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The utility of alpine cave fossil assemblages for zoological census: An example from northern Utah, United States

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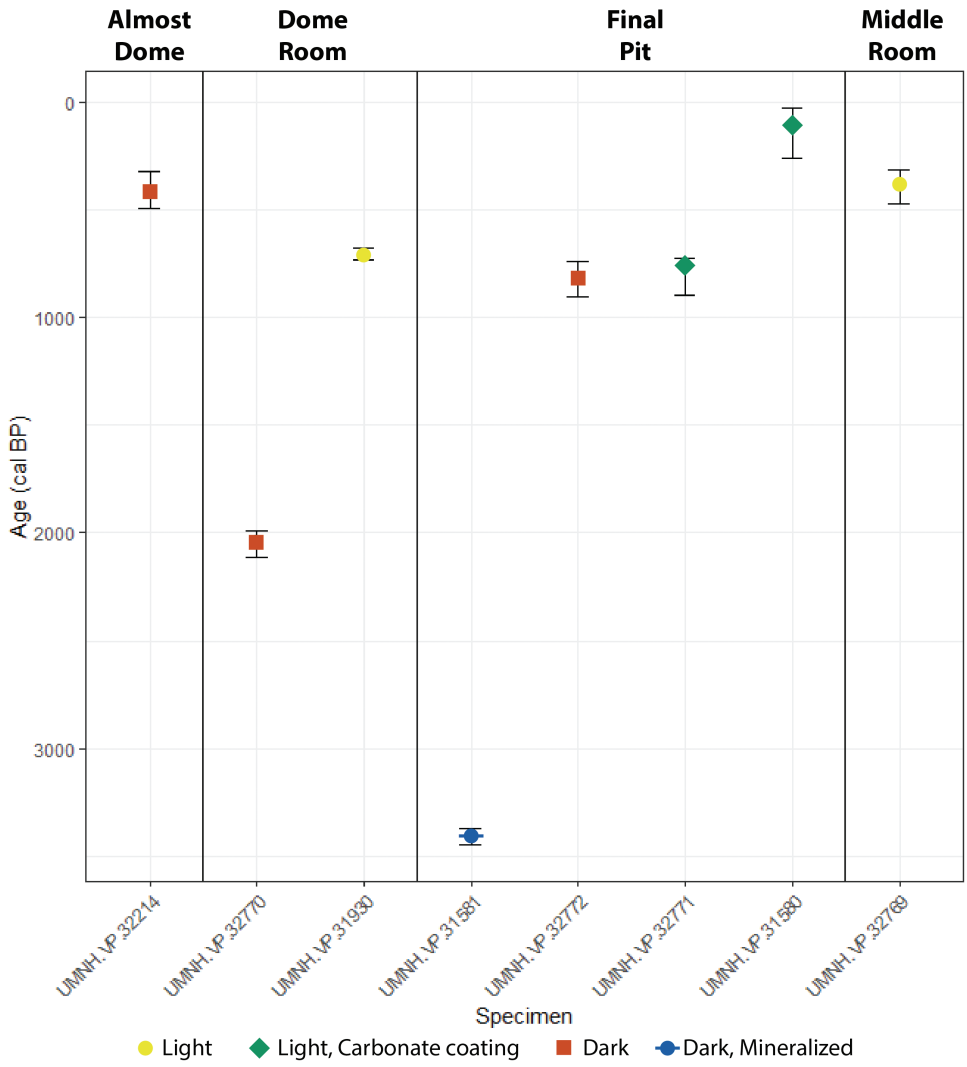

Fig. 4. Summary of calibrated accelerated mass spectrometry ^{14}C ages from Boomerang Cave, with medians and 2 con dence intervals. Bone color, mineralization, and presence of carbonate coating are noted.

C Sherman traps (Table 3). In addition, observations (sightings, tracks, scat, and calls) were made of Canis latrans, Castor canadensis, Cervus canadensis, Lepus sp., Marmota aviventris, Odocoileus hemionus, Tamiasciurus hudsonicus, and Taxidea taxus. Grazing and trampling damage from domestic cattle was noted in several places in the study area.

Comparison of fossil and recent survey data. Boomerang Cave fossil specimens were sorted into nonoverlapping taxa species were used, if possible, whereas higher taxonomic ranks were used if they contain no specimens identi ed to less-inclusive taxa. The few avian specimens were not considered, and an MNI of 36 mammalian individuals were excluded due to their placement in higher taxonomic categories, leaving an MNI of 99 individuals for statistical analysis. MNI tallies are summarized in Table 4. A chi-square test for independence shows that the body-size distributions do not differ signi cantly between Boomerang Cave, our trapping efforts, and the museum records from Arctos (^{2} = 9.27, P = 0.51). Percentage of species of each size class from each source are shown in Fig. 5.

Table 3. Summary of trapping specimens and remains collected (number of live animals released in parentheses).

Species	Line A	Line B	Line C	Line D	Remains	Total
Glaucomys sabrinus	1					1
Microtus longicaudus	3		2			5
Microtus richardsoni	5					5
Myodes gapperi	2					2
Neotoma cinerea					2	2
Peromyscus maniculatus	13	12	10 (2)	5		42
Sorex navigator	2					2
Tamias minimus	2	3	1 (3)			9
Tamias umbrinus	3	3		2		8
Thomomys talpoides	2					2
Total	33	18	13 (5)	7	2	78

The rarefaction curve for the Boomerang Cave assemblage overlaps with that of the historical Arctos records, indicating indistinguishable differences in richness at the comparable resampled size of 99 individuals (Fig. 6). This contrasts with trapping alone, which targeted small mammals and was temporally

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Table 4. Summary of nonoverlapping specimens for all data sets. Field observations noted with x.

Species	Size class	Boomerang Cave	Trapping	Arctos
Aeorestes cinereus	2			2
Callospermophilus lateralis	3	1		39
Canis latrans	5	1	x	2
Castor canadensis	5		x	
Cervus canadensis	6		x	
Corynorhinus townsendii	2			15
Eptesicus fuscus	2			13
Erethizon dorsatum	5	3		2
Glaucomys sabrinus	2		1	5
Lasionycteris noctivagans	2			6
Lemmiscus curtatus	2			8
Lepus americanus	4	4		10
Lepus sp.	4		x	
Lepus townsendi	4			4
Lynx rufus	5			2
Lynx sp.	5	2		
Marmota aviventris	4	3	x	9
Martes caurina	3	2		1
Mephitis mephitis	4			2
Microtus longicaudus	2		5	134
Microtus montanus	2			174
Microtus pennsylvanicus	2			43
Microtus richardsoni	3		5	29
Microtus sp.	2	2		
Mus musculus	2			1
Mustela richardsonii	2	3		1
Myodes gapperi	2		2	91
Myotis ciliolabrum	1			4
Myotis evotis	1			2
Myotis lucifugus	1			16
Myotis volans	1			11
Myotis yumanensis	1			4
Neogale frenata	3	14		12
Neogale vison	3	1		1
Neotoma cinerea	3	19	2	12
Ochotona princeps	3			46
Odocoileus hemionus	5		x	3
Ondatra zibethicus	4			8
Onychomys leucogaster	2			1
Otospermophilus variegatus	3			16
Pecora	5	2		
Perognathus mollipilosus	2			40
Peromyscus maniculatus	2		42	536
Peromyscus sp.	2	17		
Puma concolor	5			2
Rattus norvegicus	3			1
Reithrodontomys megalotis	2			11
Sorex cinereus	1			2
Sorex merriami	1	2		
Sorex monticola	1	1		3
Sorex navigator	2		2	14
Sorex vagrans	1			62
Spilogale gracilis	3	1		5
Sylvilagus nuttallii	3			10
Tamias dorsalis	2			17
Tamias minimus	2		9	174
Tamias sp.	2	4		
Tamias umbrinus	2		8	140
Tamiasciurus hudsonicus	3	9	x	64
Taxidea taxus	4	2	x	3
Thomomys idahoensis	3			1
Thomomys talpoides	3		2	205
Urocitellus armatus	3			70
Ursus americanus	6	1		
Vespertilionoidea	1	5		
Vulpes vulpes	4			1
Zapus princeps	2			27

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Fig. 5. Percentage of species from each size class from Arctos records, Boomerang Cave specimens, and trapping/observations.

Fig. 6. Individual-based rarefaction results for Boomerang Cave, Arctos, and trapping specimen data sets. Light ribbon represents 95% con dence intervals.

limited, resulting in much lower diversity than either the fossil sample or the Arctos data set even when accounting for differing samples sizes (Fig. 6). For higher diversity coverage, greater trapping effort in a broader range of habitats utilizing a variety of trap types (including camera traps) would be necessary.

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Our faunal analysis serves as both a census of a montane ecosystem in the Bear River Range and an empirical evaluation of the use of alpine cave assemblages for establishing mammalian zoological baselines. Of the 22 mammalian taxa identi ed, all are present in northern Utah today. Several species common in the Arctos data set (> 50 specimens) are absent from the Boomerang Cave assemblage, including Myodes gapperi (Southern Redbacked Vole), Thomomys talpoides (Northern Pocket Gopher), Sorex vagrans (Vagrant Shrew), and Urocitellus armatus (Uinta Ground Squirrel); however, the former two were recovered during our trapping efforts. The absence of these species is in part an artifact of incomplete sampling, as our rarefaction analysis predicted additional mammalian species to be present in the area (Fig. 6). Interestingly, there are remarkably few nonmammalian vertebrate remains. Reptiles and amphibians have low diversity in cold, high-elevation habitats, so their absence is expected. Birds, however, are much more common and diverse but are represented by only four specimens. The dearth of bird remains is likely due to the nature of deposition in the cave animals capable of ight are unlikely to fall to their deaths or become trapped in the cave. Alternative explanations, including that small, fragile bones were not preserved, are unlikely as the cave is dominated by the fragile bones of small mammals, including well-preserved remains of bats and shrews.

One species present in the Boomerang Cave assemblage has not previously been recorded from the study region: Sorex merriami (Merriam s Shrew), represented by two crania (Fig. 7). Sorex merriami is a widespread species across most of the western United States, but it is relatively uncommon throughout the entirety of its range; for example, a study in Wyoming devoting > 500,000 trapping days over the course of 7 years caught only 15 individuals (Kirkland et al. 1997). This shrew occurs in a wide range of habitats from low-elevation deserts and grasslands to high-elevation montane forests, most often in association with sagebrush (Armstrong and Jones 1971; Kirkland et al. 1997; Hafner and Stahlecker 2002; Armstrong et al. 2010; Shaughnessy and Woodman 2015). The nearest record of S. merriami to our study area is specimen UMNH:Mamm:20352 from approximately 60 km east in Rich County, at an elevation of

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