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Ingestion Rates, Live Weight Caloric Densities and Standing Crop Estimates for Desert Biome Rodents

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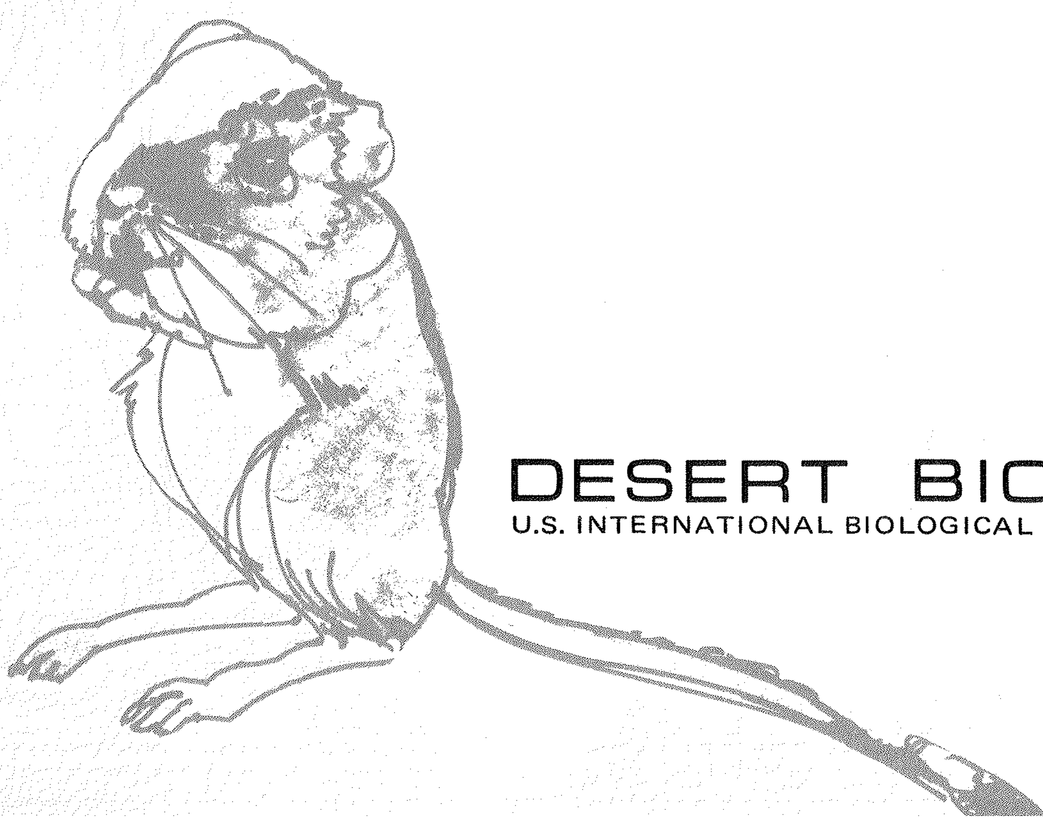

DESERT BIOME
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ABSTRACT

The investigation of certain aspects of desert rodent energetics begun in 1970 has continued through 1971. Assimilation efficiencies of *Perognathus parvus*, *Peromyscus maniculatus*, *Onychomys leucogaster*, *Reithrodontomys megalotis*, *Dipodomys ordi*, *D. microps* and *Eutamias minimus* ranged from 80 to 97%. Caloric value of the stomach contents ranged from 4.2 to 6.7 kcal/g. Estimated ingestion rates in kcal/yr and kg/yr are reported for four species. The ash, water, lean dry, and fat contents of rodent carcasses were determined. Seasonal changes in the fat indices of three species were also measured. Live weight caloric densities ranged from 1.4 to 1.8 Kcal/g. The total standing crop of rodents in sagebrush habitats in the Curlew Valley, Idaho and Utah, was estimated as 0.5 to 1.0 mcal/ha.

OBJECTIVES

Our objectives were to:

1. Refine the ingestion rates calculated earlier by measuring some of the variables which had been estimated or secured from the literature.

2. Determine the carcass composition, live weight caloric density, and standing crop of the more abundant species found on the Curlew Valley validation sites.

STUDY AREAS

The study area on the Hanford Reservation, Benton County, Washington, where rodents were collected in 1970 and 1971, has already been described (Johnson, 1971). During 1971 rodents were also trapped about 1 mile from the validation sites in Curlew Valley, Utah-Idaho, and 10 miles southwest of Mountain Home, Elmore County, Idaho. The Curlew Valley sites were described in the Desert Biome Research Design of May, 1969 (Section X-H). Trapping near Mountain Home was conducted in healthy stands of shadscale (*Atriplex confertifolia)*.

METHODS

The methods of collecting rodents and determining the composition of the carcass have already been described (Johnson, 1971; DSCODES A3UJA01 and JA02). Assimilation efficiencies (proportion of the food ingested which is assimilated) were determined for laboratory animals by direct measurement and for wild populations by the ash tracer method. Since the ash content of the carcass is maintained within narrow limits, the ash (non-combustible inorganic material) serves as a natural occurring tracer permitting the determination of assimilation efficiencies of animals living in the wild on natural diets. The method assumes that ash intake equals ash loss, since although the animal is cycling elements it tends to maintain mineral balance. This method has been used to determine assimilation efficiencies of several rodents and one lagomorph (Johnson and Maxell, 1966; Johnson and Groepper, 1970).

Assimilation efficiency is calculated as:

$$1 - \frac{(1/y_c) - 1}{(1/y_o) - 1}$$

where y_c is the ash content (%) of the feces increased by a correction factor to account for the additional ash loss in the urine, and y_o is the ash content of the food found in the stomach. In order to establish the correction factor, rodents were maintained in the laboratory on a variety of diets and the proportion of ash loss in the feces measured (Table 1). The difference between the amount of ash ingested and that recovered in the feces was assumed to have been lost in the urine. The correction factors measured for deer mice (*Peromyscus maniculatus*) and for the Ord kangaroo rats (*Dipodomys ordi*) in an earlier study (Johnson and Groepper, 1970) were used in the calculation of assimilation efficiency of those species.

Caloric values were determined by combustion in a Parr semimicro oxygen bomb calorimeter charged to 35 atmospheres. When sufficient material was available three measurements of caloric density were made and the mean accepted as the best estimate of its true value. The values reported are corrected for ash content, fuse wire combustion, and nitric acid formation.

Table 1. Metabolic statistics (Mean ± S.E.) of captive rodents on laboratory diets.

Species	Sex/ Age Group	N	Diet	Mean Wt. (g)	Ash loss in Feces (%)	Energy Flow (cal/g/day) Mainten.	Prod.	Assimilation Efficiency (%)
P. parvus	M	6	Rolled oats	17.2	55.9 ± 3.8	379 ± 40	1	94.3 ± .24
	F	6	Rolled oats	14.2	48.6 ± 3.7	480 ± 31	0	94.8 ± .24
	Immature	7	Rolled oats	11.7	41.4 ± 4.9	542 ± 68	0	95.3 ± .35
	M	2	Cheatgrass seed	13.5	31.0	214	0	85.5
	F	5	Cheatgrass seed	12.0	31.9 ± 43	265 ± 43	0	83.5 ± 1.5
R. megalotis	M	4	Rolled oats	11.2	55.5 ± 4.5	549	8	91.8 ± .65
	M	3	Sunflower seeds	11.4	58.9	457	3	87.7
E, minimus	M	6	Rolled oats	30.3	72.3 ± 2.6	579 ± 48	29	90.3 ± .4
	F	2	Rolled oats	38.3	65.4	386	2	90.8
	M	2	R. thistle seeds	29.0	64.4	331	0	79.2
	F	2	R. thistle seeds	36.7	70.7	307	0	78.7
O. leucogaster	M	3	Sunflower seeds	35.6	56.2	286	0	86.7
	F	6	Sunflower seeds	28.0	50.0 ± 5.7	412	22	85.8 ± 1.0
C. townsendi	M & F	2	Rolled oats	180.0	42.4	196	18*	94.4
	M & F	3	Rat chow	181.2	49.8	159	14*	83.7
E. minimus	M	4	Sunflower seeds	32.5	49.6 ± 3.0	329	0	89.6 ± 1.3
	F	2	Sunflower seeds	37.5	33.5	289	0	91.9

* Estimate based on *E. minimus* live weight caloric density.

FINDINGS & DISCUSSION

Ingestion rates (kcal/yr) were calculated as: $I_m = E_m/AE$ for males and Kcal $I_f = E_m + nL(E_{g1} + E_{g2})/AE$ for females where E_m is the energy expenditure for maintenance, AE is the assimilation efficiency, n is the mean litter size, L is the average number of litters/year and E_{g1} and E_{g2} are the energy costs of growth from conception to birth and from birth to weaning respectively (Johnson, 1971). The energy cost of growth from weaning to adult size was ignored.

There was little seasonal variation in the assimilation efficiency of rodents living in the wild on natural diets (Table 2). The values for deer mice, grasshopper mice (*Onychomys leucogaster*), and Ord kangaroo rats were similar to those found in North Plains populations (Johnson and Groepper, 1970). The values calculated for wild populations were also similar to those measured directly in the laboratory (Table 1).

The caloric values of the stomach contents of males and some females collected monthly were determined (Table 3). It is unlikely that there is a significant difference between the sexes because of diet similarities. The mean value for deer mice stomach contents is similar to that found in North Plains populations (Johnson and Groepper, 1970).

The heavy use of energy-rich saltbush seeds by least chipmunks (*Eutamias minimus*) in the fall is evident. Foliage and granivorous herbivores (Heteromyids) subsisted upon food of lower energy value than that utilized by omnivores such as deer mice, grasshopper mice, western harvest mice (*Reithrodontomys megalotis*), and least chipmunks (Table 3).

We have not been able to secure consistent data on activity by monitoring animals tagged with a radionuclide. Thus our estimates of energy expenditure for maintenance (E_m of Table 4) remain as calculated earlier (Johnson, 1971). The ingestion rates calculated (Table 4) are quantified in both Kcal/yr and, since the caloric density of the food is known, in kg/year also.

The carcass is composed of four major components: 1) the non-combustible ash, 2) the body water, 3) the lean dry tissue, and 4) the body fat. Although the first two provide no energy to a predator ingesting the carcass, they must be measured in order to estimate the live weight caloric density and, ultimately, the standing crop.

The ash content of the carcasses was remarkably stable, ranging from 3-4% of the live weight (Tables 5 and 6). The body water content, which ranged from 66 to 72% of the live weight, was significantly greater in gravid than in non-gravid females (Table 5), something one might anticipate because of the amniotic fluid and the recognized higher water content of embryos. Body water was reduced in least chipmunks prior to torpor (Table 6).

It is only the lean dry tissue and the fat portions of the carcass which contain energy. The lean, dry, ash-free tissue comprised 20-25% of the body weight. It was proportionally lower in gravid animals (Table 5) and higher in chipmunks prior to torpor (Table 6).

The fat (ether extract) component of carcasses ranged from 2.4 to 5.4% of the body weight (Tables 5 and 6). It's level was reduced in gravid animals and increased in chipmunks prior to torpor. Jameson and Mead (1964) observed similar changes in the water and fat content of three sciurids prior to dormancy.

Table 2. Assimilation efficiencies ($\overline{X}$ ± S.E.) of Desert Biome rodents living in the wild on natural diets. Sex in parentheses. * = combined samples.

Month	Species						
	P.p.	P.m.	O.l.	R.m.	E.m.	D.o.	D.m.
Jan		93.1 (m)	87.8 (m)				
Feb		81.9 (m)		90.7 (m)			
Mar	86.4 (m) 90.6 (f)	79.5 (m)					
Apr	86.3 (m)	84.7 (m)	93.0 (m)				
May	87.9 (m) 91.5 (f)	87.5 (m)	82.7 (m) 85.3 (f)			93.8 (m)*	
Jun	91.2 (m) 95.3 (f)	88.9 (m)	92.6 (m)		83.7 (m)	93.8 (m)*	
Jul	85.5 (m) 96.9 (f)	94.6 (m)	92.5 (m) 91.7 (f)		98.4 (m)		
Aug	93.2 (m) 88.9 (f)		93.4 (m) 90.5 (f)		92.9 (m)	94.2 (m)	
Sep	87.6 (m) 93.6 (f)	86.9 (m)	89.5 (m)		91.5 (m) 93.7 (f)		91.3 (m)
Oct	92.2 (m) 86.1 (f)	82.5 (m)	85.5 (m)		77.8 (m) 83.3 (f)		
Nov	92.5 (m) 85.6 (f)	93.2 (m)	95.8 (m)	80.4 (m)*	79.4 (m) 86.8 (f)	92.2 (m)	
Dec		95.1 (m)		80.4 (m)*			
Means M	89.2 ± 1.0	87.9 ± 1.6	90.3 ±1.4	85.6	87.3 ± 3.4	94.3	91.3
F	91.1 ± 1.4		89.2		87.9 ± 3.1		

Table 3. Caloric value (cal/g ± S.E.) of the stomach contents of Desert Biome rodents. Sex in parentheses. * = combined sample.

Month	Species						
	P.p.	P.m.	O.l.	R.m.	E.m.	D.o.	D.m.
Jan		5905 (m)	4531 (m)				
Feb	5683 (m)	5823 (m)		6003 (m)			
Mar	5240 (m)	5627 (m)	4920 (m)	5815 (m)*			
Apr	5459 (m)	5512 (m)	5313 (m)	5815 (m)*			
May	5047 (m)	6041 (m)	5294 (m)			5008 (m)*	
Jun	5166 (m)	5850 (m)	5688 (m)		5246 (m)	5008 (m)*	
Jul	4266 (m)	5655 (m)	5837 (m)		5426 (m)		
Aug	4213 (m)	5485 (m)	5007 (m)		5751 (f)	4889 (m) 4909 (f)	
Sep	4613 (m)	5628 (m)	5137 (m)		5667 (m)		4732 (m)
Oct	4847 (m)	5716 (m)	5164 (m)		6510 (m) 6411 (f)		
Nov	5226 (m)	5890 (m)	5327 (m)	5947 (m)*	6507 (m) 5791 (f)	6758 (m) 6709 (f)	
Dec		5905 (m)		5947 (m)*			
Mean M	4976 ± 154	5751 ± 49	5222±118	5922	5871±268	5416±448	4732
F					5984	5809	

Table 4. Estimated ingestion rates of Desert Biome rodents. Sample size in parentheses.

Species	Sex	E_m (Kcal/yr)	Assimilation Efficiency (%)	Mean Litter Size	No. litters per year	Growth Energy (Kcal)	Ingestion Rates (Kcal/yr)	(Kg/yr)
P. parvus	M	2539	.892				2846	0.572
	F	2012	.911	4.0(48)	1.14	59	2503	0.503
P. maniculatus	M	4420	.879				5028	0.874
	F	4246	.879	4.6(42)	1.42	80	5425	0.952
O. leucogaster	M	4881	.903				5405	1.035
	F	5354	.903	3.3(7)	1.07	120	6398	1.225
R. megalotis	M	3236	.856				3780	0.638
	F	3236	.856	3.4(7)	1.11	52	4010	0.677

Table 5. Carcass composition ($\overline{X} \pm$ S.E.) and live weight caloric density of certain non-hibernating Desert Biome rodents. Percentages in parentheses.

Species	Sex	Body Wt. (g)	Ash Content (g)	Water Content (g)	Ash-free Lean Dry Wt. (g)	Fat Content (g)	Live Wt. [a] Caloric Density (Kcal/g)
P. parvus	M	19.77 ± .96	0.80 (4.0)	13.69 ± .68 (69.2)	4.43 (22.5)	0.85 ± .09 (4.3)	1.64
	F	14.97 ± .60	0.59 (3.9)	10.66 ± .45 (71.2)	3.28 (21.9)	0.44 ± .03 (2.9)	1.49
	Gravid	17.30 ± .39	0.66 (3.8)	12.44 ± .30 (71.9)	3.68 (21.3)	0.51 ± .02 (2.9)	1.45
P. maniculatus	M	19.72 ± .38	0.80 (4.3)	12.92 ± .23 (68.9)	4.40 (23.5)	0.63 ± .04 (3.4)	1.66
	F	15.85 ± .44	0.62 (4.1)	10.46 ± .27 (69.3)	3.41 (22.6)	0.61 ± .04 (4.0)	1.67
	Gravid	20.77 ± 1.46	0.77 (3.7)	14.81 ± 1.10 (71.5)	4.36 (21.1)	0.76 ± .10 (3.7)	1.55
R. megalotis	M	10.78 ± .31	0.41 (3.8)	7.45 ± .23 (69.1)	2.38 (22.1)	0.54 ± .05 (5.0)	1.67
	F	9.48 ± .77	0.35 (4.0)	6.02 ± .42 (68.0)	2.04 (23.1)	0.44 ± .06 (5.0)	1.72
	Gravid	11.98 ± .87	0.41 (3.5)	8.36 ± .63 (71.9)	2.37 (20.4)	0.48 ± .07 (4.1)	1.49
O. leucogaster	M	22.80 ± .79	0.70 (3.3)	14.50 ± .53 (68.0)	4.97 (23.3)	1.15 ± .14 (5.4)	1.76
	F	20.84 ± .94	0.69 (3.5)	12.99 ± .49 (66.2)	4.87 (24.8)	1.07 ± .16 (5.4)	1.84

(a) Assume a fat caloric value of 9.2 Kcal/g (Sawicka-Kapusta, 1968).

Table 6. Carcass composition ($\overline{X} \pm$ S.E) and live weight caloric density of *Eutamias minimus*. Percentages in parentheses.

Month	Sex	N	Body Weight (g)	Ash Content (g)	Water Content (g)	Ash-free Lean Dry Wt. (g)	Fat Content (g)	Live Wt. Caloric Density (Kcal/g) [a]
July	M	19	31.51 ± .69	1.06 (3.4)	22.15 ± .51 (71.6)	6.90 (22.3)	0.80 ± .08 (2.8)	1.49
	F	21	32.05 ± .79	1.10 (3.5)	22.52 ± .64 (71.5)	7.11 (22.6)	0.76 ± .07 (2.4)	1.49
August	M	2	30.93	1.04 (3.4)	21.64 (71.9)	6.72 (22.3)	0.70 (2.3)	1.47
	F	4	32.03	1.06 (3.4)	22.42 (71.9)	6.85 (22.0)	0.86 (2.8)	1.49
September	M	12	30.98 ± .41	1.02 (3.5)	20.66 ± .33 (70.9)	6.64 (22.8)	0.82 ± .05 (2.8)	1.54
	F	10	32.27 ± .7	1.09 (3.6)	21.66 ± .39 (70.6)	7.10 (23.2)	0.81 ± .03 (2.6)	1.54
October	M	16	32.60 ± .47	1.12 (3.6)	21.37 ± .41 (69.6)	7.25 (23.6)	0.95 ± .03 (3.1)	1.61
	F	15	33.30 ± .64	1.14 (3.6)	22.31 ± .56 (69.9)	7.41 (23.2)	1.04 ± .05 (3.3)	1.61
November	M	2	32.48	1.11 (3.7)	20.76 (69.1)	7.21 (24.0)	0.98 (3.3)	1.64
	F	7	35.14 ± .87	1.16 (3.6)	22.50 ± .68 (69.1)	7.51 (23.1)	1.37 ± .12 (4.2)	1.68

[a] Assumes a caloric value of 9.2 Kcal/g for fat (Sawicka-Kapusta, 1968).

Some species demonstrate winter, summer, or spring-fall peaks in fat indices (Sawicka-Kapusta, 1968; McNab, 1968; Caldwell and Connel, 1968). Although Great Basin pocket mice *(Perognathus parvus)* exhibited no cyclic change in body fat there was a reduction in its level during the spring breeding season (Table 7). There was no significant difference in the fat indices between adults and immature animals or between gravid and non-gravid females (Table 7).

Table 7. Fat indices (mg fat/g lean dry tissue ± S.E.) of *Perognathus parvus*, Hanford Reservation. Adults (greater than 13 g). Sample size in parentheses.

Month	Age Group	Males	Females	Gravid/Lactating
Feb	Adult	155 (3)		
Mar	Adult	155 ± 7 (36)	120 ± 17 (7)	
Apr	Adult	121 ± 5 (31)	108 ± 9 (9)	111 ± 12 (6)
May	Adult	117 ± 5 (43)	110 ± 13 (6)	125 ± 4 (34)
Jun	Adult	133 ± 6 (62)		117 ± 5 (48)
Jul	Adult	133 ± 7 (18)		153 ± 9 (7)
	Immature	127 ± 6 (22)	153 ± 10 (17)	
Aug	Adult	157 ± 8 (19)	171 (1)	197 ± 13 (6)
	Immature	136 ± (3)	170 ± 12 (9)	
Sep	Adult	127 ± 8 (25)	135 ± 15 (12)	
	Immature	76 ± (1)	143 ± 13 (9)	
Oct	Adult	142 ±11 (7)	207 (1)	
	Immature	137 ± 8 (5)	186 (3)	
Nov	Adult	123 ± (1)	53 (1)	

Deer mice exhibited no marked seasonal change in fat indices (Table 8). Those deer mice from the Curlew Valley were generally greater than those of Hanford population. The fat indices of gravid females were generally less than those of non-gravid animals. The fat indices of chipmunks increased progressively prior to torpor (Table 9). Because of the small sample sizes, no attempt was made to identify seasonal changes in the fat indices of the other species samples (Table 10). Those of Ord and chisel-toothed kangaroo rats *(Dipodomys microps)* were the lowest measured.

Table 8. Fat indices (mg fat/g lean dry tissue ± S.E.) of *Peromyscus maniculatus*. Sample size in parentheses. Adult (weight greater than 13 g).

Month	Site	Males	Females	Gravid-Lactating
Jan	Hanford	124 ± 17 (4)		158 (1)
Feb	Hanford	50 (1)	131 (1)	85 ± 9(5)
Mar	Hanford	125 (1)		104 (1)
Apr	Hanford			161 ± 25 (8)
May	Mtn. Home	171 ± 23 (6)	199 ± 21 (4)	188 ± 26 (4)
Jun	Mtn. Home	123 ± 11 (9)		137 (2)
	Hanford	138 ± 12 (9)	139 ± 24 (5)	
Jul	Hanford	143 ± 11 (4)	161 (3)	137 ± 16 (4)
Aug	Hanford		114 (1)	190 (1)
	Curlew	142 ± 12 (13)	106 (2)	196 ± 46 (5)
Sep	Hanford	108 ± 5 (8)		125 (1)
	Curlew	120 ± 7 (23)	74 (2)	108 ± 7 (14)
Oct	Hanford	95 (3)		116 (1)
	Curlew	176 ± 29 (17)	207 ± 26 (6)	132 ± 14 (14)
Nov	Hanford	142 ± 12 (9)	150 (1)	85 (1)
	Curlew	134 ± 10 (16)	151 (2)	147 ± 11 (8)
Dec	Hanford	125 (2)	148 (1)	108 (1)

Table 9. Fat indices (mg fat/g lean dry tissue ± S.E.) of *Eutamias minimus* adults. Sample size in parentheses. Curlew Valley.

Month	Males	Females
July	90 ± 6 (19)	92 ± 6 (21)
August	90 ± (2)	109 (2)
September	106 ± 5 (13)	99 ± 4 (10)
October	112 ± 3 (16)	119 ± 5 (15)
November	118 ± (2)	158 ± 14 (7)

Table 10. Fat indices (mg fat/g lean dry tissue ± S.E.) of certain Desert Biome rodents. Sample size in parentheses.

Species	Males	Females
Onychomys leucogaster	191 ± 9 (31)	176 ± 15 (17)
Reithrodontomys megalotis	151 ± 12 (27)	178 ± 17 (12)
Dipodomys microps	75 ± (2)	
Dipodomys ordi	83 ± 4 (20)	78 ± 5 (16)

The caloric value of the lean dry carcass of these species fell within a narrow range. It was 5.55 Kcal/g for Great Basin pocket mice, 5.74 Kcal/g for deer mice, 5.46 Kcal/g for western harvest mice, 5.41 Kcal/g for grasshopper mice, and, 5.62 Kcal/g for least harvest chipmunks. The live weight caloric densities of these species ranged from 1.45 to 1.84 Kcal/g (Tables 5 and 6). These values compare favorably with that measured for *Apodemus flavicollis* (Sawicka-Kapusta, 1968) but they are much lower than the 2.58 Kcal/g Brisbin (1970) measured in a small sample of *Peromyscus polionotus* maintained in the laboratory. Golley (1960) found a live weight caloric density of 1.37 Kcal/g for *Microtus pennsylvanicus*. Gorecki (1965) suggested 1.5 Kcal/g as the average live weight caloric density of several European rodents.

Table 11. Representative standing crop of three Desert Biome rodents, Curlew Valley sagebrush sites.

Species	Mean Body[(a)] Wt. (g)	Live Weight (a) Caloric Density (kcal/g)	Density[(b)] (N/ha)	Standing Crop (Kcal/ha)
Perognathus parvus	17.37	1.57	4.2-4.5	114-123
Peromyscus maniculatus	17.79	1.67	3.5-5; 8.6-12.9	104-149; 255-383
Eutamias minimus	32.08	1.56	2.6-3.2; 6.3-6.5	130-160; 315-325

(a) Tables 5 and 6; assume a balanced sex ratio

(b) Balph (1971)

Caloric standing crop can be estimated as the product of mean weight, live weight caloric value, and density. Standing crop estimates for three species found in sagebrush habitat of the Curlew Valley ranged from 100-380 Kcal/ha (Table 11). Total rodent standing crop probably ranged from 0.5 to 1.0 mcal/ha. Chew and Chew (1970) measured a total rodent biomass of 541 kg/ha in a desert shrub community in southeastern Arizona. Assuming a live weight caloric density of 1.5 for those species, their study area supported an average rodent standing crop of 0.8 mcal/ha.

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