Characteristics of late Holocene American black bears in Missouri: Evidence from two natural traps

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Abstract: Remains of 22 American black bears (*Ursus americanus*) were excavated from 2 natural trap caves in Missouri during the late 1950s. Age, sex, and size characteristics based on analysis of ursid teeth from the caves corroborates wildlife studies that suggest that subadult to young-adult male bears are relatively vulnerable to accidental deaths in their search for food compared to members of other age–sex cohorts. This information is of interest to wildlife biologists given that North American bears and humans increasingly share habitat. Data on native Missouri black bears are also of general interest because little is known about this population, which was extirpated by the beginning of the twentieth century, and because a reintroduced population is expanding in the southern portion of the state.

Key words: American black bear, Missouri, natural traps, paleozoology, subadult male mortality, *Ursus americanus*

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Two natural trap caves excavated by paleozoologists in the 1950s in Missouri produced historic-period (post AD 1541 [O'Brien and Wood 1998]) assemblages of animal remains that are dominated by American black bear (*Ursus americanus*). The bones of 10 bears (based on frequency of femora) were recovered from Lawson Cave (Fig. 1), a vertical shaft cave in central Missouri (Wells 1959). The deposit was completely excavated and screened through 0.4 cm (¼-inch) mesh; all excavated osteological materials were kept for analysis. The cave is a bottle-shaped trap, 11.5 meters deep with a 1.78 x 0.79 meter entrance. A collapsed horizontal entrance abuts the vertical shaft, but it is 4.5 meters above the inverted walls of the trap; thus, it never served as an exit from the trap chamber. Black bear remains from the cave have been radiocarbon dated to the historic period (Wolverton and Lyman 1998, Wolverton 2001).

Jerry Long Cave in eastern Missouri also produced a faunal assemblage that is abundant in black bear remains (Fig. 1). Parmalee and Jacobson (1959) describe Jerry Long Cave, from which the remains of 12 bears were recovered (based on frequency of femora), as having a horizontal entrance leading back to a vertical fissure about 15 meters deep, which functioned as a natural trap. There are no late Pleistocene taxa in the sample, and the osteological materials were likely deposited a few hundred years prior to the present. The excavators point out that black bear remains from Jerry Long Cave likely date to the late Holocene because historic debris was intermixed with the cave's osteological material.

The taxa represented in faunas from both caves tend to be those occurring today in deciduous forest habitat (Table 1; Parmalee and Jacobsen 1959, Purdue and Styles 1987). Both caves were natural traps to which bears were attracted by carrion. Bears and members of other species were trapped in and subsequently perished within the caves. In both assemblages, remains of mammals other than bears are common including other carnivores, rodents, and lagomorphs (Table 1). Remains of domestic pig at Lawson Cave and turkey vulture at Jerry Long Cave are relatively abundant, and both species are carrion scavengers.

This paper examines the age, sex, and size distributions of the black bears recovered from Lawson and Jerry Long caves through morphometric and mortality analysis of teeth. The ursid remains from these caves are potentially of interest to wildlife biologists. Black bears are uncommon in Missouri and other parts of the agricultural Midwest because they were extirpated after Euro-American occupation; however, they have been successfully reintroduced into the Ozark highlands in Missouri and Arkansas (Schwartz and Schwartz 2001, Smith and Clark 1994). Bear remains from these caves represent individuals from before extirpation, a population about which little is known. In addition, the ursid remains from both caves are dominated by young-adult males, which relates to age- and sex-specific life

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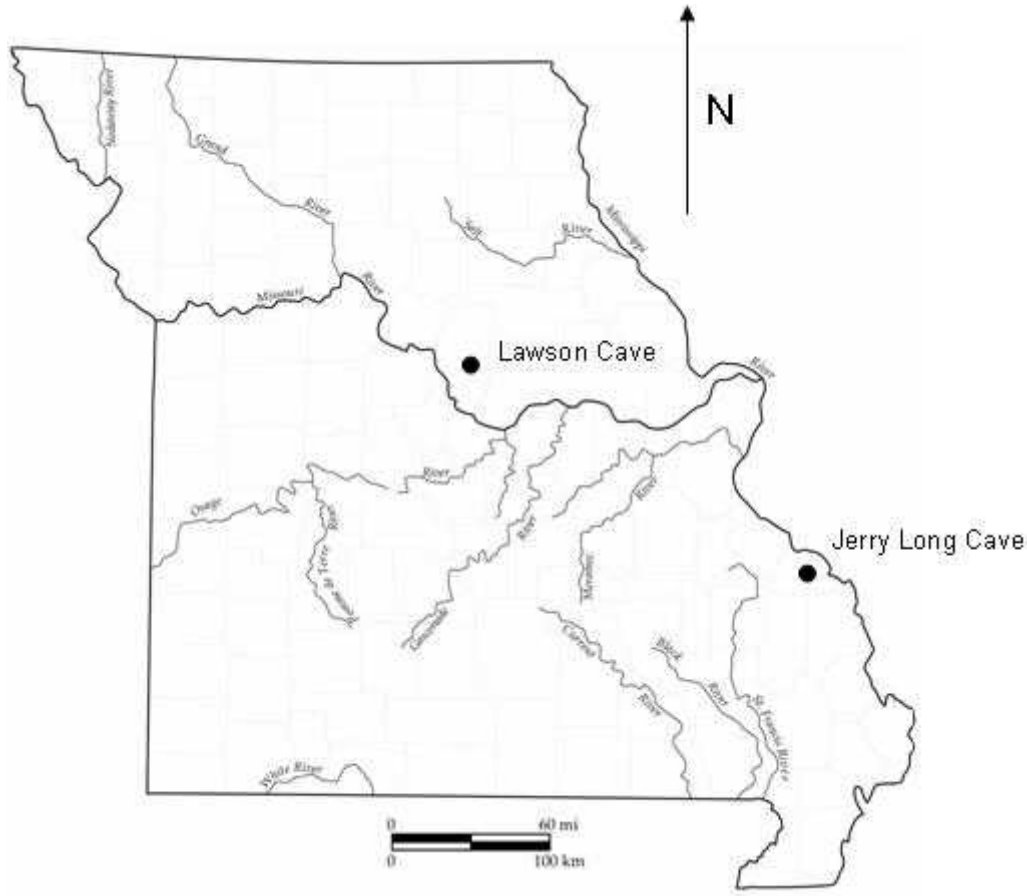

Fig. 1. Lawson Cave and Jerry Long Cave, in Missouri.

history characteristics that are relevant in modern wildlife management of bears.

Methods

Upper and lower molars were assigned to ordinal-scale ontogenetic age classes using tooth eruption and wear following a schedule published by Stiner (1998); detailed discussion of the use of tooth wear to age mammals remains, including those of ursids, from archaeological and paleontological samples can be found in Stiner (1990, 1994, 1998) and Wolverton (2006). All of the complete right and left molars (comprising a balanced ratio of lefts and rights [Wolverton 2006]) were pooled for mortality and morphometric analyses (Fig. 2 and 3), and all of the upper and lower molars were pooled for mortality analysis (Fig. 2). Most of the teeth were either in partial maxilla or mandible fragments, or were completely disarticulated from their crania and mandibles. Relatively unworn permanent molars dominated the sample (Table 2), and teeth from the natural traps were relatively large. 'Frequency,' as described in tables and figures, relates to number of teeth, which by inference reflects the proportional abundance of individuals represented in the natural traps (22 bears total).

Although a host of variables are recommended for aging black bears (Marks and Erickson 1966), not all of these are amenable for use with paleozoological specimens, such as those from Lawson Cave and Jerry Long Cave, which are commonly disarticulated from crania and mandibles or fragmentary. Further, tooth wear aging is less destructive than use of cementum annuli to age canine teeth. However, because wear rates vary by individual, the age classes used here were considered ordinal scale and assessed non-parametrically following the assumption that older individuals tend to contain relatively worn permanent teeth.

Table 1. Faunal remains from Lawson Cave (Wolverton 2001) and Jerry Long Cave (Parmalee and Jacobsen 1959), both in Missouri. NISP = number of identified specimens (bones or bone fragments).

	Lawson Cave	Jerry Long Cave
Taxon	NISP	NISP
Black bear (*Ursus americanus*)	445	222
Cottontail (*Sylvilagus floridanus*)	238	93
Domestic pig	170	0
Woodchuck (*Marmota monax*)	66	388
Dog or coyote (*Canis* sp.)	66	0
Opossum (*Didelphis marsupialis*)	42	11
Woodrat (*Neotoma* sp.)	33	437
Vole (*Microtus* sp.)	19	9
Deer mouse (*Peromyscus* sp.)	18	2
Striped skunk (*Mephitis mephitis*)	12	37
Squirrel (*Sciurus* sp.)	7	66
White-tailed deer (*Odocoileus virginianus*)	5	3
Eastern mole (*Scalopus aquaticus*)	3	3
Raccoon (*Procyon lotor*)	1	38
Beaver (*Castor canadensis*)	1	5
Plains pocket gopher (*Geomys bursarius*)	1	0
Spotted skunk (*Spilogale* sp.)	0	39
Bobcat (*Lynx rufus*)	0	33
Modern human	0	9
Big brown bat (*Eptesicus fuscus*)	0	4
Brown bat (*Myotis* sp.)	0	2
Gray fox (*Urocyon cinereoargenteus*)	0	2
Red fox (*Vulpes vulpes*)	0	2
Mountain lion (*Puma concolor*)	0	2
Mink (*Mustela vison*)	0	1
Bog lemming (*Synaptomys cooperi*)	0	1
Turkey vulture (*Cathartes aura*)	0	291
Screech owl (*Otus asio*)	0	2
Turkey (*Meleagris gallopavo*)	0	1
Prairie chicken (*Tympanuchus cupido*)	0	1

Antero-posterior length and medio-lateral width (mm) of 21 upper second molars (M^2) and eighteen lower third molars (M_3) comprised the Missouri late Holocene sample from both caves (Table 3). This sample was compared graphically and statistically to a sample from the southern Midwest (predominately Arkansas, but also Kansas, Oklahoma, and Missouri) and Southeast (Alabama) of specimens from the Smithsonian Institution, Illinois State Museum, and University of Missouri reference collections (Table 3). Skeletal remains of black bears from the Midwest, particularly from Missouri, are uncommonly represented in museum and university collections because bears were extirpated in the region by 1900 AD (Parmalee and Jacobsen 1959, Schwartz and Schwartz 2001). Thus, remains from these Missouri cave faunas are an important supplement to existing collections.

To bolster size of the modern sample as much as possible, I included in the modern sample measurements on specimens from modern reference collections for which sex was unknown but location was recorded (Table 3). Of these specimens, teeth from 2 bears from the University of Missouri collection (4 M^2s and 4 M_3s) were smaller than all of the Midwest females; therefore, they were grouped with the females in Table 3. A separate individual of unknown sex with no mandible from the University of Missouri collection was included in the modern sample (2 M^2s) but not assigned to either sex because it fell between the sizes of known males and females from the Midwest. No individuals of undocumented sex were assigned to the modern male sample (Table 3). Because samples were small, I used Mann-Whitney *U*-tests to assess whether the Missouri natural trap sample was statistically different in size from modern male and female bears.

Results

Wear patterns indicated that the natural trap sample was dominated by subadults and young adults. A high percent of molars were assigned to classes 4 to 7 (71%), and over half (51%) of the teeth from these caves fell in classes 4 and 5 (Table 2; Fig. 2). These age classes comprised fully erupted, unworn to lightly worn permanent teeth, indicating that subadult to young-adult bears tended to be trapped in these caves. Roughly 15 of the 22 trapped bears were young adults, based on the proportion of teeth in classes 4 to 7 (Table 2). In a living population, a high proportion of very young individuals is expected (Caughley 1977, Lyman 1987, Rogers 1987, Dobey et al. 2005), but remains of only a single cub were present in the Lawson Cave assemblage. Moreover, Spearman's rank-order correlation between a hypothetical living population structure with declining membership with increasing age-class and the structure in Fig. 2 showed no significant relationship ($R_s = -0.1$, $P = 0.797$). At ordinal scale, sampling of a representative living structure from natural traps should approach a high negative R_s value as the rank-order of frequency in each age class should decrease with age.

Molar size indicated that the trap sample was dominated by males; tooth size in the natural trap samples significantly differed from modern female tooth size (Table 4). Size of male bear teeth in the modern sample is on average larger than that of

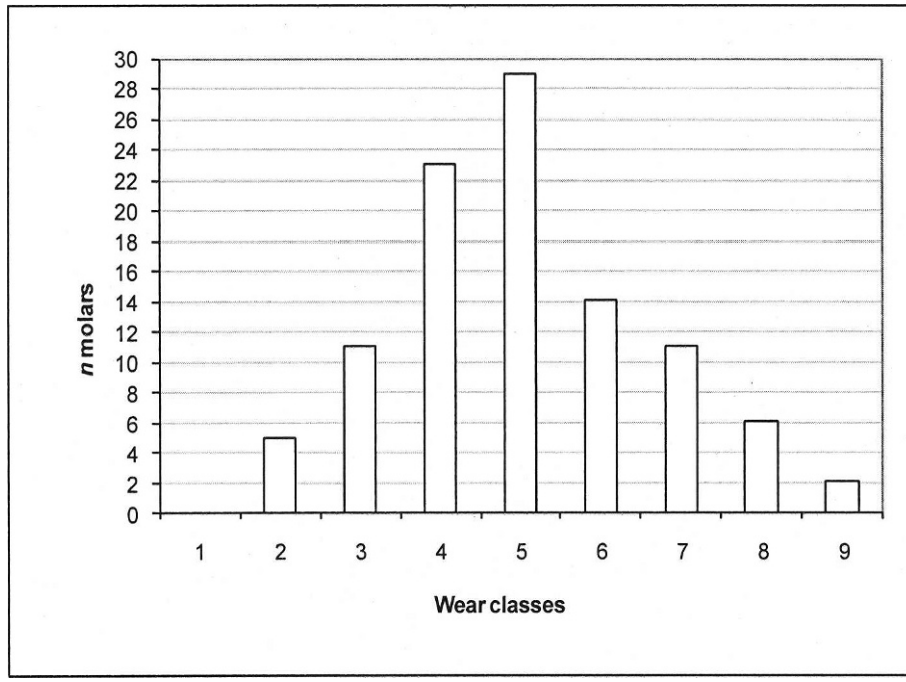

Fig. 2. Frequencies of molars in each wear class for teeth from American black bears excavated from Jerry Long and Lawson natural trap caves in Missouri. Fully erupted, unworn permanent teeth occur at the beginning of class 4.

females (Table 3), and thus I expected that if the natural trap sample was dominated by males, it should overlap with the upper half of the modern distribution. Sizes of M^2s and M_3s from bears from Lawson and Jerry Long caves were similar to the upper half of the size distribution of modern bear teeth from the Midwest and Southeast (Fig. 3), suggesting that male bears were trapped in the caves. There is one exception to this pattern, however: 1 of the 4 Mann-Whitney *U*-tests comparing teeth sizes of modern males with teeth from natural trap bears showed a significant difference (Table 4). M^2 width from the natural traps did not overlap with the upper half of the modern distribution (Fig. 3). This may have resulted from poor preservation of enamel on the lingual and buccal surfaces of multiple M^2s from the natural traps, which reduced width. On fragmented maxillary specimens and crania, the M^2 is the widest tooth and is somewhat more exposed to damage in paleozoological contexts than are other teeth. Enamel on other portions of the M^2s and M_3s is better preserved. Lower coefficients of variation for the natural trap sample relative to the modern sample is also consistent with the inference that the former sample was dominated by males and thus displayed reduced variability in size (Table 3).

The modern Midwest sample, especially bears from Arkansas, primarily represented individuals reintroduced to northern Arkansas from Minnesota (Smith and Clark 1994), which are expected to be large in body size. That this modern sample reflected size of relatively large bears is important for 2 reasons. First, that size of the natural trap individuals compares with that of males in the Midwest sample supports the interpretation that the former sample indeed represented males because the natural-trap individuals are large. Second, pre-extirpation Missouri black bears appear to have been relatively large in size, which is of interest because very little is known concerning the original Midwest population (Wolverton and Lyman 1998).

An independent indicator of sex would be the abundance of baculae. Only 5 baculae from Jerry Long Cave and 2 baculae from Lawson Cave were recovered, thus only biometric data can be used to suggest the abundance of males in the cave sample. The size and morphology of crania (sensu Graham 1991) from Lawson Cave ($n = 4$ partially complete

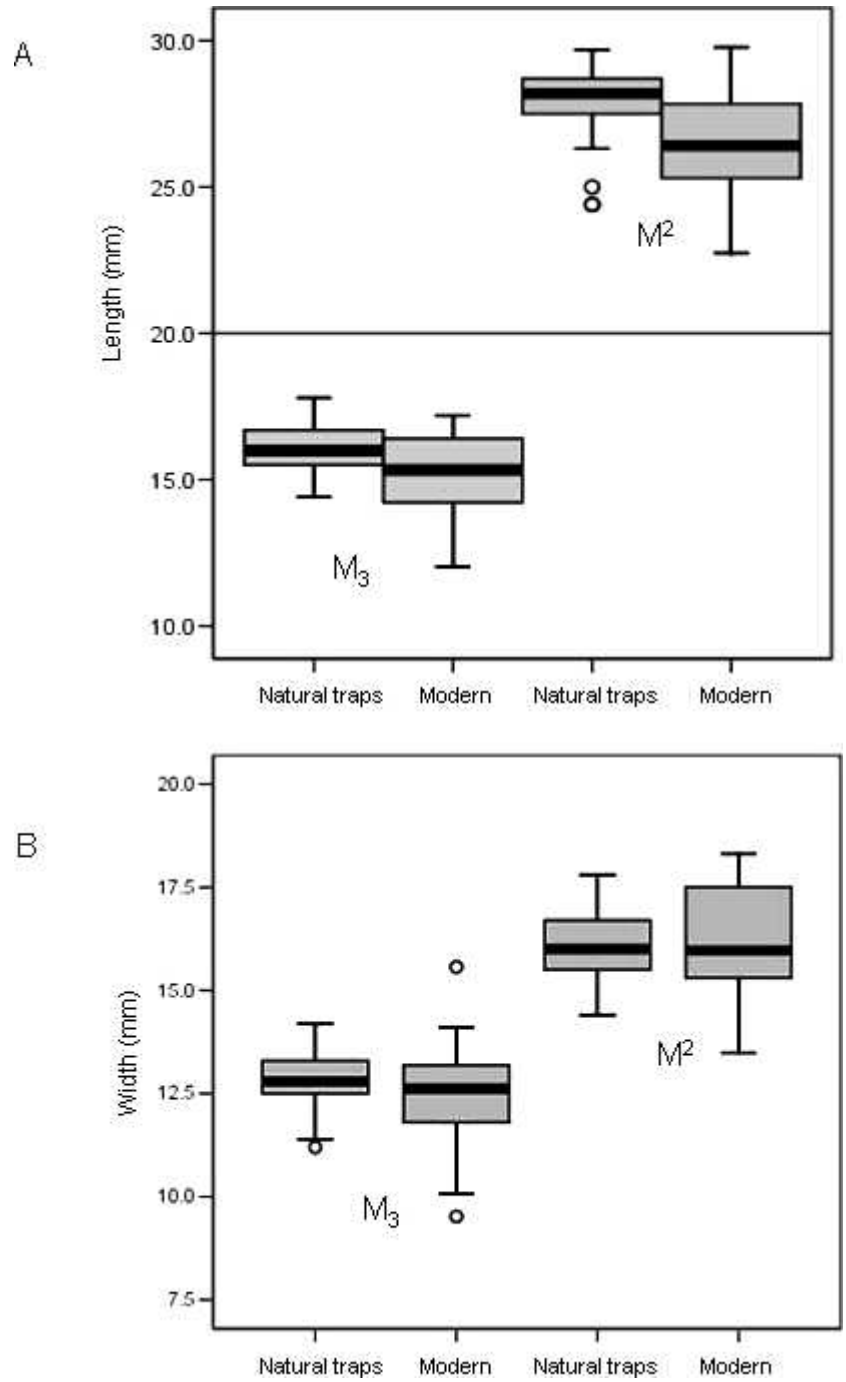

Fig. 3. (A) Box plots of antero-posterior length (mm) and (B) of medio-lateral width (mm) measurements on American black bear teeth excavated from Jerry Long and Lawson natural trap caves in Missouri and modern black bear teeth (comprises teeth from males, females, and bears of unknown sex). Circles are outliers greater than 2 box lengths away from the box. Three of the 4 comparisons indicate that natural trap teeth overlap in size with the upper halves of the modern size distributions. M^2 width is an exception that probably relates to poor preservation of enamel on portions of the natural trap teeth where width was taken.

Table 2. Frequencies of tooth type assigned to wear stages (numbered classes) from samples collected from American black bear remains in Jerry Long and Lawson caves, Missouri. Juvenile = deciduous and erupting permanent teeth; prime = fully erupted unworn to moderately worn teeth; old = severely worn teeth with substantial dentin and root pulp exposed and enamel nearly gone (Stiner 1998:312–313).

	Frequency of tooth type									
	Jerry Long Cave					Lawson Cave				
Wear stage	M^1	M^2	M_1	M_2	M_3	M^1	M^2	M_1	M_2	M_3
1 juvenile	0	0	0	0	0	0	0	0	0	0
2 juvenile	1	1	1	1	1	0	0	0	0	0
3 juvenile	1	1	2	1	2	2	1	1	0	0
4 prime	2	2	3	2	3	1	4	2	2	1
5 prime	2	2	2	0	1	6	5	4	4	3
6 prime	2	2	1	2	1	1	0	2	1	2
7 prime	1	1	0	0	0	2	1	2	2	2
8 old	0	0	0	0	0	1	1	1	2	1
9 old	0	0	0	0	0	0	0	0	1	1

crania) indicated that large tooth size relates to the sample being abundant in remains of males (Wolverton and Lyman 1998). Only one complete cranium was recovered from Jerry Long Cave.

Table 3. Descriptive and inferential statistics for black bear tooth measurements from samples collected from American black bear remains in Jerry Long and Lawson caves, Missouri.

Source Sample	*n*	Median (mm)	Mean (mm)	SD (mm)	CV (%)
Natural trap					
M^2 length	21	28.20	27.75	1.54	5.6
M^2 width	21	16.00	15.99	0.95	5.9
M_3 length	18	16.20	16.09	1.09	6.8
M_3 width	18	12.80	12.82	0.83	6.5
Modern					
M^2 length	30[a]	26.42	26.41	1.86	7.0
M^2 width	30[a]	15.88	15.95	1.35	8.5
M_3 length	22	15.34	15.23	1.43	9.4
M_3 width	22	12.61	12.38	1.46	11.8
Modern males					
M^2 length	14	27.86	27.83	1.18	4.2
M^2 width	14	17.51	17.02	0.91	5.4
M_3 length	11	16.06	15.89	0.92	5.8
M_3 width	11	13.19	13.21	1.11	8.4
Modern females					
M^2 length	14[a]	25.68	25.42	1.27	5.0
M^2 width	14[a]	15.31	15.20	0.88	5.8
M_3 length	11[a]	14.22	14.56	1.58	10.8
M_3 width	11[a]	11.81	11.55	1.30	11.3

[a]Includes bears of unknown sex.

Table 4. Mann-Whitney *U*-statistics for comparison of teeth dimensions from modern American black bears and teeth excavated from Jerry Long and Lawson natural trap caves in Missouri.

Test	*U*	*Z*	*P*
Males vs. natural traps			
M^2 length	139.5	0.874	0.382
M^2 width	65.5	2.747	<0.01
M_3 length	110	0.218	0.827
M_3 width	81.5	0.787	0.431
Females vs. natural traps			
M^2 length	38.5	3.655	<0.01
M^2 width	71.0	2.560	0.01
M_3 length	45.0	2.428	0.02
M_3 width	46.0	2.384	0.02

Taken cumulatively, tooth-size and age-structure data from both caves indicated that subadult to young-adult male bears were relatively prone to accidental deaths in natural traps during the late Holocene in Missouri.

Discussion

As urban and suburban areas continue to encroach upon wilderness in North America, the opportunity for encounters with bears (e.g., *U. americanus* and *U. arctos*) by humans has increased (Brody and Pelton 1989, Stubblefield 1993, Barden et al. 1995). In general male bears are more likely to come into contact with humans than females in a variety of circumstances. In addition, subadult to young-adult bears, males in particular, experience high rates of mortality and are more prone to poor health and accidental deaths than bears in other age classes (Poelker and Hartwell 1973, Bunnell and Tait 1981, Hellgren and Vaughan 1989, Higgins 1997; as well as Brannon et al. 1988, Knick and Kasworm 1989, McLellan et al. 1999 for *U. arctos*). During young adulthood, bears establish home ranges related to the distribution of food and mates, and this is thought to be a period of energetic stress (Pelton 2000). Along similar lines, male bears establish and maintain relatively large home ranges compared to females, which is often cited as a causal factor in relatively high trapping rates and high mortality among males (Garshelis and Pelton 1981, LeCount 1982, Hellgren and Vaughan 1989). I hypothesize that carrion in these historic-period natural traps attracted young bears related to these contingencies during dispersal from their natal

ranges (Schwartz and Franzmann 1992, Lee and Vaughan 2003).

At the wildland–urban interface, male bears take greater advantage of available resources, such as garbage and bird feeders, related to human activities (Beckmann and Berger 2003). Urban bears are on average substantially larger in terms of body mass and maintain smaller home ranges at higher population densities than do bears in rural settings (Beckmann and Berger 2003; see also Weaver 2004), which indicates that physical and social stresses related to habitat exploitation are reduced in such settings. Indeed, among grizzly bears (*U. arctos*) in Yellowstone National Park, Mattson et al. (1992) found that use of areas near human facilities increased during years of relatively low wild food availability. During the same periods, subadult males and adult females, 2 age–sex cohorts thought to experience relatively high energetic stress, exhibited greater mortality and were more likely to be trapped during management. Mattson et al. (1992:439) state that "subadult males may have been less familiar with local bears and foraging options and consequently more willing than subadult females to tolerate humans as a means of minimizing competition with other bears." Although Mattson et al.'s (1992) study examined grizzly bears, it portrays precisely the same mechanism that I propose here to account for vulnerability of young male black bears to entrapment and death in natural trap caves.

As much as the evolving relationship between humans and bears reflects modern expansion of humans into wilderness, it is equally attributable to life history evolution in bears. The black bears entrapped in Lawson Cave and Jerry Long Cave date to before modern expansion of suburban and urban development into extensive areas of wilderness and prior to the invention and use of the automobile and associated intense development of roads in rural areas. These data corroborate that young male bears can be expected to venture into unknown, even dangerous settings in search of food, including modern urban areas. Indeed, a handful of studies highlight that it may be advantageous for male bears to do so (Beckmann and Berger 2003, Weaver 2004). As such, nuisance bears are likely to be proportionally overrepresented by this age–sex cohort. Of additional interest and equally important is that black bear remains from Jerry Long Cave and Lawson Cave represent a late Holocene record of the native Missouri population. Age and size characteristics of remains from these caves should be of interest as the re-introduced population continues to expand in the southern portion of the state.

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