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INVERTEBRATE COMMUNITY OF ROARING SPRINGS CAVE, GRAND CANYON NATIONAL PARK, ARIZONA

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The few studies of cave invertebrates in the southwestern United States have noted the low species diversity in cave faunas in this region (e.g., Mitchell, 1969; Peck, 1978). Historical conditions were evidently suitable for the development of a troglobite fauna, including climatological periods when potential colonizers were able to move into the caves because of cooler and more mesic conditions in the vicinity of the cave entrances, and warmer, more arid periods when the cave populations were isolated from surface relatives and able to evolve independently. However, the combination of regional aridity and low nutrient input into the caves has apparently limited the number of cave-adapted invertebrates that have survived to present times (Peck, 1978, 1980).

In his survey of three caves in the Grand Canyon of northern Arizona, Peck (1980) found several terrestrial invertebrate species in the Roaring Springs Cave system, including at least three troglobitic species endemic to Grand Canyon caves. He found no aquatic invertebrates in the stream that flows through the cave, and attributed this to the lack of an organic food source in the groundwater feeding the stream.

We conducted an intensive survey of the Roaring Springs Cave system in 1994 and 1995, and found several aquatic invertebrates, as well as additional terrestrial species. We present a total of nine additional unreported species for Roaring Springs Cave, bringing the total known invertebrate fauna for this cave to 19 species. The fauna can be divided into a shallow cave group of species, presumably troglophilic or "accidental" (terminology of Barr, 1968), a middle cave fauna, and a single, deep-cave troglobitic amphipod. The amphipod is an undescribed, apparently endemic species in the genus *Stygobromus*. This is the first report of aquatic invertebrates from caves in the northern Arizona area.

Roaring Springs Cave is located within the Muav formation in the Bright Angel Creek drainage at an elevation of 1,585 m. The cave cuts most of its course through limestone. However, in the back reaches of the cave, there are sections where limestone is interbedded with shale, which crumbles easily to form a silty sediment. Most of the cave is angular in form, both in cross section of the passages, and in the pattern of long straight passages and angular turns and corners. The back third of the cave follows a more sinuous course. There are several interconnected passages, with relatively large streams in two of these passages. The other passages have small trickles or are dry. Average ceiling height of the cave's main stream passage ranges from 2 to 3 m (where the ceiling is flat) to about 8 m. Average width is about 2 m, widening in places to 4 to 5 m. The stream covers most of the cave floor, ranging in width from 1 to 3 m, and having rapid (1 to 1.5m/s), turbulent flow along most of its length. Stream depth varied from 0.1 to 1.25 m at the time of our survey. The stream bottom along most of its length is bare rock, swept clean by the fast-flowing water, but in a few places there are scattered boulders and rockfalls. The back third of the cave has pockets of shale and limestone cobbles and a few small protected pools and side channels with silty and sandy sediments. Water flows out of the cave entrance and cascades down a steep slope to form a tributary of Bright Angel Creek.

In addition to the invertebrates discussed here, small mammals range at least 100 m back into the cave. We captured brush mice (*Peromyscus boylii*), and noted several wood rat (*Neotoma* sp.) nests. No evidence of bats was found, in spite of careful search for them.

The cave was surveyed on 27–28 September 1994 for 14 h and for 16 h between 31 January and 2 February 1995. We carefully examined the floor, walls and ceiling of the cave for terrestrial invertebrates, and searched around and beneath boulder and debris piles, both in dry rockfalls and in the stream. We searched the area around all spider webs seen for the spiders that built the webs. Organic debris (dead insects, small mammal droppings) was carefully examined for small detritus-feeding invertebrates.

Aquatic samples were taken in three main locations along the length of the cave including: 1) 2 m in from the cave entrance; 2) the back of the first passage, 350 m from the entrance, and 3) the "dome room" at the back of the cave, 1.2 km from the cave entrance. At each site 5 to 10 sweep samples were taken with a heavy-duty, D-ring aquatic net (256 μm mesh size), sweeping the bottom, side channels, and any sediments present in the vicinity. At least three plankton tows (53 μm mesh size) were also taken in the main channel and side pools. Additional sweeps and hand net samples were taken at other points in the cave where aquatic invertebrates were seen, and where pools and rock falls offered suitable habitat for invertebrates. Adult, flying aquatic insects were collected where seen, and exuvia of immature insects were collected from the walls of the cave. Temperatures (air and water) were measured on-site and specific conductance was determined in the laboratory with a Radiometer conductivity meter (Model CDM2) from water samples collected at each site.

Water temperature throughout the cave ranged from 10 to 11°C. Specific conductance ranged from 275 μS at the back of the cave (dome room) to 254 μS at the cave entrance. Air temperature was relatively constant at 13°C.

Terrestrial invertebrates—The greatest diversity of terrestrial invertebrates, and the great majority of individuals, were in the shallow reaches of the cave, back to approximately 100 m from the cave entrance. Two species of web-building spiders were present in this region (*Achaearanea* sp. and *Lepthyphantes* sp.), along with one ground-dwelling spider (*Loxosceles* sp.). *Lepthyphantes* sp. and *Loxosceles* sp. were not previously reported by Peck (1980). The endemic springtail, *Tomocerus* sp., was noted at mouse droppings and at exuvia of stoneflies. A single ground beetle (*Bembidion* sp.) collected from boulder rubble is also a new record for the cave. We did not encounter the endemic *Ptomaphagus* sp. described by Peck from Roaring Springs Cave (Peck, 1973, 1980).

Approximately 100 m back from the cave mouth is the first of three rockfall "bridges" along the main passage, formed by collapse of large boulders from the ceiling of the cave. The first bridge forms a light barrier as well as a physical barrier; beyond this is the beginning of the dark zone of the cave or the middle cave zone. Only three insect species were found beyond this point: the stonefly, *Hesperoperla pacifica* (see below); the collembolan, *Tomocerus* sp.; and an unidentified campodeid dipluran (Campodeidae). Two specimens of the dipluran were found dead on the surface of a small pool deep in one of the dry cave passages. They were in poor condition and could not be identified beyond family level.

Aquatic invertebrates—Adults of two caddisfly (Trichoptera) species were collected just inside the cave entrance: *Lepidostoma apornum* (Lepidostomatidae) and *Micrasema onisca* (Brachycentridae), both of which apparently represent new records for the state of Arizona (Table 1, Dave Ruiter, Little, Colorado, pers. comm.). *Lepidostoma apornum* has been reported from several springs in central and southwestern Utah with a single record from Montana, while *M. onisca* is known from single collections from California, Oregon, Nevada, and Utah (Dave Ruiter, pers. comm.). It is likely these adults entered the cave from Roaring Springs just outside the cave, because no larvae were collected in the cave. Usher et al. (in litt.) reported a rich fauna of caddisfly larvae in the Roaring Springs stream outside the cave in

TABLE 1—Composite list and general distribution of invertebrates in Roaring Springs Cave in Grand Canyon, Arizona, including surveys by Peck (1978, 1980). Species marked with * are new reports for Roaring Springs Cave. "Shallow cave" refers to the area back ~100 m from the cave entrance where rockfalls form a barrier to the deeper parts of the cave. The "middle cave" extends back ~400 m from the rockfalls and the "deep cave" extends from the end of the middle cave to the back of the cave, and lacks any input of nutrients from the cave mouth (such as mouse and wood rat droppings).

	Shallow cave	Middle cave	Deep cave
CLASS: CRUSTACEA			
ORDER: AMPHIPODA (amphipods)			
***Stygobromus* (Hubbsii group)		X	X
CLASS: ARACHNIDA			
ORDER: ARANEAE (spiders)			
**Lepthyphantes* sp. (line weaving spider)	X		
**Loxosceles* sp. (recluse spider)	X		
Telema sp.	X		
Achaearanea sp. (comb-footed spider)	X		
ORDER: OPILIONES			
Leiobunum sp. (harvestman)	X		
ORDER: ACARINA (mite)			
Rhagidia sp.	X		
CLASS INSECTA			
ORDER: COLLEMBOLA (springtail)			
Tomocerus sp.	X	X	
ORDER: DIPLURA			
*Campodeid (Campodeidae) (species undetermined)		X	
ORDER: ORTHOPTERA (crickets, mantids, grasshoppers)			
Ceuthophilus sp.	X		
ORDER: PLECOPTERA (stoneflies)			
**Hesperoperla pacifica*	X	X	
ORDER: TRICHOPTERA (caddisflies)			
**Lepidostoma apornum*	X		
**Micrasema onisca* Ross	X		
ORDER: COLEOPTERA (beetles)			
**Bembidion* sp. (ground beetle)	X		
Ptomaphagus cocytus Peck (round fungus beetle)	X		
ORDER: LEPIDOPTERA (butterflies and moths)			
Pronoctua typica (noctuid moth)	X		
ORDER: DIPTERA (flies)			
Mycetophila sp. (fungus gnat)	X		
**Limonia* sp. (crane fly)	X		
Tipula rupicola (crane fly)	X		

1984, including *Lepidostoma* sp. and *Micrasema* sp.

We collected several stonefly exuvia and final instars of *H. pacifica,* (Plecoptera: Perlidae) from the walls of the cave and from edges of the stream. Two adults of this species were also captured crawling on the walls and fluttering in the darkness. *Hesperoperla* exuvia were scattered on the walls of the main stream passage back to about 300 m from the cave entrance and were very numerous in a secondary stream passage west of the main passage, where numbers reached 100 exuvia/m^2 of cave wall. Total number of exuvia on the walls of this passage was estimated at >10,000 (we do not know what time period is represented by these remains). In both passages, numbers of stonefly exuvia decreased the farther we went into the cave, suggesting the immature stoneflies moved into the cave system from the entrance. It is noteworthy that Usher et al. (in litt.) reported several stonefly taxa (*Acroneuria, Alloperla, Isogenus,* and *Nemoura*), but did not find *Hesperoperla.*

We found only one species in the deep section of the cave, an amphipod lacking pigmentation and eyes, tentatively identified as *Stygobromus* n. sp. in the Hubbsii group (John Holsinger, Old Dominion University, pers. comm.). *Stygobromus* species are found in caves, wells, seeps, springs, and cavernicolous and interstitial habitats (Pennak, 1989). In Roaring Springs Cave, *Stygobromus* was found primarily in small side channels, shallow pools, and other areas where the water was still or relatively slow-flowing. In these areas, they were frequently associated with small deposits of silty and sandy sediments. Numbers seen were always low; the most seen in a small area was 9 in a round pool 0.5 m across and 10 to 15 cm deep.

Peck (1980) did not find any aquatic invertebrates in Roaring Springs Cave, which he attributed to the lack of organic input from the highly filtered waters entering the cave. However, we did find small fragments of organic particles (typically ≤ 50 μm in diameter) in water and plankton samples from the very back reaches of the cave. These are presumably derived from surface sources percolating into the groundwater feeding the cave. Microscopic observations revealed numerous bacteria in association with the organic material. There were no protozoans, cladocerans, copepods or rotifers in any of the water and plankton samples examined. Although Peck (1980) was mistaken about the absence of aquatic invertebrates in the Roaring Springs Cave, his general thesis was correct: organic input into the deep cave system is very low, supporting an exceptionally simple food web, i.e. organic fragments/bacteria and *Stygobromus.* It is noteworthy that the organic fragments become less abundant with distance from the groundwater source, and were not present in samples from the anterior part of the cave. Furthermore, there was a 10% decrease in specific conductance from the back of the cave to the cave entrance. This suggests that ions are precipitated out along the length of the channel or are utilized by bacteria, which likely make up at least part of the food for *Stygobromus.*

David Lee organized the overall survey effort and assisted in the field work. Tim Snow and Shawn Castner also participated in the field work; Shawn was the first to note individuals of the amphipod species. We thank the National Park Service for funds to conduct this study. We also thank Dave Ruiter, James Ward, Boris Kondratieff, and John Holsinger for verifications of specimens of Trichoptera, Plecoptera, and *Stygobromus,* respectively. Voucher specimens are housed in the Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ.

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