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Structure of Burrows Used by the Idaho Ground Squirrel, *Spermophilus brunneus*

Abstract

Idaho ground squirrels, *Spermophilus brunneus*, are associated with shallow, rocky soils at most sites in their restricted range in west-central Idaho. These soils may be <50 cm deep above bedrock and water-saturated during early spring. At three sites in Adams Co., Idaho, all burrow systems in a contiguous area were excavated using hand tools. Burrows with nests (nest burrows, n = 7) were 50-121 cm in maximum depth, 700-2600 cm in length, had 3-11 openings, 2-13 branching tunnels, and 1-7 chambers. Burrows without nests (auxiliary burrows, n = 93) were shorter (15-600 cm), shallower (10-45 cm), had fewer entrances (1-8), fewer branching tunnels (0-4), and fewer chambers (0-2) than did nest burrows. Four types of auxiliary burrows were found: 1) partially open burrows under shrubs, 2) burrows excavated under large rocks, 3) plunging burrows that descended to a single chamber, and 4) horizontal burrows similar to shallow pocket gopher burrow systems. Nest burrows were located in small patches of well-drained soils >1 m deep, not in shallow soils; only auxiliary burrows were found on shallow soils. Thus although *S. brunneus* extensively utilized shallow, rocky soils, nest burrows were placed in adjacent areas with deeper soils.

Introduction

Idaho ground squirrels, *Spermophilus brunneus*, are endemic to a five-county area of west-central Idaho. There are two distinct taxa of *S. brunneus*, and the northern form, which is known from only about two dozen isolated demes in Adams and Valley counties, is the subject of this study. These demes are associated with xeric meadows surrounded by coniferous forest at mid-elevations (1150-1550 m) and typically consist of <200 adults (Yensen, in press). These xeric meadows have shallow, rocky, reddish loams or clay-loams derived from decomposing basalt lavas. Mesic meadows nearby have deeper soils and are often inhabited by Columbian ground squirrels (*S. columbianus*).

The Idaho ground squirrel has received little study. Except for its mating system (Sherman 1989), most details of its biology, including burrow structure, are undescribed. Davis (1939) stated that A. E. Borrell found Idaho ground squirrel burrow entrances under rocks and logs at a site near Bear Creek, and this statement has been repeated in faunal and popular works (e.g., Larrison 1967, Burt and Grossenheider 1976, Larrison and Johnson 1981).

Descriptions of the burrow structures of other North American and Eurasian ground squirrels (*Spermophilus*) have been summarized by Howell (1938), Ognev (1947), and Reichman and Smith (1990). Townsend's ground squirrel (*S. townsendii*) and Washington ground squirrel (*S. washingtoni*) are considered the species most closely-related to the Idaho ground squirrel (Nadler *et al.* 1984). Townsend's ground squirrel burrow systems have been described in some detail (Alcorn 1940, Scheffer 1941, Reynolds and Wakkinen 1987, Reynolds and Laundre 1988), whereas Washington ground squirrel burrow systems have been described only briefly (Scheffer 1941). Columbian ground squirrels are sympatric with *S. brunneus*, and their burrow systems have been described in eastern Washington (Shaw 1924, 1926) and Alberta (Young 1990).

Over the past decade we have repeatedly observed *S. brunneus* using burrows in xeric, rocky meadows with <50 cm of soil above basalt bedrock, although they were also occasionally observed in more mesic areas with deeper soils. Soil moisture readings using Bouyoucous soil moisture blocks indicated that these shallow soils were near or above field capacity for several weeks each spring, then dried out rapidly in early summer. Further, during some winters, the soil freezes down to at least 50 cm (J. Dyer, pers. comm.). This study was undertaken to provide a description of *S. brunneus*' burrow systems and to better understand how they live in these shallow soils.

Study Areas

Three study sites were selected to represent a diversity of microhabitats occupied by *S. brunneus*.

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One, "Squirrel Manor," has relatively deep soils that facilitate drainage, whereas at the other two sites basalt lava bedrock lies close to the surface.

"Squirrel Manor"

This 1 ha site was located on a south-facing 5% slope 2 km S of Bear, Adams Co., Idaho (T19N, R3W, NW 1/4 Sec. 11) at 1325 m elevation in a relatively flat valley between Bear Creek and Steve's Creek. Nearby hillsides were forested with ponderosa pine (*Pinus ponderosa*) and other conifers. The 1 ha study plot was dominated by diverse bunch grasses (6-8 spp.) and forbs (25-30 spp.), with small clumps of big sagebrush (*Artemisia tridentata*), green rabbitbrush (*Chrysothamnus viscidiflorus*), and Wyeth buckwheat (*Eriogonum heracleoides*). The reddish, clay-loam soil had few rocks and a depth in excess of 2 m.

"Riley Ranch"

The 4 ha study area (T19N, R3W, Sec. 34) was 8 km S of Squirrel Manor near Paradise Flat at 1370 m elevation on a 10% east-facing slope in a xeric meadow surrounded by ponderosa pine forest. The soil was a reddish skeletal loam with many basalt rocks at the surface weighing in excess of 100 kg. Soil depth varied from 30-70 cm at the center of the area to >1 m at the forest edges. The dominant plant was stiff sage (*Artemisia rigida*), with small amounts of bunch grasses, and spring forbs such as onions (*Allium* spp.), *Lomatium* spp., *Erigeron pumilus*, and camas (*Camassia quamash*) and 45% bare ground. Serviceberry (*Amelanchier alnifolia*), bitterbrush (*Purshia tridentata*), big sagebrush, rabbitbrush, and snowberry (*Symphoricarpos* spp.) occurred in deeper soils at the edges of the area. Columbian ground squirrels occupied the deep soils along the creek bottom at the east edge of the study site.

"Huckleberry"

This 2 ha site (T20N, R2W, Sec. 7) was located 10 km NNE of Squirrel Manor at 1490 m elevation in a meadow surrounded by ponderosa pine, Douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*) forests. The meadow was on an 8% south-facing slope with several low, rocky ridges and intervening grassy swales.

Our 2 ha study plot included two ridges and the swale between them. The ridges were dominated by *Eriogonum* spp., onions, *Lomatium* spp., *Gilia aggregata*, *Sedum stenopetalum*, and *Penstemon deustis* with 40% bare ground. The reddish, skeletal, sandy loam was 0-80 cm deep over basalt bedrock. The intervening swale was dominated by dense stands of grasses and forbs with 3% bare ground. The soil was a dark loam to sandy loam 1-2 m deep with few rocks.

Methods

Idaho ground squirrels were active above ground from late March until early August at the three sites. Burrows were excavated in late July and early August 1989 after the adults had immerged below ground into seasonal torpor and only a few young of the year remained active above ground. Attempts to trap squirrels at burrow entrances were unsuccessful, although at Squirrel Manor we had previously trapped squirrels at many of the burrow entrances excavated. In most cases, burrows could not be associated with squirrels of known age or sex.

At all three sites, we systematically excavated all burrow openings in a contiguous area (Squirrel Manor, 600 m^2; Huckleberry, 1500 m^2; Riley Ranch, 600 m^2) then excavated a few burrows of interest outside the selected area. At each burrow, the area around an arbitrarily chosen entrance was gridded into m^2 sections. Burrow entrance traps (Wobeser and Leighton 1979) were set at all entrances we could find within a 5 m radius.

Burrows were injected with expanding polyurethane foam (Felthauser and McInroy 1983) initially, but the method was abandoned because the foam cemented the rocks together making it difficult to remove the foam casting from the soil. We found it faster and more efficient to follow the burrows using hand tools.

Burrow systems were mapped on graph paper with depth measurements every 10 cm, or as necessary. Surface topography was determined using a transit. Lengths of the burrow systems reported below are horizontal distances rather than the running lengths of the tunnels, and depths are from the surface to the bottom of the chamber or tunnel.

Idaho ground squirrel burrow entrances were distinguished from those of other rodents at the sites (*Peromyscus maniculatus*, *Microtus montanus*, *M. longicaudus*, *Thomomys talpoides*, *Zapus princeps*, and *S. columbianus*) by size, direct observation of Idaho ground squirrel use, presence of

Idaho ground squirrel feces, recent wear at the burrow opening, and absence of soil mounds. Ambiguous burrows were omitted from the analysis. Idaho ground squirrels may modify burrows constructed by other species (see below). Hence, we focus here on burrow use, rather than burrow construction, by Idaho ground squirrels.

At each site, soil texture was determined using a hydrometer. Soil moisture was measured using a Bouyoucos soil moisture meter with soil moisture blocks buried at 30-60 cm. Soil temperatures were taken using a YSI telethermometer and thermister probes buried at 30-60 cm. Plant cover data were obtained using point frames. Soil texture, moisture, temperature, and plant cover data were collected as part of a separate study and will be reported in detail elsewhere.

Results

Although Davis (1939) reported that burrow openings were located under rocks and logs, we found 62 percent of the burrow openings in the open, 24 percent under rocks, and 14 percent under shrubs (see below). No logs were present at our three sites, although we did observe some burrow entrances under logs at other sites.

Idaho ground squirrel burrow openings were 4-15 cm wide ($\bar{x}$ = 6.3 ± 1.99 [SD]) and 4-17 cm high ($\bar{x}$ = 5.4 ± 2.04) and entered the ground at angles of 0° (into a slope) to 90° ($\bar{x}$ = 38.9° ± 22.1°). Tunnels were nearly round in cross section and 5-8 ($\bar{x}$ = 6.1) cm in diameter. Idaho ground squirrels rarely make soil mounds outside their burrow entrances; observations of captive squirrels and field observations of fresh burrows indicate that soil is scattered as it is brought to the surface.

We found two distinct categories of burrow systems: shallow (<50 cm maximum depth), simple systems lacking nests (hereafter, "auxiliary burrows"), and deeper (>50 cm maximum depth), more complex burrow systems with nests (hereafter, "nest burrows").

Nest burrows were longer (700-2600 cm) than auxiliary burrows (20-600 cm), deeper 50-121 cm (vs. 10-45 cm), with more entrances (3-11, $\bar{x}$ = 6.1 vs. 1-8, $\bar{x}$ = 1.8), more branch tunnels (2-13 vs. 0-4), and more chambers (1-7 vs. 0-2) (Table 1, all differences $p < 0.001$, Mann-Whitney U-tests).

TABLE 1. Idaho ground squirrel burrow characteristics at three study sites in Adams Co., Idaho. Values are means with range in parentheses.

site	n	max. depth (cm)	total length (cm)	# entrances
auxiliary burrows				
Squirrel Manor	19	24.6 (15-45)	147 (20-560)	1.8 (1-8)
Huckleberry	25	18.7 (0-30)	92 (20-500)	2.0 (1-3)
Riley Ranch	49	17.5 (0-40)	83 (15-600)	1.8 (1-6)
nest burrows				
Squirrel Manor	5	68 (53-80)	1092 (700-1320)	4.6 (3-7)
Riley Ranch*	2	86 (50-121)	2010 (1450-2600)	10.0 (9-11)

*One tunnel could not be followed below a large rock at 121 cm.

Auxiliary Burrows

We classified auxiliary burrows into four groups:

1) Horizontal burrows (Figure 1A). We examined 40 of these burrows that were superficially similar to shallow pocket gopher burrows. They were 25-600 ($\bar{x}$ = 147 ± 133) cm long, 10-44 ($\bar{x}$ = 19.0 ± 7.3) cm deep, and had 1-8 entrances ($\bar{x}$ = 2.1 ± 1.6). Most (30) were unbranched. In several cases, earth castings or sudden changes in tunnel diameter indicated that these were originally constructed by pocket gophers or voles and enlarged by ground squirrels.

2) Shrub-covered burrows (Figure 1B). These consisted of horizontal tunnels, or trenches roofed by branches of the shrub, that generally curved around the main root of the shrub and incorporated shrub canopy shape into the burrow design. The burrows were 15-280 ($\bar{x}$ = 69 ± 71) cm long and 10-30 ($\bar{x}$ = 16 ± 7.5) cm deep. There were 1-4 entrances ($\bar{x}$ = 1.9), often under the prostrate stems or canopy of the shrub. Some burrow systems were coextensive with one or more paths through the shrub. The shrub species used varied with the available species at each site: *Artemisia rigida* at Riley Ranch, *A. tridentata* and *Eriogonum heracleoides* at Squirrel Manor, and semishrubs of *E. sphaerocephalum* and *E. umbellatum* at Huckleberry. We found more shrub-covered burrows at Riley Ranch where shrubs were more abundant.

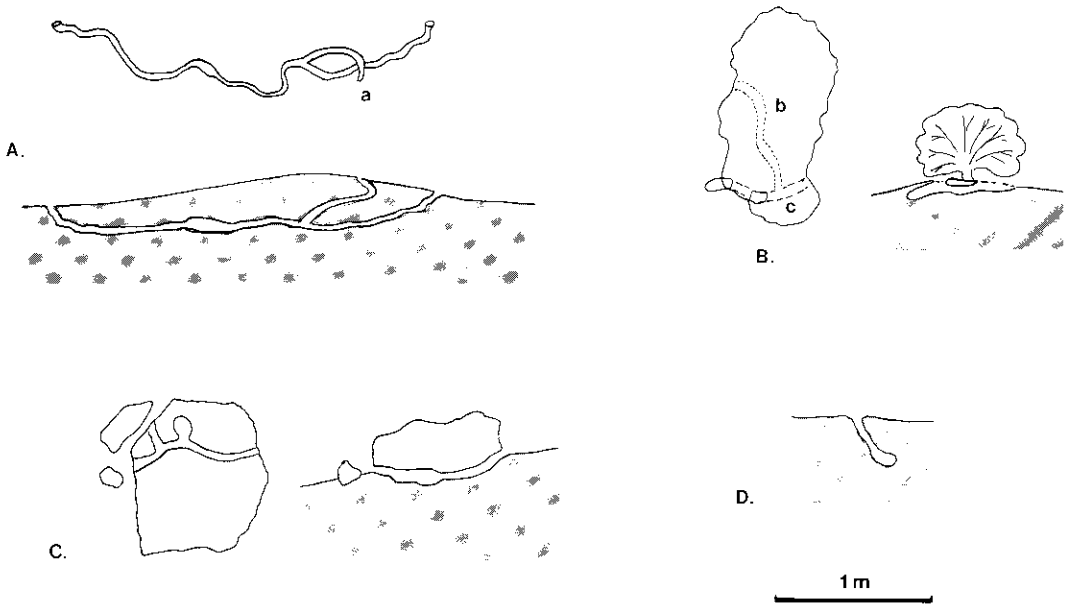

Figure 1. Auxiliary burrows of *Spermophilus brunneus*. A. Horizontal burrow, top view above, side view below; "a" indicates location of hidden entrance. B. Shrub-covered burrow, top view on left, side view on right; "b" indicates path beneath shrub; "c" indicates trench. C. Rock-covered burrow, top view on left, side view on right. D. Plunging burrow, side view. Ground is shaded.

3) Rock-covered burrows (Figure 1C). Tunnels were dug under large rocks (mostly 50 x 75 cm and larger) that were somewhat flat on the bottom and usually projected less than 15 cm below the surface. The burrows had 1-4 entrances ($\bar{x}$ = 1.9) opening at the lower edge of the rock, and were roofed by the rock itself, but sometimes continued into the soil upslope from the rock. The burrows were 15-160 (x = 64 ± 38.5) cm long. The tunnels usually converged below the rock, and frequently there was a small chamber at or near the point of convergence. These were found on the rocky hillsides at Huckleberry and Riley Ranch.

4) Plunging burrows (Figure 1D). These were short (20-120, x = 51 ± 28.6 cm), usually unbranched tunnels with a single entrance that entered the ground at a 15-90° (x = 40°) angle, continued down steeply to 11-45 ($\bar{x}$ = 23 ± 10.5) cm, and often ended in a small chamber. These occurred in open places away from rocks and shrubs, and were found at Huckleberry and Squirrel Manor.

Nests Burrows

We excavated seven nest burrows; all were located in deeper soils near ridge tops. Six of the nest burrows had a cluster of well-established entrances leading into a small, vegetated mound that was 10-20 cm tall and 1-3 m in diameter. The nest burrows built in mounds all had old, soil-filled tunnels that varied in distinctiveness and contained occasional remnants of old chambers. Thus the mounds were probably created by soil excavated by the squirrels over a period of many years. The nest burrow that lacked a mound was less complex and had no old, plugged tunnels.

Nest burrows had 3-11 entrances ($\bar{x}$ = 6.1 ± 3.1). Typically, at least one shallow tunnel extending for >1 m at <30 cm depth led into the burrow system (Figure 2). Tunnels leading to nests frequently dropped vertically 8-20 cm at some point (Figure 2) and rapidly descended to 45-50 cm depths. The nest chamber was at or near the lowest point in the burrow system, and was often near tunnel intersections.

Nest chambers were found at depths of 32-113 cm ($\bar{x}$ = 60.7 cm). Chambers were oval (x = 19 x 20 x 15 cm), but several had small pockets or other irregularities. The chambers were partially filled with nest material composed mostly of grasses, particularly *Bromus commutatus*, *B. tectorum*, *Poa bulbosa*, and *P. scabrella*. Leaves of

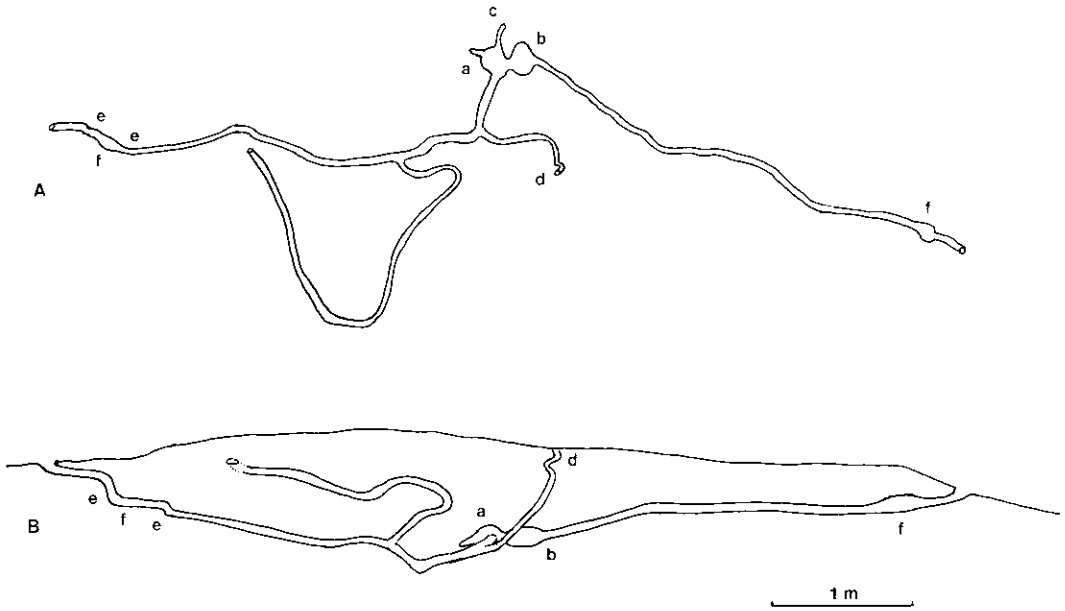

Figure 2. Nest burrow of *Spermophilus brunneus*. A. Top view, B. side view. Symbols: "a" old nest, "b" fresh nest, "c" feces-filled tunnel, "d" hidden entrance, "e" vertical drops, "f" chambers.

Lomatium nudicaule were abundant, but leaves of other dicots (*Eriogonum heracleoides* and *Amelanchier alnifolia*) were rare. Nests also included *Artemisia tridentata* bark, *Tragopogon dubius* and *Balsamorhiza* sp. seed heads, ponderosa pine needles, horse hairs, and feathers of a Brewer's Blackbird (*Euphagus cyanocephalus*). One nest was constructed almost entirely of mosses. Drains such as those described by Shaw (1926) and Edge (1934) were not found under the nests.

Nest burrows were inhabited by adults and larvae of darkling beetles (Tenebrionidae: *Eleodes* sp.) and crickets (Gryllidae). Fleas and mites were found in several nests.

Four burrow systems had a single nest, two systems had one old and one fresh nest, and one system had two fresh nests. The latter consisted of a deeper, more complex system connected with a simpler, shallower system via a plugged tunnel.

Additional Burrow Features

Hidden entrances (n = 18) were found in nest burrows and in shrub-covered and horizontal auxiliary burrows. These consisted of a nearly vertical, sometimes spiralling, tunnel that ended in an unusually small (4 cm diameter) entrance covered with leaf litter. Most hidden entrances were found below shrubs.

Vertical shafts found in four nest burrows and in one horizontal auxiliary burrow ascended from near the lowest portion of the burrow system and ended 3-4 cm below the surface. These resembled the vertical tunnels used by some Eurasian ground squirrels (*S. erythrogenys, S. fulvus, S. major, S. pygmaeus, S. suslica, S. undulatus*, and *S. xanthoprymnus;* Ognev 1947).

Short side tunnels measuring 5-10 cm long were found in both nest and auxiliary burrows. Penuska and Wade (1956) termed similar structures in Eastern chipmunk (*Tamias striatus*) burrows "galleries," and suggested they were probably used for turning around. We found galleries near entrances but occasionally elsewhere in both auxiliary and nest burrows.

Chambers were either widened areas of tunnels or hollows on the side of a tunnel that were much larger than galleries. They were largest in nest burrows ($\bar{x}$ = 9.2 x 9.8 x 10 cm, n = 9). The chambers in horizontal auxiliary burrows were about as wide and long as nest chambers, but not as tall ($\bar{x}$ = 6.0 cm, n = 10). The chambers at the end of plunging auxiliary burrows were slightly smaller ($\bar{x}$ = 8.2 x 9.7 x 6 cm, n = 10).

Chambers were found 30-300 cm ($\bar{x}$ = 152 cm) from the nearest entrance in nest burrows and we did not discern any pattern in their placement. Chambers were either empty or were filled with nest material, except for one with a food cache in the most complex burrow system excavated. The cache was in a chamber (25 x 20 x 12 cm) at 42 cm depth and contained 31 corms (35.4 g total) of bicolor biscuit-root (*Lomatium leptocarpum*).

Latrine chambers were not found, although feces were common in the deepest tunnels of a nest burrow, in two side tunnels near nests, and in rock-covered auxiliary burrows. Occasionally we found old, plugged tunnels that were full of feces in nest burrows.

Intersite variation

Frequencies of auxiliary burrow types differed significantly among sites ($p < 0.001$, G-test of independence using Williams' correction). The increase in rock-covered auxiliary burrows from Squirrel Manor (0) to Huckleberry (n = 10; 20%) to Riley Ranch (n = 14; 56%) paralleled the number of large rocks present at each site. There were also more shrub-covered burrows at Riley Ranch (n = 7; 28%) than at Squirrel Manor (n = 2; 11%) or Huckleberry (n = 5; 10%), and this also paralleled shrub abundance. The number of plunging burrows was highest at Huckleberry (n = 11; 22%) where there was more open ground. Horizontal burrows were more common and longer at Squirrel Manor (n = 13; 68%) and Huckleberry (n = 23; 47%) than at Riley Ranch (n = 4; 16%) where the soil was rockier. Squirrel Manor, which had the deepest auxiliary burrows, also had the deepest soils.

Burrow Locations

All nest burrows were located in well-drained soils >1 m deep. Four were near the top of a small ridge, and three were near the tops of slopes in deeper soil.

The proportion of Idaho ground squirrel habitat with deep soils apparently suitable for nest burrows was 3500 m^2 (35% of 1 ha) at Squirrel Manor, 1300 m^2 (7% of 2 ha) at Huckleberry, and 1950 m^2 (5% of 4 ha) at Riley Ranch.

Auxiliary burrows were located in both deep and shallow soils at all three sites, and in xeric and mesic plant associations, but marshy areas and seeps were avoided. Some auxiliary burrows occurred >100 m from the nearest known nest burrow.

At our study sites, we estimated that >90 percent of Idaho ground squirrel burrows were auxiliary burrows. Auxiliary burrows occurred at densities of 80-100/ha in the contiguous areas we selected for excavation.

Discussion

Townsend's ground squirrels also have two types of burrow systems which correspond to our nest and auxiliary burrows (Alcorn 1940, Reynolds and Wakkinen 1987, Reynolds and Laundre 1988). In these studies, auxiliary burrows were much more common than nest burrows. Because the function of auxiliary burrows is not established, we have preferred the neutral term "auxiliary" to such terms as "escape burrows," or "foraging burrows."

We found a squirrel in only one nest burrow. The animal was non-torpid and escaped. If the population was entering seasonal torpor and nest burrows are used as hibernacula, animals should have been in their nest burrows. Some sciurids (e.g., Shaw 1926, Holekamp and Sherman 1989, Kawamichi 1989) hibernate in special hibernation dens. We suspect that Idaho ground squirrels construct or separate burrows for hibernation, and that these have well-plugged entrances that we did not find despite careful searching. As evidence of this, at Huckleberry we found one burrow (not reported above) on 28 July 1989 with fresh soil around both entrances, indicating current construction. This burrow had 90 cm of horizontal tunnels and a steep descent to a small chamber at 45 cm. This may have been a hibernation den under construction by a juvenile, the only age class active at the time. P. W. Sherman (pers. comm.) has observed marked Idaho ground squirrels emerge from hibernation, use that burrow system for a few days, then move to the burrow system in which young are raised. These burrows have a single, steeply descending tunnel.

Variation in the proportions and dimensions of auxiliary burrow types between study sites in response to site characteristics seems reasonable. Grinnell and Dixon (1918) found that *S. beecheyi* made deeper burrows in softer soils. The ease of tunnel construction and availability of rocks and shrubs should influence the assortment of auxiliary burrows at a site.

All burrow entrances on rocky hillsides with shallow, seasonally water-logged soils led to auxiliary burrows. The squirrels did not nest there. However, we have observed *S. brunneus* using

these auxiliary burrows as temporary refuges, even when the soil was saturated. P. W. Sherman (pers. comm.) has seen *S. brunneus* emerge from burrow entrances with muddy fur.

Shaw (1924) concluded that drainage was important in Columbian ground squirrel nest burrow placement. Elliott (1983) found that Columbian ground squirrels placed 80% of their burrows in dry soil, 20 percent in moist soil, and 0% in wet soil, and all of the "permanent" (=nest) burrows were in the dry cover type. However, Weddell (1989) found that slope, position on slope, and number of native forbs were the most important variables for determining occupation of an area by Columbian ground squirrels. Columbian ground squirrel settlement in an area was also associated with the presence of other squirrels and burrows. Columbian ground squirrels were not restricted by soil texture, depth, or drainage, and she found burrows on shallow soils (25-51 cm to bedrock). However, Weddell did not indicate whether these were nest or auxiliary burrows.

Although the role of soil depth and moisture in determining nest site suitability for Idaho ground squirrels is not settled, we found no burrows we suspected of being nest burrows in soils <1 m deep. At most sites where *S. brunneus* occurs, there was a small area with deeper, well-drained soils not occupied by Columbian ground squirrels and usually an adjacent larger area with shallow, rocky soils (E. Yensen, pers. observations).

Areas with shallow soils are apparently used for foraging rather than nesting. Our frequent observations of Idaho ground squirrels foraging in those areas, the presence of numerous burrow openings, and the infrequent observation of Idaho ground squirrels in areas with deeper soils led to our mistaken impression that Idaho ground squirrels must somehow be able to nest in shallow soils. Abundant auxiliary burrows would allow protection for squirrels foraging on shallow soil at some distance from a nest burrow.

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