoptera	Blattidae	.002
		Coleoptera	Carabidae	.001
		Coleoptera	Staphylinidae	.001
		Hemiptera	Lygaeidae	.001
October 11	Ungrazed	Hemiptera	Lygaeidae	.012
		Hemiptera	Scutelleridae	.006
		Hymenoptera	Formicidae	.005
		Coleoptera (imm)		.002
		Coleoptera	Staphylinidae	.002
		Lepidoptera (imm)		.001
		Homoptera	Cicadellidae	.001
		Coleoptera	Carabidae	.001

Table 7 (concluded).

Date	Treatment	Order	Family	Weight
	Grazed	Hymenoptera	Formicidae	.013
		Lepidoptera (imm)		.007
		Coleoptera (imm)		.006
		Lepidoptera	Noctuidae	.005
		Coleoptera	Carabidae	.004
		Coleoptera	Curculionidae	.004
		Hemiptera	Lygaeidae	.003
		Homoptera	Cicadellidae	.003
November 7	Ungrazed	Lepidoptera	Noctuidae	.008
		Hemiptera	Scutelleridae	.003
		Hemiptera	Lygaeidae	.002
		Coleoptera	Chrysomelidae	.001
		Homoptera	Delphacidae	.001
	Grazed	Hemiptera	Pentatomidae	.009
		Homoptera	Membracidae	.005
		Hemiptera	Lygaeidae	.003
		Homoptera	Delphacidae	.002
		Homoptera	Cicadellidae	.002
		Lepidoptera (imm)		.001

imm = immature life stage.

Table 8. Total numbers (mean number/m^2) and biomass (g/m^2) of insects collected, Osage Site, July 3, 1970 through November 7, 1971.

Date	Number		Biomass	
	Ungrazed	Grazed	Ungrazed	Grazed
July 3, 1970	599.0	403.4	.118 = .12	.162 = .16
July 16	331.0	320.4	.116 = .12	.048 = .05
August 3	291.8	283.8	.074 = .07	.113 = .11
August 17	155.2	128.6	.115 = .12	.091 = .09
September 27	258.8	315.2	.085 = .09	.015 = .02
October 25	180.6	641.8	.019 = .02	.024 = .02
November 23	50.0	77.4	.015 = .02	.009 = .01
April 24, 1971	493.8	684.2	.012 = .01	.029 = .03
May 13	482.0	897.0	.032 = .03	.055 = .06
June 3	1132.2	1700.2	.117 = .12	.090 = .09
June 19	978.8	1471.4	.087 = .09	.075 = .08
July 11	1345.6	1347.2	.173 = .17	.057 = .06
July 25	836.0	878.0	.172 = .17	.064 = .06
August 6	390.8	748.0	.071 = .07	.073 = .07
August 20	1218.8	767.6	.082 = .08	.148 = .15
September 19	454.8	723.6	.044 = .04	.025 = .03
October 11	573.4	639.8	.039 = .04	.064 = .06
November 7	338.6	730.6	.022 = .02	.031 = .03

Table 9. Number (mean number/m^2) and biomass (g/m^2) of total invertebrates collected, Osage Site, June 16, 1970, through November 7, 1971.

Date	Number		Biomass	
	Ungrazed	Grazed	Ungrazed	Grazed
July 16, 1970	349.4	336.4	.129 = .13*	.074 = .07
August 3	407.0	439.2	.079 = .08*	.119 = .12*
August 17	179.4	140.6	.119 = .12*	.101 = .10*
September 27	381.4	468.4	.135 = .14*	.023 = .02
October 25	285.6	994.6	.033 = .03	.047 = .05
November 23	62.6	129.4	.017 = .02*	.012 = .01*
April 24, 1971	848.2	1491.6	.026 = .03	.053 = .05
May 13	1108.4	1857.0	.048 = .05	.075 = .08
June 3	1855.2	2529.8	.140 = .14*	.113 = .11*
June 14	1471.0	2472.0	.103 = .10	.098 = .10
July 11	2120.8	2373.6	.186 = .19*	.080 = .08
July 25	1263.6	1994.2	.184 = .18*	.077 = .08
August 6	521.8	1351.2	.080 = .08*	.086 = .09
August 20	2963.0	2289.0	.090 = .09	.186 = .19
September 19	1065.0	2022.6	.049 = .05	.051 = .05
October 11	1597.2	2429.4	.083 = .08	.109 = .11
November 7	4279.4	4410.2	.035 = .04*	.057 = .06

* The standard error of the mean dry weight exceeds 20 per cent of the mean.

Table 10. Number (mean number/m^2) and biomass (g/m^2) of Araneida collected, Osage Site, July 16, 1970 through November 7, 1971.

Date	Number		Biomass	
	Ungrazed	Grazed	Ungrazed	Grazed
July 16, 1970	14.8	13.8	.012	.024
August 3	13.0	4.0	.002	.003
August 17	13.4	5.0	.002	.009
September 27	21.0	10.8	.048	.002
October 25	17.6	16.4	.010	.012
November 23	4.4	1.8	.001	.001
April 24, 1971	35.8	10.2	.010	.005
May 13	36.4	9.8	.009	.006
June 3	17.0	5.8	.017	.010
June 19	11.2	14.4	.012	.012
July 11	24.6	29.6	.007	.013
July 25	26.0	15.2	.007	.001
August 6	21.2	14.2	.008	.004
August 20	21.0	25.8	.001	.021
September 19	6.8	11.6	.001	.015
October 11	69.4	53.6	.030	.018
November 7	17.0	11.6	.010	.015

Table 11. Number (mean number/m^2) and biomass (g/m^2) of Acarina collected, Osage Site, July 3, 1970, through November 7, 1971.

Date	Number		Biomass	
	Ungrazed	Grazed	Ungrazed	Grazed
July 16	3.6	2.2	.00024	.00034
August 3	102.2	151.4	.00198	.00345
August 17	10.8	7.0	.00120	.00052
September 27	101.6	142.4	.00228	.00565
October 25	87.4	336.4	.00324	.01110
November 23	8.2	50.2	.00038	.00128
April 24, 1971	318.6	797.2	.00400	.01900
May 13	590.0	950.2	.00700	.01400
June 3	706.0	823.8	.00600	.01300
June 19	481.0	986.2	.00400	.01100
July 11	750.6	996.8	.00600	.01000
July 25	401.6	1101.0	.00500	.01200
August 6	109.8	589.0	.00100	.00900
August 20	1723.2	1495.6	.00654	.01723
September 19	603.4	1287.4	.00360	.01100
October 11	954.4	1736.0	.01322	.02728
November 7	3923.8	3668.0	.00278	.01026

Table 12. Estimate of herbivores (%) compared to total invertebrate biomass (g/m^2).

Date	Ungrazed			Grazed		
	Herbivore (%)	Herbivore biomass	Total biomass	Herbivore (%)	Herbivore biomass	Total biomass
April 24	46	.012	.026	68	.036	.053
May 13	57	.027	.048	65	.049	.075
June 3	49	.070	.140	72	.081	.113
June 19	65	.056	.086	66	.065	.098
July 11	55	.102	.185	66	.053	.080
July 25	70	.129	.184	81	.062	.077
August 6	45	.036	.080	59	.051	.086
August 20	73	.066	.091	72	.131	.186
September 19	67	.033	.049	48	.025	.052
October 11	52	.043	.083	61	.067	.110
November 7	64	.023	.036	67	.038	.057
Average	59	.046	.078	66	.055	.083

Table 13. Orders and families (or groups) captured by sweep net in grazed and ungrazed treatments, Osage Site, 1971.

Order	Family (or group)
Collembola	Entomobryidae
Orthoptera	Acrididae
	Tettigoniidae
	Phasmidae
	Gryllidae
Homoptera	Issidae
	Cicadellidae
	Fulgoridae
	Aphididae
	Cisiidae
	Membracidae
	Delphacidae
	Dictyopharidae
	Psyllidae
Hemiptera	Scutelleridae
	Lygaeidae
	Psyllidae
	Miridae
	Tingidae
	Phymatidae
	Corimelaenidae
	Reduviidae
	Coreidae
	Pentatomidae
Coleoptera	Carabidae
	Chrysomelidae
	Cerambycidae
	Cantharidae
	Coccinellidae
	Throscidae
	Staphylinidae
	Curculionidae
	Lathridiidae
	Mordellidae
	Dermestidae
	Elateridae
	Cleridae
	Scarabaeidae
	Nitidulidae
	Ptilidae
	Cisidae
	Erotylidae

Table 13 (concluded).

Order	Family (or group)
Lepidoptera	Pyralidae
	Noctuidae
Diptera	Tachinidae
	Pipunculidae
	Chloropidae
	Rhagionidae
	Sciomyzidae
	Chironomidae
	Otitidae
	Syrphidae
	Asilidae
	Calliphoridae
	Piophilidae
	Sarcophagidae
	Pyrgotidae
	Tipulidae
	Cecidomyiidae
	Ceratopogonidae
	Culicidae
Hymenoptera	Formicidae
	Braconidae
	Pteromalidae
	Ichneumonidae
	Halictidae
	Dryinidae
	Eulophidae
Neuroptera	Chrysopidae
	Myrmeleontidae
Psocoptera	
Thysanoptera	

Table 14. Orders and families (or groups) captured by quick trap in grazed and ungrazed treatments, Osage Site, 1971.

Order	Family (or group)
Collembola	Entomobryidae
	Poduridae
	Sminthuridae
Orthoptera	Blattidae
	Gryllidae
	Acrididae
	Tettigoniidae
	Mantidae
Homoptera	Delphacidae
	Coccoidea
	Psyllidae
	Membracidae
	Cicadellidae
	Fulgoridae
	Aphididae
	Dictyopharidae
	Issidae
Hemiptera	Lygaeidae
	Miridae
	Scutelleridae
	Coreidae
	Pentatomidae
	Ploiariidae
	Tingidae
	Reduviidae
	Gerridae
	Phymatidae
Coleoptera	Carabidae
	Coccinellidae
	Curculionidae
	Throscidae
	Staphylinidae
	Eucnemidae
	Lathridiidae
	Nitidulidae
	Pselaphidae
	Phalacridae
	Elateridae
	Chrysomelidae
	Scydmaenidae
	Cleridae
	Cantharidae
	Meloidae
	Ptilidae
	Scaphidiidae
	Cisidae

Table 14 (concluded).

Order	Family (or group)
Lepidoptera	Noctuidae
	Pyralidae
Diptera	Cecidomyiidae
	Sciaridae
	Tabanidae
	Phoridae
	Chironomidae
	Chloropidae
	Scatopsidae
	Ceratopogonidae
	Syrphidae
	Otitidae
	Tipulidae
	Mycetophilidae
	Tachinidae
Hymenoptera	Formicidae
	Encyrtidae
	Pteromalidae
	Trichogrammatidae
	Thysanidae
	Eulophidae
	Dryinidae
	Scelionidae
	Braconidae
	Ichneumonidae
	Cynipidae
	Tenthredinidae
Neuroptera	Hemerobiidae
Psocoptera	
Thysanoptera	
Thysanura	Japygidae
Strepsiptera	

Table 15. Orders and families (or groups) captured by pitfall traps in grazed and ungrazed treatments, Osage Site, 1971.

Order	Family (or group)
Collembola	Entomobryidae
	Poduridae
	Sminthuridae
Orthoptera	Gryllidae
	Blattidae
	Tettigoniidae
Homoptera	Fulgoridae
	Issidae
	Delphacidae
	Cicadellidae
	Cixiidae
Hemiptera	Lygaeidae
	Coreidae
	Neididae
	Reduviidae
	Pentatomidae
Coleoptera	Silphidae
	Carabidae
	Curculionidae
	Scarabaeidae
	Chrysomelidae
	Lathridiidae
	Elateridae
	Coccinellidae
	Cicindelidae
	Staphylinidae
	Nitidulidae
	Phalacridae
	Histeridae
	Pselaphidae
	Scydmaenidae
	Scaphididae
Lepidoptera	Noctuidae
Diptera	Cecidomyiidae
	Chloropidae
	Sciaridae
	Rhagionidae
	Tachinidae
	Culicidae
	Muscidae
	Chironomidae
	Otitidae
	Dolichopodidae
	Phoridae
	Sarcophagidae
	Syrphidae

Table 15 (concluded).

Order	Family (or group)
Hymenoptera	Formicidae
	Ichneumonidae
	Braconidae
	Encyrtidae
	Pteromalidae
	Mutilidae
	Eulophidae
	Dryinidae
	Thysanidae
Neuroptera	Chrysopidae
Thysanoptera	
Dermaptera	

Table 16. Orders and families (or groups) unique to the following trapping methods, Osage Site, 1971.[a]

Pitfall	Sweep net	Quick trap
Silphidae	Halictidae	Tenthredinidae
Mutillidae	Sciomyzidae	Gerridae
Neididae	Myrmeleontidae	Meloidae
Histeridae	Dermestidae	Mantidae
Dermaptera	Pyrgotidae	Strepsiptera
Cicindelidae	Rhagionidae	Ploiariidae
	Erotylidae	Hemerobiidae
	Ephemeroptera	Scatopsidae
	Piophilidae	Tabanidae
	Asilidae	Scelionidae
	Pipunculidae	Euenemidae
	Phasmidae	Trichogrammatidae

[a] Families observed in the field but never captured.
Acroceridae
Vespidae
Danaidae
Satyridae
Nymphalidae
Coenagrionidae
Libellulidae

Table 17. Extraction of invertebrates (%) in time intervals (minutes) from the quick trap by the vacuum collector.

Invertebrates	1 min	2 min	3 min	4 min
Araneida	44	66	83	94
Acarina	32	58	77	84
Coleoptera (imm)	62	76	90	96
Lygaeidae (imm)	65	82	88	91
Formicidae	41	58	74	85
Thysanoptera	62	76	85	95
Cicadellidae	38	47	77	94
Nitidulidae	54	68	83	89
Coccoidea	58	66	86	94
Chrysomelidae	29	45	57	100
Curculionidae	0	20	80	80
Tettigoniidae	50	100		
Diptera (imm)	15	30	47	88

imm = Immature.

Table 18. Specimens (%) recovered by various sorting procedures for 1970 and 1971.

Year	Family (or group)	Berlese: D-vac material	Berlese: Grass clipping	Hand-sort: D-vac litter
1970	Formicidae	97.1	0.3	2.6
	Collembola	90.6	9.4	0.0
	Lathridiidae	89.5	10.0	0.0
	Lygaeidae	87.5	11.8	0.7
	Nitidulidae	86.3	13.7	0.0
	Cicadellidae	82.6	7.2	10.2
	Fulgoridae	78.1	0.0	21.9
	Thysanoptera	73.9	26.1	0.0
	Chrysomelidae	66.6	0.0	33.4
	Cercopidae	46.6	33.3	20.0
	Trichogrammatidae	42.1	57.8	0.0
	Coccoidea	21.6	78.2	0.0
	Psocoptera	20.0	80.0	0.0
	Tettigoniidae	19.0	4.9	76.1
	Acrididae	6.7	0.0	93.3
	Miridae	5.3	94.7	0.0
1971	Formicidae	97.2	2.2	0.6
	Nitidulidae	96.2	3.8	0.0
	Delphacidae	95.9	4.1	0.0
	Entomobryidae	94.6	5.4	0.0
	Lygaeidae	94.0	4.8	1.2
	Curculionidae	93.0	4.0	3.0
	Cicadellidae	92.9	6.4	0.7
	Araneida	92.3	3.9	3.8
	Carabidae	91.0	3.7	5.3
	Scydmaenidae	90.9	4.5	4.5
	Staphylinidae	90.0	10.0	0.0
	Sminthuridae	88.8	11.2	0.0
	Coleoptera (imm)	87.0	13.0	0.0
	Fulgoridae	83.5	16.5	0.0
	Encyrtidae	81.5	18.5	0.0
	Scutelleridae	79.1	20.9	0.0
	Eulophidae	78.5	21.5	0.0
	Diptera	78.4	21.6	0.0
	Aphididae	76.5	17.3	6.2
	Lepidoptera (imm)	75.0	11.4	13.6
	Chrysomelidae	70.0	5.0	25.0
	Thysanoptera	69.7	26.4	3.9
	Pentatomidae	69.6	30.4	0.0
	Miridae	68.1	27.2	4.5
	Acarina	64.1	35.9	0.0
	Coccoidea	56.5	43.5	0.0
	Cecidomyiidae	56.0	44.0	0.0
	Pteromalidae	50.8	19.2	0.0

Table 18 (concluded).

Year	Family (or group)	Berlese: D-vac material	Berlese: Grass clipping	Hand-sort: D-vac litter
1971	Trichogrammatidae	47.1	52.9	0.0
(contd)	Psocoptera	37.7	61.3	1.0
	Gryllidae	36.0	0.0	64.0
	Blattidae	16.6	33.3	50.0
	Tettigoniidae	0.0	0.0	100.0
	Pyralidae	0.0	0.0	100.0

Table 19. Specimens (%) recovered by Berlese funnels compared to a kerosene flotation method.*

Date	Family (or group)	Berlese funnel	Kerosene method
May 13, 1971	Thysanoptera	98.3	1.7
	Acarina	97.7	2.3
	Entomobryidae	91.5	8.5
	Formicidae	60.0	40.0
	Coleoptera (imm)	50.0	50.0
	Cicadellidae (imm)	25.0	75.0
	Lygaeidae (imm)	23.0	77.0
	Eulophidae	15.0	85.0
June 3, 1971	Psocoptera	100.0	0.0
	Scutelleridae	100.0	0.0
	Fulgoridae	100.0	0.0
	Nitidulidae	100.0	0.0
	Curculionidae	100.0	0.0
	Sminthuridae	98.6	1.4
	Coccoidea	97.4	2.6
	Cicadellidae	97.4	2.6
	Thysanoptera	96.8	3.2
	Formicidae	94.9	5.1
	Carabidae	94.6	5.4
	Acarina	90.7	9.3
	Lygaeidae (imm)	90.0	10.0
	Entomobryidae	85.2	14.8
	Araneida	84.5	15.5
	Aphididae	0.0	100.0
	Eulophidae	0.0	100.0

* Six samples were processed by the kerosene method.

The Role of Selected Invertebrates in Grasslands

Large numbers of insects have been reported from grasslands (Morris 1920, Walkden and Wilbur 1944). Watts and Bellotti (1967) recorded 120 species from black grama grass in New Mexico from nine orders and 55 families. Ahring and Howell (1968) found the most prevalent insects in grasses to be Thysanoptera.

Boyd (1960) reported grazing to affect large predatory forms such as Carabidae, Staphylinidae, and small herbivorous forms. The numerical differences between catches on grazed and ungrazed plots were great. Greater numbers of Homoptera, Tipulidae, and Apion apricans (Curculionidae), were recorded in grazed than ungrazed areas. Morris (1920) observed that many groups of invertebrates had more species and individuals in ungrazed chalk grassland in England than in grazed areas.

Whelan (1936) stated that bunch-grasses provide hibernating places for many insects, especially the chinch bug (Blissus leucopterus Say). Fifty-four species belonging to eight orders were found, not counting Hymenoptera. Species collected were: Coleoptera 26, Araneida 14, Hemiptera 7, Collembola 3, and Isoptera 1. Formicidae composed four per cent of the numbers in the grass clumps.

McDaniel and Balsbaugh (1968) noted that bovine manure piles in grazed areas serve as overwintering habitats for certain adult Coleoptera. Two species of Carabidae, two Hydrophilidae, four Staphylinidae, one Ptilidae, two Scarabaeidae, two Anthicidae, two Lathridiidae, and two Curculionidae were found. Cantharidae larvae were the only immature Coleoptera found. Hayes (1927) concluded that prairie scavenger insects derived their sustenance from buffalo droppings; Muscidae and Sarcophagidae are first attracted to such food sources, followed by Scarabaeidae. Because the soil remains moist under the droppings, wireworms, white grubs, ants, ground beetles, and crickets are present during the hotter, drier months of the season. Dead mammals and birds serve as a food source for Silphidae and Staphylinidae in prairie regions.

Coyner (1938) found that Homoptera, Orthoptera, and Lepidoptera showed a definite preference for an overgrazed habitat in Oklahoma prairie. Smith (1940) noted Coleoptera was best represented in undisturbed prairie, Chrysomelidae numbers were much less in overgrazed areas but Meloidae increased. Hemiptera, Homoptera and Halictidae also increased in numbers on grazed areas. The Arachnida occurred rather uniformly in all types of areas (grazed and ungrazed). Although the total number of insects increased under conditions of overgrazing, the total number of species declined.

Orthoptera

From the standpoint of total numbers present and size of individuals, members of the Orthoptera constitute one of the most important groups of insects of grazing lands (Smith 1940). He found an increase in the number of species in grazed prairie. They supply a large amount of food for secondary consumers.

It has been reported that grasshoppers are the only orthopteran to be a major problem in Oklahoma. Approximately 104 species are recorded for the state. The diet consists of numerous kinds of food substances, including both plant and animal materials, the former being taken in the form of plant products and secretions, dead plant materials, and living plants. Gangwere (1961) observed that many Orthoptera accept dead, dry vegetation of a type that would not ordinarily be accepted in the living condition. This suggests that much of the specificity exhibited by certain species, especially Acrididae, in selection of living food-plants may be lost following death and desiccation of the primary producer.

Nerney (1960) found that adults were more mobile and contacted preferred food plants more readily. Damage per grasshopper per square yard was higher on forbs and annual grasses than on perennial grasses. Perennial grass damage per unit area depends on the volume of the grass, number of grasshoppers, food preferences of different species, and the availability of other food plants. Anderson (1964) found grass-feeding species of Acrididae were mos numerous where perennial grasses comprised more than 40 per cent of the egetation.

Gangwere (1961) grouped rasses, sedges, and rushes as a single food-type because of their essential similarity in form, texture, and silica content and because of their similarity in terms of attractiveness to Orthoptera. The leaves, and to a lesser extent, the stems and reproductive parts of these moncots are consumed regularly by the Acrididae subfamilies Acridinae, Cyrtacanthacridinae, and Oedipodinae. He and Clark (1947) concluded that specific food-plants generally are not limiting and that environmental factors are more important. Anderson (1964) indicates that preference for specific food plants is an important determinant of areas occupied by grasshoppers.

Various scavengers including Blattidae and Gryllidae are either suspected or known to consume lower plants such as algae, fungi, and lichens. Gangwere (1961) reports that Oecanthinae, which normally feed on flowers and leaves of higher plants and bodies of small insects, feed on fruiting bodies of fungi. He classified animal foods as: animal products, wastes, or secretions, dead animal materials, and dying animals. Dung and excrements are taken by many Acrididae, Blattidae, and Gryllinae. Old partly decomposed dead animal material is consumed by members of Gryllinae, Conocephalinae, and Blattidae. Materials which are intermediate between dead and living substances are taken by the above groups as well as by Cyrtacanthacridinae and Oedipodinae and perhaps rarely by certain Phaneropterinae.

A large number of Orthoptera obtain some of their diet by being carnivorous. Mantidae are totally predaceous and consume many species of arthropods, mostly insects. Other predaceous Orthoptera usually attack smaller, weaker, more soft-bodied insects. For example, Conocephalinae and Oecanthinae are predaceous on aphids. In most cases the prey consists of other species but virtually all the above groups are occasionally cannibalistic.

Blattidae (cockroaches) were commonly collected in the Osage grazed and ungrazed pastures but the former produced more immature specimens. Gangwere (1958) observed Blattidae in the field feeding on fresh rodent dung and on a small Crataegus pome. Analyses of crop contents and fecal materials demonstrated organic debris and sclerotized insect parts. Rau (1940) found cockroaches cannibalistic on dead and injured individuals. Dead plant and animal materials appear to be preferred to living ones, though both are eaten but availability may be a factor.

Mantidae are secondary consumers due to their predaceous food habits. Didlake (1926) described a differential feeding correlation with growth of mantids. Small insects such as leafhoppers, fruit flies, and geometrid caterpillars are consumed by newly hatched nymphs while second and third instar nymphs consume large leafhoppers, large Diptera, and grasshopper nymphs. Adults capture almost any large insect including Pentatomidae, Hymenoptera, Acrididae, and Lepidoptera. Mantidae are the only entirely carnivorous Orthoptera.

Most Phasmidae are characterized by considerable specificity of food-habit. None are predators, though some may show a tendency toward cannibalism (Ball et al. 1942). Gangwere (1961) feels that Diapheromera velii and D. persimilis probably have non-dendrophagous food habits because they occur in abundance in prairie and plains environments.

Two subfamilies of Tettigoniidae were found at the Osage Site, Copiphorinae (cone-headed katydids) and Phaneropterinae (round-headed katydids). It has been recorded that Neoconocephalus triops feed on fruiting heads of the grass Sorghastrum. Gangwere (1961) noted that all N. ensiger, except two individuals, were eating grass "seeds" or grains. Analysis of crop contents and fecal materials confirmed this habit. The only other food traces were insect remains. N. ensiger, in the laboratory, show preference for Andropogon but starvation pressure may force it into predation.

Isely (1941) observed Tettigoniidae to be oligophagous. Adults showed a marked preference for flower parts and tender fruit pods. A change in flora means a shift in fauna as far as prairie katydids are concerned. Some disappear after late spring and early summer flowering plants have bloomed. He also reported on the oviposition of Arethaca ambulator in the stems of Gaillardia pulchella (rosering gaillardia). The female chews into the stem to the pith region and deposits one egg, then closes the opening with chewed fragments, moves upward a short distance, and repeats the procedure. One stem of Gaillardia five inches in length revealed 35 punctures; other forbs were also recorded with punctures.

An analysis of feeding records, crop contents, and fecal materials of some Michigan Phaneropterinae show that in order of decreasing preference, forb leaves, forb flowers, and leaves of woody plants are accepted as food (Gangwere 1961). It would seem that Phaneropterinae usually reject grasses and sedges.

Gangwere (1961) found that Gryllidae (field cricket) crop contents and fecal materials showed an extremely varied diet of organic debris, dicot leaf materials, insect remains, spores, pollen, fragments of grass leaves, and sandgrains. Savin (1927) discovered that Gryllidae accepted 42 different kinds of food material although it was normally a vegetarian which selects widely from among different plants in its habitat. Wolcott (1923) reported Acheta to consume fresh cow manure. Gryllidae has also been reported taking animals as food, particularly insects, by scavenging. Severin (1926) records Gryllidae feeding on dead birds, rodents, and reptiles. Putnam (1947) reported Acheta consuming dead insects, especially grasshoppers.

In the field, Oecanthinae were observed eating forb flowers and sometimes leaves, the leaves of woody plants, and animal prey. Insect remains and organic debris were predominant in the crop contents and feces but spores, dicot pollen, and dicot leaves were common (Gangwere 1961). He observed tree crickets eating aphids in large quantities. According to Parrott and Fulton (1914), Oecanthinae feeds on scale insects, small Hemiptera, Cicadellidae, various small Hymenoptera, and other soft-bodied insects.

The family Acrididae are plant feeders and are often destructive in grassland ecosystems. They are selective in their host plants and the degree of selectivity is inherent in each species although expression of selectivity may be determined by the habitat (Mulkern et al. 1969). Hastings and Pepper (1964) demonstrated variability in the response of populations of *Aulocara elliotti* (the big-headed grasshopper) to moisture, temperature, and starvation. Anderson (1964) found that grasshopper populations were inversely proportional to the plant height and amount of shading. He found little correlation between numbers of grasshoppers per unit area and the loss of vegetation; this may be the result of different feeding habits of various species.

Mulkern et al. (1969) determined a grass-forb index to show host plant preferences of Acrididae. Categories constructed were: Forbivorous, *Hesperotettix viridis pratensis* (Thomas), *Melanoplus differentialis* (Thomas), *Melanoplus femurrubrum femurrubrum* (DeGeer); Mixed Forbivorous, *Hadrotettix trifasciatus* (Say), *Melanoplus bivittatus* (Say), *Melanoplus femurrubrum femurrubrum* (DeGeer); and Mixed

Gramnivorous, Melanoplus bivittatus (Say), Phoetaliotes nebrascensis (Thomas); Gramnivorous, Orphulella speciosa (Scudder), Syrbula admirabilis (Uhler). Arphia sp. show preferences for Poa pratensis, Bromus japonicus, and Sorghastrum nutans, respectively. Hadrotettix trifasciatus (Say) preferences were undetermined forbs, Sphaeralcea coccinea, and Carex filifolia, respectively. Hesperotettix viridis (Thomas) showed preference for Ambrosia psilostachya, Artemisia ludoviciana and Solidago altissima. Melanoplus bivittatus (Say) preferences were Poa pratensis, Ambrosia psilostachya, and undetermined forbs. Melanoplus femurrubrum femurrubrum (DeGeer) preferences were Ambrosia psilostachya, Poa pratensis, and Achillea milleforium lanulosa. Melanoplus differentialis (Thomas) preferred Kochia scoparia, Bromus tectorum, and Agropyron smithii. Orphulella speciosa (Scudder) preferences were Poa pratensis, Bouteloua gracilis, B. curtipendula, Andropogon scoparius, and A. gerardi, respectively. Syrbula admirabilis (Uhler) showed preference for Bouteloua gracilis, Sorghastrum nutans, and Andropogon scoparius.

Isely (1938) found that species of the subfamily Acridinae, in Texas, demonstrated a 90 per cent preference for grasses as host plants. Hadrotettix trifasciatus (Say) preferred the foliage of dicotyledons. Melanoplus differentialis (Thomas) in its natural environment often feeds on coarse grasses and forbs and is often found on common ragweed (Ambrosia psilostachya), but it refused to eat the leaves and flowers except when other plants were not available. Many species of grasshoppers often showed preference for Poa sp. (bluegrass). This follows somewhat the findings of Mulkern et al. (1969). Isely

(1938) found the subfamily Cyrtacanthacridinae to be forb feeders in general while Oedipodinae and Acridinae were primarily grass feeders. Hagen (1970) concluded that Phoetaliotes nebrascensis (Thomas), Orphulella speciosa (Scudder), and Chorotophaga viridifasciata (DeGeer) feed primarily on grasses. Melanoplus bivittatus (Say) was found only in areas where forbs occurred and Hadrotettix trifasciatus (Say) was associated with short grass and forb areas.

Lavigne and Pfadt (1964), through crop analysis, found that on Wyoming rangeland, 14 of 30 species of grasshoppers contained insect parts. The following insects were fed upon: grasshoppers 37.2 per cent, ants 33.6 per cent, beetles 8.8 per cent, andrenids 1.8 per cent, thrips 0.9 per cent, leafhoppers 0.9 per cent, tenebrionids 0.9 per cent, and wasps 0.9 per cent. They recorded scavenger behavior to be more common in the latter part of the growing season. It was exhibited by 22 per cent of the male grasshoppers as opposed to 78 per cent by females. Hadrotettix trifasciatus (Say) was one of the major consumers of insects. Under natural conditions the availability of food for scavengers is dependent upon the predatory and parasitic activities of other insects in the habitat. The high percentage of ants found in grasshopper crops is probably due to the ants' habit of throwing out dead bodies in their cleaning activities. Many species of insects are made available through feeding activities of robberflies (Asilidae) which suck out most of the internal contents of their prey and discard the nearly empty bodies which become a food source for all rangeland scavengers. H. trifasciatus was observed feeding on the paralyzed prey of a hymenopterous predator, Prionyz thomae (F) and were observed scavenging on dried cow manure.

Mulkern et al. (1962) noted that during the early mornings or on cool days many grasshoppers had empty crops. Apparently, during cool evenings they do not feed and exhaust the material stored. When the temperature rises in the morning, they begin feeding and quickly fill their crops. Gangwere (1958) reported that Acrididae feed mainly from 8 A.M. to 4 P.M.

Hermann and Eslick (1939) reports that Melanoplus bivittatus (Say), M. differentialis (Thomas), and M. femurrubrum femurrubrum (DeGeer) caused damage to seedling grasses, and selection within species of grasses displayed wide differences in comparative susceptibility to damage by grasshoppers. Kelly and Middlekauf (1961) pointed out that grasshopper damage to rangeland is often beyond their actual feeding. They cut blades and stems near the crown while ingesting only a part of them, with the resulting damage greater than just the plant matter being consumed. By feeding closer to the ground than livestock, grasshoppers retard growth, prevent reseeding, and even kill plants. As a result the soil is exposed to wind and water erosion, particularly in drought years.

Mulkern et al. (1964) performed crop analysis on grasshoppers associated with sand hill prairies of North Dakota. The following information is applied to only those plant and grasshopper species found at the Osage Site. Chorotophaga viridifasciata (DeGeer) preferred Poa pratensis, Hordeum jubatum, and Andropogon scoparius. They were found mostly in the short grass areas and were not widely distributed.

They overwinter as nymphs with adults appearing in early June and the first instar nymphs in August. Hesperotettix viridis pratensis (Scudder) showed high preference for Solidago missouriensis (Missouri goldenrod), S. altissim (tall goldenrod) and Ambrosia psilostachya (western ragweed). First instar nymphs appear in early June and adults in late July. S. missouriensis was found only in the ungrazed area at the Osage site. Melanoplus bivittatus (Say) preferred Poa pratensis, Amorpha canescens (lead plant) and Ambrosia psilostachya (western ragweed). This species was classified as a mixed feeder and was widely distributed. M. femurrubrum femurrubrum (DeGeer) consumed Poa pratensis, undetermined grasses, and Ambrosia psilostachya most readily. M. differentialis (Thomas) preferred Lappula echinata (European stickseed), Cirsium undulatum (wavyleaf thistle), and undetermined grasses. Hadrotettix trifasciatus (Say) preferred sparsely vegetated habitats and was observed feeding on six species of forbs and six species of grasses. Nymphs consumed a greater range of forbs than adults (Nerney 1960).

The host plant range of a grasshopper species is inherent, but the expression of selectivity is determined by the habitat. A grasshopper with a wide host plant range may appear to be restricted in its diet due to few suitable plants in the habitat (Mulkern et al. 1964).

Homoptera

Cicadellidae can be important in grasslands because of their direct feeding and oviposition on green tissue and their role as vectors of virus diseases.

DeLong (1965) stated that most leafhoppers feed on the mesophyll tissue and cause a white stippling on the leaf. Chlorophyll is reduced and physiology is affected, causing stunting, decrease in sugar storage, retarding of plant growth, and production of honeydew which may increase fungus growth. Borror and DeLong (1971) list five major types of injury to plants by leafhoppers: (1) some species remove excessive amounts of sap and reduce or destroy the chlorophyll in the leaves, (2) some species interfere with the normal physiology of the plant; Empoasca fabae (Harris) mechanically plugs the phloem and xylem vessels in the leaves so that transport of food materials is impaired, (3) a few species damage the plants by ovipositing in plant stems, (4) many species are vectors of organisms that cause plant diseases, (5) some species cause stunting and leaf curling due to the inhibition of growth on the under surface of the leaves where the leafhoppers feed.

Osborn (1939) found Cicadellidae to reduce hay and grazing yields between 25 and 50 per cent. Osborn (1912) reported that damage by rangeland leafhoppers usually appears as wilting or discoloration of the plant leaves and stems. Coupe and Schulz (1968) found some of the more common hosts of rangeland leafhoppers to be smooth brome (Bromus inermis) and bluegrass (Poa pratensis). Blocker et al. (1972) reported 57 species of leafhoppers representing 34 genera from upland seeded pastures at Hays, Kansas. Some species were apparently highly host specific and some were generalized feeders.

Aceratagallia uhleri, Flexamia reflexa, Prairiana sp., Gyponana sp., Limotettix sp., Paraphlepsius sp., Athysanella sp. feed on Andropogon spp. (DeLong 1965). He lists an Illinois prairie succession of associations: Exitianus exitiosus, Paraphiepsius sp. and Flexamia sp. on pasture associations; Polyamia sp. on the Panicum association; Flexamia reflexa, Balclutha sp., and Xerophloea sp. on the Andropogon scoparius association; Paraphlepsius sp., Chlorotettix viridius, and Polyamia sp. on the mixed grass association; and Flexamia reflexa, Prairiana sp., and Scaphytopius sp. on the Andropogon furcatus association.

Blocker et al. (1972) noted that Athysanella emarginata (Osborn) had a preference for native mixture of warm-season grasses. Flexamia atlantica (DeLong) showed possible preference for Panicum virgatum. Gillettiella atropunctata (Gillettee) showed preference for a native mixture of grasses, and Graminella mohri DeLong was found most common in Panicum virgatum.

Crumb (1911) reported Draeculacephala mollipes Say from low pastures on bluestem and bluegrass. Poos (1929) noted this species feeding on alfalfa and soybeans and Brandes (1923) reported that it fed in the vascular bundles but the large size of the stylets made it difficult to determine the exact tissue preferred. Howe (1930) reported Chlorotettix sp. mostly on grasses and D. mollipes was found on grasses, oats, wheat, rye, and barley. Blocker et al. (1972) noted that D. mollipes perhaps moves into rangeland after an earlier generation in another host area.

Knowlton and Allen (1936) noted damage to range and crop plants by Aceratagallia uhleri in the intermountains of Utah. Oman (1933) reported large populations on sugar beets. Kretzschmar (1948) reported that Empoasca fabae had a detrimental effect upon growth of soybean in Minnesota. Smith and Poos (1931) found five species of *Empoasca* fed chiefly in the palisade layers and to some extent on the mesophyll of their host plants. Putman (1941) found most species of *Empoasca* fed in the mesophyll but *E. fabae* was found to be a phloem feeder. Virus-transmitting leafhoppers were generally phloem feeders. Bennett (1934) found that *Circulifer tenellus* (Baker) was a phloem feeder on beet foliage.

Beirne (1956) noted that *Xestocephalus pulicarius* Van Duzee occurred mainly on the soil among roots of herbaceous plants and in the litter. *Parabolocratus* is listed as having grasses as host plants. Wilbur (1954) found that *Endria inimica* (Say) preferred introduced grasses such as *Poa* (bluegrass) to native grasses (e.g., *Andropogon*) in Kansas.

Borror and DeLong (1971) stated that Fulgoroidea (planthoppers) were seldom as abundant as leafhoppers. Their host plants range from trees and shrubs to herbaceous plants and grasses. The planthoppers feed on plant juices and like many Homoptera, produce honeydew. The Cixiidae are one of the most numerous planthoppers; some species are subterranean feeders on roots during their nymphal stage. Psyllidae (jumping plant lice) feed on plant juices. Some nymphs of Membracidae feed on grass and herbaceous plants. Certain species overwinter as eggs in the bark of trees and in the spring the nymphs hatch and drop to herbaceous vegetation where development is completed.

Borror and DeLong (1971) noted that Cercopidae (spittlebugs) mostly attack grasses and herbaceous plants. Wiegert (1964) found that the cercopid *Philaenus spumarius* preferred forbs over grasses but in the absence of given forbs, grasses were used as a food source. Weaver and King (1954) listed over 375 species known to serve as hosts for cercopid nymphs; the majority of these species were forbs. Wiegert (1964) found that spittlebugs removed portions of nitrogen from the xylem sap and total production of the plants decreased proportionately to the change in the total protein content. Weaver and Hibbs (1952) found that infestations on timothy lowered yields by 13 to 45 per cent.

Coccoidea (scale) have winged males that lack mouthparts and do not feed but females are wingless. Borror and DeLong (1971) state that mealybugs may cause injury by extracting plant sap (phloem) and by excreting honeydew which can form a medium for the growth of various species of fungus. McDaniel (1971) found them to consume phloem sap from grass plants at a rate of 1 gram a month; large numbers can extract large amounts of nutrients from grasses. He found that grazed treatments contained a larger number than ungrazed. They are found both on the roots and the aerial surfaces of grasses. Dietz and Harwood (1960) reported that a grass mealybug, Heterococcus graminicola Morr., caused browning of leaf sheaths and reduction of productivity. A large amount of feeding was concentrated in the leaf sheath and caused further tissue breakdown which was followed by a die-back and shriveling of the leaf tip. They found at least 67 species of grasses as possible host plants. Fischer (1941) reported a "bend" disease of grasses of unknown cause that occurred along with mealybug infestations.

McKenzie (1967) reported Antonina graminis (Maskell), the Rhodesgrass scale, to be of major economic importance in grasslands.

Chada and Wood (1960) recorded 69 grass species as host. Schuster (1967) reported that scale numbers were not indicative of damage and that yields of 35 different species of grasses were significantly reduced.

McDaniel (1971) noted that Aphididae are found in large numbers sucking sap from the stems or leaves of grassland plants. Their presence causes certain types of insect predators to be found in grassland biomes because their gregarious habits expose them to predators such as Coccinellidae adults and larvae, the larvae of certain Syrphidae flies, adult Chrysopidae, Pteromalidae, and Braconidae. Aphids attack most plants and can utilize most parts as a feeding area. Van Cleave (1970) reported Anoecia querci (Fitch) from the roots of Andropogon scoparius. Busgen (1891) found as many as 19 drops of honeydew excreted per 24 hours by a single aphid. Webster (1899) reported that certain ant species attend certain species of aphids in order to obtain honeydew and this association can also exist with Coccoidae that produce honeydew.

Coleoptera

Much of the material in this section is taken from Arnett (1968). The family Scarabaeidae contains the well known Japanese beetle. Its eggs are laid in the soil in late July and early August in areas covered with vegetation; they hatch immediately and the grubs begin to feed on the roots of grasses and forbs. The larvae pupate in June. Adults may be dung feeders, humus feeders, fungus feeders, dry carrion feeders, and pollen and sap feeders. The order Coleoptera is known in grasslands mainly because of its damage to grasses by white grubs (Phyllophaga spp.). Schwitzgebel and Wilbur (1942) found them feeding on the roots of ironweed (Vernonia interior). Hays (1919) found ironweed an important food plant of the wheat white grub in pastures and female beetles preferred to lay their eggs at its base. Schumacher (1959) recorded that white grub damage in four Kansas counties pastures was 40 per cent. Walkden and Wilbur (1944) reported Phyllophaga spp. from overgrazed pastures in June, and from bromegrass pastures in July and August.

The family Carabidae (ground beetles) is predaceous as both adults and larvae, but the larvae of some species are parasitic. Forbes (1883) examined the stomach contents of adult carabids and found that 56 per cent was of animal origin of which 36 per cent was insect remains. The vegetable material consumed was composed of cryptogamic plants, pollen of grasses and plant tissue. Lavigne and Pfadt (1966) concluded that predaceous carabid larvae exert an influence on grasshopper abundance but populations are extremely erratic and do not correlate with grasshopper populations. McDaniel (1971) noted the larvae of most carabids live beneath the surface of the soil feeding upon the soft bodied larvae and other soil arthropods. Bell (1971) reported that only a few (particularly Cicindela and Calosoma) are limited entirely to animal food, while the others consume some vegetable matter. He noted that in open prairie, away from ponds or waterholes, as many as 80 per cent belong to the tribe Harpalini.

Arnett (1968) notes that a number of genera may attain energy directly from the flora by feeding on seeds, tender shoots, pollen, and in some cases the foliage of plants. Among the seed, plant, and berry consumers are Amara, Anisodactylus, Calathus, Clivinia, Harpalus, Omophron, Pterostichus, and Zabrus.

The Staphylinidae occur in almost every type of habitat. The larvae are usually found in the same habitat as the adults. They feed on decaying vegetation and animal matter, or are predaceous on larvae and pupae of Diptera, other Coleoptera, or other invertebrates including arachnids (Arnett 1968).

Adults and larvae of the family Histeridae are mostly carnivorous. Many are found on carrion, excrement, and decomposing plant materials. Some species are predaceous on the larvae of certain chrysomelids or caterpillars. A large percentage of species feed on fly larvae and some of the small species (e.g., Acritus) feed on Collembola. Adults of some Margarinotus spp. feed on cutworms and other abundant or gregarious lepidopterous larvae (Arnett 1968).

Elateridae larvae are herbivorous on other invertebrates. Some live in loam, clays, or sandy soils where they feed on roots, tubers, or sometimes moss. The adults are usually found in foliage. Schwitzgebel and Wilbur (1942) recorded Melanotus sp. feeding on the roots of ironweed and adults were collected from the same plants. Walkden and Wilbur (1944) found Lacon rectangularis (Say) in association with dropseed, brome pastures, little bluestem, and in overgrazed pastures. Crawford and Harwood (1964) noted that wireworms damaged newly planted stands of grasses.

All Chrysomelidae are phytophagous, both as larvae and adults. They feed on roots, stems, leaves of herbaceous plants, and some are stem borers of herbaceous plants. Most species are specific in plant preference. Many larvae of Alticinae feed on roots and the adults feed on foliage. Green (1961) states that the main hosts in prairies were goldenrod (Solidago), sage (Artemisia), ragweed (Ambrosia), and Aster. Smith (1940) showed that they declined in species and in numbers in overgrazed prairies in Oklahoma.

Curculionidae are phytophagous almost without exception. The larvae of broad-nose weevils generally live free in the soil and feed on the roots of plants; some develop in seed pods. Adult weevils feed on the green tissues of plants, on pollen, flower tissue, and some Cryptorhynchinae are fungus feeders. Schwitzgebel and Wilbur (1942a) recorded Pantomorus pallidus (Horn) adults feeding on the terminal growth of ironweed. Walkden and Wilbur (1944) found Epicaerus imbricatus (Say) associated with overgrazed pasture; little bluestem and wild rye, Hypera punctata (F.), was associated with little barley and sweetclover. Whelan (1936) reported finding Apion in pastures with Andropogon scoparius and Andropogon furcatus. Baris striatus (Say) was found on Solidago rigida.

Pselaphidae were recorded by Park (1949) in Illinois prairie. These beetles are nocturnal feeders on mites and other small arthropods at the soil surface. Some species appear dependent on social insects for food and shelter because many species are found in ant or termite nests. The larvae are believed to be predaceous and adults have been recorded as feeding on Collembola and small beetle larvae.

Arnett (1968) stated that Lathridiidae adults and larvae of most species live in moldy material, often decomposing plant material. Hinton (1941) found adults and larvae in mycetozoa and fungi, in vegetable detritus, moldy animal substances, and sometimes in ant and termite nests. Feeding of adults is apparently only on mycetozoa and fungi.

The Mordellidae are phytophagous, especially on umbelliferous flowers. Boving and Craighead (1931) noted the larvae are carnivorous and one species is parasitic on wasps. The carnivorous larvae fed on larvae of Lepidoptera and Diptera which were found in plant stems. Hendrickson (1933) reported Mordellistena erratica Smith and Mordellistena infima Lec. from an Andropogon scoparius-Bouteloua curtipendula association.

Adult Meloidae are phytophagous and the larvae are parasitic (Arnett 1968). Larval hosts include the provisions and immature stages of wild bees and the eggs of grasshoppers. Lavigne and Pfadt (1966) showed that the Meloidae population in Wyoming rangeland was correlated with increases and decreases of grasshopper numbers. No preference was shown by larvae for egg pods of different grasshopper species. Schwitzgebel and Wilbur (1942a) observed that two species had almost completely defoliated an ironweed plant.

Scydmaenidae are rather obscure beetles which live in ant and termite nests in leaf mold or litter, and under stones. They are often seen in large numbers flying at dusk (Arnett 1968).

Silphidae larvae and adults are scavengers on dead mammals, birds, or reptiles. They are found mostly on carrion and rarely on decaying vegetation (Arnett 1968).

Arnett (1968) stated adult Cantharidae are common on herbage and foliage of goldenrod (Solidago spp.), and milkweed (Asclepias spp.);

some feed on pollen and nectar. The larvae are predaceous on grasshopper eggs, small caterpillars, and maggots. Schwitzgebel and Wilbur (1942a) observed Chauliognathus pennsylvanicus on grasses, Solidago glaberrima, and S. rigida.

Lampyridae adults do not feed. The larvae are predaceous on land mollusks, earthworms, some caterpillars and other insect larvae. Larvae are nocturnal and live in moist situations under debris on the ground, or in decaying vegetation (Arnett 1968).

Nitidulidae are primarily saprophagous and mycetophagous; some live in flowers, but the majority live in decaying fruits, fermenting plant juices, and in fungi. Cybocephalus spp. larvae prey on coccids.

Cleridae are associated with flowers. McDaniel (1971) noted that larvae and adults are predaceous. Members of the genus Necrobia are found associated with carrion and feed on Diptera larvae. A species of Aulicus feeds as a larva on the eggs of a lubber grasshopper and as adults on noctuid caterpillars. Hydnocera pubescens Lec. was found on ironweed by Schwitzgebel and Wilbur (1942a).

Most Dermestidae are scavengers. Species of Thaumaglossa are found in mantid egg cases and Apsectus live in spider webs, feeding on webbing and on dried spider eggs. Adults of most smaller species are commonly found on flowers, where they feed on pollen and nectar (Arnett 1968).

Coccinellidae larvae lived exposed on vegetation and both adults and larvae feed on plant-lice, scale insects, mites, and sometimes on Thysanoptera (Arnett 1968).

Phalacridae larvae live in flowers, especially Compositae, and in the spikes of Graminaceae that have been attacked by rusts but some are found in decaying vegetation (Arnett 1968). Borror and DeLong (1964) state that Malachiidae adults and larvae are predaceous, but many are on flowers. The most common species belongs to the genus *Collops*.

Ptilidae live in dung, or beneath vegetative detritus and feed chiefly on spores of fungi. Adult Erotylidae are also fungus feeders and the larvae feed on juices of fleshy fungus. Scaphididae live in fungi, rotten wood, or dead leaves (Arnett 1968). Throscidae adults are found on flowers and the larvae are probably carnivorous (Arnett 1968).

Smith (1940) reported a decrease in the number of Coleoptera in overgrazed pastures in Oklahoma. Walkden and Wilbur (1944) noted that near Manhattan, Kansas the greatest abundance of Coleoptera was in overgrazed pastures.

Diptera

Borror and DeLong (1971) noted that Tabanidae males feed on pollen and nectar while the larvae of most species are aquatic and predaceous.

Stone et al. (1965) recorded larvae of Tachinidae as internal parasites of immature Lepidoptera, Coleoptera, Hemiptera, Orthoptera, and Hymenoptera. Schwitzgebel and Wilbur (1943) collected Tachinidae from *Vernonia interior* (ironweed).

Stone et al. (1965) found that adult Sarcophagidae apparently need sugars for survival such as nectar and homopterous honeydew used by many species. Borror and DeLong (1971) noted that sarcophagid larvae nearly all feed on some sort of animal material but a few are parasitoids of various beetles and grasshoppers.

Lavigne and Pfadt (1966) showed that Asilidae play a larger role in destroying grasshoppers than previously suspected. They can consume a maximum of six grasshopper adults or nymphs per day. Lavigne and Rogers (1970) found prey-predator preferences to be Diptera, Orthoptera, Hymenoptera, Homoptera, and Lepidoptera, respectively. Stone et al. (1965) noted that most larvae are carnivorous. Specimens were reported from grasshopper eggs and white grubs.

Wilbur and Sabrosky (1936) reported 14 genera and 53 species of Chloropidae from pasture grasses in Kansas. Borror and DeLong (1971) stated that the larvae feed in grass stems. Starks and Thurston (1962) reported silver top of bluegrass to be associated with _Oscinella neocoxendix_ Sabrisky and _O. coxendix_ Fitch. Ahring and Howell (1968) found _O. minor_ (Adams) associated with sideoats grama. Stone et al. (1965) noted that the larvae of _Thaumatomyia glabra_ are predaceous on root aphids and _Pseudogaurax_ larvae consume egg masses of spiders, mantids, and some Lepidoptera.

Borror and DeLong (1971) stated that two-thirds of the species of Cecidomyiidae cause galls on plants. Others are predaceous on aphids, Coccoidea, and other small insects. Watts and Bellotti (1967) found two species of Cecidomyiidae that destroyed embryos of developing _Andropogon_. Schwitzgebel and Wilbur (1943) noted that galls formed by _Lasioptera vernoniae_ split plant stems.

Borror and DeLong (1971) noted Sciaridae living in fungi and decaying plant material with a few larvae attacking roots of plants. Ahring and Howell (1968) reported Bradysia coprophila (Lintner) from switchgrass and sideoats grama associations.

Stone et al. (1965) report Pipunculidae as parasitic on Cicadellidae, Delphacidae, and possibly Cercopidae. Blocker et al. (1972) noted pipinculids parasitizing leafhoppers Exitianus exitiosus (Uhler), Flexamia atlantica (DeLong), and Graminella mohri DeLong. Hardy (1943) stated that larvae directly affect the leafhopper and eggs are deposited in both nymphs and adults.

It has been reported that Tipula simples Doane (Tipulidae) larvae feed on juices of clover roots, grasses, and other plants. Damage was greatest to pasture-lands. Stone et al. (1965) reported Prionocera larvae to prey on early stages of Tabanidae. Borror and DeLong (1971) stated that some adults feed on nectar.

Stone et al. (1965) found all species of Acroceridae to be solitary internal parasites of spiders. Borror and DeLong (1971) reported that some adults feed on flowers but others apparently do not feed.

Borror and DeLong (1971) state that many species of Ceratopogonidae attack other insects and suck blood. Punkies have been found on mantids, walking sticks, lacewings, certain beetles, crane flies, and mosquitoes.

Stone et al. (1965) noted adult Syrphidae are of importance in cross-pollination of many plants. Most larvae of Syrphinae are aphidophagous or predaceous on other small Homoptera or Thysanoptera. The larvae of Chrysogastrini have been reported piercing roots.

Borror and DeLong (1971) noted adult Phoridae abundant about decaying vegetation. Larvae can be found in decaying animal or vegetable matter or in fungi, and some are internal parasitoids of various insects.

Collembola

Macnamara (1924) noted that springtails feed largely on vegetable substances or molds and minute algae. Fungi are consumed by many species and both spores and mycelium are found in stomach analysis. Maynard (1951) noted that moisture is an important factor determining occurrence. Whelan (1927) found Collembola to compose 25 per cent of the winter fauna of bunch grasses of eastern Kansas. McDaniel (1971) recorded Sminthuridae as herbivores and Entomobryidae as herbivores, predators, scavengers, or multivores.

Strepsiptera

Arnett (1968) stated that all known species of Strepsiptera are parasites of Hymenoptera, Orthoptera, Thysanoptera, Homoptera, or Hemiptera. Blocker et al. (1972) noted the leafhoppers Flexamia atlantica (DeLong) and Graminella mohri DeLong were commonly parasitized by strepsipterans. Bohart (1941) described the life cycle; triungulin larvae rest on vegetation awaiting a host and enter by physical penetration using the sharp edges of the head.

Psocoptera

Borror and DeLong (1971) noted psocids to be omnivores or scavengers which feed on molds, fungi, cereals, pollen, fragments of dead insects, and similar materials.

Thysanoptera

Borror and DeLong (1971) stated that thrips destroy plant cells by their feeding. Ahring and Howell (1968) found Thysanoptera to be the most prevalent insects in grasses. Watts and Bellotti (1967) found several species common to abundant on grasses. Foliage injury was extensive and affected the general vigor and productivity. Bailey (1940) named them important vectors of plant disease. Stannard (1957) found the family Phlaeothripidae in association with decaying grasses. Cott (1956) noted that feeding habits of individuals are stabilized within generic limits (e.g., the genus Goniothrips are found in the inflorescences of grasses. Bailey (1957) observed that heavy rains destroyed populations. Crawford and Harwood (1964) noted them to be associated with shrunken and whitened seed heads of grasses.

Lepidoptera

Borror and DeLong (1971) stated that Noctuidae larvae feed on various grasses and often migrate in large numbers to a feeding area. Schwitzgebel and Wilbur (1942b) reported Papiapema cerrusata larvae to bore in the upper stems of ironweed and down the stem to the crown of the plant. Crawford and Harwood (1964) recorded larvae feeding in the crown region of grasses.

Borror and DeLong (1971) noted that the larvae of Pyralidae bore into stem, crown, and roots of grasses. Schwitzgebel and Wilbur (1942b) observed *Pyrausta oxydalis* larvae feeding on the crown and roots of ironweed. Injury limited growth of new shoots from the root stalks in the spring.

Smith (1940) found the number of Lepidoptera to be higher in grazed than ungrazed areas in mixed-grass prairie of Oklahoma. Walkden (1943) reported 24 species of cutworms and armyworms from pasture grasses, wastelands, and forage crops in Kansas. Native grass pastures, hay meadows, and wastelands were found to be poor breeding areas. Overgrazed pastures had few cutworms and armyworms.

Hymenoptera

Some Formicidae are carnivorous, some feed on plants and fungi, and many feed on sap, nectar, honeydew, and similar substances (Borror and DeLong 1971). Beck et al. (1967) reported species of *Orematogaster*, *Formica*, *Leptothorax*, *Monomorium*, and *Tapinoma* in Utah as predator-scavengers. *Tapinoma sessile* Say was observed feeding on *Microtus montanus* and California quail. Little evidence was found that any of the ants were prey-specific. They were observed invading nests of small rodents and attacking their young. Smith (1928) found *T. sessile* Say to consume small organisms, honeydew from aphids and coccids, and the floral, extrafloral, and glandular excretions of plants. Colonies ranged from a hundred to ten thousand individuals.

Creighton (1950) found the range of *Leptothorax pergandei* to be only as far west as Indiana. They nest in preformed cavities and may be found in dried grass stems or old galls. Workers usually pilfer food from nearby nests of other species. Wheeler (1905) reported that many Formica attend aphids for honeydew. Schneirla (1944) noted that F. pallidefulva Latreille are extremely quick during foraging. Their nests are hidden below clumps of grass or surface rubble. Gregg (1945) reported Monomorium peninsulatum Gregg colonies from limestone regions.

Borror and DeLong (1971) reported Scelionidae as parasitoids of insects and sometimes spider eggs. They attack eggs of grasshoppers or mantids and attach to the female of the host. They do not usually feed on the adult host, but use it as transportation. When the host oviposits the scelionid leaves and attacks the eggs. Lavigne and Pfadt (1966) found parasitism low on Wyoming rangeland and of the grasshopper egg pods parasitized, only one egg in each pod was affected.

Lavigne and Pfadt (1966) showed that Sphecidae require approximately one hour to complete the capture-burrow-and stocking pattern; grasshoppers were used to stock the burrow. Newton (1956) found that three species of Tachysphey in Idaho rangeland reduced populations of Oedaleonotus enigma (Scudder) from 20 to 30 per square yard to one in five square yards. Lavigne and Pfadt (1966) noted that the ratio of digger wasps to grasshoppers was usually small on rangeland and played a minor role in control. Borror and DeLong (1971) reported that the Sphecinae provision their nests with crickets, immature Lepidoptera, and grasshoppers. Gorytini (Nyssoninae) nest in the ground and provision with various Homoptera, chiefly Cercopidae, Cicadellidae, and Membracidae. Walkden and Wilbur (1944) recorded _Chlorion_ (Priononyx) _atratum_ from brome grass pastures near Manhattan, Kansas. Brumfiel (1919) found digger wasps to be one of the most common invertebrates in Johnson county, Iowa prairies.

Borror and DeLong (1971) noted that Eulophidae were parasitoids with a wide variety of host. The _Coccophagus_ females develop as parasitoids of scale insects. Watts and Bellotti (1967) reported them as parasites of stem borers (Hymenoptera) associated with spike muhly, blue grama, and sideoats grama.

Borror and DeLong (1971) noted that most Encyrtidae are parasitoids of aphids, scale insects, and whiteflies. _Ooencyrtus kuwanai_ (Howard) is a parasitoid of the gypsy moth. Trjapitzin (1965) found them parasitizing mealybugs on gramineous plants. The Thysanidae are also parasitoids that attack scale insects, whiteflies, and other Homoptera. Trichogrammatidae are parasitoids attacking eggs. Most of the Mutillidae, whose life histories are known, are external parasitoids of larvae and pupae of various wasps and bees but a few attack certain beetles and flies. Walkden and Wilbur (1944) found _Dasymutilla occidentalis_ (L.) and _D. vesta_ (Cress.) associated with dropseed. Figitidae are parasitoids of lacewing pupae and Diptera. Spiceratinae attack the pupae of syrphid flies while Anacharitinae attack the cocoons of lacewings.

Borror and DeLong (1971) record both Apidae and Nomiinae (Halictidae) as important pollinators. Muesebeck et al. (1951) noted 90 hosts for one species of Pteromalidae. Watts and Bellotti

(1967) found Pteromalidae parasitic on stem borers (Hymenoptera) that were associated with blue grama and spike muhly.

Borror and DeLong (1971) noted that Dryinidae are parasitoids of nymphs and adults of Fulgoroidea, Cicadellidae, and Membracidae; larvae feed internally. Fenton (1918) recorded dryinids from grasses where they searched for prey.

Borror and DeLong (1971) noted Braconidae and Ichneumonidae as parasitoids of lepidopterous larvae. Walkden and Wilbur (1944) recorded Braconidae from overgrazed pastures. Muesebeck et al. (1951) named eighty-one hosts for the ichneumonid _Itoplectis conquisitor_ (Say). Tenthredinidae larvae are external feeders on foliage. The adults insert eggs into tissues of host plants.

Hemiptera

Hayes (1927) stated that Hemiptera is perhaps the predominant order of insects of the prairie. McDaniel (1971) reported Tingidae to be found only in ungrazed grasslands at the IBP Cottonwood site in South Dakota. _Corythucha_ damages plants by laying their eggs within the host tissue. Borror and DeLong (1971) reported lacebugs to feed chiefly on the leaves of plants with continued feeding causing the leaf to turn brown.

Knowlton (1966) reported grass bugs (Miridae) to cause damage to Utah range grasslands. Schwitzgebel and Wilbur (1942b) collected seven species from _Vernonia interior_. Smith (1934) believed that saliva of Miridae is the most toxic to plants of any sucking insects.

Carter (1939) reported injury caused by some species on plant leaves causes plant shoots to be stunted. Hori (1967) found that Lygus disponsi preferred feeding on soft and succulent tissues of plants. Reduction of hay yields were noted when the bugs were abundant. McDaniel (1971) found chinch bugs (Lygaeidae) hibernating in clump-forming grasses in pastures and meadows in South Dakota. Whelan (1927) surveyed the winter fauna of Andropogon spp. and found Blissus leucopterus (Say) to constitute 35 per cent of the individuals present. Borror and DeLong (1971) classify both Reduviidae and Phymatidae as predaceous on other insects. Phymatidae are found in flowers, particularly goldenrod where they prey on bees, wasps, and flies.

Odonata

Borror and DeLong (1971) noted this order to be predaceous as adults and immatures. All nymphs are aquatic. The prey of adults are small flying insects such as midges, mosquitoes, and small moths.

Dermaptera

Forficula auricularia (Dermaptera) is an omnivore which prefers stamens and pistils of flowers, dead insects, and living, defenseless small animals. Fulton (1924) found that dead and injured F. auricularia were sometimes preyed upon by their own species. Gangwere (1961) feels most Dermaptera are omnivorous, but many have a tendency towards being carnivores.

Acarina

Crawford and Harwood (1964) found heavy infestations of Banks' grass mite in grass fields in Oregon. Holmes et al. (1961) found Aceria tulipae and Siteroptes graminum (Reuter) associated with silver top of Poa pratensis L. Watts and Bellotti (1967) noted that the wheat curl mite, Aceria tulipae (Keifer), caused damage to all parts of the floret from the lemma and palea inward in spike muhly, Muhlengergia wright Vasey.

Araneida

Bristowe (1939-41) indicated that the highest population densities of spiders are found in autumn and winter and the lowest in mid-summer. Van Der Drift (1951) showed that the smallest spiders were more numerous in lower layers and the largest in the upper layers in grasses, with the largest populations in the humus layer. Duffey (1962) found numbers to fall in December and January reaching the lowest densities in April and May. The number of species caught per month has little relation to the number of individuals. Boyd (1960) noted that the distribution of Lycosa spp. varied between grazed and ungrazed areas. Lycosa pullata is abundant on ungrazed and almost absent from grazed areas. Turnbull (1966) found no direct relationship between the number of spiders and the number of prey but spiders may contribute to stability of prey populations.

APPENDIX II

FIELD DATA

Aboveground invertebrate data collected at the Pawnee Site were recorded on Form NREL-30. These data are stored as Grassland Biome Data Set A2U300B. A sample data form and an example of the data follow.

IBP

GRASSLAND BIOME

U.S. INTERNATIONAL BIOLOGICAL PROGRAM

FIELD DATA SHEET - INVERTEBRATE

DATA TYPE	SITE	INITIALS	DATE Day	DATE Mo	DATE Yr	TREATMENT	REPLICATE	PLOT SIZE	QUADRAT	TROPHIC	HOST	ORDER	FAMILY	GENUS	SPECIES	SUBSPECIES	LIFE STAGE	TOTAL NO.	DRY WT.	NO. WEIGH

DATA TYPE

01 Aboveground Biomass
02 Litter
03 Belowground Biomass
10 Vertebrate - Live Trapping
11 Vertebrate - Snap Trapping
12 Vertebrate - Collection
20 Avian Flush Census
21 Avian Road Count
22 Avian Road Count Summary
23 Avian Collection - Internal
24 Avian Collection - External
25 Avian Collection - Plumage
30 Invertebrate
40 Microbiology - Decomposition
41 Microbiology - Nitrogen
42 Microbiology - Biomass
43 Microbiology - Root Decomposition
44 Microbiology - Respiration

SITE

01 Ale
02 Bison
03 Bridger
04 Cottonwood
05 Dickinson
06 Hays
07 Hopland
08 Jornada
09 Osage
10 Pantex
11 Pawnee

TROPHIC

0 Unknown
1 Plant feeding (tissue)
2 Plant feeding (sap)
3 Plant feeding (pollen and nectar)
4 Plant feeding (seed)
5 Predator
6 Parasitoid/ Parasite
7 ~~Parasite~~ Omnivore
8 Scavenger
9 Non-feeding stage

TREATMENT

1 Ungrazed
2 Lightly grazed
3 Moderately grazed
4 Heavily grazed
5 Grazed 1969, ungrazed 1970
6
7
8
9

LIFE STAGE

00 Undetermined
10 Adult
20 Pupae
30 Egg
40 Nymph or Larva
41 Nymph or Larva, early
42 Nymph or Larva, middle
43 Nymph or Larva, late
50 Instar
51 Instar, 1st
52 Instar, 2nd
53 Instar, 3rd

*** EXAMPLE OF DATA ***

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         1         2         3         4         5         6         7
1234567890123456789012345678901234567890123456789012345678901234567890123456789

3009RR 250771110.5001 7       HYMEFORM        10    256  .0915 993
3009RR 250771110.5001 1       COLLSMIN        10     72
3009RR 250771110.5001 0       COLLENTO        10     24
3009RR 250771110.5001         COLL                       .0012 175
3009RR 250771110.5001 5       COLESTAP        10      1  .0031   5
3009RR 250771110.5001 1       COLECOCC        10      1  .0020   1
3009RR 250771110.5001 1       COLE            40      2  .0025  57
3009RR 250771110.5001 1       COLECURC        10      1  .0363   2
3009RR 250771110.5001 2       HOMODELP        40      8  .0014  45
3009RR 250771110.5001 2       HOMOCICI        40     22  .0057  77
3009RR 250771110.5001 2       HOMOFULG        40      4  .0022  16
3009RR 250771110.5001 2       HOMOCOCC        10     10  .0025  80
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3009RR 250771110.5001 6       DIPTCECI        10      1
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3009RR 250771110.5001 5       ARAN            10      9  .0124  45
3009RR 250771110.5001 0       ACAR            10    215  .01051121
3009RR 250771110.5002 7       HYMEFORM        10     95
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3009RR 250771110.5002 0       COLLENTO        10     19
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3009RR 250771110.5002 5       COLECARA        10      6  .0098   7
3009RR 250771110.5002 5       COLESTAP        10      2  .0031   5
3009RR 250771110.5002 0       COLESCYD        10      3
3009RR 250771110.5002 1       COLE            40      3
3009RR 250771110.5002 2       HOMOCICI        40     16
3009RR 250771110.5002 2       HOMOFULG        40     11
3009RR 250771110.5002 2       HOMOAPHI        40      1
3009RR 250771110.5002 2       HOMOCOCC        10      9
3009RR 250771110.5002 3       THY2            10     73
3009RR 250771110.5002 1       LEPI            40      1  .0662   1
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3009RR 250771110.5002 0       ACAR            10    272
3009RR 250771110.5003 7       HYMEFORM        10    355
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3009RR 250771110.5003 2       HOMOCICI        40      7
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3009RR	250771110.5004	2	HOMOCOCC	10	26		
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3009RR	250771110.5005	2	HEMIPENT	40	1		
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3009RR 250771120.5001	2	HOMOCOCC	10	11	.0007	95
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3009RR 250771120.5002	2	HOMOCICI	10	3	.0067	8
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3009RR 250771120.5002	2	HOMOFULG	40	2		
3009RR 250771120.5002	2	HOMODELP	40	16		
3009RR 250771120.5002	3	THY2	10	60		
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3009RR 250771120.5002	5	ARAN	10	12		
3009RR 250771120.5002	0	ACAR	10	291		
3009RR 250771120.5003	7	HYMEFORM	10	2		
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3009RR 250771120.5003	5	COLESTAP	10	3		
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3009RR 250771120.5003	1	COLECURC	10	5		
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3009RR	250771120.5004	2	HOMOCOCC	10	15		
3009RR	250771120.5004	2	HOMOCICI	10	2		
3009RR	250771120.5004	2	HOMOCICI	40	2		
3009RR	250771120.5004	2	HOMOFULG	40	5		
3009RR	250771120.5004	2	HOMODELP	40	20		
3009RR	250771120.5004	3	THY2	10	83		
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3009RR	250771120.5004	5	HEMIREDU	40	1	.0229	1
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3009RR	250771120.5005	1	COLLSMIN	10	9		
3009RR	250771120.5005	0	COLLENTO	10	13		
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3009RR	250771120.5005	1	COLECURC	10	1		
3009RR	250771120.5005	8	COLELATH	10	1		
3009RR	250771120.5005	1	COLEELAT	10	1		
3009RR	250771120.5005	1	COLE	40	9		
3009RR	250771120.5005	2	HOMOCOCC	10	24		
3009RR	250771120.5005	2	HOMOCICI	10	2		
3009RR	250771120.5005	2	HOMOCICI	40	13		
3009RR	250771120.5005	2	HOMOFULG	40	2		
3009RR	250771120.5005	2	HOMODELP	40	13		
3009RR	250771120.5005	3	THY2	10	275		
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3009RR	250771120.5005	2	HEMILYGA	40	47		
3009RR	250771120.5005	2	HEMIPENT	40	1		
3009RR	250771120.5005	0	DIPT	40	7		
3009RR	250771120.5005	5	ARAN	10	3		
3009RR	250771120.5005	0	ACAR	10	150		

3009RR	250771510.5001	7	HYMEFORM	10	23	.0548	584
3009RR	250771510.5001	6	HYMETRIC	10	1		
3009RR	250771510.5001	6	HYMEPTER	10	1		
3009RR	250771510.5001	6	HYMEEULO	10	1		
3009RR	250771510.5001	0	COLLENTO	10	10		
3009RR	250771510.5001	1	COLLSMIN	10	21		
3009RR	250771510.5001		COLL	10		.0009	230
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3009RR	250771510.5001	5	COLECARA	10	1	.0009	2
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3009RR	250771510.5001	2	HOMOCOCC	10	29	.0010	144
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3009RR	250771510.5001	2	HOMOFULG	40	1	.0007	4
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3009RR	250771510.5002	7	HYMEFORM	10	148		
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3009RR	250771510.5002	1	COLLSMIN	10	18		
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3009RR	250771510.5002		COLL	10			
3009RR	250771510.5002	5	COLESTAP	10	1		
3009RR	250771510.5002	2	COLENITI	10	5	.0003	27
3009RR	250771510.5002	1	COLECURC	10	2	.0145	4
3009RR	250771510.5002	3	COLETHER	10	1		
3009RR	250771510.5002	1	COLE	40	13		
3009RR	250771510.5002	2	HOMOISSI	40	1	.0008	2
3009RR	250771510.5002	2	HOMOCOCC	10	10		
3009RR	250771510.5002	2	HOMOCICI	40	5		
3009RR	250771510.5002	2	HOMOFULG	40	1		
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3009RR	250771510.5002	0	ACAR	10	917		
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3009RR 250771510.5003	1	COLE	40	24		
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3009RR 250771510.5003	2	HOMODELP	40	13		
3009RR 250771510.5003	3	THY2	10	130		
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3009RR 250771510.5003	8	ORTHBLAT	10	1	.0020	1
3009RR 250771510.5003	1	LEPI	40	1	.0031	2
3009RR 250771510.5003	2	HEMILYGA	40	2		
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3009RR 250771510.5003	0	ACAR	10	598		
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3009RR 250771510.5004	6	HYMETHYS	10	3		
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3009RR 250771510.5004	0	COLLENTO	10	38		
3009RR 250771510.5004		COLL	10			
3009RR 250771510.5004	2	COLENITI	10	13		
3009RR 250771510.5004	1	COLECHRY	10	1		
3009RR 250771510.5004	1	COLE	40	22		
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3009RR 250771510.5004	2	HOMOFULG	40	2		
3009RR 250771510.5004	2	HOMOAPHI	40	1		
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3009RR 250771510.5004	3	THY2	10	94		
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3009RR 250771510.5004	2	HEMILYGA	40	2		
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3009RR 250771510.5004	5	ARAN	10	13		
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3009RR 250771510.5005	6	HYMEENCY	10	2		
3009RR 250771510.5005	6	HYMEDRYI	10	1		
3009RR 250771510.5005	6	HYMEBRAC	10	1		
3009RR 250771510.5005	6	HYMEEULO	10	2		
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3009RR	250771510.5005	1	COLLSMIN	10	21	
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3009RR	250771510.5005	2	HEMIPENT	40	1	.0003 1
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3009RR	250771520.5001	7	HYMEFORM	10	93	.0535 606
3009RR	250771520.5001	6	HYMEDRYI	10	1	
3009RR	250771520.5001	6	HYMEPTER	10	2	
3009RR	250771520.5001	6	HYMEBRAC	10		
3009RR	250771520.5001	1	COLLSMIN	10	66	
3009RR	250771520.5001	0	COLLENTO	10	28	
3009RR	250771520.5001		COLL	10		.0031 312
3009RR	250771520.5001	5	COLECARA	10	1	.0021 6
3009RR	250771520.5001	2	COLENITI	10	25	.0027 87
3009RR	250771520.5001	1	COLE	40	81	.0021 153
3009RR	250771520.5001	2	HOMOCOCC	10	167	.0005 286
3009RR	250771520.5001	2	HOMOCICI	10	1	.0251 7
3009RR	250771520.5001	2	HOMOCICI	40	4	.0071 30
3009RR	250771520.5001	2	HOMOFULG	40	1	
3009RR	250771520.5001	2	HOMODELP	40	19	.0042 121
3009RR	250771520.5001	3	THY2	10	148	.0011 250
3009RR	250771520.5001	2	HEMILYGA	10	1	.0067 33
3009RR	250771520.5001	0	DIPT	40	5	
3009RR	250771520.5001	8	DIPTPHOR	10	1	
3009RR	250771520.5001	6	DIPTCECI	10	1	
3009RR	250771520.5001	5	ARAN	10	3	.0043 42
3009RR	250771520.5001	0	ACAR	10	451	.03112312
3009RR	250771520.5001	8	PSOC	10	3	
3009RR	250771520.5001	0	HYME	10	5	.0004 11
3009RR	250771520.5002	7	HYMEFORM	10	141	
3009RR	250771520.5002	0	HYME	10	4	
3009RR	250771520.5002	6	HYMEDRYI	10	1	
3009RR	250771520.5002	6	HYMETHYS	10	4	.0007 18
3009RR	250771520.5002	6	HYMEENCY	10	3	
3009RR	250771520.5002	6	HYMETRIC	10	1	
3009RR	250771520.5002	1	COLLSMIN	10	31	
3009RR	250771520.5002	1	COLLPODU	10	5	
3009RR	250771520.5002	0	COLLENTO	10	34	

3009RR	250771520.5002		COLL	10			
3009RR	250771520.5002	5	COLESTAP	10	1	.0030	11
3009RR	250771520.5002	2	COLENITI	10	4		
3009RR	250771520.5002	1	COLECHRY	10	1	.0016	1
3009RR	250771520.5002	1	COLECURC	10	5	.0064	12
3009RR	250771520.5002	3	COLETHER	10	1	.0023	17
3009RR	250771520.5002	1	COLE	10	13		
3009RR	250771520.5002	2	HOMOCOCC	10	8		
3009RR	250771520.5002	2	HOMOCIC1	10	3		
3009RR	250771520.5002	2	HOMOCIC1	40	9		
3009RR	250771520.5002	2	HOMODELP	40	26		
3009RR	250771520.5002	3	THY2	10	110		
3009RR	250771520.5002	2	HEMIMIRI	10	1	.0009	1
3009RR	250771520.5002	2	HEMILYGA	10	1	.0021	1
3009RR	250771520.5002	2	HEMILYGA	40	5		
3009RR	250771520.5002	5	ARAN	10	9		
3009RR	250771520.5002	0	ACAR	10	386		
3009RR	250771520.5002	8	PSOC	40	1		
3009RR	250771520.5002	2	HEMIPENT	40	1	.0037	2
3009RR	250771520.5003	7	HYMEFORM	10	43		
3009RR	250771520.5003	6	HYMEDRYI	10	1		
3009RR	250771520.5003	0	HYME	10	1		
3009RR	250771520.5003	6	HYMETRIC	10	2		
3009RR	250771520.5003	6	HYMETHYS	10	4		
3009RR	250771520.5003	6	HYMEENCY	10	6		
3009RR	250771520.5003	6	HYMEPTER	10	2		
3009RR	250771520.5003	1	COLLSMIN	10	43		
3009RR	250771520.5003	0	COLLENTO	10	21		
3009RR	250771520.5003		COLL	10			
3009RR	250771520.5003	5	COLECARA	10	1		
3009RR	250771520.5003	3	COLEPHAL	10	1		
3009RR	250771520.5003	2	COLENITI	10	47		
3009RR	250771520.5003	1	COLECOCC	10	2	.0049	3
3009RR	250771520.5003	3	COLETHER	10	1		
3009RR	250771520.5003	1	COLECURC	10	2		
3009RR	250771520.5003	8	COLELATH	10	6	.0016	12
3009RR	250771520.5003	1	COLE	10	25		
3009RR	250771520.5003	0	COLESCYD	10	1		
3009RR	250771520.5003	2	HOMOCOCC	10	46		
3009RR	250771520.5003	2	HOMOCIC1	10	1		
3009RR	250771520.5003	2	HOMOCIC1	40	3		
3009RR	250771520.5003	2	HOMODELP	40	39		
3009RR	250771520.5003	3	THY2	10	155		
3009RR	250771520.5003	1	ORTHGRYL	40	1		
3009RR	250771520.5003	1	LEPI	40	1	.0589	1
3009RR	250771520.5003	5	HEMIREDU	10	1	.0126	1
3009RR	250771520.5003	2	HEMILYGA	40	14		
3009RR	250771520.5003	2	HEMIPENT	40	1		
3009RR	250771520.5003	0	DIPT	40	10		
3009RR	250771520.5003	5	ARAN	10	17		
3009RR	250771520.5003	0	ACAR	10	372		
3009RR	250771520.5003	8	PSOC	40	2		

3009RR	250771520.5003	5	NEURHEME	10	1	.0014	1
3009RR	250771520.5004	7	HYMEFORM	10	86		
3009RR	250771520.5004	6	HYMEDRYI	10	1		
3009RR	250771520.5004	6	HYMETHYS	10	5		
3009RR	250771520.5004	6	HYMEPTER	10	2		
3009RR	250771520.5004	1	COLLSMIN	10	20		
3009RR	250771520.5004	1	COLLPODU	10	1		
3009RR	250771520.5004	0	COLLENTO	10	22		
3009RR	250771520.5004		COLL	10			
3009RR	250771520.5004	5	COLECARA	10	4		
3009RR	250771520.5004	5	COLESTAP	10	3		
3009RR	250771520.5004	2	COLENITI	10	7		
3009RR	250771520.5004	1	COLECOCC	10	1		
3009RR	250771520.5004	1	COLECURC	10	2		
3009RR	250771520.5004	8	COLELATH	10	5		
3009RR	250771520.5004	3	COLETHER	10	4		
3009RR	250771520.5004	1	COLE	40	15		
3009RR	250771520.5004	2	HOMOCOCC	10	29		
3009RR	250771520.5004	2	HOMOCICI	10	2		
3009RR	250771520.5004	2	HOMOCICI	40	10		
3009RR	250771520.5004	0	COLESCYD	10	3		
3009RR	250771520.5004	3	THY2	10	166		
3009RR	250771520.5004	2	HOMODELP	40	18		
3009RR	250771520.5004	2	HEMILYGA	40	10		
3009RR	250771520.5004	0	DIPT	40	9		
3009RR	250771520.5004	5	ARAN	10	7		
3009RR	250771520.5004	0	ACAR	10	491		
3009RR	250771520.5004	8	PSOC	40	1		
3009RR	250771520.5005	7	HYMEFORM	10	243		
3009RR	250771520.5005	6	HYMEENCY	10	3		
3009RR	250771520.5005	6	HYMETHYS	10	5		
3009RR	250771520.5005	6	HYMEPTER	10	4		
3009RR	250771520.5005	6	HYMETRIC	10	2		
3009RR	250771520.5005	1	COLLSMIN	10	31		
3009RR	250771520.5005	0	COLLENTO	10	10		
3009RR	250771520.5005		COLL	10			
3009RR	250771520.5005	5	COLESTAP	10	7		
3009RR	250771520.5005	3	COLEPHAL	10	1		
3009RR	250771520.5005	2	COLENITI	10	4		
3009RR	250771520.5005	1	COLECURC	10	3		
3009RR	250771520.5005	8	COLELATH	10	1		
3009RR	250771520.5005	3	COLETHER	10	11		
3009RR	250771520.5005	1	COLE	40	19		
3009RR	250771520.5005	2	HOMOCOCC	10	36		
3009RR	250771520.5005	2	HOMOCICI	40	4		
3009RR	250771520.5005	2	HOMODELP	40	19		
3009RR	250771520.5005	3	THY2	10	184		
3009RR	250771520.5005	2	HEMILYGA	40	3		
3009RR	250771520.5005	0	DIPT	40	8		
3009RR	250771520.5005	5	ARAN	10	6		
3009RR	250771520.5005	0	ACAR	10	612		
3009RR	250771520.5005	8	PSOC	10	2		