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FOOD HABITS OF FOUR SPECIES OF RODENTS ON A SHORT-GRASS PRAIRIE IN COLORADO

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ABSTRACT.—Food habits of four rodents (*Dipodomys ordii, Onychomys leucogaster, Peromyscus maniculatus*, and *Spermophilus tridecemlineatus*) of a short-grass prairie ecosystem in northeastern Colorado were studied in 1969 and 1970 through microscopic analysis of stomach contents. Mean per cent volumes of animal matter in diets of these rodents over the entire study were: *D. ordii*, 4.4 per cent; *O. leucogaster*, 73.9 per cent; *P. maniculatus*, 39.0 per cent; and *S. tridecemlineatus*, 44.0 per cent. The greatest amount of seasonal variation in per cent volume animal matter in the diet was in *P. maniculatus*. Animal matter in diets of all four species was composed almost entirely of arthropods and a few parts of vertebrates. The most common arthropods included adult and larval Coleoptera, larval Lepidoptera, and grasshoppers (except in *D. ordii*). Plant matter in the diets of all species included leaves, stems, and flowering parts of various species of grasses, sedges, forbs, and shrubs, seeds (unidentified), and tissues of mosses, lichens, and fungi. Seeds were the most common type of plant matter in diets of *D. ordii* and *P. maniculatus*, whereas plant matter in *S. tridecemlineatus* and *O. leucogaster* was more equally divided between seeds and nonseed parts of grasses (and sedges) and forbs. Much seasonal variation in types and relative amounts of different kinds of plant and animal matter was noted.

Information on food habits of rodents in short-grass and mixed-grass prairies, such as occur in eastern Colorado, is limited. Because food habits reveal much about the niche of a species, stomach analyses were undertaken on four dominant species of rodents in the short-grass prairies of northeastern Colorado. These species were Ord's kangaroo rat (*Dipodomys ordii*), northern grasshopper mouse (*Onychomys leucogaster*), prairie deer mouse (*Peromyscus maniculatus*), and thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*). Other rodents captured or seen but not included in this study include the silky pocket mouse (*Perognathus flavus*), hispid pocket mouse (*Perognathus hispidus*), muskrat (*Ondatra zibethicus*), western harvest mouse (*Reithrodontomys megalotis*), northern pocket gopher (*Thomomys talpoides*), and black-tailed prairie dog (*Cynomys ludovicianus*).

The study area was located within the boundaries of the western division of the Pawnee National Grassland, an area of 42,494 hectares in northeastern Colorado. Most sampling occurred in the western half of the grasslands, near or in the Central Plains Experimental Range. Vegetation in this area is classified as short-grass prairie and has been described by Klipple and Costello (1960), Hyder *et al.* (1966), and Daniel W. Uresk (unpublished data, Range Science Department, Colorado State University, Fort Collins).

Native short-grass prairie in the study area was composed primarily of blue grama (*Bouteloua gracilis*), buffalo grass (*Buchloe dactyloides*), and sun sedge (*Carex heliophila*). Other associated grasses included western wheat-

grass (*Agropyron smithii*), red three-awn (*Aristida longiseta*), and needle and thread (*Stipa comata*). The commonest perennial forbs included scarlet globemallow (*Sphaeralcea coccinea*), slim flower scurfpea (*Psoralea tenuiflora*), slenderbush eriogonum (*Eriogonum effusum*), scarlet gaura (*Gaura coccinea*), and plains prickly pear (*Opuntia polycantha*). Bee spiderflower (*Cleome serrulata*), evening primrose (*Oenothera*), and slim-leaf goosefoot (*Chenopodium leptophyllum*) are a few of the characteristic annual forbs. Shrubs include broom snakeweed (*Gutierrezia sarothrae*), fringed sagewort (*Artemisia frigida*), rubber rabbitbush (*Chrysothamnus nauseosus*), and saltbush (*Atriplex canescens*).

Methods and Procedures

Lines of snap-traps (museum specials and rat traps) were used for several days each month from May 1969 through April 1970 to capture rodents for this study. Traps were baited with a mixture of peanut butter and oatmeal, and tended once each morning or more often as needed in hot weather. Trap-line areas were chosen at my discretion and were not random because it proved difficult to obtain adequate sample sizes in particular areas. However, each trap-line generally included a variety of prairie subhabitats (upland, lowland, gullies, for example) within it, thus providing a broad sampling of the prairie. Animals were taken to the laboratory where their stomachs were removed and preserved in 70 per cent alcohol for later analysis.

Stomach contents were examined under a dissecting microscope and animal matter identified from undigested parts such as chitonous body walls and appendages, hair, and lizard scales. Types of animal matter were estimated in per cent volume of total animal matter (per cent composition) rankings as follows: 1 (1 to 20 per cent), 2 (21 to 40 per cent), 3 (41 to 60 per cent), 4 (61 to 80 per cent), and 5 (81 to 100 per cent) and averages computed using the midpoints of these rankings. Therefore, these values do not represent per cent composition of total stomach contents. Total animal matter as compared with plant matter in each stomach was estimated using this same volume ranking plus an additional ranking of zero per cent. All values were computed for the entire study and for periods of 2 months.

Although it is difficult to separate ingested plant and animal matter, some good clues are available. Animal matter generally has less cell structure and is more translucent than plant matter. Moreover, much of the ingested animal matter remains connected with appendages, chiton, and hair, for example, revealing its nature. These observations agree with those of Harriss (1950). Hair alone was not included in the rankings as stomachs often contained large amounts of self-ingested hair.

Use of midpoints above for determining average per cent volumes of plant matter yielded values too low for *D. ordii* because many individuals contained 100 per cent plant matter. For this reason, per cent volume values for plant matter in *D. ordii* were obtained by subtracting the per cent volume animal matter values from 100 and rounding to the nearest whole number.

Following the above analyses, stomach contents were oven-dried and then ground in a Wiley laboratory mill. Slides were made using Hertwig's and Hoyer's solutions as described in Hansen and Flinders (1969). Twenty fields were examined under the compound microscope (10×) on each slide and the frequency percentage of different species of plants and of less specific categories such as lichens, fungi, and seeds recorded. Plant tissues were identified from reference slides of plant tissues from the study area. Per cent frequency was converted to density using a table developed by Fracker and Brischle (1944), then converted to per cent dry weight using a formula developed by Sparks and

Malechek (1968). A more detailed discussion of these microtechnique procedures is found in Hansen and Flinders (1969). Oven drying reduced animal matter to a negligible proportion of total dry weight; therefore, per cent dry weight represents plant matter only and is not based on total stomach contents. Per cent composition of the total diet of different types of plant and animal matter was estimated by multiplying the per cent composition (animal matter) or per cent dry weight (plant matter) times the fraction of animal or plant matter in the diet for that particular period.

Dipodomys ordii

Ord's kangaroo rats are primarily herbivorous, eating large amounts of seeds along with succulent leaves of grasses, forbs, and shrubs, and a few arthropods (Johnson, 1961; Wood, 1969). At the Pawnee National Grassland mean stomach contents of *D. ordii* for the entire study ($N = 216$) consisted of only 4.4 ± 0.6 (± 1 SE) per cent volume of animal matter, almost all arthropods (Table 1). Per cent volume animal matter ranged from 1.5 to 10.4 and was highest in winter, spring, and early summer and lowest from mid-summer through late autumn and early winter (Fig. 1). The cause for variation in amounts of animal matter in the diet probably was due to changes in availability of plant and animal matter, although information on seasonal availability of many types of food is not available. Adult Coleoptera and larvae of Lepidoptera and Coleoptera were, in that order, the most prevalent types of animal matter in the diet (Table 1). Larvae of Lepidoptera and Coleoptera were commonest in the diet during spring and early summer and dropped sharply by the middle of summer (Table 2). This may be explained by a decrease in larval food with drying up of the prairie and an increase in availability of new seeds (personal observations). Adult beetles were most important in the diet from the middle of winter through the middle of spring, whereas beetle populations generally peaked in the summer months and were apparently low during winter and early spring (French, 1971). Increase in adult beetles in the diet apparently does not correspond with peak beetle populations. No grasshoppers were found in stomachs of *D. ordii*.

Per cent volume plant matter in the diet averaged 96 per cent over the entire study. Values for sample periods were: May to June (93), July to August (99), September to October (98), November to December (98), January to February (92), and March to April (90). These changes through time are not graphed as was animal matter (Fig. 1) because approximately the same phenomenon would be illustrated. As explained in the methods and procedures, these are approximate values obtained in a different manner than the values shown for the remaining species. Tissues of grasses, sedges, forbs, shrubs, fungi, lichens, and mosses were present in the diet (Table 1). Grass, sedge, forb, and shrub tissues identified were epidermal tissues of leaves, stems, or flowering parts and did not include seeds. Seeds formed the predominant portion of the diet although identifications of species was not undertaken in this study. Forbs were always present in lesser amounts than seeds and were most important in late spring and early summer (Table 2).

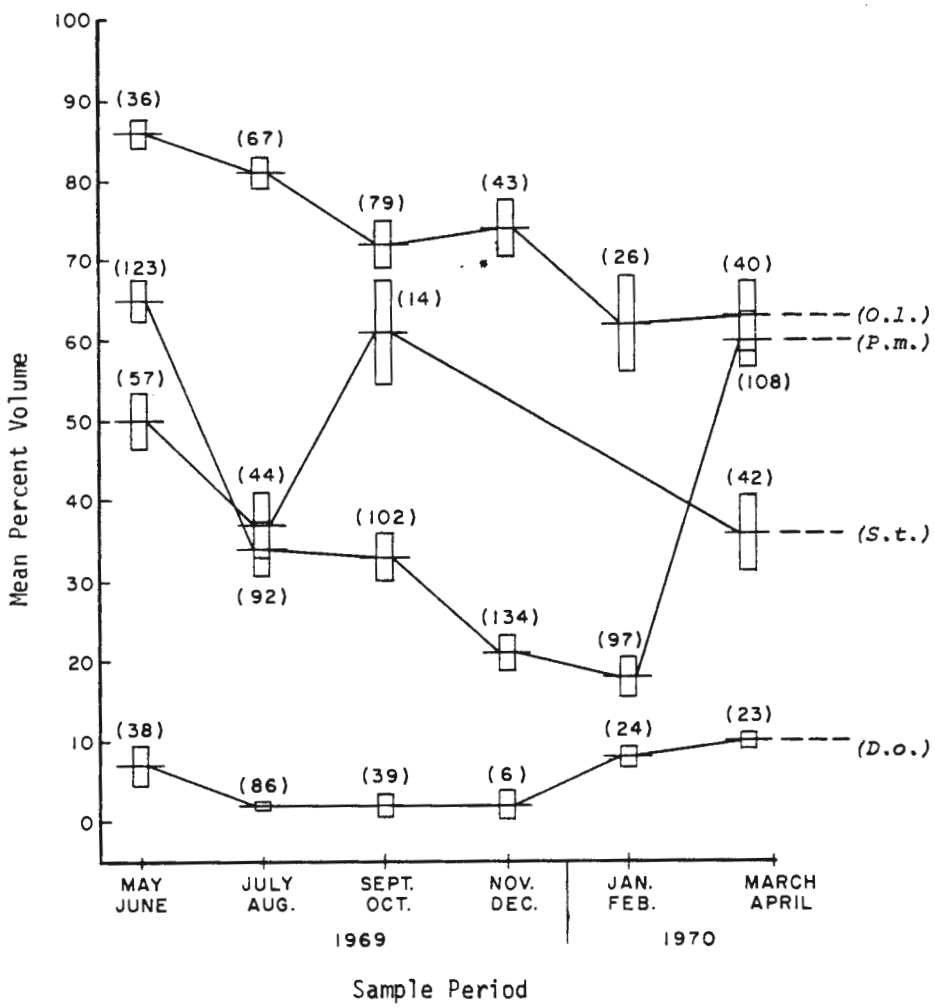

FIG. 1.—Mean per cent volume of animal matter in stomach contents of *Dipodomys ordii* (D.o.), *Onychomys leucogaster* (O.l.), *Peromyscus maniculatus* (P.m.), and *Spermophilus tridecemlineatus* (S.t.) through sample periods (lines between rectangles connect means, rectangles represent one standard error on each side of mean, and numbers in parentheses equal to sample size).

Onychomys leucogaster

Animal matter in the stomach contents of *O. leucogaster* ($N = 291$) averaged 73.9 ± 1.4 (± 1 SE) per cent volume. High percentages of animal matter and limited amounts of plant matter have previously been recorded in *Onychomys* by Bailey and Sperry (1929), Bailey (1931), Cochrum (1952), and Johnson (1961). At the Pawnee National Grassland, highest percentages of animal

matter were found in the diet in late spring and early summer and lowest levels in mid-winter, with a range of 61.5 to 85.6 per cent (Fig. 1).

Important forms of animal matter included adults and larvae of Coleoptera, grasshoppers, larval Lepidoptera, and spiders (Table 1). In addition, vertebrate tissue, primarily of the rodents *P. maniculatus* and other *O. leucogaster*, as well as feathers and lizard skin, were present. Vertebrate remains were commonest from mid-autumn through the middle of winter and likely increased in importance with decrease in availability of many arthropods (French, 1971, and personal observations). Northern-grasshopper mice sometimes ate dead rodents in nearby traps, so it is unclear how much of this was natural predation. The presence of similar vertebrate tissues in the diets of *Onychomys* has been recorded by Bailey and Sperry (1929), Bailey (1931), Cochrum (1952), and Johnson (1961); and Lechleitner (1969) recorded that they killed and ate other mice.

Adult Coleoptera were found in highest concentrations in the diet from the middle of summer through the middle of winter and in lowest amounts in spring and early summer, whereas larvae of Lepidoptera and Coleoptera were most prevalent in late spring and early summer (Table 2). Grasshoppers were present in the diet in substanial numbers throughout the year, increasing through summer and peaking in early autumn, in concordance with a general increase of grasshoppers in the study area (French, 1971). Adult beetles were more important in the diet of *O. leucogaster* than were grasshoppers. In contrast, Bailey and Sperry (1929) found grasshoppers to be the most important arthropod in *O. leucogaster*, with adult beetles second.

Per cent volume plant matter in stomachs of *O. leucogaster* averaged 25.3 ± 1.4 (± 1 SE) over the entire study. Values through sample periods were: May to June (14.4 ± 1.8), July to August (18.2 ± 2.0), September to October (25.7 ± 2.9), November to December (26.0 ± 3.8), January to February (38.1 ± 6.1), and March to April (37.0 ± 4.3). Forbs, grasses and sedges, and seeds were about equal in per cent dry weight of the diet (Table 1). Seeds increased in the diet from autumn through the middle of winter, probably in response to lower populations of arthropods (Table 2). Shrubs were more abundant in the sample for March and April than during other periods.

Peromyscus maniculatus

Food consumed by *P. maniculatus* may contain large amounts (more than 50 per cent) of animal matter, primarily arthropods, with the amounts of animal matter varying greatly between seasons with change in abundance of arthropods (Jameson, 1952; Williams, 1959; Johnson, 1961; and Whitaker, 1966). Over the entire study at the Pawnee National Grassland, 39.0 ± 1.3 (1 SE) per cent volume of total stomach contents ($N = 656$) was composed of animal matter, mostly arthropods. The highest amount occurred in spring and early summer and the lowest in the middle of winter, with a greater range of variation in *P. maniculatus* than in the other rodents (Fig. 1). Larvae and

TABLE 1.—*Mean per cent composition* of animal matter, mean per cent dry weight of plant matter, and mean per cent composition of total matter (in parentheses) in stomach contents of four rodents.*

Type of Animal or Plant Matter	*D. ordii* N = 216		*O. leucogaster* N = 291		*P. maniculatus* N = 656		*S. tridecemlineatus* N = 158	
Insects								
Diptera adult	1.3	(0.1)	1.0	(0.7)	1.2	(0.5)	0.2	(0.1)
Coleoptera								
Adult	35.5	(1.6)	40.4	(29.9)	25.2	(9.8)	35.4	(15.6)
Egg	—		0.3	(0.2)	0.6	(0.2)	0.3	(0.1)
Larva	6.5	(0.3)	12.5	(9.2)	12.3	(4.8)	16.2	(7.1)
Hemiptera								
Leaf hopper	1.7	(0.1)	2.2	(1.6)	11.9	(4.6)	1.1	(0.5)
Hymenoptera								
Ant	0.5	(**)	0.9	(0.7)	0.5	(0.2)	3.9	(1.7)
Ant egg	—		0.1	(0.1)	—		—	
Ant pupa	—		**		—		0.7	(0.3)
Lepidoptera								
Adult	0.5	(**)	0.2	(0.2)	4.8	(1.9)	0.1	(**)
Larva	27.2	(1.2)	6.1	(4.5)	15.5	(6.0)	10.8	(4.8)
Orthoptera								
Cricket	—		0.2	(0.2)	0.9	(0.4)	0.1	(**)
Grasshopper	—		25.3	(18.7)	14.3	(5.6)	26.5	(11.7)
Siphonoptera	1.3	(0.1)	0.3	(0.2)	—		—	
Other arthropods								
Spiders	1.7	(0.1)	4.4	(3.3)	6.2	(2.4)	3.2	(1.4)
Centipeds	—		**		0.2	(0.1)	—	
Unidentified	21.6	(1.0)	0.6	(0.4)	4.4	(1.7)	0.6	(0.3)
Total arthropods	97.8	(4.3)	94.7	(70.0)	99.2	(38.7)	99.1	(43.6)
Vertebrates								
Tissue of small animals	0.9	(**)	2.7	(2.0)	0.9	(0.4)	1.5	(0.7)
Feathers	—		0.1	(0.1)	—		—	
Lizard tissue	—		0.6	(0.4)	—		—	
Total vertebrates	0.9	(**)	3.4	(2.5)	1.1	(0.4)	1.5	(0.7)
Forbs								
Allium textile	**		0.1	(**)	**		—	
Astragalus	1.4	(1.3)	1.6	(0.4)	0.9	(0.5)	4.0	(2.2)
Bahia oppositifolia	**		0.1	(**)	0.1	(0.1)	0.5	(0.3)
Chrysopsis villosa	—		—		—		**	
Cirsium undulatum	**		**		—		0.8	(0.4)
Descurainia pinnata	—		—		**		—	
Descurainia sophia	**		—		0.1	(0.1)	—	
Dyssodia papposa	—		—		**		—	
Erigeron canadensis	—		—		—		**	
Erigeron divergens	**		0.1	(**)	—		0.2	(0.1)
Eriogonum effusum	—		0.3	(0.1)	0.2	(0.1)	—	
Helianthus annuus	—		0.4	(0.1)	**		1.0	(0.5)
Kochia scoparia	4.7	(4.5)	4.1	(1.0)	6.0	(3.6)	1.7	(0.9)
Lathyrus eucosmus	—		—		0.4	(0.2)	1.8	(1.0)
Lesquerella ludoviciana	—		—		**		**	
Leucocrinum montanum	1.0	(1.0)	—		0.3	(0.2)	0.1	(0.5)
Lithospermum incisum	—		0.1	(**)	—		—	
Marrubium vulgare	—		0.2	(0.1)	—		—	
Medicago sativa	1.9	(1.8)	0.1	(**)	—		—	
Mentzelia nuda	0.2	(0.2)	—		0.2	(0.1)	—	
Mirabilis linearis	—		—		0.2	(0.1)	0.6	(0.3)
Musineon divaricatum	—		—		—		2.5	(1.4)
Oenothera coronopifolia	**		0.6	(0.2)	0.2	(0.1)	0.1	(0.1)
Opuntia polycantha	**		0.1	(**)	0.3	(0.2)	2.0	(1.1)
Oxytropis lambertii	0.1	(0.1)	0.2	(0.1)	0.3	(0.2)	—	
Petalostemon candidus	—		—		—		0.3	(0.2)
Plantago purshii	—		—		0.1	(0.1)	—	
Psoralea tenuiflora	—		0.3	(0.1)	—		—	
Salsola kali	1.9	(1.8)	0.7	(0.2)	0.1	(0.1)	0.3	(0.2)
Senecio multicapitatus	—		0.2	(0.1)	—		2.2	(1.2)
Solanum rostratum	0.1	(0.1)	0.5	(0.1)	0.1	(0.1)	—	
Sophora sericae	0.1	(0.1)	0.5	(0.1)	0.3	(0.2)	1.9	(1.0)
Sphaeralcea coccinea	0.4	(0.4)	14.0	(3.5)	2.9	(1.7)	4.7	(2.6)
Tradescantia occidentalis	1.2	(1.2)	0.3	(0.1)	0.4	(0.2)	5.8	(3.2)
Tribulus terrestris	**		—		—		—	
Verbena bracteata	—		—		**		—	
Viola nuttallii	—		—		—		**	
Unknown forbs	0.1	(0.1)	1.6	(0.4)	0.2	(0.1)	5.6	(3.1)
Total forbs	13.4	(12.9)	26.1	(6.6)	13.2	(7.8)	36.2	(19.7)

TABLE 1.—*Continued.*

Type of Animal or Plant Matter	*D. ordii* N = 216		*O. leucogaster* N = 291		*P. maniculatus* N = 656		*S. tridecemlineatus* N = 158	
Grasses and sedges								
Agropyron cristatum	—		0.9	(0.2)	0.3	(0.2)	—	
Agropyron smithii	0.5	(0.5)	2.3	(0.6)	0.8	(0.5)	0.4	(0.2)
Andropogon hallii	—		0.1	(**)	—		—	
Aristida longiseta	**		0.5	(0.1)	0.1	(0.1)	**	
Bouteloua gracilis	3.7	(3.6)	19.8	(5.0)	2.2	(1.3)	13.1	(7.0)
Bromus inermis	—		—		0.5	(0.3)	0.2	(0.1)
Buchloe dactyloides	—		—		**		**	
Carex heliophila	0.1	(0.1)	2.4	(0.6)	1.5	(0.9)	5.0	(2.7)
Festuca octoflora	—		—		—		0.5	(0.3)
Muhlenbergia torreyi	—		—		**		**	
Oryzopsis hymenoides	—		0.1	(**)	—		—	
Schedonnardus paniculatus	—		0.1	(**)	—		—	
Sporobolus cryptandrus	0.7	(0.7)	1.5	(0.4)	0.1	(0.1)	0.7	(0.4)
Unknown grasses	0.2	(0.2)	0.5	(0.1)	0.2	(0.1)	0.8	(0.4)
Total grasses and sedges	5.2	(5.0)	28.1	(7.1)	5.7	(3.4)	13.8	(7.5)
Shrubs								
Artemisia frigida	0.5	(0.5)	6.2	(1.6)	2.3	(1.4)	5.0	(2.7)
Atriplex canescens	0.9	(0.9)	0.3	(0.1)	1.2	(0.7)	1.4	(0.8)
Chrysothamnus nauseosus	—		0.2	(0.1)	—		0.1	(0.5)
Eurotia lanata	—		0.2	(0.1)	0.1	(0.1)	0.1	(0.1)
Total Shrubs	1.3	(1.2)	6.9	(1.7)	3.7	(2.2)	6.5	(3.5)
Fungi (*Endogone*)	1.6	(1.5)	2.9	(0.7)	1.8	(1.1)	8.1	(4.4)
Lichens	**		1.2	(0.3)	0.7	(0.4)	1.7	(0.9)
Mosses	0.5	(0.5)	0.2	(0.1)	0.1	(0.1)	0.7	(0.4)
Seeds	77.3	(74.2)	26.4	(6.6)	65.7	(39.0)	21.6	(11.8)

* Animal matter per cent composition equal to per cent volume of each item of total animal matter in stomachs, not of total stomach matter.
** < .05.

adults of Lepidoptera and Coleoptera, as well as grasshoppers, spiders, and leaf hoppers were prominent (Table 1). Over the entire study, adult Coleoptera were the dominant arthropod, while, in Indiana, Whitaker (1966) found larval Lepidoptera to be the predominant type of animal matter in *P. maniculatus* and adult Coleoptera a distant second. He found various other types of arthropods in the diet, but grasshoppers were scarce. Previous studies by Hamilton (1941), Jameson (1952), Williams (1959), Johnson (1961), and Whitaker (1966) demonstrated that *P. maniculatus* is highly opportunistic, eating the particular types of animal and plant materials most available. This leads to substantial regional variation in diet and perhaps reflects the adaptability and broad distribution of *P. maniculatus*.

The larvae of Lepidoptera and Coleoptera were noticeably abundant in the diet in spring and early summer, and grasshoppers were generally most important from mid-summer through early autumn although they did show a peak in the period, March to April (Table 2). Leaf hoppers were more prevalent in diets of *P. maniculatus* than in the other species and reached peak levels in late winter and early spring. Total arthropods followed the same seasonal patterns as found in *O. leucogaster* and *D. ordii*.

Throughout the study, stomach contents of *P. maniculatus* consisted of 59.4 ± 1.3 (± 1 SE) per cent volume plant matter with sample period values as follows: May to June (33.7 ± 2.6), July to August (64.2 ± 3.2), September to October (65.4 ± 3.0), November to December (77.8 ± 2.1), January to February (80.3 ± 2.3), and March to April (37.5 ± 3.0). Seeds were the major type

TABLE 2.—*Mean per cent composition of major types of animal and plant matter in stomach contents of rodents through sample periods. Categories composing less than three per cent dry weight of plant matter or per cent composition of animal matter over the entire study not included.*

Rodents and major components of diet	1969 May–June	1969 July–August	1969 September–October	1969 November–December	1970 January–February	1970 March–April
D. ordii	$N = 38$	$N = 86$	$N = 39$	$N = 6$	$N = 24$	$N = 23$
Animal matter						
Coleoptera adults	—	0.2	—	—	5.0	7.1
Coleoptera larvae	1.0	—	0.2	—	—	1.0
Lepidoptera larvae	4.6	0.5	0.8	—	—	1.6
Plant matter						
Seeds	55.5	71.5	86.7	92.9	84.5	76.2
Total forbs	30.5	14.0	7.6	4.1	0.2	3.6
Kochia scoparia	11.1	6.1	0.3	0.5	—	—
Total grasses and sedges	3.0	9.6	2.1	0.7	2.0	1.2
Bouteloua gracilis	1.6	7.4	2.0	0.7	0.1	0.3
O. leucogaster	$N = 36$	$N = 67$	$N = 79$	$N = 43$	$N = 26$	$N = 40$
Animal matter						
Coleoptera adults	17.4	36.5	30.7	41.0	29.0	20.7
Coleoptera larvae	38.8	16.4	—	—	—	1.7
Grasshoppers	10.2	18.1	27.2	22.0	12.3	13.4
Lepidoptera larvae	17.8	2.0	1.2	—	2.3	12.1
Spiders	2.4	2.9	2.5	4.9	3.3	4.3
Total vertebrates	0.6	1.8	0.7	4.6	9.3	1.7
Plant matter						
Seeds	2.7	3.5	6.1	10.8	13.4	10.2
Total forbs	6.5	5.2	7.0	8.3	5.5	1.6
Kochia scoparia	0.6	1.2	1.3	0.6	1.6	—
Sphaeralcea coccinea	5.0	1.9	2.7	5.8	2.4	1.6
Total grasses and sedges	3.2	6.2	9.4	4.6	6.7	8.9
Bouteloua gracilis	2.6	5.6	7.2	3.1	2.2	1.4
Total shrubs	0.8	0.6	0.7	1.1	0.7	10.8
Artemisia frigida	0.6	0.4	0.5	1.1	0.2	10.8
P. maniculatus	$N = 123$	$N = 92$	$N = 102$	$N = 134$	$N = 97$	$N = 108$
Animal matter						
Coleoptera adults	10.9	10.8	9.8	7.6	4.8	11.0
Coleoptera larvae	24.4	1.4	1.1	0.2	0.1	3.6
Grasshoppers	2.6	5.7	7.7	5.1	2.5	6.4
Leaf Hoppers	0.1	3.4	1.7	2.1	7.0	13.3
Lepidoptera adults	2.1	4.4	1.3	0.2	0.5	2.3
Lepidoptera larvae	17.6	1.3	1.0	0.5	1.3	19.4
Spiders	2.8	2.5	2.4	2.5	0.3	2.6
Plant matter						
Seeds	11.4	40.3	47.8	65.7	65.4	22.5
Total forbs	9.5	10.4	4.8	6.3	4.3	4.7
Kochia scoparia	3.6	6.7	3.1	3.2	0.6	1.9
Total grasses and sedges	1.7	3.5	4.3	1.3	4.8	4.0
Total shrubs	1.7	1.1	0.9	0.6	2.6	3.8
S. tridecemlineatus	$N = 57$	$N = 44$	$N = 14$			$N = 42$
Animal matter						
Ants	3.6	0.9	2.6			0.4
Coleoptera adult	18.1	14.5	17.6			15.0
Coleoptera larvae	10.5	10.2	5.7			0.3
Grasshoppers	8.1	7.9	37.7	hibernating		13.4
Lepidoptera larvae	11.0	2.5	1.3			1.2
Spiders	2.0	0.5	1.8			1.7
Plant matter						
Fungi	9.0	3.1	0.2			0.3
Seeds	7.2	16.2	10.5			13.6
Total forbs	18.6	25.7	15.0			17.1
Astragalus	3.6	1.7	1.0			0.8
Sphaeralcea coccinea	2.7	2.8	4.4			1.0
Tradescantia occidentalis	1.3	1.5	3.2			7.6
Total grasses and sedges	10.0	15.4	12.6			13.8
Bouteloua gracilis	6.6	12.3	9.6			1.3
Carex heliophila	1.7	0.5	0.9			7.3
Total shrubs	1.9	0.9	—			10.3
Artemisia frigida	0.8	0.5	—			9.2

of vegetative matter in the diet of *P. maniculatus* (Table 1), as has previously been shown by Hamilton (1941), Jameson (1952), Williams (1959), Johnson (1961), and Whitaker (1966). At the Pawnee National Grassland, forbs were at peak levels from late spring through the middle of summer, whereas seeds reached peak levels in late autumn and winter (Table 2). Seeds were at lowest levels in spring and early summer when arthropods and other plant foods (forbs and new growth of shrubs) were abundant and few seeds had ripened.

Spermophilus tridecemlineatus

The omnivorous nature of *S. tridecemlineatus* has been reported by Bailey (1893), Lantz (1904), Johnson (1917), Fitzpatrick (1925), Hisaw and Emery (1927), Schmidt (1931), Criddle (1939), and Whitaker (1972); occasional predation on other vertebrates has been recorded by Bailey (1923) and Bridgewater and Penny (1966). Fitzpatrick (1925) noted a range of 25 to 80 per cent insect matter in the stomach contents, with highest amounts through summer and into early autumn and lowest percentages in early spring after emergence from hibernation. At the Pawnee National Grassland stomachs of thirteen-lined ground squirrels contained 44.0 ± 2.2 (± 1 SE) per cent animal matter over the entire study, with seasonal variation ranging from 61.4 per cent in late summer and early autumn to 36.4 per cent in early spring (Fig. 1). Adult and larval Coleoptera, Lepidoptera larvae, and grasshoppers were the most abundant animals in the diet, with adult Coleoptera the most prevalent. During the part of the year when squirrels were active, adult Coleoptera were present in the diet in stable amounts, whereas Lepidoptera and Coleoptera larvae reached peak dietary concentrations in late spring and early to mid-summer and then decreased in late summer and early autumn (Table 2). Grasshoppers were most important in late summer and early autumn. Arthropods made up the majority of animal matter consumed though small mammal tissue was present in the diet.

Plant matter averaged 54.5 ± 2.2 (± 1 SE) per cent volume throughout the study with sample period values as follows: May to June (49.6 ± 3.4), July to August (62.7 ± 4.0), September to October (38.6 ± 6.5), and March to April (58.3 ± 5.0). Vegetative matter in the diet of *S. tridecemlineatus* at the Pawnee National Grassland contained grasses, sedges, shrubs, forbs, fungi (*Endogone*), lichens, mosses, and seeds (Table 1). Of the rodents studied, *S. tridecemlineatus* had the lowest per cent dry weight of seeds in the diet and the highest per cent dry weight of fungi and mosses. Total forbs and even total grasses and sedges composed a greater portion of dry weight than did seeds. Seasonal variation of various types of matter in *S. tridecemlineatus* was limited because the ground squirrels were inactive during most of the autumn and winter (Table 2). The fungus, *Endogone*, was most abundant in the diet in late spring and early summer and was commoner in *S. tridecemlineatus* than in any other rodent.

Summary

There was great variation in the amounts of animals matter in the diet between the rodents studied, but the major types of animals eaten were similar. Adult and larval Coleoptera and larval Lepidoptera were important in all species; grasshoppers were important in all but *D. ordii*. Amounts of various types of arthropods in the diet likely depends not only on abundance but on such things as rodent preference, ease of capture, abundance of other arthropods (buffer effect), and plant foods, and activity patterns of particular arthropods as related to rodent activity. Even in highly herbivorous species, such as *D. ordii*, animal matter may be of considerable importance during certain periods of the year. For instance, *Dipodomys* reproduction appears to be directly correlated with abundance of forbs prior to and during the reproductive period (Reynolds, 1960; Chew and Butterworth, 1964; and Beatley, 1969). Likewise, larval insects also may be important in providing moisture and nutrients, as hypothesized for forbs, during the reproductive period in *Dipodomys*. Although deer mice (*P. maniculatus*), with their broad adaptability, changed their diet to heavy dependence on plant matter (seeds) in times of insect scarcity, grasshopper mice (*O. leucogaster*) did not, at least to the degree of the former, indicating the latter are adept at locating arthropods even during the colder months.

As was the case for animal matter, amounts of plant matter in the diet generally varied between rodents and through time for each species. Leaves and stems of blue grama (*B. gracilis*), sun sedge (*C. heliophila*), and western wheatgrass (*A. smithii*) were common in rodent diets and on the prairie, whereas the prairie co-dominant, buffalo grass (*B. dactyloides*), was rarely found in the diet and that present could be from ingested insects. However, seeds of the latter could be important because seeds were not identified to species. Most of the common forbs and shrubs were present in rodent diets although a few, such as slim-flower scurfpea (*P. tenuiflora*), slim-leaf goosefoot (*C. leptophyllum*), and broom snakeweed (*G. sarothrae*), were poorly represented or missing in the diets. Summer cypress (*Kochia scoparia*), *Astragalus*, and scarlet globemallow (*S. coccinea*) were the forbs of greatest overall abundance in rodent diets. Of the shrubs, fringed sagewort (*A. frigida*) was most prevalent in diets. Seeds were dominant in the diets of *D. ordii* and *P. maniculatus* and less important in diets of *S. tridecemlineatus* and *O. leucogaster*. Thirteen-lined ground squirrels are highly omnivorous and one might surmise such an animal would, like *P. maniculatus*, depend heavily on seeds during winter months if it were not a hibernator.

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