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GROWTH, DENSITY, AND BIOMASS OF GRASSHOPPERS IN THE SHORTGRASS AND MIXED-GRASS ASSOCIATIONS

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ABSTRACT

A complex of grasshopper species inhabit the shortgrass and mixed-grass associations. Twenty-seven species have been recorded on the Pawnee Site (shortgrass association) and out of these, 22 species were also found on the southeast Wyoming sites (mixed-grass association). These species were arranged into 3 categories of abundance: abundant, common and rare.

Three patterns of emergence of nymphs and adults have been detected. These patterns involve grasshoppers with life cycles of two types which can be designated as "Early" and "Late." Some of the grasshoppers are also designated as "Mid," appearing between "Early" and "Late."

On the sites selected for this study, sampling of absolute population densities of each species was done by walking a transect in a general area established on each site and counting the number on 100 one-square-foot plots. Under heavy grazing on the Pawnee Grassland the maximum number of grasshoppers was $1.94/m^2$, whereas under light-moderate grazing pressure the density was $3.28/m^2$, almost double the former. It was concluded that heavy grazing does not improve the grasshopper habitat.

The type of survivorship curve of the principal species of

grasshoppers was studied. In all cases it was observed that the overall density was highest when the grasshoppers were in their earlier instars. Mortality was greatest during the nymphal stage and lowest during the adult stage. It was concluded that the grasshoppers have a concave type of survivorship curve.

A study of the biomass of grasshoppers was also made at the Pawnee Site and southeast Wyoming sites. At Pawnee the peak of the biomass in the heavily grazed pasture reached 64.21 mg/m^2 and in the lightly-moderately grazed pasture, 97.23 mg/m^2. The peaks were reached at a time when the grasshoppers were in their fifth instar and adult stages. The peak at Lusk was 1213.51 mg/m^2 and at Hartville, 1142.74 mg/m^2. The biomass in the mixed-grass association was about 13 times that in pastures of the Pawnee Site.

There was no statistical correlation between the density of grasshoppers and vegetation cover within the same pastures at Pawnee Site.

It was hypothesized that the total body energy in the grasshoppers increases with the age. For this, too, the principal species of grasshoppers were selected from both the shortgrass and mixed-grass associations and calorimetry measurements were made. The results show a positive correlation between the energy and age groups. There was a steady increase in the Kcal/dry body wt as the age of grasshoppers progressed and the correlation coefficient was significant at 0.05 level of significance for all the species.

The energy content in Kcal/g dry wt increased in *Aulocara elliotti* as the grasshoppers aged whereas the energy content of *Cordillacris occipitalis* and *Opeia obscura* showed an erratic trend. The dips may have been due to poor nutritional condition of the test organisms, but more likely was due to the timing of collections. The energy content of Cordillacris crenulata exhibited a steady increase, though the curve took a dip in the early male stage. The body weight is important for the total amount of energy contained in the organism.

INTRODUCTION

In number of species and individuals, arthropods are generally dominant among the animal populations of natural ecosystems. Only recently, however, have ecologists begun to consider the functional role of the arthropod component. In grasslands, grasshoppers are considered to be one of the dominant insect groups.

The grasshopper component in grasslands can be expressed in terms of abundance, but also in terms of biomass and energy requirements. Some research has been done on the biomass and bioenergetics of grasshopper populations inhabiting the grasslands of the eastern United States (Odum and Smalley, 1959; Smalley, 1960; Odum et al., 1962; Wiegert, 1964, 1965; Van Hook, Jr., 1971), but little work along these lines has been done on the grasshopper populations of the shortgrass and mixed-grass associations of the west. Thus, this present study was initiated to provide information on the growth, density and biomass of grasshopper populations in these associations; on the relationship of grasshopper density to vegetation cover; and on the available energy contained within the grasshopper component. The following five hypotheses were tested:

1. Grazing pressure improves the habitat for grasshoppers at the Pawnee Site.
2. That grasshoppers have a concave type of survivorship curve (i.e. the mortality is high during the younger instars).

3. The biomass of grasshoppers is proportional to the age and density of grasshoppers.

4. Grasshopper density is directly proportional to vegetation cover at the Pawnee Site.

5. Total body energy increases with the age of grasshoppers.

A literature review indicates that these hypotheses have not yet been adequately tested in the western grasslands of North America.

The present study is financed in part by an NSF grant to the Grassland Biome Project of the International Biological Program. The study was conducted on the Pawnee Intensive Site situated approximately eight miles northeast of Nunn, Colorado. Since the density of grasshopper population on the Pawnee Site has been low during the last several years, a study of the grasshopper populations in the so-called "hot spots" or outbreak areas in southeast Wyoming is also included. The main reason for doing this additional work is to provide data for a reliable assessment of the importance of grasshoppers in the shortgrass and mixed-grass associations.

REVIEW OF LITERATURE

Grasshopper Damage

In order to appreciate the importance of grasshoppers it is necessary to consider the damage they cause. Utilizing information contained in Barnes (1948), Pfadt (1949b), Anderson and Wright (1952), Harper (1952) and Putnam (1962), Bullen (1966) calculated that on North American rangelands grasshoppers at densities of 20 per square yard cause, on the average, a vegetative loss of 7 lbs. per acre per day. At this rate the total consumption in a period of three months (i.e. summer) would be about 600 lbs. per year per acre, which could amount to the full depletion of a typical shortgrass prairie. Bullen concluded that a 10 percent loss of vegetation per year for 10 years can be tolerated, but a 100 percent loss once in a period of 10 years would be chaotic. Grasshopper densities of 20 adults per square yard are considered critical.

Mulkern (1967), Campbell (1967) and Lambley (1967) have demonstrated clearly that the species of grasshopper has to be considered when damage estimates are made; number per square yard is not sufficient. Before labelling them as economically important, the food habits of the grasshoppers in question should be observed because some of the species feed upon undesirable weeds and thus can actually be beneficial. Unlike Bullen, Anderson (1961) could find little correlation between numbers of grasshoppers per unit area and the loss of vegetation. This he attributed to the variability in the feeding habits of the various species comprising any particular grasshopper population. Anderson's results seem contradictory to Bullen's report, and some explanation to clarify the contradiction is needed. During the period of Anderson's study, with exception of the first year 1950, grasshopper populations remained much below one per square yard on both the sprayed and unsprayed study areas. The author calculated the amount of damage over a large area based on the findings in a small area, which is fallacious, and then he himself admits that the differential feeding by grasshoppers caused by the differences in food plant preference makes the number of grasshoppers per unit area a poor basis for predicting losses in vegetation. Thus it seems that Anderson's results were not adequately analyzed.

The amount of damage caused by grasshoppers is a function of several factors, viz., the amount of vegetation consumed daily by a single individual, differences in food preferences between species, the fluctuations of population size, and the relative mobility of the insect stages (Bullen, 1966). Kelly and Middlekauff (1961) pointed out that grasshoppers cause damage to rangelands in other ways than their actual consumption of vegetation. Other kinds of damage are described as cutting the leaf blades and stems near the crowns, and eating only a part of them with the resulting damage far more serious than just the loss of plant material consumed. These authors concluded that plant growth was retarded as a result of their feeding closer to the ground than grazing livestock. By their close feeding, grasshoppers prevent reseeding and may even kill the plant. Death of plants exposes the soil to wind and water erosion.

Andrezejewska and Breymayer (1967) have reported that in Poland grasshoppers slightly gnaw the leaf blade so that part of the leaf drops off and in this way they destroy four to eight times the amount of consumed plant biomass. These authors concluded that in comparison with the food intake of 4.8 mg daily per grasshopper, calculated under laboratory conditions, the devastation of plants is nearly five times the amount consumed by the insects.

Parker (1957), Cowan (1959) and others have given dollar estimates of grasshopper damage to rangeland. Cowan reported over $1,500,000 damage to North Dakota rangelands in 1957, in spite of the spraying of over one and a half million acres to control the pests. In his report entitled "The impact of insects as herbivores in grassland ecosystems," Blocker (1969) concluded that grasshoppers are the only insect group which is presently well enough known to be evaluated in detail for their impact upon the grassland. He discussed methods of population sampling and damage evaluation, and to some extent he described the pros and cons of the different techniques of insect collection.

Southwood (1966) stated that the effect of an insect population on a stand of vegetation is the product of two opposing processes--the eating of insects and the growing rate of the vegetation. The former depends on age, temperature, population size and other factors. Different life stages of insect groups also offer complications. The damage index obviously cannot be used as more than an approximate indicator of population size.

Discussing the prediction of grasshopper populations and control procedures, Shotwell (1965) stated that earliness and lateness of the hatching period of grasshoppers affects the type and amount of damage to vegetation. He also indicated a method of forecasting hatching for the 10 to 90 percent range using maximum temperature as an indicator. Such a procedure always helps in planning a control program well in advance against a destructive grasshopper population. Onsager and Mulkern (1963) emphasized that a correct assessment of potential grasshopper numbers coupled with a knowledge of the ovipositional behavior may lead to the development of sound, selective control practices directed toward the grasshoppers before they become active and depredatory.

Bird et al. (1966) discussed the responses of grasshoppers to ecological changes produced by agricultural development and indicated that farming methods have been useful for controlling grasshopper populations, e.g. the use of herbicides, grading of roadsides, and erosion control practices.

Density and Population Dynamics

Current ecological methods for the study of insect populations are adequately covered in recent texts by Southwood (1966), Watt (1966) and Clark et al. (1967). These references may be consulted for methodology useful in the study of insect populations.

Total egg production, the rate of oviposition, the length of preoviposition period and the adult longevity of the migratory grasshopper (*Melanoplus mexicanus*) were found to be significantly affected by different food plants in the short grass plains of eastern Wyoming (Pfadt, 1949a). Depending upon the food plant, total egg production varied from an average of 45 eggs to 206 eggs per female; mean preoviposition period ranged from 17 to 24 days and mean adult longevity of females ranged from 50 to 83 days.

Anderson (1964) observed in his studies on Montana grassland that grasshopper populations are always found in the area of their preferred food plants, or in other words, these species with known food plant preferences have never been found in areas devoid of such vegetation. No reports, however, are available correlating the abundance of grasshopper species with the density of these plants. In fact, in many areas a plant species may be found in varying degrees of abundance in the absence of the grasshopper species preferring that plant.

While reporting on dietary similarity of some primary consumers, Hansen and Ueckert (1970) observed that young herbivores, with smaller bodies than adults, had more limited feeding habits than adults of the same species. Also, adult male grasshoppers, which were always smaller than adult females, ate fewer species of food plants than did adult females of the same species. Thus, food preference would seem to have considerable effect on grasshopper population size.

Mulkern (1967) made a very extensive review of the food selection by grasshoppers. In his concluding remarks he commented that there are considerable morphological adaptations of the digestive system, particularly the mandibles and other organs of ingestion, in regard to type of food material ingested. Through morphological examination one can very well identify the food habits of these insects. There is a direct positive correlation between plant species selected for food and the suitability of these for the survival, growth and reproductive potential of grasshopper species. Distribution and abundance of the grasshopper populations are influenced by host plant selection because grasshopper species tend to concentrate on areas in which large amounts of host-plant occur and attain greatest biotic potential in these areas.

Both the taxonomic composition and the physical structure of the vegetation have been reported to be important environmental factors in determining the distribution of grasshoppers (Cantrall, 1943; Anderson, 1964). Vegetation has a definite influence on the selection of the habitat by grasshoppers in at least two ways. The first of these involves the relationship between the taxonomic composition of the vegetation and grasshopper feeding habits. Anderson (1964) states that a species was never found in an area which did not include its preferred host-plant (s). Secondly, he found that grasshopper occupancy was found to be influenced by the physical structure of the vegetation. He further noted that some areas which had favourable vegetation composition and structure were not occupied by grasshoppers. It was observed also that the grasshopper distribution within an area of occupancy was not random (Anderson, 1964).

Existence of subpopulations or even separated populations of the bigheaded grasshopper, *Aulocara elliotti*, within a narrowly defined area of occurrence has been reported by Hastings and Pepper (1964). Anderson (1964) also observed that grasshopper distribution within an area of occupancy was not random. He found that the distribution of grasshoppers follows the typical irregular distribution of any insect population (Milne, 1962). Anderson's observations supported Milne's thesis that population changes are "due to the sum of the actions of all effective environmental factors on all individuals of the population." Population response to these factors, however, may be modified by such things as the genetic structure, population structure, and physiological state of the individuals (Hastings and Pepper, 1964).

Working in the tallgrass prairie near Manhattan, Kansas, Arnett (1960) reported the most abundant occurrence of grasshoppers in heavily grazed range, next in burned, and thirdly in moderately grazed range. Lightly grazed pastures and pastures under deferred grazing had low populations. Van Horn (1969) conducted studies in the shortgrass association of the Pawnee Site and reported that the grasshopper population on all grazing treatments had similar growth patterns and that there were no observable differences in grasshopper numbers between grazing treatments. Van Horn's conclusions are supported by the research of Dickinson and Leetham (1971) who also worked on the Pawnee Site. During the growing season at the Pawnee Site, Dickinson and Leetham (1971) observed a bimodal growth of the insect populations as a whole. They speculated that the bimodal population growth may be an inherent characteristic of the insects of shortgrass prairie. They reported further that the population numbers fluctuate greatly through time but the biomass does not show a similar pattern.

In a study of grasshoppers on the Pawnee Site, Van Horn (1972) reported that population density of adults was greatest in late summer or early fall and that the population was mainly composed of only four to six species of grasshoppers. Peak densities of adult grasshoppers for the three years (1968 to 1970) were: 1968 October, 19.4/10 m^2; 1969 September, 7.8/10 m^2 and 1970 August and September, 5.1/10 m^2. His data indicate a variation in the peak adult population densities and peak biomass from 1968 to 1970. The peak biomass in 1968 was 1.37 gm/10 m^2, but it went down in 1969 and 1970 being only 0.55 gm and 0.33

gm/10 m^2, respectively. Van Horn (1972) attributed these changes to the hot and dry weather in June, 1968, which favored the emergence and survival of first instar nymphs, resulting in a larger adult population in the fall, and to the cold and wet weather in June, 1969, which he conjectured decreased the survival of the eggs and early nymphs. This early mortality resulted in a low adult biomass.

Bioenergetics

Engelmann (1966) prepared an exhaustive review of work done on bioenergetics, especially with regard to animals; it is a useful reference since it also offers an extensive bibliography to those who are interested in the study of bioenergetics and productivity. He discussed three approaches to the study of energetics, and an understanding of such fundamental information is quite imperative in order to begin research in this field. The three approaches are: (1) physiological studies of the metabolism and metabolic rate under normal and stress conditions; (2) analysis of maintenance energy which involves the study of numbers, biomass and oxygen consumption and (3) study of trophic dynamics and of community metabolism as proposed by the Lindeman school. The guiding principle in this type of study is the Lindeman model which consists of an energy flow diagram (Lindeman, 1942). This model leans heavily upon natural history observations, life tables, metabolic data, and phenology, and can provide a new turn to the old ecology. Slobodkin (1962) has indicated the paucity of data in field energetics and emphasizes the need for further research.

The book Bioenergetics and Growth by Brody (1945) is an important source and standard reference on energetics. Many of the chapters are of a general nature and offer invaluable information pertaining to important topics as energetics and energy units, energetic efficiencies of growth and work processes, nutrition, homeostasis and organismic theories, methods in animal calorimetry, etc. Succinctly, it deals with the processes of growth and metabolism.

One of the first investigators to apply calorimetry in ecological research was Long (1934) who found that energy values varied for different parts of the plant. Long indicated that it is helpful to know not only how much energy was utilized but also how much was stored in different parts of the plant. This kind of information allows an interspecific comparison to be made.

Golley (1961) emphasized that ecologists should directly determine the energy content of ecological materials when studying energy flow through natural systems. The caloric value of a plant or animal is a function of its genetic constitution, nutritive condition and life history. Golley (1961) advocated that ecologists making intensive measurements of energy flow through natural systems cannot depend on caloric constants or equivalents. There is too much variation between and within species. Even though the application of thermodynamic theory to ecology has progressed rapidly (Odum, 1956), an understanding of the energy dynamics of individual populations has been hampered by incomplete knowledge of the energy contents of many plants and animals.

Phillipson (1967) examined the methodological problems of studying the energy relations of invertebrates which reproduce more than once in their life span. He stated that plotting the survivorship curve is most complex when an animal has a long life span and in each breeding year produces many broods over a long period of time. Under such conditions he suggested that bioenergetic studies must be made on all life stages for at least one year.

The problem of determining production for any animal population is basically one of population dynamics; the accuracy of studies on the latter will determine the value of the former (Whittaker, 1967). This author pointed out the necessity of obtaining the calorific value of each stage in the life cycle and thus to calculate the average calorific value per individual at each census date. Kozlovsky (1968) suggested ways for calculating community efficiency and community productivity based upon a consideration of the net productivity of all trophic levels or populations.

Studies which analyze the trophic scheme of communities give the best figures on animal productivity. Such studies relate the incorporation of calories into new protoplasm in addition to estimates of maintenance energy. These growth calories increase the biomass of the population and provide more energy to the next trophic level. In this light, the works of Odum and Smalley (1959), Smalley (1960), Odum *et al.* (1962), Golley and Gentry (1964) and Wiegert (1964) are relevant. Golley (1960) approached the subject of field energetics from the standpoint of energy flow through a food chain. Two other workers, Engelmann (1961) and Teal (1962), have made some analyses at the community level.

Working on the insects of a salt marsh community, Smalley (1960) obtained basic information which has been utilized by several workers. His data for the longhorn grasshopper, *Orchelimum fidicinium*, was used by him, by Odum and Smalley (1959) and by Teal (1962) for the study of ecosystem energetics. Smalley sampled populations by sweep net and collected data both on numbers of individuals and size categories of individuals. Representative individuals from each size category were weighed and then weights were assigned to the size categories. He used a simple constant pressure respirometer to measure respiration rates, and the calorific values for various biological materials were determined in a Parr Bomb colorimeter. He calculated that a biomass equivalent of 10.8 Kcal/m^2 respired 18.6 Kcal of oxygen annually. Smalley estimated that the grasshoppers ingested 107 Kcal of the 5,200 Kcal produced annually on each m^2 of the salt marsh, which led to a gross production by the grasshoppers of 29.4 Kcal/m^2/year (an efficiency of 27 percent).

Energetics data for grasshoppers and snail populations living in the salt marsh were summarized by Odum and Smalley (1959). The longhorn grasshopper, Orchelimum, ingested 48 Kcal/m^2/year of Spartina grass. Gross production for grasshoppers was 28 Kcal/m^2/year. Net production in the grasshopper was 10.4 Kcal/m^2/year and in the snail 40.6 Kcal/m^2/year. The authors concluded that even though the numbers of individuals and biomass varied in the salt marsh community, the energy flow through the population remained relatively constant.

The studies of Odum et al. (1962) were focused on two species of grasshoppers, Melanoplus femurrubrum and Melanoplus sanguinipes. They also studied the tree cricket, Oecanthus nigricornis. In this study, the sampling was done by capturing the Orthoptera with sweep nets and cages (after the method of Smalley, 1960). Gross production for the

Orthoptera was 25.6 $Kcal/m^2/year$, or only about 2 to 7 percent of energy available in the annual crop of above ground vegetation. This study also included studies on mouse and sparrow populations.

Wiegert (1965) conducted a study of the energetics of the grasshopper population on two different southern Michigan habitats, an abandoned pasture and a first year seeding of alfalfa. He found that the population density of grasshoppers decreased at a constant rate throughout the summer. In general the growth rates of the three grasshopper populations were similar. During the early season when few adults were present, growth rate was constant. As the proportions of nongrowing adults increased, the growth rate declined and reached an asymptote in the late summer and early fall. He found out that a total of 122 mg of tissue/m^2 was added by the grasshopper population on the old field in 1959. On the same field in 1960 the average mean population density was considerably lower and the total production was only 71.7 mg/m^2. The peak energy content of the grasshopper population coincided with the peak standing crop of green vegetation. Wiegert (1965) reported the mean calorific content of dry grasshopper tissue to be 5203 cal/g; feces contained an average of 4466 cal/g dry wt.

Several other studies are relevant to this discussion, and are discussed below.

Menhinick (1967) studied the energy flow through the stand of a perennial summer legume, _Sericea lespedeza_, which was essentially a monophytic community in Aiken, South Carolina. The arthropods comprised the major portion of the grazing food chain, their biomass reaching a maximum of about 50 mg/m^2 in early summer. Orthoptera, which made up the major portion of the biomass, greatly influenced the two distinct seasonal peaks. Density increased from 0.4 individuals/m^2 in winter to a peak of about 11/m^2 in late summer. Gyllenberg (1969) examined the energy flow through a population of the grasshopper Chorthippus parallelus inhabiting a meadow in Langholmen, Finland. He obtained a production efficiency (P/A) of about 50 percent for June through August and an estimated value for the whole year was 44 percent. The amount of energy consumed and assimilated from the net production of the above ground vegetation was of the order of 1.4 to 2.7 percent consumed and 0.4 to 0.8 percent assimilated. The amount of the plant matter removed but not used was found to be 1.1 times the matter consumed.

Van Hook, Jr. (1971) developed a compartment model using population dynamics, energy budgets, and nutrient concentrations for evaluating energy flow and nutrient fluxes in the spider and orthopteran components of an eastern Tennessee grassland ecosystem. His work included the determination of whole body concentrations of Na, Ca, and K, and an estimation of biological turnover rates of these nutrients with radioactive analogs. The author reported 1,274 Kcal/m^2 as the total net primary production of the grassland ecosystem of which 89 percent was by grass species and 11 percent by green forbs. Of the net primary production, 9.6 percent was consumed by herbivores and omnivores. The annual net secondary production by the insect community was 32.05 Kcal/m^2. The total annual energy flow or total assimilation through the community was 75.6 Kcal/m^2. Herbivores, the dominant members of the arthropod fauna, attained a maximum standing crop of 927 mg/m^2, of which 705 mg/m^2 was contributed by Melanoplus sanguinipes, 200 mg/m^2

by Conocephalus fasciatus, and 22 mg/m^2 by the Homoptera and Hemiptera.

Odum (1964) in particular points to energetics as the new ecology, but not many guiding principles and predictive models have been developed to guide the new realm of the ecological world. It has to be admitted that thus far the Lindeman model has been the major guiding principle in energetics, but this approach has also been little tested and has remained practically unmodified since its inception over 20 years ago. From a close examination of the available literature, one can say that the study of terrestrial energetics is still in its infancy and more studies are warranted.

STUDY SITES

The Pawnee Site, the intensive study area of the Grassland Biome Project, lies within the western division of the Pawnee National Grasslands and is administered by the U. S. Forest Service. The site is situated approximately 12 miles northeast of Nunn, Colorado and 25 miles south of Cheyenne, Wyoming, and is one of the study areas for this project. While the densities of grasshopper population on this site have been relatively low during the past several years, the other four sites situated near Lusk, Hartville, Guernsey and Glendo in southeast Wyoming can be defined as outbreak areas as far as grasshopper populations are concerned and have been included to provide data for a reliable assessment of the importance of grasshoppers in the shortgrass and mixed-grass associations.

The Pawnee Site is representative of the shortgrass association, whereas the other four sites represent the mixed-grass association. One may refer to Jameson (1969) and Klipple and Costello (1960) for a more detailed description of the Pawnee Site. The native shortgrass range vegetation is basically blue grama and buffalograss supplemented in many areas by threadleaf and needleleaf sedges. Several midgrasses such as western wheatgrass, needleandthread, green needlegrass, little bluestem and sideoats grama grow in association with the shortgrasses. Slimflower scurfpea, scarlet globemallow, slenderbrush wild-buckwheat and scarlet guara constitute the perennial forbs. Annual forbs include Russianthistle, cryptantha, stickseed, pale evening primrose, lambsquarters and Rocky mountain beeplant. Shrub species include saltbush, fringed sagewort, winterfat, rubber rabbitbrush, broom snakeweed and big sagebrush are most commonly found. Lavigne (1969) has reported a list of orthopterans from several vegetation subtypes on the Pawnee Site.

The average annual precipitation at the Pawnee Site ranges from 10 to 15 inches and about 80 percent of the precipitation falls during the summer months of May through September. July and August are the hottest months and the average temperature fluctuates between 60 and 70°F. The common soil series are Ascalon, Vona, Renohill and Shingle. The Renohill and Shingle series are formed on shale and siltstone outcrops of the Pierre sedimentary formation, while the Ascalon series is formed predominantly by fluvial outwash materials. The Vona is formed by somewhat coarser outwash materials. Interspersed among these upland soils are alluvial plains high in clay content and are of more recent origin.

Sampling areas for biomass collection and density determination at the Pawnee Site included the lightly (Section 23 W), moderately (Section 15 E), and heavily (Section 23 E) grazed pastures located in Township 10 N; Range 66 W 6th P.M. All of the sites were divided into two plots for biomass and density determination. Collecting and sampling were usually performed during the same morning. Major sampling efforts were concentrated on grasshoppers of the family Acrididae, because to my knowledge the population of the family Tettigonidae is negligible on these pastures. Van Horn (1972) also did not obtain any data on this family.

Section 23 is mainly an upland site and is divided into eastern and western halves. The eastern half is heavily grazed and the western half is lightly grazed, resulting in a physiognomy that is quite different. The vegetation in the eastern half is very low with patches of bare soil quite common; there is an abundance of cactus and lichen.

The study sites in southeastern Wyoming are located near Lusk, Hartville, Guernsey and Glendo. The average mean monthly temperature for the period of May through September at Guernsey, Glendo and Hartville fluctuates between 62 and 75°F and at Lusk between 60 and 70°F. Average annual precipitation for the former three sites ranges from 12 to 14 inches and is about 15 inches at Lusk; about 70 to 75 percent of the precipitation falls during summer months on all these sites. There are no reports concerning the grazing pressure on these sites. Soil descriptions for each of these sites was provided by the soil conservation service of the respective areas.

The Guernsey site is situated 4 miles west of the town of Guernsey and is located in Township 27 N, Range 66 W, Section 31. Soil description falls under the following series:

J 66 Canyon fine sandy loam

G 15- A and G 15- B Mitchell silt loam

K 18- A and K 18- B Otero fine sandy loam

The Glendo site is 10 miles south of the town of Glendo and is located in Township 28 N, Range 68 W, Section 34. The soil description of this area includes the following series:

R 18- A, R 18- B and R 18- C Otero loamy very fine sand

J 66 Canyon fine sandy loam

J 18- A, J 18- B and J 18- C Otero very fine sandy loam

M 66 Canyon loamy fine sand

M 70 A Lingle loamy find sand

The Hartville study site is located 10 miles northeast of the town of Hartville and is in Township 29 N, Range 65 W, Section 33, with the following series of soil structure:

H 11- A and H 11- B Waggs gravily loam

H 14- A and H 14- B Coffee Creek loam

J 66 Canyon fine sandy loam

The Lusk site is about 19 miles southeast of the city of Lusk and is situated in Township 30 N, Range 63 W, Section 19. On this site common soil series are Rosebud, Hargreave, Trelona, and Torrington comprised of fine sandy loam, Albin loam, rock outcrop and gullied land.

On all sites, vegetation is basically blue grama supplemented in many areas by threadleaf and needleleaf sedges. Several midgrasses such as western wheatgrass, needleandthread, Japanese brome and downy brome grow in association with the shortgrasses. Of the shrub species, fringed sagewort, rubber rabbitbrush, broom snakeweed, winter fat, and big sagebrush are most commonly found. Common pricklypear and plains pricklypear are found abundantly in the areas of heavy grazing.

These sites were selected because it was found that they would be suitable for testing some of the hypothesis and provide some data to compare with that of the Pawnee Site (Pfadt and Bhatnagar, 1971).

MATERIALS AND METHOD

Collection for Grasshopper Biomass and Density Data

The collection of grasshoppers was done in the summers of 1971 and 1972 on a weekly or biweekly basis by sweeping or individual collection as conditions required. In 1971 biweekly collections were made usually on all sites, but in 1972, due to the fact that the density of grasshoppers was relatively low at the Pawnee Site, the collection was made once every week until October, 1972. Two of the sites, Hartville and Lusk, were sprayed in the summer of 1972 and most of the grasshopper population was killed so collections were stopped quite early. At the Glendo and Guernsey sites collections were made in 1971 and early 1972. The objective of all collections was to determine the average weight of grasshoppers of each species, age and sex.

Sweeping was done randomly throughout each study area, using a simple nylon insect net. On windy days sweeping was not very effective and collection was accomplished by dragging the insect net against the wind. Collection was done by handpicking for the rarer species. The collected insects were immediately transferred to the insect cage in which some grass was provided for their feeding. On returning from the field the cage containing the grasshoppers was placed in the freezer to kill and freeze the grasshoppers. Grasshoppers were kept in a frozen condition until the time of separation.

Accurate analysis of grasshopper biomass dynamics requires the separation of individuals of each species into sex and instar. The frozen grasshoppers were taken out of the cage on convenient days and were separated into species (using the key to Wyoming grasshoppers; Pfadt, 1965), instars and sexes and placed in one dram vials with an explanatory label. Thus each vial had specimens of only one species, sex and age.

The grasshoppers were oven dried at 70°C for 72 hours before weighing. It was observed that drying at 70°C for a period of 72 hours was sufficient as there was no difference in body weight between the grasshoppers dried for 72 and those dried for 96 hours. Until the weighing was done the dried grasshoppers were stored over a desiccant. The weighing was done on a Cahn Gram Electrobalance which was accurate to 0.00001 g. A total of at least 30 individuals of each age and sex of each species were weighed from the 1971 and 1972 collections, but in the case of rarer species such a minimum could not be achieved. The dominant and most abundant species, viz. Aulocara elliotti and Cordillacris occipitalis, at the Lusk site were collected for both years separately so as to find out the difference in biomass of these species, if any, for the two summers. At Hartville, Aulocara elliotti was also collected during both summers.

On the same sites used for collection of biomass data, sampling of absolute population densities of each species was done by walking a transect in a general area established on each study site.[1] The method of sampling consisted of counting number of instars and the number of

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[1]Sampling of density was done by R. E. Pfadt, Professor of Entomology, University of Wyoming, Laramie.

adults (by sex) of each species within a square foot area; 100 or 200 counts were taken biweekly in 1971 on each site. This method was used instead of quick traps because Riegert and Varley (1970) state that Orthoptera are visually repelled by the presence of quick traps and that population figures obtained by such traps are not valid representations of the actual occurrence of these insects. In 1972 counts were made weekly on the Pawnee Site and at irregular intervals on the southeastern Wyoming sites. For the final calculation of density, the data per square foot area have been converted into number per square meter.

Biomass estimates were calculated by multiplying the mean ovendry weight of specimens of a given age and sex of a species times the number of specimens of that age, sex and species in a particular area on a particular date.

Determination of Calorific Values

Only four dominant species, namely *Aulocara elliotti* and *Cordillacris occipitalis* from southeastern Wyoming sites and *Cordillacris crenulata* and *Opeia obscura* from the Pawnee Site, have been used for the determination of the calorific values for the assessment of total body energy.[2] For these determinations first and second instars were pooled in one group and third, fourth and fifth instars were pooled in a second group. Because of weight differences of the various instars, 10 males and 10 females of first instar and 5 males and 5 females of second instar were pooled in the first group and 12 males and 12 females of third, 6 males

[2]Calorimetric determinations were done by technicians in the Natural Resource Ecology Laboratory, Colorado State University, Fort Collins.

and 6 females of fourth and 3 males and 3 females of fifth instar in the second group. In the case of adults, 15 males and 15 females collected late in the summer of 1971 and the same number collected in early 1972 were analyzed in two different groups. All the specimens used for this purpose were oven dried at 70°C for 72 hours to avoid any chemical and microbial decomposition and were held in a desiccant. The dried grasshoppers of the different groups were ground separately in a Wiley Mill and a 20 mesh sieve was used. Two different types of bomb calorimeters were used, one a macrobomb (an adiabatic type as described in Parr Instrument Company manual #142) and the other a microbomb (a nonadiabatic type described by Phillipson, 1964). The latter was used for the samples which weighed less than 100 mg.

<u>Sampling for the Determination of Vegetation Cover</u>

In order to compare the density of grasshoppers with vegetation cover on the Pawnee Site, vegetation sampling was done in 1972 three times during the season corresponding to the hatching of grasshoppers, peak period of grasshopper population and the decline of grasshopper population. The canopy-coverage method described by Daubenmire (1959), employing a standard frame of 20 x 50 cm., was used for measuring the vegetation cover. Some of the good points of this method can be summarized as follows:

1. Two dimension plot method is superior to linear or plotless techniques.
2. A series of small samples is superior to a single large one in the stand and this is more efficient and accurate in an evaluation of cover.

3. Keeping plots small reduces observer error since the accuracy of estimation declines when the size of the observational unit increases.

On all study sites sample areas of about 800 to 1000 square feet were selected which were representative of the whole site. A stratified random sampling method was used in selecting the plots for the estimation of the vegetation cover with the help of the Daubenmire frame. Such a sampling method economizes time and provides a suitable degree of randomness for minimizing any possible bias. As suggested by Daubenmire (1959), 40 plots in each of the study sites were sampled at each date. For such an estimation, coverage was considered as an approximation of the area over which a species exerts its influence upon other components of the ecosystem. It involved basically an evaluation of each taxon as to its percent coverage, i.e., whether the coverage is between 0-5, 5-25, 25-50, 50-75, 75-95, 95-100 percent. In such broadly defined coverage classes there should be little chance for consistent human error in assigning coverage classes. The data were summarized following the directions of Daubenmire (1959).

RESULTS AND DISCUSSION

Species Diversity and Abundance

A complex of grasshopper species inhabit the shortgrass and midgrass associations. In this study, 27 species have been recorded on the Pawnee Site (Table 1). Out of these 27 species, 22 were found also on the southeast Wyoming sites. In Table 1 the species are arranged into 3 categories of abundance: abundant, common and rare. These categories reflect the population density as determined at their peak of abundance, regardless of whether the population is composed of nymphs, adults or a mixture of both.

Abundant = $>$ 1 individual/10 m^2

Common = 0.10 to 1.00 individual/10 m^2

Rare = $<$ 0.10 individual/10 m^2

All of the abundant species are important in biomass estimation, and some of the common and rare species are important also because they are very big, heavy bodied species with a large biomass, e.g., *Xanthippus corallipes*, *Trimerotropis campestris*.

Three definite patterns of emergence of nymphs and adults have been detected. This pattern involves grasshoppers with life cycles of three types which can be labeled as "Early," "Mid," and "Late." The early species overwinter in the later (3rd through 5th) nymphal instars and metamorphoses into the adult stage during April and May at the Pawnee Site. By the end of June they have oviposited and have largely

TABLE I

CHECK LIST OF THE GRASSHOPPERS INHABITING PAWNEE SITE

Taxon	Abundance Status (Pawnee Site)	Aspect
Family - Acrididae		
Subfamily - Acridinae (Slant faced grasshoppers)		
*Ageneotettix deorum (Scudder)	Rare	Mid
*Amphitornus coloradus (Thomas)	Rare	Mid
*Aulocara elliotti (Thomas)	Rare	Mid
*Cordillacris crenulata (Bruner)	Abundant	Mid
*Cordillacris occipitalis (Thomas)	Common	Mid
*Eritettix simplex (Thomas)	Rare	Early
*Opeia obscura (Thomas)	Abundant	Late
*Phlibostroma quadrimaculatum (Thomas)	Common	Late
*Psoloessa delicatula (Scudder)	Abundant	Early
Subfamily - Oedipodinae (Banded wing grasshoppers)		
*Arphia conspersa (Scudder)	Common	Early
*Arphia pseudonietana (Thomas)	Rare	Late
Derotmema haydenii (Thomas)	Rare	Mid
Encoptolophus sordidus costalis (Scudder)	Rare	Late
Heliaula rufa (Scudder)	Rare	Mid
Parapomala wyomingensis (Thomas)	Rare	Mid
*Spharagemon equale (Say)	Rare	Mid
*Trachyrhachys aspera (Scudder)	Common	Late
*Trachyrhachys kiowa (Thomas)	Common	Late
*Trimerotropis campestris McNeill	Rare	Late
Tropidolophus formosus (Say)	Rare	Late
*Xanthippus corallipes (Haldeman)	Common	Early

TABLE I (Continued)

Taxon	Abundance Status (Pawnee Site)	Aspect
Subfamily - Crytacanthacridinae (Spur-throated grasshoppers)		
*Melanoplus confusus Scudder	Rare	Mid
*Melanoplus foedus Scudder	Rare	Mid
*Melanoplus gladstoni Scudder	Abundant	Late
*Melanoplus infantilis Scudder	Abundant	Mid
*Melanoplus occidentalis (Thomas)	Rare	Mid
*Melanoplus sanguinipes (Fabricius)	Rare	Mid

* Found also on the southeast Wyoming sites

disappeared. The eggs lay in the ground until the following year when they hatch by mid summer.

The more typical grasshopper life cycle is the "Mid" and "Late" types in which eggs hatch in late spring or early summer and adults appear in summer or early fall. The species which appear as adults in July may be designated as "Mid" and those which appear in August and September as "Late." The aspection status of each species is shown in Table 1 in the "Aspect" column.

Weight of Nymphal and Adult Grasshoppers

Appendices A to F give in tabular form the mean dry weight (mg) with the respective ranges and standard deviations for each species, age and sex collected. An inspection of these data shows that weight differences within and between sexes in the earlier instars of a species are not notable, but that they become significantly greater among older instars and adults. This is indicated by the standard deviations which are quite high for the older instars and adults. Invariably the females of the older instars and adults were heavier than their male counterparts. This weight difference might be due to the morphological changes in the development of the genetalia especially in the later nymphal instars. Whereas in the adults, there is a sharp increase in the weight of the females due to the maturation of the eggs after the first copulation, until a maximum is reached at the first oviposition (Uvarov, 1966).

Effect of Grazing Pressure upon the Grasshopper Habitat

Does grazing pressure have any effect in improving the habitat of grasshoppers in the shortgrass plains? At the start of this work the hypothesis was made that the grazing pressure improves the habitat of the grasshoppers in the Pawnee Site, since this factor operated favourably for grasshoppers in tall grass habitats in Kansas and Michigan. Working in the tall grass habitat near Manhattan, Kansas, Arnett (1960) reported the most abundant occurrence of destructive grasshoppers in heavily grazed range. Lightly grazed pastures and pastures under deferred grazing had low populations. Dibble (1940), working in Michigan, reported that as denuding progressed and was followed by wind action on the soil, Ageneotettix deorum found conditions more suitable. This species assumed first place in numbers and importance in many areas. The egg laying habits of this species were favoured as the eggs are commonly found in bare sandy areas, mainly blowouts and washes, about small clumps of grass.

To test this hypothesis density counts were made on the Pawnee pastures. Tables 2-13 show the individual species and total density of the grasshoppers on the sampling dates; these tables also contain the biomass figures in the heavily grazed pasture and in the lightly and moderately grazed pastures combined. The data from the latter two pastures were combined because of the similarity of the habitats and in order to increase the sample size to 200 square feet, a size that seemed better for estimating the low density of grasshoppers on pastures of the Pawnee Site. Figure 1 shows that there is a greater density of grasshoppers in the lightly-moderately grazed pastures than in the heavily grazed pasture. In the lightly-moderately grazed pasture the maximum number of grasshoppers was $3.28/m^2$ ($30.5/100\ ft^2$) whereas in the heavily grazed pasture the maximum number of grasshoppers remained

TABLE 2

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF MAY 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates May 23	Collection Dates May 30
Cordillacris crenulata	D	--	3-1st
	B	--	4.63
Cordillacris occipitalis	D	1-1st	--
	B	2.18	--
Melanoplus infantilis	D	--	1-1st
	B	--	1.14
Melanoplus occidentalis	D	--	1-3rd
	B	--	9.22
Psoloessa delicatula	D	--	1-M
	B	--	22.58
Total density/100 ft^2		1	6
Total density/m^2		0.11	0.65
Total biomass/100 ft^2		2.18	37.57
Total biomass/m^2		0.23	4.04

TABLE 3

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF JUNE 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		June 7	June 14	June 2	June 26
Cordillacris crenulata	D	2-1st 8-2nd	5-2nd 1-3rd 4-4th	2-1st 1-2nd 2-3rd 1-4th	3-3rd 1-4th
	B	26.54	44.79	20.81	18.92
Cordillacris occipitalis	D	--	1-4th	1-M	--
	B	--	7.02	17.21	--
Derotmema haydenii	D	--	--	1-3rd	--
	B	--	--	7.66	--
Melanoplus infantilis	D	--	1-2nd	1-1st 1-4th	3-3rd
	B	--	2.13	10.01	13.35
Opeia obscura	D	--	--	2-1st	3-1st 1-2nd
	B	--	--	2.38	5.73
Psoloessa delicatula	D	2-M	--	--	--
	B	45.16	--	--	--
Trachyrhachys kiowa	D	2-1st 2-2nd	1-1st 3-2nd 1-3rd	3-3rd 1-4th	4-3rd 1-4th
	B	8.58	16.04	31.71	36.88
Total density/100 ft^2		16	18	16	17
Total density/m^2		1.72	1.94	1.72	1.83
Total biomass/100 ft^2		80.28	69.98	89.78	75.68
Total biomass/m^2		8.64	7.53	9.66	8.15

TABLE 4

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF JULY 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		July 5	July 11	July 19	July 24
Arphia pseudonietana	D	--	--	2-4th	--
	B	--	--	75.72	--
Cordillacris crenulata	D	2-4th 1-5th	2-M	--	1-M
	B	25.71	25.16	--	12.58
Encoptolophus sordidus costalis	D	--	1-2nd	1-2nd	--
	B	--	--	--	--
Melanoplus gladstoni	D	--	--	--	1-3rd
	B	--	--	--	10.08
Melanoplus infantilis	D	2-4th	1-4th 1-5th	1-4th	1-5th
	B	17.74	29.44	8.87	20.57
Melanoplus occidentalis	D	--	--	1-F	--
	B	--	--	98.79	--
Opeia obscura	D	5-1st 1-2nd 1-3rd	1-3rd 1-4th	1-3rd 1-4th	1-2nd 1-3rd 2-4th
	B	11.76	11.86	11.86	22.23
Phlibostroma quadrimaculatum	D	1-4th	--	1-5th	1-3rd
	B	9.81	--	16.43	5.44
Psoloessa delicatula	D	--	--	--	2-1st
	B	--	--	--	2.58
Trachyrhachys aspera	D	1-1st	--	2-3rd	2-3rd
	B	2.41	--	18.46	18.46
Trachyrhachys kiowa	D	1-3rd 2-4th	1-F	1-4th 2-M 1-F	1-5th 3-M
	B	45.51	28.65	145.43	110.77

TABLE 4 (Continued)

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		July 5	July 11	July 19	July 24
Xanthippus corallipes	D	--	--	1-2nd	1-2nd
	B	--	--	6.95	6.95
Total density/100 ft^2		17	8	15	17
Total density/m^2		1.83	0.86	1.61	1.83
Total biomass/100 ft^2		112.94	95.11	382.51	209.66
Total biomass/m^2		12.16	10.24	41.17	22.57

TABLE 5

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF AUGUST 1972

Species	D&B(mg)/ 100 ft^2	Collection Dates Aug. 1	Aug. 7	Aug. 14	Aug. 22	Aug. 29
Cordillacris crenulata	D	1-F	3-M	1-F	1-F	1-M
	B	24.30	37.74	24.30	24.30	12.58
Derotmema haydenii	D	1-5th	1-5th	--	1-5th	--
	B	34.40	34.40	--	34.40	--
Encoptolophus sordidus costalis	D	--	1-3rd	--	1-M	--
	B	--	--	--	--	--
Heliaula rufa	D	--	--	1-M	--	--
	B	--	--	--	--	--
Melanoplus gladstoni	D	1-3rd 2-4th	--	1-4th	1-4th	1-F
	B	45.78	--	17.85	17.85	91.30
Melanoplus infantilis	D	--	1-F	1-M 1-F	--	2-M
	B	--	60.85	99.03	--	72.36
Opeia obscura	D	1-4th 2-5th	1-3rd 1-4th 3-5th	1-M 1-F	1-M	2-M
	B	39.55	58.87	71.61	15.22	30.44
Phlibostroma quadrimaculatum	D	--	1-5th	--	--	--
	B	--	16.43	--	--	--
Psoloessa delicatula	D	--	1-2nd	1-2nd	1-3rd	1-2nd
	B	--	2.11	2.11	4.22	2.11
Trachyrhachys aspera	D	--	--	2-5th	1-F	1-M 1-F
	B	--	--	71.14	109.15	152.93

TABLE 5 (Continued)

Species	D&B(mg)/ 100 ft^2	Collection Dates				
		Aug. 1	Aug. 7	Aug. 14	Aug. 22	Aug. 29
Trachyrhachys kiowa	D	2-5th 2-M	2-M	2-M 1-F	1-M 1-F	1-F
	B	106.94	57.30	131.63	102.98	74.33
Xanthippus corallipes	D	2-2nd 1-3rd	--	--	1-2nd	--
	B	26.70	--	--	6.95	--
Total density/100 ft^2		15	15	13	10	10
Total density/m^2		1.61	1.61	1.40	1.08	1.08
Total biomass/100 ft^2		277.67	267.68	417.67	315.07	440.05
Total biomass/m^2		29.89	28.82	44.96	33.91	47.37

TABLE 6

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF SEPTEMBER 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		Sept. 5	Sept. 14	Sept. 24
Arphia conspersa	D	--	1-4th	--
	B	--	15.06	--
Melanoplus gladstoni	D	--	--	1-F
	B	--	--	91.30
Melanoplus infantilis	D	1-M	1-F	--
	B	38.18	60.85	--
Opeia obscura	D	--	1-M	1-M
	B	--	15.22	15.22
Phlibostroma quadrimaculatum	D	--	--	1-M 1-F
	B	--	--	105.00
Psoloessa delicatula	D	2-3rd 1-4th	1-4th	1-4th 1-5th
	B	15.38	6.94	38.83
Spharagemon equale	D	--	--	1-F
	B	--	--	258.60
Trachyrhachys aspera	D	1-M	--	2-M
	B	43.78	--	87.56
Xanthippus corallipes	D	--	1-3rd 1-4th	--
	B	--	68.11	--
Total density/100 ft^2		5	6	9
Total density/m^2		0.54	0.65	0.97
Total biomass/100 ft^2		93.34	166.18	596.51
Total biomass/m^2		10.48	17.89	64.21

TABLE 7

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE FOR THE MONTH OF OCTOBER 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates Oct. 3	Oct. 10	Oct. 17	Oct. 26
Arphia conspersa	D	--	1-5th	--	--
	B	--	72.90	--	--
Arphia pseudonietana	D	--	--	1-M	--
	B	--	--	72.30	--
Melanoplus gladstoni	D	1-F	1-M	1-M 1-F	--
	B	91.30	76.77	236.18	--
Opeia obscura	D	--	--	1-M 1-F	--
	B	--	--	71.61	--
Phlibostroma quadrimaculatum	D	--	2-F	--	--
	B	--	153.76	--	--
Psoloessa delicatula	D	1-4th	1-3rd 1-4th 2-5th	1-4th 1-5th	2-5th
	B	6.94	74.94	38.83	63.78
Trachyrhachys aspera	D	1-M	1-M	2-M	--
	B	43.78	43.78	87.56	--
Xanthippus corallipes	D	1-5th	--	1-4th	1-5th
	B	68.99	--	55.26	68.99
Total density/100 ft^2		4	9	10	3
Total density/m^2		0.43	0.97	1.08	0.32
Total biomass/100 ft^2		211.01	422.15	493.63	132.77
Total biomass/m^2		22.71	45.44	53.14	14.29

TABLE 8

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) OF THE PAWNEE SITE FOR THE MONTH OF MAY 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates	
		May 23	May 30
Ageneotettix deorum	D	--	0.5-1st
	B	--	1.36
Amphitornus coloradus	D	1.5-1st	1-1st
	B	2.02	1.35
Arphia conspersa	D	0.5-M	--
	B	46.70	--
Cordillacris crenulata	D	--	14-1st
	B	--	21.23
Cordillacris occipitalis	D	0.5-1st 0.5-2nd	0.5-3rd
	B	3.07	2.91
	D		
Melanoplus occidentalis	D	--	0.5-2nd
	B	--	1.97
Psoloessa delicatula	D	0.5-F	--
	B	31.36	--
Trachyrhachys kiowa	D	--	1-1st
	B	--	2.41
Total density/100 ft^2		3.50	17.50
Total density/m^2		0.37	1.88
Total biomass/100 ft^2		83.16	31.23
Total biomass/m^2		8.96	3.37

TABLE 9

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) ON THE PAWNEE SITE FOR THE MONTH OF JUNE, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		June 7	June 14	June 19	June 26
Ageneotettix deorum	D	1-1st 0.5-2nd	0.5-2nd	--	0.5-3rd
	B	7.53	1.74	--	3.15
Amphitornus coloradus	D	0.5-2nd 0.5-3rd	--	1-3rd	--
	B	6.91	--	9.45	--
Arphia pseudonietana	D	0.5-1st	--	--	--
	B	0.83	--	--	--
Cordillacris crenulata	D	1.5-1st 8-2nd 0.5-3rd	4.5-2nd 4-3rd	2-2nd 3.5-3rd 1.5-4th	0.5-2nd 1-3rd 2-4th
	B	29.29	34.01	33.62	29.42
Cordillacris occipitalis	D	1-2nd	0.5-4th	--	0.5-5th 0.5-M
	B	3.96	6.48	--	23.73
Melanoplus foedus	D	--	--	--	0.5-2nd
	B	--	--	--	2.89
Melanoplus infantilis	D	2.5-2nd 0.5-1st	1-2nd 0.5-4th	0.5-2nd 2.5-3rd 0.5-4th	0.5-3rd 0.5-4th
	B	6.64	6.72	16.73	6.57
Melanoplus occidentalis	D	0.5-2nd	0.5-4th	1-1st	--
	B	1.97	8.98	2.32	--
Opeia obscura	D	3-1st	1.5-1st 0.5-2nd	3.5-1st 1-2nd	3.5-1st 3.5-2nd 1-3rd
	B	3.27	2.71	6.01	18.26
Parapomala wyomingensis	D	0.5-2nd	--	--	--
	B	--	--	--	--

TABLE 9 (Continued)

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		June 7	June 14	June 19	June 26
Phlibostroma quadrimaculatum	D	--	1.5-2nd	--	1-1st 0.5-2nd 0.5-3rd
	B	--	4.80	--	6.17
Psloessa delicatula	D	--	--	0.5-M	--
	B	--	--	13.24	--
Trachyrhachys kiowa	D	3-1st 0.5-2nd	2-2nd 2-3rd	0.5-2nd 3.5-3rd	1-2nd 1-3rd 1-4th
	B	8.98	20.16	24.82	25.53
Total density/100 ft^2		24.5	19	22.5	20.5
Total density/m^2		2.63	2.04	2.42	2.2
Total biomass/100 ft^2		66.26	85.60	107.65	115.71
Total biomass/m^2		7.13	9.22	9.31	12.46

TABLE 10

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) OF THE PAWNEE SITE FOR THE MONTH OF JULY, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		July 5	July 11	July 19	July 24
Ageneotettix deorum	D	1-4th	--	0.5-5th	0.5-M
	B	15.06	--	12.77	13.88
Arphia pseudonietana	D	--	0.5-4th	--	--
	B	--	18.93	--	--
Cordillacris crenulata	D	3-5th	0.5-3rd 0.5-4th 0.5-5th 2-M 0.5-F	0.5-5th 2-M 1.5-F	1-M
	B	29.43	48.61	70.64	12.00
Cordillacris occipitalis	D	0.5-4th 1-M	--	--	--
	B	25.77	--	--	--
Derotmema haydenii	D	0.5-2nd	--	0.5-4th	0.5-3rd 0.5-4th
	B	1.16	--	5.35	9.18
Melanoplus gladstoni	D	--	--	1-3rd	0.5-2nd 2-3rd
	B	--	--	11.64	26.11
Melanoplus infantilis	D	0.5-2nd 3.5-3rd 0.5-4th	3.5-3rd 1-4th	1.5-4th	--
	B	21.23	24.35	12.95	--
Opeia obscura	D	8.5-1st 4.5-2nd 0.5-3rd	7-2nd 1.5-3rd 2-4th	0.5-2nd 8.5-3rd 4-4th 0.5-5th	1-2nd 4-3rd 3.5-4th
	B	21.38	38.84	82.30	49.97

TABLE 10 (Continued)

Species	Density & Biomass (mg)/100 ft^2	Collection Dates July 5	July 11	July 19	July 24
Phlibostroma quadrimaculatum	D	0.5-2nd	0.5-3rd 0.5-5th	0.5-2nd 2-3rd 1-4th	0.5-3rd 1-4th 0.5-5th
	B	1.61	12.41	24.80	23.20
Psoloessa delicatula	D	--	--	--	0.5-1st
	B	--	--	--	0.84
Trachyrhachys aspera	D	0.5-1st 0.5-2nd	1-2nd 2-3rd	--	1-3rd 1-4th
	B	2.96	19.85	--	25.44
Trachrhachys kiowa	D	1-3rd 1-4th 1-5th	1.5-4th 1-5th 0.5-F	0.5-4th 2-5th 1.5-M 1.5-F	1-M
	B	47.48	89.52	230.74	32.96
Xanthippus corallipes	D	--	--	--	0.5-2nd
	B	--	--	--	5.80
Total density/100 ft^2		28.5	26.5	30.5	19.5
Total density/m^2		3.07	2.85	3.28	2.10
Total biomass/100 ft^2		166.08	252.51	451.19	199.38
Total biomass/m^2		17.88	27.18	49.48	21.46

TABLE 11

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) OF THE PAWNEE SITE FOR THE MONTH OF AUGUST, 1972

Species	D&B(mg)/ 100 ft^2	Collection Dates Aug. 1	Aug. 7	Aug. 14	Aug. 22	Aug. 29
Ageneotettix deorum	D	0.5-F	0.5-M	1-F	0.5-M 0.5-F	0.5-F
	B	25.01	13.88	50.01	38.89	25.01
Arphia conspersa	D	--	--	0.5-2nd 0.5-3rd	--	0.5-4th
	B	--	--	8.96	--	7.53
Cordillacris crenulata	D	0.5-M 1-F	1.5-M 1.5-F	1-M 0.5-F	1-F	0.5-M 0.5-F
	B	33.82	59.73	25.91	27.82	19.94
Derotmema haydenii	D	0.5-M	--	--	--	--
	B	15.15	--	--	--	--
Eritettix simplex	D	--	--	--	0.5-2nd	--
	B	--	--	--	1.51	--
Melanoplus gladstoni	D	2-3rd	0.5-3rd 1-4th 0.5-5th	1-4th 1-5th	2-5th 0.5-M	1-5th
	B	23.28	54.20	75.20	147.13	53.65
Melanoplus infantilis	D	0.5-M	1-M	0.5-M 0.5-F	1-M 0.5-F	0.5-F
	B	19.53	39.06	50.03	69.56	30.50
Melanoplus sanguinipes	D	--	--	--	0.5-M	--
	B	--	--	--	49.47	--
Opeia obscura	D	2-4th 4-5th 1-M	1.5-4th 3.5-5th 0.5-M	2-5th 5-M 0.5-F	4.5-M 3-F	2.5-M 4-F
	B	99.53	78.71	140.48	209.69	219.77

TABLE 11 (Continued)

Species	D&B(mg)/ 100 ft^2	Collection Dates Aug. 1	Aug. 7	Aug. 14	Aug. 22	Aug. 29
Phlibostroma quadrimaculatum	D	0.5-3rd 2-5th	1-5th 0.5-M	1-5th 0.5-M 0.5-F	0.5-6th 0.5-F 1-M	1.5-M
	B	40.37	33.52	67.14	17.97	44.64
Psoloessa delicatula	D	2-1st	0.5-1st 1.5-2nd	3.5-2nd	1.5-2nd 6-3rd	1-2nd 2-3rd
	B	3.34	4.23	7.91	23.97	9.12
Trachyrhachys aspera	D	1-4th 1.5-5th	2.5-5th	0.5-5th	1-M 0.5-F	1.5-M 1-F
	B	78.16	101.50	20.30	106.42	189.44
Trachyrhachys kiowa	D	0.5-M	--	1.5-M 0.5-F	0.5-F	0.5-F
	B	12.72	--	90.34	40.90	40.90
Xanthippus corallipes	D	0.5-2nd	--	0.5-3rd	0.5-3rd	1-3rd 0.5-4th
	B	5.80	--	10.33	10.33	37.37
Total density/100 ft^2		20	18	22.5	26.5	19
Total density/m^2		2.15	1.94	2.42	2.85	2.05
Total biomass/100 ft^2		357.06	384.83	546.61	805.59	677.87
Total biomass/m^2		38.43	41.42	58.84	86.72	72.96

TABLE 12

DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) ON THE PAWNEE SITE FOR THE MONTH OF SEPTEMBER, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		Sept. 5	Sept. 14	Sept. 24
Ageneotettix deorum	D	0.5-F	--	--
	B	25.01	--	--
Arphia conspersa	D	--	1-4th	--
	B	--	15.06	--
Arphia pseudonietana	D	--	0.5-F	0.5-F
	B	--	118.62	118.62
Derotmema haydenii	D	0.5-F	--	--
	B	46.72	--	--
Melanoplus gladstoni	D	0.5-M 1-F	0.5-M 0.5-F	1-M 1.5-F
	B	140.02	89.93	229.95
Melanoplus infantilis	D	--	0.5-F	--
	B	--	30.50	--
Opeia obscura	D	1.5-M 2-F	1-M 3-F	1-M 1.5-F
	B	114.16	149.87	83.48
Phlibostroma quadrimaculatum	D	0.5-M 1-F	1-M 0.5-F	--
	B	82.12	63.38	--
Psoloessa delicatula	D	2-3rd 0.5-4th	0.5-2nd 2.5-3rd 1-4th 1.5-5th	1-3rd 1.5-4th 4.5-5th
	B	10.06	63.95	156.54
Trachyrhachys aspera	D	1.5-M 1-F	0.5-F	1-M 1-F
	B	189.44	59.62	166.04

TABLE 12 (Continued)

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		Sept. 5	Sept. 14	Sept. 24
Trachyrhachys kiowa	D	0.5-M	--	--
	B	16.48	--	--
Xanthippus corallipes	D	0.5-3rd	--	1-5th
	B	10.33	--	141.68
Total density/100 ft^2		13.5	14.5	15.5
Total density/m^2		1.45	1.56	1.67
Total biomass/100 ft^2		634.34	590.93	903.24
Total biomass/m^2		68.28	63.61	97.23

TABLE 13

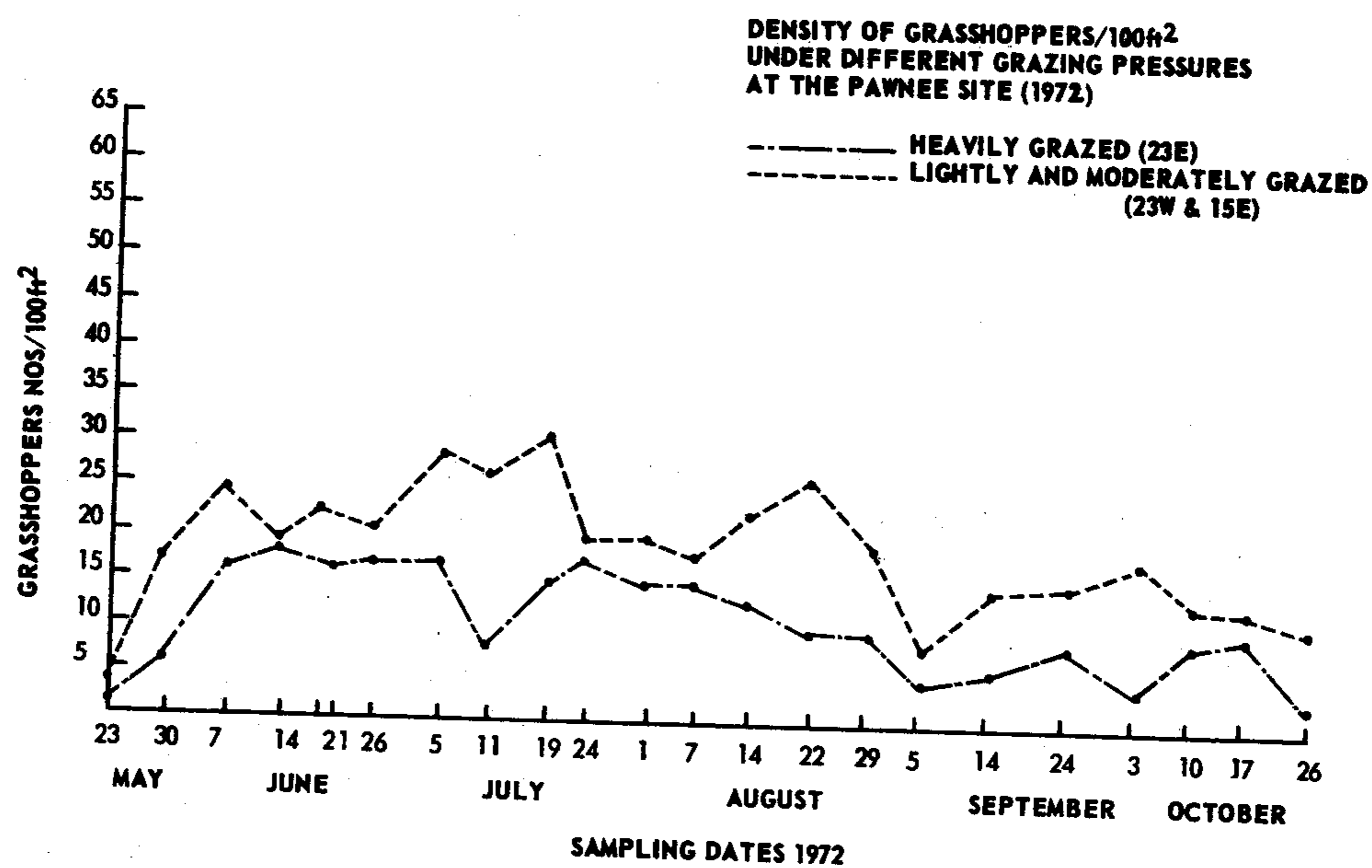
DENSITY AND BIOMASS OF GRASSHOPPERS IN THE LIGHTLY-MODERATELY GRAZED PASTURES (23 W & 15 E) OF THE PAWNEE SITE FOR THE MONTH OF OCTOBER, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		Oct. 3	Oct. 10	Oct. 17	Oct. 26
Arphia conspersa	D	0.5-5th	0.5-4th	1.5-5th	0.5-5th
	B	36.45	7.53	109.35	36.45
Arphia pseudonietana	D	0.5-F	--	--	--
	B	118.62	--	--	--
Cordillacris crenulata	D	0.5-M 0.5-F	--	--	--
	B	19.91	--	--	--
Eritettix simplex	D	--	--	--	0.5-4th
	B	--	--	--	--
Melanoplus gladstoni	D	1-F	1-M 0.5-F	1-F	0.5-M
	B	100.19	129.76	100.19	39.83
Opeia obscura	D	0.5-M 2.5-F	1.5-F	1.5-F	0.5-F
	B	119.20	66.39	66.39	22.13
Phlibostroma quadrimaculatum	D	0.5-F	--	--	0.5-M 1-F
	B	33.62	--	--	82.12
Psoloessa delicatula	D	8.5-4th 2-5th	0.5-3rd 6-4th 1.5-5th	4.5-4th 3-5th	1.5-4th 5-5th
	B	118.18	87.96	124.47	169.05
Trachyrhachys aspera	D	0.5-F	1-F	0.5-M	0.5-M 0.5-F
	B	59.62	119.24	23.40	83.02

TABLE 13 (Continued)

Species	Density & Biomass (mg)/100 ft²	Collection Dates			
		Oct. 3	Oct. 10	Oct. 17	Oct. 26
Xanthippus corallipes	D	--	0.5-4th	0.5-5th	--
	B	--	16.71	70.84	--
Total density/100 ft²		17.5	13	12.5	11
Total density/m²		1.88	1.40	1.35	1.18
Total biomass/100 ft²		587.04	437.84	494.64	432.60
Total biomass/m²		63.19	47.13	53.24	46.57

FIG. 1


DENSITY OF GRASSHOPPERS/100ft2
UNDER DIFFERENT GRAZING PRESSURES
AT THE PAWNEE SITE (1972)
HEAVILY GRAZED (23E)
LIGHTLY AND MODERATELY GRAZED
(23W & 15E)
GRASSHOPPERS NOS/100ft2
65
60
55
50
45
40
35
30
25
20
15
10
5
23
30
7
14
21
26
5
11
19
24
1
7
14
22
29
5
14
24
3
10
17
26
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
SAMPLING DATES 1972

only 1.94/m^2 (18/100 ft^2). The grasshopper numbers dipped down to only 0.32/m^2 (3/100 ft^2) towards the end of sampling season in the heavily grazed pasture, while the curve in the case of lightly-moderately grazed pastures showed 1.29/m^2 (12/100 ft^2) as the lowest numbers. There is evidence of two peaks in the lightly-moderately grazed pastures; the cause of these peaks may lie in the variations in the life cycles of the inhabitant species.

Van Horn (1969, 1972) and Dickinson and Leetham (1971) have not reported any observable differences in grasshopper numbers on the pastures of the Pawnee Site under different grazing intensities. In the sampling of the density of grasshoppers on pastures of the Pawnee Site, there is a close correspondence between the figures obtained by Van Horn, who used a large trap cage, which he entered and searched to make the collections and the figures obtained by the square-foot-count method practiced in this work. For example Van Horn (1972) showed a top density of 37.6 grasshoppers/10 m^2 in 1969 and 33.5 in 1970. In my study top density for 1972 is 38.8/10 m^2 for the lightly grazed unit, 35.5/10 m^2 for the moderately grazed unit and 19.4/10 m^2 for the heavily grazed pastures. Our data nevertheless show a difference in the density of grasshoppers between the lightly-moderately grazed pastures and the heavily grazed pasture. Hence, the present findings indicate that grazing pressure does not improve the habitat for grasshoppers at the Pawnee Site.

Here the question may be asked: Why was the density of C. crenulata lower in the lightly grazed pasture than in the heavily grazed pasture? The species composition in the different pastures was definitely different, some species were abundant in heavily, some in lightly and some in moderately grazed pasture, but the overall density of grasshoppers was lower in the heavily grazed pasture as has been explained above. A possible explanation may be that _C. crenulata_ is adversely affected by the heavy cover of the lightly grazed pasture. Further exploration in other areas of this pasture should be undertaken to determine whether populations of _C. crenulata_ are low everywhere.

Now the question arises what makes heavy grazing pressure incongenial to grasshopper numbers. Nothing on this point has been seen in the literature. Two reasons may be put forth to explain this phenomenon. Due to heavy grazing pressure, the food may not be available in adequate amounts. Lack of food may precipitate intra- and inter-specific competition which may be responsible for keeping the grasshopper numbers down. This explanation does not seem likely because the grasses were never totally removed even though the coverage was markedly lower than in the pastures with light or moderate grazing. The second explanation may lie in the effect of reduced plant cover upon the protection afforded the grasshoppers from predators. Predation can be relatively higher under heavy grazing because the grasshoppers are more exposed to birds, rodents and insect predators. In the heavily grazed pasture the vegetation is very low with patches of bare soil.

The procedure of sampling as done in this work is quite different from procedures used by Van Horn (1969) and Dickinson and Leetham (1971). This may explain the differences between my results and the results of the above workers. A comparison of the 1972 D-Vac quick trap densities with the 1972 square-foot-count densities indicates large discrepancies (see table below). In the heavily grazed pastures an average of 6 times greater density of grasshoppers was recorded by the square-foot-count method than the D-Vac and in the lightly grazed pasture, 10 times greater density was recorded on the average by the square-foot-count method than the D-Vac.

Number Grasshoppers per 10 m^2 Heavily Grazed Pasture, Pawnee Site, 1972

	D-Vac	Sq. ft. count
April 17/10[1]	0	0
May 3/16	0	0
May 22/23	0	1.1
June 19/21	0	17.2
July 18/19	2	16.1
August 7/7	4	16.1
August 17/14	4	14.0

Number Grasshoppers per 10 m^2 Lightly Grazed Pasture, Pawnee Site, 1972

	D-Vac	Sq. ft. count
April 17/10	0	1.1
May 3/16	0	0
May 22/23	0	4.3
June 19/19	0	18.3
July 18/19	8	30.1
August 7/7	0	14.0
August 17/14	2	18.3

In a Matador Project report, Riegert and Varley (1970) stated that

[1] The first number is date of D-Vac sampling, the second of sq. ft. count sampling.

Orthoptera are visually repelled by the presence of the quick traps and that population figures obtained by such traps are not valid representations of the actual occurrence of these insects. Present results can only confirm the latter conclusions. As explained above, Van Horn used a different sampling technique, which involved a large trap cage that he entered and searched to make collections. His results are in close correspondence with the figures obtained in this present study employing the square-foot-count method.

Relationship of Species Density with Age of Grasshoppers

When grasshopper numbers in relation to their age have been considered, the general idea has been held that numbers decrease due to various mortality factors as the grasshoppers age. In the present study this hypothesis was also tested, that grasshoppers have a concave type of survivorship curve. The data obtained from the Pawnee pastures and from the study sites in southeast Wyoming show that the peak densities were reached when grasshoppers were in the early nymphal instars and that densities had a concave curvilinear downward trend as the grasshoppers progressed in age (Tables 2-25). These data indicate that the above hypothesis is correct. For arriving at this conclusion the dominant species were studied on the Pawnee Site, viz., Cordillacris crenulata and Opeia obscura; on the Lusk site, viz., Aulocara elliotti and Cordillacris occipitalis; and on the Hartville site, viz., Aulocara elliotti.

Figures 2, 3 and 4 illustrate the density data of C. crenulata in the lightly, moderately and heavily grazed pastures respectively for

TABLE 14

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN JUNE 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates	
		June 8	June 22
Aulocara elliotti	D	50-1st 1-2nd	2-1st 18-2nd 46-3rd 26-4th 2-5th
	B	175.63	1320.88
Cordillacris occipitalis	D	64-1st 19-2nd	12-2nd 52-3rd 34-4th
	B	205.81	675.82
Total density/100 ft^2		134.00	192.00
Total density/m^2		14.42	20.67
Total biomass/100 ft^2		381.44	1996.70
Total biomass/m^2		41.06	214.93

TABLE 15

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN JULY 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates July 9	Collection Dates July 20
Aulocara elliotti	D	1-2nd 7-4th 85-5th 7-M 2-F	7-5th 54-M 33-F
	B	4708.55	7923.58
Cordillacris occipitalis	D	1-4th 59-5th 7-M 6-F	2-5th 42-M 43-F
	B	1349.07	3349.94
Total density/100 ft^2		175.00	181.00
Total density/m^2		18.84	19.48
Total biomass/100 ft^2		6057.62	11273.52
Total biomass/m^2		652.06	1213.51

TABLE 16

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN AUGUST 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates	
		August 9	August 16
Aulocara elliotti	D	3-5th 33-M 33-F	25-M 15-F
	B	6490.83	3484.45
Cordillacris occipitalis	D	23-M 31-F	24-M 15-F
	B	2205.84	1400.70
Total density/100 ft^2		123.00	79.00
Total density/m^2		13.24	8.50
Total biomass/100 ft^2		8696.67	4885.15
Total biomass/m^2		936.13	525.85

TABLE 17

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN SEPTEMBER AND OCTOBER, 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates			
		Sept. 1	Sept. 13	Sept. 27	Oct. 14
Aulocara elliotti	D	12-M 4-F	5-M 2-F	--	1-M
	B	1247.00	563.91	--	59.59
Cordillacris occipitalis	D	6-M 6-F	--	--	--
	B	467.04	--	--	--
Total density/100 ft^2		28	7	--	1
Total density/m^2		3.01	0.75	--	0.11
Total biomass/100 ft^2		1714.04	563.91	--	59.59
Total biomass/m^2		184.50	60.70	--	6.41

TABLE 18

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN JUNE 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Date June 10
Aulocara elliotti	D	46-1st 15-2nd 4-3rd
	B	302.69
Total density/100 ft^2		65
Total density/m^2		7
Total biomass/100 ft^2		302.69
Total biomass/m^2		32.58

TABLE 19

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN JULY 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates	
		July 2	July 21
Aulocara elliotti	D	3-2nd 7-3rd 82-4th 90-5th 2-M	26-5th 85-M 48-F
	B	6168.01	10616.08
Total density/100 ft^2		184.00	159.00
Total density/m^2		19.91	17.12
Total biomass/100 ft^2		6168.01	10616.08
Total biomass/m^2		663.95	1142.74

TABLE 20

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN AUGUST 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates August 5	August 18
Aulocara elliotti	D	60-M 41-F	22-M 20-F
	B	7384.54	3214.96
Total density/100 ft^2		101.00	42.00
Total density/m^2		10.87	4.52
Total biomass/100 ft^2		7384.54	3214.96
Total biomass/m^2		794.89	346.07

TABLE 21

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN SEPTEMBER, 1971

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		Sept. 2	Sept. 14	Sept. 28
Aulocara elliotti	D	4-M 3-F	1-F	2-M
	B	519.54	102.14	106.56
Total density/100 ft^2		7	1	2
Total density/m^2		0.75	0.11	0.22
Total biomass/100 ft^2		519.54	102.14	106.56
Total biomass/m^2		55.92	10.99	11.47

TABLE 22

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN MAY, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		May 18	May 24	May 31
Aulocara elliotti	D	--	36-1st	124-1st 8-2nd
	B	--	114.12	444.84
Cordillacris occipitalis	D	2-1st	78-1st 6-2nd	133-1st 49-2nd
	B	4.00	179.28	456.12
Total density/100 ft^2		2	120	314
Total density/m^2		0.22	12.92	33.8
Total biomass/100 ft^2		4.00	293.40	900.96
Total biomass/m^2		0.43	31.58	96.98

TABLE 23

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS IN MIXED-GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN JUNE, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates		
		June 8	June 16	June 22
Aulocara elliotti	D	78-1st 95-2nd 15-3rd	9-1st 52-2nd 76-3rd 6-4th	2-1st 10-2nd 31-3rd 13-4th 2-5th 1-M
	B	1075.21	1607.93	1014.14
Cordillacris occipitalis	D	26-1st 94-2nd 42-3rd 2-4th	4-1st 23-2nd 68-3rd 20-4th 1-5th	1-1st 10-2nd 41-3rd 47-4th 3-5th
	B	776.90	898.10	993.27
Total density/100 ft^2		352	259	163
Total density/m^2		37.89	27.88	17.55
Total biomass/100 ft^2		1852.11	2506.03	2007.41
Total biomass/m^2		199.37	269.76	216.08

TABLE 24

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN JUNE 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates June 1	June 15
Aulocara elliotti	D	55-1st 9-2nd	4-1st 14-2nd 31-3rd 48-4th 1-5th
	B	269.75	2059.46
Total density/100 ft^2		64	98
Total density/m^2		6.89	10.55
Total biomass/100 ft^2		269.75	2059.46
Total biomass/m^2		29.04	221.69

TABLE 25

DENSITY AND BIOMASS OF THE DOMINANT SPECIES OF GRASSHOPPERS, *Aulocara elliotti*, IN MIXED-GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN JULY & AUGUST, 1972

Species	Density & Biomass (mg)/100 ft^2	Collection Dates	
		July 6	August 2
Aulocara elliotti	D	1-5th	1-M 1-F
	B	47.26	130.10
Total density/100 ft^2		1	2
Total density/m^2		0.11	0.22
Total biomass/100 ft^2		47.26	130.10
Total biomass/m^2		5.09	14.00

FIG. 2

RELATIONSHIP OF DENSITY AND AGE OF *Cordillacris crenulata* ON THE PAWNEE SITE IN A LIGHTLY GRAZED (23W) UNIT OF SHORTGRASS PRAIRIE

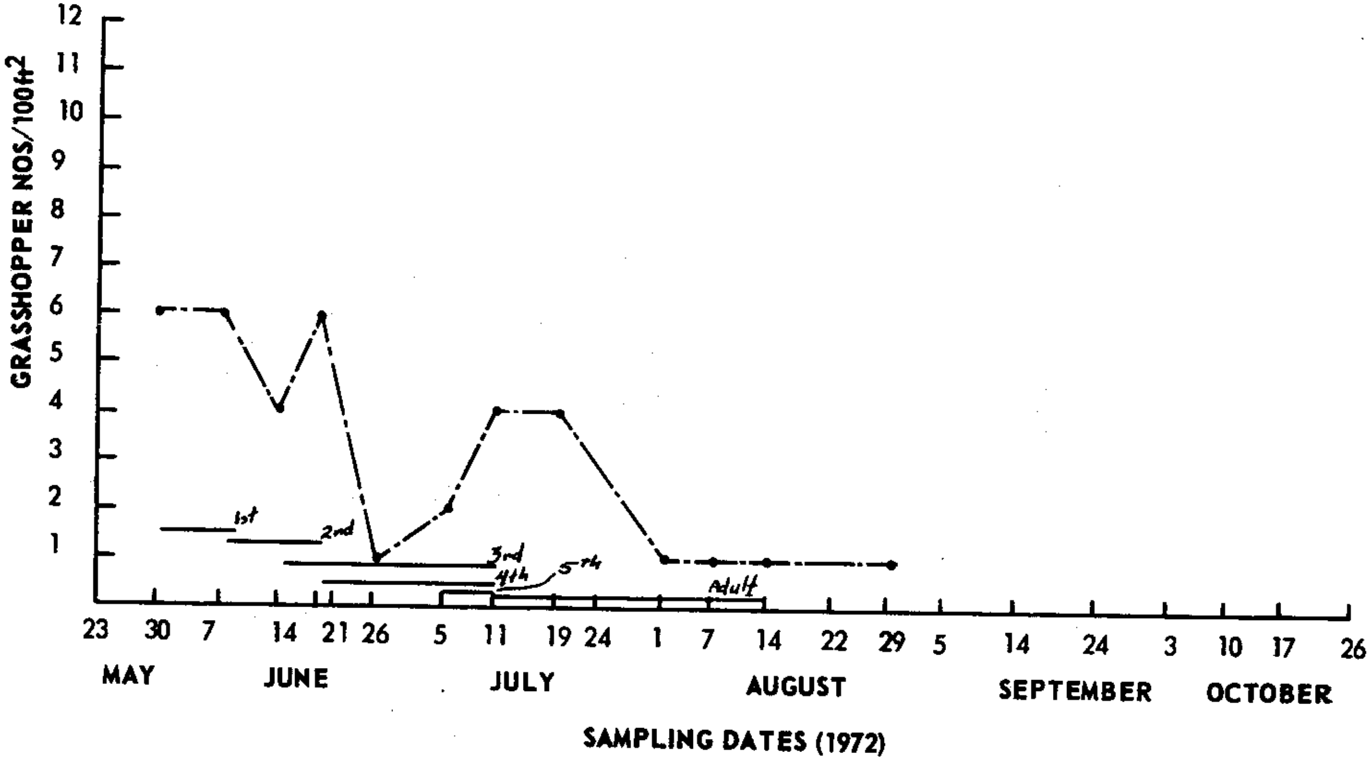


FIG. 3

RELATIONSHIP OF DENSITY AND AGE OF *Cordillacris crenulala* ON THE PAWNEE SITE IN A MODERATELY GRAZED (15E) UNIT OF SHORTGRASS PRAIRIE

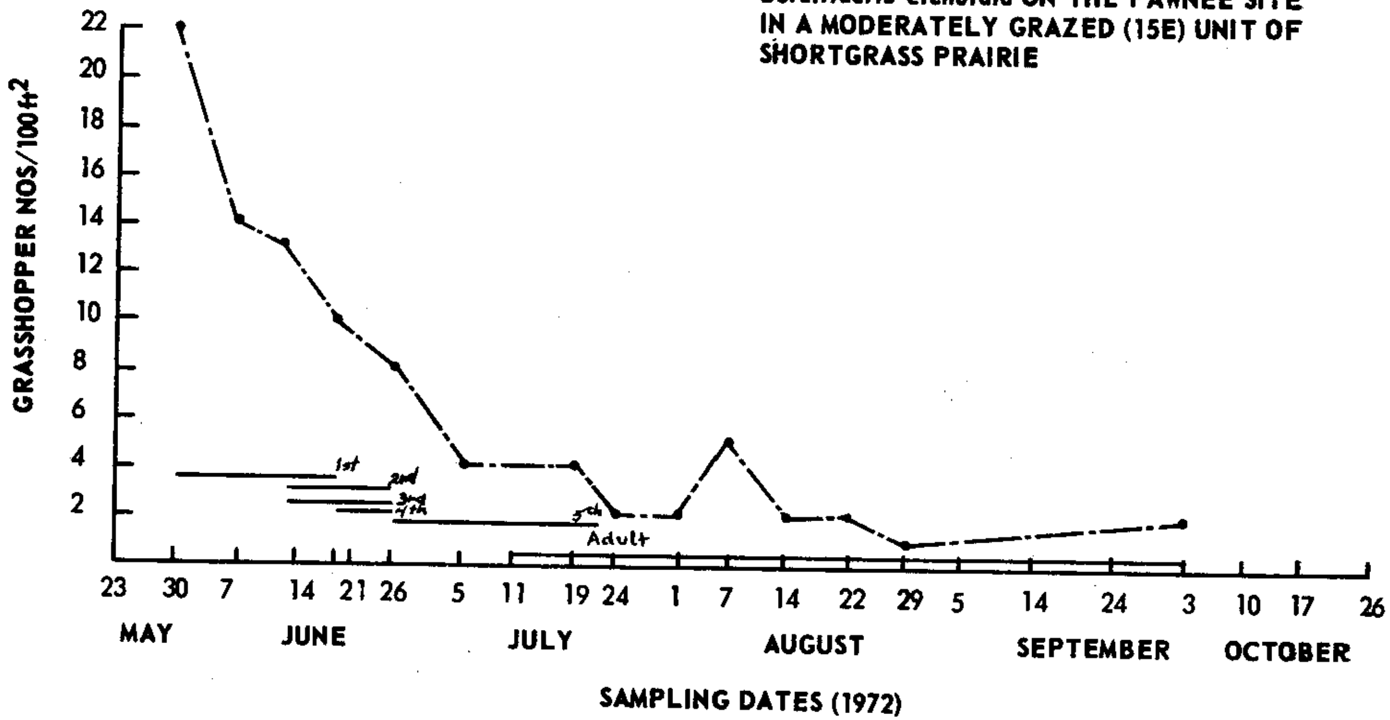
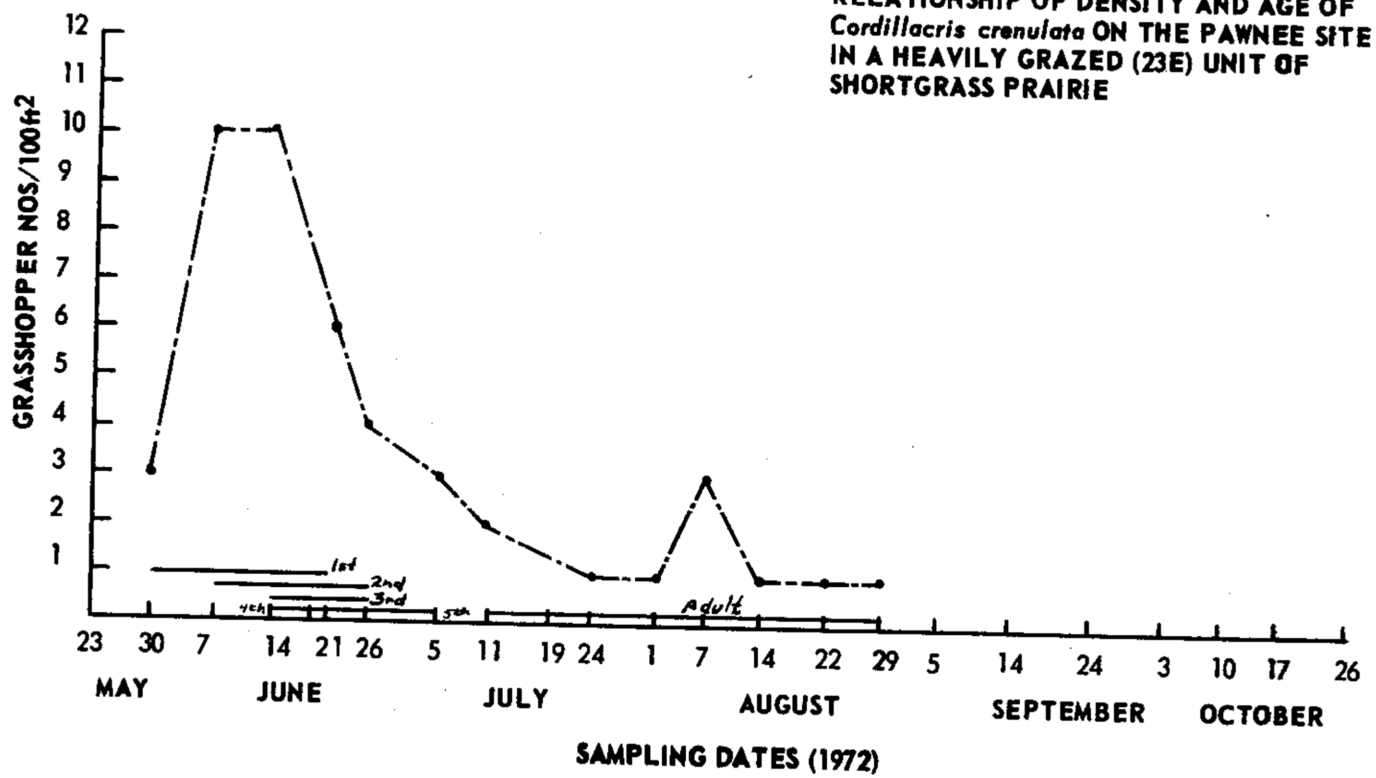


FIG. 4



RELATIONSHIP OF DENSITY AND AGE OF *Cordillacris crenulata* ON THE PAWNEE SITE IN A HEAVILY GRAZED (23E) UNIT OF SHORTGRASS PRAIRIE

1972. Figures 3 and 4 show more typical curves which support the hypothesis. In the moderately grazed pasture the peak of density was reached when the first instar nymphs were present. From this high point the density steadily goes down as the grasshoppers advance in age. The second, though not significant peak on August 7 can be explained as one of the vagaries of sampling low populations of adults. The adult females are definitely longer lived, much more so than the males. In sampling over an extended period one should probably expect variations of this magnitude of 0.22-0.54/m^2 (2 to 5/100 ft^2). The same explanation will account for Figure 4 as well. Here also the peak was reached in the first and second instars and then the curve shows a steep decline until August 7 where there is an insignificant peak of the adult population. Figure 2 shows a dip in the curve on June 26; this estimate of density probably did not represent the population accurately. On this particular date only one individual of fourth instar was observed in the sampling counts.

The density data for Opeia obscura is illustrated in Figures 5, 6 and 7. Figure 5 shows a reasonable density trend of this species. The peak came when individuals of first, second and third instars were making up the total density. The curve then goes down smoothly to August 14. Sampling of the few surviving adults indicated a population between 0.32 and 0.75/m^2 (3 and 7/100 ft^2) over an extended period. The several peaks and dips of Figures 6 and 7 are more difficult to explain. But if smooth curves are generated by drawing lines between the peaks and dips, the curves show a steady downward trend. The results indicate

FIG. 5

RELATIONSHIP OF DENSITY AND AGE OF *Opeia obscura* ON THE PAWNEE SITE IN LIGHTLY GRAZED (23W) UNIT OF SHORTGRASS PRAIRIE

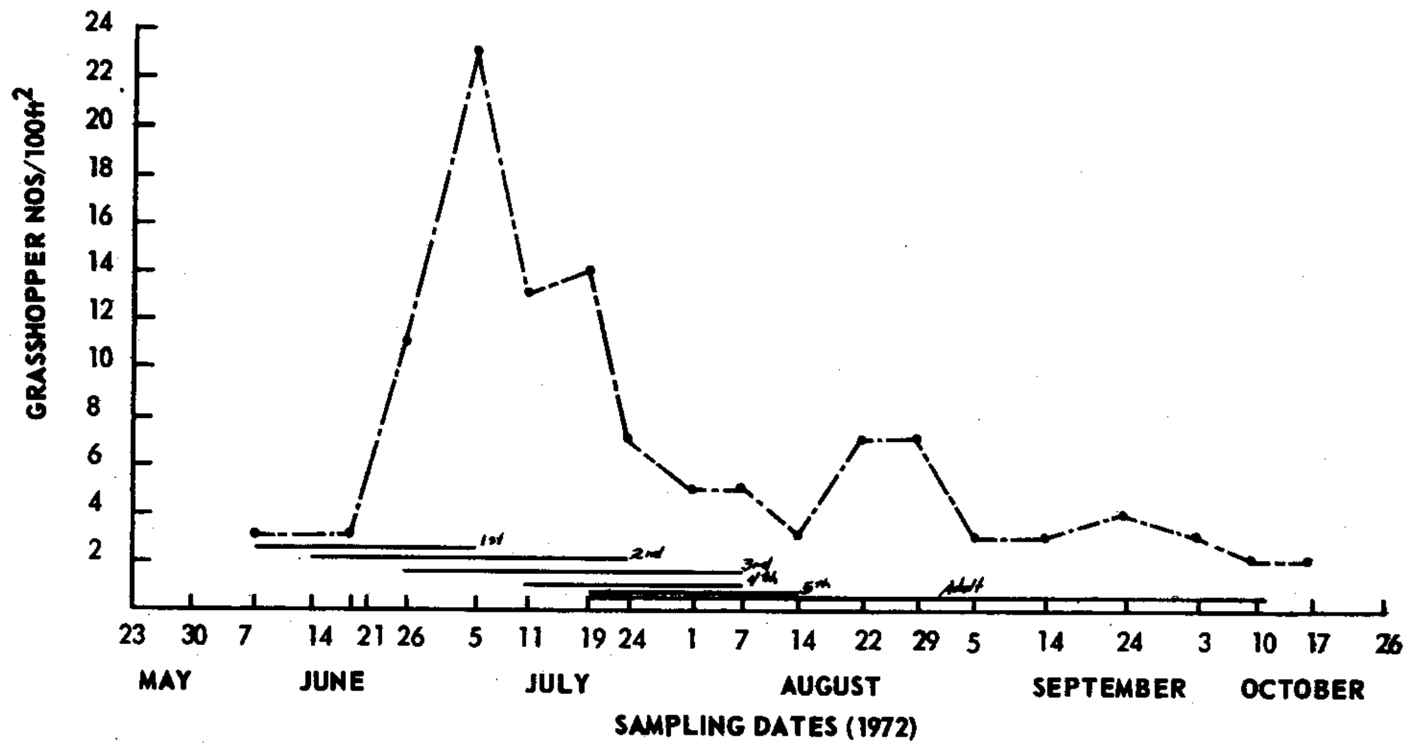


FIG. 6

RELATIONSHIP OF DENSITY AND AGE OF *Opeia obscura* ON THE PAWNEE SITE IN MODERATELY GRAZED (15E) UNIT OF SHORTGRASS PRAIRIE

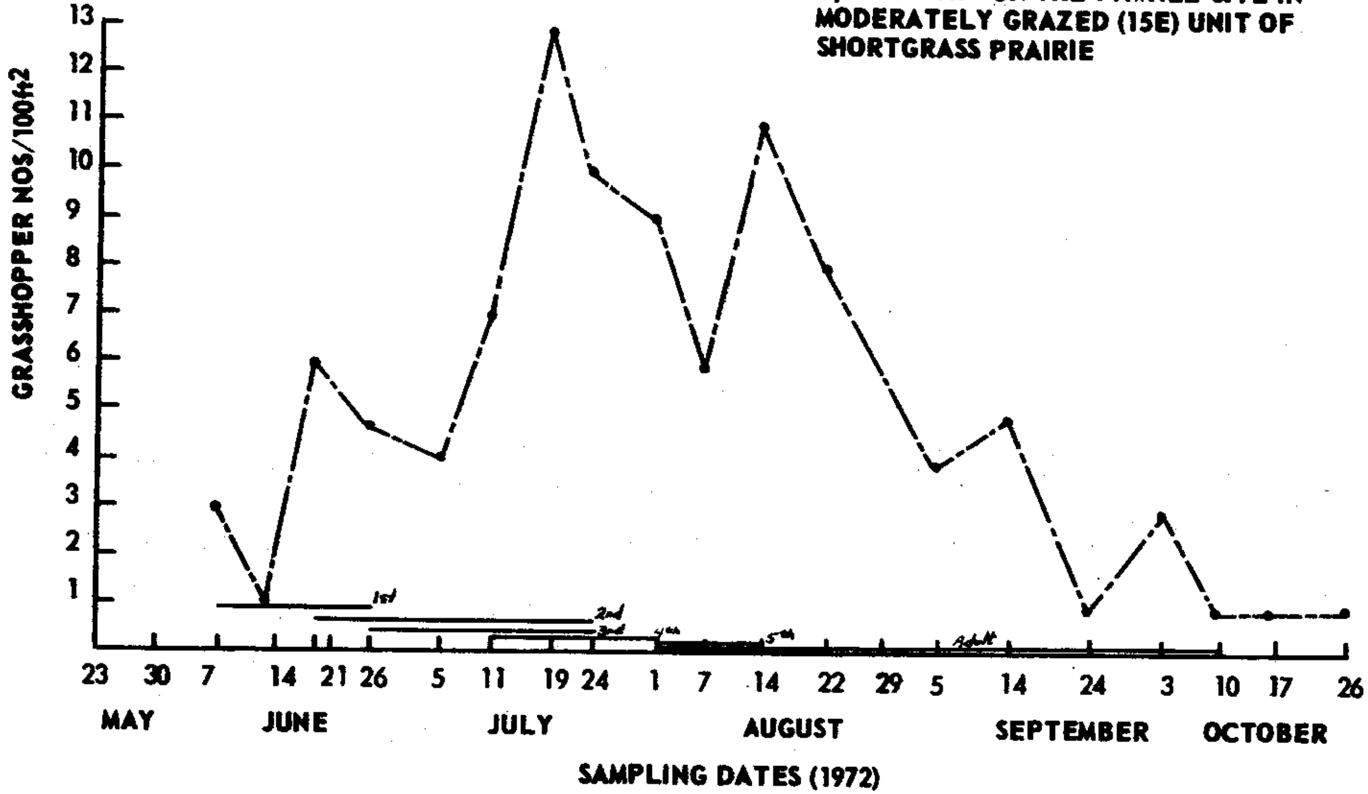
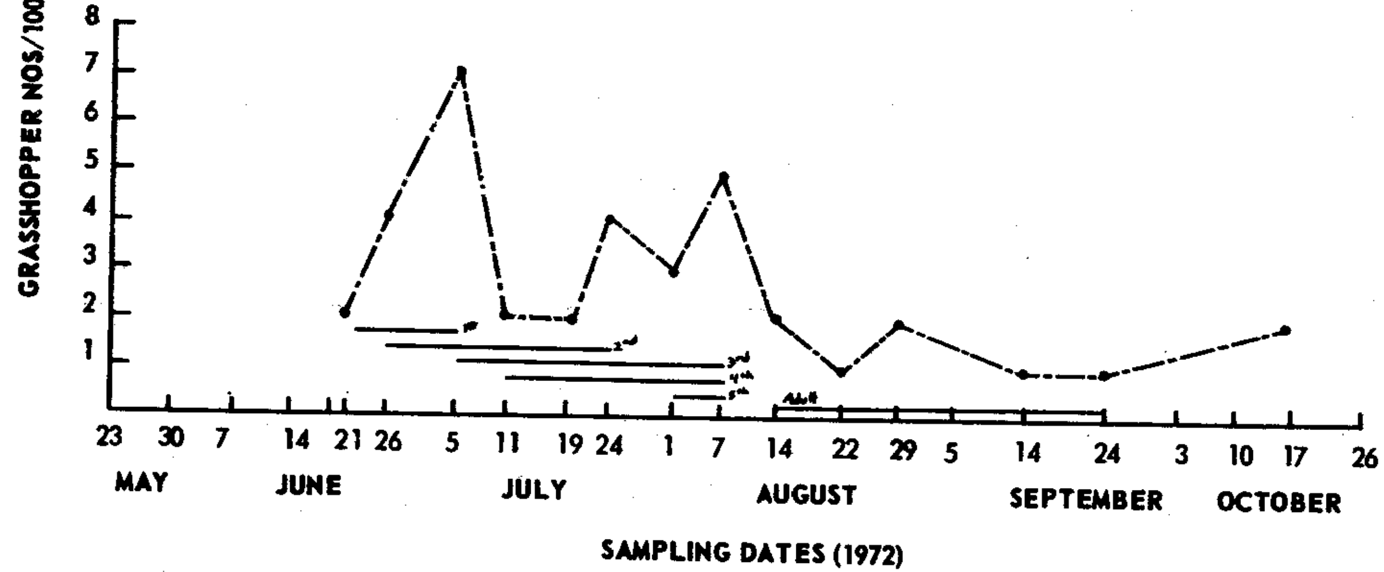


FIG. 7

RELATIONSHIP OF DENSITY AND AGE OF *Opeia obscura* ON THE PAWNEE SITE IN HEAVILY GRAZED (23E) UNIT OF SHORTGRASS PRAIRIE



that a larger number of samples should be taken when the density of species is this low.

The density data of the principal species of grasshoppers in southeast Wyoming sites are shown in Figures 8 and 9 for 1971 and 1972 respectively. The peak of density was reached when the species were present in the first through third instars and then there is a steady slope showing the decrease in numbers as the grasshoppers entered into the late instars and adult stage. Pfadt and Bhatnagar (1971), while reporting the results on the density and biomass of grasshoppers on the Lusk site, also concluded that the peak density of grasshoppers was reached when they were in the early nymphal stages. Van Horn (1972) pointed out that the density was greatest in mid-summer due to the presence of large nymphal components.

Relationship of Biomass to Density and Age of Grasshoppers

Mean ovendry weight was calculated for both sexes of the nymphal instars and adults for all the grasshoppers collected by sweeping with an insect net at all the study sites. Tables 2 through 25 summarize the data of density and biomass for the Pawnee Site and the southeast Wyoming sites, while Figures 10 to 12 show the biomass curves for these sites.

Figure 10 shows curves of grasshopper biomass on the heavily grazed pasture and the lightly-moderately grazed pastures at Pawnee. The peaks of the biomass were reached when grasshoppers were in the last nymphal instars and early and mid-adult stages. Peaks of biomass generally followed peak densities by 2 to 3 weeks. The peaks of biomass were

FIG. 8

DENSITY OF THE PRINCIPAL SPECIES OF GRASSHOPPERS/m2 IN SOUTHEAST WYOMING SITES (1971)

—·—·—·— HARTVILLE
– – – – – – LUSK

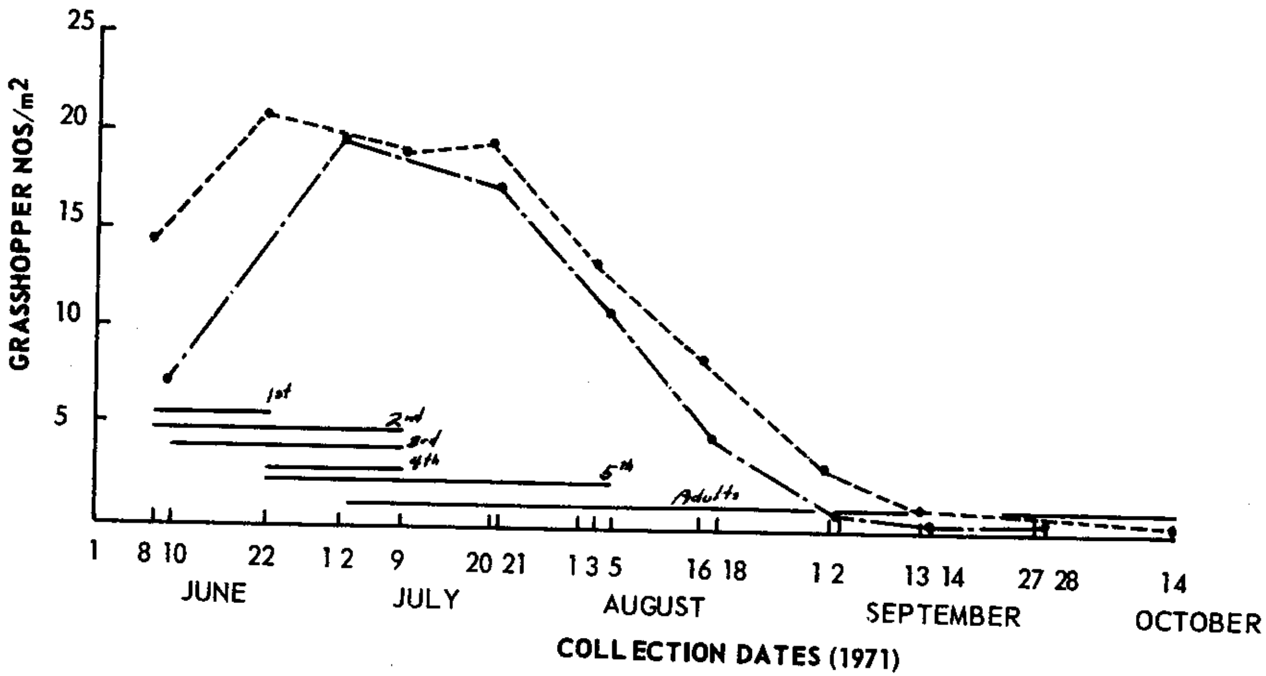


FIG. 9

DENSITY OF THE PRINCIPAL GRASSHOPPERS/m2 ON THE SOUTHEAST WYOMING SITES (1972)

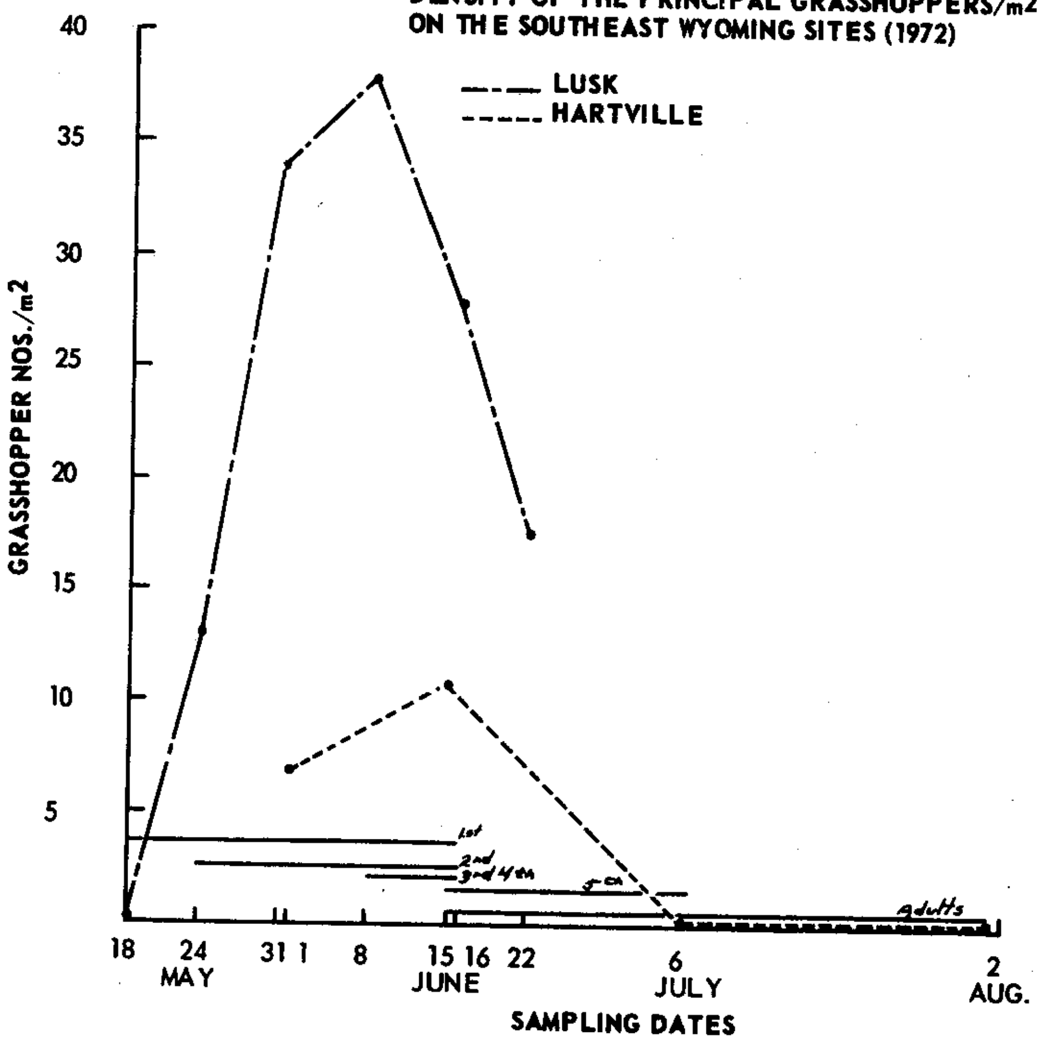
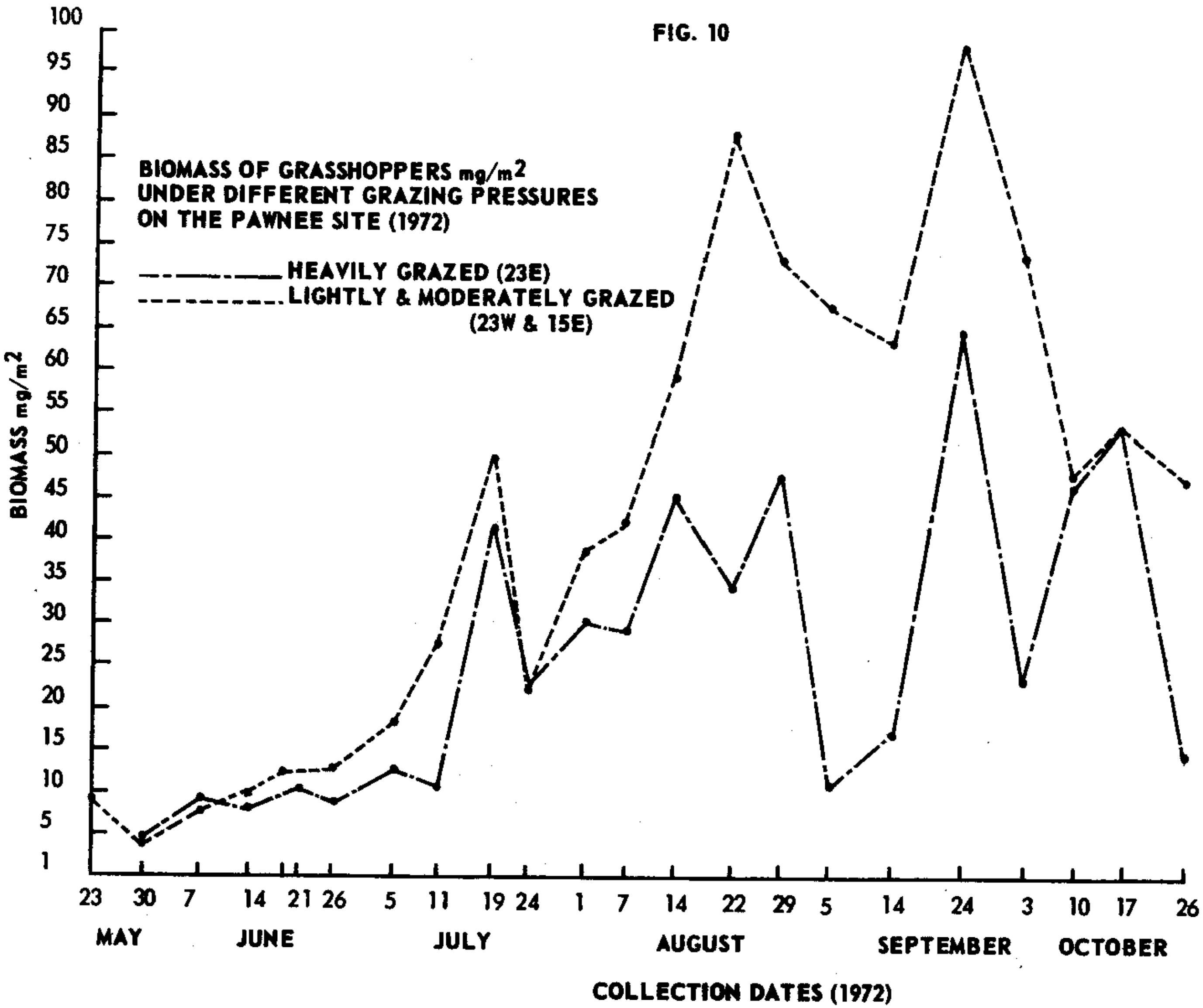


FIG. 10


BIOMASS OF GRASSHOPPERS mg/m2
UNDER DIFFERENT GRAZING PRESSURES
ON THE PAWNEE SITE (1972)
HEAVILY GRAZED (23E)
LIGHTLY & MODERATELY GRAZED (23W & 15E)
BIOMASS mg/m2
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
1
23 30 7 14 21 26 5 11 19 24 1 7 14 22 29 5 14 24 3 10 17 26
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION DATES (1972)

reached on September 24 in both management units. In the case of heavily grazed pasture, the peak biomass amounted to 64.21 mg/m^2 while for the lightly-moderately grazed pastures it amounted to 97.23 mg/m^2. Around September 5 and 14 both the curves show a significant dip which can be explained from life cycle information. Around these dates the nymphs of *Psoloessa delicatula* and *Xanthippus corallipes* were in their earlier instars but by September 24 both these species had reached the fifth instar in the field and were adding significantly to the biomass represented by the surviving adults of the mid and late species. *Xanthippus corallipes* in the fifth instar and further in the adult stage weighed considerably more than other species, as they are very heavy-bodied insects. The first peak on July 19 is due to the presence of larger numbers of earlier instars of most of the mid-species. The difference in the biomass under the two different grazing intensities is only due to the difference in the total densities on these pastures already discussed and explained above.

In his report Van Horn (1972) reported for 1970 a total biomass of 80 mg/10 m^2 during spring, which rose to 320 mg/10 m^2 during September and then fell to 100 mg/10 m^2 at the end of the year when the adults died off. He also concluded that the increase in biomass of the grasshopper population is much more a function of the appearance of adults during the late summer or early fall. The results of my study agree with his and confirm his conclusions.

Figure 11 shows the biomass picture for the principal species of grasshoppers of the Lusk and the Hartville sites for 1971. Figure 12 shows the biomass for 1972, but this particular curve does not give a

FIG. 11

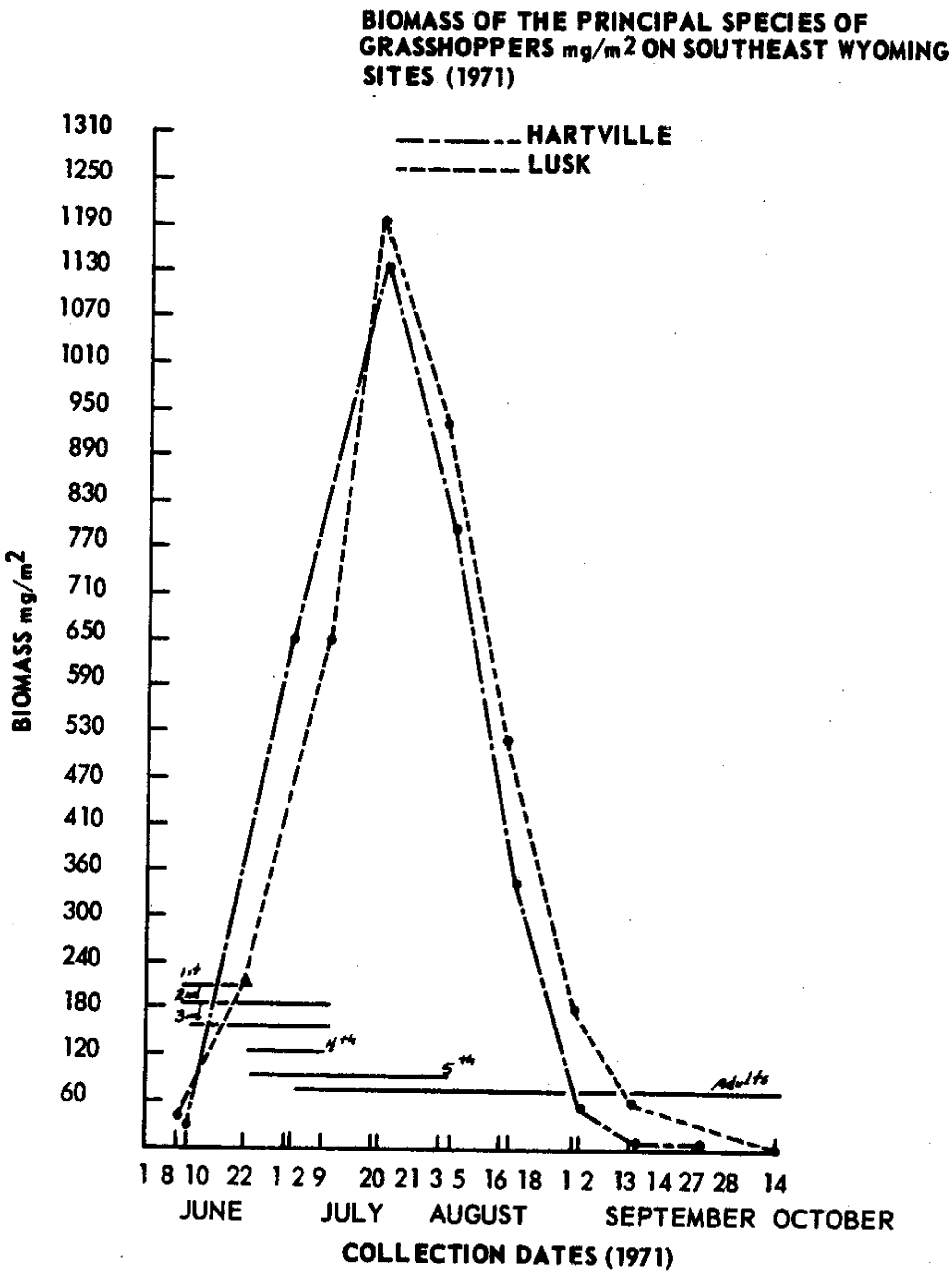
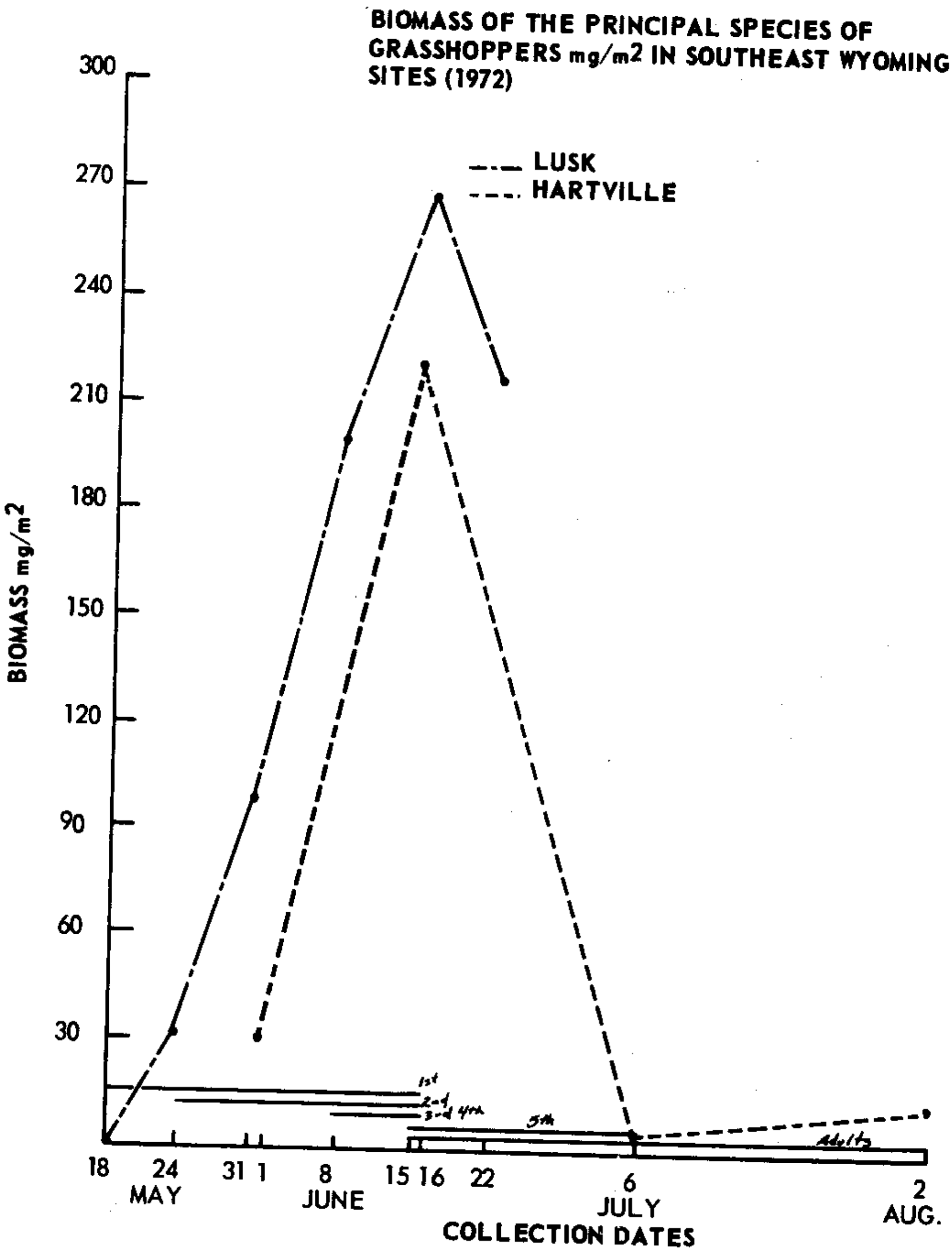

BIOMASS OF THE PRINCIPAL SPECIES OF GRASSHOPPERS mg/m2 ON SOUTHEAST WYOMING SITES (1971)
HARTVILLE
LUSK
BIOMASS mg/m2
1310
1250
1190
1130
1070
1010
950
890
830
770
710
650
590
530
470
410
360
300
240
180
120
60
1st
2nd
3rd
4th
5th
Adults
1 8 10 22 1 2 9 20 21 3 5 16 18 1 2 13 14 27 28 14
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
COLLECTION DATES (1971)

FIG. 12


BIOMASS OF THE PRINCIPAL SPECIES OF GRASSHOPPERS mg/m2 IN SOUTHEAST WYOMING SITES (1972)
LUSK
HARTVILLE
BIOMASS mg/m2
300
270
240
210
180
150
120
90
60
30
18
24
MAY
31 1
8
JUNE
15 16
22
6
JULY
2
AUG.
COLLECTION DATES

realistic picture because both sites were sprayed in the early part of the summer to control the grasshoppers.

In 1971 the peak of biomass reached 1213.51 mg/m^2 at the Lusk site and 1142.74 mg/m^2 at the Hartville site. Both of these peaks came when the grasshoppers were in their late nymphal instars and early adult stage. From these high points there was a steady downward trend in the biomass and by mid-fall the figures went down as low as 6.41 mg/m^2, when only a few surviving adults were left. In 1972 the peaks of biomass were not achieved because spraying operations reduced the populations before they had time to build up to their maximums.

A comparison of grasshopper populations on the Lusk site with those on the lightly-moderately grazed pastures of the Pawnee Site shows that the peak biomass of the Lusk site is about 13 times the Pawnee Site, even when only the principal species of the Lusk site have been taken into account. Pfadt and Bhatnagar (1971), in comparing the peak of grasshopper biomass on the Pawnee Site with that of all species of the Lusk site, reported a difference of 14 times. Such a comparison clearly shows the economic importance of grasshoppers in certain mixed-grass associations at certain times.

A few other workers have reported on grasshopper biomass. Menhinick (1967), while studying the energy flow through a stand of <u>Sericea lespedeza</u>, found that orthopterans made up the major portion of the Arthropod biomass which reached a maximum of 50 mg/m^2. Van Hook, Jr. (1971) found that the Arthropod fauna attained a maximum standing crop of 927 mg/m^2 of which 705 mg/m^2 was contributed by the grasshopper, <u>Melanoplus sanguinipes</u>.

Relationship of Grasshopper Density to Vegetation Cover

Assuming that the grasshopper density may have a relationship with the vegetation cover of their habitats, a hypothesis was established that grasshopper density is directly proportional to vegetation cover on the Pawnee Site. Table 26 includes data of grasshopper numbers and the average percentage of vegetation cover in the lightly, moderately and heavily grazed pastures for the months of June, July and August 1972. The sampling for vegetation cover was done once each month using the Daubenmire canopy coverage method.

The purpose of a correlation analysis is to measure the intensity of association observed between any pair of variables and to test whether it is greater than could be expected by chance alone. In this case also a correlation coefficient was run taking the above two figures as two different variables in order to find out if there is a significant positive or negative correlation in the grasshopper numbers and the average percentage of vegetation cover. The last column of Table 26 includes the figures of the correlation coefficient for each month. None of the figures show any significant positive or negative correlation at 0.05 level of significance. From the table of critical values for correlation coefficients for one degree of freedom, 0.997 is the critical value at 0.05 level of significance (Rohlf and Sokal, 1969) and the figures as obtained in this case were: -0.4090, +0.8248 and +0.1287 for June, July and August respectively. For the month of June there seems to be a negative, though insignificant correlation, but for July and August there is a positive correlation which is also not significant. Thus it is concluded that the density of grasshoppers did not have any

TABLE 26

THE DENSITY OF GRASSHOPPERS AND AVERAGE VEGETATION COVER AT THE PAWNEE SITE (JUNE-AUGUST, 1972) WITH THE CORRELATION COEFFICIENTS

Sampling Month	No. of Sampling Dates	Grazing Pressure						Correlation Coefficient
		Heavy (23 E)		Light (23 W)		Moderate (15 E)		
		Grasshopper Nos/100 ft^2	Average % Vegetation Cover	Grasshopper Nos/100 ft^2	Average % Vegetation Cover	Grasshopper Nos/100 ft^2	Average % Vegetation Cover	
June	4	16.75	65.13	16.75	70.76	26.50	65.76	-0.4090
July	4	14.25	64.65	26.75	78.69	25.75	69.84	+0.8248
August	5	12.60	55.82	17.40	78.43	25.00	61.78	+0.1287

correlation with the vegetation cover. This, however, does not mean that vegetative cover has no influence upon the distribution of species and numbers of grasshoppers. Data summarized above indicated that the heavy cover of the lightly grazed pasture did not favour the high numbers of Cordillacris crenulata but favoured high numbers of Opeia obscura. Anderson (1964) wrote that no published reports are available that demonstrate a correlation between the abundance of grasshoppers and density of plants in the areas of grasshopper inhabitance.

Relationship of Body Energy to Age of Grasshoppers

Since Lindeman (1942) exerted a synthesizing influence on trophic-dynamic theory, the tendency to utilize the calorie as a common denominator has increased steadily among ecologists. Several summaries of caloric data have already appeared (Slobodkin and Richman, 1961; Golley, 1961). For the present study it was felt desirable to determine the caloric content of the principal species of grasshoppers: namely Aulocara elliotti and Cordillacris occipitalis from the Lusk site and Cordillacris crenulata and Opeia obscura from the Pawnee Site. A correlation analysis was done to find whether there is a positive or negative correlation between the energy contained and the age of grasshoppers.

Table 27 gives the mean weight, Kcal/g dry wt., Kcal/dry body wt. and the correlation coefficient for each of the species used in this work. In all cases the correlation coefficient was positively significant at 0.05 level of significance. It can be clearly seen that the amount of the energy contained steadily increased with the age of

TABLE 27

THE ENERGY CONTAINED IN THE DIFFERENT AGE GROUPS OF THE PRINCIPAL SPECIES OF GRASSHOPPERS IN SOUTHEAST WYOMING SITES AND PAWNEE SITE

Species	Age	Mean Wt. (g)	Kcal/g dry Wt.	Kcal/dry body Wt.(g)	Correlation Coefficient
Aulocara elliotti	1st & 2nd	0.0056	5.024	0.0281	
	3rd, 4th & 5th	0.0299	5.092	0.1523	+0.9629
	M(earlier) 1972	0.0309	5.084	0.1571	significant
	M(later) 1971	0.0600	5.163	0.3098	at the
	F(earlier) 1972	0.0803	5.246	0.4213	0.05 level
	F(later) 1971	0.1270	5.312	0.6746	
Cordillacris occipitalis	1st & 2nd	0.0030	5.692	0.0171	
	3rd, 4th & 5th	0.0120	5.108	0.0614	+0.9621
	M(earlier) 1972	0.0199	4.952	0.0985	significant
	M(later) 1971	0.0280	5.069	0.1419	at the
	F(earlier) 1972	0.0241	5.930	0.1429	0.05 level
	F(later) 1971	0.0500	5.136	0.2568	
Cordillacris crenulata	1st & 2nd	0.0021	5.421	0.0114	
	3rd, 4th & 5th	0.0070	5.790	0.0405	+0.9373
	M(earlier) 1972	0.0099	4.517	0.0447	significant
	M(later) 1971	0.0118	4.626	0.0546	at the
	F(earlier) 1972	0.0263	5.301	0.1394	0.05 level
	F(later) 1971	0.0277	6.439	0.1784	
Opeia obscura	1st & 2nd	0.0022	5.466	0.0120	
	3rd, 4th & 5th	0.0098	5.195	0.0509	+0.9311
	M(earlier) 1972	0.0171	4.131	0.0706	significant
	M(later) 1971	0.0166	5.820	0.0966	at the
	F(earlier) 1972	0.0443	5.293	0.2345	0.05 level
	F(later) 1971	0.0678	5.361	0.3635	

grasshoppers in all the species. Not only this, there is an increment in the amount of contained energy in the adult grasshoppers collected in the latter part of the season as compared to those collected in the earlier part, and this is also true in all four species. This increase can be attributed to the difference in the weights of grasshoppers collected at these two different times, the one collected in the latter part of the season invariably weighed heavier, and the difference was considerably greater in the case of females, due to their being in the oviferous stage. Within the range of calorific values determined for whole individuals of a given species, variables such as season of collecting, life history stage, sex, reproductive condition and nutritional history assume considerable importance (Cummins and Wuycheck, 1971).

Figures 13 and 14 show this relationship clearly for the principal species from the Lusk site and the Pawnee Site, respectively. These show a steady rise in the amount of energy contained as the age of the grasshoppers progressed. The data indicate that the hypothesis is correct, grasshoppers contain more energy as they age and gain in weight.

Cummins and Wuycheck (1971) have recorded caloric data for a few species of grasshoppers. They reported 5151.7 gcal/g dry wt. for adults of Melanoplus femurrubrum and 5155.1 gcal/g dry wt. and 5281.7 gcal/g dry wt. respectively for the nymphs and adults of Schistocerca americana. These figures closely conform to the caloric values obtained in this study for the four species of grasshoppers.

Richman and Slobodkin (1960) emphasized the constancy of the caloric value of animal tissue. Except under starvation or storage conditions, animal tissue averages about 5000 gcal/g dry wt. They

RELATIONSHIP OF TOTAL BODY ENERGY CONTAINED WITH THE AGE OF PRINCIPAL SPECIES OF GRASSHOPPERS IN THE LUSK SITE (1971-1972)

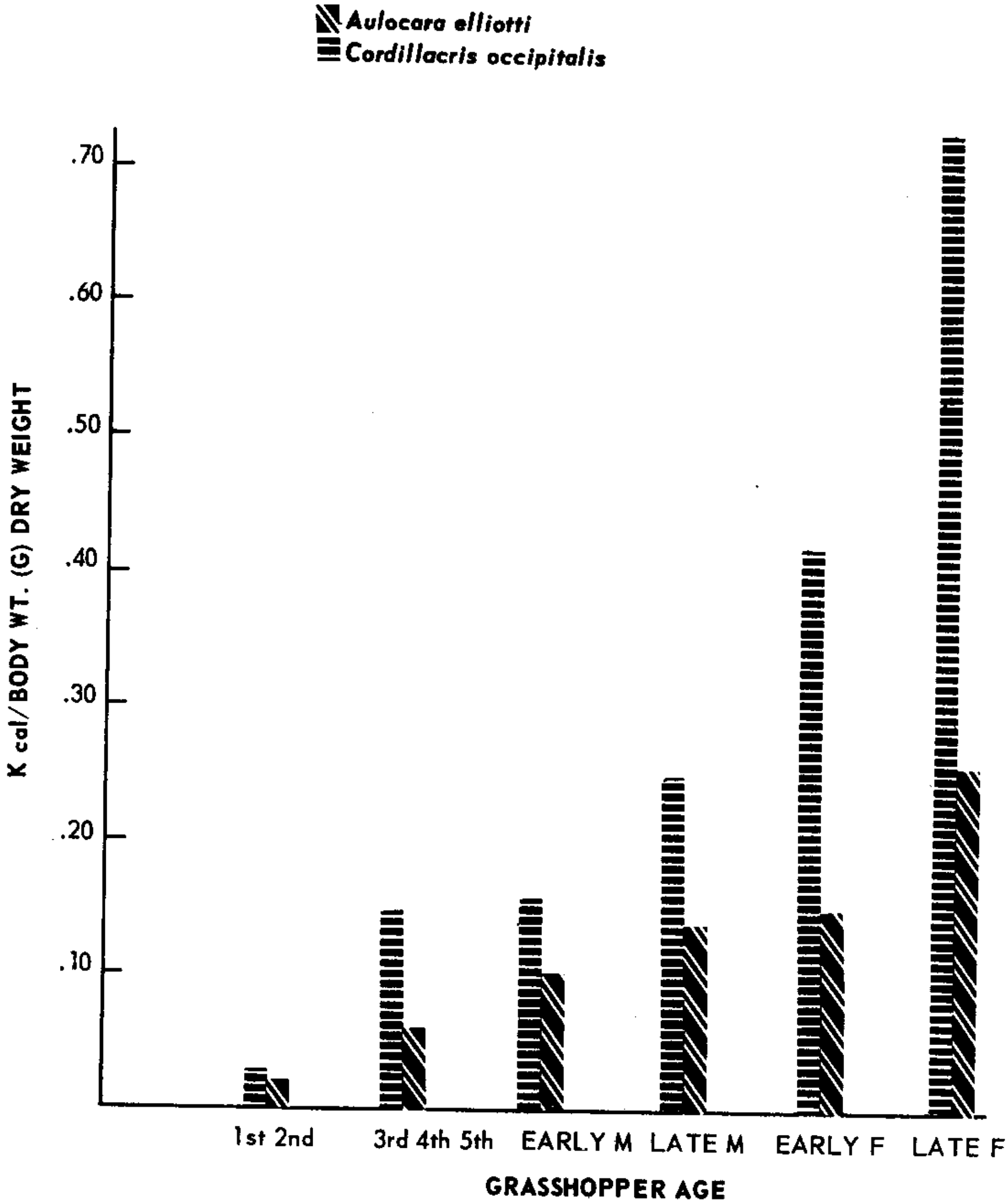
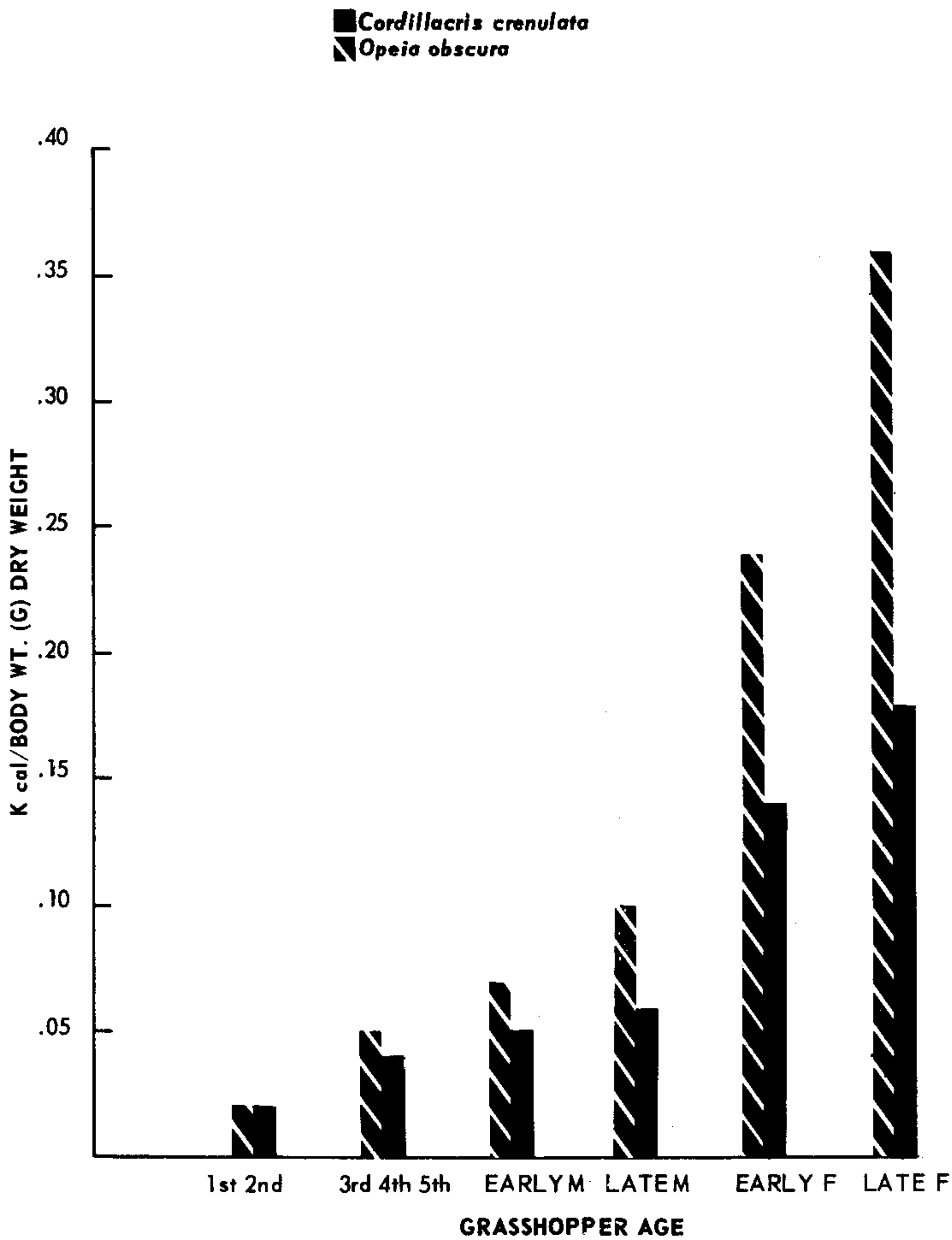


FIG. 14

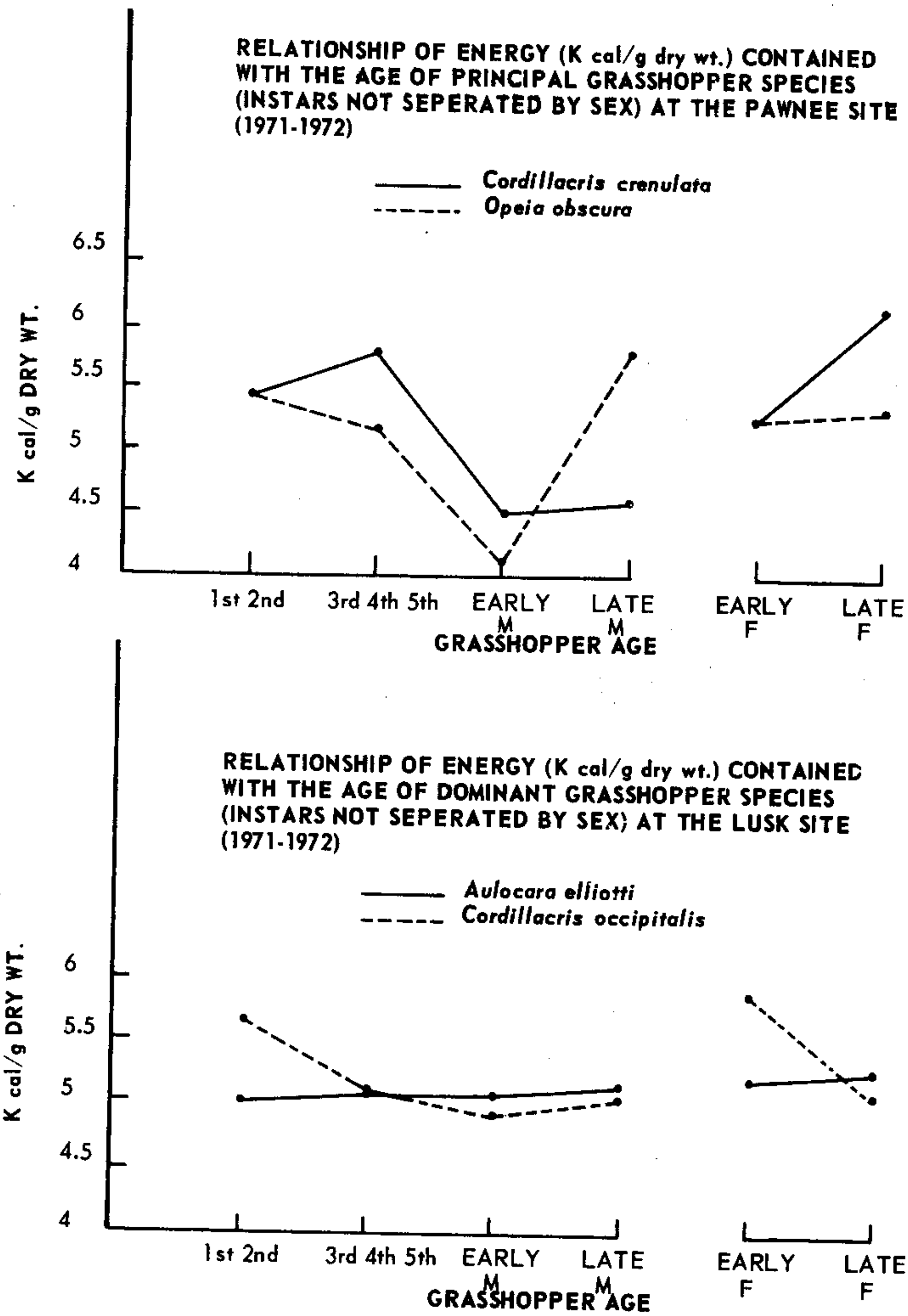
RELATIONSHIP OF TOTAL BODY ENERGY CONTAINED WITH THE AGE OF THE PRINCIPAL SPECIES OF GRASSHOPPERS AT THE PAWNEE SITE (1971-1972)



further state that when an animal is storing food material before hibernation, or a non feeding portion of the life cycle, the energy value of the body may increase to 6000 to 7000 gcal/g dry wt. Slobodkin and Richman (1961) found that higher caloric values are found only when energy is temporarily accumulated, such as when food is super abundant or the organism is under preparation for a fast. The authors further stated that the values in cal/g can provide an index of the nutritional condition of animals in the field, provided that the normal pattern of variation in the species is known.

Table 27 contains data for the energy content (Kcal/g dry wt.) of the different age groups of all four species, Aulocara elliotti and Cordillacris occipitalis from the Lusk site and Cordillacris crenulata and Opeia obscura from the Pawnee Site. Figure 15 shows the trends of such data. In the case of Aulocara elliotti females there is steady rise in the amount of energy contained from 5.024 Kcal/g dry wt. to 5.312 Kcal/g dry wt. as the species progressed in age. The trend for the males is similar though the maximum energy content is lower. The increase in the males and females collected in the latter part of the season is noteworthy, the reason being in the case of females that they were in an oviferous stage and more fat tissue is found in their body at this time (Uvarov, 1966). The curve for Cordillacris crenulata presents also the above trend, though in this case there is a considerable decrease in the amount of energy contained in the early male stage, from 5.790 Kcal/g dry wt. to 4.517 Kcal/g dry wt. Slobodkin and Richman (1961) stated that the values in cal/g can provide an index of the nutritional condition of animals in the field, and such a dip is possibly an

FIG. 15


RELATIONSHIP OF ENERGY (K cal/g dry wt.) CONTAINED WITH THE AGE OF PRINCIPAL GRASSHOPPER SPECIES (INSTARS NOT SEPERATED BY SEX) AT THE PAWNEE SITE (1971-1972)
Cordillacris crenulata
Opeia obscura
K cal/g DRY WT.
6.5
6
5.5
5
4.5
4
1st 2nd
3rd 4th 5th
EARLY M
LATE M
EARLY F
LATE F
GRASSHOPPER AGE
RELATIONSHIP OF ENERGY (K cal/g dry wt.) CONTAINED WITH THE AGE OF DOMINANT GRASSHOPPER SPECIES (INSTARS NOT SEPERATED BY SEX) AT THE LUSK SITE (1971-1972)
Aulocara elliotti
Cordillacris occipitalis
K cal/g DRY WT.
6
5.5
5
4.5
4
1st 2nd
3rd 4th 5th
EARLY M
LATE M
EARLY F
LATE F
GRASSHOPPER AGE

indication of poor nutritional condition at the time of collection.

In the case of Cordillacris occipitalis and Opeia obscura, the curves show erratic or bimodal trends. The data show a decrease in the amount of energy contained (in 3rd, 4th and 5th instars and early male stage) in C. occipitalis from 5.692 Kcal/g dry wt. to 4.952 Kcal/g dry wt. and from 5.466 Kcal/g dry wt. to 4.131 Kcal/g dry wt. in O. obscura between the instars and early male stage of development. These dips might also be due to the poorer nutritional conditions of the sampled individuals at the early male stage. But there is an increase (very noticeable for O. obscura) in the late male stage, the reasons for which are not clear. With regards to females, the curve for C. occipitalis from the Lusk site shows a downward trend in the late female stage which could be due to the fact that in females sharp reduction occurs in the fat content just before the first eggs are laid due to the reduced feeding at this period (Uvarov, 1966). The females used in this study might have been in such a condition at the collection time.

It is interesting to note that the early females of all the species did not show a decline in caloric content, and except for C. occipitalis there is a steady increase to the late female stage. Some of the above reasons explaining the erratic trends of the contained energy in Kcal/g dry wt. are discussed in their work by Cummins and Wuycheck (1971). These data (Kcal/g dry wt.) do also conform with the figures of Richman and Slobodkin (1960). The use of energy content per dry weight might well serve to indicate grasshopper vigour or stage of development better than more casual observations. A variety of questions are raised for future research, e.g. why the decline in energy content in early males, and why should different species have different seasonal patterns for energy content?

A comparison of the data of energy in Kcal/dry body wt. and Kcal/g dry wt. (Table 27) as also illustrated by Figures 13, 14 and 15, indicate that in Kcal/dry body wt. in the case of all the test insects, there was a steady upward trend which demonstrates that body weight is of course, important for the total amount of energy contained in the organism.

SUMMARY AND CONCLUSIONS

A complex of grasshoppers inhabit the shortgrass and mixed-grass associations. Twenty-seven species were found at the Pawnee Site, 22 of which have also been found on the southeast Wyoming sites. These species were arranged into 3 categories of abundance: abundant, common and rare.

Three definite patterns of emergence of nymphs and adults have been detected. This pattern involves grasshoppers with life cycles of two types which can be labeled as "Early" and "Late." Some of the grasshoppers are also labeled as "Mid" which appear in between "Early" and "Late" ones.

For testing the hypothesis that grazing pressure improves the grasshopper habitat on the Pawnee grassland, the total density of grasshoppers in the heavily grazed pasture and the lightly-moderately grazed pastures was determined, using the square-foot-count method. Under heavy grazing the maximum number of grasshoppers was $1.94/m^2$, whereas under light-moderate grazing the density rose to $3.28/m^2$, almost double the former. At the end of the sampling period, the minimum numbers found under heavy grazing pressure were $0.32/m^2$ and on light-moderate grazing pressure, $1.94/m^2$, almost four times the former. It was concluded that the grazing pressure does not improve the habitat for grasshoppers on the Pawnee Site.

The principal species of grasshoppers were selected for the study of the survivorship curve of grasshoppers. These figures were also obtained by the square-foot-count method. A cursory observation showed that the grasshopper numbers fall as the age of the grasshoppers progresses. In the case of all the species selected for this work, the peak of density occurred during the earlier instars and density fell significantly when the grasshoppers reached the later instars and adult stage. The conclusion was reached that the grasshoppers have a concave type of survivorship curve.

Another hypothesis was tested: the biomass of grasshoppers is proportional to the age and density of grasshoppers. Ovendry-weight data were accumulated for both sexes of all nymphal instars and adults for all the grasshoppers captured by sweeping with an insect net at all study sites. In contrast to peaks of density, the peaks of biomass were reached when grasshoppers were in the last nymphal instars and the early or mid adult stage. The peaks of biomass were attained on September 24 in both the heavily grazed pasture and in the lightly-moderately grazed pastures. Peak biomass in the heavily grazed unit was 64.21 mg/m^2 and in the lightly-moderately grazed unit, 97.23 mg/m^2. The difference in the biomass under two different grazing intensities was due primarily to the differences in the total densities of these sites. The peak of grasshopper biomass at the Lusk site reached 1213.51 mg/m^2 and at the Hartville site, 1142.74 mg/m^2; both of these peaks came when the grasshoppers were in their late nymphal instars and adult stage. A comparison of grasshopper biomass showed that peak biomass on the Lusk site was 13 times the peak biomass of the Pawnee Site. Such a comparison clearly shows the economic importance of grasshoppers on certain mixed-grass rangeland sites at certain times. The data supported the hypothesis that the biomass of grasshoppers is proportional to the age and density of grasshoppers.

It was hypothesized further that the grasshopper density is directly proportional to vegetation cover at the Pawnee Site. To test this the density figures were used and vegetation cover was measured once each month using the Daubenmire canopy coverage method. A correlation analysis was done in order to find out if there was any significant positive or negative correlation between the grasshopper density and the vegetation cover. The results showed no significant correlation.

The last hypothesis was that the total body energy increases with the age of grasshoppers. For this study two principal species of grasshoppers from the Pawnee Site and two from the Lusk site were selected. From the results it was concluded that the total body energy contained (Kcal/dry body wt.) steadily increased with the age of grasshoppers in all the four species. Not only this, there was an increment in the amount of contained energy in the adults collected in the latter part of the season as compared to those collected in the earlier part, this was true for all four species. This increase can be attributed to the difference in the weights of grasshoppers collected at two different times, the one collected in the latter part of the season invariably weighed heavier and the difference was considerably greater in the case of females which was possibly due to their being in the oviferous stage. A correlation analysis was done and the results showed significant positive correlations in all cases. Thus it was concluded that the total body energy increases with the age of grasshoppers.

An examination of the data for the energy contents in Kcal/g dry wt. (Table 27) of the different age groups of all four species, A. elliotti and C. occipitalis from the Lusk site and C. crenulata and O. obscura from the Pawnee Site gives an interesting picture. There is a steady increase in the energy contents from early to late females in all the species except C. occipitalis. This decrease could be probably due to the reduced feeding of the females which might have already laid the first batch of eggs at the time of collection. In the case of A. elliotti there is a steady rise in the amount of energy contained from 5.024 Kcal/g dry wt. to 5.312 Kcal/g dry wt. as the species progressed in age. The curve of C. crenulata presents also this trend, though in this case there is a considerable decrease in the contained energy in the early male stage which could be indicative of poor nutritional condition of the sampled grasshoppers. In the case of C. occipitalis and O. obscura the curves show erratic or bimodal trends. The data show a decrease in the amount of energy contained in C. occipitalis from 5.692 Kcal/g dry wt. to 4.952 Kcal/g dry wt. and from 5.466 Kcal/g dry wt. to 4.131 Kcal/g dry wt. in O. obscura between the instars and early male stage. These dips might be also due to poor nutritional condition of the test organisms. It is concluded that the body weight is of course, important for the total amount of energy contained in the organism.

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APPENDIX

APPENDIX A

OVENDRY WEIGHTS OF GRASSHOPPERS COLLECTED IN THE LIGHTLY AND MODERATELY GRAZED PASTURES (23 W; 15 E) OF THE PAWNEE SITE IN 1971 AND 1972

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Ageneotettix deorum	1	3	M	2.72	2.40 - 3.00	0.0346
	2	4	M	3.19	2.71 - 5.21	1.3352
	2	8	F	3.77	2.31 - 4.56	0.5862
	3	4	M	6.48	4.00 - 8.44	2.2759
	3	8	F	6.12	3.18 - 11.04	2.3786
	4	2	M	12.82	12.44 - 13.19	0.5302
	4	2	F	17.29	13.51 - 21.06	5.3386
	5	3	M	16.94	14.19 - 22.59	5.9396
	5	1	F	34.12	---	---
	Adult	7	M	27.76	20.52 - 35.08	6.1204
	Adult	5	F	50.01	29.41 - 69.56	17.5531
Amphitornus coloradus	1	1	M	1.35	---	---
	2	2	M	4.36	3.42 - 5.29	1.3222
	3	1	M	8.82	---	---
	3	2	F	10.08	5.44 - 14.72	6.5619
	4	2	M	12.47	10.39 - 14.55	2.9415
	4	4	F	14.83	10.40 - 25.28	6.6491
	5	1	M	31.02	---	---
	Adult	2	M	34.88	33.18 - 36.57	2.3970
	Adult	2	F	77.23	72.47 - 81.99	6.7316
Arphia conspersa	1	4	M	2.75	1.35 - 3.50	0.9140
	2	6	M	5.29	4.12 - 6.92	1.0274
	2	10	F	4.82	3.10 - 7.22	1.5464
	3	5	M	12.48	7.98 - 18.60	4.8633
	3	11	F	13.22	7.18 - 23.05	4.4225

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Arphia conspersa (continued)	4	1	M	18.50	---	---
	4	2	F	11.61	11.21 - 12.00	0.5585
	5	1	F	79.90	---	---
	Adult	25	M	93.41	70.25 -103.78	8.2881
	Adult	6	F	247.99	212.05 -287.10	24.0680
Arphia pseudonietana	1	1	M	1.66	---	---
	3	1	M	9.78	---	---
	3	1	F	14.48	---	---
	4	1	F	36.86	---	---
	5	5	M	96.44	80.79 -106.40	11.5905
	5	4	F	113.71	55.80 -143.55	39.7633
	Adult	5	F	237.23	130.00 -285.00	66.3375
Cordillacris crenulata	1	30	M	1.71	0.91 - 2.21	0.3228
	1	30	F	1.33	0.85 - 2.31	0.3613
	2	40	M	3.04	1.92 - 4.71	0.6941
	2	36	F	3.07	1.72 - 5.24	0.8698
	3	21	M	5.74	3.05 - 10.14	2.2732
	3	8	F	4.37	2.92 - 7.04	1.2286
	4	35	M	5.87	3.01 - 8.80	1.1376
	4	30	F	7.15	3.90 - 10.52	1.8860
	5	1	M	6.51	---	---
	5	20	F	13.10	7.56 - 20.52	3.8032
	Adult	37	M	12.00	8.43 - 16.27	1.8414
	Adult	32	F	27.82	12.60 - 36.17	5.3700
Cordillacris occipitalis	1	7	M	2.08	1.04 - 3.34	0.7020
	1	10	F	2.29	1.35 - 2.88	0.4341
	2	6	M	3.97	3.04 - 4.51	0.6391

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Cordillacris occipitalis (continued)	2	9	F	3.94	2.50 - 4.98	0.9334
	3	11	M	5.53	4.10 - 9.00	1.6232
	3	16	F	6.11	3.65 - 9.12	1.9946
	4	12	M	12.57	8.92 - 16.00	2.1827
	4	18	F	13.40	8.02 - 20.37	3.5376
	5	7	F	28.18	20.42 - 33.52	4.7931
	Adult	31	M	19.27	14.88 - 23.35	2.5653
	Adult	26	F	43.60	24.81 - 53.16	6.9711
Derotmema haydenii	1	2	M	0.94	0.86 - 1.01	0.1058
	1	2	F	0.91	0.90 - 0.91	zero
	2	1	F	2.31	---	---
	4	2	M	11.18	10.28 - 12.08	1.2727
	4	1	F	10.19	---	---
	5	1	M	13.60	---	---
	5	1	F	47.78	---	---
	Adult	1	F	93.43	---	---
Eritettix simplex	1	1	M	1.71	---	---
Melanoplus confusus	3	1	M	12.19	---	---
Melanoplus foedus	3	1	M	5.60	---	---
Melanoplus gladstoni	3	12	M	10.28	8.61 - 14.41	1.5092
	3	16	F	12.99	8.58 - 19.92	3.8420
	4	9	M	20.34	13.55 - 26.61	4.5425
	4	8	F	22.75	13.29 - 42.72	9.3959
	5	11	M	43.47	41.04 - 59.00	8.6414

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Melanoplus gladstoni (continued)	5	9	F	63.82	37.65 - 81.05	16.3429
	Adult	21	M	79.66	52.39 -106.39	15.0553
	Adult	16	F	100.19	62.65 -158.06	25.0581
Melanoplus infantilis	1	24	M	1.41	0.85 - 2.72	0.4298
	1	20	F	1.29	0.69 - 2.81	0.4915
	2	30	M	2.26	1.36 - 4.90	0.8502
	2	24	F	2.47	1.01 - 3.40	0.7957
	3	21	M	4.60	2.49 - 7.79	1.3454
	3	26	F	4.37	2.99 - 6.20	0.9873
	4	13	M	8.68	4.11 - 8.90	1.3708
	4	12	F	8.58	4.92 - 16.21	4.1949
	5	4	M	21.15	14.02 - 31.28	8.1839
	5	5	F	23.73	10.54 - 37.05	11.0161
	Adult	10	M	39.06	29.91 - 43.10	3.9845
	Adult	17	F	61.00	50.31 - 75.00	8.3690
Opeia obscura	1	16	M	1.01	0.65 - 1.82	0.3235
	1	20	F	1.17	0.81 - 1.56	1.2374
	2	19	M	1.91	1.25 - 2.85	0.5235
	2	16	F	2.42	1.26 - 4.01	0.6354
	3	19	M	4.02	4.36 - 5.43	0.8055
	3	27	F	5.32	3.39 - 8.23	1.9473
	4	29	M	6.47	3.60 - 9.99	1.7883
	4	32	F	10.16	6.81 - 14.28	4.2298
	5	28	M	10.28	5.82 - 15.81	5.3700
	5	29	F	22.62	14.29 - 37.70	6.3823
	Adult	30	M	17.09	10.71 - 25.08	3.8515
	Adult	27	F	44.26	28.66 - 77.40	14.8905

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Parapomala wyomingensis	Adult	3	M	17.51	17.12 - 17.90	zero
	Adult	3	F	37.60	25.86 - 47.12	10.1472
Phlibostroma quadrimaculatum	1	8	M	1.41	0.98 - 2.49	0.4953
	2	1	M	2.51	---	---
	2	2	F	3.91	2.73 - 5.08	1.6616
	3	1	M	6.29	---	---
	3	4	F	6.05	7.12 - 8.10	1.9146
	4	3	M	8.73	7.63 - 9.96	1.1680
	4	5	F	12.85	6.83 - 19.51	4.8784
	5	11	M	16.38	12.50 - 24.91	3.8366
	5	4	F	20.89	19.27 - 23.70	2.4959
	6	10	F	33.17	18.50 - 49.60	11.6123
	Adult	13	M	29.76	24.33 - 35.78	9.2778
	Adult	11	F	67.24	37.08 -135.78	36.3635
Psoloessa delicatula	1	7	M	1.53	1.32 - 1.98	0.0808
	1	2	F	1.80	1.08 - 2.51	1.0111
	2	17	M	2.31	1.31 - 3.12	0.2611
	2	8	F	2.20	1.31 - 2.76	0.2311
	3	18	M	3.13	2.32 - 5.00	0.8394
	3	16	F	3.73	1.91 - 5.45	1.0766
	4	12	M	6.54	4.78 - 8.75	1.4487
	4	10	F	6.26	4.50 - 9.43	1.7880
	5	4	M	23.99	22.27 - 27.50	2.4574
	5	14	F	39.78	37.05 - 46.80	4.4922
	Adult	16	M	26.48	21.75 - 30.15	2.7674
	Adult	12	F	62.71	59.00 - 71.37	5.0783

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Spharagemon equale	2	1	M	7.60	---	---
	3	1	F	20.61	---	---
	4	1	M	19.91	---	---
	4	1	F	46.91	---	---
	5	1	F	45.51	---	---
Trachyrhachys aspera	3	6	F	8.18	4.58 - 11.58	2.8593
	4	6	M	13.55	8.08 - 20.65	4.7128
	4	6	F	20.97	15.89 - 29.61	4.9094
	5	6	M	31.38	23.60 - 40.17	5.8124
	5	13	F	49.81	22.60 - 78.72	20.8094
	Adult	24	M	46.80	32.92 - 61.30	8.4437
	Adult	16	F	119.24	55.00 -170.61	31.9806
Trachyrhachys kiowa	1	1	M	2.41	---	---
	1	1	F	2.41	---	---
	2	6	M	3.16	1.61 - 4.28	1.0049
	2	9	F	3.81	2.46 - 4.93	0.8730
	3	11	M	6.32	4.45 - 7.58	1.1942
	3	14	F	6.86	4.12 - 10.23	2.1319
	4	19	M	14.03	7.23 - 20.68	3.9698
	4	10	F	16.87	6.83 - 24.64	6.3663
	5	8	M	18.43	9.09 - 28.80	7.0564
	5	19	F	32.45	15.33 - 46.44	9.7723
	Adult	30	M	32.96	23.48 - 41.06	7.7565
	Adult	30	F	81.79	35.88 - 98.00	20.8152
Trimerotropis campestris	Adult	3	M	85.23	78.41 - 91.75	6.6746
	Adult	1	F	141.60	---	---

APPENDIX A (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Xanthippus corallipes	1	1	M	5.76	---	---
	2	1	M	6.71	---	---
	2	1	F	11.60	---	---
	3	10	M	17.88	9.32 - 28.01	5.8843
	3	4	F	23.45	17.22 - 34.78	7.7768
	4	4	M	36.28	14.42 - 50.09	17.3672
	4	7	F	30.54	15.92 - 46.74	10.8354
	5	9	M	97.77	45.41 -172.05	37.4564
	5	10	F	185.60	91.45 -272.78	75.8207

APPENDIX B

OVENDRY WEIGHTS OF GRASSHOPPERS COLLECTED IN THE HEAVILY GRAZED PASTURE (23 E) OF THE PAWNEE SITE IN 1971 AND 1972

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Ageneotettix deorum	1	1	M	1.65	---	---
	1	4	F	2.19	1.55 - 2.80	0.9674
	2	10	M	4.64	3.21 - 5.04	0.5959
	2	5	F	4.03	3.24 - 5.21	0.7411
	3	5	M	7.18	4.48 - 9.69	2.0318
	3	5	F	6.77	4.62 - 10.08	2.3225
	4	1	M	20.53	---	---
	4	2	F	15.72	15.51 - 15.92	0.2898
	5	1	F	22.90	---	---
	Adult	2	M	27.31	22.56 - 32.06	6.7176
	Adult	5	F	55.88	51.40 - 61.50	4.3853
Amphitornus coloradus	1	1	M	2.78	---	---
	3	1	F	8.94	---	---
	Adult	2	F	78.67	71.80 - 85.53	9.7025
Arphia conspersa	2	2	M	4.85	3.60 - 6.10	1.7677
	3	1	F	21.40	---	---
	5	1	F	72.90	---	---
	Adult	11	M	95.72	82.65 -109.70	8.5770
	Adult	2	F	242.10	232.60 -251.60	13.4350
Arphia pseudonietana	2	1	M	5.24	---	---
	3	1	F	18.39	---	---
	5	1	M	65.58	---	---
	5	1	F	48.37	---	---

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Arphia pseudonietana (continued)	Adult	2	M	72.30	67.60 - 77.00	6.6468
	Adult	1	F	291.55	---	---
Cordillacris crenulata	1	30	M	1.60	0.95 - 2.24	0.3301
	1	30	F	1.50	0.82 - 2.80	0.4216
	2	30	M	2.53	1.46 - 3.72	0.7290
	2	30	F	3.32	1.51 - 5.09	1.0445
	3	30	M	3.87	2.72 - 5.34	0.7109
	3	11	F	4.41	3.46 - 5.25	0.6830
	4	30	M	4.73	2.60 - 8.91	1.2805
	4	20	F	8.27	5.30 - 10.96	2.0854
	5	13	F	12.71	7.99 - 12.76	3.1809
	Adult	30	M	12.58	9.56 - 15.78	1.6147
	Adult	30	F	24.30	15.61 - 30.72	4.4120
Cordillacris occipitalis	2	4	M	3.13	2.22 - 4.38	0.9047
	2	4	F	2.62	2.09 - 2.71	0.3269
	3	1	F	4.51	---	---
	4	4	M	7.52	5.82 - 8.21	1.1325
	4	1	F	6.52	---	---
	5	1	M	14.31	---	---
	Adult	3	M	17.21	16.00 - 17.90	1.0464
Derotmema haydenii	1	1	F	0.88	---	---
	3	1	M	7.22	---	---
	3	3	F	8.09	3.68 - 10.28	3.3058
	4	2	M	11.95	8.91 - 15.00	4.3062
	4	2	F	11.60	7.70 - 15.50	5.5154
	5	3	F	34.40	33.40 - 36.11	1.4856

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Derotmema haydenii (continued)	Adult	4	M	30.30	20.85 - 37.10	6.9376
	Adult	5	F	77.37	35.00 -104.00	27.9442
Melanoplus foedus	2	1	M	2.71	---	---
	2	1	F	2.65	---	---
	4	1	F	17.42	---	---
	Adult	2	M	188.25	178.50 -198.00	13.7885
Melanoplus gladstoni	2	1	M	6.48	---	---
	2	3	F	4.82	4.01 - 5.39	0.7206
	3	7	M	10.78	5.50 - 20.30	6.1974
	3	7	F	9.38	7.89 - 15.61	3.7574
	4	5	M	16.41	11.90 - 28.00	6.2590
	4	5	F	19.16	13.40 - 30.25	6.3970
	5	6	M	40.20	30.60 - 57.10	10.0627
	5	4	F	51.54	27.59 - 73.40	21.2169
	Adult	2	M	76.77	68.27 - 85.26	12.4137
	Adult	1	F	91.30	---	---
Melanoplus infantilis	1	30	M	1.08	0.52 - 1.70	0.3331
	1	26	F	1.19	0.71 - 2.02	0.3872
	2	30	M	2.05	0.92 - 3.41	0.6616
	2	30	F	2.20	1.35 - 3.20	0.5465
	3	30	M	4.02	2.61 - 6.00	0.9667
	3	30	F	4.88	2.49 - 9.44	1.9480
	4	18	M	7.78	2.58 - 14.25	3.0842
	4	8	F	9.14	4.10 - 16.31	4.9271
	5	4	M	14.82	9.52 - 22.25	5.4356
	5	7	F	26.32	17.85 - 35.40	6.9180

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Melanoplus infantilis (continued)	Adult	7	M	38.18	25.95 - 49.50	8.6280
	Adult	7	F	60.85	50.72 - 75.89	10.0124
Melanoplus occidentalis	3	1	F	6.89	---	---
	Adult	1	M	77.45	---	---
Melanoplus sanguinipes	1	3	F	2.23	1.93 - 2.64	0.3675
	2	1	M	6.01	---	---
	3	1	M	7.88	---	---
	Adult	2	F	131.50	114.00 -149.00	24.7487
Opeia obscura	1	30	M	1.07	0.79 - 1.61	0.2734
	1	31	F	1.31	0.71 - 1.62	1.0298
	2	22	M	2.18	1.33 - 3.00	0.5723
	2	29	F	2.13	1.52 - 2.69	0.2598
	3	14	M	3.70	2.05 - 6.55	1.1469
	3	24	F	3.59	2.24 - 4.94	1.1221
	4	21	M	6.01	4.31 - 9.36	1.1688
	4	29	F	10.41	4.12 - 18.55	3.8569
	5	17	M	9.83	6.76 - 15.78	2.5953
	5	11	F	21.51	8.51 - 33.96	7.3166
	Adult	10	M	15.22	10.88 - 20.50	5.6278
	Adult	23	F	56.39	22.50 - 65.89	13.4146
Parapomala wyomingensis	5	1	M	15.40	---	---
	Adult	1	M	13.95	---	---
Phlibostroma quadrimaculatum	1	7	M	1.35	1.02 - 2.04	0.3301
	1	4	F	1.86	1.25 - 2.36	0.4614
	2	3	M	3.13	2.34 - 3.82	0.8075
	2	1	F	4.02	---	---

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Phlibostroma quadrimaculatum (continued)	3	5	F	5.44	2.33 - 6.71	1.7798
	4	6	M	10.30	4.60 - 18.80	5.3209
	4	3	F	9.31	3.72 - 11.90	4.2345
	5	8	M	17.82	9.12 - 29.10	6.3260
	5	5	F	15.03	10.79 - 20.76	4.0633
	6	10	F	36.43	22.22 - 56.10	13.3213
	Adult	13	M	28.12	15.01 - 38.85	6.4691
	Adult	11	F	76.88	40.00 -116.39	24.7747
Psoloessa delicatula	1	10	M	1.27	0.73 - 1.79	0.3828
	1	9	F	1.31	1.02 - 1.71	0.2745
	2	14	M	2.07	1.59 - 2.40	0.1786
	2	15	F	2.14	1.31 - 2.80	0.4576
	3	12	M	4.61	3.05 - 6.65	1.0943
	3	9	F	3.82	3.05 - 4.59	0.3976
	4	2	M	6.43	6.30 - 6.55	0.1766
	4	6	F	7.44	5.69 - 9.10	1.2134
	5	1	M	7.86	---	---
	5	1	F	7.86	---	---
	Adult	4	M	22.58	21.00 - 25.10	1.9287
	Adult	4	F	71.98	71.75 - 72.25	0.2174
Spharagemon equale	2	3	M	6.10	5.45 - 6.92	0.7427
	2	2	F	6.09	5.71 - 6.46	0.5302
	3	1	F	7.34	---	---
	4	1	M	17.51	---	---
	5	1	F	78.90	---	---
	Adult	1	F	258.60	---	---

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Trachyrhachys aspera	3	5	M	9.55	6.19 - 10.92	1.8498
	3	8	F	8.90	6.06 - 11.29	2.2893
	4	9	M	14.52	8.51 - 23.45	5.2992
	4	6	F	18.38	13.54 - 23.30	4.1288
	5	13	M	31.10	16.96 - 48.66	6.0912
	5	15	F	40.01	26.60 - 75.26	14.9878
	Adult	21	M	43.78	29.00 - 58.00	9.3503
	Adult	20	F	109.15	62.16 - 155.65	33.2036
Trachyrhachys kiowa	1	8	M	1.45	0.69 - 2.22	0.5162
	1	13	F	1.34	0.82 - 2.00	0.4316
	2	27	M	2.59	2.09 - 4.33	0.5253
	2	25	F	3.18	2.02 - 5.31	1.1763
	3	18	M	5.74	3.23 - 8.38	1.5148
	3	28	F	6.19	4.12 - 10.22	1.8051
	4	13	M	12.59	6.82 - 15.97	3.1077
	4	15	F	16.22	9.85 - 23.62	4.3108
	5	10	M	20.99	12.92 - 25.38	5.2332
	5	11	F	28.40	18.50 - 42.43	7.6649
	Adult	33	M	28.65	20.52 - 40.60	5.2410
	Adult	28	F	74.33	33.72 -105.25	22.1442
Trimerotropis campestris	1	1	M	2.82	---	---
	5	2	M	43.56	39.61 - 47.50	5.5790
	Adult	13	M	72.91	50.35 - 86.65	10.5868
	Adult	4	F	158.35	136.40 -190.40	26.5693

APPENDIX B (Continued)

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Xanthippus corallipes	2	4	F	6.95	4.62 - 8.18	1.6167
	3	3	F	12.83	10.10 - 18.62	4.3946
	4	1	M	41.06	---	---
	4	2	F	69.46	65.00 - 72.96	5.6285
	5	1	F	68.99	---	---

APPENDIX C

OVENDRY WEIGHTS OF THE ABUNDANT SPECIES OF GRASSHOPPERS COLLECTED IN MIXED GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN 1971

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Aulocara elliotti	1	30	M	3.21	1.62 - 4.98	0.9591
	1	30	F	3.53	1.84 - 5.06	0.9439
	2	30	M	6.95	4.78 - 9.84	1.5609
	2	30	F	7.30	4.06 - 10.64	1.7286
	3	30	M	12.53	8.12 - 20.04	3.4852
	3	30	F	11.63	7.00 - 19.34	3.8159
	4	30	M	17.06	8.55 - 25.50	4.2166
	4	30	F	29.91	12.04 - 38.14	7.0314
	5	30	M	30.78	16.80 - 47.80	8.9700
	5	44	F	59.89	26.20 - 87.36	15.1218
	Adult	30	M	59.59	44.00 - 76.00	6.8633
	Adult	37	F	132.98	79.00 -178.80	18.8999
Cordillacris occipitalis	1	30	M	1.80	1.02 - 3.00	0.7348
	1	30	F	1.73	1.02 - 3.00	0.7225
	2	30	M	4.63	2.40 - 5.96	0.9462
	2	30	F	5.10	2.34 - 6.94	1.2837
	3	1	M	6.50	---	---
	3	12	F	5.61	2.88 - 9.00	2.3945
	4	30	M	7.29	4.70 - 10.44	1.7353
	4	30	F	10.48	4.38 - 14.74	2.7758
	5	34	M	14.40	9.84 - 13.12	3.4556
	5	31	F	14.31	9.30 - 21.84	3.3675
	Adult	32	M	25.90	19.50 - 38.00	5.6128
	Adult	30	F	51.94	41.00 - 58.80	6.1988

APPENDIX D

OVENDRY WEIGHTS OF THE ABUNDANT SPECIES OF GRASSHOPPERS COLLECTED IN MIXED GRASS ASSOCIATION 19 MILES SOUTHEAST OF LUSK, WYOMING IN 1972

Species	Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
Aulocara elliotti	1	30	M	3.33	1.72 - 4.48	0.8287
	1	30	F	3.00	1.46 - 4.66	0.8558
	2	33	M	6.14	4.00 - 10.27	1.9070
	2	32	F	6.79	4.03 - 11.12	2.0135
	3	30	M	13.13	9.68 - 19.14	3.0183
	3	30	F	15.31	7.09 - 21.18	3.6743
	4	13	M	24.47	10.42 - 40.19	11.0641
	4	11	F	29.61	17.29 - 52.08	10.7830
	5	10	M	55.01	29.14 - 70.00	14.8726
	5	14	F	61.09	30.10 - 87.28	17.4244
	Adult	21	M	34.66	26.00 - 50.93	5.9490
	Adult	24	F	80.53	63.15 -122.95	16.9523
Cordillacris occipitalis	1	30	M	2.00	1.18 - 3.40	0.6172
	1	30	F	2.00	1.10 - 3.53	0.6627
	2	23	M	3.32	1.81 - 6.00	1.0084
	2	29	F	4.43	2.33 - 6.80	0.7587
	3	30	M	8.69	6.07 - 11.80	1.3822
	3	13	F	7.37	4.32 - 9.27	1.6704
	4	20	M	13.66	8.39 - 17.02	1.0579
	4	30	F	9.26	7.07 - 12.12	2.1621
	5	22	F	25.62	16.30 - 30.90	5.3707
	Adult	10	M	19.92	13.40 - 24.69	4.2592
	Adult	14	F	25.22	20.18 - 26.93	2.2052

APPENDIX E

OVENDRY WEIGHTS OF *Aulocara elliotti* COLLECTED IN MIXED GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN 1971

Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
1	30	M	3.00	1.65 - 5.00	0.8826
1	30	F	3.10	1.75 - 6.25	1.7957
2	39	M	6.25	3.15 - 10.00	1.9901
2	24	F	9.13	6.90 - 14.20	1.8963
3	32	M	9.88	5.23 - 18.30	3.0476
3	30	F	13.64	9.00 - 19.70	3.4007
4	27	M	15.70	8.55 - 25.50	4.4173
4	27	F	29.56	15.45 - 56.00	9.1957
5	28	M	26.01	16.90 - 47.05	8.9007
5	39	F	65.10	28.90 - 87.75	14.2640
Adult	32	M	53.28	32.00 - 76.45	7.9984
Adult	30	F	102.14	45.45 -162.00	31.3378

APPENDIX F

OVENDRY WEIGHTS OF *Aulocara elliotti* COLLECTED IN MIXED GRASS ASSOCIATION 10 MILES NORTHEAST OF HARTVILLE, WYOMING IN 1972

Age	No.	Sex	Mean Wt. (mg)	Range (mg)	Standard Deviation (mg)
1	30	M	3.98	1.89 - 5.79	1.2467
1	32	F	3.43	1.63 - 5.72	1.0432
2	22	M	7.62	3.81 - 11.08	2.3876
2	14	F	6.97	4.00 - 10.52	2.1774
3	30	M	15.13	9.56 - 24.75	4.2947
3	30	F	16.31	8.81 - 23.84	4.1201
4	3	M	31.04	22.75 - 35.14	6.3187
4	17	F	27.61	12.80 - 48.28	13.1166
5	1	M	43.60	---	---
5	20	F	50.92	37.30 -102.05	24.1468
Adult	19	M	42.90	31.05 - 57.60	7.1321
Adult	10	F	87.20	65.25 -185.25	36.4017