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COYOTE-PREY RELATIONSHIPS IN CURLEW VALLEY DURING A PERIOD OF LOW JACKRABBIT DENSITY

by

Stephen W. Hoffman

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Ecology

Approved:

Major Professor

Committee Member

Committee Member

Dean of Graduate School

UTAH STATE UNIVERSITY
Logan, Utah

1979

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Steve Hoffman

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ABSTRACT

Coyote-Prey Relationships in Curlew Valley
During a Period of Low Jackrabbit Density
by
Stephen W. Hoffman, Master of Science
Utah State University, 1978

Major Professor: Dr. Frederick F. Knowlton
Department: Wildlife Science

Coyote-prey relationships were examined in Curlew Valley, northern Utah and southern Idaho, during a period of low jackrabbit density (from September 1973 to May 1975). The Utah and Idaho portions of Curlew Valley were treated separately. Field work provided estimates of relative and absolute rodent densities as well as relative coyote density each spring and fall. Laboratory analysis of over 2,300 scats and 249 stomachs provided detailed information on coyote diets. Jackrabbit population data for northern Utah were obtained from L. Charles Stoddart.

Four species, Peromyscus maniculatus, Perognathus parvus, Eutamias minimus, and Dipodomys ordii comprised over 90 percent of the rodent individuals snap trapped. Estimated mean densities were greatest for Peromyscus (3.3-5.3/ha), and progressively less for Perognathus (2.3-3.6/ha), Dipodomys (0.5-1.8/ha), and Eutamias (0.5-0.7/ha).

Jackrabbits comprised half the annual diet of coyotes in Utah, but only 10 percent in Idaho, where rodents were the principal prey consumed. Marked seasonal and site-specific variation in rodent and jackrabbit consumption occurred in both areas. Seasonal trends probably resulted from changes in rodent abundance and availability.

Relative coyote densities did not vary appreciably during the period and were greater in the Idaho portion of the study area.

Despite low jackrabbit densities in 1973-1975, jackrabbit comprised two-thirds or more of the coyote's diet in Utah during the late fall and winter. This suggests a dearth of available alternate prey at that time. A clumped dispersion of jackrabbits during the winter may have contributed to this phenomenon.

In Utah, coyote utilization of some rodents was correlated with snap trap indices, suggesting that: (1) coyote predation upon these rodents was a random event, or (2) rodent density changes were not of sufficient magnitude to alter coyote predatory behavior. In Idaho, a three-fold increase in pocket gopher and cottontail consumption compensated for a reduction in the availability of deer and microtine rodents.

The importance of various prey species in the diet was compared with their relative densities. Jackrabbit appeared to be "preferred" over rodent; within the rodent group *Microtus* and *Lagurus*, *Reithrodontomys*, *Perognathus*, and *Dipodomys* were preferred over *Peromyscus* and *Eutamias*. Implied prey preferences are explained principally on the basis of optimization theory, and the significance of prey dispersion patterns is emphasized.

Winter food supply is suggested as the critical factor limiting coyote densities in Curlew Valley and throughout the Great Basin. Availability of jackrabbit, livestock carrion, and to a lesser extent, deer, microtine rodents, and cottontails is likely to be most influential in determining coyote density in the Great Basin Desert.

(139 pages)

INTRODUCTION

The coyote (Canis latrans) is the most abundant and controversial large carnivore in North America. The need for controlling depredations upon livestock, with a concomitant recognition of the ecological and aesthetic importance of the coyote causes a conflict which might be resolved through more intensive management (Knowlton 1972). Sound predator management must be based upon intimate ecological knowledge of both predator and prey. Specifically, factors which influence coyote density and demography need to be more clearly defined (Hornocker 1972).

It has been hypothesized that available food supply, acting in concert with behavioral mechanisms, regulate coyote densities in the absence of human exploitation (Knowlton and Stoddart 1978). The importance of food in determining coyote population levels has been suggested by several researchers. Gier (1968 and pers. comm.) believes that coyote densities in Kansas vary in response to changes in rodent abundance. Knowlton (1972) compared two areas in Texas and noted a direct relationship between rodent biomass and coyote numbers. In South Texas, the coyote density index declined by over 40 percent following a severe reduction in woodrat (Neotoma micropus) and cotton rat (Sigmodon hispidus) populations (Knowlton et al. 1971). Nellis and Keith (1976) observed a marked decline in coyote abundance coincident with low microtine (Microtus spp.) and snowshoe hare populations (Lepus americanus) populations. Weaver (1977) learned that availability of winter elk carrion accounted for

84 percent of the variation in spring coyote density indices during his 2-year study in Jackson Hole, Wyoming. The importance of winter carrion in regulating coyote distribution and density has also been demonstrated by Todd and Keith (1976) in Alberta, Canada.

In Curlew Valley, along the Utah-Idaho border, Clark (1972) reported that changes in coyote density coincided with fluctuations in their principal prey, the black-tailed jackrabbit (*Lepus californicus*). This area has been the site of long-term demographic studies of coyotes (Clark 1972, Knudsen 1976) and jackrabbits (Gross et al. 1974, Stoddart 1972, Wagner and Stoddart 1972). Jackrabbit and coyote densities have fluctuated widely since the inception of that research in 1963 (Fig. 1).

Previous coyote food habit studies in Curlew were conducted during moderate to high jackrabbit densities (Clark 1972, Knudsen unpubl. data). Based on stomach analyses of coyotes killed in winter, it was determined that jackrabbit dominated the diet during this time (1968-1973).

Despite these findings, several aspects of coyote food habits in Curlew Valley remained unknown: (1) seasonal and geographic patterns, and (2) dietary habits during a period of low jackrabbit density. In addition, few quantitative data were available regarding the abundance, distribution, and extent of population fluctuations of prey resources other than jackrabbit.

In the spring of 1974, the jackrabbit density index (Stoddart 1977) reached a point lower than any recorded previously for Curlew Valley (Fig. 1). This provided an opportunity to investigate coyote-

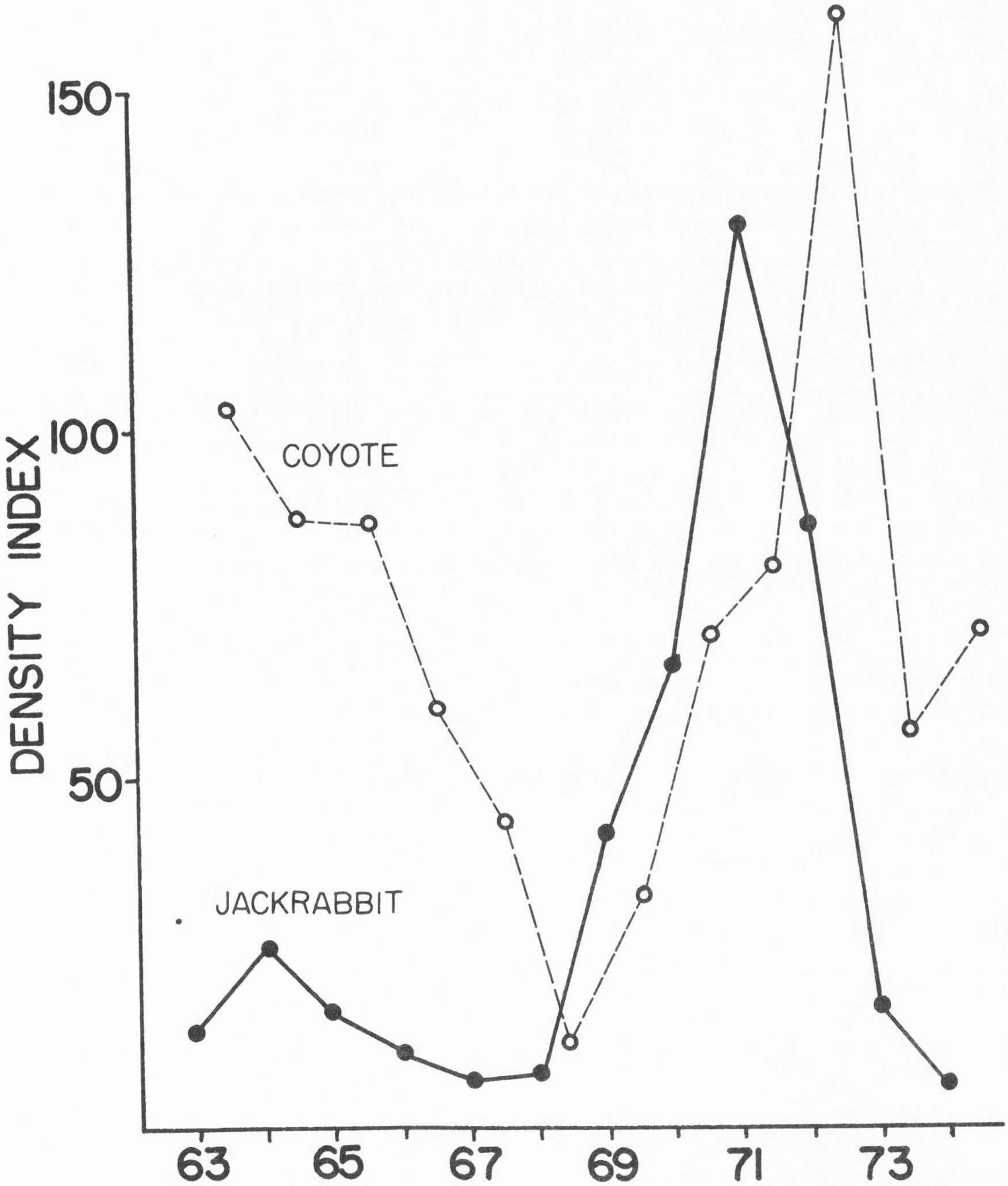

Figure 1. Fluctuations in coyote and jackrabbit populations in Curlew Valley, 1963-1974 (from Stoddart 1977).

prey relationships in an area of comparatively limited prey diversity and biomass, during a time of relative scarcity of the major prey species (jackrabbit). At such a time, the importance of alternate prey may be greatly enhanced. If alternate prey are not available, or if coyotes fail to use the resource, then the density of coyotes in Curlew may be determined primarily by numbers of jackrabbits, as suggested by Clark (1972).

This study was undertaken to investigate the importance of alternate (non-jackrabbit) prey to coyotes and to determine the relationship between prey availability and coyote density. The specific objectives were to:

1. Estimate relative and absolute rodent densities each spring and fall.
2. Determine the relative abundance of coyotes in spring and fall.
3. Describe geographic and seasonal variations in the coyote diet.
4. Compare relative densities of rodent and jackrabbit with their relative importance in the diet of coyotes.
5. Examine the importance of available prey to coyote density.

STUDY AREA

The 1770-km^2 study area is situated in Box Elder County, Utah and Oneida and Cassia Counties, Idaho (Fig. 2). The area was divided into two sub-regions--Utah and Idaho (or the Utah and Idaho study areas), comprising 806 and 968 km^2, respectively.

Physiography

All of the Utah study area and about half of the Idaho area lie within Curlew Valley, a semi-arid intermountain basin, once covered by Pleistocene Lake Bonneville (Flint 1957). The remaining area in Idaho encompasses the foothill regions of several nearby mountain ranges, with the Black Pines Mountains (max. elev. 2680 m) to the west, the Subletts (max. elev. 1947 m) to the north, and the North Promontories (max. elev. 1926 m) to the east. The Idaho portion of Curlew Valley is divided into an eastern and western arm by the Sublett Range. .In Utah, Curlew Valley extends south beyond the limits of the study area to the Great Salt Lake flats. Two isolated, remnant volcanic cones, the Wildcat Hills (max. elev. 1553 m) and Cedar Hill (max. elev. 1585 m), are prominent features of the Utah study area. Valley floor elevations range from 1280 m in Utah to 1585 m in Idaho.

Stone Reservoir, the only large body of water within the study area, is located midway between Snowville and Holbrook in the eastern arm of Curlew Valley, Idaho. A small stream, Deep Creek, flows

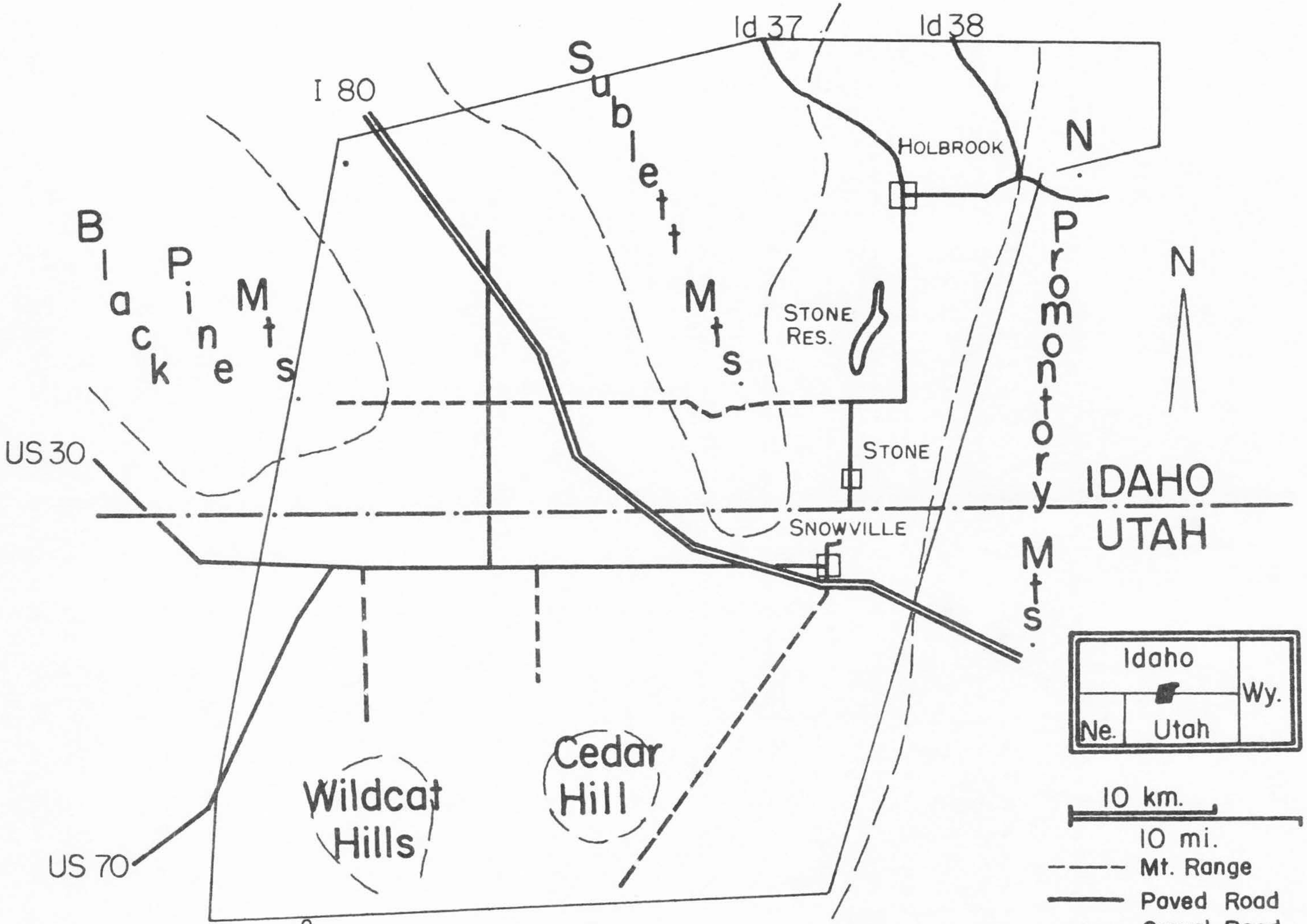

Figure 2. Map of the 1770-km^2 Curlew Valley study area, Utah and Idaho.

through the area, but disappears underground just south of the Utah-Idaho border. A few isolated springs are scattered throughout the region.

Soils in the Curlew Valley study area are characterized by extreme variations in alkalinity and salinity (Gates et al. 1956). Soil textures are also highly variable, and include gravels, sandy volcanics, sandy loams, silt loams, and clay loams (A. R. Southard, pers. comm.).

Climate

A decreasing gradient of precipitation occurs from north to south across the study area, with an annual average of 20-25 cm in Utah and 30-36 cm in Idaho (Gross et al. 1974). Most of the precipitation occurs between November and May. Winter snow depth rarely exceeds 30 cm on the valley floor (US/IBP Desert Biome, unpubl.), but may reach 80 cm or more in nearby foothills. Mean temperatures during the study period (1973-1975) for January, the coldest month, and July, the warmest month, were -6° C and 22° C, respectively (Desert Biome, unpubl.). Maximum temperatures of 38° C occur in summer, and minima of -32° C in January (Mitchell 1965).

Vegetation

Vegetation is characteristic of the Great Basin Floristic Province (Gleason and Cronquist 1964) or "northern shrub desert biome" (Fautin

1946). Typically, one or two species of shrubs or trees dominate vegetation zones, which are limited by soil moisture and/or salinity (Gates et al. 1956).

Vegetation and/or soil characteristics were used to classify plant communities into eight habitat types suitable for the present study. These include five natural types (sage-annuals, sage-bunchgrass, shadscale, juniper, and Douglas-fir/aspen), two agricultural types (alfalfa and cereal grains), and one modified range type (seeded crested wheatgrass). The distribution patterns (mapped from an ERTS infrared aerial photograph) and percent areal coverage (estimated by sampling the habitat map with a grid overlay) of the eight habitat types are shown in Fig. 3 and Table 1, respectively. Brief descriptions of each type follow. Scientific names follow Cronquist et al. (1972).

Sage-annuals is the predominant type, comprising 49 and 52 percent of the Utah and Idaho study areas, respectively. Big sagebrush (*Artemisia tridentata*) is the dominant shrub, but may be associated with rabbitbrush (*Chrysothamnus nauseosus* or *C. viscidiflorus*), greasewood (*Sarcobatus vermiculatus*), or blacksage (*Artemisia arbuscula*). Greasewood occasionally forms pure stands in areas of high salinity. Annual forbs are important associated plants; halogeton (*Halogeton glomeratus*), peppergrass (*Lepidium perfoliatum*), Russian thistle (*Salsola kali*), and bassia (*Bassia hyssopifolia*) were the predominant annuals present in most areas. Vegetation ground cover in this type is variable, ranging from less than 5 percent to to more than 70 percent. At higher elevations in Idaho, a somewhat

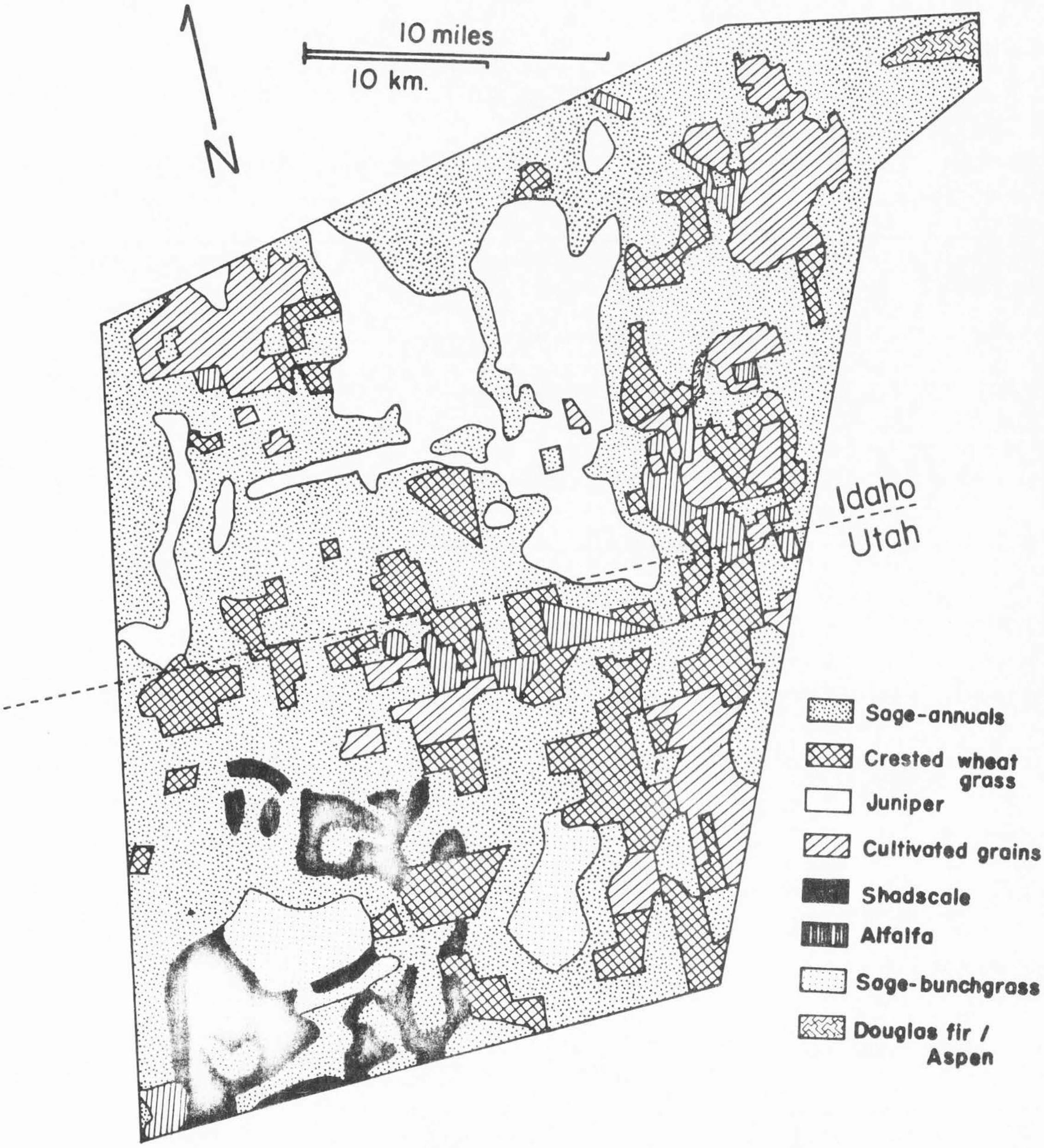

Figure 3. The spatial distribution of eight habitat types in the Curlew Valley study area.

Table 1. Areal coverage of eight habitat types in the Curlew Valley Study area, Utah and Idaho.

	Utah (809 km^2)		Idaho (964 km^2)	
	km^2	percent	km^2	percent
Sage-annuals	392	48.6	507	52.4
Crested wheatgrass	151	18.7	95	9.8
Juniper	2	0.2	200	20.7
Cultivated grains	63	7.8	119	12.3
Shadscale	105	13.0	-	-
Alfalfa	33	4.1	33	3.4
Sage-bunchgrass	63	7.8	-	-
Douglas-fir/aspen	-	-	10	1.0

different big sagebrush community is present, where serviceberry (*Amelanchier alnifolia*), mountain mahogany (*Cercocarpus ledifolius*), and bitterbrush (*Purshia tridentata*) are important co-dominants.

The sage-bunchgrass type is restricted to the Wildcat Hills and Cedar Hill, and·covers 7.8 percent of the Utah study area. Soils are primarily sandy-volcanics; dunes are present in a few areas. Shrub cover is typically rather uniform, averaging about 40 percent. Associated shrubs include hopsage (*Grayia spinosa*), budsage (*Artemisia spinescens*), and horsebrush (*Tetradymia* spp.). Bluebunch wheatgrass (*Agropyron spicatum*), sandberg bluegrass (*Poa sandbergii*), Idaho fescue (*Festuca idahoensis*), and Indian ricegrass (*Oryzopsis hymenoides*) are important perennial grasses in this habitat type.

The shadscale (*Atriplex confertifolia*) type is common in the southern end of Curlew Valley, covering 13 percent of the Utah study area. This salt-desert type is characterized by low, widely-spaced shrubs; vegetation ground cover is less than 10 percent. Other woody species besides shadscale which are locally common include gray molley (*Kochia americana*), winterfat (*Ceratoides lanata*, [*Eurotia*, Howell 1971]), and Nuttall saltbrush (*Atriplex falcata*). Associated grasses and forbs include cheatgrass (*Bromus tectorum*), squirreltail (*Sitanion hystrix*), prickly-pear (*Opuntia polyacantha*), globemallow (*Sphaeralcea munroana*), and cushion wild buckwheat (*Eriogonum ovalifolium*). Shadscale intermixes with sagebrush in many areas, often with clumps of sagebrush present as islands surrounded by shadscale.

At somewhat higher elevations in the foothills, open stands of Utah juniper (*Juniperus osteosperma*) occur, occupying 20.7 percent of the area in Idaho. Big sagebrush is an abundant understory shrub. Forbs common to this type include wild onion (*Allium acuminatum*), death camas (*Zigadenus paniculatus*), arrowleaf balsamroot (*Balsamorhiza sagittata*), skyrocket gilia (*Gilia aggregata*), locoweed (*Astragalus* spp.) and wild buckwheat (*Eriogonum* spp.).

As a range improvement practice, large areas of sagebrush have been plowed and seeded with crested wheatgrass (*Agropyron desertorum*). These areas represent 18.7 percent of Utah, and 9.8 percent of Idaho. Some seedings were unsuccessful, and these areas are usually dominated by Russian thistle and halogeton. In Idaho, sagebrush has begun to re-invade older seedings.

Cultivated land comprises 11.9 and 15.7 percent of Utah and Idaho, respectively. Most is planted to cereal grains (primarily winter wheat), almost half of which remains fallow each year (Soil Conserv. Serv., pers. comm.). The remaining cultivated land is irrigated, primarily for growing alfalfa (*Medicago sativa*).

Aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*) forest occur in the extreme northeastern corner of the Idaho study area (Fig. 3); its areal coverage is quite small.

Fauna

The vertebrate fauna of Curlew Valley has never been studied systematically. Potential coyote prey of widespread occurrence in Utah and Idaho include the deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), northern grasshopper mouse (*Onychomys leucogaster*), desert and bushy-tailed woodrats (*Neotoma leipda* and *N. cinerea*), Great Basin pocket mouse (*Perognathus parvus*), Ord's kangaroo rat (*Dipodomys ordii*), least chipmunk (*Eutamias minimus*), Townsend's ground squirrel (*Spermophilus townsendi*), sagebrush vole (*Lagurus curtatus*), montane vole (*Microtus montanus*), black-tailed jackrabbit, and mountain and pygmy cottontails (*Sylvilagus nuttallii* and *S. idahoensis*). Rodents found almost exclusively in the Idaho study area include the Uinta and golden-mantled ground squirrels (*Spermophilus armatus* and *S. lateralis*), cliff chipmunk (*Eutamias dorsalis*), northern pocket gopher (*Thomomys talpoides*), long-tailed vole (*Microtus longicaudus*), pinon mouse (*Peromyscus truei*), and porcupine (*Erethizon dorsatum*). The little pocket mouse (*Perognathus longimembris*) and Great Basin kangaroo rat (*Dipodomys microps*) are restricted to dunes and shadscale areas in Utah, and the muskrat (*Ondatra zibethica*) inhabits areas permanently inundated by water.

Two species of ungulates are present. Mule deer (*Odocoileus hemionus*) over-winter in Idaho and pronghorn antelope (*Antilocapra americana*) are restricted to the western and southern portions of the study area.

Numerous passerines, seven species of galliforms, and 13 species of raptors (Howard 1975, Platt 1971) nest in the study area. Reptiles include at least six species of snakes and eight of lizards.

Several other carnivores inhabit the study area, including badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*), bobcats (*Lynx rufus*), striped skunks (*Mephitis mephitis*), and occasionally kit fox (*Vulpes macrotis*), mountain lion (*Felis concolor*), and red fox (*Vulpes vulpes*).

Land Use

Approximately 60 percent of the study area is public land administered by the Bureau of Land Management. The remainder is privately owned, and is devoted to agricultural and grazing purposes. The area is grazed by domestic sheep in winter (Utah) and spring (Idaho), and by cattle year-round.

METHODS

Indices of Rodent Abundance

Linear snap trap transects were used to assess relative and absolute numbers of rodents. Each transect consisted of a 90-meter line with 10 M-4 rat snap traps with expanded treadles (Carley and Knowlton 1971) spaced 10 meters apart. Traps, baited with peanut butter and rolled oats, were set for 3 consecutive days. Species, sex, age class (adult, subadult or juvenile), and weight of captured individuals were recorded. Sprung and "inoperable" traps (insensitive treadle), and traps with missing bait were also noted. All data were coded and recorded in the field to be later punched directly onto computer cards. Trapping indices are expressed as "catch per effort," where effort is defined by the following equation (L. C. Stoddart, pers. comm.):

$$E = \frac{N_t/N_o - 1}{\ln_e N_t/N_o}$$

where: E = effort (or number of "trap nights")

N_o = initial number of operable traps

N_t = N_o minus the number sprung (with or without rodents)

As traps become filled or sprung, they no longer contribute to the effort. Stoddart's assumption that the rate at which traps are snapped decreases in proportion to the number of traps still operable at any time during the trapping period is intuitively appealing.

Transect locations were determined in two ways. First, transects were set along four continuous 24-km sections of unimproved dirt road (two each in Utah and Idaho, Fig. 4). These census routes were chosen to correspond with existing coyote census lines. Twenty-five transects, oriented perpendicular to the road axis and alternating to the right and left side of the road, were spaced at 1-km intervals along each road section. These 100 transects were operated each May and September to monitor rodent population trends in the study area.

Additional transects were located in plant associations and geographic areas not adequately sampled by the above design. Due to the size of the study area, locations of these transect sites varied among sampling periods. As a result each sampling period contained some transects in areas or vegetation types that had not been censused at any time previously.

Percent distribution of transects by habitat type is given in Table 2.

Calibration of Rodent Indices

Although rodent snap trap indices could be used as a relative measure of rodent numbers, estimates of absolute density were needed to compare with rodent consumption by coyotes. Live trap grids were set for the exclusive purpose of calibrating snap trap indices. Sequential live and snap trapping (Yang et al. 1970) on these grids served to correlate (by linear regression) snap trap indices with

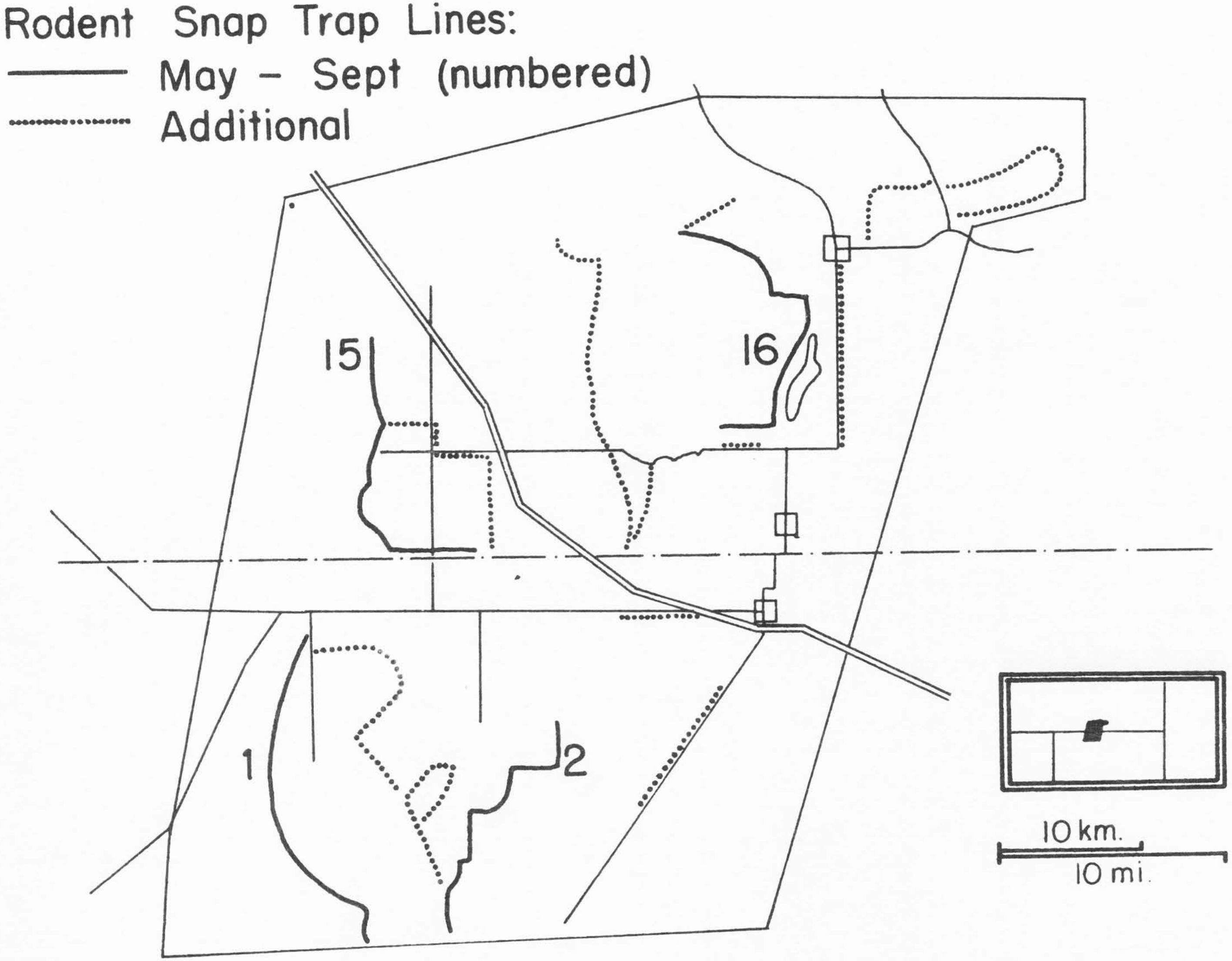

Figure 4. Locations of rodent snap trap lines in the Curlew Valley study area.

Table 2. Distribution of rodent snap trap transects by habitat type for each census period in Curlew Valley, Utah and Idaho. Number of transects in parentheses.

	Percent of area	Percent of transects			
		Sept. 1973	May 1974	Sept. 1974	May 1975
Utah		(46)	(61)	(66)	(92)
Sage-annuals	48.6	22	21	21	26
Crested wheatgrass	18.7	30	30	23	22
Shadscale	13.0	46	34	32	28
Sage-bunchgrass	7.8	2	8	12	12
Cultivated grains	7.8	-	3	-	4
Alfalfa	4.1	-	3	12	8
Idaho		(50)	(35)	(117)	(94)
Sage-annuals	52.4	44	55	52	49
Juniper	20.7	4	22	9	16
Cultivated grains	12.3	-	2	11	5
Crested wheatgrass	9.8	50	20	20	27
Alfalfa	3.4	2	-	2	3
Douglas fir/aspen	1.0	-	-	6	-

density estimates. The May and September indices could then be converted to densities via regression formulae.

Density estimation

The estimation of rodent densities from mark-recapture data is comprised of two aspects: (1) determining the population size, and (2) estimating the area actually sampled.

Estimating population size. Much attention has been given to the statistical treatment of mark-recapture data, and the interested reader is referred to Cormack (1968, 1972), Otis et al. (1978), and Seber (1973) for a thorough discussion of the topic. For this study, a single estimator of population size was sought that could be meaningfully applied to all live-trap data. Twelve different population estimators were calculated and compared (Appendix I). However, these estimators all have certain basic assumptions; when these assumptions are not met, population estimates may be extremely biased (Cormack 1972, Otis et al. 1978).

Testing the validity of assumptions is difficult, and seldom are the necessary assumptions met in rodent mark-recapture studies. Otis et al. (1978) developed a complex computer algorithm which tests three critical assumptions; these are: (1) equal catchability, (2) behavioral response to capture, and (3) time-specific variation in capture probability. For a given data set the algorithm suggests an appropriate maximum likelihood estimator(s) that meets the necessary assumptions that appear to be valid. This procedure was followed in the present study.

Results indicated that the necessary assumptions were frequently violated and that no single estimator could be justifiably used for all the mark-recapture data. Therefore, the total number of individuals live trapped (excluding trap mortalities) was used as a conservative estimate of population size. This is consistent with the work of Krebs (1966), MacMahon (1975, 1976) Turner and McBrayer (1974) and others.

Estimating area sampled. To determine the area sampled by the live trap grids, an estimate of movements was necessary. Brant's (1962) mean maximum distance between any two recapture points (MMD) served as an "index to home range size," and one-half this distance was used as the width of the border zone. This method was also used by Chew and Chew (1970), French et al. (1976), Kauffeld (1977), and Stickel (1960). More recent methods (Otis et al. 1978) were found to be unsatisfactory. The total area sampled by the trapping grid was calculated as follows:

$$A_w = A + pw/c + \pi w^2/c$$

where: A_w = size of area sampled

A = area trapped

p = grid perimeter

w = width of border zone

c = conversion factor ($c = 10{,}000$ for meters to hectares)

The procedure for calculating rodent movements (MMD) within grids follows. MMD was calculated for each species by averaging the values of each individual for which two or more recaptures were available. If movement data were not available for at least three individuals within a grid, a pooled estimate of MMD (based on data from all grids) was used. Individual maximum moves that exceeded 150 meters were treated as outliers and removed from the calculations. "Trap-happy" animals that exhibited no movement were also deleted.

Live trapping procedure

In keeping with Stickel's (1948) recommendations, grid locations were selected systematically to sample low and high population densities in a variety of habitats. When selecting specific trapping sites, consideration was given to habitat uniformity as well as accessibility.

The 3-hectare configuration follows that used by the U.S. International Biological Program (French et al. 1976, Balph 1973). Sherman live traps (7.6 x 7.6 x 25.4 cm), one at each station, were distributed in a 12 x 12 grid pattern. Traps were spaced 15 meters apart (Smith et al. 1975) and baited with rolled oats (Hansson 1967). A number-and-letter coordinate system denoted each trap site. Surplus food within each trap reduced overnight mortality to less than 5 percent (Lewellyn 1950, Howard 1951). Traps were checked at daybreak, left closed during the day, and re-opened approximately 2 hours before twilight. Grids were operated for 4-6 (usually 5) consecutive nights, depending upon the frequency of new captures. Halfway through the trapping period, traps were moved half the distance to the next station (7.5 m). This helped to: (1) randomize trap locations (Eberhardt 1963), (2) prevent traps from interfering with normal movements (Brant 1962), (3) reduce the probability of trap-prone animals learning specific trap sites (Chitty 1937), and (4) increase the probability of new captures.

The trap location, species, weight, sex, and age class of each captured individual were recorded. Animals were toe-clipped for individual identification and released at the site of capture.

Snap trap placement within grids

Snap trap transects placed within the live trap grids were used to correlate (via regression techniques) absolute density estimates with relative indices. Similar attempts by Yang et al. (1970) and Montan (1977) met with some success. Immediately following the live trapping, two or three snap trap transects identical to those used for the indices were set within each grid. Two to five additional transects were placed near each grid. Transect placement was a compromise between the desire to obtain a variance estimate and the problem of closely spaced transects competing for the same animals.

Jackrabbit Density Index

All jackrabbit population data used in this report were obtained from L. C. Stoddart (1977 and pers. comm.). Density indices were measured only in the Utah portion of Curlew Valley. Each March and October, Stoddart walked between 63 and 72 one-mile foot transects and recorded flushing angles and flushing distances of observed rabbits. Since flushing behavior of jackrabbits varies seasonally and with density (Stoddart 1972), the number of rabbits seen on the transects could not be used as the index. Instead, flushing angles and distances were used in an equation derived by Gates (1969) to correct transect results. A detailed account of Stoddart's methodology is given by Gross et al. (1974).

Coyote Diets

Coyote diets were assessed by examining scats collected each month along 240 km of dirt roads and by examining stomachs of coyotes killed in winter (1974-75 only).

Scats

The date, location, and approximate age of each scat was recorded. Prior to examination, scats were sterilized in an autoclave for 30 minutes. In the laboratory, scats were air-dried, weighed, and then broken apart by hand. To facilitate recovery of small items, the scat material was sorted into four size classes with 2, 1, 0.5, and 0.25 mm wire mesh sieves. Identification was aided by a binocular microscope and a laboratory reference collection of study skins, skulls, and other skeletal material of mammals occurring in or near the study area. To quantify contents of scats, the percent volume (to the nearest 5 percent) for major food categories (i.e., rodent, jackrabbit, bird, cow, deer, reptile, insect, and vegetation) was estimated visually. The accuracy of this method was not evaluated, but similar techniques were used by Clark (1957), Tisch (1961), Russell (1975), Knowlton (1964), and Hawthorne (1972). Food items comprising less than 5 percent of a scat were recorded as trace.

For quantification within the rodent group, the minimum number of individuals consumed was determined by using the diagnostic part (e.g., mandibles, teeth, bones, feet) that gave the highest count (Murie 1935, Nellis et al. 1972). Scat data were summarized in four ways: (1) percent frequency of occurrence with each scat representing a sampling unit, (2) percent total volume, (3) mean percent volume ("aggregate percentage method" of Davis and Zippin [1954]), and (4) mean number of (rodent) individuals detected per 100 scats.

"Percent total volume" (2) was calculated in the following way:

$$PTV_i = \frac{\sum_{j=1}^{N} W_j P_{ij}}{T} \times 100$$

where: N = number of scats in sample,

W_j = weight of scat j,

P_{ij} = proportion of food item i in scat j, and

T = total weight of scats in sample.

This method equates weight and volume of scats, and large scats are more important than small ones. In contrast, "mean percent volume" (3) represents an unweighted mean; that is, all scats (regardless of size) are given equal importance. Results of the two methods were similar, and only "percent total volume" data are presented.

Stomachs

Carcasses were obtained in the winter of 1974-75 from aerial gunners, trappers, ranchers, sportsmen, and snowmobilers who killed coyotes within and around the study area. Collectors were provided with tags to attach the date and location to each kill. Stomachs were frozen until examined. Contents were separated by species and weighed. Data were tabulated in two ways: (1) percent frequency of occurrence, and (2) percent of total weight.

Relative Coyote Numbers

Fall coyote population trends were assessed by three independent indices: scent-post response, trapping, and scat collecting. Only the scent-post method was used for a spring index.

Scent station index

Eight standard carnivore scent station lines (Linhart and Knowlton 1975, Lindzey et al. 1977) were established along continuous 24 km sections of dirt road (Fig. 5). The lines were run for five consecutive days each May and October. Index values for each scent station line were computed as follows:

$$I = \frac{V \times 1{,}000}{N}$$

where: I = index value,

V = total number of coyote visits, and

N = number of "operable" (i.e., readable) scent station nights.

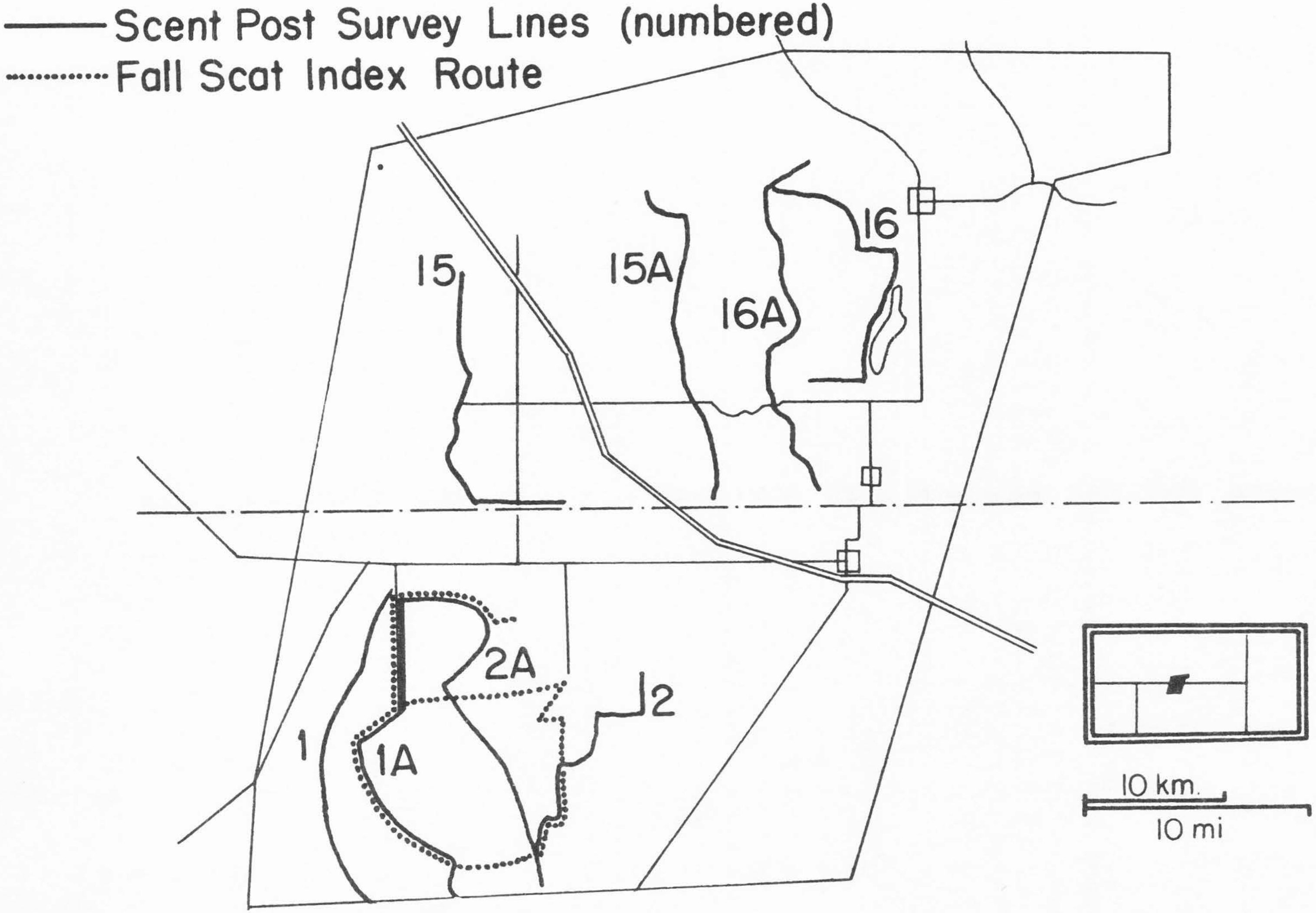

Figure 5. Locations of coyote scent station lines and scat index route in the Curlew Valley study area.

Scat collection rates

Each fall (late October) a 60-km network of dirt roads in the Utah portion of the study area (Fig. 5) was cleared of coyote scats. Scats were collected along this route twice each fall at biweekly intervals. The mean number of scats deposited per day served as the second relative measure of fall coyote densities.

Coyote trapping

The third index of fall coyote abundance was derived from trapping efforts conducted by experienced Fish and Wildlife Service personnel. Two trap lines were located in Idaho and one in Utah. A detailed account of the trapping methodology is given by Clark (1972) and Knudsen (1976).

Each line consisted of 50 trap stations operated for 1 month, and the number of coyotes trapped per 1,000 trap nights served as the index.

RESULTS

Rodent populations, relative coyote numbers, and coyote feeding patterns were monitored periodically from September 1973 to May 1975.

Rodent Snap Trapping

The purposes of the May and September snap trapping efforts were three-fold: (1) assess changes in rodent abundance on the study area; (2) determine rodent distribution and abundance in relation to habitat type; and (3) estimate rodent densities and biomass over the entire study area. The first two objectives were accomplished with a relative index, whereas the latter required conversion of indices to absolute density.

Overview of snap trap indices

A total of 3,804 rodents, representing 12 genera and 20 species, were captured in 16,120 snap trap nights accumulated during the four census periods (Table 3). Although the Idaho portion of the study area had a somewhat more abundant and diverse rodent fauna, the overall species composition in Utah and Idaho was similar. Four species--the deer mouse *Peromyscus maniculatus*, Great Basin pocket mouse *Perognathus parvus*, least chipmunk *Eutamias minimus*, and Ord's kangaroo rat *Dipodomys ordii*--comprised 92 and 94 percent of the catch in Utah and Idaho, respectively. (Hereafter these four species will be designated by the generic name only.) *Peromyscus* predominated,

Table 3. Numbers of rodents snap trapped during four census periods from September 1973 to May 1975 in Curlew Valley, Utah and Idaho.

	Utah (6,916)[a]		Idaho (9,204)		Total (16,120)
Species	Number captured	Mean index[b]	Number captured	Mean index	
Peromyscus maniculatus	753 (56.2)[c]	10.9	1,607 (65.2)	17.5	2,360 (62.1)
Perognathus parvus	250 (18.7)	3.6	329 (13.4)	3.6	579 (15.2)
Eutamias minimus	76 (5.7)	1.1	240 (9.7)	2.6	316 (8.3)
Dipodomys ordii	154 (11.5)	2.2	146 (5.9)	1.6	300 (7.9)
Dipodomys microps	47 (3.5)	0.7	1 (tr)	tr	48 (1.3)
Onychomys leucogaster	6 (tr)	tr	35 (1.4)	0.4	41 (1.1)
Perognathus longimembris	33 (2.5)	0.5	1 (tr)	tr	34
Eutamias amoenus	-		29 (1.2)	tr	29
Ammospermophilus leucurus	14 (1.0)		9		23
Eutamias dorsalis	-		22		22
Reithrodontomys megalotis	3		15		18
Neotoma lepida	1		9		10
Peromyscus truei	-		5		5
Microtus longicaudus	-		4		4
Spermophilus armatus	-		3		3
Spermophilus townsendi	1		1		2
Lagurus curtatus	1		1		2
Microtus montanus	-		2		2
Neotoma cinerea	-		2		2
Thomomys talpoides	-		2		2
Total	1,339	19.4	2,465	26.8	3,804

[a] Total effort

[b] Average catch per 100 trap nights

[c] Percent of total

forming 56 percent of the total catch in Utah and 65 percent in Idaho. Several rodent species were infrequently trapped, suggesting they: (1) were only locally abundant, (2) occurred in very low numbers throughout the study area, and/or (3) exhibited trap avoidance. These points are discussed later.

The rodent species composition in Curlew Valley is similar to that found in many other Great Basin areas (Allred 1973, Larrison and Johnson 1973, Johnson 1977, Kauffeld 1977, and Montan 1977). The predominance of *Peromyscus* is typical, although O'Farrell (1975) found *Perognathus* to be the most abundant rodent below 2,500 feet (760 m) in southeastern Washington. The intense grazing pressure in much of Curlew Valley may enhance the importance of *Peromyscus* in the study area (Larrison and Johnson 1973, Quast 1948, Phillips 1936).

Seasonal variations in rodent abundance

Seasonal and annual variations in rodent abundance were noted during the study period (Fig. 6). Index line values in both Utah and Idaho for *Peromyscus*, *Eutamias*, and *Dipodomys* differed among the four trapping periods ($p \leq .05$, Kruskal-Wallis Test). *Peromyscus* and *Dipodomys* populations fluctuated widely, and trends differed markedly between Utah and Idaho. *Dipodomys* density indices in Idaho did not vary significantly, but a 390 percent increase was noted in Utah from fall 1973 to fall 1974. Variations in *Eutamias* indices were less dramatic, with similar trends between Utah and Idaho.

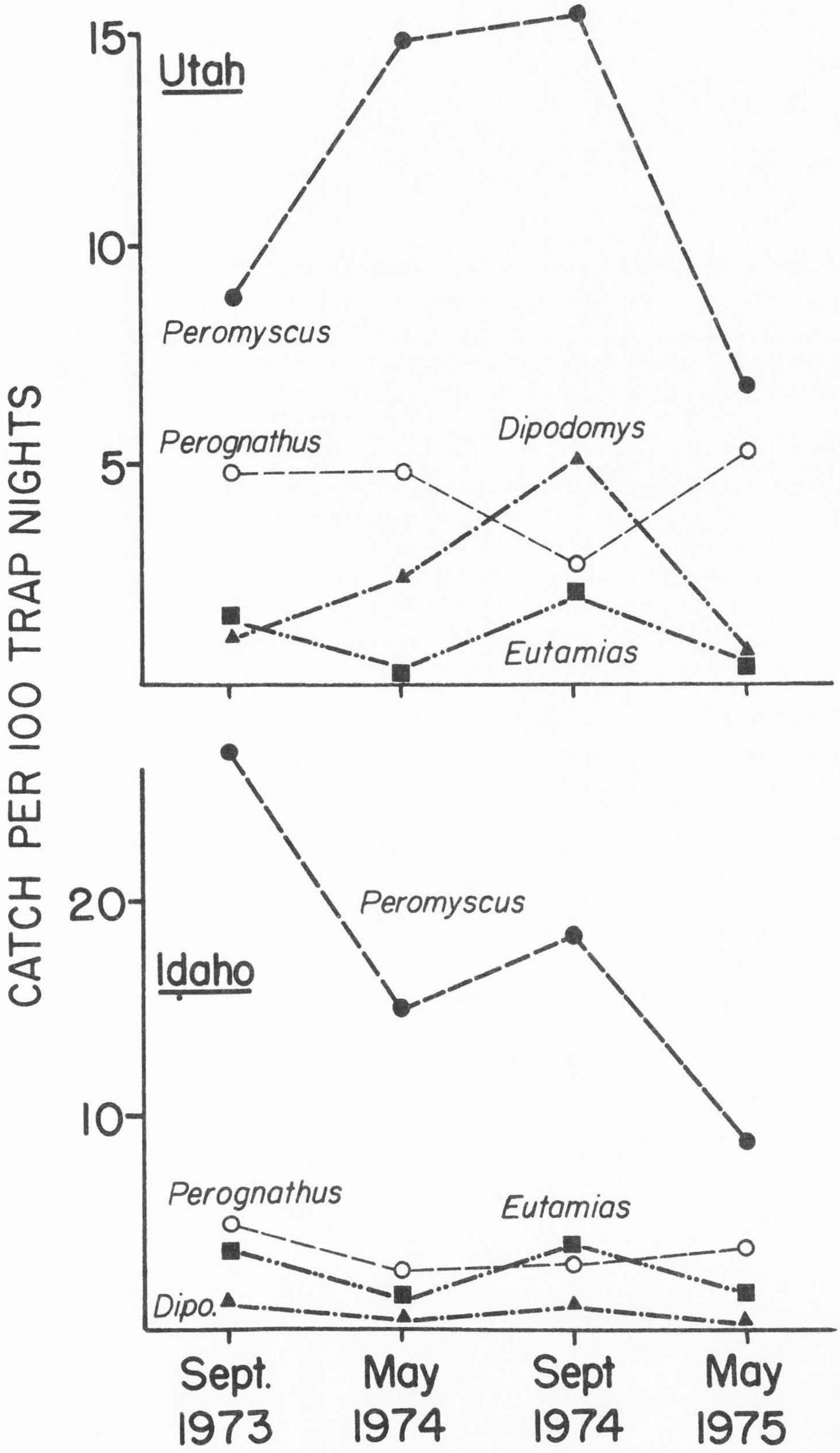

Figure 6. Seasonal variation in rodent abundance from September 1973 to May 1975 in Curlew Valley, Utah and Idaho.

Rodent-habitat relationships

If one assumes equal capture probabilities among all habitats (probably not a valid assumption), rodent species composition and density varied considerably among habitat types ($p < .10$, Kruskal-Wallis Test). A composite of the rodent catch in relation to habitat type is shown in Table 4. Native vegetation (sagebrush, shadscale, juniper) generally supported greater rodent diversity and total biomass than introduced grass and agricultural types. The sage-bunchgrass type supported the greatest total rodent biomass.

Peromyscus was the only species trapped in all habitats; it predominated in every type except shadscale, where *Perognathus* was trapped in comparable numbers. The ubiquity of *Peromyscus* in the Great Basin region is well known (Allred 1973, Larrison and Johnson 1973, Montan 1977, Fautin 1946, and others). Although *Dipodomys* and *Peromyscus* occurred in most habitats, high index values were obtained consistently only in the sage-bunchgrass type. *Eutamias* was common only in the sage-annuals and juniper communities, while *Dipodomys microps* was restricted to areas of shadscale due to its specialized feeding behavior (Kenagy 1972). Habitat affinities of species infrequently trapped could not be adequately evaluated.

Calibration of Rodent Indices

Although snap trap transects are an efficient method of assessing rodent populations over large areas (Calhoun 1964), estimates of actual density were needed to compare with the relative importance

Table 4. Mean snap trap indices (expressed as catch per 100 trap nights) in relation to habitat type in Curlew Valley, Utah and Idaho.

	Sage-bunchgrass.	Sage-annuals		Juniper	Shadscale	Crested wheatgrass		Alfalfa	Cultiv. grain
	(37)[a]	UT (61)	ID (176)	(47)	(89)	UT (67)	ID (91)	(23)	(25)
Peromyscus maniculatus	20.4	23.2	23.6	14.6	5.0	6.2	9.8	21.6	11.9
Perognathus parvus	14.6	2.2	5.9	6.6	4.8	1.4	0.8	tr	1.1
Eutamias minimus	0.8	3.5	4.5	1.7	tr[b]	tr	0.6	-	-
Dipodomys ordii	12.4	3.4	1.6	1.1	0.9	1.3	1.0	-	0.5
Dipodomys microps	1.0	-	-	-	1.2	-		-	-

[a] Number of 10-trap transects.

[b] trace (< 0.5).

of rodents in the diet of coyotes. To accomplish this, snap trap indices were correlated with estimates of absolute density by sequential live and snap trapping (Yang et al. 1970) on several quadrat plots.

Live trapping

Rodent densities were estimated on 20 2.8-ha live trap grids set during summer 1974 and spring 1975. James S. Wakeley contributed data from three additional grids. Grid trapping sampled all habitats, accumulating 3,826 captures of 1,605 individuals (10 genera, 12 species) in 15,696 trap nights (Appendix II).

Individuals of four species were captured in sufficient numbers to allow density estimates on several grids. Peromyscus was captured on all grids, whereas Perognathus, Eutamias, and Dipodomys were present on 20, 18, and 11 grids, respectively. Estimates of population size, movements (MMD), sampling area, and density for each of the four species are shown in Appendix III (Tables 34-37).

A wide variation in species densities was encountered. The highest density sampled for any species was 25.9 animals per hectare, estimated for Peromyscus (Table 34). The highest densities encountered for Perognathus, Eutamias, and Dipodomys were 12.3, 6.3, and 11.9 individuals per hectare, respectively (Tables 35-37).

Snap trapping on grids

Immediately after live trapping, snap trap transects were set within and adjacent to each grid. Despite apparent uniformity of habitat surrounding each grid site, significantly larger index values

($p < .10$, paired t-test) were obtained from transects located within the grids (Appendix IV). This was true for all species except Dipodomys and suggests that the 5-day live trapping period modified rodent movements and/or density by concentrating animals within the grid from surrounding areas. Since grid density estimates reflect the number of animals captured within the grids, only the in-grid index values were used for the index-density regressions which follow.

Index-density relationships

Relationships between the snap trap index (x) and density based upon live trapping (y) were quantified using a linear regression model ($y = a + bx$). Regression equations are later used to estimate rodent densities for the entire study area.

Index-density relationships for each of the four species are depicted in Figs. 7-10 and summarized in Table 5. Single outlying points for Perognathus (#17) and Eutamias (#10) were excluded from the analysis. All four regressions are highly significant ($p < .01$), with slopes and y-intercepts different from each other (F-test). The correlation is highest for Dipodomys ($r^2 = .85$) and lowest for Perognathus ($r^2 = .60$).

The slope of the regression line is related, in part, to the species' probability of capture in live traps relative to snap traps. The steep slope (.404) for Perognathus suggests a lower capture probability in snap traps than live traps. In contrast, the regression lines for Eutamias and Peromyscus showed gradual slopes (0.67 and .125, respectively), inferring a higher vulnerability to snap traps.

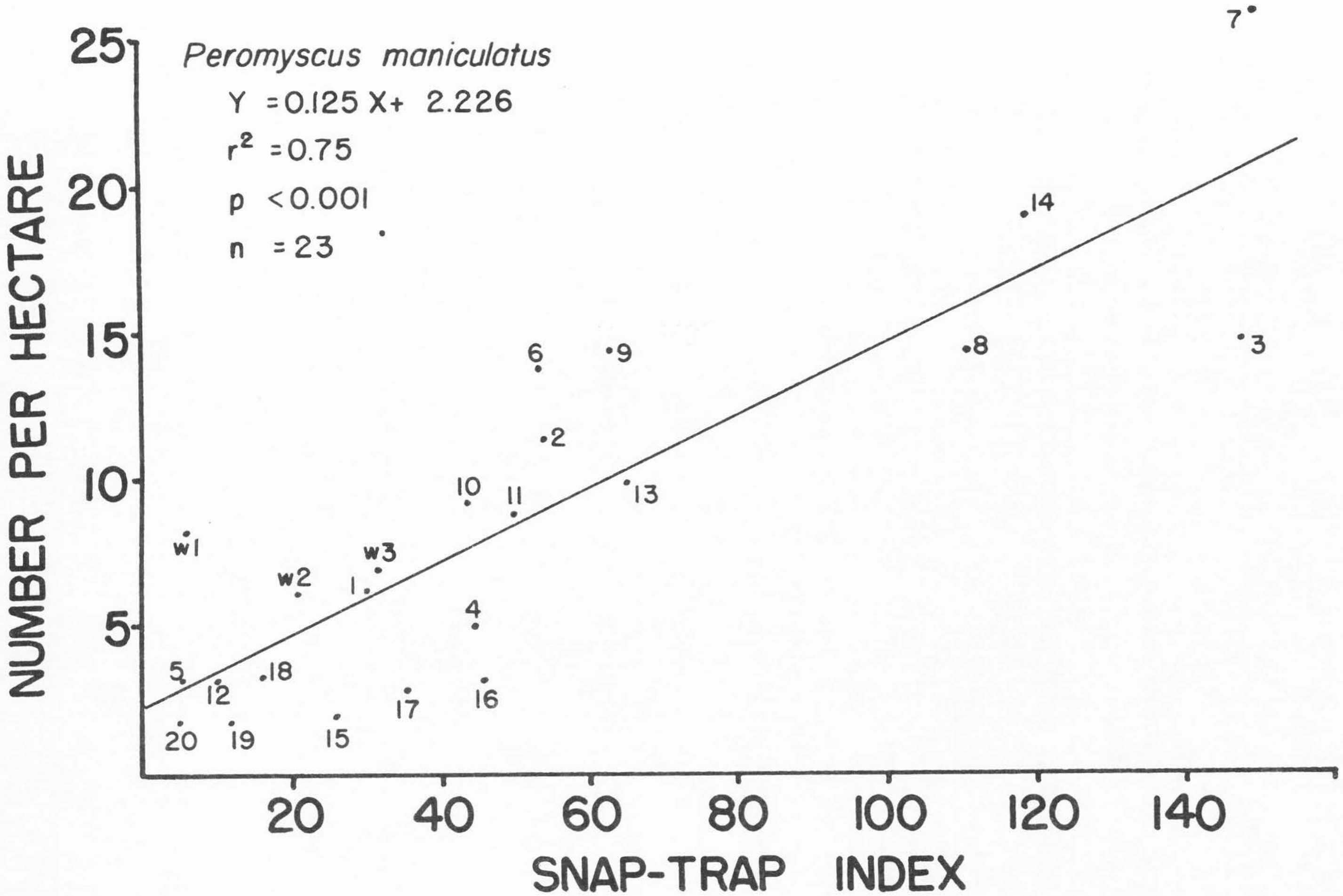

Figure 7. Linear regression between density estimated from live trapping (y) and snap trap indices (x) for Peromyscus on 23 live trap grids.

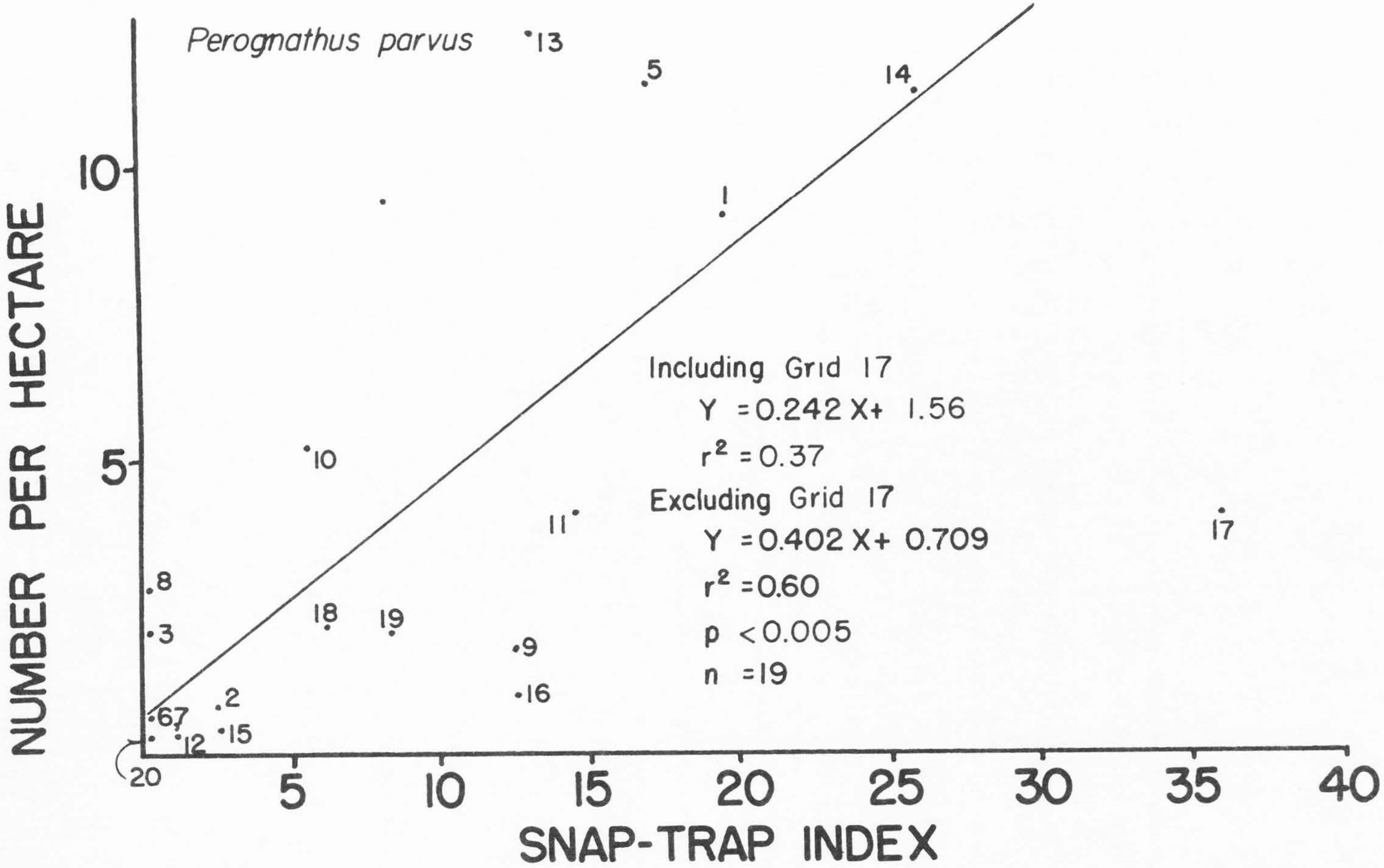

Figure 8. Linear regression between density estimated from live trapping (y) and snap trap indices (x) for Perognathus on 19 grids.

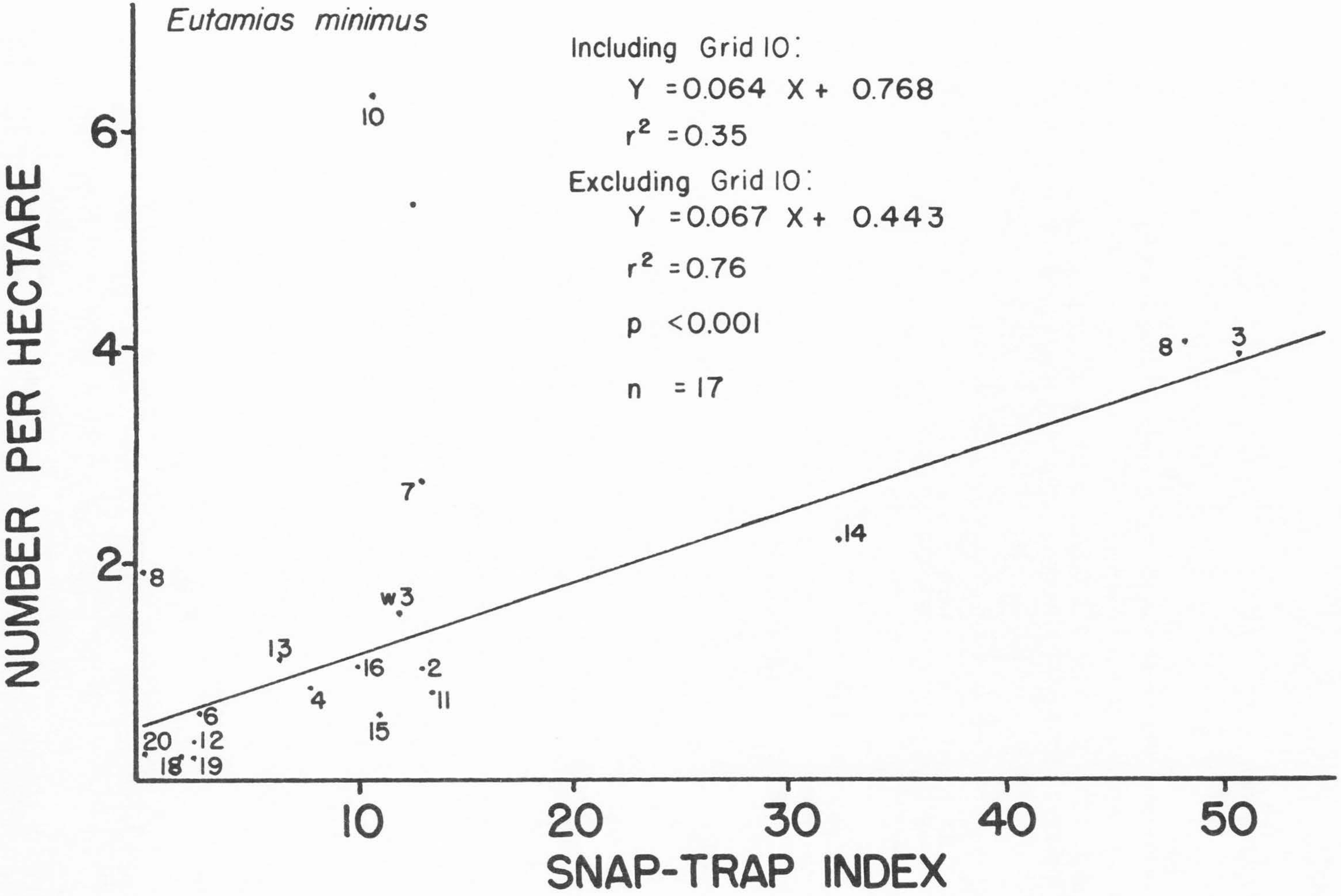

Figure 9. Linear regression between density estimated from live trapping (y) and snap trap indices (x) for Eutamias on 17 grids.

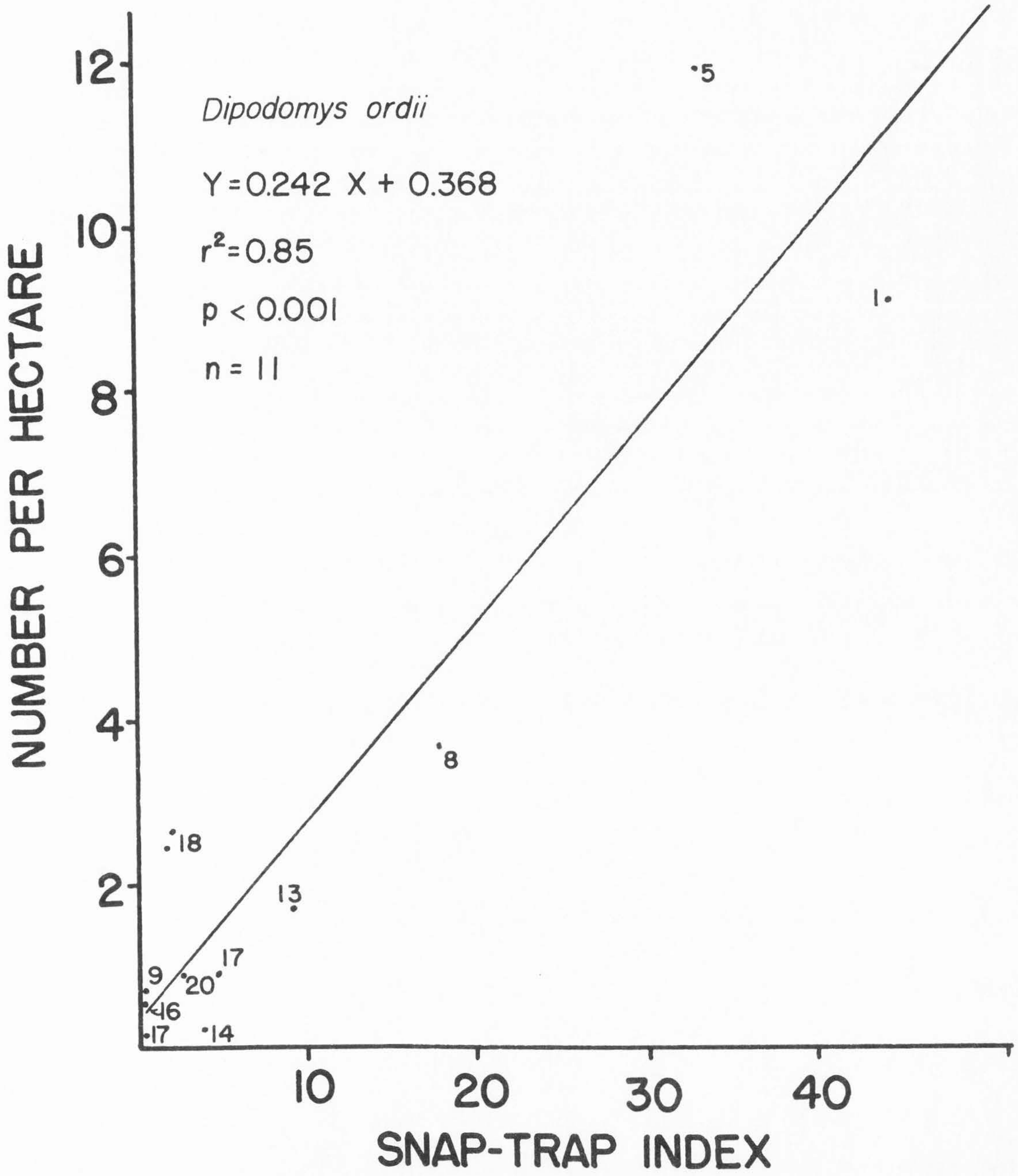

Figure 10. Linear regression between density estimated from live trapping (y) and snap trap indices (x) for Dipodomys on 11 grids.

Table 5. Summary of the index-density regression calculations ($y = a + bx$), where y = density from live trap data, and x = snap trap index.

	No. grids	slope (b)	y-intercept (a)	r^2	p-value
Peromyscus maniculatus	23	.125	2.226	.75	.001
Perognathus parvus (all)[1]	20	.242	1.56	.37	.01
Excluding Grid 17	19	.404	0.673	.60	.005
Eutamias minimus (all)[1]	18	.064	0.768	.35	.01
Excluding Grid 10	17	.067	0.443	.76	.001
Dipodomys ordii	11	.242	0.368	.85	.001

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[1] Values were not used in density calculations, but are presented for comparison.

This inference is realistic for *Peromyscus*; regression results for *Eutamias* may reflect a low probability of capture in live traps for this diurnal rodent.

Although relationships between line catches and density have been previously demonstrated for *Peromyscus* (Montan 1977, Petticrew and Sadlier 1970), to my knowledge this is the first attempt for *Perognathus*, *Eutamias*, and *Dipodomys*. Relationships may vary with population density (Hansson 1975), food availability (Smith and Blessing 1969), season (Fitch 1954, Pucek 1969, Hansson 1967), and habitat (Blair 1941, Stickel 1948, Montan 1977). The low sample sizes obtained in this study preclude a detailed investigation of such questions. Moreover, because the x and y variables are estimated parameters with unknown variances, the index-density relationships presented are crude estimates, but the only ones currently available.

Density and biomass estimates

Rodent snap trap indices, densities, and percent biomass by habitat type for each census period are shown in Tables 6-9. Densities were calculated from the regression formulas (Table 5), and biomass figures are based on mean weights of trapped animals (Table 10).

To calculate average density for the entire study area, snap trap indices for each habitat type were weighted in proportion to their areal coverage to obtain a mean index value. (Utah and Idaho were calculated separately, except for indices in alfalfa and cultivated grain.) This mean index was then converted to an estimate of density via regression formulas.

Table 6. Rodent snap trap indices (catch per 100 trap nights), estimated densities and biomass by habitat type in Curlew Valley, Utah and Idaho, September 1973.

	Utah				Idaho		
	Sage-annuals	Crested wheatgrass	Shadscale	Sage-bunchgrass	Sage-annuals	Juniper	Crested wheatgrass
No. of transects	10	14	21	1	22	2	25
Peromyscus maniculatus							
Index ± SE	23.6 ± 2.2	8.7 ± 2.5	1.9 ± 0.5	14.8	39.0 ± 3.1	3.9 ± 0.2	18.3 ± 2.9
No./ha.	5.2	3.3	2.5	4.1	7.1	2.7	4.5
Biomass (g/ha)	99.8	63.4	48.0	78.7	137.0	52.1	86.8
Perognathus parvus							
Index ± SE	1.5 ± 1.1	1.7 ± 0.8	7.6 ± 1.8	29.5	9.0 ± 1.7	11.7 ± 0.5	1.1 ± 0.4
No./ha.	1.3	1.4	3.7	12.6	4.3	5.4	1.1
Biomass (g/ha)	23.4	25.2	66.6	226.8	78.7	98.8	20.1
Eutamias minimus							
Index ± SE	4.8 ± 1.5	0.8 ± 0.6	-	-	7.3 ± 2.3	-	0.3 ± 0.2
No./ha.	0.8	0.5			0.9		0.5
Biomass (g/ha)	25.8	16.1			30.2		16.8
Dipodomys ordii							
Index ± SE	2.7 ± 1.0	1.1 ± 0.6	-	19.7	1.8 ± 0.8	-	1.1 ± 0.6
No./ha.	1.0	0.6		5.1	0.8		0.6
Biomass (g/ha)	49.6	29.8		253.0	41.8		31.4

Table 7. Rodent snap trap indices (catch per 100 trap nights), estimated densities and biomass for each habitat type in Curlew Valley, Utah and Idaho, May 1974.

	Utah				Idaho				
	Sage-annuals	Crested wheatgrass	Shadscale	Sage-bunchgrass	Sage-annuals	Juniper	Crested wheatgrass	Cultivated grain[1]	Alfalfa[1]
No. of transects	13	18	21	5	47	19	17	3	2
Peromyscus maniculatus									
Index ± SE	31.4 ± 7.4	2.2 ± 0.7	6.5 ± 1.7	31.7 ± 4.9	27.1 ± 4.0	20.9 ± 4.2	27.1 ± 4.0	18.5 ± 10.3	95.7 ± 35.2
No./ha.	6.2	2.5	3.0	6.2	5.6	4.8	2.9	4.5	14.2
Biomass (g/ha)	115.9	46.8	56.1	115.9	105.3	90.2	54.5	84.6	265.5
Perognathus parvus									
Index ± SE	3.2 ± 1.6	0.2 ± 0.2	5.0 ± 1.5	18.9 ± 5.9	4.9 ± 1.1	5.8 ± 1.1	4.9 ± 1.1	1.5 ± 1.5	-
No./ha.	2.0	0.8	2.7	8.3	2.6	3.0	0.8	1.3	
Biomass (g/ha)	40.8	16.3	55.1	169.3	54.9	63.3	16.9	27.4	
Eutamias minimus									
Index ± SE	0.8 ± 0.5	-	-	-	2.7 ± 0.6	3.7 ± 1.3	2.7 ± 0.6	-	-
No./ha.	0.5				0.6	0.7	0.5		
Biomass (g/ha)	17.5				23.2	27.1	19.4		
Dipodomys ordii									
Index ± SE	3.5 ± 1.2	-	1.3 ± 0.5	10.1 ± 3.5	1.0 ± 0.3	0.7 ± 0.4	1.0 ± 0.3	1.3 ± 1.3	-
No./ha.	1.2		0.7	2.8	0.6	0.5	0.7	0.7	
Biomass (g/ha)	60.7		35.4	141.7	28.0	23.3	32.6	32.6	

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[1] Utah and Idaho transects combined.

Table 8. Rodent snap trap indices (catch per 100 trap nights), estimated densities and biomass for each habitat type in Curlew Valley, Utah and Idaho, September 1974.

	Utah				Idaho				
	Sage-annuals	Crested wheatgrass	Shadscale	Sage-bunchgrass	Sage-annuals	Juniper	Crested wheagrass	Cultivated grain[1]	Alfalfa[1]
No. of transects	14	15	21	8	61	11	23	13	10
Peromyscus maniculatus									
Index ± SE	28.5 ± 4.8	10.6 ± 2.5	9.6 ± 2.0	15.2 ± 3.3	25.7 ± 1.6	28.6 ± 4.0	12.0 ± 1.9	11.9 ± 2.2	13.2 ± 3.1
No./ha.	5.8	3.6	3.4	4.1	5.4	5.8	3.7	3.7	3.9
Biomass (g/ha)	94.0	58.3	55.1	66.4	92.3	99.2	63.3	63.3	64.7
Perognathus parvus									
Index ± SE	2.0 ± 0.9	3.2 ± 1.3	3.2 ± 0.8	6.8 ± 1.5	5.2 ± 0.7	5.3 ± 1.6	0.3 ± 0.2	1.1 ± 0.5	-
No./ha.	1.5	2.0	2.0	3.4	2.8	2.8	0.8	1.1	
Biomass (g/ha)	24.4	32.6	32.6	55.4	49.3	49.3	14.1	19.4	
Eutamias minimus									
Index ± SE	6.2 ± 2.0	0.5 ± 0.3	1.2 ± 0.5	3.6 ± 1.7	6.7 ± 1.0	2.6 ± 1.1	0.8 ± 0.3	-	-
No./ha.	0.9	0.5	0.5	0.7	0.9	0.6	0.5		
Biomass (g/ha)	27.8	15.4	15.4	21.6	28.7	19.1	16.0		
Dipodomys ordii									
Index ± SE	7.3 ± 1.6	4.6 ± 1.8	2.6 ± 1.4	16.8 ± 3.8	2.0 ± 0.4	2.0 ± 1.4	1.4 ± 0.5	0.5 ± 0.4	-
No./ha.	2.1	1.5	1.0	4.4	0.8	0.8	0.7	0.5	
Biomass (g/ha)	103.5	73.9	49.3	216.9	41.3	41.3	36.1	25.8	

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[1] Utah and Idaho transects combined.

Table 9. Rodent snap trap indices (catch per 100 trap nights), estimated densities and biomass for each habitat type in Curlew Valley, Utah and Idaho, May 1975.

	Utah				Idaho				
	Sage-annuals	Crested wheatgrass	Shadscale	Sage-bunchgrass	Sage-annuals	Juniper	Crested wheatgrass	Cultivated grain[1]	Alfalfa[1]
No. of transects	24	20	26	11	46	15	25	9	10
Peromyscus maniculatus									
Index ± SE	14.1 ± 3.6	3.5 ± 1.8	2.8 ± 1.0	7.8 ± 3.3	9.1 ± 1.6	7.5 ± 2.0	5.5 ± 2.0	7.2 ± 2.9	17.2 ± 2.7
No./ha	4.0	2.7	2.6	3.2	3.4	3.2	2.9	3.1	4.4
Biomass (g/ha)	85.6	57.8	55.6	68.5	72.8	68.5	62.1	66.3	94.2
Perognathus parvus									
Index ± SE	2.2 ± 1.2	0.5 ± 0.3	4.3 ± 1.0	16.3 ± 4.6	5.4 ± 1.0	4.4 ± 1.2	1.8 ± 0.6	0.8 ± 0.5	0.8 ± 0.8
No./ha.	1.6	0.9	2.4	7.3	2.8	2.4	1.4	1.0	1.0
Biomass (g/ha)	33.4	18.8	50.2	152.6	53.8	46.1	26.9	20.0	20.0
Eutamias minimus									
Index ± SE	2.8 ± 0.9	-	-	0.8 ± 0.5	2.3 ± 0.5	0.8 ± 0.4	0.8 ± 0.4	-	-
No./ha.	0.6			0.5	0.6	0.5	0.5		
Biomass (g/ha)	21.0			17.5	24.4	20.3	20.3		
Dipodomys ordii									
Index ± SE	0.3 ± 0.2	-	-	4.7 ± 2.3	1.4 ± 0.6	2.0 ± 1.5	0.5 ± 0.3	-	-
No./ha.	0.4			1.5	0.7	0.8	0.5		
Biomass (g/ha)	22.8			85.4	37.5	42.9	26.8		

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[1] Utah and Idaho transects combined.

Table 10. Mean weights (in grams) of four rodent species snap trapped in Curlew Valley, Utah and Idaho.

	Sept. 1973		May 1974		Sept. 1974		May 1975		Total	
	N	$\bar{X}$ (S.E.)	N	$\bar{X}$ (S.E.)	N	$\bar{X}$ (S.E.)	N	$\bar{X}$ (S.E.)	N	$\bar{X}$
Peromyscus maniculatus										
Utah	104	19.2(0.3)	140	18.7(0.4)	281	16.2(0.2)	167	21.4(0.4)	692	18.4
Idaho	298	19.3(0.2)	258	18.8(0.3)	686	17.1(0.1)	173	21.4(0.4)	1415	18.4
Perognathus parvus										
Utah	55	18.0(0.5)	43	20.4(0.5)	52	16.3(0.3)	85	20.9(0.4)	235	19.1
Idaho	53	18.3(0.4)	53	21.1(0.4)	97	17.6(0.3)	85	19.2(0.4)	288	18.8
Eutamias minimus										
Utah	13	32.2(0.6)	2	35.0(0.0)	34	30.9(0.4)	18	35.0(1.6)	67	32.4
Idaho	33	33.5(0.4)	32	38.7(1.1)	122	31.9(0.2)	30	40.6(1.0)	217	34.3
Dipodomys ordii										
Utah	15	49.6(1.7)	19	50.6(2.3)	98	49.3(0.6)	13	56.9(0.8)	145	50.2
Idaho	15	52.3(2.5)	22	46.6(2.5)	74	51.6(0.6)	25	53.6(2.0)	136	51.2

Mean indices, estimated mean densities, and percent biomass by census period for Utah and Idaho are presented in Table 11. Unfortunately, in fall 1973 and spring 1974 the trapping effort was inadequate in three habitats (alfalfa, cultivated grain, and sage-bunchgrass). These habitats occupy small proportions of the total area in Utah and Idaho, and the low sampling frequencies probably did not significantly bias the mean density estimates for the two census periods.

Mean rodent densities were quite similar to estimates reported for the same area by the US/IBP Desert Biome (MacMahon (1975, 1976). Mean densities for Peromyscus varied from 3.3 to 5.3 per hectare during the study, and were comparable in Utah and Idaho. Perognathus densities did not vary appreciably, with estimates of 1.7 to 2.4 per hectare in Utah, and 2.3 to 3.6 in Idaho. Although mean index values for Eutamias varied markedly in both Utah and Idaho, estimated densities remained between 0.5 and 0.7/hectare. In Idaho, mean densities for Dipodomys were low (0.6 to 0.8/ha); reached 1.8/hectare in fall 1974.

Biases of density estimates

Because density estimates were calibrated via live trapping, estimates will be negatively biased for species that are not susceptible to entering Sherman traps. As mentioned previously, there is some evidence to suggest that Eutamias, and to a lesser extent, Dipodomys, are not prone to entering Sherman live traps. In the

Table 11. Mean snap trap indices, estimated mean densities, and percent biomass by census period for Curlew Valley, Utah and Idaho.

	Utah			Idaho		
	Mean index	Density[1] (no/ha)	Percent biomass[2]	Mean index	Density (no/ha)	Percent biomass
September 1973						
Peromyscus maniculatus	15.3	4.1	40.2	23.7	5.2	45.2
Perognathus parvus	4.3	2.4	22.1	7.2	3.6	29.7
Eutamias minimus	2.5	0.6	9.9	3.9	0.7	10.5
Dipodomys ordii	3.1	1.1	27.8	1.0	0.6	14.6
May 1974						
Peromyscus maniculatus	24.3	5.3	46.3	24.6	5.3	50.2
Perognathus parvus	3.8	2.2	21.3	4.0	2.3	24.2
Eutamias minimus	0.4	0.5	7.7	2.2	0.6	11.5
Dipodomys ordii	2.8	1.0	24.7	1.0	0.6	14.1
September 1974						
Peromyscus maniculatus	19.7	4.7	35.2	22.5	5.0	45.6
Perognathus parvus	2.6	1.7	13.1	3.0	2.3	21.2
Eutamias minimus	3.5	0.7	9.7	3.1	0.7	12.2
Dipodomys ordii	6.1	1.8	42.0	1.7	0.8	21.0
May 1975						
Peromyscus maniculatus	9.7	3.4	45.9	8.3	3.3	40.8
Perognathus parvus	3.1	1.9	25.0	4.0	2.3	25.9
Eutamias minimus	1.4	0.5	11.8	1.5	0.5	12.8
Dipodomys ordii	0.5	0.5	17.4	1.2	0.7	20.6

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[1] Calculated from regression formulas (Table 5).

[2] Mean weights were taken from Table 16.

case of Eutamias, this may be partly a result of its diurnal habits, as traps remained closed during most of the daylight hours.

Insight into the question is provided by marked-to-unmarked ratios of rodents snap trapped on the grids (Table 12). A high percentage of Peromyscus and Perognathus were marked (82 and 91 percent, respectively), whereas only 75 percent of Dipodomys and 67 percent of the Eutamias snap trapped were previously marked during the live trapping period. These data suggest that grid densities for Eutamias and Dipodomys were substantially underestimated. Thus, densities predicted from the regression equations (Tables 6-9, 11) for Dipodomys and especially Eutamias are likewise underestimated.

Table 12. Percentage of rodents snap trapped inside the live trap grids that were marked.

	Number marked	Number unmarked	Percent marked
Peromyscus maniculatus	330	71	82.3
Perognathus parvus	61	6	91.0
Eutamias minimus	48	23	67.1
Dipodomys ordii	37	12	75.5

Coyote Diets

Coyote food habits were assessed by examining 2,359 scats collected primarily between September 1973 and May 1975. Additional data were obtained from 249 stomachs taken from coyotes killed in the winter of 1974-75. (Stomach results are presented after the scat data [p. 71]).

Analysis of scat data

Food habits data are presented in three ways: (1) percent occurrence, (2) estimated percent total volume, and (3) for small rodents, the minimum number of individuals detected, given as the number per 100 scats. Percent occurrence indicates how frequently an item is present, whereas percent volume estimates the relative quantities consumed. A scat presumably represents much less than an entire meal; it therefore is not surprising that occurrence and volume data are correlated ($r^2 = .79$, $n = 14$, $p < .01$). Unless otherwise stated, percent volume data are used when discussing the scat results below.

Potential biases of scat data

Quantification of food habits via scat analyses is subject to several potential biases. One problem relates to differential digestibility of prey (Scott 1943, Korschgen 1957, Lockie 1959). This bias may be severe when comparing the relative importance (based on volume) of certain major food categories (e.g., fruit vs. mammal, insect vs. bird, etc.), but recent information (J. Litvaitis unpubl.) suggests that differential digestibility is not a significant problem when comparing rodents and rabbits.

To compare relative numbers and/or biomass of rodents in scats, the assumption that all individuals consumed are detected, or that the detection rate is constant among all species must be made. Recent studies indicate that this assumption may not be valid, and that the detection rate for small rodents varies approximately in proportion to body size (Weaver and Hoffman, in press). The precise nature of this relationships is yet to be determined, and I believe that the minimum number of individuals detected in scats is the most reasonable estimate of consumption, and provides significantly more information than occurrence data alone. For most species of small rodents, the number of individuals and number of occurrences were highly correlated ($r^2 = .52 - .99$), since most occurrences represented only one or two individuals.

Year-round coyote food habits: Utah vs. Idaho

In general, the diet of Curlew Valley coyotes was similar to that described for other Great Basin areas (Ferrel et al. 1953, Kauffeld 1977). Food habits in Utah and Idaho were compared on a year-round basis (Tables 13 and 14), and differences between the two areas in the occurrence of black-tailed jackrabbit, cottontail (*Sylvilagus* spp.), rodent, livestock, and deer were highly significant ($x^2 = 419.4$, df = 4, $p < .0001$).

Mammals (42 species identified) comparised 90-95 percent of the diet of coyotes in Curlew Valley (Table 13). Jackrabbit was the

Table 13. Year-round coyote feeding patterns in Curlew Valley, Utah and Idaho, September 1973 to May 1975.

	Utah (1,628)		Idaho (666)	
	Percent occurrence[1]	Percent volume[1]	Percent occurrence[2]	Percent volume[2]
Mammal[3]				
Lagomorph[4]	71.3	63.0	40.2	24.2
Lepus californicus	55.3	52.0	16.5	11.0
Sylvilagus spp.[5]	14.0	9.1	19.2	10.9
Rodent[6]	58.8	25.0	67.7	37.8
Livestock[4]	13.7	7.0	32.0	17.5
Cow	12.8	6.0	27.5	14.8
Sheep	1.2	0.6	5.8	2.7
Deer	0.1	0.1	13.4	9.4
Bird	12.6	0.6	12.6	2.5
Invertebrate	24.7	2.4	20.6	2.9
Plant material	17.3	1.4	31.6	4.9

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[1] Unweighted monthly means.

[2] Unweighted seasonal means.

[3] Includes unidentified mammal and species of minor importance.

[4] Includes unclassified items.

[5] *S. nutallii* and *S. idahoensis*.

[6] See Table 14 for species proportions.

Table 14. Coyote utilization of rodents on a year-round basis, Curlew Valley, Utah and Idaho, September 1973 to May 1975.

	Utah (1,628)		Idaho (666)	
	Percent occurrence[1]	No. indivs./ 100 scats[1]	Percent occurrence[2]	No. indivs./ 100 scats[2]
Cricetidae				
Microtinae[3]	16.5	29.0	37.3	61.0
Microtus spp.[4]	4.3	3.6	19.8	28.6
Lagurus curtatus	12.2	19.4	17.4	25.4
Cricetinae				
Peromyscus maniculatus	13.9	19.8	12.0	15.9
Reithrodontomys megalotis	13.7	20.7	5.4	6.4
Heteromyidae				
Perognathus parvus	21.2	35.8	12.9	18.2
Dipodomys ordii	11.2	12.9	10.8	11.4
Dipodomys microps	3.4	3.8	-	-
Sciuridae				
Eutamias minimus	5.5	6.2	3.4	4.4
Spermophilus townsendi	5.4	5.9	1.0	1.0
Geomyidae				
Thomomys talpoides	0.1	0.1	7.2	8.7

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[1] Unweighted monthly means.

[2] Unweighted seasonal means.

[3] Includes unclassified items.

[4] *M. montanus* and *M. longicaudus*.

principal prey item in Utah, comprising half the annual diet. Rodent (25 percent), cottontail (9 percent), and cow (6 percent) comprised lesser amounts of the annual diet of Utah coyotes. In contrast, rodents were the most important prey in Idaho (38 percent). Cow (15 percent), jackrabbit (11 percent), cottontail (11 percent), and deer (9 percent) also contributed significant amounts to the coyote diet in the Idaho portion of the study area. Birds, reptiles, invertebrates, and plant material were incidental food items in both Utah and Idaho.

Major differences in rodent utilization were evident between Utah and Idaho ($x^2 = 587.7$, df = 9, $p < .0001$, Table 14). Coyotes consumed a greater diversity of species in Utah, with *Perognathus* occurring most frequently (21 percent). *Peromyscus* (14 percent), *Reithrodontomys* (14 percent), *Lagurus* (12 percent), and *Dipodomys ordii* (11 percent) were also eaten consistently. In Idaho, microtines (*Microtus* spp. and *Lagurus*) occurred most often (37 percent), with *Perognathus*, *Dipodomys*, *Thomomys*, and *Peromyscus* also occurring frequently (13, 11, 7, and 12 percent, respectively).

Seasonal variation: Utah

In Utah, coyote food habits were monitored from September 1973 to May 1975 (Figs. 11-13, Tables 15 and 16). Feeding patterns were evaluated on a monthly basis in spring (March-May) and fall (September-November), and seasonally in summer (June-August) and winter (December-February).

Lagomorph. Jackrabbit varied seasonally in the diet more than any other food item, contributing 70-80 percent of the total scat

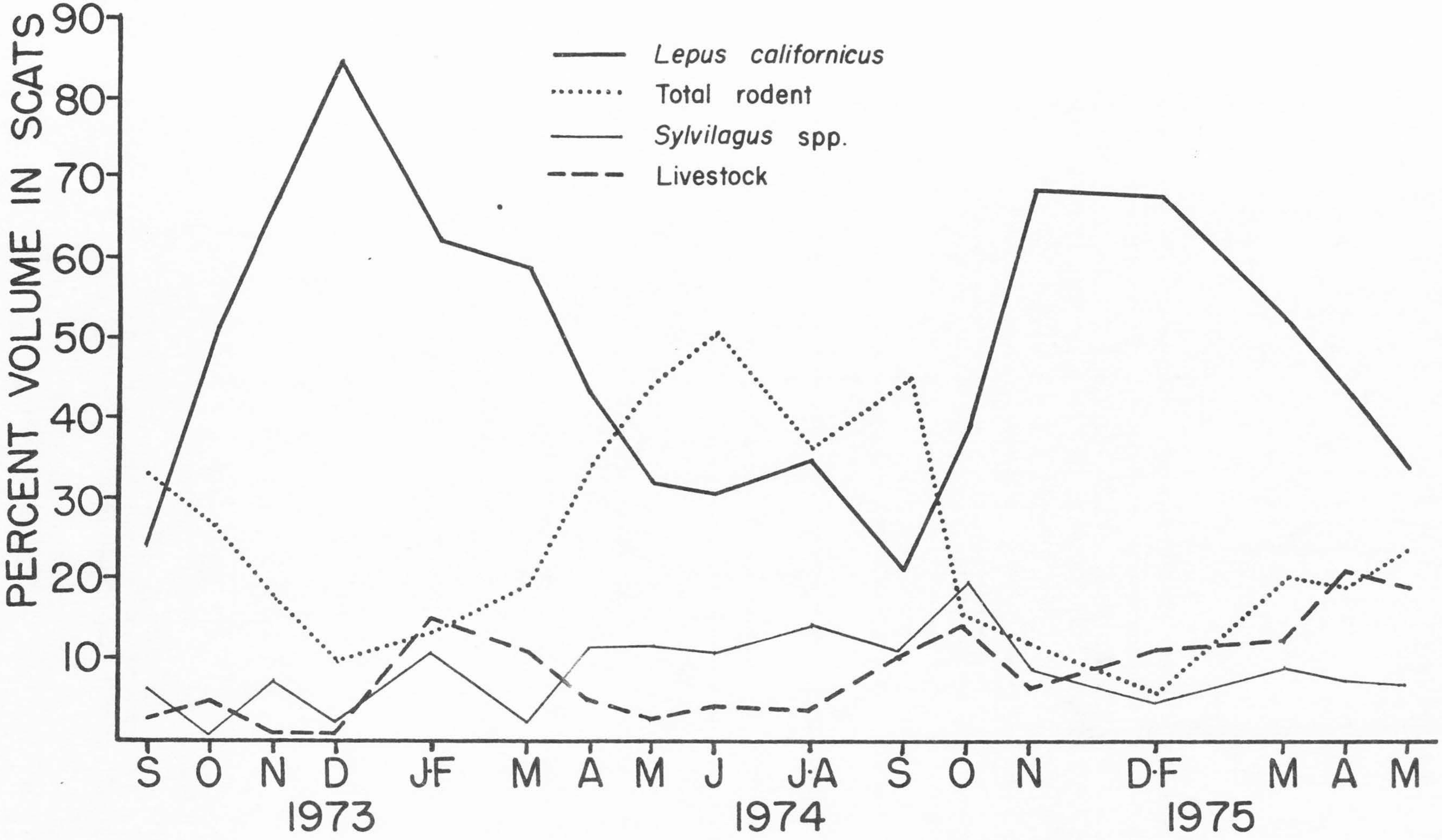

Figure 11. Seasonal patterns of coyote food habits in the Utah study area, September 1973 to May 1975.

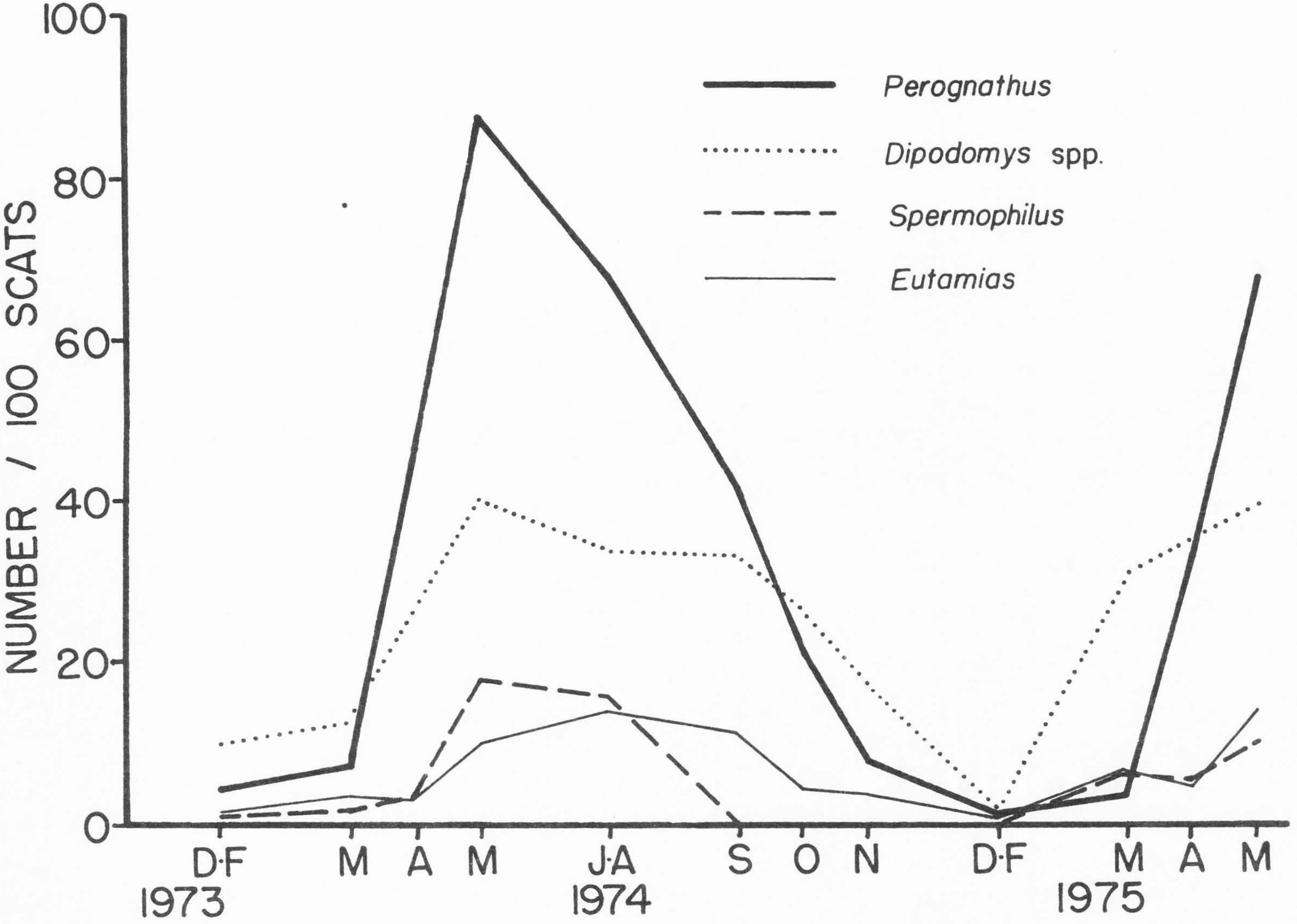

Figure 12. Seasonal patterns in coyote utilization of four rodent species in the Utah study area, December 1973 to May 1975.

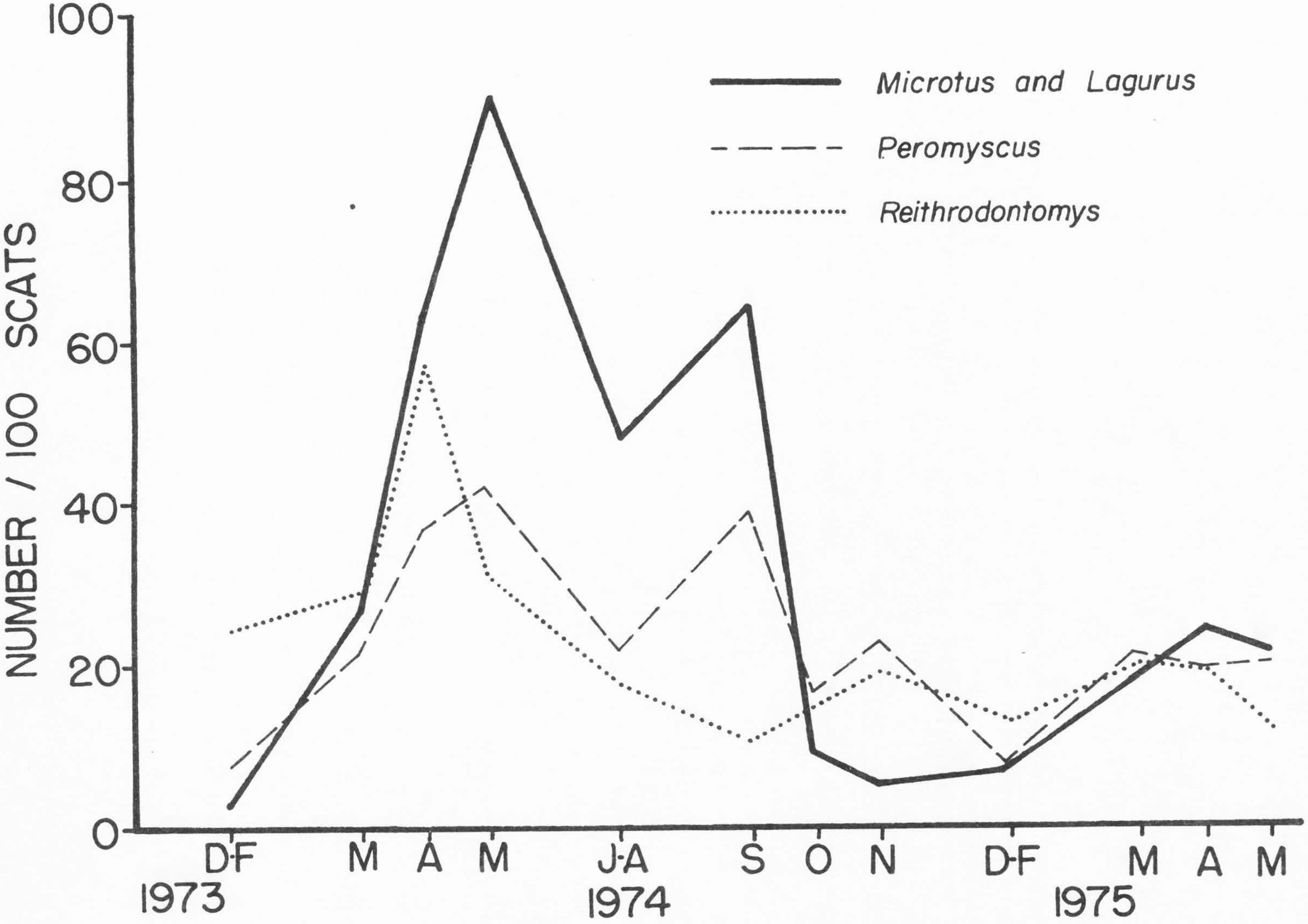

Figure 13. Seasonal patterns in coyote utilization of four rodent species(Microtus and Lagurus, Peromyscus, Reithrodontomys) in the Utah study area, December 1973 to May 1975.

Table 15. Coyote food habits (expressed as % occurrence and % volume in scats) in Curlew Valley, Utah from September 1973 to May 1975.

	1973 Sept.[1] (19)		Oct. (32)		Nov. (71)		1973-74 Wntr. (72)		1974 March (81)		April (65)		May (50)		Sum. (182)		1974 Sept. (36)		Oct. (146)		Nov. (103)		1974-75 Wntr. (201)		1975 March (130)		April (136)		May (50)	
	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.	% occ.	% vol.
Mammal[2]	84.2	66.8	96.9	84.6	95.8	96.1	97.2	97.3	98.8	95.8	98.5	99.1	100.0	94.4	98.4	92.8	100.0	91.7	99.3	95.5	99.0	98.2	100.0	97.4	100.0	95.7	99.3	97.9	98.0	90.9
Lagomorph[3]	52.6	30.9	68.8	52.2	87.3	75.6	90.3	87.7	69.1	64.5	76.9	58.7	54.0	46.3	61.0	51.4	47.2	34.3	68.5	63.9	84.5	80.1	87.6	80.2	73.1	62.7	72.1	56.2	58.0	45.9
Lepus	41.2	24.7	62.5	51.9	76.1	67.8	77.8	83.6	60.5	61.5	53.8	43.5	36.0	33.9	43.4	35.4	22.2	21.6	43.2	40.6	65.0	69.2	72.1	68.7	59.2	53.2	55.9	46.6	42.0	36.9
Sylvilagus[3]	10.5	6.3	-	-	12.7	7.6	6.9	2.8	7.4	2.2	18.5	11.3	18.0	12.1	19.2	13.9	11.1	10.7	22.6	21.3	17.5	9.2	11.9	5.3	13.1	9.3	16.2	7.4	16.0	7.2
S. nuttallii	5.3	1.9	-	-	8.5	5.2	6.9	2.8	3.7	1.7	3.1	0.3	10.0	10.1	13.2	9.2	11.1	10.7	15.1	15.4	12.6	6.1	10.4	4.7	7.7	5.6	6.6	1.3	6.0	2.6
S. idahoensii	5.3	4.4	-	-	4.2	2.3	-	-	1.2	-	9.2	6.9	4.0	0.9	5.5	3.7	-	-	9.6	5.8	3.9	3.0	2.5	tr	4.6	3.2	11.0	5.8	4.0	-
Rodent	73.7	33.2	56.3	27.2	45.1	17.6	26.4	7.9	46.9	20.1	78.5	34.6	88.0	45.6	81.3	37.3	83.3	45.7	54.1	16.3	49.5	12.2	24.4	6.2	66.2	20.2	56.6	20.7	74.0	25.5
Livestock	5.3	2.6	28.1	5.1	2.8	1.3	5.6	1.6	17.3	10.5	9.2	5.0	2.0	tr	6.6	2.4	25.0	11.7	26.7	15.2	12.6	5.3	18.4	10.1	28.5	12.4	33.1	20.5	28.0	16.3
Cow	5.3	2.6	25.0	3.7	2.8	1.3	5.6	1.6	17.3	10.5	6.2	2.7	2.0	tr	6.6	2.4	25.0	11.7	26.0	15.2	11.7	5.2	16.9	8.4	25.4	11.0	30.1	18.8	24.0	15.4
Sheep	-	-	3.1	1.4	-	-	-	-	-	-	3.1	2.3	-	-	-	-	-	-	tr	tr	1.0	tr	1.5	1.8	3.1	1.4	3.0	1.7	4.0	1.0
Bird[4]	10.5	0.2	9.4	0.6	8.5	tr	5.6	1.7	1.2	tr	7.7	tr	16.0	tr	20.9	tr	11.1	tr	10.3	1.3	4.9	tr	5.0	tr	16.9	2.1	11.0	tr	38.0	1.0
Passeriformes	10.5	tr[7]	-	-	1.4	tr	-	-	-	-	3.1	tr	6.0	tr	1.6	tr	-	-	2.7	tr	2.9	tr	1.0	tr	4.6	tr	3.7	tr	4.0	tr
Galliformes	-	-	3.1	0.6	-	-	1.4	0.9	-	-	-	-	-		1.1	tr	5.6	tr	tr	tr	-	-	1.0	tr	1.5	tr	tr	-	-	-
Unidentified	-	-	-	-	-	-	-	0.8	1.2	tr	1.5	tr	6.0	tr	8.8	tr	5.6	tr	9.6	1.3	2.0	tr	3.0	tr	10.8	1.3	4.4	tr	22.0	tr
Eggshell	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.1	-	-	-	-	-	-	-	-	-	-	-	-	-	14.0	tr
Reptile	-	-	9.4	0.8	8.5	1.6	-	-	-	-	-	-	14.0	2.2	4.9	tr	-	-	2.1	tr	-	-	-	-	tr	tr	-	-	6.0	tr
Invertebrate[5]	73.7	32.6	53.1	14.5	33.8	1.9	11.1	0.3	1.2	tr	4.6	tr	18.0	1.3	37.9	4.8	61.1	4.0	20.5	tr	7.8	tr	tr	tr	10.0	tr	11.0	tr	36.0	2.0
Orthoptera	73.7	32.4	50.0	12.1	32.4	1.7	8.3	0.1	1.2	tr	-	-	8.0	tr	25.3	3.3	58.3	4.0	19.9	tr	2.9	tr	tr	tr	9.2	tr	9.6	tr	10.0	tr
Coleoptera	31.6	0.2	6.3	2.4	16.9	0.2	8.3	0.2	-	-	4.6	tr	6.0	tr	15.9	1.5	13.9	tr	4.1	tr	4.9	tr	-	-	tr	tr	2.2	tr	26.0	tr
Vegetation[6]	52.6	tr	34.4	tr	18.3	0.4	19.4	0.4	16.0	3.9	10.8	tr	16.0	1.3	9.3	1.6	27.8	3.1	13.7	2.4	18.4	1.4	12.4	1.9	13.8	1.5	18.4	tr	28.0	5.4
Grass	52.6	tr	34.4	tr	16.9	0.3	9.7	0.3	13.6	3.2	6.2	tr	10.0	tr	4.9	1.0	13.9	tr	6.2	tr	9.7	tr	8.5	tr	6.2	tr	11.0	tr	22.0	3.3
Woody	-	-	3.1	tr	1.4	tr	8.3	tr	2.5	tr	4.6	tr	-	-	2.2	tr	2.8	tr	3.4	tr	6.8	tr	2.0	tr	3.8	tr	6.6	tr	4.0	tr

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[1] Number of scats in sample.

[2] Includes small amounts of coyote, deer, fat residue and unidentified mammal.

[3] Includes unclassified material.

[4] Includes small amounts of Anseriformes and Falconiformes.

[5] Includes small amounts of lepidoptera, diptera, scorpion (*Vejovis*), spider, and unidentified invertebrate.

[6] Includes seeds and fruit.

[7] trace (< 0.5%).

Table 16. Coyote utilization of rodents (expressed as % occurrence and number of individuals per 100 scats) in Curlew Valley, Utah, September 1973 to May 1975.

	1973 Sept. (19)[1]		Oct. (32)		Nov. (71)		1973-74 Wintr. (72)		1974 March (81)		April (65)		May (50)		Sum. (182)		Sept. (36)		Oct. (146)		Nov. (103)		1974-75 Wintr. (201)		1975 March (130)		April (136)		May (50)	
	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats	% occ.	#/100 scats
Heteromyidae																														
Perognathus parvus	42.1	84.2	15.6	21.9	11.3	15.5	4.2	4.2	6.2	7.4	30.8	46.2	38.0	88.0	40.1	68.1	30.6	41.7	13.7	20.5	7.8	7.8	tr	tr	3.8	3.8	17.6	33.1	38.0	68.0
Perognathus longimembris	5.3	5.3	-	-	1.4	2.8	-	-	-	-	7.7	10.8	4.0	4.0	3.3	3.8	-	-	-	-	-	-	-	-	-	-	2.2	4.4	2.0	2.0
Dipodomys spp.[2]	-	-	12.5	15.6	19.7	22.5	9.7	9.7	11.1	12.3	24.6	26.2	40.0	40.0	28	34.1	33.3	33.3	22.6	26.7	17.5	17.5	1.0	1.0	27.7	30.8	27.2	35.3	30.0	40.0
D. ordii	-	-	3.1	3.1	7.0	8.4	6.9	6.9	6.2	6.2	15.4	15.4	20.0	20.0	17.6	21.4	19.4	19.4	10.3	13.7	8.7	8.7	-	-	16.2	18.5	16.2	21.3	20.0	30.0
D. microps	-	-	6.3	9.4	9.9	9.9	2.8	2.8	2.5	2.5	4.6	4.6	4.0	4.0	3.3	3.8	2.8	2.8	4.1	4.1	4.9	4.9	-	-	4.6	4.6	4.4	5.9	4.0	4.0
Cricetidae																														
Microtinae[2]	10.5	10.5	12.8	18.8	5.6	23.9	2.8	2.8	18.5	27.2	30.8	63.1	36.0	90.0	27.5	48.4	25.0	63.9	8.2	8.9	4.9	4.9	5.5	7.5	15.4	17.7	14.7	24.2	20.0	22.0
Lagurus curtatus	5.3	5.3	9.4	15.6	5.6	18.3	1.4	1.4	12.3	18.5	23.1	38.5	26.0	66.0	22.0	31.9	19.4	55.6	5.5	6.2	3.9	3.9	3.5	3.5	10.0	10.8	12.5	19.9	14.0	16.0
Microtus montanus	5.3	5.3	3.1	3.1	1.4	1.4	1.4	1.4	4.9	6.2	7.7	18.5	14.0	20.0	7.7	11.5	5.6	5.6	-	-	1.0	1.0	1.5	2.5	5.4	5.4	1.5	1.5	2.0	2.0
Peromyscus maniculatus	21.1	21.1	12.5	18.8	11.3	12.7	5.6	8.3	11.1	22.2	27.7	36.9	22.0	42.0	17.6	22.5	19.4	38.9	14.4	17.1	12.6	24.3	5.0	7.5	14.6	22.3	13.2	19.1	14.0	20.0
Reithrodontomys megalotis	10.5	15.8	9.4	28.1	16.9	19.7	12.5	25.0	12.3	29.6	41.5	56.9	24.0	32.0	14.3	17.6	11.1	11.1	13.0	14.4	14.6	19.4	8.0	12.5	12.3	20.0	8.8	19.1	10.0	12.0
Neotoma spp.[3]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	tr	tr	-	-	0.7	0.7	-	-	-	-	0.8	0.8	2.2	2.2	-	-
Sciuridae																														
Eutamias minimus	-	-	6.3	6.3	-	-	1.4	1.4	3.7	3.7	3.1	3.1	10.0	10.0	11	13.2	8.3	11.1	4.1	4.1	3.9	3.9	-	-	6.2	6.9	3.7	4.4	14.0	14.0
Spermophilus townsendii	-	-	-	-	-	-	-	-	1.2	1.2	3.1	3.1	16.0	18.0	14.8	15.9	-	-	-		-	-	-	-	6.2	6 9	5.1	5.1	8.0	10.0
Ammospermophilus leucurus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.4	-	-	-	-	-	-	-	-	-	-
Geomyidae																														
Thomomys talpoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.7	-	-	-	-	0.8	0.8	-	-	-	-
Unidentified Rodent	15.8		3.1	-	11.3	-	-	-	8.6	-	4.6	-	8.0	-	8.8	-	11.1	-	10.3	-	9.7	-	10.0	-	16.9	-	6.6	-	8.0	-

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[1] Number of scats in sample.

[2] Includes unclassified material.

[3] *N. lepida* and *N. cinerea*.

volume in winter but only 25-35 percent between May and September (Fig. 11, Table 15). Limited food habit data from Curlew during 1966-69 (Clark 1972) suggested a high occurrence of jackrabbit during all seasons. The seasonal pattern in jackrabbit utilization found in this study is similar to that found in several other Great Basin studies (Ferrel et al. 1953, Kauffeld 1977, Stoel 1976), although the variations found in this study were generally more extreme.

Cottontails contributed 2-20 percent of the scat volume for any particular month (Table 15). No seasonal trends in these variations were evident (Fig. 11).

Rodents. Rodent consumption was lowest in winter (6-8 percent), and highest between May and September (35-45 percent, Table 15). *Peromyscus* and *Reithrodontomys* were the only species utilized to a significant degree in winter, occurring in 5-10 percent of the scats (Table 16). Trends in sciurid (*Eutamias* and *Spermophilus*) and heteromyid (*Dipodomys* and *Perognathus*) consumption were distinct, and were consistent between years (Fig. 12); trends in utilization of microtines (*Microtus* and *Lagurus*) and cricetines (*Peromyscus* and *Reithrodontomys*) were more erratic (Fig. 13). Consumption of all rodent species reached a maximum in April, May, or June, and was highest in the spring of 1974 (Table 16).

Livestock. The importance of livestock (primarily cow) to the coyote's diet varied from trace amounts to over 20 percent (Table 15). Consumption was greatest in winter and early spring (especially spring 1975, Fig. 11). Sheep was seldom present in scats collected from the Utah portion of Curlew Valley.

Other prey. In general, birds, reptiles, invertebrates, and plant material were incidental food items. However, in fall 1973, invertebrates (almost entirely acridid grasshoppers and Jerusalem crickets (*Stenopelmatus fuscus*)) comprised 32 and 14 percent of the total scat volume in September and October, respectively (Table 15).

Seasonal variation: Idaho

Due to small sample sizes, coyote feeding patterns in Idaho were evaluated on a seasonal basis only. Results from scats showed markedly different food habits between spring 1974 and spring 1975 ($x^2 = 15.1$, df = 3, $p < .01$; Table 17); data from different years were not combined for this reason.

Lagomorph. Jackrabbit and cottontail were equally important to the coyote diet in Idaho (Table 13), and seasonal trends were similar (Table 17). Utilization increased sharply in winter, and gradually increased from spring 1974 to 1975 (Fig. 14).

Rodents. Seasonal trends in rodent consumption paralleled those in Utah, with utilization highest in spring and summer (44-47 percent), and lowest in winter (19 percent, Fig. 14). Most rodents shared this seasonal pattern except microtines, which declined steadily in the diet during 1974 (Table 18, Fig. 15). Utilization of all species (except microtines) was significantly higher in spring 1975 than in spring 1974 ($x^2 = 60.7$, df = 4, $p < .001$, Table 18); this was particularly true for *Thomomys* (Fig. 15).

Livestock. Consumption of livestock was greatest in winter (29 percent), and lowest in summer (9 percent, Fig. 14). Sheep

Table 17. Seasonal food habits of coyotes in Curlew Valley, Idaho, spring 1974 to spring 1975.

Food items	1974 March - May (161)[1]		1974 June - Aug. (157)		1974 Sept. - Nov. (165)		1974-75 Dec. - Feb. (73)		1975 March - May (110)	
	Percent occurrence	Percent volume	Percent occurrence	Percent volume	Percent occurrence	Percent volume	Percent occurrence	Percent volume	Percent occurrence	Percent volume
Mammal[2]	98.8	96.1	94.3	81.5	97.0	84.2	98.6	93.7	100.0	95.5
Lagomorph	27.3	13.6	40.8	19.0	31.5	19.0	52.1	36.2	49.1	26.1
Lepus	8.7	6.5	15.3	8.6	14.5	9.7	24.7	17.0	15.5	8.2
Sylvilagus	14.3	5.7	19.7	9.3	11.5	7.3	24.7	15.5	30.0	16.5
S. nuttallii	7.5	3.2	12.7	7.2	6.1	3.4	17.8	10.0	18.2	10.8
S. idahoensis	5.0	2.5	3.8	1.3	4.8	3.7	8.2	5.5	4.5	1.5
Rodent	75.2	45.0	75.2	46.7	72.1	36.6	47.9	19.1	76.4	43.7
Livestock	29.2	13.8	15.9	8.9	30.9	16.4	50.7	29.1	32.7	18.0
Cow	21.1	8.0	11.5	7.2	25.5	13.7	50.7	28.6	23.6	11.2
Sheep	9.3	5.8	5.7	1.7	6.7	2.7	1.4	0.5	9.1	6.8
Deer	28.0	23.7	3.8	2.8	15.8	10.3	12.3	7.0	12.7	7.4
Bird[3]	11.2	1.8	20.4	5.2	12.1	1.0	6.8	3.4	10.9	0.5
Galliformes	0.6	0.7	1.9	1.0	tr	tr	2.7	3.4	1.8	0.4
Passeriformes	1.2	tr[6]	3.8	3.2	1.8	tr	-	-	-	-
Eggshell	3.7	0.1	8.3	tr	0.6	tr	-	-	-	-
Reptile	0.6	0.3	2.5	0.2	1.2	tr	-	-	0.9	tr
Invertebrate[4]	7.5	0.5	51.0	11.0	23.0	1.3	-	-	10.0	tr
Orthoptera	3.7	tr	35.0	2.9	17.6	0.6	-	-	6.4	tr
Coleoptera	5.6	0.3	30.6	7.4	4.8	0.5	-	-	4.5	tr
Vegetation[5]	30.4	1.3	27.4	2.1	46.7	13.5	21.9	2.7	30.9	4.3
Seeds and fruit	11.8	tr	9.6	tr	21.2	7.5	1.4	tr	8.2	1.7
Grass	17.4	0.6	12.7	1.0	19.4	1.7	13.7	1.2	18.2	0.5

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[1] Number of scats in sample.

[2] Includes small amounts of porcupine, badger, fat residue, and unidentified mammal.

[3] Includes trace amounts of sharp-shinned hawk and unidentified bird.

[4] Includes small quantities of scorpion (*Vejovis*), diptera and unidentified invertebrate.

[5] Includes woody stems.

[6] trace (< 0.1%).

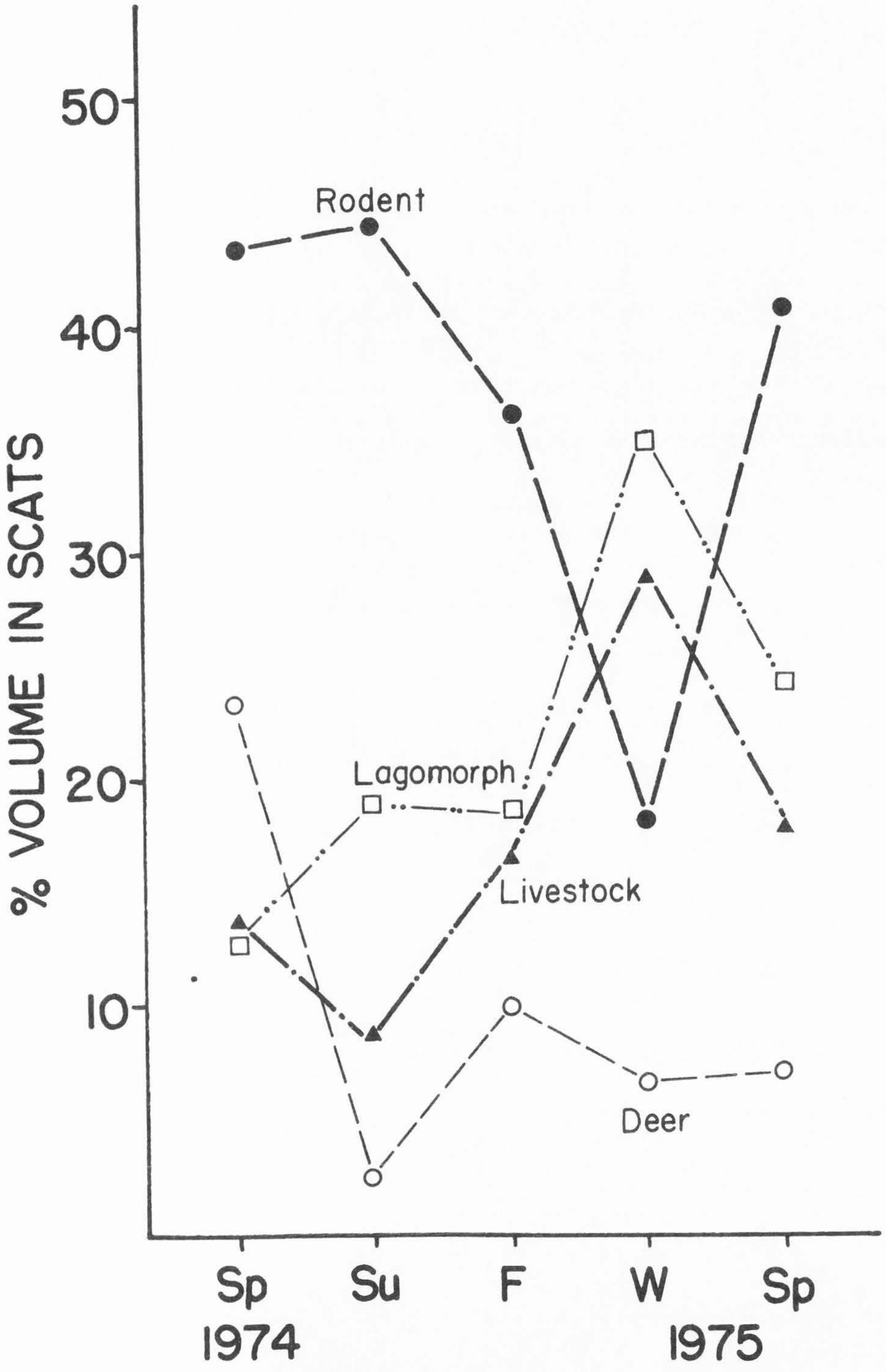

Figure 14. Seasonal patterns of coyote food habits in Idaho from spring 1974 to spring 1975.

Table 18. Seasonal utilization of rodents by coyotes in Curlew Valley, Idaho, spring 1974 to spring 1975.

Food item	1974 March - May (161)[1] Percent occurrence	No./ 100 scats	June - August (157) Percent occurrence	No./ 100 scats	Sept. - Nov. (165) Percent occurrence	No./ 100 scats	Dec. - Feb. (73) Percent occurrence	No./ 100 scats	1975 March - May (110) Percent occurrence	No./ 100 scats
Cricetidae[2]										
Microtine	52.8	106.2	43.9	71.3	32.7	53.9	31.5	38.4	23.6	42.7
Microtus spp.[3]	26.7	46.0	26.8	40.8	17.0	22.4	15.1	19.2	10.9	11.8
Lagurus curtatus	33.5	52.2	17.2	22.3	15.8	25.5	11.0	12.3	14.5	25.5
Cricetine										
Peromyscus maniculatus	10.6	15.5	15.3	21.7	14.5	17.6	6.8	8.2	12.7	17.3
Reithrodontomys megalotis	1.9	1.9	6.4	7.6	8.5	10.3	2.7	2.7	7.3	9.1
Neotoma spp.[4]	0.6	0.6	1.9	1.9	0.6	0.6	1.4	1.4	1.8	1.8
Heteromyidae										
Perognathus parvus	19.3	24.2	22.3	35.0	12.1	14.5	-	-	14.5	21.8
Dipodomys ordii	10.6	11.2	12.1	12.1	14.5	17.0	-	-	22.7	24.5
Sciuridae										
Eutamias spp.[5]	6.2	8.7	5.1	5.1	6.1	8.5	-	-	10.0	10.9
Spermophilus townsendi	-		3.2	3.2	0.6	0.6	-	-	0.9	0.9
Spermophilus armatus	1.9	1.9	2.5	3.2	-	-	-	-	-	-
Ammospermophilus leucurus	-		-		-	-	-	-	0.9	0.9
Marmota flaviventris	1.2	1.2	0.6	0.6	-	-	-	-	-	-
Geomyidae										
Thomomys talpoides	7.5	8.7	6.4	6.4	4.8	5.5	4.1	4.1	22.7	33.6
Erethizon dorsatum	-	-	0.6	-	0.6	-	-	-	-	-
Unid. rodent	8.7	-	9.6	-	16.4	-	15.1	-	15.5	-

[1] Number of scats in sample.

[2] Includes unclassified material.

[3] *M. montanus* and *M. longicaudus*.

[4] *N. lepida* and *N. cinerea*.

[5] *E. minimus* and *E. dorsalis*.

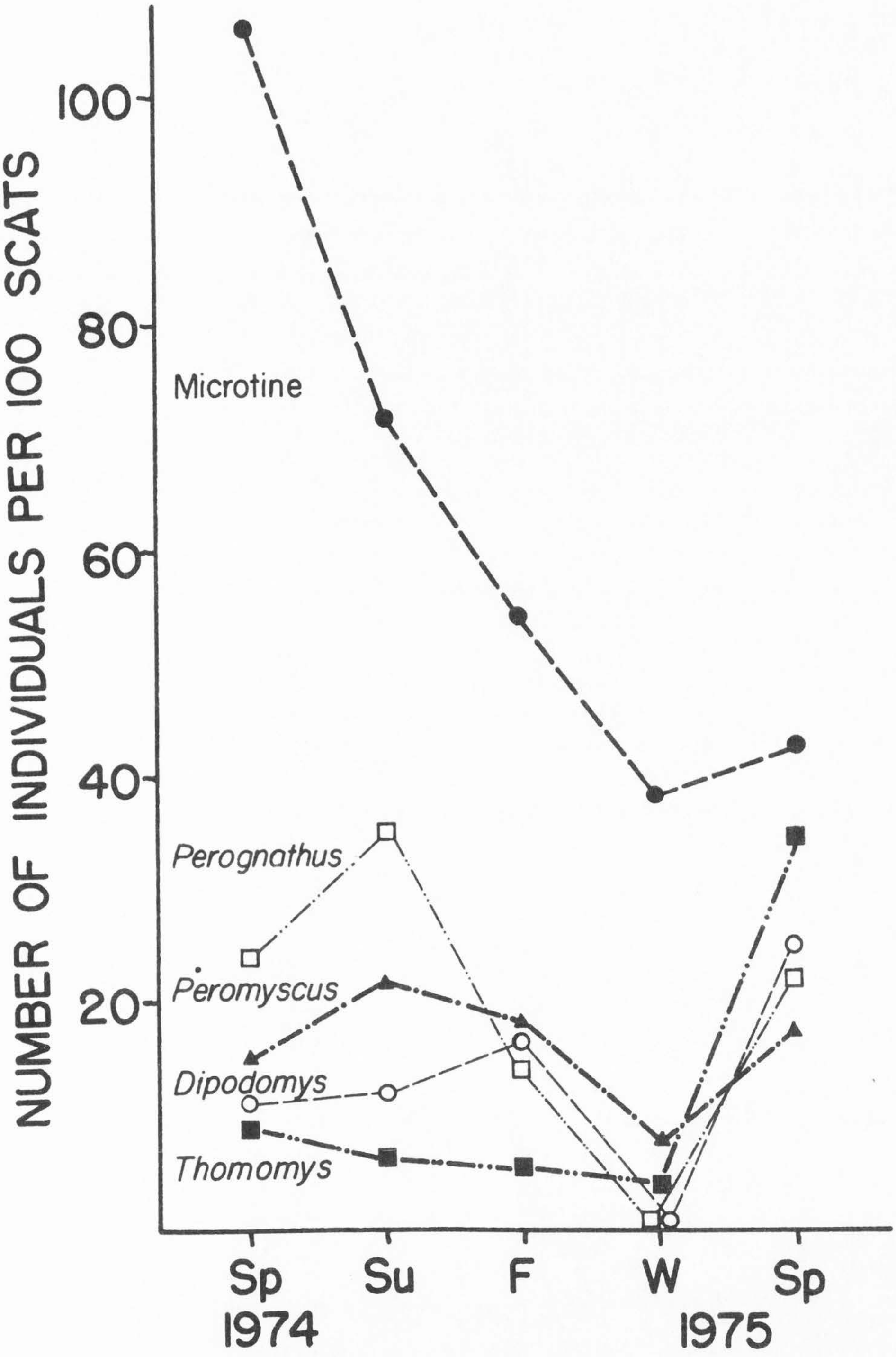

Figure 15. Seasonal patterns of rodent utilization by coyotes in Idaho, spring 1974 to spring 1975.

was an important food item only during the spring lambing period in May (Table 17).

Deer. Mule deer was heavily utilized in spring 1974, when it comprised 23.7 percent of the diet. Thereafter it contributed less than 10 percent, except in fall when it increased to 10.3 percent, coincident with the hunting season in October (Table 17).

Other prey. Reptiles and birds were not important coyote prey in Idaho, comprising less than 5 percent of the diet during all seasons (Table 17). Invertebrates (primarily Coleoptera) were eaten in significant amounts only in summer, when they contributed 10 percent to the diet. Plants (mostly seeds and fruits) were commonly eaten in the fall, comprising 13.5 percent of the scat volume at this time.

Site variation: Utah

Summer food habits on Cedar Hill (40 km^2) were compared with the rest of the Utah study area (Tables 19-20). Cedar Hill coyotes appeared to be predatory specialists, utilizing small rodents almost exclusively. The difference in rodent and lagomorph utilization between the two areas was significant ($x^2 = 6.1$, df = 1, $p < .02$), and in part reflects a local abundance of rodents in the Cedar Hill area (as noted on live trap grids 13 and 14 [see Appendix II]). The dearth of lagomorph in the diet of Cedar Hill coyotes is particularly interesting.

Most rodent species (except sciurids and *Perognathus*) were more intensively utilized on Cedar Hill (Table 20). A seven-fold difference in consumption of *Lagurus* represents the greatest contrast;

Table 19. Comparison of coyote food habits on Cedar Hill (Utah) and the remainder of the Utah study area, summer 1974.

	Utah		Cedar Hill	
	(182)[1]		(65)	
Food item	Percent occurrence	Percent volume	Percent occurrence	Percent volume
Mammal[2]	98.4	92.8	100.0	97.5
Lagomorph[2]	61.0	51.4	36.9	11.7
Lepus	43.4	35.4	15.4	7.7
Sylvilagus spp.	19.2	13.9	15.4	3.7
Rodent	81.3	37.3	95.4	85.6
Livestock	6.6	2.4	4.6	tr
Bird	20.9	tr[3]	21.5	tr
Reptile	4.9	tr	4.6	tr
Invertebrate	37.9	3.3	27.7	1.0
Vegetation	9.3	1.1	16.9	tr

[1] Sample size.

[2] Includes unclassified material.

[3] trace (< 1.0%).

Table 20. Comparison of coyote utilization of rodents (presented as the number of individuals per 100 scats) on Cedar Hill (Utah) and in the remainder of the Utah study area, summer 1974.

Food item	Utah (182)[1]	Cedar Hill (65)
Cricetidae		
Microtinae[2]	48.4	287.7
Lagurus curtatus	31.9	223.1
Microtus montanus	11.5	53.8
Cricetinae		
Peromyscus maniculatus	22.5	46.2
Reithrodontomys megalotis	17.6	38.5
Heteromyidae		
Perognathus parvus	68.1	61.5
Dipodomys ordii	21.4	26.2
Dipodomys microps	3.8	-
Sciuridae		
Eutamias minimus	13.2	3.1
Spermophilus townsendi	15.9	1.5

---

[1] Sample size.

[2] Includes unidentified microtine.

utilization of Microtus in the two areas differed by a factor of four. Consumption of Peromyscus and Reithrodontomys was double on Cedar Hill. Consumption of Dipodomys was similar in the two areas, and utilization of Perognathus was slightly lower on Cedar Hill. The wide array of rodent species consumed by Cedar Hill coyotes is noteworthy, and differs from most previous studies.

Site variation: Idaho

Small sample sizes from Idaho precluded examination of the spatial aspects of coyote feeding patterns except in summer. In Tables 21-22 coyote food habits in three ecologically different areas are compared: (1) the western arm of Curlew Valley, dominated by sagebrush and seeded crested wheatgrass; (2) the foothills of the Sublett Range, composed of juniper interspersed with sagebrush, and (3) the eastern arm of Curlew, an area of intensive agriculture; alfalfa and cereal grains are the dominant crops.

Summer food habits were quite different among the three areas ($x^2 = 28.7$, df = 10, $p < .001$). The western arm of Curlew is ecologically similar to the Utah study area, and the summer food habits were not significantly different in these two areas (2 x 4 contingency test). Although jackrabbit was an important food item in this part of Idaho, it seldom occurred in the diet elsewhere, being replaced in part by rodents. Deer was a frequent food item in the Subletts, and invertebrates composed 20 percent of the diet in the highly agriculturalized eastern arm.

Table 21. Coyote food habits (based on percent occurrence and percent volume in scats) in three areas of Curlew Valley, Idaho, summer, 1974.

	Western Valley		Eastern Valley		Sublett Hills	
	(49)[1]		(73)		(35)	
Food item	% occ	% vol	% occ	% vol	% occ	% vol
Mammal[2]	95.9	85.5	91.8	72.3	97.1	90.7
Lagomorph[2]	61.2	30.4	32.9	14.3	28.6	14.1
Lepus	36.7	23.2	6.8	1.0	2.9	1.4
Sylvilagus[2]	24.5	6.5	16.4	9.1	20.0	12.5
S. nuttallii	12.2	2.8	9.6	7.2	20.0	12.6
S. idahoensis	10.2	3.5	1.4	tr	-	-
Rodent	75.5	36.3	74.0	47.8	77.1	56.1
Livestock	12.2	7.7	16.4	9.0	20.0	10.5
Deer	2.0	tr[3]	2.7	tr	8.6	10.1
Bird	12.2	7.6	23.3	4.6	25.7	2.2
Reptile	6.1	tr	1.4	tr	-	-
Invertebrate	36.7	3.5	60.3	21.1	51.4	6.0
Vegetation	20.4	3.3	32.9	1.6	25.7	1.1

---

[1] Sample size.

[2] Includes unclassified material.

[3] trace (< 1.0%).

Table 22. Coyote utilization of rodents, presented as the number of individuals per 100 scat, for three areas of Curlew Valley, Idaho, summer 1974.

Food item	Western Valley (49)[1]	Eastern Valley (73)	Sublett Hills (35)
Cricetidae			
Microtinae[2]	85.7	68.5	57.1
Lagurus curtatus	22.4	21.9	22.9
Microtus spp.	44.9	43.8	28.6
Cricetinae			
Peromyscus maniculatus	26.5	26.0	5.7
Reithrodontomys megalotis	12.2	8.2	-
Heteromyidae			
Perognathus parvus	63.3	16.4	34.3
Dipodomys ordii	14.3	9.6	14.3
Sciuridae			
Eutamius minimus	10.2	2.7	2.9
Spermophilus armatus	-	1.4	11.4
Spermophilus townsendi	-	5.5	2.9
Geomyidae			
Thomomys talpoides	-	9.6	8.6

[1] Sample size.

[2] Includes unclassified microtine.

Disparities in rodent utilization among the three areas were less obvious but significant ($x^2 = 25.3$, df = 12, $p < .02$) (Table 22). Microtines and Perognathus were heavily utilized in the western arm, whereas Thomomys and Spermophilus were important dietary items in the Subletts and eastern arm. Disparities among the three areas presumably reflect differences in prey availability.

Stomach analyses

Of 324 coyote stomachs obtained from within and near the study area, 75 (23 percent) were empty and only 94 of the remainder were from coyotes collected within the study area. Results from the 94 stomachs are given here.

Utah (52 stomachs) and Idaho (42) data are compared in Table 23. Differences between the two areas are significant ($x^2 = 6.94$, df = 2, $p < .05$), and similar to differences shown by the scat data. Idaho coyotes consumed more deer and livestock (cow), and less jackrabbit than coyotes in Utah.

Comparisons of stomach and scat data for the same area and period revealed significant ($p < .01$) and consistent differences. The most obvious disparity is a greater proportion of livestock remains in the stomachs. Because the scat data are based upon larger samples obtained over a broader area, they are probably more representative of the winter diet of coyotes in Curlew Valley.

Table 23. Results from 94 coyote stomachs (given as percent occurrence and percent total weight) from within the Curlew Valley study area, winter, 1974-75.

	Utah		Idaho	
Sample size (n)	(52)[1]		(42)	
	% occ.	% wt.	% occ.	% wt.
Mammal	100.0	100.0	95.2	96.8
Lagomorph[2]	50.0	54.9	23.8	5.2
Lepus californicus	36.5	49.6	9.5	1.4
Sylvilagus spp.	7.7	4.2	9.5	3.6
Rodent	26.9	7.5	33.3	7.1
Microtinae				
Microtus spp.	7.7	1.1	7.1	2.1
Lagurus curtatus	3.8	tr[3]	4.8	0.6
Ondatra zibethica	1.9	4.4	-	-
Cricetidae				
Peromyscus maniculatus	5.8	0.5	7.1	0.6
Reithrodontomys megalotis	-	-	2.4	tr
Neotoma spp.	-	-	2.4	tr
Onychomys leucogaster	-	-	2.4	0.8
Geomyidae				
Thomomys talpoides	3.8	0.5	2.4	2.4
Erethizon dorsatum	1.9	tr	2.4	tr
Unid. Rodent	7.7	0.8	9.5	tr
Livestock	55.8	37.6	83.3	77.7
Cow	51.9	35.0	83.3	77.7
Sheep	3.8	2.6	-	-
Deer	1.9	tr	7.1	6.8
Unid. Mammal	1.9	tr	-	-
Bird	1.9	tr	16.7	2.2
Invertebrate	1.9	tr	2.4	tr
Plant material	-	-	4.8	0.9

---

[1] Sample size.

[2] Includes unclassified lagomorph.

[3] trace (< 0.5%).

Relative Coyote Numbers

Reliable population indices for the coyote, a highly mobile and wary species, are difficult to obtain and invariably based on small samples.

Composite fall indices

To evaluate fall-to-fall trends in coyote numbers, several independent indices were pooled to produce a single composite index. In Utah, three indices were used: two scent-station lines, one trapline, and a scat collection route. In Idaho, two scent-station lines and two traplines provide four independent indices. Before these different indices could be pooled, they first had to be normalized, or scaled to a common base. Each index value was adjusted as follows:

$$x_1 = \frac{x_i}{\bar{x}} \times 100$$

where: x_1 = adjusted index value,
x_i = observed value, and
$\bar{x}$ = mean of all observed values for the index method.

Mean, or composite indices were then calculated with the adjusted values and results for fall 1973 and 1974 compared (Table 24). The indices suggest that coyote numbers in both Utah and Idaho remained relatively static between fall 1973 and fall 1974.

Table 24. Relative and composite coyote population indices, Curlew Valley, Utah and Idaho, fall 1973-74.

	Utah				Idaho				
	Scent-post[1]	Trapline	Scat index	Composite index[2]	Scent-post		Trapline		Composite index[2]
					15	16	Juniper	Holbrook	
Fall 1973									
Unadjusted	10	4.8	2.6		25	36	6.2	7.7	
Adjusted[3]	133	86	91	103	94	153	106	59	103
Fall 1974									
Unadjusted	5	6.4	3.1		28	11	5.5	18.2	
Adjusted[3]	67	114	109	97	106	47	94	141	97
Unadjusted Means	7.5	5.6	2.8		26.5	23.5	5.8	13.0	

[1] Mean of two survey lines.

[2] Mean of the constituent indices.

[3] See text for derivation.

Scent station indices

According to Wood (1959) and Griffith (1977), interseasonal comparisons of scent station results are probably not valid due to seasonal variations in coyote activity patterns. Therefore, only spring-to-spring and fall-to-fall comparisons were made (Fig. 16). The scent station method was my sole index of spring-to-spring changes in coyote numbers, and results of four lines in each of Utah and Idaho suggest that coyote population levels did not change appreciably between spring 1974 and spring 1975. In contrast, comparison of the fall scent station indices for Utah and Idaho suggest slight population declines from fall 1973 to fall 1974. It should be noted, however, that the composite index is my best estimate of fall-to-fall changes in coyote numbers.

Coyote numbers: Utah vs. Idaho

The Mann-Whitney U-test (Sokal and Rohlf 1969:391) was used to compare relative coyote numbers between Utah and Idaho. The scent station indices for Idaho were significantly higher ($p \leq .10$) than those for Utah in all instances except in spring 1975 (Table 25).

Trapping results in Idaho also suggested higher coyote densities than in Utah.

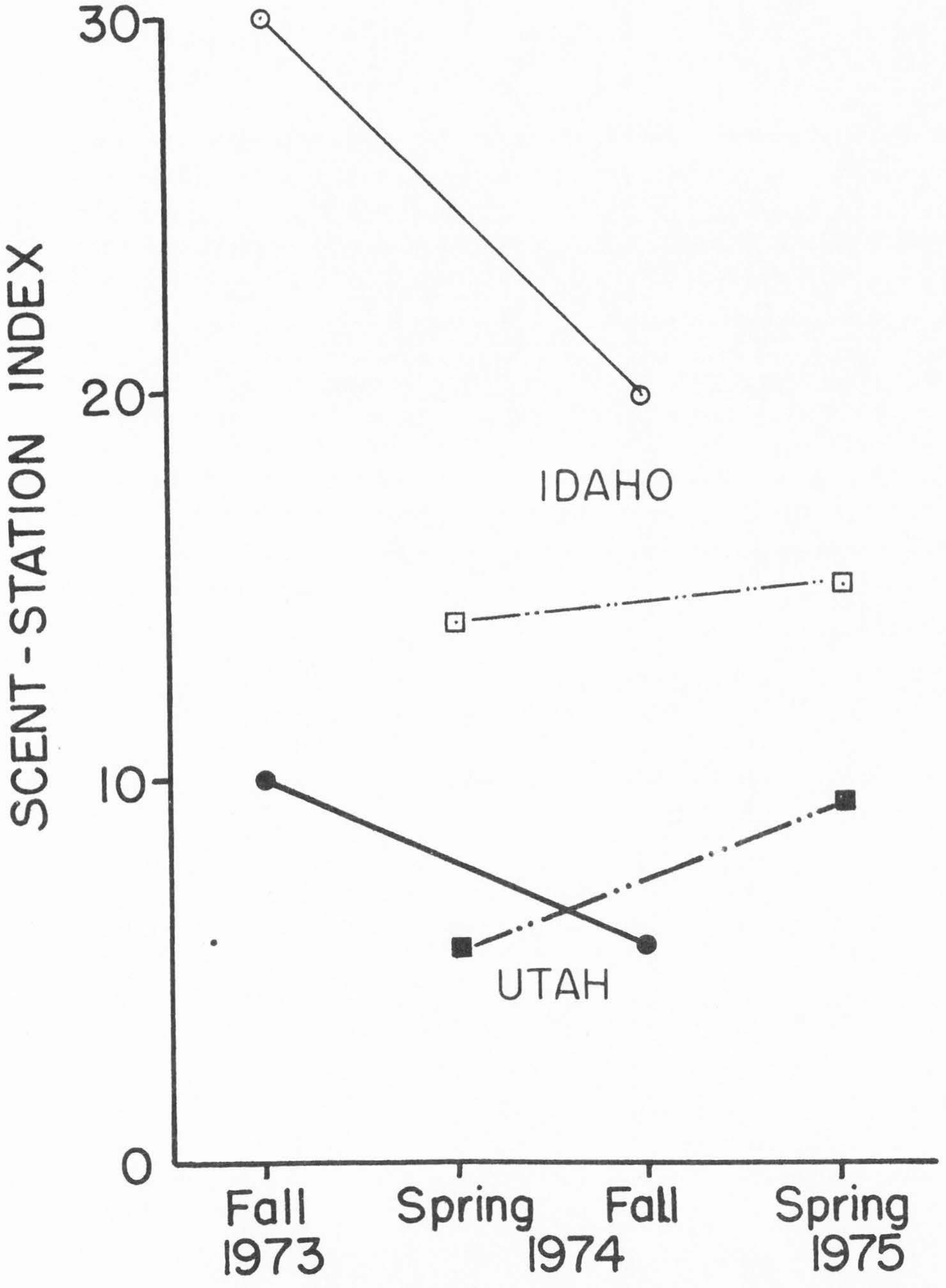

Figure 16. Coyote population trends based on the scent station index in Curlew Valley, fall 1973 to spring 1975.

Table 25. Comparison of Utah and Idaho scent station results, fall 1973 to spring 1975.

	Utah					Idaho					
	1	1A*	2	2A*	Mean	15	15A*	16	16A*	Mean	P-value[1]
Fall 1973	16	-	4	-	10.0	25	-	36	-	30.5	.10
Spring 1974	4	4	0	13	5.25	8	27	5	16	14.0	.075
Fall 1974	0	0	10	9	4.75	28	20	11	65	31.0	.025
Spring 1975	12	12	13	0	9.25	18	9	4	26	14.25	.18

* Not run in fall 1973.

[1] Mann-Whitney U-Test.

DISCUSSION

A primary objective of this study was to assess the dietary importance of jackrabbits to coyotes during a period of low jackrabbit density. Do coyotes show a functional response coincident with declining jackrabbit numbers? Furthermore, if alternate prey are available, is utilization by coyotes proportional to prey abundance? A discussion of these questions follows, and relates to the final objective--an examination of the importance of available prey biomass to coyote density in the Great Basin Desert.

Functional Response

The term "functional response" was introduced by Solomon (1949) to describe, for any individual prey species, "the way in which the number of prey eaten per predator changes with prey density" (Murdoch 1969:347). Reviews of the topic are given by Murdoch (1973) and Krebs (1973). Analyses of predator functional responses should provide insight into the dynamics of complex predator-prey systems.

Previous workers have demonstrated the coyote's functional responses to changing prey densities for a variety of species, including cottontail rabbits (*Sylvilagus floridanus*, Korschgen 1957), voles (*Microtus* spp., Weaver 1977), snowshoe hares (Nellis and Keith 1976), cotton rats (Knowlton 1964, Gier 1968), and *Perognathus* (Stoel 1976).

Jackrabbit (Utah)

Jackrabbit numbers in Utah were low and did not vary appreciably from year to year during this study (Stoddart 1977). To examine the coyote's functional response to changes in jackrabbit populations it was necessary to use food habit data for a period when jackrabbits were more abundant (i.e., before 1973). Additional data came from two sources: scats collected in the Utah study area in fall 1972, and stomachs obtained in and around the study area during winter (1970, 1972-73; Knudsen unpubl.).

For the period 1970-1975, the percentage of jackrabbit in the diet was plotted against the corresponding jackrabbit index (Fig. 17). Rabbit indices were estimated from Stoddart's October and March censuses. Food habit data came from four sources: (1) stomachs (1970, 1972-73); (2) scats from winter (1973-75); (3) scats collected in November (1972-73); and (4) scats collected in March (1974-76). Scat data from winter and November of the same year were averaged.

The relationship appears to be nonlinear, and approximates Holling's (1959) type-2 functional response. At low jackrabbit densities, a notable drop in the coyote's diet corresponds with a slight decrease in the rabbit index. This suggests that jackrabbit abundance is instrumental in determining coyote feeding ecology in Curlew Valley. Furthermore, despite low jackrabbit densities in 1973-1975,

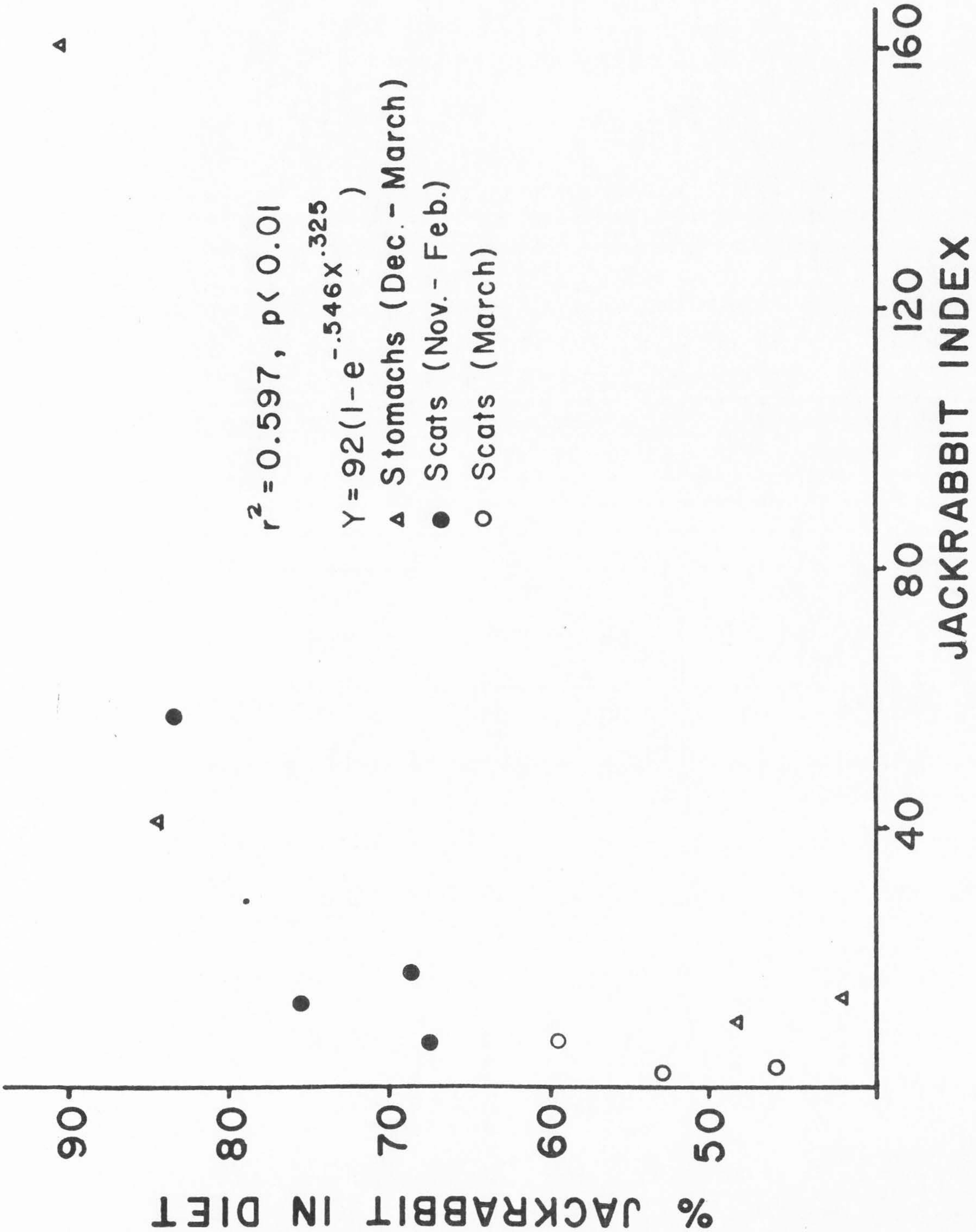

Figure 17. Coyote food habit response to changing jackrabbit densities as shown by stomachs (% weight) and scats (% volume). Stomach data for winters beginning in 1970, 1972, and 1973 were obtained from Knudsen (unpubl.), and jackrabbit density indices are from Stoddart (1977).

they comprised two-thirds or more of the coyote's diet in Utah (based on scat data) during late fall and winter. This suggests a dearth of available alternate prey at that time.

During peak rabbit density (1970), the coyote diet (from stomachs) consisted of 90 percent jackrabbit (Fig. 17). The observation that predators maintain a varied diet has been noted by several workers (Gibb (1958, Holling 1959, Kear 1962, Tinbergen 1960, Tullock 1971). Royama (1970) suggests that a predator frequently exploring new areas for food is at a selective advantage in a constantly changing environment. In this case, coyotes probably encounter other acceptable prey while searching for jackrabbits; I suspect coyotes seldom ignore such opportunities to secure food.

Rodent (Utah)

Total rodent biomass (g/ha) was correlated with the percentage of total rodent in the diet, and a significant relationship was noted (Fig. 18). Relationships for individual species were also examined; May and September trapping indices were compared with the corresponding number of individuals detected in spring and fall scats for four census periods (Fig. 19). Since both x + y variables are measured with error and contain unknown variances, the subsequent regressions are interpreted in a general way.

The two parameters were significantly correlated for Perognathus ($r^2 = 0.98$, $p < .01$); the relationship was not statistically significant for Peromyscus. These results suggest coyotes did not alter their hunting behavior in response to fluctuating densities of these two rodents.

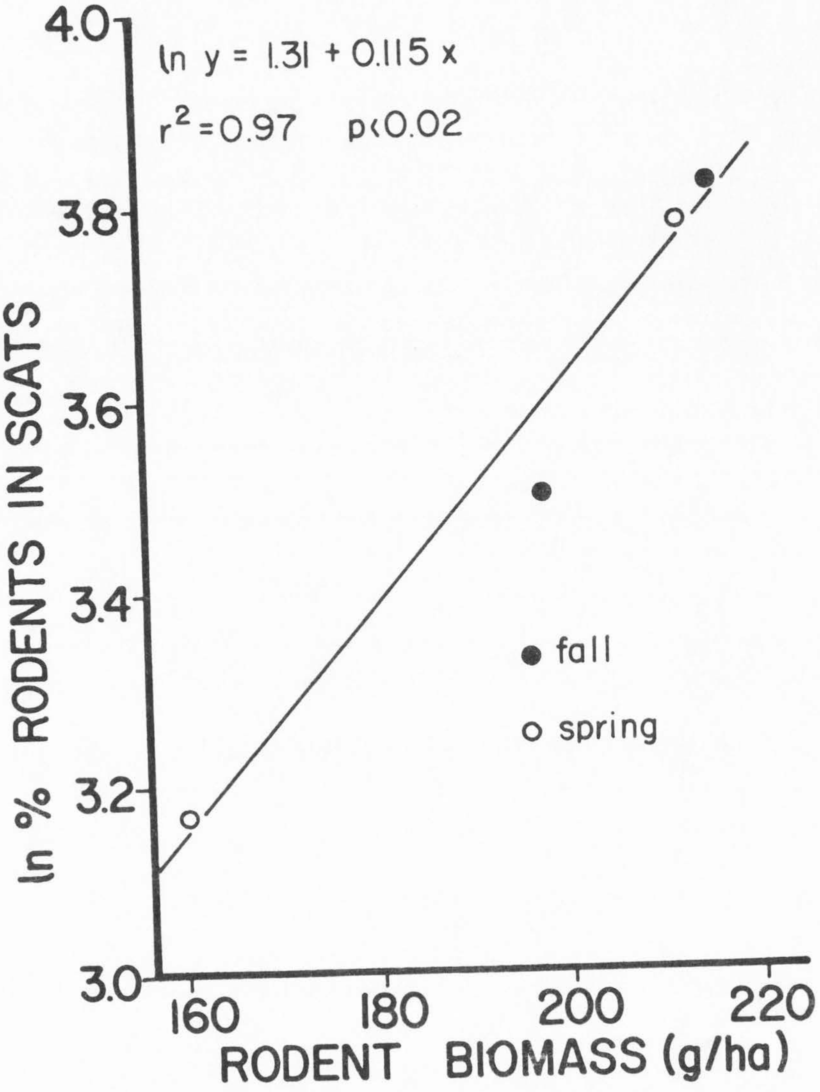

Figure 18. Functional relationship between rodent biomass (g/ha) and the percentage rodent (by volume) in coyote scats, Curlew Valley, Utah.

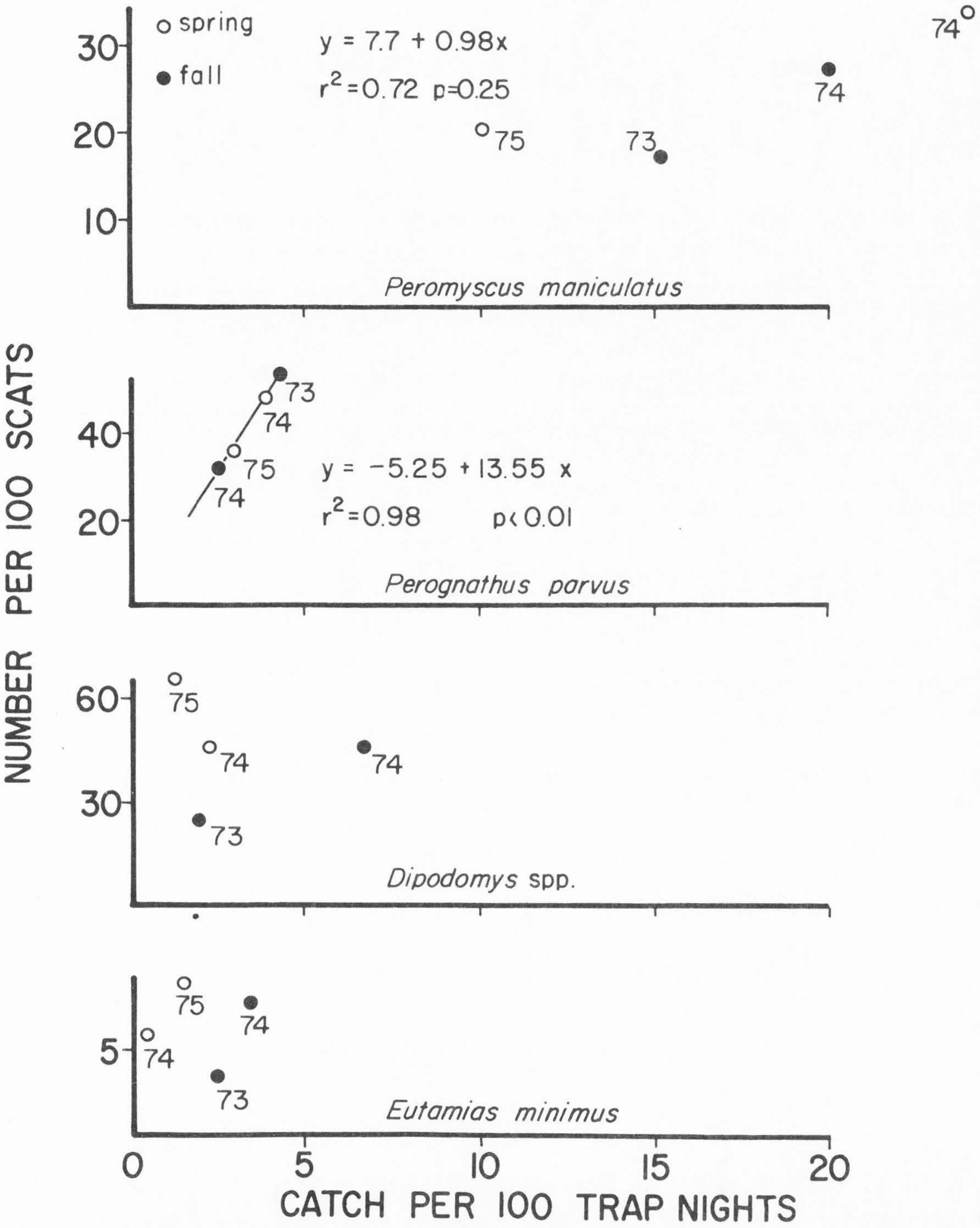

Figure 19. Coyote functional responses to changing relative densities of Peromyscus, Perognathus, Eutamias, and Dipodomys spp. in Curlew Valley, Utah.

Coyote utilization of Eutamias relative to the trapping index was consistently greater in spring, and changes between years (within a season) were in the same direction. Greater consumption of Eutamias in spring is probably related to one or more of the following factors: (1) spring breeding activities causing increased vulnerability to predation, (2) the comparative scarcity of other prey in spring, and/or (3) differences between adult and juvenile coyotes in their ability to capture Eutamias. (According to Knudsen [1976], juveniles represent over two-thirds of the fall coyote population.)

Consumption of Dipodomys spp. was not correlated with the trap index. In May 1975, consumption increased markedly, despite a decline in trapping success. It is note-worthy that rodent and jackrabbit densities were particularly low during that time.

These functional relationships are difficult to interpret with respect to coyote predatory behavior. The linear correlations could be explained by random encounters. This assumes that a coyote eats a constant proportion of the rodents it inadvertently meets. If rodent density doubles, a coyote should randomly encounter twice as many rodents and consequently eat twice as many.

The concept of "profitability" (Royama 1970) may also apply. A coyote should alter his hunting patterns only if it is profitable to do so. Perhaps the rodent density changes encountered in this study were not of sufficient magnitude to influence profitability significantly. Thus, even when the density of a particular rodent increased, coyotes may have continued to hunt(or not hunt) that rodent at about the same intensity.

The functional responses of coyotes with respect to these species have not been reported previously (except for Perognathus, see Stoel 1976), since they are seldom important constituents of the coyote diet (Ferrel et al. 1953, Fichter et al. 1955, Hawthorne 1972, Murie 1935, Weaver 1977).

Invertebrate (Utah)

In September and October 1973, invertebrates (primarily Jerusalem crickets) comprised 32 and 14 percent, respectively, of the total scat volume in Curlew Valley, Utah. The respective percentages in 1974 were 4 and 0 (trace). Pitfall trapping of ground invertebrates indicated Jerusalem crickets were 3-5 times more abundant in fall, 1973 than in fall, 1974 (W. Osborne, pers. comm.). This functional response demonstrates the adaptability of the coyote; it is apparently capable of efficiently utilizing a wide spectrum of potential prey sources in its environs, including Jerusalem crickets weighing 0.3 grams.

Idaho

The four most abundant rodent species were the only coyote prey intensively monitored in the Idaho portion of the study area; data were insufficient to evaluate functional responses. None of the four species was consumed as frequently as in Utah, probably a consequence of a more diverse assemblage of prey in Idaho.

Marked differences in feeding patterns between the springs of 1974 and 1975 provide some insight into coyote-prey dynamics in Idaho.

Two food items of major importance (i.e., microtines and deer) in the spring of 1974 were seldom eaten in 1975 (they probably were less available as a result of the mild, dry winter of 1974-75). Deer and microtines comprised 46 percent of the diet in spring 1974, but only 13 percent during the same period in 1975 (Fig. 20). Coincident with this decline, utilization of all other mammalian prey increased. Pocket gopher and Nuttall's cottontail showed the greatest percentage increase, tripling in the diet. Although I have no quantitative data on the abundance of either species, there is no evidence to indicate any marked changes in abundance.

Bond (1939) noted a similar "switch" to cottontails when voles became scarce in northern California. Cottontails have been shown to be important coyote prey in the Midwest (Korschgen 1957, Mathwig 1973), Great Plains (Fichter et al. 1955, Gier 1968, Murie 1945), and South (Brown 1977, Wilson 1967), but their densities were thought to be too low in Curlew to be of significance to coyotes.

In spring and summer in the West, pocket gophers are often an important constituent of the coyote diet (A. Murie 1940, O. Murie 1935, Weaver 1977). In Curlew, abundant gopher sign was observed only in alfalfa fields. Coyotes may have spent considerable time hunting specifically in alfalfa, a type of predatory behavior termed "niche hunting" (Krebs 1973), which occurs in a wide array of predators (Croze 1970, Dawkins 1970, Hassell 1971, Royama 1970).

Although the reasons may not be fully understood, Nuttall's cottontail and pocket gophers are important alternate prey in Idaho.

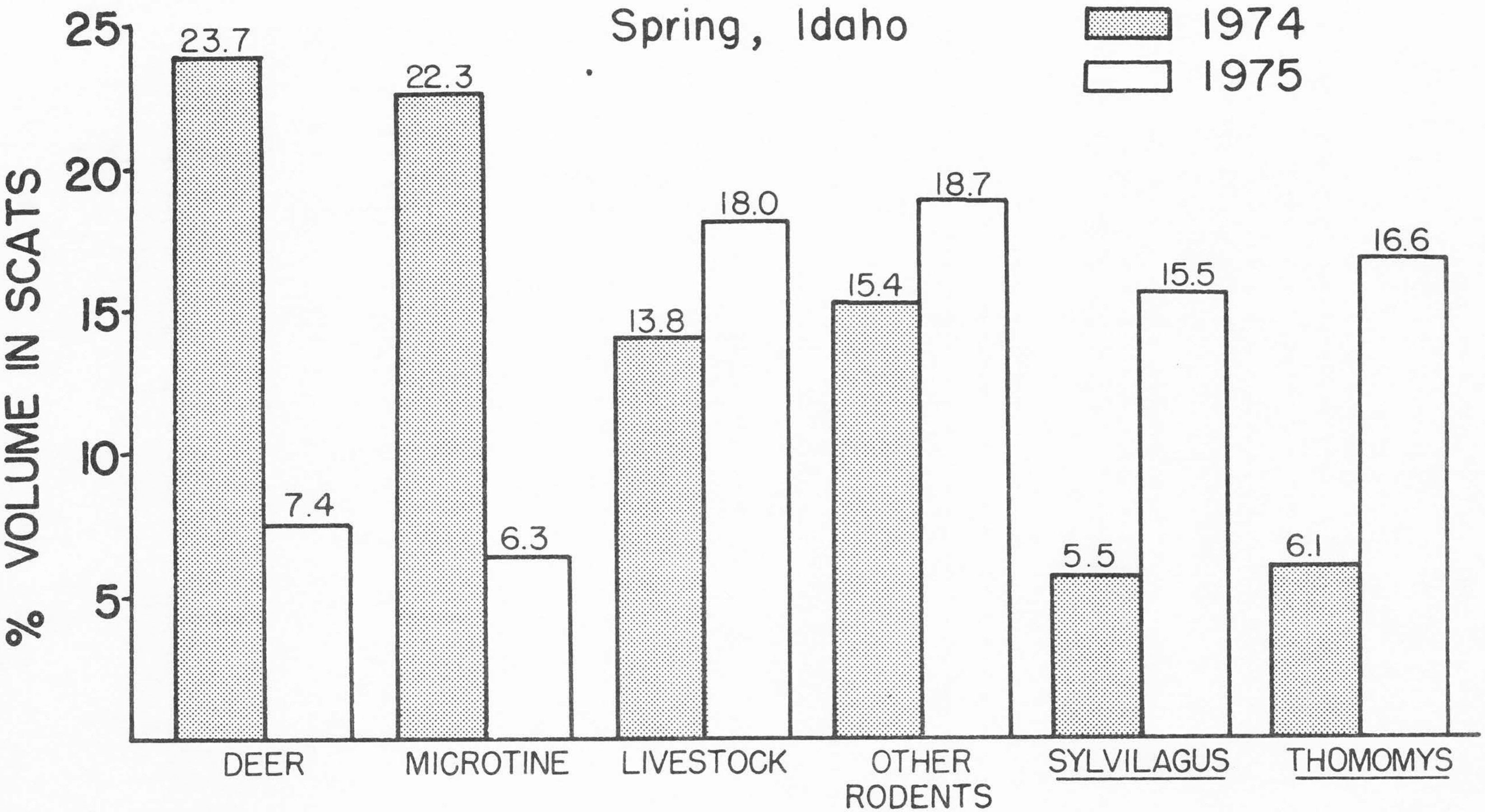

Figure 20. Comparison of coyote feeding patterns between spring 1974 and spring 1975 in Curlew Valley, Idaho.

The nature of the functional response exemplifies the complexity of the prey base in the Idaho study area. When populations of one or two major prey species fail, coyotes can choose from an array of alternate prey. This is not the case in Utah.

Seasonal Variations of Feeding Patterns in Utah

Abrupt changes in rodent and jackrabbit utilization by coyotes were noted in Utah, particuarly in spring and fall (Fig. 11). To determine if these variations represent functional responses to changing prey densities, available jackrabbit biomass (g/ha) was compared to jackrabbit utilization on a monthly basis. Jackrabbit biomass calculations are based on demographic parameters estimated by L. C. Stoddart (pers. comm). An inverse relationship is evident (Fig. 21); jackrabbit is lowest in the diet in September, when available biomass is high. Conversely, utilization is highest in winter, when biomass is low. Clearly, seasonal variations in jackrabbit utilization cannot be solely the result of a positive functional response.

Similar monthly data for rodents are not available, but bimonthly (1973) and monthly (1975) live trapping conducted by the Desert Biome in Curlew Valley provide some seasonal density trends. Although trends varied among species and habitats, overall rodent biomass appears to have increased rapidly from April to June, gradually declining thereafter (Balph 1974, MacMahon 1975, 1976). These trends are consistent with data from several other rodent studies in

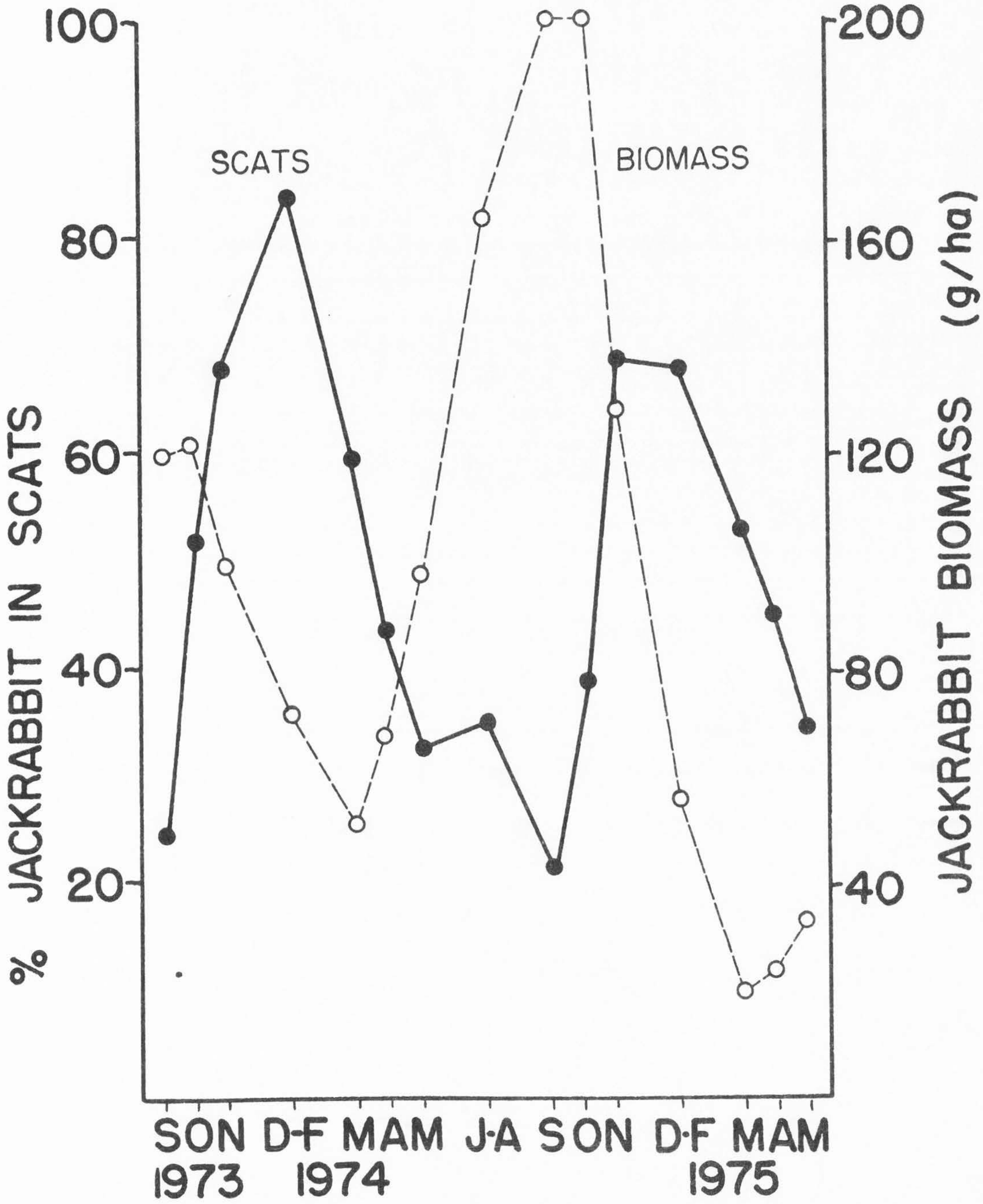

Figure 21. Comparison of available jackrabbit biomass (g/ha) with utilization by coyotes from September 1973 to May 1975, in Curlew Valley, Utah.

the Great Basin (Hedlund and Rogers 1976, Larrison and Johnson 1973, Montan 1977, and O'Farrell 1974), and generally coincide with seasonal trends in utilization by coyotes (Figs. 12-13).

When jackrabbit populations are low in Curlew Valley, seasonal variation in consumption of jackrabbit and rodent may be primarily a result of changes in the availability and abundance of rodents. Breeding activities may increase the vulnerability of rodents to predation. Maximum utilization of many species of rodents by coyotes corresponds closely with breeding periods. For example, breeding activity of Reithrodontomys typically reaches a maximum in April, with a less pronounced peak occurring in October (Smith 1936). Correspondingly, numbers of this species detected in coyote scats increased sharply in April, with a lesser peak occurring in November (Fig. 13).

In fall and winter, many rodent species become torpid, and consequently are unavailable to coyotes. Snow cover may further reduce rodent availability. Winter food habits data support this idea, as only 6-11 percent of the winter diet consisted of rodents in Curlew Valley, Utah (Table 14).

The question remains: how do coyotes efficiently exploit a low-density jackrabbit population in winter? In Curlew Valley jackrabbits are not distributed uniformly; densities are greatest where the habitat is most favorable. This observation is supported by Stoddart's transect data. He walked 68 1-mile transects in March 1972, and observed 107 jackrabbits; 89 (83 percent) of these were flushed from only 20 (29 percent) of the transects. The frequency distribution of jackrabbits observed on Stoddart's transects was compared with the Poisson distribution and found to be significantly non-random (Kolmogorov-Smirnov Test: $D = 0.313$, $p < .01$). These aggregations may permit coyotes to efficiently exploit a low-density jackrabbit population in Curlew Valley.

Furthermore, short-term, local concentrations of jackrabbits occur in winter after heavy snowfalls (Stoddart, pers. comm.), augmenting the already clumped dispersion pattern of rabbits. Although these concentrations persist for only a few days, they may occur frequently enough to be of significance.

In addition to short-term phenomena, rabbit concentrations of longer duration may also occur in winter. Rusch (1965:30), studying jackrabbit movements in Curlew Valley, summarized one aspect of his findings: "These data indicated large changes in hare densities on certain areas, occurring in late fall or early winter, and again in late winter or early spring." Although Rusch's statement is consistent with the observations of Bronson and Tiemeier (1959) and French et al. (1965), it is based on meager data. The idea of longterm rabbit concentrations in winter remains speculative.

Coyote Prey Selection

It is commonly said that "coyotes eat whatever is most abundant and available." "Availability" is usually equated with abundance, or density, but quantitative data on prey abundance are seldom presented. Is abundance the primary factor determining utilization?

If coyotes feed randomly, the relative importance of various prey species in the diet must approximate their relative abundances.

Rodent vs. jackrabbit

Comparisons between jackrabbits and rodents were made only during May and September. Biomass (grams live weight per hectare) and utilization (as indicated by percent volume in scats) of jackrabbits and rodents in Utah were compared during four periods (Table 26). Values for total rodent are probably conservative, since they represent data for only four species. A relative utilization or "preference" index was calculated by dividing the percentage of total food in the diet by the percentage of total available biomass (Petrides 1975). An index value of 1.00 indicates that consumption of a particular prey species was proportional to its abundance. Expected values for the dietary percentages were computed from the biomass figures. Chi-square tests indicated that coyotes "preferred" jackrabbit ($p < .05$) over rodent in May (1974 and 1975 (Table 26). No obvious "preference" for either prey type was evident in September 1973; rodents were "preferred" to a slight degree in September 1974.

These data suggest greater relative utilization of jackrabbit in spring, and slightly greater relative use of rodents in late summer and early fall. One explanation for this result relates to the predatory behavior of young coyotes. Pups may be conditioned to prey upon rodents until they gradually learn and/or gain experience with more formidable prey (jackrabbit).

Table 26. Comparison of available rodent and jackrabbit biomass with utilization by coyotes in in Curlew Valley, Utah.

	Available biomass (g/ha) (a)	Percent available (b)	Percent in diet[1] (c)	Relative percent in diet (d)	Relative preference index (e=d/b)
Sept. 1973 (n=19)[2]					
Jackrabbit	120	38	24.7	43	1.13
Total rodent	198	62	33.2	57	0.92
Sept. 1974 (n=36)					
Jackrabbit	205	49	21.6	32	0.65
Total rodent	216	51	45.7	68	1.33*
May 1974 (n=50)					
Jackrabbit	98	32	32.4	43	1.34*
Total rodent	213	68	43.6	57	0.84
May 1975 (n=50)					
Jackrabbit	33	17	34.5	59	3.47*
Total rodent	161	83	23.8	41	0.49

[1] Percent volume in scats.

[2] Number of scats in sample.

* Significant preference (p <.05).

Selection for rodent prey

General considerations. Although 20 species of rodents were trapped during the study, density estimates were obtained for only four. The others were trapped infrequently and assumed to be quite rare. The coyote food habits data indicated that many of these "rare" species were commonly eaten. *Lagurus*, *Microtus*, *Reithrodontomys*, and *Spermophilus* were seldom trapped, yet all were frequent items in scats from the Utah study area.

One explanation for this disparity is interspecific differences in trappability. This has been noted by many authors (Smith et al. 1975). Perhaps the species mentioned above are not readily captured in snap traps. Calhoun (1964) and Smith et al. (1971) considered *Microtus pinetorum* to have a comparatively low trappability, and Briese and Smith (1974) thought this to be true of *Reithrodontomys humulis*. Similarly, Johnson et al. (1948) noted that *Lagurus* did not readily accept trap bait. Although trap shyness cannot be discounted, there is evidence to indicate that these species were rare on the study area.

Microtus, *Lagurus*, *Reithrodontomys*, and *Spermophilus* inhabit grassy areas (Feldhamer 1977, Rickard 1960, Smith 1936) and require lush green growth for food (Johnson 1961) and cover (Feldhamer 1977). The Utah study area does not provide such habitat. Rainfall is low and grazing is heavy; grass cover rarely exceeds 25 percent in seeded crested wheatgrass, and native vegetation types average 0-10 percent grass cover (W. R. Clark, unpubl.). Furthermore, extensive searches for microtine sign (e.g., runways, burrows) in the most favorable habitats were often futile. The available evidence suggests that microtines were indeed scarce and restricted to small patches of suitable habitat. Spermophilus was also rare, with just a handful of colonies present in the area. No additional observations were made for evaluating the abundance and distribution of Reithrodontomys.

The apparent clumped dispersion pattern of these rodents also may have been an important factor influencing trap success. Although trapping was conducted over a large area, it actually sampled less than 1 percent of the study area. Consequently, the probability of encountering an area of local abundance must have been quite low.

Rodent preference indices. To compare rodent densities with utilization by coyotes, two types of data (scats and trapping) must be combined; both estimates are subject to an unknown degree of experimental error. Biased relative utilization indices may result from the interaction of inaccurate density estimates with differential detectability in scats. The accuracy of the density estimates is difficult to quantify; but as previously mentioned, density estimates for Eutamias and Dipodomys are probably low. Detectability differences in scats can be quantified (Weaver and Hoffman, in press), although the accuracy of such corrections is not known. As a partial solution, relative rodent utilization indices were calculated with adjustments in consumption made for detectability differences (see Weaver and Hoffman [in press] for adjustment calculations); unadjusted values are also presented for comparison.

In view of these biases, rodent "preference" ratings are interpreted in a general way. Indices are applicable insofar as they compare the coyote's relative utilization among the rodents with respect to each other. Also, since densities of Eutamias and Dipodomys were probably under-estimated (see results section), indices calculated for these two species are probably too high.

Densities and utilization for the four most abundant rodent species are compared in Table 27. Data for May 1975 from Utah, and September 1974 from Idaho were most useful, due to large sample sizes. Chi-square test results were significant ($p = .05$), implying that coyotes do show "preferences" for individual rodent species. (The term "preference," as used by Petrides [1975], merely indicates a disparity between the estimated parameters [expressed as a percentage of the total] for abundance and consumption.) A mean "preference" index of 2.1 for Perognathus implies that this species is particularly sought after or vulnerable to predation by coyotes. A slight "preference" is suggested for Dipodomys (1.35), but Eutamias (0.75) and especially Peromyscus (0.42) are not as readily eaten by coyotes.

Preference ratings for Utah in May and Idaho in September are similar. Utilization relative to absolute abundance, however, was proportionately greater for all species in Utah.

In addition to the four major species, coyotes consumed considerable numbers of microtines, Reithrodontomys, Spermophilus, and Thomomys. Although the abundances of Thomomys and Spermophilus were not assessed in this study, estimates of Reithrodontomys and Lagurus numbers were obtained from one small area. Cedar Hill (Utah) was intensively sampled in early August (1,440 trap-nights, grid numbers 13 and 14 in Appendix II). Rodents were the principal dietary item in this locale,

Table 27. Rodent density versus consumption by coyotes for four species in Curlew Valley, Utah and Idaho.

	Density (no/ha)[1] (a)	Percent available (b)	Number consumed[2] (c)	Percent in diet (d)	Relative preference index (e=d/b)
Utah - May 1975 (n=50)[3]					
Perognathus	1.9	30	156 (34)	63 (52)	2.13 (1.73)
Dipodomys	0.5	8	27 (15)	11 (23)	1.25 (2.88)
Eutamias	0.5	8	14 (7)	6 (11)	0.75 (1.38)
Peromyscus	3.4	54	49 (10)	20 (15)	0.37 (0.28)
Idaho - September 1974 (n=52)					
Perognathus	2.3	26	69 (15)	54 (41)	2.08 (1.58)
Dipodomys	0.8	9	17 (11)	13 (30)	1.44 (3.33)
Eutamias	0.7	8	8 (4)	6 (11)	0.75 (1.38)
Peromyscus	5.0	57	34 (7)	27 (19)	0.47 (0.33)

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[1] From table 15.

[2] Adjusted for differences in detectability (unadjusted values are given in parentheses).

[3] Number of scats in sample.

as noted in 65 scats collected on Cedar Hill between late June and mid-August.

Strong relative "preferences" for *Lagurus* and *Reithrodontomys* are suggested (Table 28). *Lagurus* appears to be highly vulnerable to coyotes, with a "preference" index of 14.5. *Reithrodontomys* and *Dipodomys* were slightly "preferred," whereas *Perognathus*, *Peromyscus*, and especially *Eutamias* were not utilized to a significant extent. The relative "untrappability" of *Lagurus* and *Reithrodontomys* (c.f. Johnson et al. 1948, Briese and Smith 1974) may have caused preference indices for these species to be over-estimated.

In comparing these ratings with those from the remainder of the study area (Table 27), it should be noted that, relative to each other, *Dipodomys* and *Perognathus* reversed positions, as did *Peromyscus* and *Eutamias*. Heteromyids were still "preferred" over *Peromyscus* and *Eutamias*. Although no *Microtus* were trapped on Cedar Hill, coyotes consumed 105!

These findings are consistent with several previous studies. The low utilization of *Peromyscus* and *Eutamias* as coyote food has been noted by many authors (Gier 1968, Murie 1945, Niebauer and Rongstad 1977, Stoel 1976, Weaver 1977), whereas several studies have reported microtines to be the primary rodents consumed (Hawthorne 1972, Ferrel et al. 1953, Murie 1935, Mathwig 1973). Similar trends in rodent utilization were noted by Scott and Kilmstra (1955) for the red fox (*Vulpes vulpes*).

Relative abundance apparently is not the sole determinant of availability. Ultimately, energetic efficiency may determine prey

Table 28. Abundance versus consumption (based on analyses of 65 scats) of six rodent species on Cedar Hill, Utah, summer 1974.

	Density (no/ha)[1] (a)	Percent available (b)	Number consumed[2] (c)	Percent in diet (d)	Relative preference index (e=d/b)
Lagurus	1.0	3.2	435 (145)	46.4 (53.7)	14.50 (16.80)
Reithrodontomys	1.8	5.7	125 (25)	13.3 (9.3)	2.33 (1.63)
Dipodomys	1.0	3.2	42 (28)	4.5 (10.4)	1.41 (3.25)
Perognathus	11.7	37.1	184 (40)	19.6 (14.8)	0.53 (0.40)
Peromyscus	14.3	45.4	147 (30)	15.7 (11.1)	0.35 (0.24)
Eutamias	1.7	5.4	4 (2)	0.4 (0.7)	0.08 (0.13)
Microtus montanus			105		
Spermophilus townsendi			1		

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[1] Based upon 1,440 live trap nights (see methods section for density calculations).

[2] Adjusted for differences in detectability (unadjusted values are given in parentheses).

selection by coyotes. Theoretically, to maximize fitness in an evolutionary sense, a predator should hunt for prey that, on the average, provide the greatest net energy gain per unit of time (Emlen 1966, Rapport 1971). Thus, coyotes should pursue each prey type according to its relative "profitability." This concept has been termed "optimal prey selection," as reviewed by Krebs (1973:104), and developed by Charnov (1973) and Schoener (1971).

Consistent with optimization theory, I suggest that the following prey characteristics influence utilization by coyotes: (1) relative and absolute abundance; (2) dispersion patterns; (3) circadian and seasonal activity patterns; (4) size; (5) ease of capture; and (6) previous experience. Density, dispersion, and activity patterns relate to searching time, and catchability affects pursuit time and success rate. Size determines energy gain/capture. How do these prey characteristics relate to the observed "preferences?"

If prey size is a major determinant of coyote prey selection, "preference" indices should be greatest for larger species. This was not found (Tables 26-28); Perognathus, Reithrodontomys, and Lagurus are small rodents, yet all were consumed more frequently than predicted from relative biomass data. These data indicate that coyotes may respond to the frequency of capture (or reward) in addition to the quantity of the food reward.

One factor influencing relative utilization by coyotes is the degree of synchrony in circadian rhythms between coyotes and their prey. In southeastern Idaho, Woodruff (1977) found coyote activity levels to be somewhat higher at night than in the daytime. Most rodents present in Curlew Valley are nocturnal (Speth 1969); *Eutamias* and *Spermophilus*, however, are active only during the day. These activity patterns may, in part, explain the coyote's "negative preference" for *Eutamias*.

Olaus Murie (1945:38) contemplated the comparatively low utilization of *Peromyscus* and *Eutamias* by coyotes and suggested:

> Such species as *Peromyscus*, *Eutamias*, and *Sciurus*, although acceptable food, are not often captured. Such animals are not easily caught, and do not lend themselves so readily to a routine hunting technique for the coyote.

Murie was referring to the catchability of these rodents. Gier (pers. comm.) and A. Murie (1940) agree with his interpretation.

Ozoga (1963) snow-tracked coyotes in Michigan and noticed that *Peromyscus* was often killed and left uneaten on the surface of the snow. Scott (1947) and Murie (1936) also observed this behavior in the red fox. These observations raise the question as to the importance of palatability in influencing the utilization of certain coyote prey. Experimental work conducted by MacDonald (1977) and Lund (1962) suggested taste as a factor influencing consumption and caching of rodents by captive red fox. To my knowledge, no experimental work with coyotes has been conducted.

Dispersion and density of prey is probably of primary importance in determining the coyote's diet. *Peromyscus* was the most abundant and ubiquitous species on the study area. Live trapping data indicated densities as high as 25 per hectare, with 5 per hectare common. *Eutamias* numbers were generally low, with 6 per hectare the highest density encountered. Estimated densities of *Perognathus* and *Dipodomys* did not exceed 15 per hectare.

In contrast, densities of *Microtus* often exceed 200 per hectare (Krebs 1966) in areas of suitable habitat. Although microtines (i.e., *Microtus* and *Lagurus*) are rare over the entire study area, densities may be quite high in local areas, such as alfalfa fields, areas historically protected from grazing, and mesic sites adjacent to springs and seeps. *Lagurus* is a colonial species (Maser 1974), which could further exaggerate high densities in local areas. The densities and distribution of *Reithrodontomys* in Curlew Valley are not known, but the dependence of this rodent upon grassy habitats (Smith 1936) also implies a clumped dispersion pattern. A similar spatial distribution characterizes the colonial Townsend's ground squirrel. The dispersion pattern of these rodents (particularly microtines), their potential for attaining locally high densities (in contrast to the uniformly moderate densities typical of *Peromyscus* and *Eutamias*), and the coyote's apparent ability to locate and efficiently exploit these prey aggregations probably contribute to the coyote's dietary "preferences" in Curlew Valley. Clumped disperson of prey was also mentioned to explain the high level of coyote predation upon jackrabbits in winter during this study.

Prey Availability and Coyote Density

Prey abundance is an important variable affecting the population densities of large carnivores. In this regard, Peterson (1974:326) states:

> Population levels of large carnivores are generally regarded as being adjusted in some way to their underlying resource base, the prey populations. In some cases, the "food supply" for predators may be correlated directly with prey densities, and predator populations will fluctuate in direct response to changes in prey population levels.

Peterson suggests a direct link between food supply and predator densities. Evidence for such a link has been reported for a wide array of mammalian carnivores, including mustelids (Erlinge 1974, Fitzgerald 1977, MacLean et al. 1974, Robina 1960), felids (Brand et al. 1976, Nellis et al. 1972, Schaller 1972), and canids (Jordan et al. 1967, MacPherson 1969, Mech 1972).

Population responses by coyotes to variations in prey availability has been reported by several authors. Changes in the abundance of small rodents (Gier 1968, Knowlton et al. 1971), livestock carrion (Todd and Keith 1976), microtines and snowshoe hares (Nellis and Keith 1976), and elk carrion (Weaver 1977) were accompanied by concurrent changes in coyote abundance.

In Curlew Valley, coyote populations varied in response to fluctuations in jackrabbit numbers (Clark 1972, Knudsen 1976). However, these findings may be confounded by the fact that coyote populations on the area were intensively exploited by man (Knudsen 1976). A more thorough examination of this question seems warranted.

Knudsen learned that mortality of coyotes in winter in Curlew was almost entirely man-induced. This clearly argues against the suggested food-limitation hypothesis for Curlew Valley.

It is important, however, to consider the factors affecting man's hunting success. I suggest that hunting success, and consequently coyote population levels, are related primarily to food availability.

To illustrate: when food is scarce, coyotes probably spend more time and effort searching for food, thereby increasing their exposure to potential human exploitation. When food supplies are abundant, coyotes may be less active and consequently less vulnerable. Under these circumstances, success by hunters might be rather low.

If we are eventually to predict coyote demographic patterns from information on food abundance, it would seem advantageous to: (1) identify the critical season(s) when food is in shortest supply and/or when it is most likely to influence coyote demography, and (2) enumerate the prey species or food types which are available to coyotes at that time. It is the availability of these foods in a given area that would be most influential in determining coyote density and demography.

In northern areas, winter appears to be a critical period for coyotes. Weaver (1977) compared coyote densities in three areas in Jackson Hole, Wyoming and found a high correlation between coyote numbers and the abundance of elk carrion in winter. He sought comparable relationships between coyote abundance and hunter-killed elk in fall, as well as rodent abundance in spring and summer, but found none. In Alberta, Todd and Keith (1976) reported that winter removal of livestock carrion resulted in lower coyote numbers.

In Curlew Valley, prey was indeed scarce in winter. Jackrabbit populations are lowest in February (Fig. 20). Rodent activity is minimal throughout most of the winter; Townsend's ground squirrels hibernate from late July until late February, and Dipodomys and Perognathus become torpid in late fall, remaining inactive until late February or March (US/IBP Desert Biome, unpubl.). Microtines, although active all winter, generally remain below the snow surface, rendering them less vulnerable to coyotes than during other seasons.

These interpretations are supported by the food habits data in Utah, where rodents comprised only 6-11 percent of the winter diet.

There is some direct evidence for a scarcity of coyote food in winter. Murie (1940) identified starvation as the cause of death of several coyotes recovered in January and February in Yellowstone. Knudsen (1976) reported a coyote mortality in late February resulting from pneumonia, but the animal was obviously emaciated. R. Davidson (pers. comm.) attributed the winter deaths of three coyotes in southern Idaho to starvation.

Three additional factors relate to the importance of winter food supply. Coyotes in Curlew Valley breed between late January and late February (Knudsen 1976:42), and a relationships between winter food availability and coyote reproductive success has been reported (Gier 1968, Clark 1972). Winter is also a time when maintenance energy demands are very high. In addition, it is the time of greatest human exploitation, the success of which may be related to food supply (see above, p. 104).

Assuming winter food supply to be an important regulator of coyote populations in Curlew Valley and throughout the Great Basin, what prey species in this region are potentially capable of supporting coyotes?

Based on scat data from this study, two-thirds of the coyote winter diet in the Utah study area consisted of jackrabbit. Coyote stomachs from Utah indicated that cow (presumably carrion) was also an important food item, contributing 38 percent (by weight) to the diet.

Winter food habits data from the Idaho portion of the study area are meager, but suggest a more complex situation. Cow was the principal food item in stomachs and scats, accounting for 78 and 29 percent by weight and volume, respectively. From the scat data, I found that jackrabbit, cottontail, and rodent (primarily microtine) each contributed more than 15 percent to the total scat volume.

A survey of food habits studies from other Great Basin areas revealed similar findings. Kauffeld (1977) found jackrabbit to be the chief (60 percent) food item in winter in Nevada. Hawthorne (1972) and Ferrel et al. (1953) reported cow, deer, and Microtus as the primary winter foods in their respective study areas in eastern California. Stoel (1976) reported that leporids, livestock, and microtines comprised the greatest portion of the coyote's winter diet in southeastern Washington. Food habits data from two areas in the Snake River Plains of southern Idaho indicate that Nuttall's cottontail is a dominant food item in areas where it is particularly abundant (Johnson 1978, Hornocker et al. 1978).

According to these studies, jackrabbit and livestock are consistently represented in the winter diets of coyotes in the Great Basin, with deer, microtine rodents, and occasionally cottontails important in some areas. Heteromyids, ground squirrels, and pocket gophers, although frequent dietary items at other seasons, apparently are not available in winter. Only Stoel (1976) considered Townsend's ground squirrels and Perognathus to be significant winter foods (particularly in February). However, Stoel's study area is situated at an unusually low elevation (150-335 m) where squirrels become active in late January and Perognathus emerges in February.

Peromyscus is the most abundant and ubiquitous rodent in the Great Basin and it remains active throughout the year. Yet, it has never been reported as an important winter food item. As mentioned previously, anti-predator behavior and/or dispersion patterns may be responsible for this puzzling observation.

To summarize: despite human exploitation in many areas, winter food availability seems to be the critical factor affecting coyote densities in the Great Basin Desert. Jackrabbit and livestock carrion are the principal winter foods in most areas; deer, microtines, and cottontails are important in some locales.

Suggestions for Future Research

Coyote-prey relationships in Curlew Valley

Many problems concerning coyote-prey relationships in Curlew Valley remain unresolved. These can be tackled most efficiently by conducting intensive studies in the Utah portion of Curlew Valley.

Currently, detailed information regarding the temporal and spatial distribution of jackrabbits is not available. We need to know precisely when and where jackrabbits congregate, and how dispersion patterns are affected by changes in overall jackrabbit density.

Secondly, coyote food-habits data in spring and summer during the increasing and peak phases of the jackrabbit cycle are needed to determine how extensively coyotes feed upon rodents at these times.

The abrupt temporal shifts in the diet that were documented in this study need to be investigated in greater detail, perhaps by bi-weekly or monthly censuses and scat collections. Although such studies would be logistically feasible only on a small scale, they could provide valuable information concerning how quickly coyotes respond functionally to changes in prey availability.

Presently we have little knowledge of the densities and spatial distributions of several important prey species in Curlew Valley. In particular, data for microtines and cottontails are lacking. It would be desirable to know how widely they are distributed, and to what extent populations fluctuate.

Technical refinements

Before significant strides in our understanding of coyote-prey relationships can occur, analytical techniques must be qualitatively and quantitatively refined. For example, more experiments relating scat contents to the prey quantities consumed are needed before the relative importance of each prey species can be properly assessed.

Although a multitude of rodent population studies have been conducted, our trapping regimes have not been validated. After intensively trapping a given area, we do not know how many rodents inhabit the area. Electric fences, pitfall trapping, and various other innovative sampling regimes should be explored in an attempt to validate trapping data.

The experimental approach

In the past the approach to ecological research on coyotes has been primarily observational. It now seems appropriate to also attempt more manipulative approaches. Todd and Keith (1976) pioneered this approach with their carrion-removal experiment in Alberta. Similar experiments should be feasible in the Great Basin, and in view of the prime importance of livestock carrion to Great Basin coyotes, such perturbations may prove valuable. The removal and/or addition of carrion in an area at various times may be the most fruitful approach to understanding the effect of food supply upon the various stages of reproduction, as well as the patterns and timing of dispersal.

Probably the most comprehensive approach to investigating coyote-food base dynamics is to simultaneously monitor prey populations, food habits, and coyote demographics on a long-term basis. This has not been done. Over a period of years, patterns should begin to emerge. In this way, we may ultimately be able to translate prey population changes and coyote food habits responses into the population processes of natality, mortality and movements.

Summary

Coyote-prey relationships were investigated on a 1770-km^2 area in Curlew Valley, Utah and Idaho, during a period of low jackrabbit numbers (From September 1973 to May 1975). Relative and absolute rodent densities, coyote food habits, and relative coyote numbers were assessed. Rodent snap trapping along line transects was conducted each May and September, and sequential live and snap trapping on quadrats facilitated conversion of snap trap data to estimates of actual density via regression techniques. Coyote feeding patterns were assessed by analyzing scats collected monthly from March to December, and by examining stomachs of winter-killed coyotes. Scent station surveys provided spring and fall indices of coyote abundance, and coyote trap lines and a scat collection route supplied additional fall indices. Data on jackrabbit population in Utah was provided by L. Charles Stoddart.

Rodent snap trapping efforts revealed similar species composition and abundance in Utah and Idaho, with four species--*Peromyscus maniculatus*, *Perognathus parvus*, *Eutamias minimus*, and *Dipodomys ordii* comprising over 90 percent of the catch. *Peromyscus* predominated in all habitats. *Dipodomys* and *Peromyscus* numbers fluctuated widely.

Relationships between snap trap indices and density based upon live trapping were established on 23 3-ha quadrats. Significant regressions for each of the four principal species enabled conversion of the snap trap data to estimates of density. Mean study area densities were greatest for *Peromyscus*, followed in order of decreasing density by *Perognathus*, *Dipodomys*, and *Eutamias*.

Coyote diets were markedly different in Utah and Idaho. Jackrabbit comprised half of the year-round diet of coyotes in Utah, but only 10 percent in Idaho. Rodents were the principal prey consumed in Idaho (35 percent by volume). in addition, coyotes in the Utah study area utilized a greater diversity of rodent species.

Extreme seasonal and annual variations in coyote feeding patterns occurred during the study. In Utah, jackrabbit comprised 70-80 percent of the winter diet, but only 25-35 percent between May and September. Rodents were unimportant in winter, but heavily utilized in spring and summer. Seasonal trends in the Idaho study area were more complex, but generally paralleled those in Utah.

Site-specific variation in coyote food habits was also noted. In contrast to those in most of the Utah study area, coyotes on Cedar Hill preyed almost exclusively upon small rodents. A comparison of three ecologically different areas in Idaho revealed several disparities which probably reflected differences in prey availability.

Although analyses of winter stomachs disclosed a somewhat different pattern of coyote food habits, a large sample of winter scats probably represented the winter food habits of coyotes more accurately.

Results of three index methods revealed that coyote numbers in Curlew Valley did not vary appreciably during the study period. Scent station and trapping data suggested higher coyote densities in Idaho.

The coyote's food habits response to changing rodent and rabbit densities in Utah was examined. Despite extremely low jackrabbit densities from 1973 to 1975, they comprised two-thirds or more of the coyote's diet (based on scat data) during late fall and winter. This suggests a dearth of available alternate prey during this time. Coyote utilization of some rodents was correlated with snap trap indices, suggesting that: (1) coyote predation upon these rodents was a random event, or (2) rodent density changes were not of sufficient magnitude to alter coyote predatory behavior.

In Idaho, a 3-fold increase in pocket gopher and cottontail consumption from spring 1974 to spring 1975 compensated for a reduction in the availability of deer and microtine rodents.

Seasonal trends in jackrabbit and rodent consumption in Utah probably resulted primarily from changes in rodent abundance and availability. Aggregations of jackrabbits in Curlew Valley may have permitted coyotes to more efficiently exploit a low-density population in winter.

To determine if coyotes fed in a selective manner, the relative proportions of various prey species in the diet were compared with their relative abundances. Jackrabbit was "preferred" over rodent in May; no obvious "preference" for either prey type was evident in September. Among the rodents, microtines, and to a lesser extent *Reithrodontomys*, *Perognathus*, and *Dipodomys* were apparently quite vulnerable to coyote predation. Although *Peromyscus* and *Eutamias* were abundant and widely distributed, they were not often taken by coyotes. Implied "preferences" were explained primarily on the basis of optimization theory, and the importance of prey dispersion patterns was emphasized.

I suggest winter food supply to be the critical factor limiting coyote densities in Curlew Valley and throughout the Great Basin. In this region, jackrabbit and livestock carrion are the principal foods available to coyotes in winter, with deer, microtines, and cottontails important in some areas. The abundances of these foods are probably most influential in determining coyote density in the Great Basin Desert.

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APPENDICES

APPENDIX I

Table 29. Comparison of 12 different population estimators applied to mark-recapture data for *Peromyscus maniculatus* on 23 live trap grids.

Grid number	Minimum estimate[1]	Lincoln index[2]	Jackknife[3]	Generalized removal[4]	Darroch (1958)	Schnabel (1938)	Schumacher-Eschmeyer (1943)	Overton (1969)	Poisson[5]	Geometric[5]	Geometric regression[5]	Negative binomial[6]
1	34	42	58	--	37	30	33	44	44	68	62	58
2	51	69	63	52	53	45	46	61	67	104	94	69
3	72	78	94	--	73	54	51	88	105	165	120	119
4	24	35	25	33	24	21	22	27	27	39	29	25
5	14	--	23	15	15	14	14	18	18	28	23	20
6	62	86	88	67	65	63	64	75	75	116	90	79
7	110	144	147	142	113	101	00	133	127	187	158	128
8	68	77	77	68	68	65	66	76	76	111	83	72
9	67	72	72	74	67	60	60	74	72	100	78	70
10	39	39	41	40	39	37	38	2	41	56	45	40
11	44	60	54	50	44	38	40	50	47	65	52	48
12	14	--	15	14	14	14	14	16	16	24	20	15
13	43	48	56	--	43	38	40	50	46	66	53	48
14	86	98	106	132	87	73	77	104	87	142	151	98
15	13	21	15	14	13	10	10	16	15	21	16	15
16	19	22	22	--	19	16	18	23	23	36	31	22
17	18	27	28	--	18	15	16	22	21	31	23	24
18	15	--	18	18	15	16	16	18	19	29	24	18
19	9	--	12	--	--	--	--	12	12	19	16	17
20	9	--	12	12	12	--	--	13	17	28	20	15
w1	32	--	39	--	33	31	31	40	39	60	56	40
w2	30	--	41	30	30	31	30	41	43	70	60	44
w3	33	--	37	36	33	33	34	38	37	54	52	36

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[1] Number actually marked.

[2] From Lincoln (1930). Calculated from marked-unmarked ratio of snap trapped animals (if 10 or more captures).

[3] From Burnham (1972) and Otis et al. (1978).

[4] From Otis et al. (1978).

[5] From Eberhardt (1969), Edwards and Eberhardt (1967), and Nixon et al. (1967).

[6] From Tanton (1965).

Table 30. Comparison of 12 different population estimators applied to mark-recapture data for _Perognathus parvus_ on 20 live trap grids.

Grid number	Minimum estimate[1]	Lincoln index[2]	Jackknife[3]	Generalized removal[4]	Darroch (1958)	Schnabel (1938)	Schumacher-Eschmeyer (1943)	Overton (1969)	Poisson[5]	Geometric[5]	Geometric regression[5]	Negative binomial[6]
1	40	51	55	--	46	38	37	54	60	99	97	56
2	5	--	--	--	--	--	--	--	--	--	--	--
3	10	--	19	--	10	--	--	13	12	17	14	13
5	45	51	55	71	47	42	44	54	55	84	69	58
6	4	--	--	--	--	--	--	--	--	--	--	--
7	4	--	--	--	--	--	--	--	--	--	--	--
8	16	--	19	19	17	17	18	20	22	34	29	21
9	7	--	11	7	7	--	--	--	--	--	--	--
10	21	--	24	31	22	20	21	24	23	4	29	23
11	18	20	23	18	18	19	19	22	20	29	24	23
12	2	--	--	--	--	--	--	--	--	--	--	--
13	51	--	74	--	57	53	56	63	64	102	110	68
14	44	--	42	48	45	42	44	--	--	--	--	--
15	3	--	--	--	--	--	--	--	--	--	--	--
16	7	--	9	7	7	--	--	--	--	--	--	--
17	19	19	21	20	19	17	17	22	20	29	21	20
18	9	--	12	10	9	--	--	10	10	14	11	10
19	9	--	10	--	--	--	--	11	11	17	15	12
20	2	--	--	--	--	--	--	--	--	--	--	--
w3	2	--	--	--	--	--	--	--	--	--	--	--

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[1] Number actually marked.

[2] Lincoln (1930. Calculated from marked-unmarked ratio of snap trapped animals (if 10 or more captures).

[3] Burnham (1972) and Otis et al. (1978).

[4] Otis et al. (1978).

[5] Eberhardt (1969), Edwards and Eberhardt (1967), Nixon et al. (1967).

[6] Tanton (1965).

Table 31. Comparison of 12 different population estimators applied to mark-recapture data for *Eutamias minimus* on 18 live trap grids.

Grid number	Minimum estimate[1]	Lincoln index[2]	Jackknife[3]	Generalized removal[4]	Darroch (1958)	Schnabel (1938)	Schumacher-Eschmeyer (1943)	Overton (1969)	Poisson[5]	Geometric[5]	Geometric regression[5]	Negative binomial[6]
2	6	--	10	--	6	--	--	--	--	--	--	--
3	24	24	30	27	24	21	23	28	32	46	23	38
5	--	--	--	--	--	--	--	--	--	--	--	--
6	4	--	--	--	--	--	--	--	--	--	--	--
7	16	--	20	16	17	18	16	20	19	29	26	22
8	21	26	28	21	22	21	20	26	28	44	38	29
9	12	--	17	22	15	14	14	16	16	25	20	47
10	29	--	67	33	45	45	47	40	56	97	51	--
11	5	--	--	--	--	--	--	--	--	--	--	--
12	2	--	--	--	--	--	--	--	--	--	--	--
13	7	--	8	--	7	--	--	--	--	--	--	--
14	12	24	22	--	15	--	--	16	19	31	20	57
15	4	--	--	--	--	--	--	--	--	--	--	--
16	6	--	9	6	6	--	--	--	--	--	--	--
18	1	--	--	--	--	--	--	--	--	--	--	--
19	1	--	--	--	--	--	--	--	--	--	--	--
20	1	--	--	--	--	--	--	--	--	--	--	--
w3	12	--	17	12	12	10	8	14	13	19	15	16

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[1] Number actually marked.

[2] Lincoln (1930). Calculated from marked-unmarked ratio of snap trapped animals (if 10 or more captures).

[3] Burnham (1972) and Otis et al. (1978).

[4] Otis et al. (1978).

[5] Eberhardt (1969), Edwards and Eberhardt (1967), Nixon et al. (1967).

[6] Tanton (1965).

Table 32. Comparison of 12 different population estimators applied to mark-recapture data for Dipodomys ordii on 11 live trap grids.

Grid number	Minimum estimate[1]	Lincoln index[2]	Jackknife[3]	Generalized removal[4]	Darroch (1958)	Schnabel (1938)	Schumacher-Eschmeyer (1943)	Overton (1969)	Poisson[5]	Geometric[5]	Geometric regression[5]	Negative binomial[6]
1	35	51	52	--	41	42	40	47	57	96	86	49
5	47	70	58	65	49	45	47	56	68	108	89	72
8	17	--	27	17	17	18	18	21	21	31	24	23
9	3	--	--	--	--	--	--	--	--	--	--	--
11	1	--	--	--	--	--	--	--	--	--	--	--
13	12	--	13	14	12	--	--	14	13	19	15	15
14	1	--	--	--	--	--	--	--	--	--	--	--
16	2	--	--	--	--	--	--	--	--	--	--	--
17	4	--	--	--	--	--	--	--	--	--	--	--
18	11	--	13	14	13	--	--	14	17	27	13	13
20	4	--	--	--	--	--	--	--	--	--	--	--

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[1] Number actually marked.

[2] Lincoln (1930). Calculated from marked-unmarked ratio of snap trapped animals (if 10 or more captures).

[3] Burnham (1972) and Otis et al. (1978).

[4] Otis et al. (1978).

[5] Eberhardt (1969), Edwards and Eberhardt (1967), Nixon et al. (1967).

[6] Tanton (1965).

APPENDIX II

Table 33. Summary of live trap data, showing species and number of individuals captured (marked), habitats, and time of year for 23 grids operated in Curlew Valley, summer 1974 and spring 1975.

Grid No.	Habitat	Month & year trapped	*Peromyscus maniculatus*	*Perognathus parvus*	*Eutamias minimus*	*Dipodomys ordii*	*Onychomys leucogaster*	*Reithrodontomys megalotis*	*Lagurus curtatus*	Other[a]
1	sage-grass	June 1974	34	40	-	35	2	-	3	
2	sage-annuals	July 1974	51	5	6	-	-	-	-	
3	sage-shadscale	July 1974	72	10	24	-	-	-	1	
4	alfalfa	July 1974	24	-	-	-	-	-	-	
5	sage-grass	July 1974	14	45	5	47	4	-	-	
6	cultiv. wheat	July 1974	62	4	4	-	-	1	-	3
7	greasewood-sage	July 1974	110	4	16	-	-	-	2	
8	black sage-rabbitbrush	July 1974	68	16	21	17	4	-	1	
9	sage	July-Aug 1974	67	7	12	3	-	-	1	1
10	sage-forbs	July-Aug 1974	39	21	29	-	3	-	-	
11	juniper-sage	Aug. 1974	44	18	5	1	1	-	-	1
12	crested wheat-grass-sage	Aug. 1974	14	2	2	-	1	-	-	
13	sage-grass	Aug. 1974	43	51	7	12	1	2	2	
14	sage-grass	Aug. 1974	86	44	12	1	-	11	5	
15	sage-annuals	Apr-May 1975	13	3	4	-	3	-	-	
16	sage-forbs	Apr-May 1975	19	7	6	2	1	4	-	
17	juniper-sage	May 1975	18	19	-	4	-	-	-	6
18	sage-grass	May 1975	15	9	1	11	-	-	-	
19	shadscale	June 1975	9	9	1	-	-	2	-	2
20	annuals	June 1975	9	2	1	4	-	-	-	
w1[b]	annuals	July 1974	32	-	-	-	-	-	-	
w2[b]	alfalfa	June 1974	30	-	-	-	-	-	-	7
w3[b]	crested wheat-grass-sage	June-July 1974	33	2	12	-	-	-	-	
TOTAL			906	318	168	137	20	20	15	20

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[a] *Microtus montanus*, *Eutamias dorsalis*, *Dipodomys microps*, *Neotoma lepida*, and *Mus musculus*.

[b] Trapping conducted by James S. Wakeley.

APPENDIX III

Table 34. Estimated population size, mean maximum distance between any two capture points (MMD), size of grid sampling area, and density for *Peromyscus maniculatus* on 23 live trap grids, Curlew Valley, 1974-75.

Grid number	Minimum population estimate	MMD ± SE (m)	N	Sampling area (ha)	Density (no/ha)
1	34	69.5 ± 6.6	11	5.57	6.1
2	51	44.5 ± 4.0	18	4.50	11.3
3	72	54.9 ± 4.6	37	4.94	14.6
4	24	51.8 ± 8.3	12	4.81	5.0
5	14	49.6 ± 19.5	6	4.71	3.0
6	62	44.8 ± 5.1	20	4.52	13.7
7	110	38.2 ± 3.6	55	4.25	25.9
8	68	50.8 ± 5.3	32	4.77	14.3
9	67	48.5 ± 4.0	49	4.67	14.3
10	39	39.5 ± 4.3	27	4.30	9.1
11	44	57.7 ± 6.4	27	5.06	8.7
12	14	45.4 ± 6.7	6	4.54	3.1
13	43	41.9 ± 4.4	24	4.40	9.8
14	86	45.9 ± 5.6	45	4.56	18.9
15	13	88.4 ± 9.0	9	6.45	2.0
16	19	83.5 ± 11.9	6	6.21	3.1
17	18	81.4 ± 17.8	8	6.12	2.9
18	15	46.6 ± 16.7	4[a]	4.59	3.3
19	9	-	*	4.69[b]	1.9
20	9	-	*	4.69[b]	1.9
w1	32	28.0 ± 2.9	8	3.85	8.3
w2	30	53.4 ± 12.2	6	4.87	6.2
w3	33	50.7 ± 6.1	12	4.76	6.9
Totals and means	906	49.1	425	4.69	8.4

[a] *=fewer than three individuals with two or more recapture points.

[b] Based upon the pooled MMD (49.1).

Table 35. Estimated population size, mean maximum distance between any two capture points (MMD), size of sampling area, and density for Perognathus parvus on 20 live trap grids, Curlew Valley, 1974-75.

Grid number	Minimum population estimate	MMD ± SE (m)	N	Sampling area (ha)	Density (no/ha)
1	40	42.0 ± 7.3	7	4.40	9.1
2	5	84.0 ± 8.6	4	6.24	0.8
3	10	48.3 ± 9.4	7	4.66	2.1
5	45	30.3 ± 4.9	18	3.94	11.4
6	4	-	*[a]	4.60[b]	0.9
7	4	-	*	4.60[b]	0.9
8	16	-	*	4.60[b]	3.5
9	7	33.8 ± 3.3	3	4.08	1.7
10	21	33.3 ± 4.3	10	4.06	5.2
11	18	41.5 ± 8.8	8	4.38	4.1
12	2	-	*	4.60[b]	0.4
13	51	36.0 ± 8.2	15	4.16	12.3
14	44	29.6 ± 3.7	24	3.92[b]	11.2
15	3	-	*	4.60[b]	0.6
16	7	48.9 ± 13.3	4	6.96	1.0
17	19	49.5 ± 7.9	12	4.71	4.0
18	9	34.2 ± 4.2	4	4.09	2.2
19	9	55.0 ± 17.8	3	4.94	1.8
20	2	-	*	4.60[b]	0.4
w3	2	-	*	4.60[b]	0.4
Totals and means	318	46.9	114	3.60	3.6

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[a] *=fewer than three animals with two or more recapture points.

[b] Based on the pooled MMD (46.9).

Table 36. Estimated population size, mean maximum distance between any two capture points (MMD), size of sampling area, and density for Eutamias minimus on 18 live trap grids, Curlew Valley, 1974-75.

Grid number	Minimum population estimate	MMD ± SE (m)	N	Sampling area (ha)	Density (no/ha)
2	6	*[a]	*	6.24[b]	1.0
3	24	83.1 ± 8.5	15	6.19	3.9
5	5	*	*	6.24[b]	0.8
6	4	*	*	6.24[b]	0.6
7	16	75.7 ± 16.6	5	5.85	2.7
8	21	63.2 ± 10.6	5	5.29	4.0
9	12	*	*	6.24[b]	1.9
10	29	46.6 ± 0.8	3	4.59	6.3
11	5	*	*	6.24[b]	0.8
12	2	*	*	6.24[b]	0.3
13	7	*	*	6.24[b]	1.1
14	12	*	*	6.24[b]	2.2
15	4	*	*	6.24[b]	0.6
16	6	*	*	6.24[b]	1.0
18	1	*	*	6.24[b]	0.2
19	1	*	*	6.24[b]	0.2
20	1	*	*	6.24[b]	0.2
w3	12	119.2 ± 25.0	6	7.99	1.5
Totals and means	168	84.2	41	6.24	1.6

[a] *=fewer than three individuals with two or more recaptures.

[b] Based on the pooled MMD (84.2).

Table 37. Estimated population size, mean maximum distance between any two capture points (MMD), size of sampling area, and density for <u>Dipodomys ordii</u> on 11 live trap grids, Curlew Valley, 1974-75.

Grid number	Minimum population estimate	MMD ± SE (m)		N	Sampling area (ha)	Density (no/ha)
1	35	27.7	7.9	4	3.84	9.1
5	47	24.1	2.4	19	3.70	11.9
8	17	46.3	13.3	7	4.58	3.7
9	3	-		*[a]	4.30[b]	0.7
11	1	-		*	4.30[b]	0.2
13	12	103.2	19.0	4	7.17	1.7
14	1	-		*	4.30[b]	0.2
16	2	-		*	4.30[b]	0.5
17	4	-		*	4.30[b]	0.9
18	11	-		*	4.30[b]	2.6
20	4	-		*	4.30[b]	0.9
Totals and means	137	39.4		38	4.30	2.9

[a] *=fewer than three individuals with two or more recaptures.

[b] Based on the pooled MMD (39.4).

APPENDIX IV

Table 38. Comparison of grid snap trap results between transects placed inside and adjacent to (outside) each grid.

Grid number	No. transects		*Peromyscus maniculatus*		*Perognathus parvus*		*Eutamias minimus*		*Dipodomys ordii*	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
1	2	3	29.8	6.4	19.5	4.5	-	3.1[a]	49.5	22.5
2	2	3	54.3	29.5	7.5	0.0	13.0	7.4	-	-
3	2	6	147.7	67.2	0.0	7.2	51.0	28.1	-	1.3[a]
4	2	5	44.4	15.8	-	-	-	-	-	-
5	3	5	5.1	2.0	16.8	11.6	5.3	6.0	32.9	28.1
6	3	3	53.7	34.6	0.0	0.0	2.7	0.0	-	1.5[a]
7	2	3	149.8	94.2	0.0	0.0	13.3	20.8	-	3.5[a]
8	2	3	110.3	44.2	0.0	1.9	48.4	33.1	17.7	6.0
9	2	4	62.6	31.8	0.0	2.4	0.0	4.4	0.0	0.0
10	2	2	43.8	61.9	5.4	6.1	11.0	8.2	-	2.0[a]
11	3	3	50.2	23.5	14.5	7.2	13.5	4.4	0.0	0.0
12	3	4	65.1	25.8	13.1	6.4	6.7	15.6	9.0	1.2
14	3	2	118.8	121.4	26.0	19.4	32.4	27.0	3.9	2.4
15	2	3	26.0	15.3	2.6	2.8	11.2	7.1	-	1.4[a]
16	2	3	46.3	19.7	12.4	5.1	10.2	6.7	0.0	6.9
17	2	2	35.6	17.0	36.2	14.8	-	-	4.8	2.2
18	2	2	16.2	8.3	6.2	2.0	2.0	0.0	2.0	5.8
19	2	2	11.5	18.8	8.2	0.0	2.6	4.1	-	-
20	3	2	4.1	2.0	0.0	0.0	0.0	0.0	2.6	0.0
w1	3	3	5.8	4.9	-	-	-	-	-	-
w2	3	0	20.6	-	-	-	-	-	-	-
w3	2	4	31.5	31.4	0.0	0.0	12.0	0.0	-	-
Mean	(55)	(68)	49.7	31.0	10.9	6.1	14.0	10.4	13.6	8.3
p-value			< .001		< .05		< .10		< .15	

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[a] Omitted from calculation of mean, as no individuals were live trapped.