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Rodent Density and Species Composition in the Snake River Birds of Prey Natural Area, Idaho

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RODENT DENSITY AND SPECIES COMPOSITION IN THE SNAKE RIVER BIRDS OF PREY NATURAL AREA, IDAHO

by

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

of

MASTER OF SCIENCE

in

Wildlife Ecology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1977

ACKNOWLEDGMENTS

I would like to express my deep appreciation to my wife, Kathleen, for her unselfish assistance in the field. Without her help, I could not have accomplished half of the work I set out to do.

In addition, thanks go to the Bureau of Land Management for funding the study: "Density and Species Composition of Small Mammals and Birds," Contract No. 52500-CT5-1003, of which this research was a part.

Appreciation is extended to Dr. Rex L. Hurst, Chairman of the Utah State University Applied Statistics and Computer Science Department for his assistance with statistical analysis of the data.

I would particularly like to thank Dr. Michael Wolfe and Robert Anderson for their helpful suggestions regarding the experimental design.

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by

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Utah State University, 1977

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Rodent densities were estimated in the major vegetation types of the Snake River Birds of Prey Natural Area in 1975 and 1976 by a combination of live-trapping and kill-trapping. Only deer mice (Peromyscus maniculatus) were numerous enough to permit reliable density estimates. Relative densities of other rodent species were indicated by kill-trap capture rates. Densities of deer mice correlated well (r = 0.99) with kill-trap capture rates. The use of kill-trapping in place of live-trapping in 1976 permitted extensive sampling throughout the 1930 km^2 study area. Differences were found among the major vegetation and land-use types in their ability to support the rodent species representing potential prey for feeding raptors.

(50 pages)

INTRODUCTION

This investigation is an outgrowth of a large, integrated study entitled "The Snake River Birds of Prey Research Project. This project is funded by the Bureau of Land Management, U. S. Department of the Interior, and involves seven different studies, each of which investigates a component of an ecosystem that harbors the densest concentration of breeding raptors in the world (Kochert and Bammann 1976). The major objectives of the project are to determine raptor habitat use and to ensure continued availability of adequate prey biomass to support the present levels of breeding raptors.

Of particular concern is the availability of three key prey species: (1) Townsend ground squirrels (Spermophilus townsendii), (2) black-tailed jackrabbits (Lepus californicus), and (3) mountain cottontails (Sylvilagus nuttallii). Townsend ground squirrels are particularly important to prairie falcons (Falco mexicanus) and red-tailed hawks (Buteo jamaicensis). In 1975, Townsend ground squirrels comprised 66 and 49 percent of the prey biomass consumed by these raptors (Kochert and Bammann 1976). Golden eagles (Aquila chrysaetos) preferentially preyed on jackrabbits and cottontails. Kochert and Bammann found biomass fractions in golden eagle diets of 55 and 12 percent for these prey species, respectively, with Townsend ground squirrels comprising only 4 percent. In contrast, both prairie falcons and red-tailed hawks together consumed from 12-14 percent jackrabbits and 6-9 percent cottontails. Great horned owls (Bubo virginianus) and barn owls (Tyto alba) concentrated on nocturnal rodents, having consumed 17 and 28 percent kangaroo rats (*Dipodomys spp*.), 3 and 14 percent deer mice (*Peromyscus spp*.), and 3 and 25 percent meadow voles (*Microtus spp*.), respectively, in 1973 (Kochert 1974). Because of the importance of the Townsend ground squirrel, it was necessary to measure the supply and distribution of alternate rodent prey, should there be a future decline in ground squirrel numbers. Possible causes for such a decline include mortality from the plague bacillus *Yersinia pestis*, which is known to be endemic in the area (Johnson and Melquist 1976), and loss of habitat from the conversion of native rangeland into agricultural developments. It might be especially serious if a decline in ground squirrel numbers coincided with a low point in the jackrabbit cycle. This cycle of approximately 7 years has been documented by Gross et al. (1974) in Curlew Valley, Utah, and is being studied by Kochert and Bammann (1976) in the Birds of Prey Study Area. In addition to habitat losses from agricultural developments, other land-use practices which could influence Townsend ground squirrel numbers include livestock grazing, range fires, extent of natural and range-farm ecotones, and road construction.

The hypothesis tested in this study was that differences among land-use practices and vegetation types are correlated with support of alternate rodent prey species. A kill-trap index was used to measure these differences in species composition and densities among habitat types and identify those habitats which contribute significant numbers of prey. This information will allow the B. L. M. to preserve quality prey habitats and identify possible management practices which may be necessary in the future to mitigate for habitat losses.

STUDY AREA

The Snake River Birds of Prey Study Area (hereafter referred to as the study area) encompasses a 1930 km^2 area adjacent to the Snake River from Walter's Ferry to Indian Cove, Idaho (Figure 1). Within the study area is an intensive study area which includes the Birds of Prey Natural Area plus an 11 km segment southeast along the Snake River. The intensive study area covers 130 km^2. In concept, the various component studies of the Snake River Birds of Prey Research Project were designed to obtain relatively high-resolution results in the intensive study area and then extrapolate the results to the larger study area.

The canyon is the main feature of the Birds of Prey Natural Area and provides nesting habitat for most of the raptors. The canyon is composed of basalt lavas overlaying sedimentary deposits. Cliffs up to 180 m high form the walls with the river as much as 240 m below the rim. Above the canyon the terrain is flat or rolling with occasional lava outcroppings. Annual precipitation is approximately 20 cm at Swan Falls Dam. Permanent water is found in a few springs and streams which drain into the Snake River from side draws. Summers are hot and dry with most precipitation occurring in the winter months. Ecologically, the area is classified as belong to the Upper Sonoran Life Zone and, more specifically, in the Northern Desert Shrub Biome (Fautin 1946).

Major vegetation types which occur as relatively discrete units are big sagebrush (*Artemisia tridentata*), winterfat (*Eurotia lanata*),

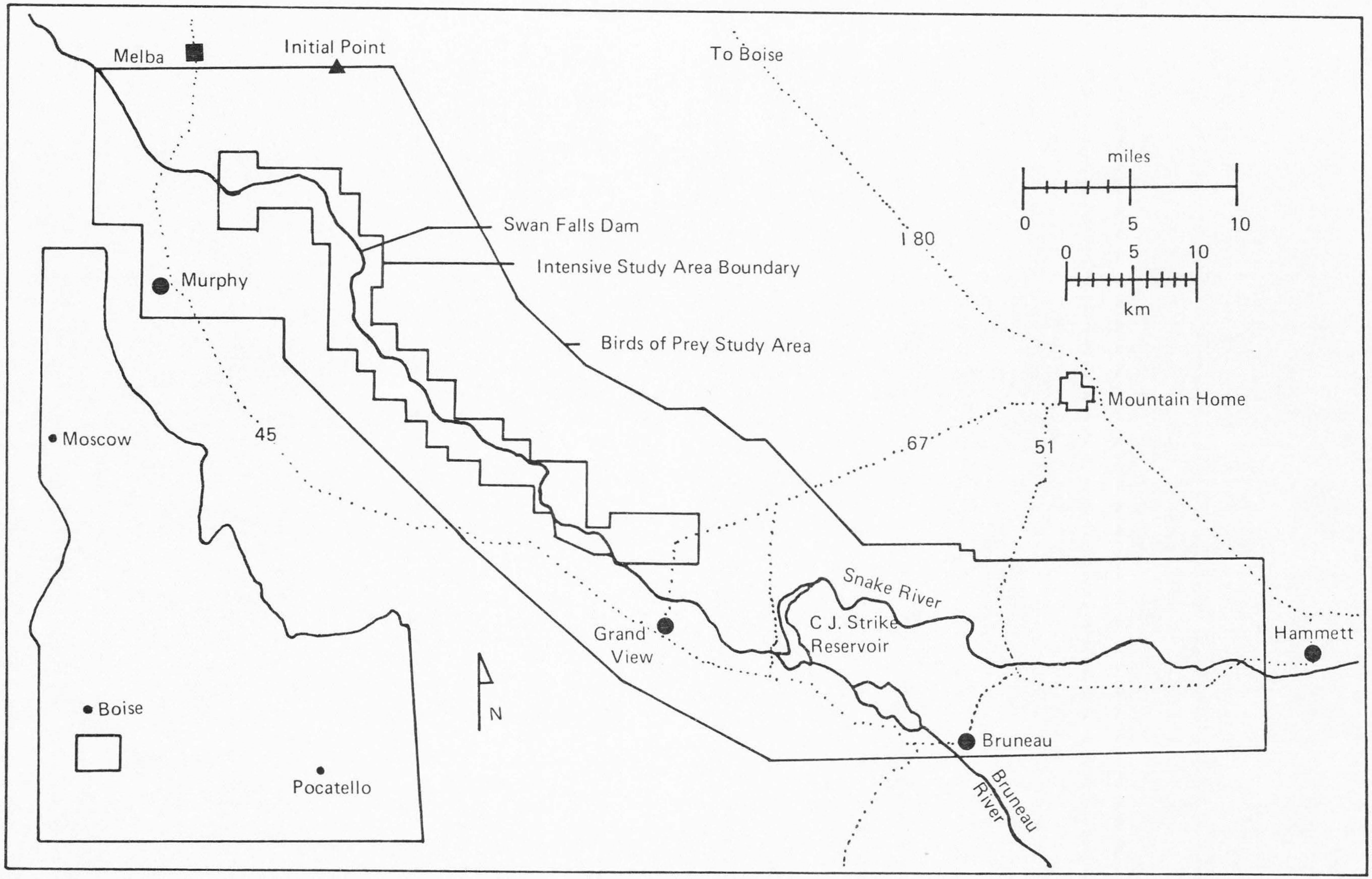

Figure 1. Map of the Snake River Birds of Prey Study Area.

greasewood (*Sarcobatus vermiculatus*), shadscale (*Atriplex confertifolia*), and cheatgrass (*Bromus tectorum*). Other less widely distributed or subdominant species include rabbitbrush (*Chrysothamnus* spp.), spiny hopsage (*Grayia spinosa*), budsage (*Artemisia spinescens*), four-winged saltbrush (*Atriplex canescens*), horsebrush (*Tetradymia* spp.), and grasses such as Sandberg bluegrass (*Poa sandbergii*), fescues (*Festuca* spp.), and wheatgrasses (*Agropyron* spp.). Adjacent to the Snake River and permanent tributaries is the narrow riparian community comprising a large variety of species. A more detailed treatment of the vegetation and physiography is given by Sigler et al. (1972) and Meiners (1970). Wilson (1975), Sigler et al. (*Ibid.*), and Goodnight (1973) have described the fauna.

The two major land uses in the study area are irrigated farming and livestock grazing. Currently there is a moratorium on new agricultural developments within the study area until the research project terminates at the end of 1979. The lands within the Birds of Prey Natural Area have been withdrawn from farming, although a few farms in operation before the withdrawal are still active. Principal crops are alfalfa, potatoes, sugar beets, and small grains (Kochert 1972). Cattle and sheep grazing is permitted within the Birds of Prey Natural Area. The Idaho National Guard uses an approximately 35 km^2 portion of the study area as a firing range and also conducts maneuvers over a larger, undetermined portion of the study area on the north side of the Snake River.

METHODS AND MATERIALS

Density determination

To adequately measure rodent densities within the study area called for the development of a simple and rapid technique. Index line capture rates using kill-traps seemed to offer promise as truly representing densities (Petticrew and Sadlier 1970, Hansson 1967). Larrison and Johnson (1973) had measured relative rodent densities by means of index lines in the Raft River Valley and in proximity to the Birds of Prey Natural Area, but had not calculated actual densities. Actual densities were desired by the B. L. M. for the purpose of parameterization in a proposed simulation model of the Birds of Prey ecosystem. For the purposes of this study, however, it was not necessary that an index measure absolute densities, only that it accurately reflect differences in density for a given species among trapping sites and over time. The significance of this point will be clarified in the subsequent discussion of the problems involved in density determination. The use of assessment lines (Smith et al. 1971), or sequential live- and kill-trapping (Yang et al. 1970) appeared to be a satisfactory means of correlating actual densities with an index. The development of a kill-trap index made extensive sampling possible by allowing kill-trapping to be substituted for live-trapping in 1976.

The problem of determining rodent densities by live-trapping comprises two aspects: (1) enumerating the animals, and (2) determining the area actually sampled. Reviews of the complex subject of censusing and density determination are given in Overton (1969) and Seber (1973).

Enumeration. There are basically three stratagems for estimating the number of animals using live-trapping (Overton *Ibid.*). One approach is to plot either daily catch or cumulative catch versus the day of the census, or daily catch versus cumulative catch. Both methods graphically reveal when the limit of catchable animals is approached. Neither method can estimate the uncatchable portion of the animals in question and therefore tends to produce minimal estimates. The second is to use one of a number of variations on the so-called Petersen or Lincoln Index (Lincoln 1930). The methods of Schnabel (1938), Schumacher-Eschmeyer (1943), Hayne (1949), Leslie et al. (1953), Darroch (1958, 1959), Seber (1962, 1965), and Jolly (1963, 1965) represent approaches to the basic Lincoln Index model. Each of these methods seeks to minimize the bias and error of the estimate. All have assumptions which must be satisfied regarding the behavior of the animals, but are often violated by trap-wary or trap-prone individuals, mortality, and immigration-emmigration shifts. Confidence intervals can be placed around the estimate, but can only be regarded as valid if the assumptions are met. The third strategy is to plot the frequency of capture (abscissa) against the number of captures (ordinate) and fit a distribution curve to the points. By extrapolating the curve to the Y-axis, an estimate of those animals never captured (the zero capture class) can be obtained. Adding this estimate to the sum of the other frequency classes gives an estimate of the total number of animals subject to capture (Edwards and

Eberhardt 1967, Eberhardt 1969, Marten 1970). No explanation of the behavioral properties of the animals is necessary, as the shape of the distribution curve is largely determined by these behavioral characteristics.

Frequency of capture methods are not without some drawbacks. For one, the estimate of the zero class is quite sensitive to how well the distribution fits the points. In fact, several distributions could conceivably fit well, all having nonsignificant Chi-square values. Simply choosing the distribution with the best fit (lowest Chi-square) is not statistically valid. Another potential problem is that no confidence intervals can be placed around the estimate. This is objectionable only if one is attempting to measure absolute numbers of animals, which was not the case in this study. A newly developed, statistically robust frequency of capture model known as the "jack-knife" estimator will allow confidence intervals to be placed around such estimates (Burnham 1972). This method was not used for reasons covered in the Results section.

Estimating area sampled. To estimate the area actually sampled without interfering with animals' movements requires a measure of mean home range which can be added to the area of the trapping grid. Jennrich and Turner (1969:233) define home range as the smallest area that accounts for 95 percent of an animal's habitat utilization. Various sophisticated methods for home range and sample area measurement include drift fences and pitfall traps (Briese and Smith 1974), radioactive detection (Kaye 1960), dropping boards (Emlen 1957), and feeding stained baits (Randolph 1973). The method requiring the least additional equipment is simply to record the capture locations on the trapping grid and compute the home range.

A review of methods to compute home range is found in Jennrich and Turner (1969). These authors point out that biases in traditional methods requiring the assumption of circular home range can be reduced by using an elliptical model. Irregularly-shaped home ranges have been observed in birds and mammals by Stumpf and Mohr (1962). Furthermore, Jennrich and Turner demonstrate that earlier home range methods are not comparable. Their method offers the advantage of allowing comparisons without bias among animals with both circular and noncircular home ranges. To accomplish this, their method generates an elliptical home range from the covariance matrix of capture loci.

In summary, the task of determining accurate density estimates was one of choosing an appropriate enumeration model whose assumptions could be met and applying the Jennrich and Turner home range formulas to the capture data to calculate the area actually sampled.

Vegetation analysis of the total study area

A vegetation and land-use map of the study area (1 cm = 0.64 km) was constructed by projecting 23 X 23 cm color infrared aerial transparencies onto Mylar overlays and tracing the boundaries with a grease pencil. Corrections were then made after validating aerial imagery on the ground. In addition, a range map prepared by the B. L. M. was used to differentiate understories of cheatgrass, Sandberg bluegrass, and range seedings of crested wheatgrass

(Agropyron cristatum) in areas north of the Snake River. Percent ground coverage was estimated by cutting out regions of the vegetation map and weighing them on a Mettler balance.

Live-trapping

The results of the extensive vegetation analysis revealed that four vegetation types, characterized by the dominant plant species, formed major, relatively discrete regions within the study area. These were big sagebrush, greasewood, shadscale, and winterfat. Cheatgrass was also considered important because it often results from range fires. A burned area resulting from a fire in June 1974 in big sagebrush and winterfat was also investigated as an early successional stage. The experimental design called for a live-trap grid (hereafter called a grid) in each of these types. In order to sample possible zoogeographical differences in species composition (Davis 1939), grids were established on both sides (north and south) of the Snake River when conditions permitted. Trapping sites were chosen on a nonrandom basis, partly for accessibility and partly due to the uneven distribution of vegetation types.

Grid sites were selected in homogeneous stands of the dominant plant species. The dominant species was defined as the one whose basal area intercepted the greatest number of centimeters along a 30 m linear transect (Smith 1966). One transect was run at each grid site during the spring of 1975. Each grid consisted of a 10 X 10 arrangement of Sherman traps (8 X 8 X 26 cm) spaced at 15 m intervals. The traps were baited with a mixture of peanut butter and rolled oats. Traps were operated for 5-night periods during the first 6 weeks of spring, summer, and fall, 1975. The 5-night trapping period was patterned after U. S. I. B. P. Biome procedures (Swift and French 1972). Dacron batting was used to prevent chilling the rodents at night. Traps were opened between 1500 and 1800 and checked between 0700 and 1100 before the mid-day heat killed the animals. Toe-clipping and ear-tagging with fingerling tags were used to identify individuals. Species, sex, age class, weight, and capture locations were recorded.

Kill-trapping

On the last two nights of each 5-night live-trapping period a line of 50 kill-traps (Victor mousetrap), baited with peanut butter and rolled oats and spaced 15 m apart, was placed near each grid in the same vegetation type. A 2-night trapping period was chosen for ease of application during 1976. It was also suspected that averaging captures over two nights would help reduce bias due to factors such as response to traps as novel objects, overloading of traps by trap-prone individuals, depletion of resident rodents after the first night with subsequent influx of new individuals, interspecific inter-actions, and weather. Since one of the objectives of marking animals in the live-trapping operation was the possible recovery of eartags in raptor pellets, captures of marked animals in kill-traps were purposely avoided by placing traplines at least 500 m from each grid. In 1976 Victor "M-4" rat traps were substituted for the smaller mousetraps, but the treadles were enlarged to retain sensitivity (Carley and Knowlton 1971). Preliminary experimentation with the placement of kill-traplines was done in 1975. As a result, major ecotones were sampled in 1976 by placing two lines of 25 traps each on either side and parallel to an ecotone and one line of 25 traps along the ecotone. Well-delineated, linear ecotones were selected when possible. Lines of 25 traps were operated for two nights on all other sites in 1976. Special areas of interest to the B. L. M., such as crested wheatgrass seedings, were also sampled.

A kill-trap index was calculated as:

$$\frac{(\text{no. captures})(100)}{[\text{no. trap nights}-(\text{no. sprung traps} + \text{no. missing traps})]}$$

One trap night was considered as one trap left open for one night. Sprung and missing traps due to wind, rain, beetles, and removal by coyotes (*Canis latrans*) and badgers (*Taxidea taxus*), were excluded. No compensation was necessary for bait removal by ants. Evidently, trap treadles retained the odor of bait despite removal by ants. In 1976, the number of Townsend ground squirrels, woodrats (*Neotoma cinerea* and *N. lepida*), and white-tailed antelope squirrels (*Ammospermophilus leucurus*) were also added to the denominator within the inner parentheses. The reason for this modification was that the larger traps used in 1976 caught species which escaped from the smaller traps in 1975.

Data analysis

Live-trapping data were analyzed with the aid of computer program developed for the U. S. I. B. P./Desert Biome by Kim Marshall at Utah State University. This program for each species calculates the number of animals subject to capture by the methods of Schumacher-Eschmeyer (1943), Jolly (1963, 1965), and Overton (1965), as well as the respective confidence intervals. It also tests goodness-of-fit for the following capture-frequency distributions: geometric (maximum likelihood estimator), geometric regression, Poisson, negative binomial, and Overton's nonparametric method (Overton 1969:446). Sex and age counts by capture day were also computed.

The area actually sampled by the grid for each species was estimated by expanding each side of the grid by the diameter of a circle the area of which was equal to the mean Jennrich and Turner home range. If the movement of individuals was so minimal or infrequent that no Jennrich and Turner home range could be calculated, a regression equation was used to estimate the home range (Balph 1973: 234). This regression relationship is independent of the particular species on which it is being applied. The equation was $Y = 0.078 + 0.098 X^2$; ($r^2 = 0.65$), where X equals the mean distance travelled between successive captures as measured in grid units. In this case one grid unit was 15 m. Y represents the home range in hectares. If no mean movement between successive captures was observed (because the animals went into the same traps repeatedly), then this parameter was assumed to be 15 m, the intertrap distance. For each species, an analysis of variance employing a randomized block design (without replication) was used to differentiate kill-trap densities among seasons and trapping sites. All statistical tests were made at the $P < 0.05$ level.

RESULTS

Vegetation analysis

Percent ground coverage of major vegetation and land-use types is given in Table 1. Big sagebrush association are grouped in the table because it was sometimes difficult to differentiate "pure" versus "mixed" understories. The map in Figure 2 represents a simplification of the original vegetation map, in which only the major vegetation associations are represented. On specific live-trapping grids, the basal areas of dominant plant species covered from 12-77 percent of the transects (Table 2). There was no overlap of major shrub species on any one grid. For example, on the big sagebrush grids there was no shadscale. Conversely, on the greasewood grid there was no big sagebrush. Relatively large percentages of bare ground and cheatgrass were often found, one indication of a history of livestock grazing.

Density estimates from live-trapping

Only deer mice (*Peromyscus maniculatus*) were captured in sufficient numbers to permit accurate density estimates (Tables 3-6). Analysis of the computer results revealed that the geometric regression method (Edwards and Eberhardt 1967) yielded expected distributions which consistently agreed well with the observed distribution of capture frequencies for deer mice ($X^2 < 5.51$, $p = 0.05$; $df = 4$). Other distributions sometimes had Chi-square values greater than 5.51 and were not used. For deer mice, a 5-night trapping period

Table 1. Estimated percent ground coverage by major vegetative associations of the Snake River Birds of Prey Study Area, 1 November 1976.

Description		% Coverage	km^2
Greasewood-cheatgrass[a]		30.6	591
Big sagebrush-cheatgrass		8.6	166
Big sagebrush-winterfat	22.3 {	7.7	149
Big sagebrush-Sandberg bluegrass		6.0	117
Farms		18.6	360
Shadscale/budsage[b]		18.2	352
Snake River and reservoirs		2.7	51
Spiny hopsage/shadscale		2.2	43
Shadscale-winterfat		1.9	37
Mountain Home Air Force Base		0.9	17
Cheatgrass		0.7	14
Winterfat		0.6	11
Cheatgrass-shadscale/greasewood		0.6	11
Bruneau Sand Dunes		0.3	6
Crested wheatgrass		0.3	6
Burn (previously big sagebrush-winterfat)		0.1	3
Sandberg bluegrass		0.1	3
Totals		100.0	1937

[a]Hyphen indicates former is numerically or physically dominant and latter is less frequent or exists as an understory.

[b]Slash indicates co-dominance or patches of pure stands of either vegetation type.

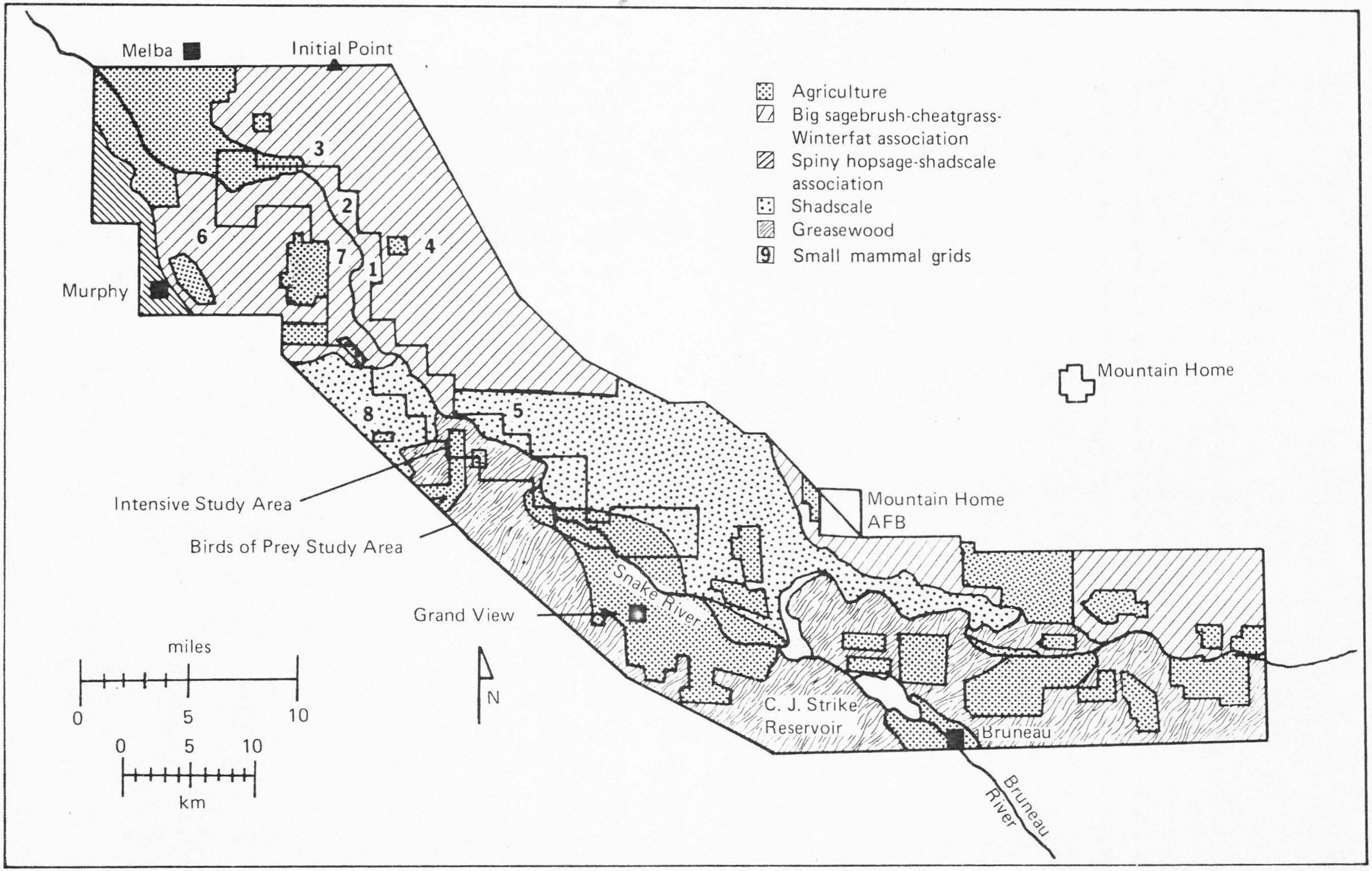

Figure 2. Major vegetative associations of the Snake River Birds of Prey Study Area, 1976.

Table 2. Vegetative composition as measured by percent coverage of transects on live-trap grids. Snake River Birds of Prey Study Area, May 1975.

Grid no.	Name	A. t.	A. s.	S. v.	A. c.	E. l.	B. t.	P.	L.	Forbs	Bg.
1	Burn (N)						39.2	1.5		0.4	59.0
2	Winterfat (N)					25.0		12.5	6.0		56.4
3	Big sage (N)	29.7						2.6	2.7	0.6	64.4
4	Cheatgrass (N)	0.8					76.6	3.1			19.5
5	Shadscale (N)		3.3		12.0[a] 16.0[b]						68.7
6	Greasewood (S)			24.9			53.9				21.2
7	Big sage (S)	20.0[a] 4.5[b]					47.7	11.9	0.5		15.7
8	Shadscale (S)		13.6	2.1[a] 13.6[b]				0.9	5.9		63.9

[a]Healthy = greater than 50% leaves.
[b]Dead or decadent = less than 50% leaves

A.t. = _Artemisia tridentata_
A.s. = _Artemisia spinescens_
S.v. = _Sarcobatus vermiculatus_
A.c. = _Atriplex confertifolia_

E. l. = _Eurotia lanata_
B. t. = _Bromus tectorum_
P. = _Poa spp._

L. = Lichen
Bg. = Bare ground
Forbs = _Descurainia pinnata_ and _Sisymbrium altissimum_

Table 3. Spring rodent live-trapping (*P. maniculatus* only) in the Snake River Birds of Prey Study Area, 22 March-25 April 1975.

Grid no.	Vegetation	North or south of river	Number caught	Home range (ha)	Mean distance moved (m)	Density (animals/ha)
1	Burn (24 June 1974)	N	7	6.3	62.0	0.4
2	Winterfat	N	6	1.7	64.6	0.7
3	Big sage	N	18	1.4	58.8	4.0
4	Cheatgrass	N	2	0.2[a]	18.8	0.5
5	Shadscale	N	68	1.6	45.3	13.4
6	Greasewood	S	18	2.2	47.5	3.1
7	Big sage	S	14	1.5	32.1	2.7
8	Shadscale	S	3	0.0	0.0	1.1
		Total:	136	Means: 2.1	47.0	3.2

[a]Home range calculated using regression equation (Balph, 1972).

Table 4. Summer rodent live-trapping (*P. maniculatus* only) in the Snake River Birds of Prey Study Area, 1 July-1 August 1975.

Grid no.	Vegetation	North or south of river	Number caught	Home range (ha)	Mean distance moved (m)	Density (animals/ha)
1	Burn (24 June 1974)	N	26	0.2	47.6	9.9
2	Winterfat	N	3	2.0[a]	67.1	0.3
3	Big sage	N	20	0.2	31.8	8.5
4	Cheatgrass	N	3	1.2	49.8	0.4
5	Shadscale	N	16	1.6	54.5	3.3
6	Greasewood	S	4	2.1	68.1	0.4
7	Big sage	S	1	0.5[a]	30.0	0.2
8	Shadscale	S	2	2.5[a]	75.0	0.2
		Total:	75	Means: 1.3	53 .0	2.9

[a]Home range calculated using regression equation (Balph, 1972).

Table 5. Fall rodent live-trapping (*P. maniculatus* only) in the Snake River Birds of Prey Study Area, 22 September-4 October 1975.

Grid no.	Vegetation	North or south of river	Number caught	Home range (ha)	Mean distance moved (m)	Density (animals/ha)
1	Burn (24 June 1974)	N	6	0.5	52.5	1.1
2	Winterfat	N	0	0.0	0.0	0.0
3	Big sage	N	9	0.5	37.4	3.2
4	Cheatgrass	N	0	0.0	0.0	0.0
5	Shadscale	N	No data			
6	Greasewood	S	12	0.9	42.0	3.0
7	Big sage	S	0	0.0	0.0	0.0
8	Shadscale	S	6	0.0	0.0	2.2
		Total:	33	Means[a] = 0.5	33.0	2.4

[a]Sites with zero captures omitted.

Table 6. Seasonal rodent captures (all species except P. maniculatus) on live-trap grids in the Snake River Birds of Prey Study Area, 1975.

Grid	Perognathus parvus			Dipodomys ordii			Dipodomys microps			Eutamius minimus			Onychomys leucogaster			Reithrodontomys megalotis			Ammospermophilus leucurus		
	Sp[a]	Su[b]	F[c]	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su	F
1	5	1	2	4	4	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
3	2	1	0	0	0	0	0	0	0	1	5	2	1	1	1	0	0	0	0	0	0
4	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0
6	1	0	0	3	3	5	0	2	0	0	0	0	0	0	0	1	0	2	0	0	2
7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	2	0	2	0	0	0	0	3	2	0	0	0	0	3	0
Totals:	9	3	2	7	7	5	2	3	2	1	5	2	1	9	6	1	0	2	0	3	2

[a] 22 March-25 April.

[b] 1 July-1 August.

[c] 22 September-4 October.

seemed to be of optimal length for applying capture-frequency methods. Too brief a trapping period yields too few captures for reliable estimates and a long period skews the frequency distribution to the right, sacrificing goodness-of-fit.

Live-trapping correlation with kill-trapping

Figure 3 illustrates the relationship between the kill-trap index and live-trapping density estimates for deer mice. Not all grids yielded enough deer mice to permit a reliable estimate. Therefore, of a possible 20 data points, only 11 appear in Figure 3. No density estimator is reliable when a small number of animals are caught. In this case, the computer program did not calculate density if less than 10 individuals of the same species were caught on any one grid during each 5-night trapping period.

Both regression equations showed a high degree of correlation and their slopes were significantly different from each other ($F = 101.1$, $p = 0.01$; $df = 1,7$). Reasons for the smaller slope in the big sagebrush equation are unknown. Despite a number of complex factors involving probabilities of capture and behavioral phenomena which influenced the validity of density determination and the kill-trap index, both live-trapping and kill-trapping methods have documented the same quantity: namely, density.

It might be argued that the geometric regression estimator was not reliable because no confidence intervals could be placed around the estimate, and that the "jackknife" method would have been more appropriate. The "jackknife" method was not used for two reasons.

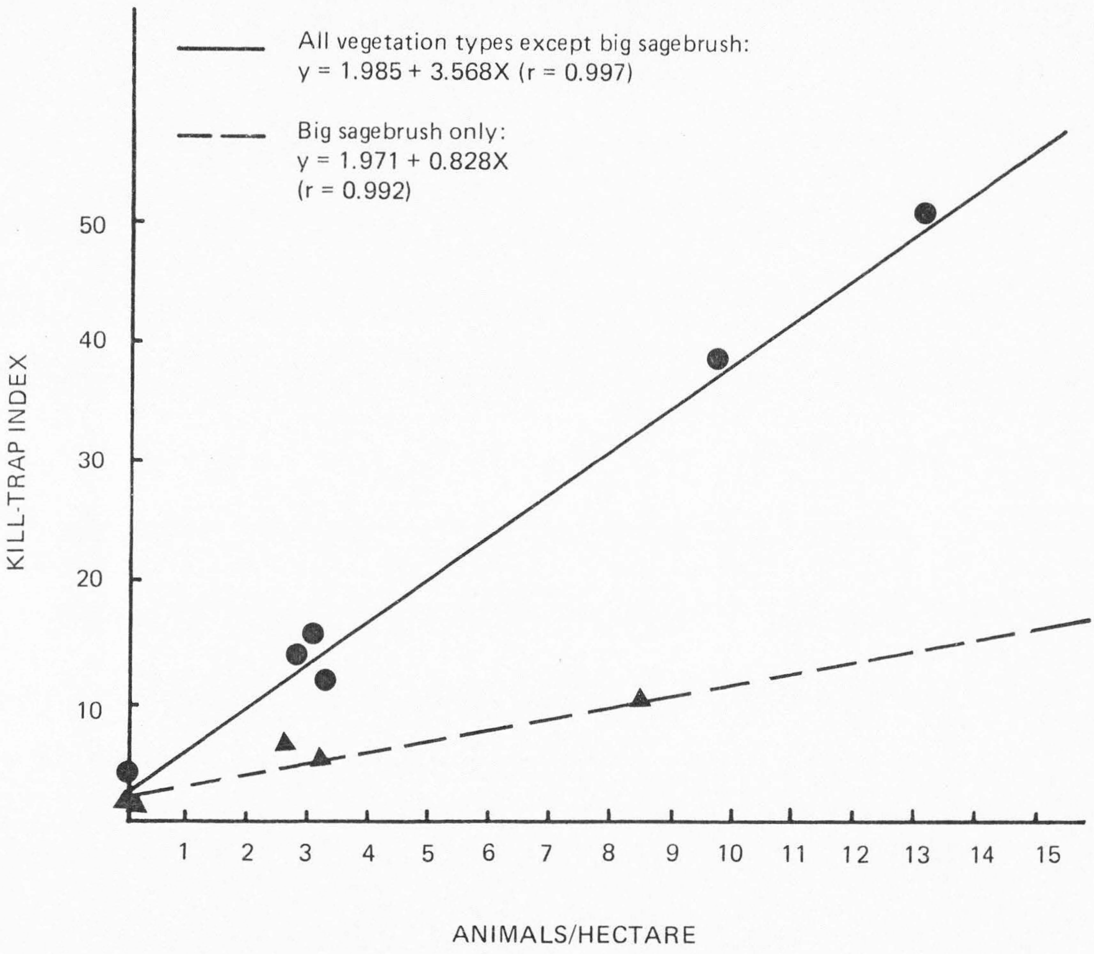

Figure 3. Density relationship for *Peromyscus maniculatus*.

First, the geometric regression estimator fit the frequency distribution so well that there was little doubt the estimate of the zero class was close to the actual value. Second, the size of the confidence interval afforded by the "jackknife" estimator is dependent on the size of the sample (Burnham 1972). In this research, the number of captures were usually marginal for application of the latter method, and would have produced broad confidence intervals.

It might also be argued that the kill-trap index did not account for the fact that after an animal was caught, the probability that other animals would be captured was reduced. The only requisite of an index is that it reliably document change. In whatever manner that index is defined is unimportant as long as it truly measures change in the desired quantity. The fact that the kill-trap index correlates so highly with live-trap estimates demonstrates that it is a reliable index. All of the points fit the regression lines closely despite the fact that they represent determinations made at different sites and times of the year.

It must be emphasized that a kill-trap index has only been demonstrated for deer mice. Furthermore, this index can only resolve differences among seasons or trapping sites. It bears no relation to kill-trap values for other rodent species. However, for the purposes of the discussion, kill-trap indexes will be assumed valid for other rodent species. These indexes will be used to evaluate differences in rodent densities among sites and seasons.

Assessment of habitats as contributors of prey

The number of rodent species caught or observed ranged from a high of 12 in the riparian zone along the Snake River to three in an irrigated wheatfield (Table 7). Expressing the "value" of a particular habitat to feeding raptors by simply enumerating the species present or calculating a species diversity index can be misleading. Even if a measure of species diversity were of some value, a legitimate index could not be calculated in this case. The minimal information needed to derive such an index is the number of species and a measure of the frequency by which each species is represented (Margalef 1958). The kill-trap index does not permit frequency comparisons between species, only within a species among sites or over time.

The only diurnal rodent species, other than the Townsend ground squirrel, are the white-tailed antelope squirrel and the least chipmunk (Eutamius minimus). Occasionally, kangaroo rats (Dipodomys spp.), meadow voles (Microtus spp.), and woodrats (Neotoma spp.) have been observed during the daytime, but their time spent exposed was brief compared to the Townsend ground squirrel.

It should be assumed that no importance should be assigned to the nocturnal rodents simply because they presently comprise a very small fraction of the diets of diurnal raptors (Kochert and Bammann 1976). It is possible that more nocturnal rodents could be consumed by diurnal raptors in the future. Also, nocturnal rodents are important to owls.

Having discussed the framework for interpretation of trapping results, it is now appropriate to examine the distribution of each

Table 7. Number of rodent species at 34 sites in and around the Snake River Birds of Prey Study Areas, 1976.

Site	Description	Species caught	Other species seen	Total
1	Burn (North of river)	4	1	5
2	Winterfat (N)	5		5
3	Big safebrush (N)	5		5
4	Cheatgrass (N)	4	1	5
5	Shadscale (N)	2	2	4
6	Greasewood (South of river)	8		8
7	Big sagebrush (S)	3		3
8	Shadscale (S)	3		3
9	Cheatgrass (S)	2	1	3
10	Big sagebrush (Mtn. Home area, N)	4	1	5
11	Shadscale (Simco Rd., N)	2	1	3
12	Spiny hopsage (S)	4		4
13	Big sagebrush-cheatgrass (N)	5		5
14	Big sagebrush-cheatgrass (S)	3		3
15	Big sagebrush-shadscale (N)	2	2	4
16	Shadscale-winterfat (N)	3		3
17	Big sagebrush-winterfat (N)	5		5
18	Big sagebrush-shadscale (S)	4		4
19	Greasewood-cheatgrass (S)	3		3
20	Big sagebrush/winterfat-farm (N)	3		3
21	Big sagebrush-farm (Mtn. Home, N)	4	1	5
22	Shadscale-farm (N)	3		3
23	Winterfat-farm (N)	3		3
24	Big sagebrush-farm (S)	4		4
25	Greasewood-farm (S)	3	1	4
26	Siberian wheatgrass (1st spring in 1976, N)	3	1	4
27	Crested wheatgrass-wildrye (2nd spring in 1976, N)	3	1	4
28	Crested wheatgrass (Old seeding, 10 yrs., N)	3		3
29	Canyon talus (N)	4	1	5
30	Canyon flats (N)	3	1	4
31	Canyon riparian (N)	8	4	12
32	Road effect in big sagebrush (N)	4	1	5
33	Marsh (N)	4	1	5
34	Wheatfield (S)	2	1	3

1-8 = 1975 live-trapping sites
9-12= Other range vegetation
13-19 = Range ecotones
20-25 = Range-farm ecotones
26-28 = B.L.M. seedings
29-31 = Canyon sites
32-34 = Miscellaneous

species. While Larrison and Johnson (1973) found least chipmunks most abundant in depleted shadscale stands, this study found, as did Fautin (1946), that they were restricted to big sagebrush. Chisel-toothed kangaroo rats (Dipodomys microps) were largely confined to shadscale because of their specialized tooth morphology which allows them to excise hypersaline epidermal tissue from this plant and feed on the less saline mesophyll (Kenagy 1972) (Tables 8-10). Only two individuals were captured in greasewood. Ord's kangaroo rats (Dipodomys ordii) were widely distributed but were most common on sandy substrates as was noted by Fautin (1946) and Maxwell and Brown (1968). Bushy-tailed woodrats (Neotoma cinerea) were found within the canyon proper, on rocky buttes in the Kuna Desert, and in dense greasewood stands along Rabbit Creek near Murphy. Desert woodrats (Neotoma lepida) were found only along the canyon rim and in the dense greasewood of Rabbit Creek. Western harvest mice (Reithrodontomys megalotis), house mice (Mus musculus), and meadow voles (Microtus montanus) were only caught in very wet sites, such as riparian habitats or along irrigation ditches. Canyon mice (Peromyscus crinitis) were specific to canyon talus slopes. Deer mice, grasshopper mice (Onychomys leucogaster), and Great Basin pocket mice (Perognathus parvus) were widely distributed, although deer mice were captured most often.

The Snake River represents a zoogeographical barrier to rodents (Davis 1939). With the exception of greasewood, number of rodent species was lower on the south side of the river. There were no least chipmunks caught or seen on the south side. This species was replaced by the white-tailed antelope squirrel, which did not occur on

Table 8. Captures/100 trap nights[a] at 34 sites in and around the Snake River Birds of Prey Study Area, 23 March-29 April 1976.

Site[b]	Pm[c]	Pp	Do	St	Em	Ol	Nc	Nl	Al	Dm	Rm	Mm	Mim	Pc
1	16.3	1.3	17.5											
2	19.2	1.1	2.1	3.1		2.1								
3	17.6	1.1		2.2	2.2									
4	14.6		2.4											
5	23.3													
6	32.7	2.0	4.0				2.0							
7	30.0	2.5												
8	17.5					2.5				5.0				
9	8.9		2.2											
10	19.5													
11	38.1					2.4								
12	19.5		9.8							2.4				
13	6.3	2.1		2.0										
14	26.7								6.3					
15	8.3									4.2				
16	12.2			2.0		2.0								
17	29.3	4.9	2.4	4.7										
18	2.1		4.3							4.3				
19	14.9		29.8											
20	7.0		25.6	2.3										
21	20.5		2.3	2.2										
22	33.3			2.0										
23	16.2		16.2	14.0										
24	20.5		43.6											
25	30.2		4.7											
26	8.7	2.2												
27	16.3		2.3											
28	26.2			6.7										
29	35.3	11.8												8.8
30	23.7	7.9	2.6											
31	31.7													
32	23.4	2.1	2.1											
33	12.8										2.6		2.6	
34														
Means	19.5	1.1	5.1	1.2	0.1	0.3	0.1	0.0	0.2	0.5	0.1	0.0	0.3	0.3

[a] See text for definition.

[b] See Table 7 for site names.

[c] See Appendix for common and specific names.

Table 9. Captures/100 trap nights[a] at 34 sites in and around the Snake River Birds of Prey Study Area, 28 June-29 July 1976.

Site[b]	Pm[c]	Pp	Do	St	Em	Ol	Nc	Nl	Al	Dm	Rm	Mm	Mim	Pc
1	27.1	4.2	16.7											
2	18.2	4.6				2.3								
3	6.5	8.7		2.1	4.4									
4	2.1	4.3	2.1	2.1										
5	4.2					2.8								
6			11.9					2.2	6.5					
7														
8									2.9	3.0				
9														
10	29.6	4.6	2.3		9.1									
11	6.1					2.0								
12			8.3						2.0					
13	8.6		2.9	16.7		2.9								
14			2.2						6.1					
15	8.5													
16	2.1													
17	16.0					2.0								
18									13.9	3.2				
19			2.1											
20	2.2		13.0											
21	23.9				2.2									
22	10.9					2.2								
23	6.8		2.3											
24	2.9		5.7						16.7					
25	26.8											2.4		
26	8.5													
27		2.2	2.2											
28	8.2					4.1								
29	26.2	4.8					2.4							11.9
30		4.4												
31	28.6						2.4				2.4			
32	12.5		8.3											
33														
34	10.3													
Means	8.7	1.1	2.4	0.6	0.5	0.5	0.1	0.1	1.4	0.2	0.1	0.1	0.0	0.4

[a]See text for definition. [b]See Table 7 for site names. [c]See Appendix for common and specific names.

Table 10. Captures/100 trap nights[a] at 34 sites in and around the Snake River Birds of Prey Study Area, 7 September-30 September 1976.

Site[b]	Pm[c]	Pp	Do	St	Em	Ol	Nc	Nl	Al	Dm	Rm	Mm	Mim	Pc
1														
2	4.0													
3	8.5													
4														
5	8.0													
6	17.8								4.3					
7	2.2	2.2							4.2					
8														
9	2.0													
10	22.9	6.3			4.2									
11	4.2													
12														
13		4.0												
14									4.1					
15	4.2													
16	2.0					2.0								
17						2.1								
18			6.7						4.3					
19	6.3	2.1							2.0					
20	4.4		4.4											
21	20.4					2.0								
22	8.2													
23	6.5		2.2											
24	6.4	2.1	2.1											
25	38.7													
26	2.0	2.0												
27														
28	8.0					2.0								
29	4.4	2.2												2.2
30	5.3													
31	7.7										2.6	7.7		
32	7.1	4.8				2.4								
33												4.2		
34	20.0												2.2	
Means	6.5	0.7	0.5	0.0	0.1	0.3	0.0	0.0	0.6	0.0	0.1	0.4	0.1	0.1

[a]See text for definition. [b]See Table 7 for site names. [c]See Appendix for common and specific names.

the north side except near Grandview, where it is presumed to have crossed a bridge. The river has also affected the distribution and subspeciation of the Townsend ground squirrel. Spermophilus townsendii idahoensis has a continuous distribution north of the river, but is absent on the south side. S. t. mollis is found on the south side, but only in a small, local population near Fossil Butte. On the north side, shadscale seemed to support fewer Townsend ground squirrels than other vegetation types, possibly a result of shallow soil and a lack of food grasses. Kill-trap indexes failed, however, to show this statistically.

Other rodent species observed, though not trapped in the course of this research, were pocket gophers (Thomomys townsendii), yellow-bellied marmots (Marmota flaviventris), beaver (Castor canadensis), and muskrat (Ondatra zibethica). Pocket gophers occurred in places of adequate soil moisture, and with a texture friable enough to allow tunnelling. Irrigated fields, irrigation ditchbanks, alluvial soils of the canyon bottom and side streams, and certain north-facing slopes in Con Shea Basin and on Sinker Butte harbored these animals. Marmots were found exclusively in close proximity to rocky areas. Talus slopes, boulders on the canyon floor, and lava outcroppings, especially near alfalfa fields, supported populations of these sciurids. Beaver and muskrat were restricted to aquatic and riparian habitats along the Snake River. Neither of these species were particularly abundant.

Seasonal density changes

To assess differences in density among seasons and sites, the kill-trap values from Tables 8-10 for each species were subjected to an analysis of variance. Kill-trap values for deer mice were converted to densities before the analysis because of the observed disparity between index values for big sagebrush versus other areas.

Deer mice, Ord's kangaroo rats, and chisel-toothed kangaroo rats all showed significant declines as the year progressed. Other rodent species showed no statistically significant seasonal changes. However, one species which obviously became unavailable was the Townsend ground squirrel. In July this species goes underground to estivate until late January.

Effect of native range types and agricultural ecotones

Several species exhibited significant differences among trapping sites (Table 11). Most of these differences have been previously explained as strong habitat specificity. Deer mice, Ord's kangaroo rats, and Great Basin pocket mice showed less obvious habitat specificity. If the analysis of variance showed significant differences among sites, then a series of t-tests (using only spring densities) were used to isolate habitats with higher densities of these species.

For deer mice, big sagebrush and associated ecotones supported significantly higher densities than all other sites. Ecotones between big sagebrush and other range vegetation did not significantly concentrate deer mice in comparison to pure stands of big sagebrush, nor did big sagebrush-agriculture ecotones when compared to adjacent big sagebrush. Great Basin pocket mice occurred in higher densities

Table 11. Analysis of variance F-values for rodent kill-trapping data from 34 sites in and around the Snake River Birds of Prey Study Area, 1976.

Species	Season	Site
Peromyscus maniculatus	14.8[a]	3.9[b]
Dipodomys ordii	6.1[a]	1.9[b]
Perognathus parvus	0.5	1.9[b]
Spermophilus townsendii	2.4	1.1
Eutamius minimus	2.0	2.7[b]
Onychomys leucogaster	0.9	1.6
Neotoma cinerea	1.2	0.9
Neotoma lepida	1.0	1.0
Ammospermophilus leucurus	2.5	1.4
Dipodomys microps	3.6[a]	2.5[b]
Reithrodontomys megalotis	0.0	2.3[b]
Mus musculus	1.5	1.0
Microtus montanus	0.5	1.0
Peromyscus crinitis	1.0	7.1[b]

[a]Values larger than 3.15 ($p = 0.05$; df = 2,66) indicate a significant difference among seasons.

[b]Values larger than 1.6 ($p = 0.05$; df = 33,66) indicate a significant difference amont trapping sites.

at sites within the canyon when compared to all other sites. It is not known why the canyon floor proved so favorable to this species. Ord's kangaroo rats had significantly higher densities along range-agriculture ecotones. It is probable that disturbed soil from roads (around every farm sampled) plus dunes of wind-eroded soil from the fields created favorable burrowing conditions for kangaroo rats (Johnson 1961).

Neither the important Townsend ground squirrel nor the potentially important white-tailed antelope squirrel showed significant concentrations in any particular habitat. Capture rates were highly variable, however, and more extensive sampling might have revealed differences. It appears from the data that any concentrations of these species that did occur were strictly sporadic, local phenomena and not typical of a particular habitat.

Miscellaneous effects

Several special effects could not be substantiated statistically, but nevertheless showed results worth noting. Roads constructed in big sagebrush created suitable burrowing conditions for Ord's kangaroo rats (Table 9), providing travel lanes across unfavorable habitats. This observation has also been made by Johnson (1961). Range-fire burns seemed to attract higher numbers of deer mice during the summers of 1975 and 1976 than adjacent big sagebrush and winterfat stands. B. L. M. range seedings following range fires (sites 26-28) seemed to support more deer mice and Townsend ground squirrels as the seedings aged. As summer progressed, these differences became less pronounced.

A planted wheat field south of the river did not harbor any rodents until the wheat grew high enough to provide cover. The ubiquitous deer mice then moved into the interior of the field. Later in summer meadow voles colonized the field under large-diameter irrigation feeder pipes. By fall, deer mice had established a large, breeding population. When the wheat was cut, the rodents' vulnerability increased and raptors, particularly red-tailed hawks, were seen hunting the field extensively.

Effect of livestock grazing

Due to the lack of nongrazed control sites, the experimental design did not include an evaluation of grazing effects. Work by Larrison and Johnson (1973), Phillips (1936), and Quast (1948) have shown that range depletion tends to diminish the numbers of Western harvest mice and Great Basin pocket mice, and increase the number of deer mice. The study area is known to have a history of constant and apparently heavy grazing. The low capture rates of the first two species mentioned probably reflects this grazing intensity. Reynolds (1958) has shown that grazing improves the habitat of Merriam's kangaroo rats (*Dipodomys merriami*) in southern Arizona by reducing the density of the perennial grass understory. Grazing in wet sites limits the distribution of meadow voles by eliminating the thick grass cover under which runways are constructed. Linsdale (1946) and Howard (1953) found that heavy grazing favors increased numbers of ground squirrels in California. Johnson and Melquist (1976) have noted similar effects in the Birds of Prey Study Area.

CONCLUSIONS

Agriculture

Although range-agriculture ecotones supported concentrations of Ord's kangaroo rats, these ecotones have not been shown to concentrate any other rodent species. If, for example, an area of big sagebrush were converted to a wheat field, all rodents would be temporarily eliminated from the cultivated region. Ord's kangaroo rats, which previously had not existed in big sagebrush, would increase around the periphery of the field. Therefore, diurnal raptors would lose ground squirrels, as well as jackrabbits, and receive limited compensation in the form of kangaroo rats. It is unknown to what extent diurnal raptors could increase their consumption of kangaroo rats beyond current levels. More kangaroo rats could probably be utilized, but some upper limit must occur due to the different activity schedules of predators and prey. Owls would benefit from an increase in kangaroo rats, but these benefits would be moderated by losses of deer mice and other nocturnal rodents. Another factor to consider is that as the size of a cultivated region increases, the relative size of the perimeter (ecotone) decreases. Therefore, the larger an agricultural development becomes, the lower the contribution of prey along the ecotone relative to the loss of prey within the cultivated region.

The yearly schedule of prey availability is also an important consideration. Although irrigated wheat fields will attract breeding deer mice and meadow voles, by the time this occurs the wheat has grown to a height which renders them less vulnerable to predation.

Also, the critical raptor breeding season has passed. After the wheat is cut in the fall, the prey become vulnerable, benefiting resident raptors. Fields which in early spring supported no rodents support more vulnerable prey in the fall than almost any other habitat in the study area (Table 10).

Native range types, ecotones and burns

The riparian zone had the greatest number of rodent species, but because of its small size relative to other habitat types and lack of Townsend ground squirrels, it was not considered the most important contributor of prey. This zone is, however, important nesting habitat for short-eared owls (*Asio flammeus*), long-eared owls (*Asio otus*), screech owls (*Otus asio*), and marsh hawks (*Circus cyaneus*) (Kochert and Bammann 1976). The riparian zone may also be important to these raptors as a source of prey. The greasewood vegetation type south of the river had the next highest number of species, but it was the presence of an extensive Townsend ground squirrel population north of the river which caused raptors to preferentially hunt the big sagebrush-winterfat-cheatgrass complex on the north side (Dunstan, personal communication[1]). The big sagebrush type north of the river ranked overall as the most important contributor of prey. Not only did it have a relatively large number of rodent species (five), including the Townsend ground squirrel, but it also supplied the diurnal least chipmunk. Big sagebrush is valuable to golden eagles as prime habitat for black-tailed jackrabbits. Greasewood south of

[1]Personal communication from Dr. Thomas Dunstan, 19 October 1976, Boise, Idaho.

the river ranked second in importance because of the less abundant white-tailed antelope squirrel. Greasewood on either side of the river is particularly important to golden eagles because it supports both black-tailed jackrabbits and mountain cottontails. Shadscale seemed to be relatively poor in its ability to support Townsend ground squirrels. Based on visual observations, winterfat and cheatgrass appeared to be good habitats for Townsend ground squirrels, but poor for other rodents. Range ecotones had no significant ability to concentrate rodents. Burns consistently seemed to attract deer mice and Ord's kangaroo rats during the summers of 1975 and 1976, and prescribed burning may have some potential as a management tool. However, extensive destruction of big sagebrush might be seriously detrimental to the jackrabbit population.

Availability of prey

Simply identifying and preserving valuable prey habitats is only the first step toward management of the raptor prey base. Questions of vulnerability must also be considered. Ideal prey habitat may not be synonymous with ideal raptor hunting habitat. For example, it is reasonable to assume that raptors experience greater hunting success in areas of low vegetation than in shrubby sites. Perhaps it would be desirable to intersperse low vegetation, such as cheatgrass, with big sagebrush to provide higher prey densities adjacent to zones of high vulnerability. To determine whether such a practice would be worthwhile, it must be demonstrated conclusively that raptors actually do have a greater hunting success in areas of low vegetation. This is the subject of future research.

At the present time it is clear that the population of Townsend ground squirrels must not be seriously jeopardized, either by disease or loss of habitat. The only common, alternate diurnal rodent species for prairie falcons, red-tailed hawks, and ravens are least chipmunks and white-tailed antelope squirrels. Least chipmunks are difficult to capture because of their preference for the dense cover of big sagebrush. White-tailed antelope squirrels are less abundant and more secretive in their habits than Townsend ground squirrels, and are restricted to the south side of the river.

It therefore appears that, in the event of a Townsend ground squirrel decline, prairie falcons, red-tailed hawks, and ravens would find little alternate rodent prey. Although not conclusively demonstrated, it is likely that prairie falcons would spend more time hunting ground squirrels to compensate for reduced numbers. It is also probable that there would be a shift toward greater consumption of cottontails, jackrabbits, reptiles, gamebirds, and passerines by all raptors. Breeding success, especially in prairie falcons, would be reduced by an unknown amount due to the greater difficulty and energetic expense of capturing these prey species.

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APPENDIX

Common and specific names of rodents in Tables 8-10.

Species code	Common name	Specific name
Pm	Deer mouse	*Peromyscus maniculatus*
Pp	Great Basin pocket mouse	*Perognathus parvus*
Do	Ord kangaroo rat	*Dipodomys ordii*
Dm	Chisel-toothed kangaroo rat	*Dipodomys microps*
St	Townsend ground squirrel	*Spermophilus townsendii*
Em	Least chipmunk	*Eutamius minimus*
Ol	Grasshopper mouse	*Onychomys leucogaster*
Nc	Bushy-tailed woodrat	*Neotoma cinerea*
Nl	Desert woodrat	*Neotoma lepida*
Al	White-tailed antelope squirrel	*Ammospermophilus lecurus*
Rm	Western harvest mouse	*Reithrodontomys megalotis*
Mm	House mouse	*Mus musculus*
Mim	Mountain meadow vole	*Microtus montanus*
Pc	Canyon mouse	*Peromyscus crinitus*