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PLANT/INSECT INTERACTIONS OF SELECTED INSECTS
AT THE PAWNEE SITE

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ABSTRACT

The diets of prevalent phytophagous insects other than orthopterans were studied on the light and no grazing pastures at the IBP Pawnee Site eight miles northeast of Nunn, Colorado, during the summer of 1970.

The methods used were those of visual observation and microscopic analysis of the contents of beetle stomachs. Plant-insect matrices were used for interpretation of the results of observations. The relative percent dry weight of the species of plants in the insect diets and indices of preference were calculated for those beetles whose diets were studied by the microscopic technique.

Eleodes obsoleta fed primarily on *Psoralea tenuiflora* and *Oenothera coronopifolia*. *E. fusiformis* chose *Bouteloua gracilis* and *Carex heliophila* consistently. *E. extricata* had *O. coronopifolia* and *C. heliophila* as major foods. *E. hispilabris* selected *B. gracilis* and *O. coronopifolia* predominantly. *E. tricostata* ate chiefly *Thelesperma megapotamicum* and *P. tenuiflora*. *Edrotes* sp. ate primarily *B. gracilis*, while *Epicauta parva* chose chiefly *Oxytropis sericea*. *Lytta* sp. selected *Sophora sericea* primarily. *Cratacanthus dubius* fed on *B. gracilis* and *Agropyron smithii*, while *Moneilema annulata* ate chiefly *Opuntia polyacantha*.

The family of insects most commonly observed was Aphididae, followed by Cicadellidae, Chrysomelidae, Membracidae, and Meloidae. Cicadellidae was the insect family observed in the greatest numbers on the most species of plants, followed by Chrysomelidae, Meloidae, and Formicidae.

Cuerna costalis was the most observed species of insect, followed by *Campylenchia latipes*, *Carpophilus pallipennis*, *Epicauta stuarti*, *Nodonata puncticollis* and *Chauliognathus limbicollis*^{1/}. *Gutierrezia sarothrae* was the species of plant most often visited by insect species, followed by *Chrysothamnus nauseosus* and *Cirsium undulatum*.

^{1/} Identification uncertain.

INTRODUCTION

This study was carried out as a part of the International Biological Program (IBP) investigations at the Pawnee Intensive Site situated approximately eight miles northeast of Nunn, Colorado, on several sections of Range 66 West, Township 10 North.

This study was undertaken in an attempt to determine the plant association habits of prevalent phytophagous species so that their role in nutrient cycling might better be understood. Prevalent insects other than orthopterans were studied by observations of feeding on sections 15 and 23 and by pit trap collections on section 27.

The data presented here is a summary. A more detailed record can be found in Yount (1971).

Data Collection

The two methods of data collection employed were visual observation of insects and microscopic examination of contents of beetle crops for identification of plant materials contained.

Visual observations of insects were made randomly on the common plants adjacent to four herbage dynamics study areas as described by Uresk (unpublished Ph.D. thesis) where the vegetation had been previously determined. Two of the areas were ungrazed and two were lightly grazed by cattle so that large amounts of vegetation remained for insect forage. Observations were made twice weekly from 8:30 AM to 4:30 PM from May through September 1970.

The common species of plants were examined for insects. When it was evident that a species was feeding on the plant, the insect was collected by

means of an aspirator and placed in a freezer for killing shortly thereafter, then taken to the laboratory for identification.

A sample of the plant was also collected for later identification by comparisons with plants verified by Dr. W. M. Klein and Dr. H. D. Harrington with the aid of graduate students trained in the identification of all species of plants present.

Standard biome data sheets were used to record expected trophic level; host plant; insect order, family, genus, and species; life stage, and the number of that species of insect obviously eating the plant.

A computer program was written to show the numerical relationships between the insects and their host plants in the form of matrices. From the matrices one can determine the relative frequency that individual insect species were found on various plant species.

The second method of data collection involved identification of plant material taken from the crops of beetles collected in pit traps. A reference collection of slides made from the tissues of plant species occurring at the Pawnee Site had been previously made. Plant material from the crops of the beetles was thus examined microscopically and identified to species. (Technical Report No. 70, Hansen 1971).

A total of 228 slides, one per specimen, were read by the microscopic technique for determination of the contents of beetle crops. Five species in the genus *Eleodes* (Tenebrionidae) contributed 154 slides and one species in the genus *Edrotes* (Tenebrionidae) furnished five slides. Two members in the family Meloidae, *Epicauta parva* (Hald.) and *Lytta* sp., contributed 41 and 8 slides, respectively. *Cratacanthus dubius* (Carabidae) provided 17

slides and *Moneilema annulata* (Cerambycidae) furnished three slides. Only those insects identified to species are reported here. Data on *Edrotes* sp. and *Lytta* sp. are reported in Yount (1971).

Results of Microscopic Technique Diet Analysis

Diet of Eleodes obsoleta (Say). The crops of 77 beetles were used for diet analysis, yielding 25 species of plants, insect parts, fungus, and moss with a mean of 1.9 food items per crop. In June grasses accounted for 16%, in July 8%, and in August 17% of the diet with a combined mean of 14% of the total food items ingested. Forbs comprised 74%, 54%, and 50% of the diet in June, July, and August, respectively, with a combined mean of 61% of the total. Shrubs made up 5% in June, 27% in July, and 18% in August of the total food ingested with a combined mean of 16% of the diet. Insect parts made up 0.2% of the total in June, but contributed 8% in July and 16% in August giving a combined mean of 8%.

In June the major foods as percent of the total were *Sphaeralcea coccinea* 19%, *Oenothera coronopifolia* 18%, *Lepidium densiflorum* 10%, *Psoralea tenuiflora* 10%, and *Bouteloua gracilis* 9%. In July the major foods were *Gutierrezia sarothrae* accounting for 16%, *Oenothera coronopifolia* 16%, *Oxytropis sericea* 14%, and *Chrysothamnus nauseosus* 10% of the food digested. In August *Psoralea tenuiflora* made up 35% of the diet, followed by insect parts 16%, *Agropyron smithii* 11%, *Artemisia frigida* 11%, and *Oenothera coronopifolia* 11% of the total. The major foods from the combined means were *Psoralea tenuiflora* making up 16%, *Oenothera coronopifolia* 15%, and *Sphaeralcea coccinea* 19% of the diet (Table 1).

Table 1. Mean percent dry weight of food items in the diet of *Eleodes obsoleta* at Pawnee Site 1970.

Food Items	Month (Sample Size)			
	June (39)	July (20)	August (18)	Combined (77)
Grasses and Grass-Likes				
<i>Agropyron smithii</i>	3.9	-	11.4	5.1
<i>Aristida longiseta</i>	0.3	-	-	0.1
<i>Bouteloua gracilis</i>	9.4	3.9	4.8	6.0
<i>Carex heliophila</i>	2.6	3.5	0.2	2.1
<i>Festuca octoflora</i>	-	-	0.1	0.0
<i>Sporobolus cryptandrus</i>	-	0.4	0.1	0.2
Total:	16.2	7.8	16.6	13.5
Forbs				
<i>Bahia oppositifolia</i>	1.3	-	-	0.4
<i>Chrysopsis villosa</i>	-	0.4	-	0.1
<i>Cirsium undulatum</i>	2.8	-	-	0.9
<i>Erigeron divergens</i>	-	8.0	-	2.7
<i>Eriogonum effusum</i>	0.5	-	-	1.7
<i>Helianthus annuus</i>	-	†	-	†
<i>Lepidium densiflorum</i>	10.1	-	-	3.4
<i>Mirabilis linearis</i>	0.6	-	-	0.2
<i>Oenothera coronopifolia</i>	17.9	16.1	10.6	14.9
<i>Oxytropis sericea</i>	5.3	14.3	0.1	6.6
<i>Psoralea tenuiflora</i>	9.5	5.0	34.8	16.4
<i>Salsola kali</i>	7.2	-	-	2.4
<i>Sphaeralcea coccinea</i>	18.8	4.8	4.0	9.2
<i>Thelesperma megapotanicum</i>	-	5.1	-	1.7
Total:	74.0	53.7	49.5	60.7
Shrubs				
<i>Artemisia frigida</i>	-	-	10.9	3.6
<i>Atriplex canescens</i>	4.3	-	-	1.4
<i>Chrysothamnus nauseosus</i>	-	10.0	-	3.3
<i>Gutierrezia sarothrae</i>	0.2	16.2	0.1	5.5
<i>Opuntia polyacantha</i>	0.1	0.6	7.0	2.6
Total:	4.6	26.8	18.0	16.4
Other				
Insect parts	0.2	8.3	15.9	8.1
Fungus	0.5	-	0.1	0.2
Moss	3.9	3.4	-	2.4

† Signifies amount less than 0.1%.

Nine food items were selected consistently during June, July, and August: *Bouteloua gracilis*, *Carex heliophila*, *Oenothera coronopifolia*, *Oxytropis sericea*, *Psoralea tenuiflora*, *Sphaeralcea coccinea*, *Gutierrezia sarothrae*, *Opuntia polyacantha*, and insect parts. *Oenothera coronopifolia* was the species that was chosen uniformly in the greatest amounts. *Psoralea tenuiflora* was the overall major food item in terms of percent dry weight in the diet, and *Sphaeralcea coccinea* was selected in the greatest amounts in June. *Bouteloua gracilis* was a major food item from June through August. *Oxytropis sericea* was a major food in June and July. *Opuntia polyacantha* was consistently eaten in small amounts during June and July. *Gutierrezia sarothrae* was eaten in the largest amount in July.

Kulczynski's Index of Similarity was used to compare the June diet with the July diet and the July diet with the August diet for *Eleodes obsoleta*. This species' June diet was also compared to the June diets of the other beetles if the sample numbers were large enough to allow comparison. The Index of Similarity between June and July was 20.7 and between July and August was 21.1 showing that the food items varied considerably from month to month, probably as a result of the seasonal succession of plants.

Diet of Eleodes fusiformis (Leconte). The crops of 38 beetles were used for diet analysis, yielding 25 species of plants, insect parts, fungus, and moss as food items with a mean of 2.4 foods per crop. Grasses comprised 62% of the food items in June, 13% in July, and 54% in August. Forbs accounted for 35% of the food items in June, 44% in July, and 41% in August. Shrubs made up 3% and 30% of the total foods in June and July, respectively, with none occurring in August. In June *Bouteloua gracilis* and *Carex heliophila*

comprised 22% and 18% of the total foods. In July *Kochia scoparia* and *Chrysothamnus nauseosus* made up 16% and 19% of the total foods eaten. *Carex heliophila* and *Thelesperma trifidum* made up 52% and 41% of the total foods in August. Insect parts contributed 8% in July and 5% in August to the total food items ingested (Table 2).

Only two food items were eaten consistently June through August, *Bouteloua gracilis* and *Carex heliophila*. *Bouteloua gracilis* was the species eaten in largest amounts in June. *Carex heliophila* was second in amount in June and highest in amount in August. *Oenothera coronopifolia* was selected in small amounts in terms of percent dry weight in June. *Bromus tectorum* and *Sophora sericea* were the second and third most preferred food items in June. In July *Chrysothamnus nauseosus* was selected in the largest amounts. *Townsendia grandiflora* was eaten in moderate amounts, and *Kochia scoparia* and *Gutierrezia sarothrae* were second and third. Only two specimens were used for the August analysis so that the results are indeterminate, but *Carex heliophila* and *Thelesperma trifidum* together made over 92% of the total food ingested.

Kulczynski's Index of Similarity showed that between *E. obsoleta* and *E. fusiformis* there was an index of 15.1 in the June diets showing that the diets of the two species are quite dissimilar. A comparison between the diets for June and July for *E. fusiformis* gave an index of 15.2 indicating great dissimilarity between those two months.

Diet of Eleodes extricata (Say). Crops of 22 specimens collected only in June and July, yielded 13 species of plants, insect parts, moss, fungus, and lichens with a mean of 2.6 foods per crop. In June 22% and in July 72%

Table 2. Mean percent dry weight of food items in the diet of *Eleodes fusiformis* at Pawnee Site 1970.

Food Items	Month (Sample Size)		
	June (25)	July (11)	August (2)
<u>Grasses and Grass-likes</u>			
<i>Agropyron smithii</i>	4.4	-	-
<i>Aristida longiseta</i>	9.0	1.9	-
<i>Bouteloua gracilis</i>	22.3	5.7	2.9
<i>Bromus tectorum</i>	2.1	-	-
<i>Buchloe dactyloides</i>	0.5	0.3	-
<i>Carex heliophila</i>	19.7	4.7	51.5
<i>Oryzopsis hymenoides</i>	1.6	-	-
<i>Sporobolus cryptandrus</i>	2.0	0.4	-
Total:	61.6	13.0	54.4
<u>Forbs</u>			
<i>Astragalus</i> spp.	4.0	-	-
<i>Bahia oppositifolia</i>	3.1	-	-
<i>Erigeron divergens</i>	5.0	0.3	-
<i>Kochia scoparia</i>	1.0	16.0	-
<i>Lithospermum incisum</i>	0.2	-	-
<i>Mirabilis linearis</i>	4.0	1.3	-
<i>Oenotnera coronopifolia</i>	3.9	-	-
<i>Penstemon albidus</i>	3.7	-	-
<i>Salsola kali</i>	0.4	-	-
<i>Solanum rostratum</i>	1.2	-	-
<i>Sophera sericea</i>	1.9	-	-
<i>Sphaeralcea coccinea</i>	6.6	0.3	-
<i>Thermopsis divaricarpa</i>	-	9.1	-
<i>Thelesperma trifidum</i>	-	8.3	40.9
<i>Townsendia grandiflora</i>	-	8.9	-
Total:	35.0	44.2	40.9
<u>Shrubs</u>			
<i>Chrysothamnus nauseosus</i>	-	19.0	-
<i>Gutierrezia sarothrae</i>	2.8	11.4	-
Total:	2.8	30.4	
<u>Other</u>			
Insect parts	-	8.1	4.7
Fungus	0.6	3.5	-
Moss	-	0.9	-

of the total food consisted of grasses. Forbs made up 62% and 4% of total food items in June and July, respectively. Shrubs accounted for 2% of the food in June and none in July. Insect parts constituted 2% and 7% of the diet in June and July. Moss comprised 1% in June and 18% in July of the food items ingested. Both fungus and lichens accounted for 6% of the diet in June and did not occur in July. The major food items in June in percent dry weight were *Oenothera coronopifolia* 32%, *Sphaeralcea coccinea* 23%, and *Bouteloua gracilis* 23% of the food ingested (Table 3).

Five food items occurred in both June and July, the two months when this species was collected. *Bouteloua gracilis*, *Carex heliophila*, *Sphaeralcea coccinea*, insect parts, and moss occurred both months. In June and July *Bouteloua gracilis* was chosen in moderate amounts. *Carex heliophila* was the species eaten in the greatest amounts in July. *Sphaeralcea coccinea* was the species second highest in amount in June. Moss occurred in small amounts in June, but was chosen in large amounts in July. *Oenothera coronopifolia* occurred only in the June specimens. *Bahia oppositifolia* was chosen in small amounts in June.

Kulczynski's Index of Similarity between *E. extricata* and *E. obsoleta* for June gave an index of 18.5, showing a great dissimilarity between the diets of the two species. The index of similarity between *E. extricata* and *E. fusiformis* was 12.3, showing dissimilarity between these two species also.

Diet of Eleodes hispilabris (Say). Crops of 12 beetles were analyzed for determination of contents, yielding 16 species of plants, insect parts, and fungus with a mean of 2.7 foods per crop. The one sample from May showed 88% insect parts. In June grasses comprised 15% and in July 11% of the total

Table 3. Mean percent dry weight of food items in the diet of *Eleodes extricata* at Pawnee Site 1970.

Food Items	Month (Sample Size)	
	June (18)	July (4)
<u>Grasses and Grass-likes</u>		
<i>Aristida longiseta</i>	0.1	-
<i>Bouteloua gracilis</i>	12.3	22.5
<i>Carex heliophila</i>	9.3	49.1
Total:	21.7	71.6
<u>Forbs</u>		
<i>Bahia oppositifolia</i>	3.6	-
<i>Chrysopsis villosa</i>	0.1	-
<i>Oenothera coronopifolia</i>	31.7	-
<i>Oxytropis lambertii</i>	0.8	-
<i>Petalostemon candidus</i>	2.0	-
<i>Salsola kali</i>	0.4	-
<i>Sphaeralcea coccinea</i>	23.4	4.2
Total:	62.0	4.2
<u>Shrubs</u>		
<i>Artemisia frigida</i>	0.1	-
<i>Chrysothamnus nauseosus</i>	0.9	-
<i>Opuntia polyacantha</i>	0.9	-
Total:	1.9	-
<u>Other</u>		
Insect parts	2.3	6.7
Moss	0.9	17.5
Fungus	5.6	-
Lichen	5.6	-

ingested food. Forbs accounted for 66% in June, 39% in July, and essentially 100% in August of the total food items. In June 18% and in July 10% of the diet consisted of shrubs. The major foods eaten in June were *Oenothera coronopifolia* supplying 34%, *Sphaeralcea coccinea* 26%, *Atriplex canescens* 12%, and *Bouteloua gracilis* 11% of the total. In July *Chrysopsis villosa* was a major food accounting for 20% of the food ingested, while *Psoralea tenuiflora* supplied 19%, *Artemisia frigida* 10%, and *Bouteloua gracilis* 10% of the total. The one specimen from August showed nearly 100% *Psoralea tenuiflora* (Table 4).

Bouteloua gracilis was the only species chosen in large amounts during both June and July. *Oenothera coronopifolia* was eaten in the largest amounts in June, but was not chosen in July. *Sphaeralcea coccinea* was second highest in amount taken in June. In terms of percent dry weight *Atriplex canescens* was third during June. During July the species selected most was *Chrysopsis villosa*. *Psoralea tenuiflora* was second in percent dry weight for July. *Artemisia frigida* was the third highest species in percent dry weight for July.

Diet of Eleodes tricostata (Say). The crops of five specimens collected during July and August were used for analysis, yielding six species of plants with a mean of 2.8 foods per crop. Grasses made up 7% and 20% of the diet in July and August, respectively. Forbs accounted for 93% in July and 80% in August of the food items ingested. In July *Thelesperma megapotanicum* was the major food item, contributing 83% of the total. *Psoralea tenuiflora* and *Erigeron divergens* accounted for 47% and 30% of the food in August (Table 5).

During July *Thelesperma megapotanicum* made up the major portion of the diet, while during August it contributed only a small amount to the diet.

Table 4. Mean percent dry weight of food items in the diet of *Eleodes hispilabris* at Pawnee Site 1970.

Food Items	Month (Sample Size)			
	May (1)	June (5)	July (5)	August (1)
<u>Grasses and Grass-likes</u>				
<i>Agropyron smithii</i>		0.6	0.7	
<i>Bouteloua gracilis</i>		10.6	9.6	0.5
<i>Carex heliophila</i>		3.5	-	
<i>Sporobolus cryptandrus</i>		-	0.4	
Total:		14.7	10.7	0.5
<u>Forbs</u>				
<i>Astragalus</i> spp.		1.1	0.3	
<i>Bahia oppositifolia</i>	2.3	-	-	
<i>Chrysopsis villosa</i>		-	19.7	
<i>Lepidium densiflorum</i>		4.3	-	
<i>Lithospermum incisum</i>	2.3	-	-	
<i>Oenothera coronopifolia</i>	7.4	33.9	-	
<i>Psoralea tenuiflora</i>		-	18.8	99.5
<i>Sphaeralcea coccinea</i>		26.3	-	
<i>Thelesperma trifidum</i>		-	0.4	
Total:	12.0	65.6	39.2	99.5
<u>Shrubs</u>				
<i>Artemisia frigida</i>		-	10.2	
<i>Atriplex canescens</i>		12.1	-	
<i>Gutierrezia sarothrae</i>		5.7	-	
Total:		17.8	10.2	
<u>Other</u>				
Insect parts	87.9	-	-	
Fungus		1.8	-	

Table 5. Mean percent dry weight of food items in the diet of *Eleodes tricostata* at Pawnee Site 1970.

Food Items	Month (Sample Size)	
	July (2)	August (3)
<u>Grasses and Grass-likes</u>		
<i>Bouteloua gracilis</i>	7.0	1.2
<i>Carex heliophila</i>	-	18.4
Total:	7.0	19.6
<u>Forbs</u>		
<i>Erigeron divergens</i>	-	30.1
<i>Kochia scoparia</i>	-	0.9
<i>Psoralea tenuiflora</i>	10.1	46.8
<i>Thelesperma megapotamicum</i>	82.8	2.6
Total:	92.9	80.4

Psoralea tenuiflora was selected in moderate amounts during July, but was taken in much greater amounts during August. *Bouteloua gracilis* was chosen during both July and August. *Erigeron divergens* was eaten only in August, but was the second highest in amount that month.

Bouteloua gracilis made up over 50% of the amount eaten. *Oenothera coronopifolia* was eaten in small amounts in terms of percent dry weight. *Carex heliophila* was selected in moderately high amounts.

Diet of Epicauta parva (Hald.). The crops of 41 specimens collected in June were used for diet analysis yielding 11 species of plants with a mean of 1.1 foods per crop. Grasses comprised 2%, forbs 89%, and shrubs 9% of the total food ingested. The major food was *Oxytropis sericea* which accounted for 59% of the food ingested while *Sophora sericea* comprised 20%, *Artemisia frigida* 9%, and *Salsola kali* 4% of the diet (Table 6).

During June *Oxytropis sericea* was chosen in the greatest amounts. *Sophora sericea* and *Artemisia frigida* were also major foods. The combined species of *Astragalus* were selected in small amounts.

Diet of Cratacanthus dubius (Beauvois). Slides were made from the contents of the crops of 28 beetles, but 11 of these appeared to be empty so that only 17 of the slides could be used. Six species of plants, insect parts, moss and lichen made up the food items for this species with a mean of 1.8 foods per crop. Grasses made up 75% in July and 100% in August of the diet. Forbs comprised 8% and insect parts 15% of the food items in July. *Bouteloua gracilis* was the major food in July accounting for 61% of the diet, followed by insect parts 15% and *Agropyron smithii* 14%. In August *Agropyron smithii* was the major food comprising 97% of the diet (Table 7).

Table 6. Mean percent dry weight of food items in the diet of *Epicauta parva* at Pawnee Site 1970.

Food Items	Month (Sample Size)
	June (41)
<u>Grasses and Grass-like</u>	
<i>Bouteloua gracilis</i>	1.9
Total:	1.9
<u>Forbs</u>	
<i>Aster tanacetifolius</i>	2.4
<i>Astragalus</i> spp.	2.4
<i>Lepidium densiflorum</i>	0.6
<i>Oxytropis lambertii</i>	0.1
<i>Oxytropis sericea</i>	58.9
<i>Polanisia trachysperma</i>	0.6
<i>Salsola kali</i>	4.2
<i>Sophora sericea</i>	19.5
<i>Sphaeralcea coccinea</i>	0.3
Total:	89.0
<u>Shrubs</u>	
<i>Artemisia frigida</i>	9.0

Table 7. Mean percent dry weight of food items in the diet of *Crataeanthus dubius* at Pawnee Site 1970.

Food Items	Month (Sample Size)	
	July (14)	August (3)
<u>Grasses and Grass-likes</u>		
<i>Agropyron smithii</i>	13.6	96.5
<i>Aristida longiseta</i>	0.6	-
<i>Bouteloua gracilis</i>	60.6	3.5
<i>Carex heliophila</i>	0.3	-
Total:	75.1	100.0
<u>Forbs</u>		
<i>Lithospermum incisum</i>	0.5	-
<i>Sphaeralcea coccinea</i>	7.1	-
Total:	7.6	0.0
<u>Other</u>		
Insect parts	15.1	-
Moss	0.3	-
Lichen	1.5	-

Bouteloua gracilis made up the major portion of the diet in July. *Lithospermum incisum* in July was selected in small amounts in terms of percent dry weight. *Agropyron smithii* was chosen in large amounts especially in August. A higher percentage of insect parts might have been expected since this species is thought to be chiefly predaceous.

Diet of *Moneilema annulata* (Say). Crops of three beetles were used for diet analysis, yielding four species of plants with a mean of 1.7 foods per crop. *Opuntia polyacantha* was the major food item accounting for 67% of the food ingested, while *Sphaeralcea coccinea* comprised 30% of the diet (Table 8).

Opuntia polyacantha supplied the major portion of the diet. *Sphaeralcea coccinea* furnished less than 30% of the total food.

Results of Observations

The observations of insects observed on plants were combined regardless of date or sampling area so that overall matrices might be developed between the insects and plant species. The matrix presented here consisted of:

$$\text{for each insect species } i \quad \frac{\text{Observations on plant species } j}{\text{Total observations for insect species } i} \times 100$$

Insect abbreviations used in this matrix are shown in Table 9.

A total of 70 genera of insects were observed upon 41 species of plants. Fifty-eight species of insects were identified. Forty-seven of these species and genera had an overall total of fewer than ten insects observed during the sampling period May through September and are not included here (for these data, see Yount 1971). Twenty-six species of insects had a total of ten or more insects observed feeding and are reported here (Table 10).

Table 8. Mean percent dry weight of food items in the diet of *Moneilema annulata* at Pawnee Site 1970.

Food Items	Month (Sample Size)
	June (3)
<u>Grasses and Grass-like</u> s	
<i>Agropyron smithii</i>	1.8
<i>Bouteloua gracilis</i>	1.8
<u>Forbs</u>	
<i>Sphaeralcea coccinea</i>	29.7
<u>Shrubs</u>	
<i>Opuntia polyacantha</i>	66.7

Table 9. Entomological abbreviations and species list as used in this study at Pawnee Site 1970.

Insect Names	Symbols	Type of Study
<u>COLEOPTERA</u>	Col	
<u>Cantharidae</u>	Can	
<i>Chauliognathus limbicollis</i> ^{a/}	Cha/lim	F
<u>Chrysomelidae</u>	Chr	
<i>Acalymna virgifera</i>	Aca/vir	F
<i>Diabrotica undecimpunctata</i>	Dia/und	F
<i>Nodonata puncticollis</i>	Nod/pun	F
<i>Phyllotreta pusilla</i>	Phl/pus	F
<u>Coccinellidae</u>	Coc	
<i>Epilachus varivestis</i>	Epi/var	
<u>Curculionidae</u>	Cur	
<i>Apion</i> sp.	Api/sp.	F
<u>Meloidae</u>	Meo	
<i>Epicauta ferruginea</i>	Epi/fer	F
<i>Epicauta pennsylvanica</i>	Epi/pen	F
<i>Epicauta parva</i>	Epi/par	M-F
<i>Epicauta purinosa</i>	Epi/pru	F
<i>Epicauta stuarti</i>	Epi/stu	F
<i>Nemognatha lurida</i> ^{a/}	Nem/lur	F
<u>Melyridae</u>	Mel	
<i>Listrus</i> sp.	Lis/sp.	F
<u>Nitidulidae</u>	Nit	
<i>Carpophilus</i> sp.	Car/sp.	F
<u>Tenebrionidae</u>	Ten	
<i>Bathrotes canaliculatus</i>	Bot/can	F
<u>DIPTERA</u>	Dip	
<u>Tephritidae</u>	Tep	
<i>Trupanea actinobola</i> ^{a/}	Tru/act	F

Table 9. (Continued)

Insect Names	Symbols	Type of Study
<u>HEMIPTERA</u>	Hem	
<u>Coreidae</u>	Cre	
<i>Chelinidea vittiger</i>	Che/vit	F
<i>Lygaeus reclinatus</i>	Lyg/rec	F
<i>Nysius ericae</i>	Nys/eri	F
<i>Nysius minutus</i>	Nys/min	F
<u>Miridae</u>	Mir	
<i>Chlamydatus asseciatus</i>	Chl/ass	F
<i>Strongylocoris stygius</i>	Str/sty	F
<u>HOMOPTERA</u>	Hom	
<u>Cicadellidae</u>	Cic	
<i>Acerategallia uhleri</i>	Acc/uhl	F
<i>Balclutha neglecta</i>	Bal/neg	F
<i>Cuernia costalis</i>	Cuc/cos	F
<u>Fulgoridae</u>	Ful	
<i>Brucomorpha oculata</i> ^{a/}	Bru/ocu	F
<u>Membracidae</u>	Mem	
<i>Campylenchia latipes</i>	Cam/lat	F
<u>LEPIDOPTERA</u>	Lep	
<i>Pieris protodice</i>	Pie/pro	F

^{a/} Identification uncertain.
 F = Field observation.
 M = Microscopic slide analysis.

Table 10. (Continued)

Insect	Plant Symbols										
	Symbols	CAME	CHNA	CHVI	CIUN	CLSE	DEPI	ERCA	EREF	GUSA	HEAN
<u>COLEOPTERA</u>											
<u>Can</u>											
<u>Cha/lim</u>		41						2	31	21	
<u>Chr</u>											
<u>Aca/vit</u>		15		8					8	15	
<u>Dia/und</u>		2		27				2	3	29	
<u>Nod/pun</u>		16					1	2	8	12	
<u>Phl/pus</u>		5				20	16			19	
<u>Coc</u>											
<u>Epi/var</u>								9		9	
<u>Meo</u>											
<u>Epi/fer</u>			4		3	1			1	78	
<u>Epi/for</u>			2							98	
<u>Epi/par</u>	8										
<u>Epi/pru</u>										97	
<u>Epi/stu</u>									2	97	
<u>Nem/lur</u>					100						
<u>Ten</u>											
<u>Bot/can</u>					31				6	25	
<u>DIPTERA</u>											
<u>Tep</u>											
<u>Tru/act</u>									19	62	
<u>HEMIPTERA</u>											
<u>Cre</u>											
<u>Che/vit</u>											
<u>Lyg/rec</u>					50		10		10		
<u>Nys/eri</u>				8							17
<u>Nys/min</u>											
<u>Mir</u>											
<u>Chl/ass</u>		15								77	
<u>Str/sty</u>										100	
<u>HOMOPTERA</u>											
<u>Cic</u>											
<u>Ace/uhl</u>					33					50	
<u>Bal/neg</u>										1	
<u>Cue/cos</u>		8		2	28			4	1	10	1
<u>Ful</u>											
<u>Bru/ocu</u>		15					5			10	
<u>Mem</u>											
<u>Cam/lat</u>		13			16					13	2
<u>LEPIDOPTERA</u>											
<u>Pie</u>											
<u>Pie/pro</u>					85		15				

A summary of major insect feeders is shown in Table 11. High numbers in this table indicate that few insect species were found there; low numbers indicate a greater variety of insects.

Gutierrezia sarothrae showed the highest number of individual insects that were able to be identified to species. Of 4139 insects observed, 928 or 22% were found on this plant species. The plant species with the second highest total of insects identified to species is *Cirsium undulatum*, with 918 insects or 22% of the total. *Psoralea tenuiflora* had 11%, *Chrysothamnus nauseosus* 9%, and *Artemisia frigida* 6% of the total for the 37 plant species, so that these five species of plants had 70% of the observed insects.

DISCUSSION

Slides Read by Microscopic Technique

Among the five species in the genus *Eleodes*, there was apparently little competition for food because of the large variety of foods taken. From 6 to 25 different food items occurred in the diets of the various species with a range of from 1.9 to 2.8 foods per crop. These results indicate little host plant specificity, insuring a plentiful food supply for these beetles. Several food items were highly preferred for all species within the genus except *Eleodes tricostata*, which had a very small sample size. *Oenothera coronopifolia* was the most highly preferred food item in June when it is succulent and blooming. *Sphaeralcea coccinea*, *Psoralea tenuiflora*, and *Sophora sericea* are additional forbs that were preferred foods during the months when they were green and succulent. *Carex heliophila* and *Bromus*

Table 11. Major species of insects observed on plants at Pawnee Site 1970.

Plant Symbols	Insect Symbol	% ^{a/}	No. ^{b/}	Insect Symbol	%	No.	Insect Symbol	%	No.
AGSM	Cue/cos	26.0	(21)	Cam/lat	2.0	(2)	Nod/pun	2.0	(2)
ARFR	Cue/cos	51.0	(159)	Cam/lat	15.0	(45)	Nod/pun	10.0	(31)
ARLO	Nod/pun	81.0	(52)	Cue/cos	2.0	(1)	Bli/leu	2.0	(1)
ASTA	Lis/sp.	33.0	(3)	Epi/fer	11.0	(1)	Chl/ass	11.0	(1)
ATCA	Cue/cos	39.0	(64)	Dia/und	5.0	(8)	Api/sp.	4.0	(6)
BAOP	Cam/lat	12.0	(202)						
BOGR	Bal/neg	26.0	(66)	Cue/cos	11.0	(27)	Nod/pun	9.0	(22)
CHNA	Cha/lim	23.0	(92)	Cue/cos	22.0	(90)	Cal/lat	20.0	(79)
CHVI	Cue/cos	41.0	(24)	Cro/dis	7.0	(4)	Lis/sp.	7.0	(4)
CIUN	Car/sp.	26.0	(341)	Cue/cos	25.0	(327)	Cam/lat	7.0	(96)
CLSE	Phl/pus	22.0	(21)	Api/sp.	4.0	(4)			
DEPI	Phl/pus	6.0	(16)	Nod/pun	1.0	(2)	Pie/pro	1.0	(2)
ERCA	Cue/cos	69.0	(49)	Nod/pun	7.0	(5)	Cha/lim	7.0	(5)
EREF	Cha/lim	40.0	(70)	Nod/pun	15.0	(26)	Cue/cos	7.0	(12)
GUSA	Epi/stu	25.0	(320)	Cue/cos	10.0	(123)	Cam/lat	8.0	(109)
HEAN	Cam/lat	22.0	(10)	Cue/cos	13.0	(6)	Lis/sp.	2.0	(1)
LEDE	Phl/pus	30.0	(25)	Cue/cos	7.0	(6)	Nod/pun	2.0	(2)
LIPU	Epi/fer	47.0	(8)	Nod/pun	12.0	(2)	Cue/cos	12.0	(2)
MILI	Cue/cos	9.0	(8)	Sco/sec	3.0	(3)	Dia/vir	1.0	(1)
OECO	Nod/pun	57.0	(13)	Cue/cos	26.0	(6)	Aca/vit	4.0	(1)
OPPO	Che/vit	45.0	(79)	Car/sp.	36.0	(64)	Lis/sp.	13.0	(23)
OXSE	Epi/par	59.0	(20)						
PSTE	Cue/cos	35.0	(222)	Api/sp.	23.0	(149)	Nod/pun	4.0	(26)
SIHY	Nys/min	40.0	(16)	Nod/pun	20.0	(8)	Bru/ocu	5.0	(2)
STCO	Nod/pun	67.0	(31)	Cha/lim	7.0	(3)	Bal/neg	2.0	(1)
VEBR	Cam/lat	82.0	(42)	Cue/cos	10.0	(5)			

^{a/} Signifies percent of insects on plant in relation to the total.
^{b/} Signifies number of insects making up the percent.

tectorum were preferred grasses by these species, and *Bouteloua gracilis* was preferred by *Eleodes tricostata*. It appeared that forbs were generally preferred to grasses or shrubs. Fungus appeared in the diet of four of the beetles, possibly taken inadvertently with plant materials. Moss occurred in three of the diets and was a major food for *Eleodes extricata* in July, accounting for 18% of the diet, suggesting that this may be a preferred food item. Insect parts appeared in four of the diets, probably as a result of the beetles' scavenging activities. A lichen appeared as 6% of the June diet of *Eleodes extricata* and could be a preferred food item.

The meloid beetles studied had more selective feeding habits that were closely timed with the flowering of their food plants; *Epicauta parva* fed on only 11 species of plants, indicating high specificity in feeding. The foods preferred were almost exclusively the flowers and foliage of the legumes *Sophora sericea* and *Oxytropis* spp.

The carabid beetle *Cratacanthus dubius* is usually presumed to be predaceous, but was shown in this study to choose primarily abundant grasses with insect parts making up a small portion of the diet. Carabid beetles are generally found in moist regions and are supplanted in arid regions by the euryphagous tenebrionid beetles. Possibly this species has been able to compete successfully by becoming less selective in its food habits, taking both plant and animal materials.

The cerambycid beetle *Moneilema annulata* has long been known to feed primarily on *Opuntia* spp. and in this study did choose cactus for 67% of the diet, although it often fed on *Sphaeralcea coccinea* also.

Field Observations

The cantharid beetle *Chauliognathus limbicollis*^{2/} was observed on ten plant species, primarily *Chrysothamnus nauseosus*, *Eriogonum effusum*, and *Gutierrezia sarothrae*.

Diabrotica undecimpunctata was observed on eight plant species, chiefly *Gutierrezia sarothrae*, *Cirsium undulatum*, and *Psoralea tenuiflora*.

Nodonota puncticollis was observed on 20 species of plants including grasses, forbs, and shrubs. *Aristida longiseta*, *Chrysothamnus nauseosus*, and *Gutierrezia sarothrae* were frequented.

Phyllotreta pusilla was observed on ten different species of plants, chiefly *Lepidium densiflorum*, *Cleome serrulata*, *Gutierrezia sarothrae*, and *Descurainia pinnata*. Swarming on these plants was obvious and they are probably used for egg deposition.

The meloid beetle *Epicauta ferruginea* was observed on eight plant species, *E. pruinosa* on two, *E. pennsylvanica* on two, *E. stuarti* on three, and *E. parva* on three plants. All species but *E. parva* were observed almost entirely on the flowers of *Gutierrezia sarothrae*. *E. parva* was observed almost entirely on *Oxytropis sericea*. *Nemognatha lurida*^{3/} was observed entirely on *Cirsium undulatum* at the time of its flowering. All of the meloids have apparently adapted their life cycles to the time of flowering of their food and host plants. There may also be interaction with the timing of grasshopper emergence since some of the meloid larvae feed on grasshopper eggs.

Carpophilus pallipennis was observed on two species of plants, *Cirsium undulatum* and *Opuntia polyacantha*. These beetles and their larvae were

^{2/} Identification uncertain.

^{3/} Identification uncertain.

also seen feeding within the flowers of these plants, apparently on the souring plant fluids, pollen, nectar, and fungus if present. This species and a species of the genus *Listrus* were often found together in the flowers in large numbers.

The tephritid fly, *Trupanea actinobola*, was observed on four species of plants, primarily *Gutierrezia sarothrae* where it possibly was ovipositing in the plant stems.

The bug *Chelinidea vittiger* was observed on two plants, but 99% of the time was on *Opuntia polyacantha*. Both nymphs and adults fed together on the cactus, and eggs were laid on the spines of the cactus.

The leafhopper *Balclutha neglecta* was observed on five species of plants, but *Bouteloua gracilis* was frequented 94% of the time. It is possible that this leafhopper is closely restricted to feeding on *Bouteloua* spp. since it has also been associated with black grama grass.

The leafhopper *Cuernia costalis* was observed on 27 species of plants including grasses, forbs, and shrubs, but was chiefly on *Cirsium undulatum* and *Psoralea tenuiflora*. This was by far the most abundant insect observed during this study. It apparently was more selective for host plants in which to lay its eggs, swarming to perennial plants such as *Artemisia frigida*, *Cirsium undulatum*, and *Psoralea tenuiflora*. The nymphs and adults were together on the same plants.

The treehopper *Campylenchia latipes* was observed on 11 species of plants, chiefly *Cirsium undulatum*, as adults while the nymphs were found on *Bahia oppositifolia*, *Gutierrezia sarothrae*, and *Chrysothamnus nauseosus*.

The above species by virtue of their numbers appear to be very well adapted to the arid climate at the Pawnee Site and to the vegetation there.

These successful species are not highly host specific or competitive and can thus survive in an area of relatively sparse vegetation. A great many more species not discussed are also successful at the Pawnee Site, but were either too small or not sedentary enough to be observed.

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APPENDIX I

FIELD DATA

Data on insect/host relationships were collected on the Pawnee Site and are stored as Grassland Biome Data Set A2U301B. Data were recorded in the following format.

<u>Column</u>	<u>Contents</u>
1-2	Data type
3-4	Site (11 = Pawnee)
5-7	Initials
8-9	Day
10-11	Month
12-13	Year
14	Treatment (code)
15	Replicate
23	Trophic level of insect (code)
25-29	Host (first two letters of genus and species)
31-33	Order of insect
35-37	Family of insect
39-41	Genus of insect
42-44	Species of insect
45	Subspecies of insect
47-48	Life stage of insect (code)
50-55	Number of individuals of this insect taxon on this host

<u>Column</u>	<u>Contents</u>
57-62	Number of times this number of insects of this taxon seen on this host (if left blank, assume 1)
73-80	Sequence number in data deck

Codes Used in Data

TROPHIC

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

TREATMENT

- 1 Ungrazed
- 2 Lightly grazed
- 3 Moderately grazed
- 4 Heavily grazed
- 5 Grazed 1969, ungrazed 1970

LIFE STAGE

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

An example of the data follows.

3711VAY09067024	3	SPCO	HYM	AND	10	1	3
3711VAY09067024	1	CAHF	COL	CHR	10	1	
3711VAY09067024	1	SCPR	COL	CHR	10	1	
3711VAY09067024	3	SPCO	HYM	FOR	10	2	2
3711VAY09067024	2	SETR	THP		10	1	3
3711VAY09067024	1	SETR	COL	CUR	10	1	2
3711VAY09067024	2	SETR	HOM	CIC	10	1	3
3711VAY09067024	3	SETR	HYM		10	1	2
3711VAY09067024	5	HOGP	COL	COC	10	1	
3711VAY09067024	5	ARFR	COL	COC	10	1	
3711VAY09067024	5	ERFF	COL	COC	10	1	
3711VAY16067018	2	SETR	HEM	MTR	40	2	3
3711VAY180670	2	CTUN	HOM	CIC	42	1	
3711VAY180670	1	CTUN	COL	CUR	10	1	
3711VAY180670	3	CTUN	COL	MEO	10	2	2
3711VAY180670	3	CTUN	COL	MEO	10	3	2
3711VAY180670	1	CTUN	COL	CHR	10	1	
3711VAY180670	3	CTUN	HYM	HAL	10	1	3