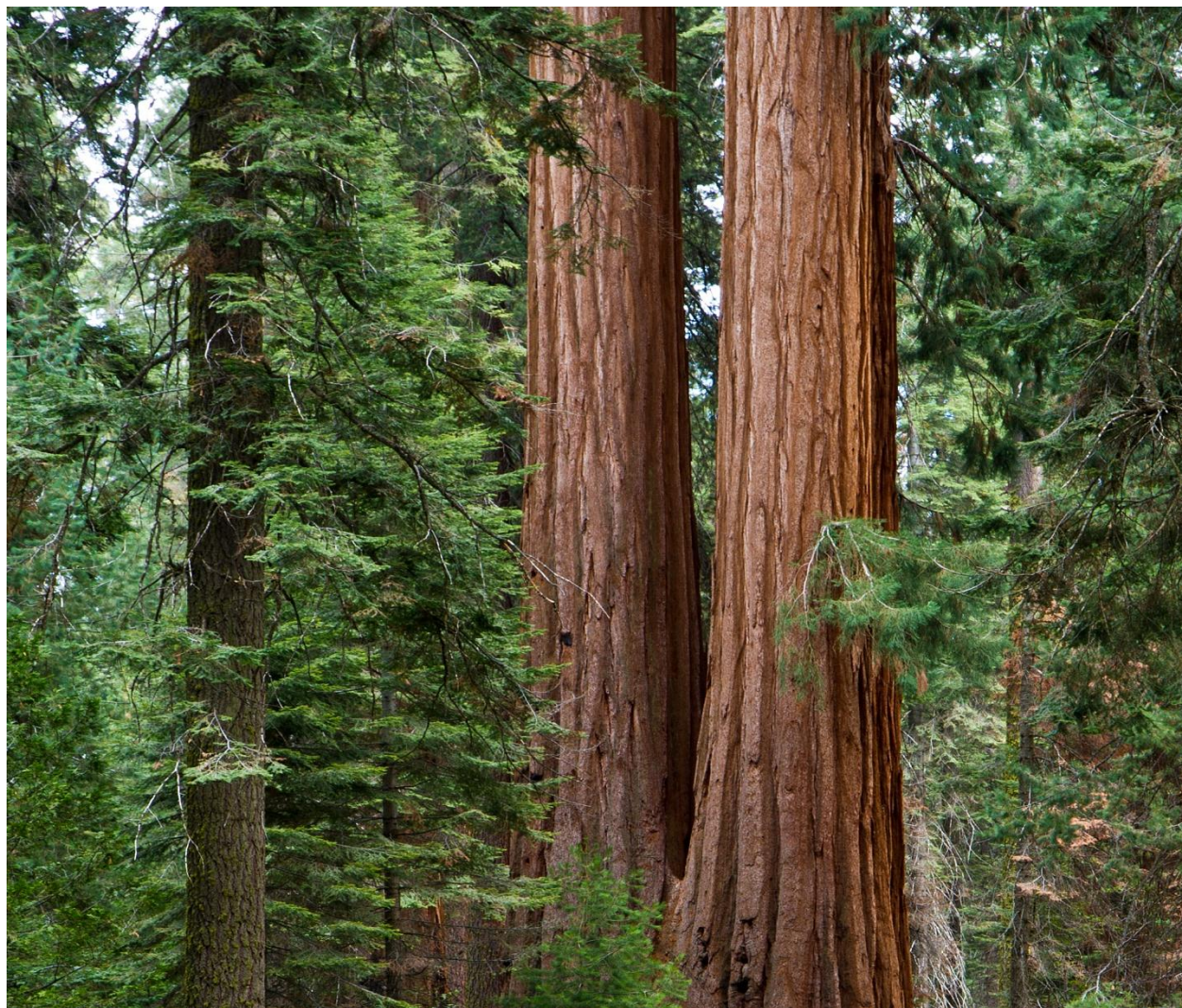




A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks

Appendix 18 - Cave Invertebrates

Natural Resource Report NPS/SEKI/ NRR—2013/665.18



ON THE COVER

Giant Forest, Sequoia National Park
Photography by: Brent Paull

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Appendix 18 - Cave Invertebrates

Natural Resource Report NPS/SEKI/ NRR—2013/665.18

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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This document contains subject matter expert interpretation of the data. The authors of this document are responsible for the technical accuracy of the information provided. The parks refrained from providing substantive administrative review to encourage the experts to offer their opinions and ideas on management implications based on their assessments of conditions. Some authors accepted the offer to cross the science/management divide while others preferred to stay firmly grounded in the presentation of only science-based results. While the authors' interpretations of the data and ideas/opinions on management implications were desired, the results and opinions provided do not represent the policies or positions of the parks, the NPS, or the U.S. Government.

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Scope of Analysis

To date, 275 caves have been found in Sequoia and Kings Canyon Parks (SEKI). The number continues to rise, making the parks home to one of the most extensive cave-rich landscapes in the western United States. Caves are found primarily in the western one-third of the parks in narrow northwest-to-southeast-trending bands of marble. They are found at a diversity of elevations, from 1,640 feet to more than 9,800 feet (500 m - 3,000 m). As a result, cave temperatures range from just above freezing to over 60 °F. Cave temperatures are often constant and reflect adjacent surface temperatures. Some caves have active stream systems, but many are the dry and abandoned remnants of ancient, water-flow patterns. Areas where caves are found include the South Fork of the Kaweah, Mineral King, Paradise Ridge, Deep Canyon, Yucca Creek and Redwood Canyon.

Caves are host to a diversity of animals. In SEKI, scientists have discovered at least 40 new invertebrate species since 1965—a large number for such a small area. Observations of cave species rise as caves continue to be inventoried. Some of these species may be endemic to the parks and indeed endemic to individual caves or watersheds within the parks. Caves provide a unique environment, isolated from their surroundings, difficult to access, harder to survive in. That life could flourish in them is remarkable. That species could evolve within individual caves is exceptional. That these species have been documented is a result of the intense scientific effort of highly specialized and uniquely skilled cave biologists. The protection of these rare species requires a wholly new perspective in park management, an awareness and appreciation of caves as a vast underground resource. In SEKI, an active cave management program starting in 1992 and the Cave Management Planning efforts started in 1994.

In general, cave climates (temperature and humidity) vary little, but there is enough change in these parameters that the seasonal activity levels of the animals do vary. Many cave invertebrate populations have been shown to have a high annual variability based on annual food availability and changing conditions. This has been seen, for example, in Clough Cave (Daryl Ubick, pers. comm.). This effect may be muted in the cave environment where annual conditions generally change far less compared to surface environments. Because of their sensitivity to the environment, cave-adapted invertebrates can act as indicators of environmental problems or changes. If park cave animals decline, it may point to other problems in the park environment. Caves also often act as an environmental refuge, providing a cool wet environment for animals that are intolerant of dry, hot surface conditions. Often, the closest relatives of cave dwelling animals may be found hundreds of miles away where surface conditions more closely match those found within the cave. Today a significant percentage of animals on the Endangered Species list are cave dwelling invertebrates and bats (Despain 2007).

This report will focus on assessing condition of invertebrates from 6 caves in Sequoia and Kings Canyon National Parks: Clough Cave, Overhang Cave, Kaweah Cave, Lost Soldier's Cave, Crystal Cave and Lilburn Cave (Figure 1). South Fork caves (the first three) and their inhabitants are located close to each other and to the Kaweah River at elevations between 750 and 1300 m. They are within 2 kilometers of the western boundary of Sequoia Park. Lilburn and Crystal Caves are in the North Fork drainages of the Kaweah (Figure 1) while Kaweah Cave is found in the Middle Fork watershed. This assessment is restricted to SEKI-endemic, cave-

adapted invertebrates and does not include animals known to be found in park caves outside of this area.

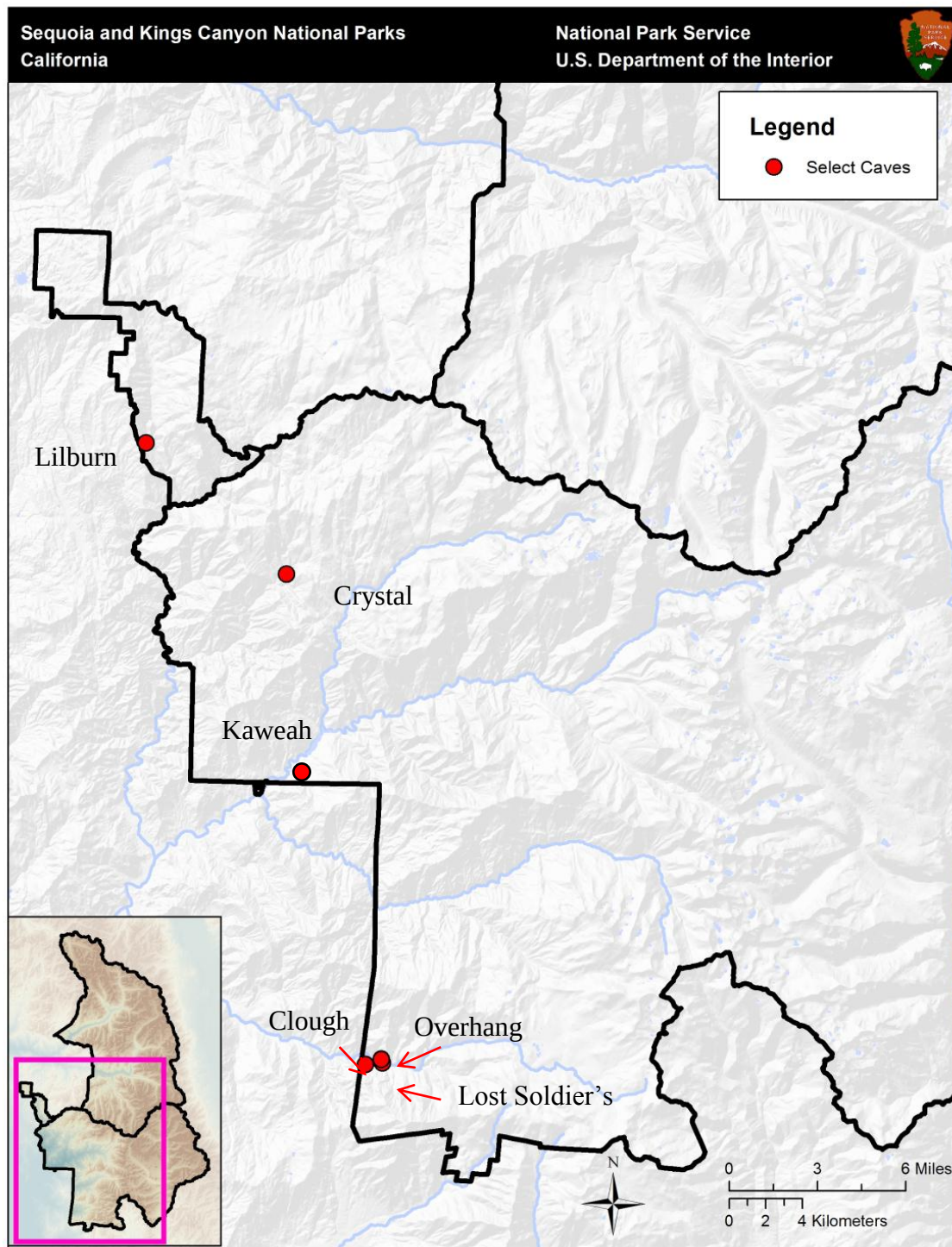


Figure 1. Approximate locations of select caves analyzed in this report.

Species of Interest

Species that will be included in this report are listed in Table 1. The report focuses on these species because they are troglobites (cannot survive outside caves) or troglaphiles (may live in a cave, but can also survive above ground), endemic and rare species whose primary refuge is in the parks. Furthermore, caves were included from across multiple park karst areas to capture a wide geographic range of cave habitats in the parks. Millipedes were included because they are the Parks' best studied animals and they include new and endemic species and genera. The South Fork area caves since they include the most diverse cave (Overhang) and the one with the most endemics (Clough).

Table 1: Endemic cave-adapted invertebrates of SEKI.

Animal Type	Taxa	Known Characteristics
Scorpions	<i>Uroctonites sequoia</i>	Troglophilic, elevation range 900-1,500m
Spiders	<i>Blabomma</i> sp.	Troglobitic
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	South Fork cave cluster, 1,140-1,310m
	<i>Usophila</i> sp.	Clough cave only, 1,310m
Harvestmen	<i>Calcina cloughensis</i>	Troglobitic, 800-1,310m
Pseudoscorpions	<i>Neochthonius</i> sp.	800-1,310m
	<i>Fissilliercreagris</i> sp.	800-1,310m
Dipluran	Family <i>Japygidae</i>	~1,300m
Beetles	Family <i>Carabidae</i> (endemic genus)	~1,300m
Millipedes	<i>Amplaria adamsi</i>	Probably troglaphilic, elevation 1,140-1,380m
	<i>Amplaria muii</i>	Probably troglaphilic, only found in Crystal Cave, 1,380m
	<i>Sequoiadesmus krejcae</i>	Found in Sequoia and in Kings Canyon, 1,300-1,600m
	<i>Pratherodesmus despaini</i>	Known only from Kaweah Cave, 500m
	<i>Taiyutyla</i> sp.	South Fork cave cluster, 1,140-1,310m
Isopods	<i>Bowmanasellus sequoia</i>	Aquatic, 1,130-1,680m
Rock Hopper	<i>Grylloblattidae</i> sp.	Troglophilic, ≥1600m

Scorpions are predators that eat other arthropods including terrestrial isopods, springtails, millipedes, and surface accidental animals such as beetles. Three species of scorpions are found in the parks. *Uroctonites sequoiae* (Figure 2) are pale scorpions up to several centimeters in length and one of the most rarely encountered species of scorpion in California, being known from fewer than a dozen specimens in four localities. A single immature specimen is known from Plumas County; all other specimens are known from caves or limestone outcrops of Sequoia



Figure 2. *Uroctonites sequoia*. Printed with permission of Dr. Jean K. Krejca, Zara Environmental LLC.

National Park (Gertsch and Sologlad 1972). It is found in at elevations of 900-1,500 meters.

Pseudoscorpions are small, predatory arachnids. Japygidae are bristletails with pinchers at the tip of their tail. They are also sometimes called “forceps tails” or “earwig-like entrophs”. Japygidae can be either herbivorous or predatory. What SEKI taxa eat is unknown.

Harvestmen are omnivorous, eating primarily small insects, plant material and fungi; some are scavengers, feeding upon dead organisms, bird dung and other fecal material. *Calcina cloughensis* (Figure 3) is known only from caves along the S. Fork of the Kaweah.



Figure 3. *Calcina cloughensis* is a Clough Cave denizen endemic to SEKI. © NPS photo by Joel Despain.

Millipedes are generally detritivores eating various organic matter including scat, carrion, leaves, and woody debris. *Amplaria muiri* (Figure 4) has only been found in the caves of the Crystal Cave cluster (Bear Den Cave, Carmoe Crevice, Crystal Cave, Hurricane Crawl Cave, Lange Cave, Pet Cemetery Cave, Lilburn Cave and Weisraum Cave. Pigmentation indicates they may not be cave-limited (Shear and Krejca



Figure 4. *Amplaria muiri*. Photo by Dr. Jean K. Krejca, Zara Environmental LLC.

2007). *Amplaria adamsi* (Figure 5) is noticeably smaller than *A. muiri* and consistently pigmented. *A. adamsi* is probably a troglophile, and surface collecting in suitable habitats will undoubtedly turn it up (Shear and Krejca 2007). It was first observed in Overhang Cave (Shear and Krejca 2007), but has since been seen in Clough Cave (Graening 2010). The millipede *Sequoiadesmus krejcae* has Hurricane Crawl Cave as a type locality but has also been identified in Clough and Lilburn caves giving this animal a fairly wide range across the western sections of the parks. The millipede *P. despaini* is known only from Kaweah Cave where the animals have been seen feeding on roots and rodent scat.



Figure 5. *Amplaria adamsii*. Photo by Dr. Jean K. Krejca, Zara Environmental LLC.

Bowmanasellus sequoiae (Figure 6) are cave-adapted aquatic isopods that are blind, lack pigmentation, and are found in the North Fork of the Kaweah River watershed in the drainages of Redwood and Yucca Creeks at elevations between 1,130 and 1,680 m within both Sequoia and Kings Canyon parks. They constitute a genus endemic to the park. Specifically they are

known from Lilburn, Big Springs, Hurricane Crawl and Crystal caves and Mossy and Contact springs.

Grylloblattidae sp. (Figure 7) are troglophiles found in caves of the Redwood Canyon area and at high elevations in the parks as far south as Mineral King. These animals are commonly called “Icehoppers” or “Rockhoppers.” They constitute a suborder with one family, five genera and 25 species found in North American and northern Asia. Five species have been described in the US. The species here may be new to science and is the southern-most population in the US (pers. comm. Sean Scoville, UC Berkeley and CA Academy of Sciences). They are wingless and nocturnal detritus feeders.

Some of these species may be eligible for listing under the Endangered Species Act due to small populations and ranges, however no petition seeking such a listing has been created or is planned to be created in the future. These species are protected under the Federal Cave Resources Protection Act, which creates penalties for any person who “knowingly destroys, disturbs, defaces, mars, alters, removes or harms any significant cave or alters the free movement of any animal or plant life into or out of any significant cave located on Federal lands” This restriction is extended to cave “Animal Life.”



Figure 6. *Bowmanacellus sequoia* are aquatic isopods. Its organs can be seen within its body. Photo by Dr. Jean K. Krejca, Zara Environmental LLC.



Figure 7. *Grylloblattidae* from Lilburn Cave. Photo by Dr. Jean K. Krejca, Zara Environmental LLC.

Critical Questions

The best indicator of cave invertebrate condition is the species' presence or absence in their host caves and population range over a period of five to ten years or more.

- What cave-dwelling, endemic invertebrate species are present or absent in select caves over the period of record?
- What can be determined from existing data about the population range of these species?

Analyses

Sequoia and Kings Canyon National Parks are participating in a California statewide assessment of macrofauna in subterranean habitats initiated in 2009 and ongoing over the next decade (Graening et al. 2011). Results from 2010 include the bio-inventory of 13 SEKI caves, including most of the caves in this report. That data will be summarized here. Also included here (and in Graening) is the intensive inventory work by Krecja (2006) that attempted to rapidly inventory as many cave invertebrates as possible across all park karst geographic regions. Sequoia and Kings Canyon also maintain an ongoing research and monitoring program to assess the populations of these animals. This work has included timed-area searches and more than 60 0.3 m square plots in a dozen park caves that are checked for the presence or absence of the invertebrates when time allows. This work to date has produced relatively sparse data that has not been analyzed and is therefore not included here. This work has also produced range extensions for animals first recognized by Krecja and other earlier researchers such as Briggs.

Methods

Within the caves of interest, both studies restricted their focus to subterranean habitats that are primarily dark, or have extremely limited photosynthetic input, and that have temperature and moisture regimes more similar to the subsurface than to the surface. Subsurface environments tend to have very little fluctuation in temperature and maintain the average annual temperature of the region, and have humidity levels near or at saturation.

Results

In this report, we provide results cave by cave for individual caves because information about the caves provides context for the invertebrates found within and basic knowledge of cave ecology. A summary of invertebrate distribution among these caves is reported in the Assessment part of the document.

The Caves

The first three caves reported below are in close proximity to each other in the South Fork of the Kaweah.

Clough Cave

Clough Cave has had heavy public use since it was discovered in the late 1800's. Thousands of the original stalactites, stalagmites, soda straws, cave pearls and columns were removed and/or broken by visitors, and walls blackened by the smoke of pine torches (Despain 2003). The cave has been gated since 1964 and a permit is required for entrance and allowed only during the month of August. It is short, with only 229 m of mapped passageway, but its passages are spacious and wide.

Clough Cave is the Park's cave with the greatest endemic invertebrate diversity (Figure 8). At 1,310 m elevation, it is warm and seasonally wet, and its water resource is drip pool, combined with steady sources of food from tree roots and bat and rodent guano that provide ideal conditions for cave life. This cave is home to 11 species of invertebrates that do not live outside of the park's boundary, including a harvestman and several species of spiders. It is possible that numerous other endemic species that once lived in this cave have been lost by its history of visitation and abuse.

Table 2. Endemic invertebrates in Clough Cave. Presence is indicated by (+), absence by (–)

Common Name	Taxa	Clough Cave presence/absence
Scorpion	<i>Uroctonites sequoia</i>	+
Spider	<i>Blabomma</i> sp.	+
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	+
	<i>Usophila</i> sp.	+
Harvestmen	<i>Calcina cloughensis</i>	+
Pseudoscorpions	Family <i>Chthoniidae</i>	–
	<i>Neochthonius</i> sp.	+
	<i>Fissilliercreagris</i> sp.	+
Dipluran	Family <i>Japygidae</i>	+
Beetles	Family <i>Carabidae</i> (endemic genus)	+
Millipedes	<i>Amplaria adamsi</i>	+
	<i>Amplaria muiri</i>	–
	<i>Sequoiadesmus krejcae</i>	+
	<i>Pratherodesmus despaini</i>	–
	<i>Taiyutyla</i> sp.	+
Isopod	<i>Bowmanasellus sequoia</i>	–
Rock Hopper	<i>Grylloblattidae</i> sp.	–

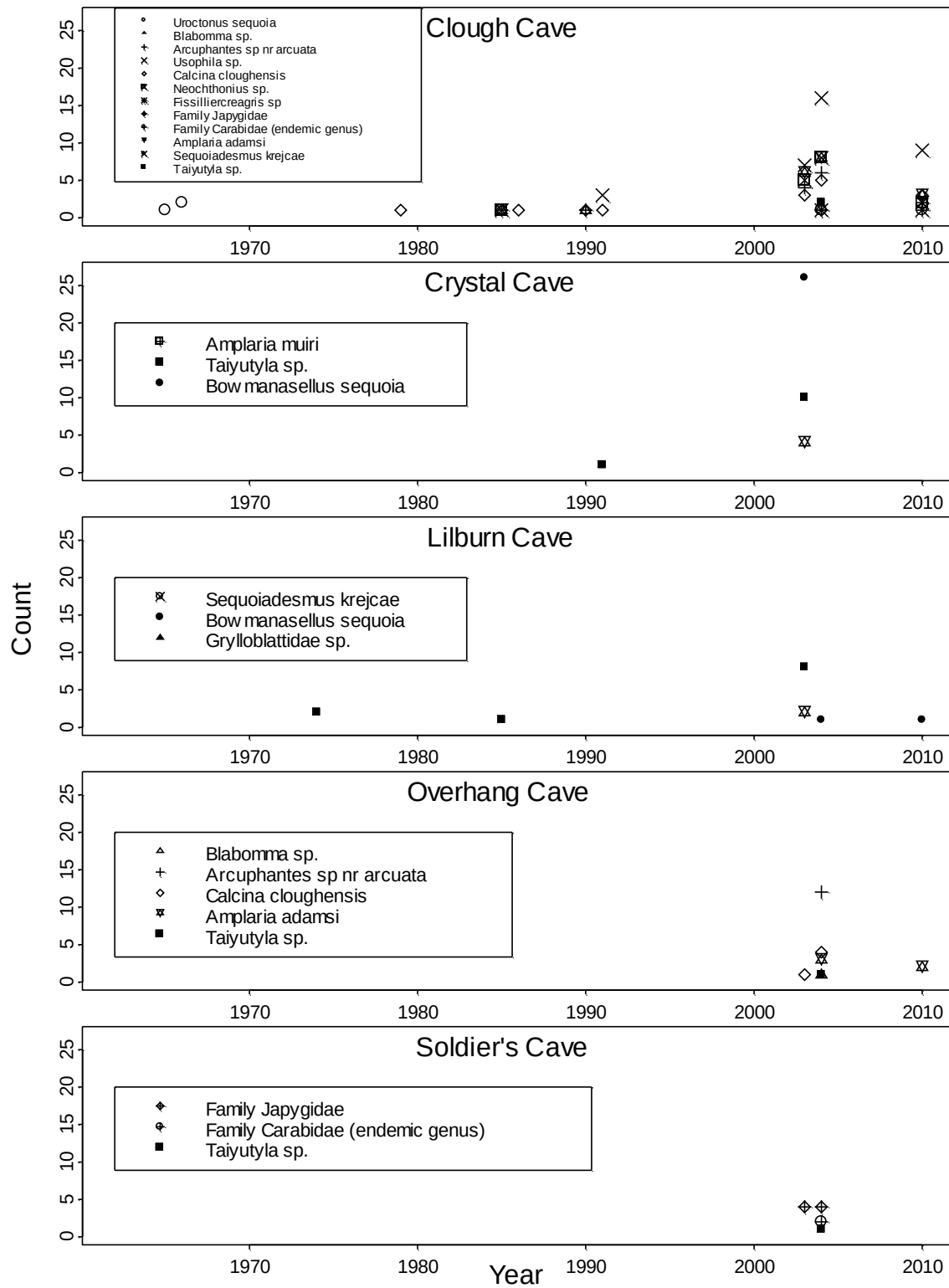


Figure 8. Timeline of species counts in caves since 1965.

Lost Soldier's Cave

Lost Soldier's Cave is at 1,300 m elevation and has 2,405 m of mapped passageway. Much of the cave is dry, save a rarely flowing stream and a perennial lake at the back of the cave. It is gated and currently receives light public use, although this wasn't always the case. Outside of the legendary soldier rescued from the cave around 1910, the cave went unexplored until 1949. But by 1991, trash and mud littered the cave, and a number of speleothems had been destroyed by careless cavers over the years. In 1993 a careful cleaning effort removed trash and mud, and thereafter visitation was strictly controlled. The cave has since been well-protected, and many of the original mineral formations remain intact as some of the most aesthetic in California (Despain 2003).

Lost Soldier's Cave doesn't have a large diversity of endemic invertebrates (Figure 8), but it does boast an endemic beetle in the family Carabidae, found in no other SEKI cave to date (Table 3).

Table 3. Endemic invertebrate species in Soldier's Cave. Presence is indicated by (+), absence by (-).

Common Name	Taxa	Soldier's Cave presence/absence
Scorpion	<i>Uroctonites sequoia</i>	—
Spider	<i>Blabomma</i> sp.	—
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	—
	<i>Usophila</i> sp.	—
Harvestmen	<i>Calcina cloughensis</i>	—
Pseudoscorpions	Family <i>Chthoniidae</i>	—
	<i>Neochthonius</i> sp.	—
	<i>Fissilliercreagris</i> sp.	—
Dipluran	Family <i>Japygidae</i>	+
Beetles	Family <i>Carabidae</i> (endemic genus)	+
Millipedes	<i>Amplaria adamsi</i>	—
	<i>Amplaria muiri</i>	—
	<i>Sequoiadesmus kreycae</i>	—
	<i>Pratherodesmus despaini</i>	—
	<i>Taiyutyla</i> sp.	+
Isopod	<i>Bowmanasellus sequoia</i>	—
Rock Hopper	<i>Grylloblattidae</i> sp.	—

Overhang Cave

Overhang Cave is an ungated cave at 1,143 m. It gets its water from a drip pool source and receives light public visitation. It was, however, heavily vandalized in November 2003 and “every formation that once decorated this cave was destroyed” (Shane Fryer, in Kaweah Commonwealth 2004). Whether this affected cave fauna is difficult to say, as only a few invertebrate species were found on a previous monitoring effort in 2001. Krejca inventoried the cave 10 days after the incident to find one endemic and a number of other invertebrates. Six months later, the number of endemics had jumped (Figure 8). Overhang Cave has the largest overall number of invertebrates (not diversity, and not necessarily endemics – see Clough Cave) collected within it in the parks. But, this is likely due to the numerous surface invertebrates collected in the cave’s large overhanging entrance.

Table 4. Endemic invertebrate species in Overhang Cave. Presence is indicated by (+), absence by (–).

Common Name	Taxa	Overhang Cave presence/absence
Scorpion	<i>Uroctonites sequoia</i>	–
Spider	<i>Blabomma</i> sp.	+
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	+
	<i>Usophila</i> sp.	–
Harvestmen	<i>Calcina cloughensis</i>	+
Pseudoscorpions	Family <i>Chthoniidae</i>	–
	<i>Neochthonius</i> sp.	–
	<i>Fissilliercreagris</i> sp.	–
Dipluran	Family <i>Japygidae</i>	–
Beetles	Family <i>Carabidae</i> (endemic genus)	–
Millipedes	<i>Amplaria adamsi</i>	+
	<i>Amplaria muiri</i>	–
	<i>Sequoiadesmus krejcae</i>	–
	<i>Pratherodesmus despaini</i>	–
	<i>Taiyutyla</i> sp.	+
Isopod	<i>Bowmanasellus sequoia</i>	–
Rock Hopper	<i>Grylloblattidae</i> sp.	–

Crystal Cave

Crystal Cave is at 1,384 m elevation. It has 4,770 m of mapped passageway and is fed by a perennial stream. There is an oral history indicating that Crystal Cave has been visited by native Inyana people for possibly thousands of years and was an important ceremonial site (Despain 2003). Westerners first discovered the cave in 1918, but it wasn't until the 1930's that it was developed for general public access. Development inside the cave included blasting to enlarge passages, quarrying to make restrooms, adding fill for cave trails (dirt, gravel, sand, cement), altering the course of the cave stream, and laying thousands of feet of two-inch cable (Despain 2003). The cave opened commercially to the public in 1940. Visitation peaked at 65,000 people/year in the 1960's, but has been restricted after 1992 to approximately 54,000 people/year. It is possible that the intense development and use has destroyed endemic cave species and/or their habitat, but visitors are restricted to 20% of the entire cave system.

Cosmogenic burial dates show Crystal Cave to be approximately 1.1 million years old (Despain and Stock, 2005). It has large rooms, mazes, an active stream and many speleothems. It is the type locality for the *A muiri* millipede and also home to two aquatic cave adapted species and two cave adapted isopods, one aquatic (*B. Sequoiae*) and one terrestrial (*B. heroldi*). Crystal has a wider range of temperatures than many of the other larger park caves due to large entrances and strong airflow. Vertebrate species are also common in this cave with at least six bat species, two salamander species, ring-tailed cats and several bird species nesting in entrances.

Table 6. Endemic invertebrate species in Crystal Cave. Presence is indicated by (+), absence by (–).

Common Name	Taxa	Crystal Cave presence/absence
Scorpion	<i>Uroctonites sequoia</i>	–
Spider	<i>Blabomma</i> sp.	–
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	–
	<i>Usophila</i> sp.	–
	<i>Calcina cloughensis</i>	–
Harvestmen	Family <i>Chthoniidae</i>	–
Pseudoscorpions	<i>Neochthonius</i> sp.	–
	<i>Fissilliercreagris</i> sp.	–
	Family <i>Japygidae</i>	–
Dipluran	Family <i>Carabidae</i> (endemic genus)	–
Beetles		
Millipedes	<i>Amplaria adamsi</i>	+
	<i>Amplaria muiri</i>	+
	<i>Sequoiadesmus krejcae</i>	–
	<i>Pratherodesmus despaini</i>	–
	<i>Taiyutyla</i> sp.	+
Isopod	<i>Bowmanasellus sequoia</i>	+
Rock Hopper	<i>Grylloblattidae</i> sp.	–

Lilburn Cave

The longest cave discovered on the western slope of North America (Despain 2003), Lilburn cave has 33,512 m of mapped passages (over 20 miles), with active exploration still underway. It is at 1,600 m elevation, near Redwood Mountain Grove in Kings Canyon National Park. Its

water sources are several perennial stream, and access is only allowed for scientific study so the cave gets light public use.

Since its discovery in 1903, consistent exploration by several caving groups, including the Cave Research Foundation, has systematically uncovered increasingly more cave area. Despite its size and in part because of its undecorated and robust walls, it hosts relatively little cave life. Cave invertebrates are widely distributed through miles of passages or are found in the cave stream or in upper level areas of the cave with roots and surface organic matter. (Despain 2003). Endemic species include millipedes, the *B. Sequoiae* isopod and the *Grylloblattidae* rock hopper.

Table 7. Endemic invertebrate species in Lilburn Cave. Presence is indicated by (+), absence by (-).

Common Name	Taxa	Lilburn Cave presence/absence
Scorpion	<i>Uroctonites sequoia</i>	—
Spider	<i>Blabomma</i> sp.	—
	<i>Arcuphantes</i> sp. nr <i>arcuata</i>	—
	<i>Usophila</i> sp.	—
Harvestmen	<i>Calcina cloughensis</i>	—
Pseudoscorpions	Family <i>Chthoniidae</i>	—
	<i>Neochthonius</i> sp.	—
	<i>Fissilliercreagris</i> sp.	—
Dipluran	Family <i>Japygidae</i>	—
Beetles	Family <i>Carabidae</i> (endemic genus)	—
Millipedes	<i>Amplaria adamsi</i>	+
	<i>Amplaria muiri</i>	—
	<i>Sequoiadesmus krejcae</i>	+
	<i>Pratherodesmus despaini</i>	—
	<i>Taiyutyla</i> sp.	—
Isopod	<i>Bowmanasellus sequoia</i>	+
Rock Hopper	<i>Grylloblattidae</i> sp.	+

Kaweah Cave

Kaweah Cave is the lowest elevation cave in the parks, It contains narrow twisting passages, modest rooms and lakes at the water table. Kaweah has a large entrance that likely saw Native American use. The cave is frequently used by bats and salamanders as well as invertebrates. Kaweah is the type locality for the *P. despaini* millipede and has at least one other unique millipede species (Cambalid), as well as cave adapted pseudoscorpions and spiders. Data from this cave was not available for this report.

Stressors

Climate

Cave invertebrates are susceptible to climate change – both the direct effect of increased temperatures and the indirect effect of decreased summer water availability due to decreased high elevation snowpack. Most caves have cool temperatures and humidity at or near saturation, to which the invertebrates are sensitively tuned. If temperatures continue to rise at their current rate, some may not adapt. Observations in Clough Cave have demonstrated a change in the numbers of active animals throughout the summer season. While many animals are present and active in the spring months when the cave is at its wettest with the highest humidity, later in the year animals are no longer active and very difficult to find (Daryl Ubick, pers comm.).

Of all the species, *Grylloblattidae* sp. is likely to be the most impacted, as they are at the south end of their range for the sub-Class.

Streamwater flow reduction associated with climate change is the greatest potential stressor for the aquatic species, for example *B. sequoiae*. Unknown is the location of extent of actual or potential impacts.

Air Quality/Water Quality

It is possible that airborne nitrogen fertilizers and pesticides from the heavily farmed upwind San Joaquin Valley, and from illegal marijuana cultivation within the parks' backcountry, find a way into water systems that enter the caves. Currently the impact is unknown.

Fire

B. sequoiae is susceptible to altered fire regimes, as fires cause chemical changes to surface streams, which then flow underground to become sub-surface streams. Fires also cause increased organic matter in streams. Fire-fighting efforts can include fire-retardants that are known to be toxic to invertebrate species, which are washed into streams after application. Stream chemical changes as a result of fire are particularly relevant in the watersheds of Redwood and Yucca creeks, where surface streams are diverted underground to form cave streams that are habitat for these animals. However, evidence shows *B. sequoiae* to be robust to fire effects--the Yucca Creek and Redwood Canyon watersheds have seen extensive fires in recent decades, including fire retardant application in 2008 (Tobin et al. 2009), and *B. sequoiae* appear to persist in these watersheds without change in measured populations. South Fork caves are less impacted because subterranean waters are less susceptible to surface chemistry. However, if fires burn the trees with roots in the caves that are food sources for invertebrates, the invertebrate populations could be adversely impacted. This is particularly true for Clough Cave.

Fire suppression actions can also effect invertebrates through the use of chemical fire retardants, the clearing of fire lines and the use of heavy equipment.

Land Use Fragmentation

The Generals Highway crosses both watersheds containing *B. sequoiae* and spills of hazardous materials along the highway could be dangerous to these animals. For South Fork caves and

Crystal Cave human cave use has trampled animals and causes enrichment of food sources. This has been actively witnessed in the caves.

Past Management Actions

The development of Crystal Cave likely effected *B. sequoiae* from 1938-40. The long term lack of management at Clough Cave has also likely had impacts on South Fork area invertebrates. Past management actions at these two caves in particular have had a strong influence on an understanding of current conditions. Both caves are seriously degraded in unknown ways and the original condition of these caves is unknown.

Assessment

The best indicator of cave invertebrate condition is the presence or absence of species in their host caves over a period of five to ten years or more. The scope of this analysis covers 6 caves and 45 years of observation. There is not enough data to do robust statistics, but some general trends can be noted (Table 8).

Generally, species are shared between caves when the caves are spatially close. That is, the South Fork caves share more species than they share with the northern caves. All species in Clough cave are found in one of the other caves in the cluster, except *Chthoniidae* and *Usophila* sp. To date, these latter species are unique to Clough Cave. *Arcuphantes* sp. nr *arcuata* is the most abundant endemic species shared among the South Fork cave cluster. Clough is an important cave for invertebrate species diversity.

There is one species that is found in only both northern caves, *Bowmanasellus sequoia*. Unique to individual caves in the north are *Grylloblattidae* sp. and *Amplaria muiri*.

The species that are found in both northern and southern caves are *Sequoiadesmus krejcae*, and *Taiyutyla* spp. These are either common species that are found in many species throughout the intervening region, or can somehow disperse over large distances.

Over the period of record, the most consistently observed invertebrate is *Calcina cloughensis*. However, the species of longest record, that was first observed in 1965 and as recently as last year, is *Uroctonites sequoia*, specific to Clough Cave.

B. sequoia appears to be the most susceptible to human stressors, particularly because it is aquatic.

The parks cave millipede diversity is significant while aquatic species numbers are low and amphipods, common cave species in other regions, are absent.

Elevation clearly plays a role in overall cave diversity with lower elevation and warmer caves having more species, more cave-adapted species and more endemics. Higher elevation caves, such as in Mineral King, were not included in this study due to their lower numbers of animals.

It is evident that SEKI caves benefitted from the increase in protection and monitoring resulting from an active cave management program starting in 1992 and the Cave Management Planning efforts started in 1994. Some passages are open to visitation, some sections have visit restrictions and other passages are completely closed to protect delicate cave features. Although the data are not abundant enough to demonstrate cause and effect of cave management, the protection of cave habitat from degradation and destruction is a prerequisite to invertebrate species' health. That new species continue to be discovered at SEKI, and that SEKI is a hub of cave invertebrate faunal diversity provides ample incentive to continue such efforts.

Table 8. Summary of cave invertebrate number and diversity in 6 study caves since 1965, by species.

Species	Cave	1965	1966	1974	1979	1985	1986	1990	1991	2001	2003	2004	2010
<i>Blabomma</i> sp.	Clough					1		1					
	Overhang											1	
<i>Arcuphantes</i> sp. <i>nr</i> <i>arcuata</i>	Clough					1		1			4	6	2
	Overhang											12	
<i>Calcina cloughensis</i>	Clough		6		1	1	1	1	1		3	5	3
	Overhang										1	4	
<i>Neochthonius</i> sp	Clough					1					5	8	2
<i>Fissilliercreagris</i> sp.	Clough												1
Family Japygidae	Clough												
	Soldiers										4	1	
												4	
Family Carabidae (endemic genus)	Clough											1	
	Soldiers											2	
<i>Amplaria adamsi</i>	Clough										6	8	3
	Overhang											3	2
<i>Sequoiadesmus krejcae</i>	Clough											1	
	Lilburn										2		
<i>Taiyutyla</i> spp	Clough											2	
	Soldiers											1	
	Overhang											1	
	Crystal										4		
<i>Bowmanasellus sequoia</i>	Lilburn			2		1					8		
	Crystal								1		10		
Unique to individual caves													
<i>Grylloblattidae</i> sp.	Lilburn											1	1
<i>Amplaria muiri</i>	Crystal										26		
Family Chthoniidae	Clough												
<i>Usophila</i> sp.	Clough								3		7	16	9
<i>Uroctonites sequoia</i>	Clough	1	2			1							1

Gaps in Understanding

More data on populations, distribution and seasonal variations are needed. Krejca (2006) envisioned a database that can be queried to address specific questions, which she started to populate. For example a query on the microhabitat in which all *Calicina sp.* harvestmen occur would help scientists describe the needs of the species and land managers protect those microhabitats within the cave. An examination of the average and range of distances into caves *Calicina sp.* harvestmen occupy may help a taxonomist determine if the taxon is an obligate troglophile or a troglaxene (needs to leave the cave for some life stages), which would also lead to different management strategies to protect the species. Trends of population levels are difficult to determine from sporadic monitoring by a variety of researchers, but the database could facilitate extracting data, such as sampling intensity for each species, which will help determine more reliable estimates of relative abundance for different taxa (Krejca 2006).

Another knowledge gap is the quantification of energy flow into caves. Energy flow into caves is generally sparse and sporadic and probably represents the most common cause of extirpation or extinction of cave species.

There is also a need to continued inventory work as new species and range extensions for known species are frequently being recognized within park caves. The final species lists for all park caves have yet to be determined.

Recommendations for management and future research

Management of the caves in Sequoia and Kings Canyon National Parks has been set at a high standard. Cave access is generally restricted to all but the commercial Crystal Cave and some recreational use of Lost Soldiers Cave by special permit. Sites that have been threatened with visitation are gated. Protection and monitoring recommendations include watershed protection, surface vegetation protection, monitoring human use of caves, and monitoring long term population patterns of key species (Krejca 2006). Also recommended is the addition of human activity sensors to at least one of the easier access caves that contain a large diversity of sensitive species, Kaweah Cave. An activity sensor would verify that the use of this cave by unauthorized visitors is minimal. If visitation increases significantly, a small, unobtrusive gate in a narrow section at the back of the first room may be warranted. Park managers may have insight into other caves that are close to roads or receiving unwanted visitation (Krejca 2006).

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