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## Models of Ingestion Rates for Desert Biome Rodents Process Study

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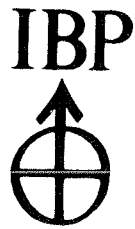
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# DESERT BIOME

US/IBP ANALYSIS OF ECOSYSTEMS

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1970

PROGRESS REPORT

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PROCESS STUDY

Models of Ingestion Rates for Desert Biome Rodents

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University of Idaho  
Moscow, Idaho

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Models of Ingestion Rates for Desert Biome Rodents (2.3.5)

Donald R. Johnson, University of Idaho, Moscow, Idaho

## Abstract

Ingestion rates (kcal/year) for males of four species of desert biome rodents are calculated as  $E_m/AE$  where  $E_m$  is the energy expended for maintenance and AE represents the assimilation efficiency. Ingestion rates for females are calculated as  $E_m + n(Eg_1 + Eg_2)/AE$  where  $n$  is the mean litter size,  $l$  is the number of litters per year, and  $Eg_1$  and  $Eg_2$  represent energy expenditures for growth of embryos and nestlings.

These estimates of ingestion rates will be improved once information on activity patterns becomes available. Those for Great Basin pocket mice compare reasonably well with the ingestion rates predicted from a model developed by Tucker (1966) for captive California pocket mice.

Models predicting heteromyid reproduction rates, ingestion rates, and density must ultimately include the pattern and amount of winter precipitation as a variable.

## Objectives

With the assistance of R. K. Schreiber, I have investigated several aspects of the bioenergetics of Great Basin pocket mice (Perognathus parvus), deer mice (Peromyscus maniculatus), grasshopper mice (Onychomys leucogaster), and western harvest mice (Reithrodontomys megalotis) on the AEC Reservation, Richland, Washington, during 1970. Our objectives were: (1) to develop a model of ingestion rate, and (2) to calculate ingestion rates for these species. We were also able to make some observations on rodent density, seed and herbage production of cheatgrass (Bromus tectorum), the seasonal variation in fat content, and the effects of different baits on the probability of capture.

The assistance of T. P. O'Farrell, Batelle-Northwest Laboratory; Wayne Cassatt and Walter Haerer of the Joint Center for Graduate Study, Richland; R. M. Chew, University of Southern California, and Vincent Schultz and George, Hinman, Washington State University, is greatly appreciated.

## Study Area

The primary study area was established on the east side of the Arc-6 Road, 11 miles northwest of Richland, Benton County, Washington, at an elevation of 650 ft (220 m). Edaphic and climatological data for the nearby Arid Lands Ecology Reserve have been summarized by Hinds and Thorp (1969). The dominant shrubs are bitterbrush (Purshia tridentata) and big sagebrush (Artemisia tridentata). Two rabbitbrushes (Chrysothamnus nauseosus and C. viscidiflorus) are also present in the area. The understory consists of several species of forbs and Sandberg's bluegrass (Poa secunda).

Within the last 80 years, the entire region has undergone a significant vegetational change (Daubenmire, 1970). About 1890, cheatgrass, a strongly competitive winter annual, was introduced into eastern Washington. It rapidly spread throughout the region where heavy grazing and fire had seriously depleted the original vegetation. Native species are unable to replace it, despite prolonged protection from grazing and fire. Cheatgrass remains the dominant grass at lower elevations on the AEC Reservation despite total protection since 1943.

A range fire swept over a large area north of the study site in 1955. It has shown little recovery and supports little other than cheatgrass. Fires set by the electrical storm of July 16, 1970, swept over 22,500 acres of the reservation (including the area burned in 1955), totally destroying the vegetation on the study area (and 250 snap traps). We then moved to another site on the B-27 Road (3 miles northwest). Rodent densities there were lower than at the original site. Our thermograph, which survived the fire, was placed in operation on the new site.

Herbivores occurring on the reservation include mule deer and black-tailed jackrabbits. Darkling beetles of four species are a conspicuous part of the insect fauna (Rickard, 1970). Grasshoppers apparently have not reached destructive densities on the reservation since its establishment. Side-blotched lizards and bull snakes are the principal reptile inhabitants.

Carnivores and raptors include coyotes, badgers, burrowing owls, short-eared owls, kestrels, and marsh hawks. Gulls gathered in large numbers following the fire, apparently to feed on disoriented mice wandering about the surface.

### Methods

Rodents were collected monthly in snap traps baited with either rolled oats or a mixture of rolled oats and peanut butter. The sex and weight of each were recorded, together with the position of the testes and the number of embryos or placental scars.

The stomachs were removed, the contents washed in cool water, dried in an oven at 70 C for 24 hrs, and weighed to the nearest mg. The dried contents were combined by sex and age group, refined in a Wiley mill fitted with a 40 mesh/inch screen, and stored in stopped jars. The ash content of the food and feces was determined after combustion in a furnace at 600 C for 2 hours.

The carcasses (with stomachs excised) were dehydrated in a vacuum oven at 70 C for 48 hours, after which each was pulverized and sewn between two sheets of round filter paper. The fat was extracted in a Soxhlet apparatus using ether as a solvent. Extraction required 24 hours.

Rodents were live-trapped, acclimated to captivity, and maintained on laboratory diets for five days. Water was provided *ad lib* to all species except heteromyids which were deprived of water and subsisted upon that produced metabolically. Assimilation efficiency was calculated directly by subtracting the weight of the dried feces from that of the food ingested. Assimilation efficiencies of animals living in the wild on the natural diet were calculated using the ash tracer method (Johnson and Groepper, 1970).

Cheatgrass was harvested on 60 0.1m<sup>2</sup> circular plots placed systematically along three transect lines in the study area. The production on each plot was stored in a paper bag, air dried, and weighed to the nearest mg. The mean density and number of culms were calculated. Seed production was determined from the density-production figure in Hulbert (1955). The seeds from the cheek pouches of pocket mice collected in August (and thus assumed to be those produced in 1970) were recovered and weighed. Production was calculated as the product of the number/unit area and the mean weight. Herbage production was calculated as the difference between total and seed weight.

We monitored surface ( $T_s$ ) and soil ( $T_d$ ) temperatures on the study area with a 2-pen thermograph beginning in June 1970. Soil temperature was monitored at 0.5 m, an average depth of burrows exposed by a road excavation and examined by O'Farrell (personal communication). Ambient temperatures (Table 1) are those from a weather station 13 miles west of the B-27 study area. Because of the close positive relationship between ambient temperature and those of the soil and surface, I have predicted the latter for the biological year commencing June 1, 1970 (Table 1).

### Findings

Ingestion rate (I) was calculated as:

$$E_r + E_a / AE = E_m / AE$$

where  $E_r$  and  $E_a$  are the rates of energy expenditure at rest and when active,  $E_m$  is their sum, and AE is the assimilation efficiency (the proportion of the food ingested which is assimilated).

#### Ingestion rates:

Perognathus parvus: Metabolic rates for this species have been measured by Anderson (1970) and by Guthrie (personal communication). Guthrie's metabolic rates (ml O<sub>2</sub>/ g / hr) are: active,  $8.6 - 0.24 T_a$  and torpor,  $0.38 + 0.014 T_a$  where  $T_a$  is the ambient temperature. I have used his "active" rate as  $E_r$  since it is similar to that measured for Perognathus baileyi, a species of similar body size (Chew and Chew, 1970).

Caloric expenditures for males and females have been calculated separately (Table 2) because of differences in body weight and seasonal activity.

We have not yet successfully determined daily and seasonal activity patterns for these species. We employed a technician who developed a burrow monitor similar to those used by Inglis *et al.* (1968), and Frigerio and Eisler (1968). The monitor records the presence of a mouse labeled with a radionuclide (Tantalum 182). We are only now beginning to gather data with this system.

Lacking specific activity patterns, I have estimated them (Table 2) based on seasonal changes in trapping success and the observations of Scheffer (1938). He found pocket mice inactive (presumably in torpor) from late November to early March in eastern Washington. We have found little above-ground activity since early October. Scheffer also found that males became active earlier in the spring than did females; a fact we have also observed.

In calculating  $E_m$ , I have assumed that (1) this species is active above ground 4 hours daily during months of favorable weather, (2) it encounters above-ground temperatures of  $T_a$  rather than  $T_s$  since surface activity has been completed by dawn; the time when  $T_s$  is measured (Scheffer 1938; Haerer, personal communication), (3) this species remains in torpor 20 hours daily during the winter months since Tucker (1966)

found that *Perognathus californicus* did not remain in torpor more than 24 hours, and, 4) this species consumes sufficient food from underground caches to maintain its body weight during the winter months (Table 2).

To account for the insulating effects of a nest, I have used  $7.0 - 0.165 T_d$  as the resting rate below 20.5 C. This was plotted as  $.81 E_r$  at 1 C and  $.87 E_r$  at 12 C, metabolic rate reductions (Pearson, 1960; Fig. 1) measured for the harvest mouse in a natural nest. Because of the low metabolic rate while in torpor, the presence of a nest results in only a 4% saving in the energy cost of maintenance (Table 2).

Pocket mice living in the wild on natural diets demonstrated assimilation efficiencies of 83.8, 90.8, 88.5, and 88.4% in April, May, July, and August respectively. Using the mean of 87.9% the ingestion rate for males is calculated as:

$$I_m + E_m; AE = 2539 / .879 = 2889 \text{ kcal/year.}$$

Table 2. Estimated resting, active and maintenance metabolic rates for *Perognathus parvus*.

Month	Hrs. Daily		Males			Hrs. Daily		Females				
	Rest.	Act.	Body Wt. (g)	Kcal			Rest.	Act.	Body Wt. (g)	Kcal		
				$E_r$	$E_a$	$E_m$				$E_r$	$E_a$	$E_m$
Jun	20	4	19.62	164	90	254	20	4	17.17	143	80	223
Jul	20	4	18.37	115	81	196	20	4	16.92	106	75	181
Aug	20	4	16.39	107	76	183	20	4	15.64	102	73	175
Sept	23	1	18.76e	217	25	242	23	1	13.87e	161	19	180
Oct	23.5	0.5	18.76e	295	15	310	23.5	0.5	13.87e	218	11	229
Nov	4	20t	18.76e	83	0	83	4	20t	13.87e	62	0	62
Dec	4	20t	18.76e	88	0	88	3	20t	13.87e	65	0	65
Jan	4	20t	18.76e	90	0	90	4	20t	13.87e	66	0	66
Feb	4	20t	18.76e	78	0	78	4	20t	13.87e	58	0	58
Mar	22	2	18.76	289	62	351	23.5	0.5	13.87	228	12	240
Apr	20	4	19.68	238	118	356	22	2	16.08	214	48	262
May	20	4	18.91	203	105	308	20	4	16.64	178	93	271
Sum				1967	572	2539				1601	411	2012
Without nest					2643 (104%)						2092 (104%)	

In order to calculate the ingestion rate for females, one must account for the energy cost of pregnancy and lactation (Kaczmarski, 1966; Johnson and Groepper, 1970). This energy is used for both respiration and growth by embryos. I have already accounted for respiration by embryos by including gravid females in the calculations of mean weight (Table 2). The energy cost of growth can be calculated as  $W_1 K_1 / E_1 + W_2 K_2 / E_2 + W_3 K_3 / E_3$  (Chew and Chew, 1970), or simply as  $Eg_1 + Eg_2 + Eg_3$ , where  $W_1$ ,  $W_2$  and  $W_3$  are the weight gains from conception to birth, from birth to weaning, and from weaning to adult weight respectively.  $K_1$ ,  $K_2$ , and  $K_3$  represent the caloric values of the tissues during these time periods.  $E_1$ ,  $E_2$  and  $E_3$  represent growth efficiencies (that proportion of the food assimilated used in growth).

The weight of pocket mice at birth is unknown but assumed to be 1.e g, the greatest weight of an embryo found in utero. Adding 27% for the weight of embryonic tissues (Kaczmarski, 1966),  $W_1 = 1.7$ . Using the weight of the smallest pocket mouse trapped (6.4 g) as the weaning weight,  $W_2 = 4.7$ . Adult males weigh about 19 g and adult nongravid females about 14 g (table 2). Thus,  $W_{m3} = 14.3$  and  $W_{f3} = 9.3$ .

Until data for this species are available, I have used growth efficiencies of 0.138, 0.146, and 0.5 respectively (Kaczmarski, 1966; Brody, 1945) and tissue caloric values of 1.03, 1.43, and 1.5 kcal/g respectively (Kaczmarski, 1966; Gorecki, 1965).

Thus  $I_f = E_m + n l (Eg_1 + Eg_2) / AE$   
 where  $n$  is the mean litter size (4,  $N = 48$ ) and  $l$  is the number of litters per year (1.14,  $N = 48$ ).  
 Therefore  $I_f = 2012 + 268 / .879 + 2594 \text{ kcal/year.}$

$Eg_3$  (growth of weaned mice) has been ignored in this and later calculations. It amounts to only 49 kcal/year for males and 32 kcal/year for females.

Based on the kinds of food carried in the cheek pouches, about 95% of the diet of pocket mice consists of cheatgrass seeds (caryopses). Cheatgrass density on sixty 0.1m<sup>2</sup> plots averaged 94 plants (9.4/dm<sup>2</sup>). From Fig. 15 of Hulbert (1955) cheatgrass at this density produces about 21 seeds/dm<sup>2</sup> (2100/m<sup>2</sup>).

Cheatgrass seeds removed from the cheek pouches of pocket mice weighed an average of 590/g. Thus seed production is calculated as  $3.56 \text{ g/m}^2$  (35.6 kg/ha). Since the caloric value of brome seeds is 4.35 kcal/g (Johnson and Robel, 1968), seed production represents 154,860 kcal/ha.

The catch of pocket mice from single trap lines of 50 traps each averaged 17.5, 13.125, and 10.25 for three consecutive days of trapping in June, 1970 (Table 3). Using the technique of Zippin (1958) the total trapable population ( $\pm$  S. E.) is estimated as  $74 \pm 33$ . Continued trapping would have narrowed the confidence limits but this estimate will suffice to make a rough calculation of density.

One must know the effective trapping area (the area occupied by mice susceptible to trapping) in order to determine density.

The pair of lines placed 50 feet apart (Table 3) caught fewer pocket mice than those placed at greater distances. Lines only 50 feet apart have overlapping effective areas while those spaced at 100 feet or more show no interference. Thus the distance from the trap line to the edge of the effective area was more than 25 feet but less than 50 feet. I have chosen the intermediate distance (37.5 ft) as the extent of effectiveness on each side of the trap line. Each 500-foot line of traps had an effective area of  $500 \times (37.5 \times 2) + \pi(37.5)^2$  or about 43,000 sq. ft. (0.4 ha). Therefore the density of pocket mice in June was  $74/.4 = 185/\text{ha}$ . This is perhaps an overestimate but density was very high on the study area at this time.

Table 3. Catch of pocket mice from pairs of trap lines (50 traps each), June 9-11, 1970

Pair No.	Spacing between lines (ft)	Catch			Sum
		1st Day	2nd Day	3rd Day	
1	50	37	21	10	68
2	100	40	24	20	84
3	150	31	24	26	81
4	200	42	22	17	81
5	250	27	35	19	81
Means for single line (Pairs 2-5)		17.5	13.125	10.25	

If pocket mice could recover one-half of the cheatgrass seeds produced, no more than 28/ha could survive for one year on the 1970 seed crop (using the ingestion rates calculated and assuming a balanced sex ratio). I would predict then disaster for this population, something, regrettably, that cannot be verified because of the holocaust of July 17.

#### Peromyscus maniculatus:

For this species I have used  $E_r = 9.3 - 0.2 T_b$  by adjusting the minimum rate measured by McNab and Morrison (1963, Table 1 and Fig. 13) to a resting level as suggested by Chew and Chew (1970). The insulating effects of a nest (Pearson 1960) reduce this to  $7.4 - 0.13 T_b$  below 26.5 C.

Deer mice are active throughout the year even in rigorous climates (Johnson and Groepper 1970). I have assumed that cached food was not available (i. e. a 20-4 activity cycle throughout the year, Table 4). The use of a nest represents a saving of 8% in maintenance energy cost (Table 4).

Deer mice living in the wild on the North Plains on natural diets demonstrated assimilation efficiencies of 86-91% (Johnson and Groepper 1970). Using a mean of 89.1%, the ingestion rate for males is calculated as:

$$I_m = 4420 / .891 = 4961 \text{ kcal/ year.}$$

Deer mice at birth weigh an average of 1.4 g (McCabe and Blanchard 1950). Correcting for embryonic tissues,  $W_1 = 1.8$ . Deer mice at weaning weigh about 8.6 g (McCabe and Blanchard 1950). Therefore,  $W_2 = 6.8$ . Adult body weight of males averaged 17.8 (N = 52) and that of non-gravid females 16.6 g (N = 9). Thus,  $W_{m3} = 9.2$  and  $W_{f3} = 8.0$ .

Using the caloric values and growth efficiencies cited earlier, a mean litter size of 5.1 (Scheffer, 1924; N = 48) and assuming 1.5 litters per year:

$$I_f = 4246 + 612 / .891 = 5452 \text{ kcal/ year.}$$

The ingestion rates for deer mice greatly exceed those for pocket mice (Table 2), evidence of the energy saved in torpor.

Table 4. Estimated resting, active and maintenance metabolic rates for Peromyscus maniculatus.

Month	$E_r$	Males		$E_r$	Females	
		$E_a$	$E_m$		$E_a$	$E_m$
Jun	212	91	303	204	87	291
Jul	188	90	278	180	87	267
Aug	193	93	286	185	90	275
Sept	227	103	330	218	99	317
Oct	276	119	395	265	114	379
Nov	283	126	409	271	122	393
Dec	308	131	439	296	126	422
Jan	323	137	460	311	131	442
Feb	278	117	395	267	113	380
Mar	287	122	409	275	118	393
Apr	257	112	369	247	107	354
May	240	107	347	230	103	333
Sum	3072	1348	4420	2949	1297	4246
Without nest			4781 (108%)			4592 (108%)

The caloric value of the food ingested by deer mice varied 5.52 to 5.60 (Johnson and Groepper 1970). Using a mean of 5.56 kcal/g, each male in the population under study would ingest about 890 g/year and each female 980 g of food/year.

Deer mice are omnivorous, subsisting upon a variety of arthropods, seeds, and herbage (Johnson 1961). They demonstrate marked seasonal variation in diet (Johnson 1964). Their effect on the availability of cheatgrass seeds, the primary food of pocket mice, remains to be determined.

#### Onychomys leucogaster

For this species I have used  $E_r = 7.24 - 0.17 T_a$ , that determined by Chew and Chew (1970) for O. torridus, a species of similar body size. The insulating effects of a nest (Pearson 1960) reduce this to  $5.86 - 0.12 T_d$  below 27.5 C.

Grasshopper mice are active throughout the year. I have assumed that cached food was not available (a 20-4 activity cycle occurred throughout the year, Table 5). The use of a nest represents a saving of 9% in maintenance energy (Table 5).

Grasshopper mice living in the wild on the North Plains demonstrated assimilation efficiencies of 85.7-87.0% (Johnson and Groepper 1970). Using the mean of 86.3%, the ingestion rate for males is calculated as:

$$I_m = 4881 / .863 = 5656 \text{ kcal/year.}$$

I have calculated the additional energy cost of embryo and nestling growth ( $E_e$  and  $E_g$ ) as follows: grasshopper mice at birth weight 2.8 g (Horner 1968). With embryonic tissues,  $W_1 = 3.6$ . At weaning they weight 13.1 g (Horner 1968). Therefore,  $W_2 = 9.5$ . Adult body weight of males averaged 25.1 g (N=14) and that of non-gravid females 27.1 g (N= 8). Thus,  $W_{m3} = 15.6$  and  $W_{f3} = 17.6$

Using the caloric values and growth efficiencies cited earlier, 3.7 as the mean litter size (Pinter 1970), and assuming 1.5 litters/ female/ year, the ingestion rate for females is calculated as:

$$I_f = 5354 + 666 / .863 = 7873 \text{ kcal/ year.}$$

Grasshopper mice subsist on a variety of arthropods, seeds, and leaves. Some use of flesh has also been observed (Bailey and Sperry 1929; Johnson 1961). Captives demonstrated a seasonal change in food preference (Jahoda 1970). The caloric value of the stomach contents of North Plains grasshopper mice was 5.65 kcal/g (Johnson and Groepper 1970). Thus each male in the population under study would ingest about 1 kg of food per year and each female about 1.4 kg.

#### Reithrodontomys megalotis

For this species I have used  $E_r = 11.41 - 0.27 T_a$  (Pearson 1960). The insulating effects of a nest will reduce this to  $9.2 - 0.18 T_d$  below 26.5 C.



Table 5. Estimated resting, active and maintenance metabolic rates for Onychomys leucogaster.

Month	$E_r$	Males		$E_r$	Females	
		$E_a$	$E_m$		$E_a$	$E_m$
June	210	110	320	230	120	350
Jul	187	107	294	205	117	322
Aug	194	112	306	213	122	335
Sep	232	124	356	253	136	389
Oct	292	142	434	319	156	475
Nov	311	147	458	341	161	502
Dec	344	160	504	376	176	552
Jan	359	164	523	393	180	573
Feb	304	143	447	334	155	489
Mar	307	148	455	336	162	498
Apr	275	135	410	301	148	449
May	247	127	374	270	139	409
Sum	3262	1619	4881	3571	1772	5353
Without nest			5303 (109%)			5807 (109%)

Harvest mice are active throughout the year. As with deer mice and grasshopper mice, I have assumed a 20-4 activity cycle. The use of a nest represents a saving of about 12% (Table 6).

I have calculated assimilation efficiency as 94.8% by the ash tracer method. Ingestion rate for males is calculated as:

$$I_m = 3236 / .948 = 3413 \text{ kcal/year.}$$

I have calculated the energy cost of embryo and nestling growth as follows: harvest mice at birth weight 1.5 g (Svihla, 1931). Correcting for embryonic tissues,  $W_1 = 1.9$ . Weaning weight is assumed to be 5.4 g (prorated from that for deer mice). Therefore,  $W_2 = 3.9$ . Based on a small sample size (N=14) adult body weight average 10.8 g. Thus  $W_3 = 5.4$ .

Table 6. Estimated resting, active and maintenance metabolic rates for Reithrodontomys megalotis.

Month	$E_r$	$E_a$	$E_m$
June	149	63	212
July	132	62	194
August	138	66	194
September	165	73	238
October	202	87	389
November	212	90	302
December	235	98	333
January	244	102	346
February	209	88	297
March	212	90	302
April	187	81	268
May	174	77	251
Sum	2259	977	3236
Without nest			3508 (112%)

Using the caloric values and growth efficiencies cited earlier, a mean litter size of 3.6 (Bancroft 1968), and assuming 1.5 litters/ female/ year, the ingestion rate for females is calculated as:

$$I_f = 3236 + 283 / .948 = 3712 \text{ kcal/year.}$$

Harvest mice subsist upon a variety of arthropods, seeds, and herbage (Johnson 1961). The caloric value of their food is assumed to be the same as that of deer mice (5.56 kcal/q). Thus each male in the population under study would consume about 614 g/year and each female 668 g/year.

#### Seasonal Variation in Fat Content:

Rodents demonstrate three types of seasonal change in fat content: 1) the peak occurs during the winter months as in Apodemus flavicollis (Sawicka-Kapusta, 1960), 2) peaks alternate with the spring-fall breeding seasons as in Peromyscus polionotus (Caldwell and Connell, 1968), and 3) the peak occurs during the summer months as in Peromyscus crinitus (McNab, 1968). Although all samples have not been analyzed, it appears that Perognathus parvus exhibits a Type I (winter) peak (Appendix I).

#### Bait Effectiveness:

Pocket mice show a strong preference for rolled oats in a paste form over that of a mixture of rolled oats and peanut butter used as bait (Appendix II).

### Discussion

Although many investigators have measured ingestion rates of small mammals in the laboratory (Sealander, 1952 and literature cited there), it was Pearson (1960) who first attempted to calculate the ingestion rate of a small mammal living in the wild. McNab (1963) developed an energy budget model with time, microenvironmental temperature, and metabolic rate as variables. McNab lacked specific information on activity patterns, microenvironmental temperatures, and assimilation rates. His model ignored the energy cost of pregnancy and lactation.

The study of ingestion rates of heteromyid rodents offers a particular challenge because of the added complexity of torpor and its relationship to food availability and microenvironmental temperature. Tucker (1966) described the relationship between weight loss, food intake, and torpor for Perognathus californicus as:

$$Y = 7.63 - 0.44X_1 - 0.26X_2$$

where Y is the percent of the original body weight lost per day,  $X_1$  is the food intake in g/100 g original body weight, and  $X_2$  is the hours in torpor daily at 15 C. When body weight is constant:

$$X_1 = 17.3 - 0.59X_2 .$$

Using this equation and assuming a 20-hour daily torpor (Table 2),  $X_1 = 5.5/100$  g or 1 g daily for a 19 g pocket mouse (male) and 0.77 g daily for a 14 g female. These ingestion rates amount to 155 and 113 kcal/month (on Tucker's laboratory diet of 4.9 kcal/q). They exceed the ingestion rates I have calculated by about 70% ( $E_m/AE$  estimates for winter months). However, Perognathus californicus weighs about 25% more than Perognathus parvus. Thus our estimates are reasonably close despite the different approaches used in calculating them.

My estimates of ingestion rates for these four species will be improved once specific information on activity cycles becomes available. My assumption that a 20-4 cycle persists throughout the year is almost certainly in error since Hatfield (1940) found that excursions of captive deer mice from the nest to a food source were greatly reduced at 0 C.

The survival, reproduction, and density of heteromyid rodents is closely tied to the availability of seeds of winter annuals, a fact recognized almost 50 years ago (Vorhies and Taylor, 1922), and, most recently by Beatley (1969). Speth et al. (1968) found juvenile Perognathus parvus breeding during the summer of 1967, a year of high seed production. The survival of annuals is in turn dependent upon the amount and pattern of precipitation (Beatley 1967).

Cheatgrass yields in southern Idaho are correlated closely with precipitation. Sneva (1965) has described this relationship as:

$$Y = 37.5 + 1.368X$$

where Y is the yield estimate is percent of the mean yield and X is the total precipitation for October, April, and May expressed as a percent of the mean for those months.

The pattern and amount of precipitation than should be used as a variable in a model predicting the frequency and pattern of breeding in heteromyids of the Desert Biome, and, ultimately, in predicting their density.

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#### Appendix I

Fat content (mg)  $\pm$  S.E. of Perognathus parvus. Sample size in parentheses.

	Males	Females
March, 1970	790 $\pm$ 0.05 (36)	610 $\pm$ 0.2 (4)
April	610 $\pm$ 0.03 (31)	450 $\pm$ 0.03 (12)
May	580 $\pm$ 0.03 (43)	530 $\pm$ 0.02 (41)
June	630 $\pm$ 0.04 (33)	540 $\pm$ 0.04 (18)
July	610 $\pm$ 0.04 (18)	560 $\pm$ 0.1 (17)
August	660 $\pm$ 0.04 (24)	620 $\pm$ 0.05 (16)

#### Appendix II

Catch from 500 traps on July 16, 1970.

	Peanut butter	Rolled oats
<u>Perognathus parvus</u>	43	80*
<u>Peromyscus maniculatus</u>	2	0
<u>Onychomys leucogaster</u>	3	1
<u>Reithrodontomys megalotis</u>	3	1

\* Significant difference (P < .05).