

A PETITION TO LIST

THE BIG SPRINGS ISOPOD,
Bowmanasellus sequoiae,
AS A THREATENED SPECIES UNDER THE
ENDANGERED SPECIES ACT



Figure 1: A Big Springs Isopod (*Bowmanasellus sequoiae*) captured during a biological inventory project [REDACTED] Sequoia National Park, California. These animals represent a genus endemic to Sequoia and Kings Canyon National Parks, California. Photo by Jean Krejca.

Prepared by Joel Despain, MS
Retired, National Cave and Karst Research Institute
Former Cave Management Specialist for the USDA, Forest Service
and the USDI, National Park Service

Acknowledgments

I wish to thank and acknowledge the many cavers who, over decades, have worked diligently to map, document and study the fantastic caves of California and Sequoia and Kings Canyon National Parks. These volunteer, citizen-science efforts have revealed so much, including the Big Springs Isopod. Without volunteer California cavers, we would know almost nothing of the caves of the 31st State.

I also wish to thank and acknowledge the authors of the seminal book, the *Cave Fauna California*, which provided the first and only comprehensive understanding of the amazing animals that live in the caves of the Golden State: Drs. William R. Elliott, James R. Reddell, D. Craig Rudolph, G.O. Graening, Thomas S. Briggs, Darrell Ubick, Rolf Aalbu, Jean Krejca and Steven J. Taylor.

And I wish to thank and acknowledge Dr. G. O. Graening for his tireless work managing the California cave life database, without which the aforementioned book and this petition would have been impossible to produce.

March 18, 2025

Secretary of the Interior,
Mr. Doug Burgum
Department of the Interior
1849 C Street, N.W.
Washington, D.C. 20240

Dear Secretary Burgum,

Thank you for your time today. It is my honor to fulfill my responsibilities as an American citizen in petitioning the US Fish and Wildlife Service, an agency under your direction, to list *Bowmanasellus sequoiae* as a Threatened Species under the Endangered Species Act. These animals are commonly known as the Big Springs Isopod. This petition also includes the request to designate critical habitat for this very rare, cave-adapted species. Habitat for these animals lies solely within Tulare County, California and within the boundaries of Sequoia and Kings Canyon National Parks. This is a single species genus making this an endemic genus to Sequoia and Kings Canyon National Parks, administered by the National Park Service, another agency under your direction. Please allow this cover letter to be your official notification of this Petition and to be the required date and signature for this Petition to the Service.

I am filing this petition under the Endangered Species Act, 16 U.S.C. sections 1531-1543 (1982). Petitions to grant Threatened or Endangered status to a species or populations are described under 5 U.S.C. section 553(e), and 50 C.F.R. part 424.14 (1990). These regulations grant citizens, citizens groups and interested parties the right to petition for the issuance of rules to protect a species from the Assistant Secretary of the Interior.

I request that Critical Habitat be designated for *B. sequoiae* as described in 16 U.S.C. 1533(b)(6)(C) and 50 CFR 424.12, and pursuant to the Administrative Procedures Act (5 U.S.C. 553).

It is unusual for a private citizen to file a petition. Perhaps people are put-off by the requirements and bureaucracy. I am petitioning out of a deep concern for the well-being of the unique and important ecosystems and species found in the southern Sierra Nevada. As a former federal employee (now retired) who worked in cave management at Sequoia and Kings Canyon, I know the area well.

These are amazing animals that have adapted to survive in a completely dark cave environment with little food or resources. They have evolved to such an extent as to be a unique genus. And the Park Service is ignoring these animals while their habitat is radically altered by fire, climate change and on-going visitor services. It is important that rare species be protected in the National Parks, our most cherished landscapes.

Most Sincerely,

Joel D. Despain

[REDACTED]

[REDACTED]

A Petition to List the Big Springs Isopod, *Bowmanasellus sequoiae*, as a Threatened Species under the Endangered Species Act

Table of Contents

Cover page	1
Figure 1: <i>Bowmanasellus sequoiae</i>	1
Acknowledgments and Reviewers	2
Cover Letter / Notice of Petition	3
Table of Contents	5
Federal Cave Resources Protection Act Notice	6
1. Natural History and Biology of the Big Springs Isopod	7
A. Geographic Distribution and Habitat	7
Figure 2: Type locality for the Big Springs Isopod	7
Figure 3: Range of the Big Springs Isopod	8
B. Taxonomic History and Physical Characteristics	10
Figure 4: Map of Crystal Cave	10
C. Ecological Role, Ecological Importance and Behavior	11
2. Classifications and Status	13
A. State and Federal Classifications	13
B. Status of the Big Springs Isopod	13
Figure 5: Big Springs	13
3. Current and Potential Threats -- A Summary of Factors for Consideration	15
A. The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range	15
1. Crystal Cave Development	15
2. Crystal Cave Tours	15
3. Potential impacts of the Generals Highway	17
Figure 6: <i>B. sequoiae</i> watersheds and park roads	17
4. On-going Drought and Climate Change	18
5. Fires Exacerbated by Climate Change and Their Impacts	18
6. KNP Complex BAER Report	19
7. Climate Change Exacerbated Flooding	20
8. Fire Suppression Impacts	20
B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes	21
C. Disease or Predation	21
D. The Inadequacy of Existing Regulatory Mechanisms	21

1. The NPS Organic Act	
2. Shortcomings of NPS Management	22
E. Other Natural or Manmade Factors Affecting its Continued Existence	22
4. Critical Habitat Determination	22
5. Requirements for Petitions	23
6. Conclusion	22
7. References	23
8. Glossary	24

Federal Cave Resources Protection Act Notice

Some information in this petition may be protected under the Federal Cave Resources Protection Act, which protects significant caves found on Federal land. All National Park Service caves are considered significant and are protected under this law. The release or dissemination of information in this document by a federal employee could be a violation of this Act.

A Petition to List
The Big Springs Isopod,
Bowmanasellus sequoiae,
As a Threatened Species under the Endangered Species Act

1. Natural History and Biology of the Big Springs Isopod

A. Geographic Distribution and Habitat

The Big Springs Isopod (Figure 1) is an aquatic, cave-adapted and troglobitic species found only within cave streams and karst aquifers in the drainage of the North Fork of the Kaweah River in Tulare County, California (Elliott, et al. 2017). It is the only species in a genus that is endemic to the North Fork. This watershed is part of the southern Sierra Nevada and is largely contained within Sequoia and Kings Canyon National Parks (US Department of the Interior, National Park Service [NPS]); Giant Sequoia National Monument (US Department of Agriculture, National Forest Service, Sequoia National Forest); and Bureau of Land Management (US Department of the Interior) lands as well as private lands at low elevations in the community of Three Rivers. The cave and karst areas that contain habitat for the animals are limited to lands within the two national parks, making the *Bowmanasellus* an endemic park genus. Save a nematode in Crystal Cave, it is one of only two aquatic cave-adapted animals in the national parks where more than 40 cave-adapted species and many endemics occur. Most of the range of the animal (save Crystal Cave and the area right around it) is federally-designated Wilderness.



Figure 2: A caver with the Cave Research Foundation

██████████ in the depths of Lilburn Cave, Kings Canyon National Park. ██████████
██████████. Photo by Greg Roemer

The caves and karst aquifers within the watershed and across the area are formed within narrow, elongated bands of Mesozoic marble that occupy only a tiny percentage of the landscape being only a few square kilometers in size. Despite the small size of the carbonate bodies, this region contains some of the most significant cave and karst development in California. ██████████
██████████

Here the flow of Redwood Creek is diverted underground to form the cave stream (Figure 2). The Cave Research Foundation (CRF) conducts research and inventory work in this cave under permit from the NPS.

Along Yucca Creek is Crystal Cave, a popular show cave within Sequoia National Park with 4,741 meters of mapped passages and Hurricane Crawl Cave at 3,132 meters in length. These three caves all contain cave streams and lakes that are habitat for the isopod. (Elliott, et al. 2017; Despain 2004; Lewis 2008, Tinsley, et al. 1981).

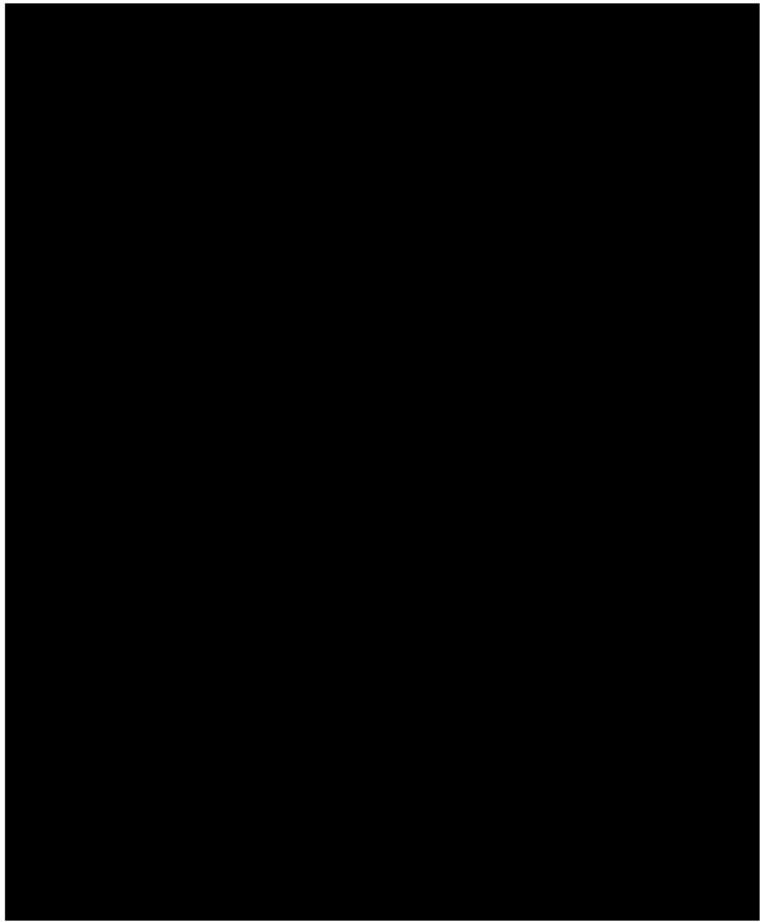


Figure 3: Range of the Big Springs Isopod in the watershed of the North Fork of the Kaweah River in Sequoia and Kings Canyon National Parks, Tulare County, California. Marble adopted from Moore and Sisson 1987.

Also found in the area are more than 50 smaller caves, sinkholes, sinking streams and multiple karst

springs. The Big Springs Isopod has been found in a number of these springs

(Elliott, et al. 2017). All of the springs are found at the margins of deep canyons adjacent to surface streams (Figure 3).

The caves and karst springs of the region have not been thoroughly inventoried for cave animals. Often, multiple visits are required to fully document the fauna of a cave or karst area (Krejca and Weckerly 2008). And the low number of cave-adapted species in the region compared to other better studied areas reveals that more species are likely to be found (Gibert and Deharving 2002). However, initial cave biological inventory work was completed in the area in 2006 by Zara Environmental, Buda Texas under contract with the NPS.

With only the limited initial inventory, it is likely that more species will be found in the caves and karst springs of the region and that additional populations of *B. sequoiae* may be discovered. However, for this cave-obligate species, all possible populations would be restricted to caves and karst within the small bands of marble in the area.

This region of the southern Sierra Nevada has a Mediterranean climate with wet, cool winters and long dry, hot summers. The terrain is steep with deep river and stream canyons and rising mountains to the east. The caves and karst springs the isopods are found in, range in elevation from 1200 to 1600 meters. These elevations within the national parks include diverse plant communities varying from California chaparral brush with chamise and several manzanita species, to black oak woodlands, to lower elevation mixed conifer forests and Giant Sequoia groves.

In the watersheds containing the isopods, spring floods are common due to heavy seasonal rains and melting snows. Annual flooding moves organic matter and debris from the surface into the cave and karst systems. For many months, from late summer into fall, streams flow at base level with almost no variation in discharge. At this time of the year the karst aquifers of the Kaweah River watershed provide a high percentage of the stream and river flows found in the entire basin (Tobin and Schwartz 2020) via the numerous karst springs found in the North, Marble, Middle, East and South forks. This makes the karst a critical component of park riparian and stream-side habitats by providing perennial water during the driest and hottest times of the year. Big Springs Isopods and their populations, distributions and health are potential indicators of the health and status of these critical aquifers.

Caves of the region are characterized by anastomotic mazes (Tinsley, et al. 1981; Despain 2004; Despain, et al. 2016) where dense interconnected passages form parallel to each other due to inundation by sediments and flooding. Sediments are derived from the granitic rocks upstream that predominate in the Sierra Nevada.

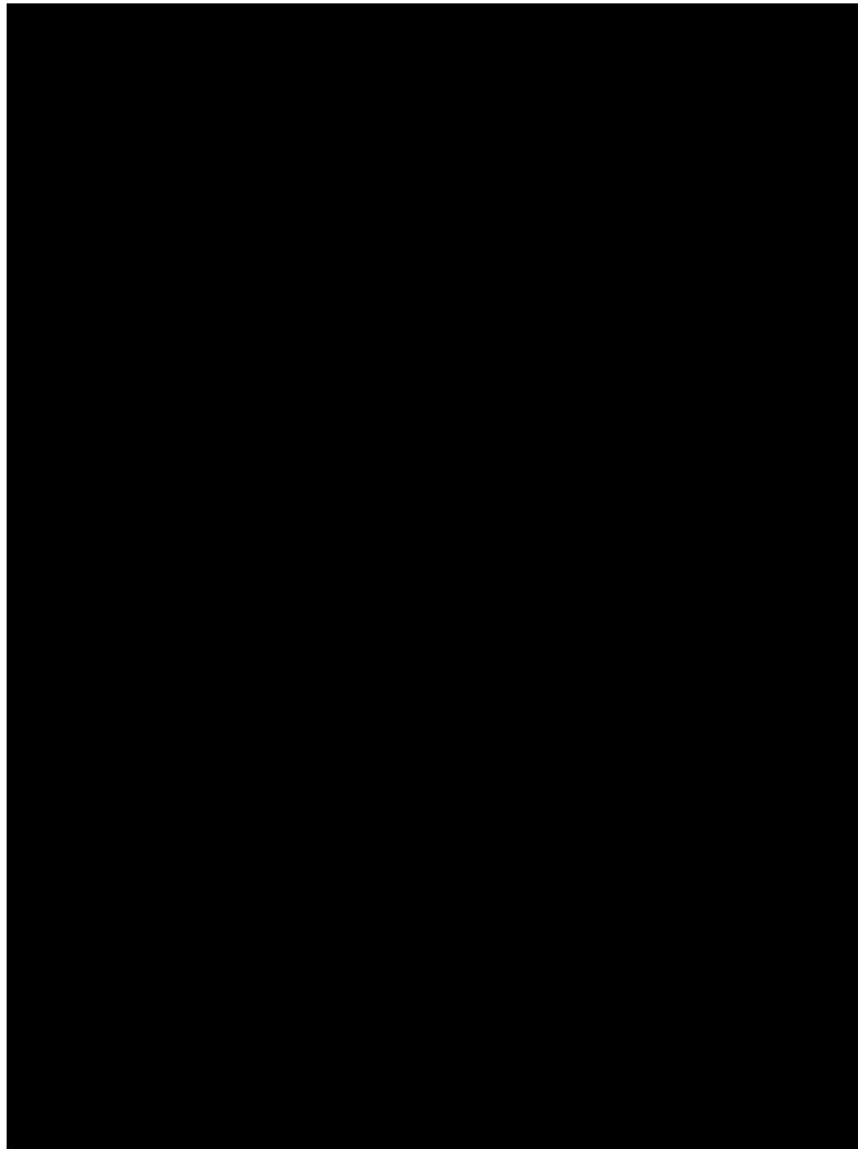
Isopods must adapt to withstand the aforementioned seasonal floods that bring food into their environment, but that also create high-velocity, turbulent water with a heavy sediment load of sand and gravel. Presumably they can find refuge in small, calm areas away from the main flow. The rest of the year, the species has likely been left with a dense interconnected network of rooms and passages with low velocity flow creating a large area of habitat despite the small area of karst. This can be seen in the lowest, upstream areas of Crystal Cave where numerous phreatic lakes are found, some with underwater branching passages. And in Lilburn Cave, where passages can flood to a depth of 40 meters rendering much of this very complex cave inaccessible to humans but as habitat for isopods for months

or years at a time (Tinsley, et al. 1981).

Population distribution of the animals is not even and is likely determined by the extent of habitat and food sources in this very low energy environment where food is often scarce (Gibert and Deharving 2002).

As detritivores, aquatic isopods go where plants and decaying plant matter can be found. This includes stream and flood deposits of detritus such as sticks and leaves.

The extent of surface originating flood deposits is limited in the cave environment by natural constrictions in cave passages (Despain, et al 2016). Water backs up behind these constrictions, slows and organic material and sediments fall out of the water column to be deposited on the floor of the cave passage. This means that plant detritus will be more common in the upstream sections of caves. Thus, there may be more food and more isopods in upstream locations.



[REDACTED]

B. Taxonomic History and Physical Characteristics

Isopods are crustaceans, which are a vast and diverse group of aquatic, terrestrial and marine invertebrate animals with approximately 10,000 species worldwide (King 2004). The Big Springs Isopod is named for the large spring that terminates the greater Lilburn Cave system [REDACTED] Kings Canyon National Park. Big Spring is the resurgence for this large karst system that extends north for at least 5 kilometers where marble underlies the canyon floor. The spring has been hydrologically connected to Lilburn, but is considered a separate cave since no human has ever passed between the two caves that have separate entrances (Tinsley, et al. 1981). [REDACTED]

[REDACTED]

[REDACTED]

Big Springs Isopods are nearly clear and colorless and can be very difficult to see while in a cave stream. Their transparent bodies reveal their internal organs. They are small. The male and female used to describe the species were 5.3 and 3.3 mm long, respectively. (Bowman 1975).

Bowman originally described the species in 1975 as *Caecidotea sequoiae* (Bowman 1975). In 2008, Lewis re-examined the specimens and after research on several western isopods, he reclassified them based upon the additional taxonomic investigations. Lewis defined the new genus *Bowmanasellus* with *sequoiae* as its only species (Lewis 2008).

The Big Springs isopods have many cave-adapted characteristics. Besides lacking the pigment found in their surface-dwelling relatives, they are completely eyeless. They also have elongated appendages and antennae, an adaptation to the open environment of the karst aquifers they call home. They are likely to have a different life history than their surface relatives, living longer and laying fewer eggs over a longer period of time (Gibert and Deharving 2002). As a fully cave-adapted and troglobitic species, *B. sequoiae*, is entirely restricted to the cave environment. They cannot successfully feed, breed or survive on the surface or in surface streams.

B. sequoiae is the southernmost member of the Asellidae family of isopods. The relatives of these animals all live farther to the north where climatic conditions are likely to be cooler and more wet. This makes these populations more susceptible to global warming and drought while simultaneously making it more important to protect the genus since it represents the southernmost examples of these animals and the utilization of this ecological niche (Elliott, et al. 2017).

C. Ecological Role, Ecological Importance and Behavior

Isopods breed after females molt, and they grow their young internally. They are born as juveniles with fewer body segments than adults. Big Springs isopods are believed to be detritivores that feed on plant and organic material within the cave streams. They are most often found and are in the highest concentrations where there are abundant food resources [REDACTED] or where organic matter such as sticks, pine needles and leaves have gathered in cave lakes and streams subsequent to annual spring floods.

As detritivores, scavengers and parasites, isopods often are at lower or middle trophic levels in ecosystems. But cave ecosystems are odd with no primary producers and few or no top predators. These ecosystems are described as "truncated" (Gibert and Deharvang 2002). This holds true in the cave habitats of the southern Sierra Nevada. *B. sequoiae* has no known predators and no known competitors. No fish or amphipods or other aquatic invertebrates or vertebrates are found in these karst aquifers with the exception of the undescribed nematode [REDACTED]. The isopods almost have it all to themselves. Thus, limits on population sizes are likely to be determined by the available food resources and suitable habitat.

While *B. sequoiae* has been seen free swimming in the open water column [REDACTED] on multiple occasions, most observations of these animals have been in association with the bottom and sides of springs and underwater cave passages. Often the animals are intermingled with their food. This has been seen [REDACTED], where the animals were in among leaf litter, at [REDACTED] where they have been seen among decaying sticks on the bottom of a sedimented stream and in [REDACTED]

As nearly the only invertebrate detritivores in aquatic cave systems of the area, Big Springs Isopods play an important ecological role in the decomposition and utilization of organic matter in these aquifers. While it is an understudied area, ecosystem services by groundwater invertebrates have been documented to include water purification, bioremediation and water infiltration. Due to their important ecological role, they can be seen as "keystone" species in aquatic cave environments (Boulton, et al). Griebler and Avromov (2014) concluded that 1) purification of water and its storage in good quality for decades and centuries, 2) active biodegradation of anthropogenic contaminants and inactivation and elimination of pathogens, 3) nutrient recycling, and 4) mitigation of floods and droughts are directly connected to the presence and activities of groundwater organisms, such as the Big Springs Isopod.

2. Classifications and Status

A. State and Federal Classifications

Natureserve species rankings are used by the California Department of Fish and Wildlife to assess declining species and their status in the state. On their web page *B. Sequoiae* is listed as an S2 species (Natureserve 2025). Natureserve defines an S2 species as:

"Imperiled: At high risk of extinction or collapse due to very restricted range, very few populations or occurrences, very steep declines, or other factors."



Figure 5: Big Springs and researchers with the Cave Research Foundation.

Photo by William Frantz.

The “S” refers to the sub-national range of animals in this category and the localization of the rankings. Natureserve refers to these animals as the Sequoia Cave Isopod.

The Big Springs Isopod is not currently protected under federal law. However, an internal NPS report,

"Appendix 18 -- Cave Invertebrates A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks" (Panek and Despain 2013), describes the isopods and other park cave animals and their management in detail. It identifies the need for cave management in the parks to study and monitor cave invertebrate species. It includes cave invertebrate monitoring data to date, describes stressors for park cave-adapted animals, discusses key caves and species individually and concludes that of the cave-adapted animals studied:

"*B. sequoiae* appears to be the most susceptible to human stressors." (Panek and Despain 2013)

B. Status of the Big Springs Isopod

The status of the Big Springs Isopod is uncertain, but their numbers are believed to be declining due factors including climate change, forest fires exacerbated by human actions, and park tourism and infrastructure. These stressors are detailed below in Section 3. Limited monitoring of these animals ended in about 2012 due to the reprioritization of NPS funds and changes in personnel.

The very limited range and required habitat of the Big Springs Isopod is key to the threats to this rare animal. Compared to other freshwater isopod species, its total numbers and population would be expected to be comparatively small due to the limited range and lack of suitable habitat. Its habitat needs are very specific and those needs are met in a very small geographic area limited to a few cave and karst systems. This makes *B. sequoiae* particularly threatened with possible severe declines and extinction.

A potential factor in the animals' decline is the extensive development, infrastructure and on-going use and ecosystem impacts immediately adjacent to the largest known population of the animals with the commercial cave tours and operation at Crystal Cave (Despain 2004). Other park developments lie upstream of the animal's very limited habitat.

An important impact is the drought believed to be exacerbated by anthropogenic climate change and associated massive tree and vegetation die off across the west side of the Sierra Nevada between 2013 and 2016. Trees died by the thousands across the entire range of *B. sequoiae* and tree-derived organic matter and roots are readily utilized food sources for the isopods. The on-going drought and vegetation death may have also contributed to the very large forest fire that burned the isopods' entire known habitat, the 2021 KNP Complex. These status-impacting conditions are detailed below in Section 3, below.

3. Current and Potential Threats -- A Summary of Factors for Consideration

A. The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range

1. Crystal Cave Development

B. sequoiae habitat in Crystal Cave has been heavily altered due to tour infrastructure development in the past (Figure 3).

Crystal Cave was developed for the public between 1938 and 1940 by Depression-era crews of the Civilian Conservation Corp. To make flat trail surfaces, passages big enough to walk through and platforms for groups to gather, extensive blasting, alteration and in-fill of cave passages and floors took place. The tour route follows the cave stream and lies above multiple cave lakes, and so tour route construction impacts were extensive in the areas of these areas. The isopod was unknown at the time, and the impacts on the animals at that time due to the construction are also unknown. Cave resources and wildlife were generally not considered during the development of national parks for many decades leading to serious impacts in many NPS caves that were developed for public tours (Pate, undated). As such, these impacts are not a surprise or unusual.

Construction work channelized the cave stream with fill from the first bridge on the tour trail to the start of the Junction Room. The Junction Room itself was greatly altered. The floor on the east side of the room, where the stream originally flowed in a meandering fashion across a wide, open area, was raised as much as two meters. The infill area is 22 meters long and up to 6 meters wide. It channelized the stream along the west side of its original channel. The total fill volume is estimated to be more than 75 cubic meters (2,649 cubic feet). Historic photographs taken during the construction show the passage as it originally appeared with a much lower and wider floor.

There have been NPS proposals to restore the area and install an elevated platform above the stream for the tours. These proposals never got far as the project would be a significant financial undertaking for the park and would have required extensive legal compliance assessments.

Another aspect of the early development of the cave is the Spider Web Gate at the main, large entrance to the cave (there are four other much smaller entrances into Crystal Cave) installed in 1939. This gate is creative, scenic, historic and very popular with visitors to Crystal (except for some young children who are terrified of it). Unfortunately, however, the gate is a barrier to more than just unauthorized people, it is also a barrier to the wildlife that would have naturally originally entered the cave. The first cave specialist for the National Park Service, Ronal Kerbo, suggested that the gate be removed and be placed in the Cascade Creek Canyon outside of the cave entrance for viewing by the public and be replaced with a bat and animal friendly gate to improve ecological conditions inside of Crystal Cave. The gate was modified with some openings being enlarged in the 1990s to allow more bat access following a visit by Kerbo to Sequoia National Park. However, large groups of bats or larger bats would still likely not be able to enter the cave. And larger animals such as black bears and ringtail cats cannot get into the cave even though for an unknown but very long period of time, they could walk right in. Bears frequently den in caves of the region, in fact one other cave near Crystal is named "Bear Den" for the many bear nests found inside.

These comparatively large animals would have had a large impact on the ecology of the cave. Their

nests, fecal materials and bodies would have provided enormous food sources for animals in the cave including the Big Springs Isopod in the stream as well as many other cave-adapted species found in dry parts of Crystal Cave. The exclusion of these animals from the cave due to the gate has likely had a large impact on the cave's original ecosystem, significantly robbing it of nutrients and organic material and radically changing the ecology of the cave. It has been well documented that excluding bats from caves can have large and detrimental impacts on cave ecosystems including aquatic species like the isopod. (Miller 2013, White and Seginak 1987, Sakoui et al. 2020)

2. Crystal Cave Tours

B. sequoiae habitat in Crystal Cave is being curtailed and modified by ongoing commercial cave activities, cave tour infrastructure and large numbers of cave tours and cave visitors.

Commercial cave tour activities are well known to have varied impacts upon the cave environment and the animals contained therein. These impacts include trampling, changes in temperature and atmospheric gas concentrations and nutrient enrichment and ecosystem alteration due to lint, plant and waste introduction. (Eberhard 1999, Chelius, et al. 2009, Dainelli, et al. 2025, Moulds 2005) Most often these impacts fall directly on terrestrial animals, but aquatic species still suffer impacts due to a reduction in ecosystem enrichment. This is most exacerbating in situations with tour caves, such as Crystal Cave.

Crystal Cave opened for tours in 1940. Shortly after World War II, it became the most popular tour cave in California and likely remains so today. The cave is open seasonally, usually from May through September. In busy summers and falls as many as 60,000 people tour the cave and a total of more than four million have traversed its passageways since 1940. Very large tours sometimes exceeding 200 people with a single guide regularly took place on holiday and summer weekends from the 1960s through the 1980s. Following the damage of a cave speleothem ("The Organ") during a large tour and after a significant public outcry that included a negative editorial in a Visalia newspaper, the park limited tours to 70 people per guide. Today most tours are capped at 50 people. However, to keep the number of paying visitors seeing the cave high, the number of tours and operating times for the cave have been expanded. More than 15 tours may travel through the cave on some days.

However, tour operations at Crystal Cave have been suspended since the Covid-19 pandemic starting in 2020. The reopening of Crystal Cave was further delayed by the 2021 KNP complex fires that severely impacted the forests along the Crystal Cave road (although the fire's impacts at the area of the cave itself were not as severe). Thousands of hazardous, dead trees lined the road and clearing them was an enormous job. To make the situation even more dire for the parks and their wildlife and visitors, the winter of 2021 to 2022 had extreme flooding under very heavy precipitation. That winter the parks received more than 300% of their average annual rain and snowfall. After the fires of the preceding fall, the impacts of the rains were severe. Landslides and flooding were widespread and the park's roads, including the Crystal Cave road, were damaged in hundreds of locations. Work to repair the damage by the NPS has been ongoing ever since. Understandably, the primary park roads were prioritized for this work, and the work on the Crystal Cave road continued through 2024. Crystal Cave has now been scheduled for reopening in the summer of 2025 (Sequoia Parks Conservancy 2025).

The tours bring tens of thousands of people into the cave along a trail that is immediately adjacent to the cave stream, [REDACTED]. One of the tour highlights is actually the cave stream itself. Its flow exposes the beautiful banded marble bedrock that is obscured in most

dry parts of the cave. Tours marvel at the lit-up polished marble below the creek.

Cave tours artificially enrich the low energy environment inside of caves in ways that do not mimic natural enrichment from mammals. People bring with them many things that can be sustenance for cave invertebrates and exotic species. This can include trash, small bits of food, clothing fibers, material tracked in from the outside on shoes and more. With the cave trail immediately adjacent to the cave stream, where *B. sequoiae* is found, these materials can be washed into the stream during the winter months when it is raining outside and very wet inside the cave. This can alter the environment and habitat of the isopods. With the large number of people that tour the cave during the short summer season, a great deal of this anthropomorphic material may be present on the trail and the adjacent areas of the cave floor and end up in the stream.

More than 200 lights lie along the cave tour trail. These provide energy for exotic plants that are now common along the tour route. They include algae, moss and even grass. This also enriches and alters the cave environment in an unnatural way including the cave stream.

Crystal Cave is a profitable tour cave operation, and the Conservancy has operated the cave since 1982. Costs for infrastructure such as the cave lighting, restrooms and roads are paid for by the NPS using federal money. This makes Crystal Cave very inexpensive to operate compared to other privately owned cave tour operations found in California and across the US. Tour ticket prices have risen steadily over the years from \$6 in 1985 to more than \$20 in 2019. Crystal Cave provided revenues of \$830,565 in 2015, \$855,733 in 2016 (Sequoia Parks Conservancy 2016) and \$842,366 in 2017, (Sequoia Parks Conservancy 2017) the last year for which annual reports and statements are available on the Conservancy web page prior to the cave being closed. Hundreds of thousands of dollars of that money goes to the NPS each year. Funds from the cave have been used to staff visitor centers, to support educational programs, to buy and rent bear canisters, for park improvements and myriad other things. But only rarely have funds been used for cave research, cave monitoring and other cave work to benefit the caves of the park and the natural features and animals they contain, including *B. sequoiae*.

3. Potential Impacts of the Generals Highway

Upstream of all karst watersheds containing populations of *B. sequoiae* lies a road known as the Generals Highway that traverses the middle elevations of Sequoia and Kings Canyon National Parks. The Crystal Cave road and the Redwood Canyon road also enter these watersheds.

The Generals Highway crosses the headwaters of Cascade, Yucca and Redwood creeks, all streams that feed into caves and springs in *B. sequoiae* habitat (Figure 6). The road is traversed by thousands of cars, recreational vehicles and occasional delivery trucks each day throughout the summer and early fall. Traffic is much lighter during winter and early spring and the road is sometimes closed for at least brief periods of time (sometimes longer) due to snow. The Generals Highway has hundreds of curves and dozens of switchbacks. It rises than 1,500 meters from the park entrance up to the most developed of the Sequoia stands, Giant Forest and then traverses the mountains to the northwest crossing multiple watersheds on its way to Grant Grove in Kings Canyon National Park.

Accidents along the Generals Highway are common, but are usually minor due to the slow speeds of vehicles traversing this very curvy mountain road. Commercial truck traffic is prohibited and for at least two decades there has not been a gas station in the park meaning that large fuel delivery trucks do not generally traverse this road.

While the risk of a large spill of fuel or another toxic chemical is low for the Generals Highway, the potential damage is very high as entire populations of *B. sequoiae* could be eradicated by the water pollution that is likely to move downstream.

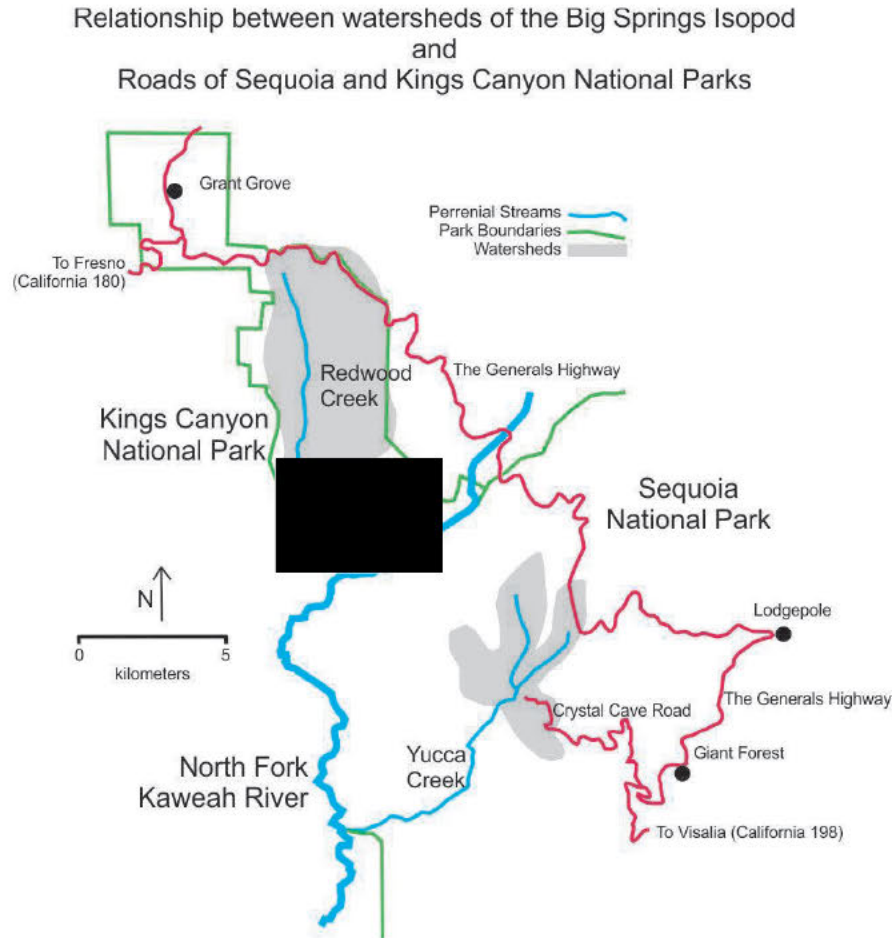


Figure 6: Watersheds where *B. sequoiae* occur and their relationship to park roads, a potential source for spills and hazardous materials.

4. On-going Drought and Climate Change Impacts

Drought in the southern Sierra Nevada associated with climate change has caused major impacts. The national parks are in the area of California impacted by massive tree die off due to drought from 2012 through 2017. Millions of trees died including vast numbers in the parks and in the habitat of the Big Springs Isopod. (Fettig, et al. 2019). While the parks studied and attempted to manage the intense impacts of the drought and the tree die-off, that work was not directed at the isopod. The isopods are dependent on plants, plant material and roots for food and their survival.

Being aquatic animals, the Big Springs Isopods are also dependent on karst groundwater systems for their survival. This means that drought is a direct threat to these animals and their limited habitat. Many of the locations where the animals have been found are springs where water comes to the surface along

the margins of deep canyons. These groundwater and spring systems can be greatly reduced or even disappear due to climate change induced drought (Fiorillo 2009). Without adequate groundwater, these animals' habitat is curtailed, modified and even potentially destroyed. With the impacts of climate change continuing to increase, more droughts are very likely in southern California, exacerbating this situation for these animals.

Drought reduces spring runoff in these watersheds, reducing spring flooding that brings food into these subterranean habitats. Flood waters also nourish roots that the isopods feed upon. With climate change exacerbated droughts, food supplies for the isopods will potentially be reduced.

5. Fires Exacerbated by Climate Change and Their Impacts

The range of these animals is limited (Figure 3) and these watersheds have seen strong impacts from two forest fires in recent years. In 2009, the Hidden Fire burned over much of the range of the isopods in the Yucca Creek drainage.

In the fall of 2021, the KNP Complex fire burned through the entire range of *B. sequoiae* consuming much of the vegetation in the middle elevations of the North Fork of the Kaweah. Post fire effects in montane watersheds are well known and include flooding and landslides. *B. sequoiae* is dependent upon plant material and roots as a food source. The loss of these sources of food could have had serious impacts on the populations of these animals. The NPS has laid blame for intensity and veracity of the KNP complex fires on human-induced climate change. The fire was widely described by the National Park Service and the press in terms of its impact on Giant Sequoia trees, which was severe in some groves. However generally not mentioned were the thousands of other species impacted by the fires, including the Big Springs isopod. Giant sequoias are not at risk of extinction from this fire, Big Springs are, since their entire range burned.

National Park Service staff have also reported that post fire debris flows may have come down the canyons (being Yucca, Cascade and other unnamed creeks) around Crystal and Hurricane Crawl caves, as is common post forest fires and flooding. It is possible that the entrances to Hurricane Crawl Cave have been buried by these debris flows, and that the nearby springs that are also habitat for the isopod have been buried as well. This could have a severe impact on the habitat for *B. sequoiae*. Apparently, however, the NPS has not investigated these reports and these locations in consideration of the isopod and its well-being. (Anonymous personal communication, 2024)

6. KNP Complex BAER Report

Following fires, the federal land management agencies including the Park Service, Forest Service and Bureau of Land Management assemble teams of agency experts to assess fire impacts and to propose actions to mitigate or reduce those impacts. This is known by the acronym BAER, for Burned Area Emergency Response, and the work of the agency team includes a final report of threats, risks and mitigations. Specific natural and cultural resources are considered in the BAER process including roads, buildings and other infrastructure, cultural resources, archaeological sites, landslides and flooding, soil damage, rare plants, invasive species and rare animals. BAER reports are usually done quickly and most often include a request for funding for the recommended actions. The KNP Complex BAER report provides important insight into the consideration and importance of the Big Springs Isopod to the NPS.

Even though the entire range of *B. sequoiae* was burned over and this animal is an endemic genus in the national parks, these animals are not mentioned in the report. The KNP Fire BAER team included three cultural resource specialists and three botanists but one wildlife biologist despite the presence of *B. sequoia* and many other rare cave-adapted species in the burn area. Most often BAER reports focus on species listed under the Endangered Species Act, illuminating a clear reason to list the Big Springs Isopod under this law. The KNP complex BAER Report does consider and list rare plants impacted by the fires that are not ESA listed species, but the isopod and any other potentially sensitive non-plant species are not included.

7. Climate Change Exacerbated Flooding

With climate change when rains, snow and spring runoff do occur, the results may be severe flooding beyond the normal range of floods that the isopod evolved to withstand in their limited habitat. Warmer air can hold more moisture creating the potential for larger precipitation events and larger floods (Swain, et al. 2018). Such flooding can alter isopod habitat by moving sediments, detritus and tree roots in ways that did not occur in the past. Such floods can directly impact and kill the isopods, who may have fewer refuges of calm water during these larger flood events.

During the winter of 2021 to 2022 Sequoia and Kings Canyon National Parks receive more than 300% of their average annual rainfall causing widespread damage to park roads and infrastructure. Many roads and sections of the park were closed for months and even years while repairs took place. The impacts of this climate-change-enhanced event on the isopod remain unknown.

8. Fire suppression impacts

The watersheds containing *B. sequoiae* have seen multiple rounds of fire suppression chemicals dropped from aircraft in recent years. This includes the Hidden Fire in 2009 and the KNP complex fires in 2021. These chemicals contain compounds that act as plant nutrients and fertilizers, potentially impacting the landscapes upon which the chemicals are dropped. The ecological impacts of these chemicals can be serious and problematic as has been documented by multiple researchers. (Hamilton, et al, 1998; Haur and Spener 1998; McDonald, et al. 1996) In addition, research by the NPS showed the uptake of fire-retardant chemicals in the Yucca Creek watershed containing Crystal, Hurricane Crawl cave and multiple springs where the Big Springs Isopod is known to live. (Figure 3).

In the abstract, the authors wrote: “Dissolved nitrate concentrations sharply increased at most monitoring sites with the onset of winter precipitation and seasonal snowmelt in the spring of 2009, remained elevated during seasonal sampling at some sites in 2010, and were significantly lower in 2011 and 2012. Average nitrate concentrations in sub-basins during the 2009 high-discharge period are strongly correlated with the amount of retardant applied in each sub-basin, but not correlated with the sub-basin area. Dissolved phosphate concentrations were highest upstream of sink points where streams directly recharge marble karst aquifers, and decreased between recharge sites and springs; indicating organic and/or inorganic uptake of P in the subterranean system. Although measured nutrient concentrations were within the range documented post-fire in other aquatic systems that did not receive fire retardant, evidence from the Hidden Fire strongly suggests that fire retardant derived nutrients entered and flushed through the Yucca Creek system, and that managers should consider the potential impacts of retardant application on aquatic ecosystems even when retardant is not applied directly on waterways.” (Tobin, et al. 2015) Thus the habitat of the isopod was impacted by the fire fighting chemicals and isopods themselves may have been impacted. New research has also shown that fire suppression chemicals are rife with heavy metals, which are highly toxic, particularly in aquatic

systems (Schammel, et al 2024). Populations of the Big Springs Isopod have been exposed to these chemicals multiple times.

B. Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

B. sequoiae is not utilized by humans for commercial, recreational or educational purposes. They have no commercial value and they are not used for educational purposes.

The animals have been collected by biologists under NPS permit at each of their known locations from one to three times and each collection included from one to four animals. This number of individuals collected over three decades is not expected to impact the populations of the isopods.

The range of the animals is largely in Congressionally-designated wilderness and is remote, isolated and steep and is generally not accessible by roads. The one road into the Yucca Creek area is the road to Crystal Cave. It is closed with a locked gate during the winter and each summer evening after cave tours end. This severely limits collection opportunities by collectors or hobbyists interested in owning a rare or exotic animal.

C. Disease or Predation

Diseases have not been studied in these isopods and are unknown. Since they occur in a "truncated" (Gibert and Deharvang 2002) cave ecosystem, there are also no known predators of the Big Springs Isopod. Their populations are thus unlikely to be limited by competition or predation, but rather are likely to be limited by the availability of habitat and food resources.

D. The Inadequacy of Existing Regulatory Mechanisms

1. NPS Organic Act

The [NPS Organic Act of 1916](#) (16 U.S.C. § 1), states that "the fundamental purpose of the said parks...is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Despite the clear direction in the Organic Act, National Park Service documents and policies on cave management are limited in their content and specificity and do not specifically protect cave-adapted animals within the parks and as such do afford protection to *B. sequoiae*. NPS policy does clearly state that animals protected under the ESA will receive protection, monitoring and on-going management, again clearly showing the need to list the Big Springs Isopod under this law (NPS Directives System undated). The Federal Cave Resources Protection Act of 1988 directs federal land managers to inventory and list caves and cave resources and also protects cave locations from being released under Freedom of Information Act requests. But this law does require any specific actions to protect cave species. Cave wildlife is a criterion under which caves can be considered significant, but the NPS considers all caves to be significant and to be protected under this law making the consideration of biota irrelevant (Pate undated; Code of Federal Regulations, 2004). For the most part, such management actions and considerations are left to the discretion of park superintendents.

2. Shortcomings of NPS Management

Sequoia and Kings Canyon National Parks created a cave management plan in 1997, but it too does not include specific requirements for the management of cave adapted species. Most cave-adapted species now known from the parks were not known at the time of the creation of this plan. The park has made efforts to update this plan in the 2000s, but a new cave management plan has never been completed by the parks.

As such, Sequoia and Kings Canyon National Parks do not have at their disposal the needed regulatory mechanisms to ensure adequate study, monitoring and management of populations of the *B. sequoiae*. Nor has any such work taken place in the parks since 2012. This leaves these animals at risk of extinction and declining populations due to the threats outlined above and also creates a great deficit in our knowledge and understanding of this endemic park genus. This predicament is exemplified by the KNP Complex Fire BAER report as described above.

E. Other Natural or Manmade Factors Affecting its Continued Existence

Collectively the threatened destruction, modification and curtailment of the habitat of the Big Springs Isopod and the lack of management actions by the NPS presents an important and real threat to these animals that could easily lead to their extinction. With the impacts that have already taken place, the risk is imminent and significant for the extinction of the isopods.

4. Critical Habitat Determination

With the limited range of these animals, the fact that their entire range burned in a single fire and that the entire range of the animal was impacted by severe flooding and the lack of attention from the NPS to the situation, it is requested that the entire range of this animal including all watersheds, springs and caves be declared as critical habitat for the Big Springs Isopod. These animals clearly need all of their very limited habitat to survive into the future under threats from cave tours operations at Crystal Cave, and climate-change exacerbated fires, droughts and floods.

5. Requirement for petitions

The requirements for petitions are listed here to be clear that this information is included in this document. Requirements for petitions for listing under the Endangered Species Act are defined in the Federal Register Page 66484, Volume 81, Number 187, September 27, 2016, Section 424.14, Part C:

(c) Date of Petition: March 18, 2025

(1) Contact Information:

Name: Joel Despain

Signature: Please see the cover letter

Address: 27171 State Highway 299 East, Bella Vista California, 96008

No additional affiliations

(2) Species Information:

Scientific name: *Bowmanasellus sequoiae*

Common Name: Big Springs Isopod, or Sequoia Isopod

(3) Requested Administrative Action:

- a) A finding that the species is Threatened under the Endangered Species Act.
- b) The determination of critical habitat for the Big Springs Isopod.

(4) Detailed Narrative:

Please see the contents of this document

(5) Detailed Citations:

Please see the References section of this document

(6) Supporting Documents:

Please see the References section of this document

(7) Determination of Species Information:

Please see section 1B of this document for the history of the taxonomy of this species.

(8) Species Range:

The range of *B. sequoiae* has not changed and has only come to light in the last 20 years. This animal was not known historically. The animal is found only in Tulare County, California in Sequoia and Kings Canyon National Parks.

(9) Notification Documents Shared with the State of California

Please see the References section of this document

6. Conclusion

The Big Springs isopod is one of the most unique animals found in Sequoia and Kings Canyon National Parks and is likely the only endemic genus found in the parks. The conservation and protection of these animals is a basic challenge for the National Park Service in managing these parks. A strong focus on Giant Sequoia forests, despite the vast numbers of other species found in these parks, has led to a precarious and uncertain future for *B. sequoiae* that can be remedied by protecting this species under the Endangered Species Act. One of the former Chiefs of the Resource Management Division at the parks, entrusted with managing and protecting the plants and animals found there, once stated that the park could only address and manage natural resources clearly protected under federal law (personal communication, Charisse Sydoriak). This is clearly a clarion call to list the Big Springs Isopod under the ESA.

Fortunately, there is a ready source of funding to do the work required to study, manage and protect this species and that is the money generated by ticket sales for Crystal Cave, managed by the Sequoia Parks Conservancy. As described above, these funds have been used by the parks for many things, but only rarely to protect and manage cave resources, even though the money is derived from the use of a park cave containing the Big Springs Isopod. While not a traditional source of funding for biological work in the national parks, Conservancy funds are an available source of money to get this work done.

The Big Springs Isopod is the tip of the cave biology iceberg at Sequoia and Kings Canyon. Many

other cave-adapted species are found in these parks and many are endemic with very limited ranges that are impacted by park activities, fires and climate change. Many of these animals, found in caves across the western section of the parks, are likely to be strong candidates for protection under the ESA.

7. References

Anonymous, personal communication, Sequoia and Kings Canyon National Parks staff member, October 9, 2024. (The individual's name is being withheld to preclude any impacts to or retribution against the employee.)

Boulton, Andres J., Graham D. Fenwick, Peter J. Hancock, Mark S. Harvey, 2008, Biodiversity, functional roles and ecosystem services of groundwater invertebrates, *Invertebrate Systematics*, 22(2) 103-116. <https://doi.org/10.1071/IS07024>

Bowman, T. E., 1975, Three new troglobitic adelids from Western North America (Crustacea: Isopoda: Asellidae), *International Journal of Speleology*, 7 339-356.

Chelius, Marisa K, Guy Beresford, Howard Horton, Meghan Quirk, Greg Selby, Rodney T. Simpson, Rodney Horrocks and John C. Moore, Impacts of Alterations of Organic Inputs on the Bacterial Community within the sediments of Wind Cave, South Dakota, USA, *International Journal of Speleology* 38(1) 1-10.

Code of Federal Regulations, 2004, NPS Regulations Implementing the Federal Cave Resources Protection Act, Title 43, Part 37, 521-524.

Dainelli, Luisa and Alejandro Martínez, Fabrizio Serena, Leandro Gammuto¹, Caio Graco-Roza, Joachim Langeneck, Stefano Mammola, Giulio Petroni, 2025, Macroinvertebrate diversity patterns in a guano-rich temperate cave, privately published, <https://doi.org/10.1101/2025.02.09.637321>

Despain, Joel D., 2004, *Hidden Beneath the Mountains, Caves of Sequoia and Kings Canyon National Parks*, Cave Books, Dayton Ohio, 128 pages.

J.D. Despain, B.W. Tobin, and G.M. Stock, 2016, Geomorphology and paleohydrology of Hurricane Crawl Cave, Sequoia National Park, California. *Journal of Cave and Karst Studies*, 78(2) 72–84. <https://doi.org/10.4311/2013ES0114>.

Eberhard, Stefan, 1999, *Cave Fauna Management and Monitoring at Ida Bay, Tasmania*, Tasmanian Parks and Wildlife Service, Hobart, Tasmania, Australia.

Elliott, William R., James R. Reddell, D. Craig Rudolph, G.O. Graening, Thomas S. Briggs, Darrell Ubick, Rolf F. Aalbu, Jean Krejca, Steven J. Taylor, 2017, *Cave Fauna of California*, California Academy of Sciences, Golden Gate Park, San Francisco, California. 311 pages. Please see pages 19, 41 (endemic genus), 65 (image), 67 (cave obligate), 99, 161 (records).

Fettig, Christopher J., and Leif A Mortenson, Beverly M. Bulaon, Patra B. Foulk, 2019, *Tree Mortality Following Drought in the Central and Southern Sierra Nevada, California, US*, *Forest Ecology and*

Management, 432 164-178.

Fiorillo, Francesco, 2009, Spring hydrographs as indicators of droughts in a karst environment, *Journal of Hydrology*, 373 (2-3) 290-301. <https://doi.org/10.1016/j.jhydrol.2009.04.034>

Gibert, Janine and Louis Deharving, 2002, Subterranean Ecosystems: A Truncated Functional Biodiversity, *BioScience* 52(6).

Griebler, Christian and Maria Avramov, 2015, Groundwater ecosystem services: a review, *Freshwater Science* 34(1), 355–367, DOI: 10.1086/679903.

Hamilton S, Larson D, Finger S, Poulton B, Vyas N, Hill E (1998) Ecological effects of fire retardant chemicals and fire suppressant foams, Jamestown, ND. US Geological Survey Northern Prairie Wildlife Research Center. <http://www.npwrc.usgs.gov/resource/habitat/fireweb/index.htm>.

Hauer FR, Spencer CN (1998) Phosphorus and Nitrogen dynamics in streams associated with wildfire: a study of immediate and long-term effects. *International Journal of Wildland Fire* 8 183–198.

Jordon, Clayton, Signatory, 2021, KNP Complex Fire BAER Emergency Stabilization & Rehabilitation Plan, National Park Service. Available at https://www.nps.gov/seki/learn/nature/upload/2021_BAER_KNP_EmergencyStabilizationPlan_508_2.pdf

King, Rachel, 2004, Isopods, Southeastern Regional Taxonomic, Center South Carolina Department of Natural Resources. Available at <http://www.dnr.sc.gov/marine/sertc/>

Krejca, J. K., and Weckerly, B., 2008, Detection Probabilities of Karst Invertebrates, in *Proceedings of the Cave and Karst Management Symposium*, 18, 283-289.

Lewis, Julian J., 2008, *Oregonasellus* and *Bowmanasellus*, two new subterranean isopod genera from the western United States (Crustacea: Isopoda: Asellidae), *Subterranean Biology* 6 23-30

McDonald SF, Hamilton SJ, Buhl KJ, Heisinger, JF, 1996, Acute toxicity of fire control chemicals to *daphnia magna* (straus) and *selenastrum capricornutum* (printz). *Ecotoxicol Environmental Safety* 33:62–72

Miller, Christopher, 2013, *Ecosystem Disturbance and Recovery in Shelta Cave*, MS Thesis, Department of Biological Sciences, University of Alabama, Huntsville.

Moore, James G. and Thomas W. Sisson, 1987, Preliminary Geologic Map of Sequoia and Kings Canyon National Parks, California, US Geological Survey, Open File Report 87-651.

Moulds, Timothy A., 2005, Guanophilic invertebrate ecology and conservation in caves, *Cave and Karst Management in Australasia*, Proceedings of the 16th ACKMA Conference, Westport, New Zealand.

Natureserve, data and information retrieved 03-15-2025.

National Park Service, Management Directives System, Management Policies, Chapter 4, Natural Resource Management, retrieved from <https://www.nps.gov/subjects/policy/mp-4-natural.htm>.

Panek, Jeanne and Joel D. Despain, 2013, A Natural Resource Condition Assessment for Sequoia and Kings Canyon National Parks, Appendix 18 -- Cave Invertebrates.

Pate, Dale, undated, National Programs: Overview of National Park Service Policies for Cave and Karst Management, internal NPS publication, Carlsbad New Mexico.

Sakoui, Souraya, and Reda Derdak, Boutaina Addoum, Aurelio Serrano-Delgado, Abdelaziz Soukri and Bouchra El Khalfi, 2020, The Life Hidden Inside Caves: Ecological and Economic Importance of Bat Guano, International Journal of Ecology, 2020, Article 9872532. <https://doi.org/10.1155/2020/9872532>

Schammel, Marella H., Samantha J. Gold and Daniel L. McCurry, 2014, Metals in Wildfire Suppressants, Environmental Science and Technology Letters 11, 1247-1253.

Sequoia Parks Conservancy, 2016, 2016 Annual Report, Sequoia Parks Conservancy, Three Rivers, California.

Sequoia Parks Conservancy, 2017, 2017 Financial Statement, Sequoia Parks Conservancy, Three Rivers, California.

Sequoia Parks Conservancy, 2025, Web page at <https://sequoiaparksconservancy.org/adventure/crystal-cave/> accessed 03-15-2025.

Swain, Daniel L., Baird Langenbrunner, J. David Neelin, and Alex Hall, 2018, Increasing precipitation volatility in twenty-first-century California, Nature Climate Change 8, 427-433.

Sydoriak, Charisse, November, 2010, Personal Communication

Tinsley, John C., David J. Des Marais, Gail McCoy, Bruce W. Rogers, and S. R. Ulfedlt, 1981, Lilburn Cave's Contribution to the Natural History of Sequoia and Kings Canyon National Parks, in Beck, Barry F., Editor, The Proceedings of the International Congress of Speleology, Bowling Green, Kentucky, 287-290.

Tobin, Benjamin W. and Benjamin F. Schwartz, 2020, Quantifying the role of karstic groundwater in a snowmelt-dominated hydrologic system, Hydrological Processes 34(16) 3439-3447. <https://doi.org/10.1002/hyp.13833>

Tobin, B.W., B. F. Schwartz, M., Kelly, J., Despain, 2015, Fire retardant and post-fire nutrient mobility in a mountain surface water—karst groundwater system: the Hidden Fire, Sequoia National Park, California, USA. Environmental Earth Sciences 73, 951–960. <https://doi.org/10.1007/s12665-014-3444-x>

White, Donald H and John T Seginak, 1987, Cave Gate Designs for Use in Protecting Endangered Bats, Wildlife Society Bulletin, 15(3) 445-449.

8. Glossary

Karst describes a landscape and hydrology found in soluble rocks such as limestone and marble. It includes caves, sinking streams, sinkholes, springs, collapses and other geographic features.

Troglobitic animals are those that are restricted to the cave environment. They are fully cave adapted and can only survive inside of caves. The Big Springs Isopod is troglobitic.

Troglophiles are animals that prefer and are most often found in caves, but that may live and be found outside of the cave environment.

Trogloxenes are animals that come and go from caves. They include bats and humans.

Phreatic describes the zone below the water table where the pores and spaces within rocks, soil and caves are filled with water.

Vadose describes the zone below ground that is above the water table where spaces within rocks, soil and caves are air filled.