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Cave Monitoring

2017–2018 Results from Lava Beds National Monument

Former Lava Beds staff Katrina Smith and park intern search for invertebrates near a cave bait station.
NPS / ALICE CHUNG-MACCOUBREY

Cave Monitoring: 2017–2018 Results from Lava Beds National Monument

Science Report NPS/SR—2025/347

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Contents

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Tables

Appendices

Page

Abstract

The National Park Service Klamath Inventory and Monitoring Network conducts long-term environmental monitoring in six national park units in southern Oregon and northern California. Park and network staff collaborate to monitor vital signs of cave environments and communities at Lava Beds National Monument (LABE) and Oregon Caves National Monument and Preserve (ORCA). This protocol aims to detect changes in cave climate, water levels in subterranean pools (ORCA only), quantity of cave ice (LABE only), invertebrate community composition, hibernating bat populations, and entrance vegetation communities. In addition, we survey scat and other organic material to aid park management and also monitor human visitation to potentially explain variation in other parameters. Where appropriate, parameters are monitored in the entrance, middle, and deep zones within each cave. At LABE, we monitor a random sample of 30 deep caves (i.e., caves that contain a dark zone) to make inferences about the park's population of deep caves. Furthermore, we sample six bat caves that contain the majority of hibernating Townsend's big-eared bats (*Corynorhinus townsendii*) in the park (three from the random sample plus three nonrandom additions) and five caves with significant ice resources (one randomly sampled cave plus four nonrandom additions). Monitoring frequency, timing, and location (i.e., zones) vary by parameter. Since several parameters are monitored biennially, biennial reports will summarize two years of data. Monitoring at ORCA follows a different sampling design and schedule; it will be detailed in a separate report.

Monitoring protocols for cave environments and communities are somewhat experimental since these ecosystems are understudied compared to other natural resources. Consequently, initial years of monitoring were spent developing and refining methods. In addition, the scarcity of baseline cave data suggests that prolonged monitoring may be required to distinguish trends from background noise.

This report summarizes data from the first two years of standardized monitoring (2017–2018) at LABE. Due to the quantity of data, in some cases we report summaries, subsets, or examples of larger datasets that are available in full upon request. Various data gaps reflect the logistical and technological challenges hindering data collection in 2017–2018. For example, a prolonged lapse in natural resources staff caused incomplete sampling of some metrics (e.g., ice in 2018) or delayed implementation, causing data loss (e.g., TRAFx visitation counters). Nonetheless, this first report provides a comprehensive overview of the biotic and abiotic monitoring at LABE and establishes a baseline for evaluating future data.

Acknowledgments

Reports such as this one owe much of their content to the original authors of the monitoring protocol and the development of the overall Klamath Inventory and Monitoring Vital Sign Plan. For this, we thank the authors of the protocol, especially Dr. Jean Krejca and the early network staff who recognized the importance of cave resources: the late Drs. Daniel Sarr and Dennis Odion. The development of the protocol and implementation owes much to other network and park staff, too numerous to list. Secondly, great thanks go to the field crews who tirelessly implement the procedures to collect the data. Lastly, we acknowledge the help of staff who have helped with the revision and review of the report, particularly Dave Hayes, Emma Sutphin, and Sierra Heimel.

Introduction

The Klamath Inventory and Monitoring Network (KLMN) monitors status and trends in the condition of natural resources within six National Park Service (NPS) units in southern Oregon and northern California: Crater Lake National Park, Lava Beds National Monument (LABE, "Lava Beds"), Lassen Volcanic National Park, Oregon Caves National Monument and Preserve (ORCA, "Oregon Caves"), Redwood National and State Parks, and Whiskeytown National Recreation Area. These parks encompass natural resources within each of four domains: terrestrial, subterranean, freshwater, and marine. Subterranean resources are found specifically at Lava Beds and Oregon Caves.

Lava Beds National Monument is located south of Tulelake, California, and covers approximately 188 km^2 on the northeastern slopes of the Medicine Lake Volcano. This landscape of volcanic fields and caves amidst the semi-arid high desert is protected by two designated wilderness areas covering most of the park's total area. There are more than 800 volcanic caves ranging from 15 to 2500 m in passage length. Most are lava tubes, but fissures and open vertical conduits also formed from eruptions through volcanic vents. Most caves are open to the public, and the park specifically advertises 23 developed caves of varying difficulty. Trails guide visitors through most of the developed caves, and one cave is artificially lighted. While ranger-led tours are available in the summer season, most visitors explore caves without a tour guide after receiving basic safety and resource protection information from the website and Visitor Center. Cave closures protect fragile resources in a select few caves throughout the monument.

The Integrated Monitoring Protocol for Cave Entrance Communities and Cave Environments in the Klamath Network (Krejca et al. 2017) describes how we monitor subterranean resources (biotic and abiotic) at the two cave parks in the Klamath Network and is hereafter referred to as the "cave protocol," or the "protocol." Caves are less studied than other environments, and thus, methods for monitoring cave environments and communities are relatively experimental. The effectiveness, efficiency, and statistical power of monitoring methods for other natural resources (e.g., birds and water quality monitoring) are much better known (e.g., USEPA 2013). The development time for this protocol was lengthy due to these and other challenges with testing and implementation. This protocol monitors four physical parameters (climate, visitation, ice [LABE only], and subterranean pools [ORCA only]) and four biological components (invertebrates, bats, scat/organic inputs, and entrance vegetation) of subterranean (cave) ecosystems. Figure 1 is a conceptual model that depicts the relationship among these elements and with external human influences (Krejca et al. 2017). While the protocol describes standardized methods to be used at both parks, caves at each park differ in underlying geology, shape, and size, thus necessitating separate sample designs, data analyses, and reports for each park.

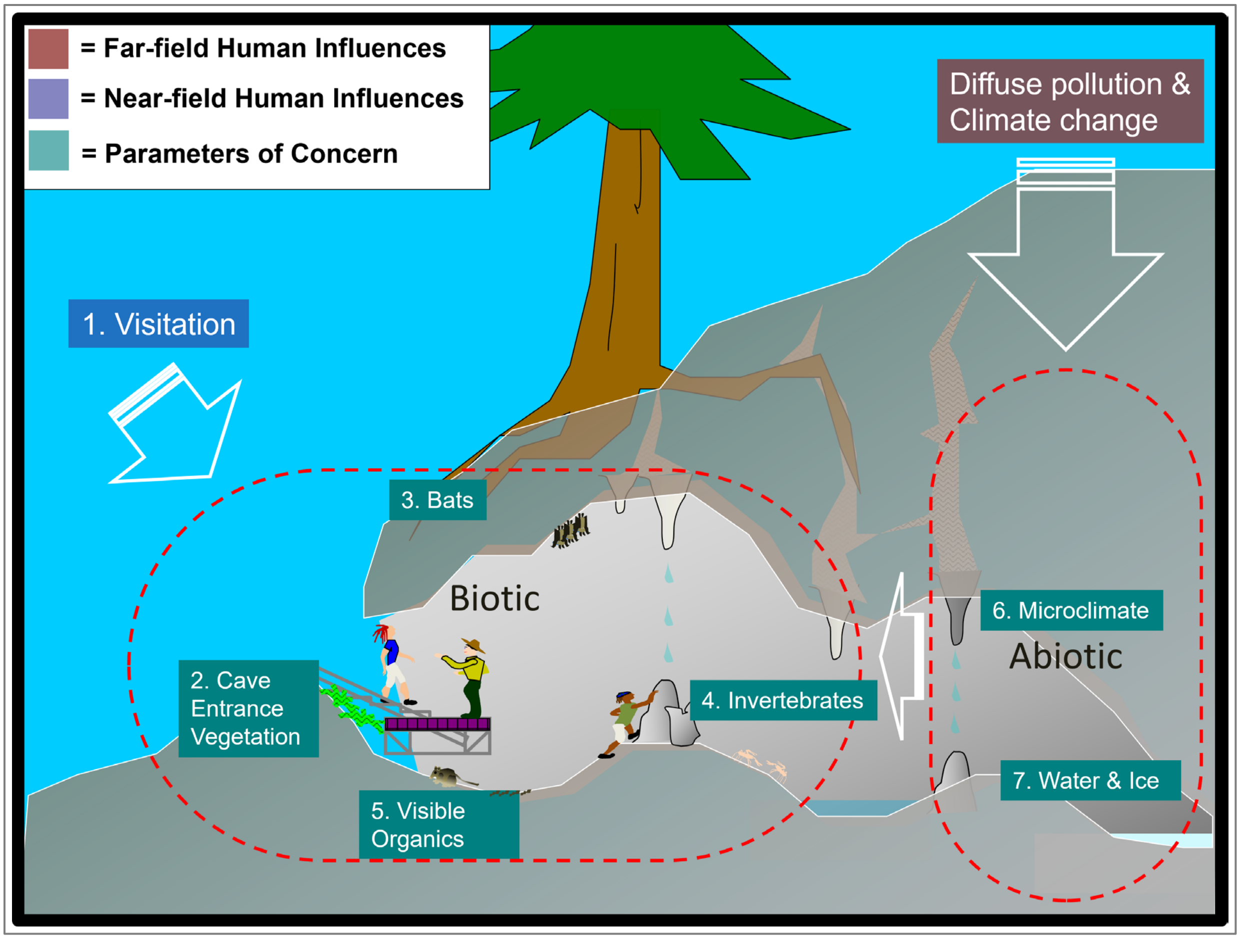

Figure 1. Conceptual model of a cave ecosystem, illustrating biotic, abiotic, and anthropogenic parameters (numbers 1–7) monitored by the Klamath Network cave protocol. Number 7 includes two separate metrics: subterranean pool water levels and ice.
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Specific objectives of the KLMN cave protocol are to:

1. Monitor the status and trends of cave climate (temperature and relative humidity[1])
2. Monitor the status and trends in elevation and surface area of ice (Lava Beds) or water level in subterranean pools (Oregon Caves).
3. Monitor the status and trends of focal species and communities.
4. Monitor the status and trends in human visitation.

To address these objectives at Lava Beds, we monitor the following parameters:

[1] Due to technical limitations, we are not currently monitoring or reporting on relative humidity. See text for further details.

- **Cave Climate:** Changes in climate directly affect the suitability of cave environments for inhabitants such as microbes, invertebrates, and bats, as well as the quantity and persistence of ice.
- **Ice:** Ice helps buffer cave temperatures by absorbing or releasing energy, thus playing an important role in stabilizing and maintaining cave temperatures.
- **Visitation:** Human visitation can impact cave environments through vegetation trampling, introducing nutrients, disturbing cave invertebrates and bats, and other means. Correlations between levels of visitation and trends in cave parameters can be used to inform visitor management.
- **Cave Invertebrates:** Not only are cave invertebrates unique, otherworldly, and sometimes endemic to local caves, they are important to cave ecosystems. They serve a variety of roles, such as decomposers in nutrient cycling and prey in the food chain.
- **Bats:** Bats are a high-profile park resource that generate visitor interest and serve important functions in cave ecosystems. While bats use caves at Lava Beds for both maternity roosts and hibernacula, this protocol focuses on hibernating Townsend's big-eared bats (*Corynorhinus townsendii*) and other incidental bat species (e.g., *Myotis* spp.).
- **Scat and Visible Organics:** This parameter documents the movement of organic material from the surface into cave ecosystems, primarily through rodents, humans, and other animals and their associated scat, food, bones, nesting materials, and other material. It may be a useful covariate to understand trends in other parameters, such as invertebrates.
- **Entrance Vegetation:** Vascular plants, bryophytes, and lichen in cave entrances are unique, often locally rare, and vulnerable to impacts from human visitation.

These parameters are monitored at a random sample of deep caves and a nonrandom sample of bat and ice caves on an annual, semi-annual, or biennial basis, depending on the parameter. The lack of baseline data from these and other caves in general suggests that it will take more years of data collection to differentiate trends from background noise.

Reporting is a collaborative effort between park and network staff. This report provides an overview of methods and a summary of data collected in 2017 and 2018, the first two years of standardized monitoring following protocol completion (i.e., publication). For more details about protocol development and methods, see the protocol (Krejca et al. 2017). In many cases, the data presented herein represent summaries or subsets of larger datasets, which are available upon request.

Methods

Site Selection

At the time of protocol development, Lava Beds had 775 recorded caves. We selected caves for monitoring using a combination of random and judgment sampling. Since we were interested in monitoring conditions within the deep zones of caves, we created a sampling frame consisting of 114 caves ≥91 m in length, a length that is most likely to contain the three desired zones (entrance, middle, and deep) according to the expert opinion of park staff. From this sampling frame, we used the Generalized Random Tessellation Stratified (GRTS) approach to draw a spatially balanced, ordered, and random sample of 30 caves for monitoring. We rejected selected caves if they contained fragile resources, posed safety concerns, or if they did not meet the criteria for having a deep zone, and we replaced them with the next caves in the ordered GRTS oversample (Appendix A).

Invertebrates, scat, climate, visitation, and vegetation are monitored at these 30 randomly selected caves. However, two primary resources of park concern (bats and ice) were underrepresented in this random sample. When the protocol was established in 2016, six caves at Lava Beds were believed to contain a majority (approximately 70%) of the known hibernating population of Townsend's big-eared bats in the park. Consequently, all six bat caves are monitored each year, three of which are part of the random sample and three of which were nonrandomly added as a judgment sample. To reduce sampling time and cost, only bats, climate, and visitation are monitored at the three nonrandom bat caves. The park also manages five caves with perennial ice resources. All five ice caves are monitored each year, one of which is represented in the random sample and the remaining four of which were added as judgment sites. All parameters except scat are monitored in the four judgement ice caves (Appendix B).

In total, the protocol monitors 37 caves (30 random caves plus 3 additional bat caves and 4 additional ice caves). This report refers to individual caves either by their full name or by a cave code, depending on their sensitivity classification in the LABE Cave Management Plan.

Delineating Cave Zones

Cave zones are a useful generalization for locating sampling areas along a subterranean environmental gradient. This sampling framework enables comparisons among zones that likely differ in biotic (invertebrates) and abiotic conditions (e.g., light, temperature, humidity). For all caves monitored at Lava Beds, we delineated three zones based on descriptions modified from Poulson and White (1969) and Culver (1982) and specific field conditions at Lava Beds:

Entrance: Light present; active air exchange with exterior; temperature and relative humidity are most variable on daily and seasonal time scales; frequent use by opportunistic surface wildlife species that leave organic material or potentially consume cave biota; includes the more commonly described twilight zone.

Middle: Generally beyond the zone of visible light; less air exchange with the outside and greater use by both cave obligates (troglomorphs [species with morphologic and occasionally physiological cave adaptations] and troglobites), and certain nonobligates (troglophiles and trogloxenes); intermediate variability in temperature and relative humidity.

Deep: Nonbioluminescent light absent; relatively stable temperature and relative humidity; minimal surface wildlife usage; conditions most favorable for cave obligate species but other species occur as well.

When possible, we used notable changes in cave morphology, such as ceiling height or passage width, as well as other obvious cave features (i.e., unique boulders, benches, aprons) to mark zone boundaries. For caves with multiple entrances, we selected the entrance with the highest diversity or greatest abundance of vegetation, or the highest likelihood of vegetation trampling due to visitor use. Zone boundaries are well documented in site dossiers and do not change over time.

Field Methods

Monitoring methods are summarized in this section; more detail may be found in the protocol. Field data collection is performed by park staff, volunteers, and interns, with costs supplemented by KLMN during even years when the sampling effort is greatest.

The frequency, timing, and location (specific zones) of monitoring vary by parameter. Some parameters are monitored annually and others biennially (Table 1). Climate, scat, and invertebrates are monitored in all three cave zones. Vegetation is monitored in the entrance zone, and visitation is monitored nearby, but may be outside the defined zone. Bats, ice, and subterranean pools are monitored where they occur, which is typically in the deep zone.

Table 1. Cave parameters monitored by the Klamath Network cave protocol at Lava Beds and Oregon Caves, including definitions and sampling schedules. Climate and visitation protocols collect data continuously. Climate data are downloaded every 6 to 12 months and visitation data are downloaded monthly (TRAFx sensors) or annually (cave registers).

Parameter	Type	Definition	Sampling Frequency	Sampling Schedule
Climate	Abiotic	Temperature and relative humidity per zone in each cave and at select surface locations	Annual	Continuous
Ice or Water	Abiotic	• (LABE): ice levels and surface area • (ORCA): water levels in cave pools	Annual, Seasonal	• Ice: March • Water: May, August, November–February
Visitation	Abiotic	Number of humans (visitors and park staff) entering each cave	Annual	Continuous
Vegetation	Biotic	Percent cover of vegetation types (vascular plants, bryophytes, and lichens) and growth forms (graminoid, fern, herb, shrub) in cave entrances	Biennial	April–July

Table 1 (continued). Cave parameters monitored by the Klamath Network cave protocol at Lava Beds and Oregon Caves, including definitions and sampling schedules. Climate and visitation protocols collect data continuously. Climate data are downloaded every 6 to 12 months and visitation data are downloaded monthly (TRAFx sensors) or annually (cave registers).

Parameter	Type	Definition	Sampling Frequency	Sampling Schedule
Bats	Biotic	Abundance of hibernating bats (primarily *Corynorhinus townsendii*) per cave	Annual	January
Scat and Organic Material	Biotic	Presence/absence of scat and other organic material per zone in each cave	Biennial	May–September
Invertebrates	Biotic	Community composition and biodiversity per zone in each cave	Biennial	May–August

Some parameters are sampled throughout the year, while others are sampled in specific seasons or months (Table 1). Entrance vegetation, scat, and invertebrate surveys are conducted every other year in even years (biennially), during the summer. Climate and visitation are measured continuously, with data downloaded or collected at regular intervals throughout the year. The remaining parameters (bats, ice, and subterranean pools) are measured annually at specific seasonal intervals relevant to those unique resources.

Cave Climate

Temperature and relative humidity values were recorded hourly using Onset HOBO Pro v2 dataloggers placed on the floor or wall behind a visual barrier within each zone of all caves (random and judgement sites). While the hidden placement of these dataloggers may not provide the most accurate representation of the entire zone, this location was considered acceptable given the risk of equipment disturbance or loss in publicly accessible caves. In addition to subterranean data loggers, 12 dataloggers were installed on 4-foot-tall poles (inside solar radiation shields) at the surface, no more than 1.2 km from any monitored cave entrance. Each shield and pole were painted light sage green to provide camouflage.

With a resolution of 0.21 ºC in temperature, these dataloggers are effective at recording natural daily and seasonal variation in temperature and will also indicate major climatic changes in the cave environment. After implementation, it became clear that technological limitations of the dataloggers prevented accurate recording of relative humidity after extended exposure to humidity above 95%, which is common in deep cave environments. Per the manufacturer's recommendations, we retrieved dataloggers periodically (every 6 months) to let the relative humidity sensors dry out before returning them to a cave. Downloading data every six months also helped minimize losses due to equipment malfunction. Despite these efforts, the relative humidity data collected to date require extensive review to determine data quality. The relative humidity data are not reported here but will be presented in future reports if possible.

Ice

Ice survey methods provide quantitative descriptions of the elevation and surface area of ice floors. The surface area of ice deposits is calculated from a laser distometer with azimuth, inclination, and distance measurements recorded from a tripod in the center of the ice floor to dozens of points around the floor's perimeter. The azimuth, inclination, and distance values provide spherical coordinates, and when used with a semi-permanent tie-in point, were used to create a Cartesian coordinate polygon showing relative spatial change over time. Together, these values can be used to estimate changes in volume. This report includes elevation measurements as well as descriptions of delineated polygons for each ice body and the areal extent for each year monitored.

Quantitative measurement of other ice features in the caves such as frozen waterfalls, icicles, hoodoos, and hoarfrost is not logistically feasible. Thus, they are documented qualitatively through annual photo point monitoring.

Human Visitation

Methods for estimating human visitation differ between parks due to the type, frequency, and nature of visitation, the number of caves at each park, and the visitor-related infrastructure between parks. At Lava Beds, human visitation is estimated using a combination of infrared trail counters, cave registers, and NPS tracking logs. In frontcountry (i.e., high visitor use) caves with established trails, trip-beam style TRAFx Infrared Trail Counters are used to estimate visitation. In backcountry caves, paper cave registers are located in plain sight at the cave entrance so that visitors may voluntarily sign their name. One frontcountry cave, SENT*, contains both a TRAFx sensor and a cave register. While registers may not capture all human visitation, they are a cost-effective and efficient way to collect data at remote caves. Because many backcountry caves receive very low visitation rates, NPS staff visitation may be a significant or primary source of visitation and cave impact. Finally, prior to Crystal Ice Cave closing to the general public in 2019, it was historically open only for ranger-led tours and research, so visitation data were recorded in NPS tracking logs.

Cave Entrance Vegetation

Ferns, moss, lichen, and other plants not often found in the surrounding high desert landscape provide visually impressive displays of color and texture at cave entrances. However, identifying vascular and nonvascular plant species and determining their abundance requires specialized expertise that is beyond the ability of most cave monitoring field technicians. Therefore, cave entrance vegetation is accomplished using both simple quantitative transects and qualitative photo monitoring at 34 sites (30 randomly selected caves and 4 nonrandomly selected ice caves).

The line-transect, point-intercept method provides rapid estimates of cover by broad vegetation class (vascular plants, bryophytes, lichens, or soil substrate) and growth form (i.e., shrub, fern, herb, or graminoid, for vascular plants) and is highly effective for monitoring changes in percent cover (Elzinga et al. 2001). Although it is desirable to note plant species, especially of the more common shrub and fern species, it is not necessary to collect species-level information. A simple photographic

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* Denotes a frontcountry cave.

identification guide is included in the protocol Standard Operating Procedures (SOPs) to help with identification. Two transects are placed in the cave entrance, perpendicular to the passage orientation and vegetation growth forms are recorded at 20 sampling points along each transect (Figure 2). Where no vegetation is present, bare substrate categories include rock, soil (nutrient-poor, primarily pumice), and organic (leaf litter and/or other detritus).

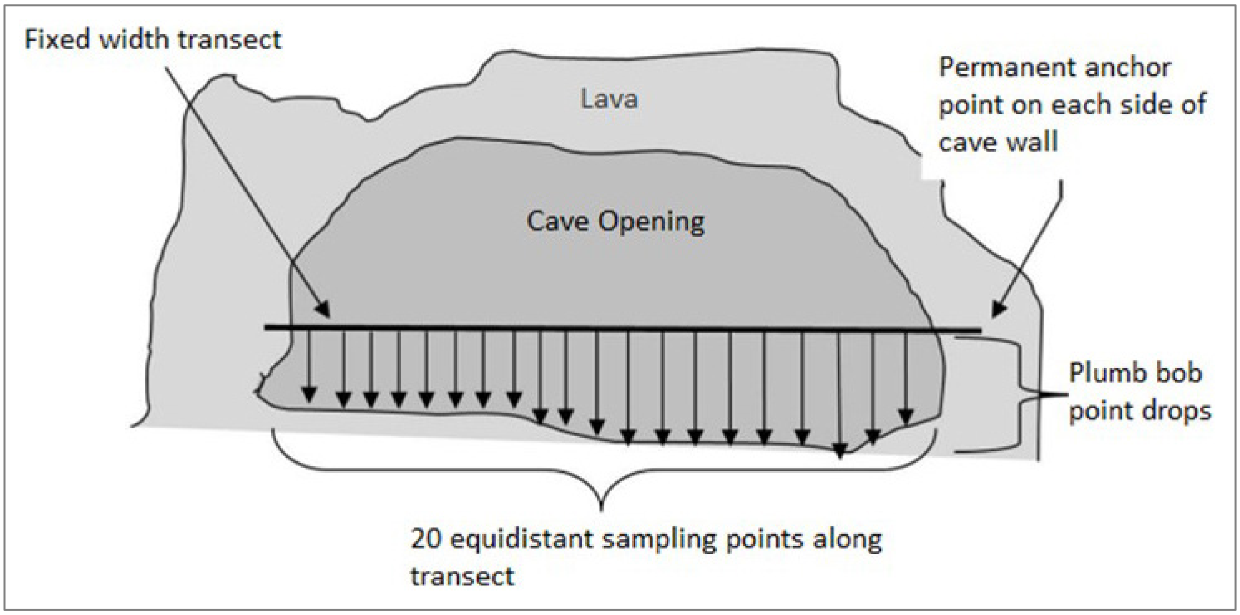

Figure 2. Lateral view of a point drop transect used for sampling cave entrance vegetation. Two parallel transects were established at each of 34 caves, each 0.5–1 m apart with 20 equidistant points of measurement.
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Photo monitoring consists of one or more standardized photographs taken of the entrance at each cave. When multiple images are taken of the same location using a variety of exposure settings to control light level, the entire visual context of vegetation around each cave entrance is easily compared across years. A few examples are presented in the results section of this report; original photo files are available upon request.

Bat Populations

Bat populations are monitored using in-cave visual encounter surveys at six hibernacula that contain a substantial portion of the park's Townsend's big-eared bat population. Other bat species (*Myotis* spp. and *Eptesicus fuscus*) are also infrequently observed in Lava Beds National Monument caves. While many additional hibernacula have been discovered and monitored since this protocol was established, annual monitoring of these six caves provides a feasible minimum survey requirement for the sparse staff availability during the winter season. Data from these and additional surveys will be published in a separate manuscript describing the parkwide population estimate.

Hibernacula surveys typically occur in mid-January but may occur anytime from December to March. Each cave is visited only once per season by an experienced team of two to three surveyors who conduct a complete visual count of the number and species of bats hibernating in each cave. Surveyors focus heavily on reduction of noise and light during surveys to minimize disturbance to bats and use only decontaminated caving equipment to reduce potential transmission of white-nose syndrome. To reduce discrepancies associated with bat movement between sites, all sites are visited within a short time frame (usually within a single week). Ceiling and air temperature measurements are recorded using an infrared thermometer within each cave zone (data not presented). While binoculars and spotlights are necessary in some caves with tall ceilings, most Townsend's big-eared bats roost individually and are easily located and identifiable due to their conspicuous roosting behavior on exposed walls and ceilings, as opposed to within cracks and crevices. In some cases, photography is used to confirm accurate counts of large clusters (e.g., more than 20 bats). Counts are tallied by species, with Townsend's big-eared bats making up more than 95% of the bat observations.

Scat and Organic Material

This parameter documents the movement of surface nutrients into caves, a process that may support other biological processes within cave ecosystems. Surveyors conduct a visual census of each zone to record the presence or absence of several different types of scat and organic material (e.g., bones, owl pellets, bird waste, bat guano, pika scat, etc.) as well as human-introduced trash (organic and inorganic) at 30 randomly selected caves. During pilot years of implementation, we experimented with quantitative estimates of scat abundance but found this to be logistically difficult and unrepeatable.

Cave Invertebrate Community

Cave invertebrates represent an important component of biodiversity in cave ecosystems but are sparsely distributed and difficult to detect. It may require many years of sampling to observe significant changes in this community due to the low detectability of these species, their high temporal variability, and the infrequent nature of our sampling (every other year). This monitoring is not a replacement for the more basic level research that is needed on these rare species, but rather a method for gathering baseline data that may prompt targeted research. Bait stations were determined to be the most effective method for monitoring this community, given the many considerations such as species detectability and distribution, observer bias, and level of expertise required. Bait stations are used in Carlsbad Caverns National Park and Great Basin National Park to increase the detection of organisms within small areas. The protocol's bait methods are similar to those used at Mammoth Cave National Park and those already in use at Oregon Caves, thus facilitating biological comparisons across parks.

To monitor for invertebrates, technicians randomly place three bait stations in each zone of a cave and then return in 14–16 days to count all taxa in a one square meter area around the bait station. Invertebrates are identified to the most practical taxonomic level given the limited experience of field technicians. In many cases, taxa are categorized into broad groups (e.g., spider, fly) but some unique invertebrates are identified to genus (e.g., springtails of either *Tomocerus* or *Entomobrya*). Bait stations consist of ½ teaspoon of peanut butter placed on a small piece of paper inside a metal mesh tea-steeping ball wired to a fist-sized or larger rock; this prevents woodrats from removing the bait but still provides access to smaller cave invertebrates. Upon removal, bait stations are carefully checked for remaining invertebrates and sanitized for reuse in future years.

Data Management

Park staff enter data for ice, scat, vegetation, and invertebrates into the KLMN Microsoft Access Cave Monitoring database, bat data into an internal Lava Beds database, and cave register visitation data into a spreadsheet. The KLMN data manager then imports bat, cave register, and TRAFx data into the Cave Monitoring database and uploads climate data to the Aquarius data repository. Data are verified and validated by park staff, with support from the KLMN data manager, who flags notable records and works with park staff to resolve issues. The final Cave Monitoring database and other data products are stored on the LABE and KLMN servers.

Results

In this report we provide summaries of data collected from 2017 to 2018. An extended lapse in Lava Beds park staffing over the period covered by this report interfered with data collection activities and resulted in gaps in data for climate, ice, and visitation. For some datasets, it was impractical to present all data in this report. Thus, we report a subset of the data for caves of management interest (e.g., temperature data for ice and bat caves) or provide overviews or examples (e.g., entrance vegetation photos) of data that may be obtained from the NPS Integrated Resource Management Applications (IRMA) portal. Throughout this report, cave names are represented by four-letter cave codes. Frontcountry caves are accessible through NPS-maintained trails and visited frequently by the public. Names of frontcountry caves are listed in Appendix C. Backcountry caves are located off-trail and not designated for public access. Since they often contain sensitive and fragile resources, backcountry caves are specifically protected in the Lava Beds Cave Management Plan and their names are therefore not disclosed in this report.

Cave Climate

Cave climate dataloggers monitored air temperature in the entrance, middle, and deep zones of all 37 caves for the entire 2017–2018 monitoring period. However, due to sensor malfunctions, there are occasional gaps in the temperature record for some caves (e.g., DRHE, COIC, SKIC*). In this report, we illustrate detailed temperature data from the six bat caves (Figure 3) and five ice caves (Figure 4) from 2017 to 2018 because temperature trends in these caves are the most relevant for park management due to the vulnerability of bat and ice resources. Table 2 and Table 3 display 7-day moving average temperatures that reflect the mean temperature during an average week, as well as mean temperature during the coldest and hottest weeks in 2017 and 2018. Figure 5 depicts broad trends in temperature aggregated across all 30 randomly selected caves.

* Denotes a frontcountry cave.

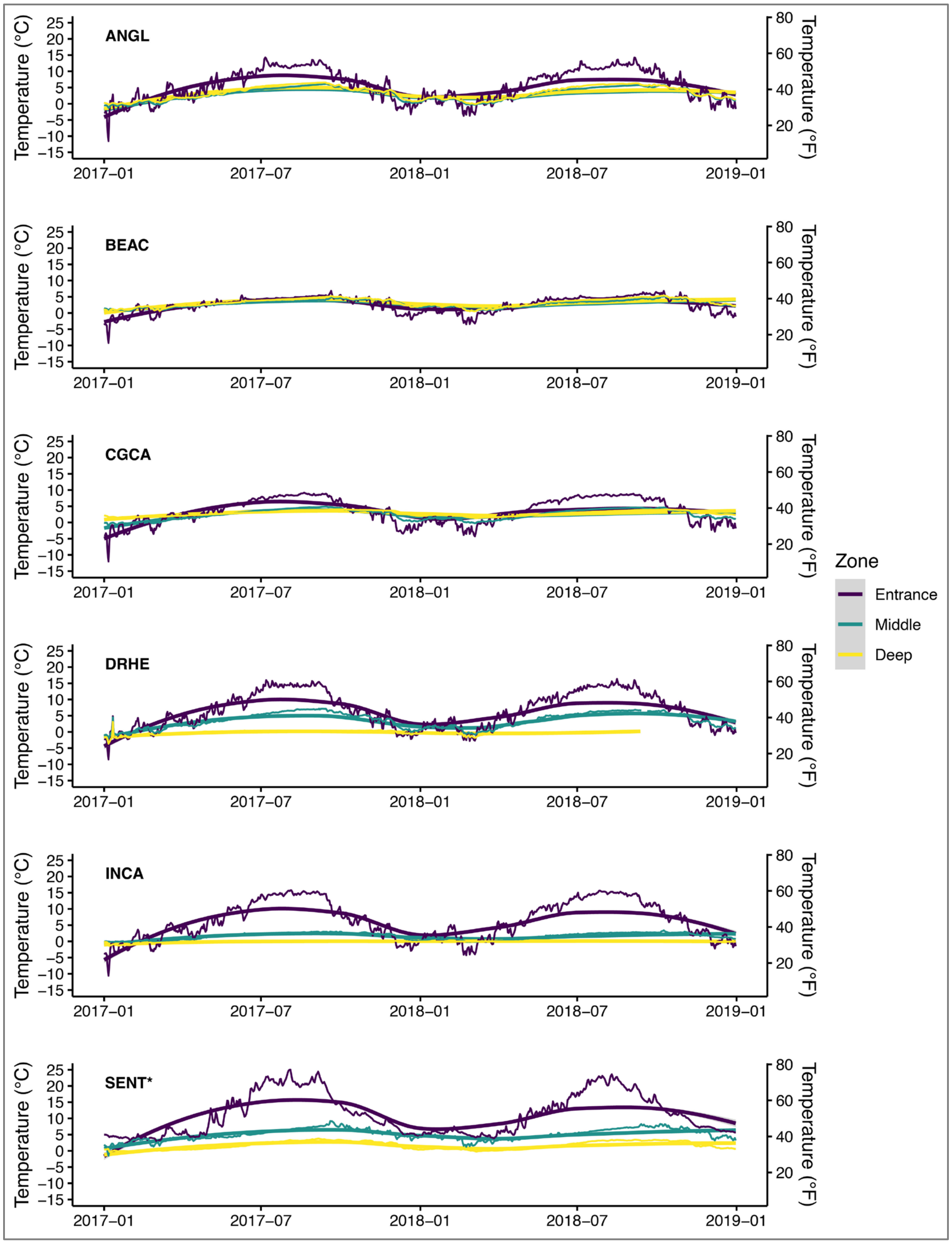

Figure 3. Temperature data for different zones within the six bat caves (ANGL, BEAC, CGCA, DRHE, INCA, SENT*) in Lava Beds National Monument in 2017–2018. Each zone (color) has a jagged line of the daily average and a smoothed line (LOESS—locally weight smoothing), the latter of which facilitates recognition of patterns. Data are missing from the deep zone in DRHE in late 2018 and from INCA between February and August 2018.

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* Denotes a frontcountry cave.

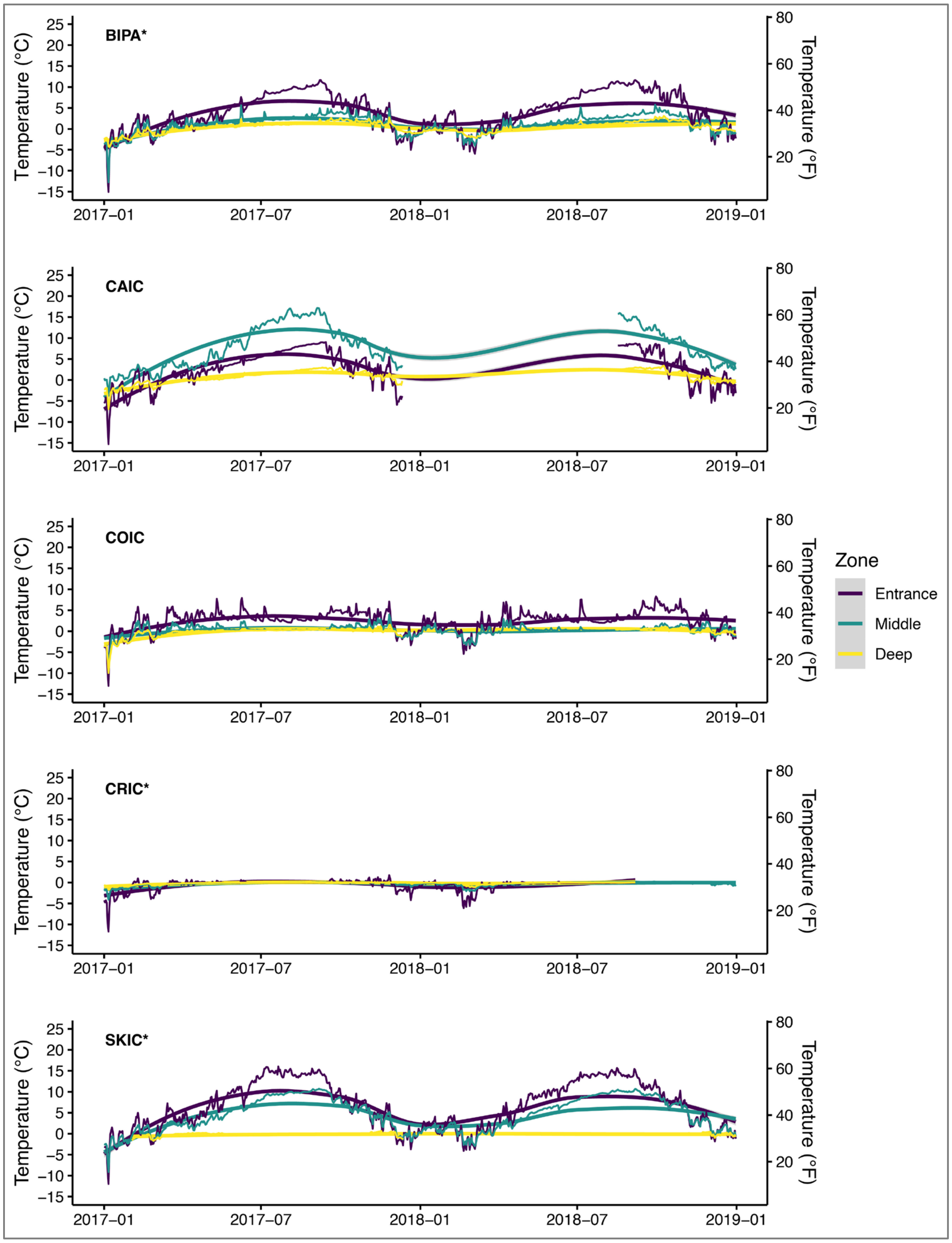

Figure 4. Temperature data for different zones within the five ice caves (BIPA*, CAIC, COIC, CRIC*, SKIC*) in Lava Beds National Monument in 2017–2018. Each zone (color) has a jagged line of the daily average and a smoothed line (LOESS—locally weight smoothing), the latter of which facilitates recognition of patterns. Data are missing from the deep zone in COIC and SKIC*, as well as from CAIC between winter 2017 and winter 2018 and from CRIC* in late 2018.

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* Denotes a frontcountry cave.

Table 2. Summarized temperature data from bat and ice caves in 2017 in Lava Beds National Monument. Rolling 7-day averages depict the mean annual temperature, as well as the mean temperature during the coldest ("Min" value) and hottest ("Max" value) weeks in 2017. Values are presented as Mean (Minimum, Maximum) in degrees Celsius for each cave zone. An en dash (–) indicates missing or unavailable data.

Cave	Entrance Zone Mean (Min, Max)	Middle Zone Mean (Min, Max)	Deep Zone Mean (Min, Max)
ANGL	5.62 (−7.01, 14.39)	2.94 (−0.94, 6.07)	3.42 (−0.14, 6.54)
BEAC	2.59 (−6.14, 6.25)	2.9 (0.68, 4.84)	3.22 (0.59, 5.16)
BIPA [A]	3.87 (−9.49, 11.57)	1.17 (−8.42, 4.88)	0.42 (−3.85, 2.53)
CAIC	2.74 (−9.73, 9.13)	7.75 (−1.39, 17.1)	0.59 (−4.8, 2.94)
CGCA	3.52 (−8.8, 9.14)	2.44 (−0.64, 4.86)	2.89 (1.39, 4.04)
COIC	2.54 (−8.59, 7.16)	0.35 (−5.83, 2.78)	–
CRIC [A]	−0.49 (−8.08, 1.08)	−0.32 (−2.93, 0.12)	−0.17 (−1.4, 0.05)
DRHE	6.47 (−5.76, 17.83)	3.5 (−1.52, 7.21)	−0.22 (−2.85, 0.54)
INCA	6.26 (−7.14, 16.02)	1.6 (−0.22, 3.05)	–
SENT [A]	11.34 (2.89, 25.76)	4.97 (0.06, 9.14)	1.67 (−0.24, 3.76)
SKIC [A]	6.55 (−8.2, 19.57)	4.41 (−5.85, 10.7)	–

[A] Indicates that this is a frontcountry cave.

Table 3. Summarized temperature data from bat and ice caves in 2018 in Lava Beds National Monument. Rolling 7-day averages depict the mean annual temperature, as well as the mean temperature during the coldest ("Min") and hottest ("Max") weeks in 2018. Values are presented as Mean (Minimum, Maximum) in degrees Celsius for each cave zone. An en dash (–) indicates missing or unavailable data.

Cave	Entrance Zone Mean (Min, Max)	Middle Zone Mean (Min, Max)	Deep Zone Mean (Min, Max)
ANGL	5.87 (−4.63, 13.88)	3.16 (−0.28, 5.82)	3.48 (−0.02, 6.32)
BEAC	2.81 (−3.61, 6.56)	2.91 (0.72, 5.27)	3.24 (0.54, 5.37)
BIPA [A]	4.64 (−6.78, 17.42)	1.28 (−4.11, 5.98)	0.54 (−2.12, 3.16)
CAIC	3.4 (−5.31, 8.78)	9.01 (2.49, 16.13)	1.44 (−0.96, 3.3)
CGCA	3.79 (−4.75, 8.79)	2.52 (−0.2, 4.62)	2.79 (1.37, 4.01)
COIC	2.68 (−5.1, 8.59)	0.29 (−3.08, 3.05)	–
CRIC [A]	−0.52 (−6.27, 0.87)	−0.21 (−2.11, 0.21)	−0.1 (−1.11, 0.06)
DRHE	6.97 (−3.44, 17.44)	3.73 (−0.72, 6.83)	−0.21 (−1.78, 0.4)
INCA	6.87 (−4.35, 15.94)	1.6 (−0.28, 3.34)	–
SENT [A]	11.38 (3.72, 24.14)	5.14 (1.42, 8.44)	1.65 (−0.19, 3.44)
SKIC [A]	6.86 (−4.95, 18.22)	4.8 (−3.08, 10.58)	–

[A] Indicates that this is a frontcountry cave.

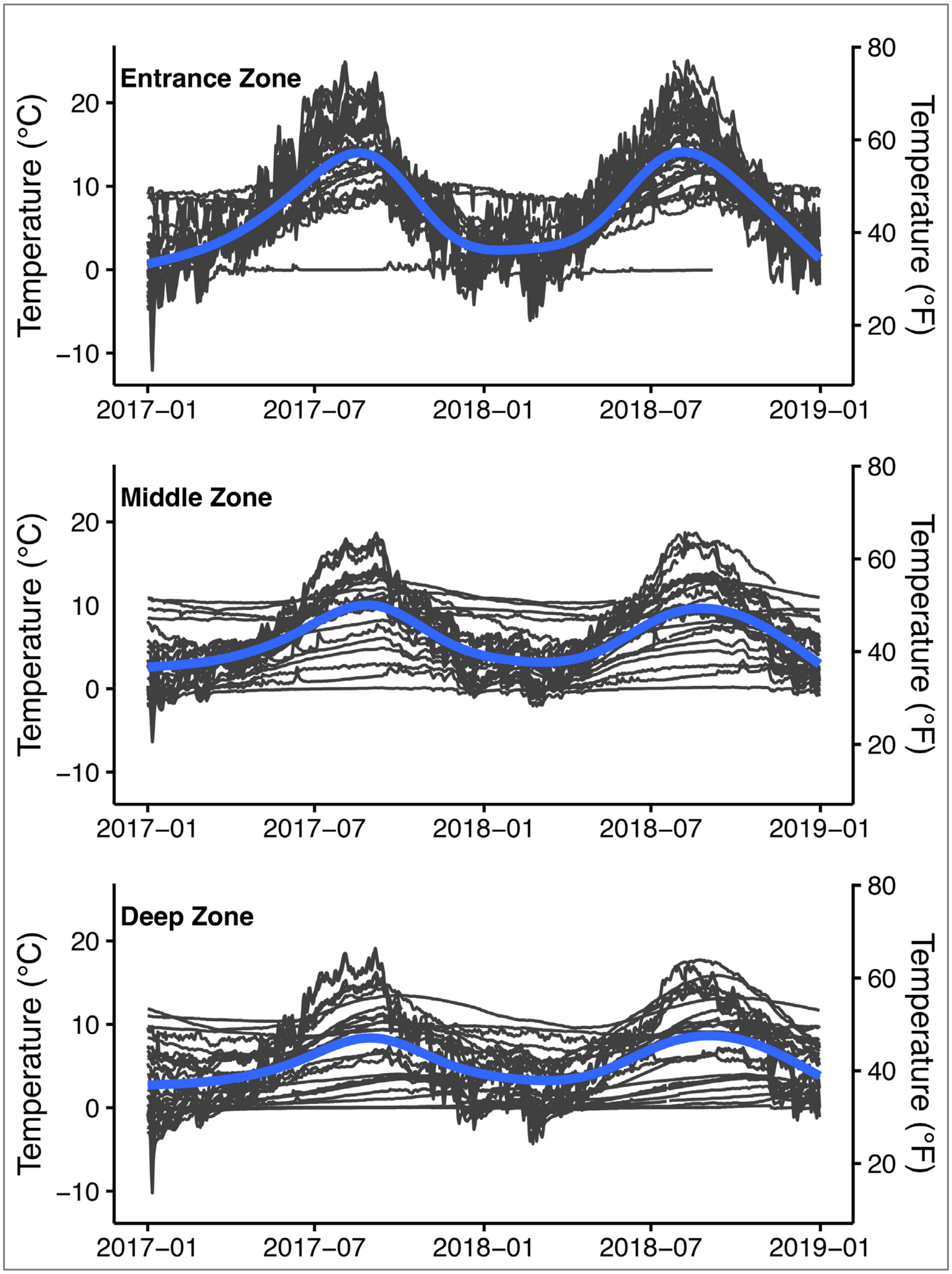

Figure 5. Broad trends in cave climate by zones across 30 randomly-selected caves in Lava Beds National Monument in 2017–2018. Individual black lines depict daily temperatures in each cave, whereas the thick blue line (LOESS—locally weight smoothing) averages across caves.

NPS

Ice

The cave protocol specifies ice monitoring in spring (March) and fall (October), with the fall measurement representing the annual minima of ice extent. However, we discovered that fall sampling was impractical due to large amounts of water covering the ice, which prevented accurate measurement of the ice perimeter and elevation. Consequently, we focused monitoring and reporting on the ice extent during March and April, which should represent the annual maxima of ice extent.

There are significant amounts of missing ice data because major staffing shortages in 2017–2018 prevented data collection, especially in March 2018 when no ice caves were surveyed. To provide two timepoints at each cave for ice extent (Table 4) and elevation (Table 5), we present data from other years, including March/April ice measurements from 2016 (the pilot year) and/or 2019 (Table 4). In the figures below, the ice surface area polygons were aligned relative to semi-permanent tie-in stations in each cave. The only exception is BIPA*, which lacked tie-in data in 2017.

Table 4. Ice surface area in five ice caves in Lava Beds National Monument in 2017–2018. Due to the absence of 2018 data, survey dates reflect measurements taken in 2016, and in some cases 2019, for comparison.

Cave	Room or Polygon	Year 1 Date	Year 2 Date	Year 1 Area (m^2)	Year 2 Area (m^2)
BIPA [A]	Main	8 March 2016	31 March 2017	18.03	10.4
CAIC	Main	10 March 2016	20 March 2017	29.66	22.88
COIC	Main	8 March 2016	21 March 2017	116.2	112.68
CRIC [A]	Blue Glacier	11 March 2016	28 March 2019	34.75	38.45
CRIC [A]	Red Ice Room	11 March 2016	27 April 2017	18.96	15.91
SKIC [A]	Boneless Cavern	9 March 2016	28 March 2017	67.37	57.48
SKIC [A]	Front Room	9 March 2016	27 March 2019	112.23	115.57

[A] Indicates that this is a frontcountry cave.

Table 5. Ice elevation relative to fixed points in five ice caves in Lava Beds National Monument in 2017–2018. Due to limited data availability from 2017 and 2018, associated survey dates reflect measurements taken in 2016 (when available) and in 2019 for comparison. An en dash (–) indicates that data were not collected prior to 2019.

Cave	Cave Section	Station Identifier	Year 1 Date	Year 2 Date	Year 1 Elevation (m)	Year 2 Elevation (m)
BIPA [A]	Main	BIPA 001	3/8/2016	3/25/2019	1.69	1.71
CAIC	Main	CAIC001	3/20/2017	3/26/2019	2.73	3.05
CAIC	Main	CAIC002	3/10/2016	3/20/2017	2.19	2.59
COIC	Main	COIC001	3/8/2016	3/25/2019	1.54	1.51

[A] Indicates that this is a frontcountry cave.

* Denotes a frontcountry cave.

Table 5 (continued). Ice elevation relative to fixed points in five ice caves in Lava Beds National Monument in 2017–2018. Due to limited data availability from 2017 and 2018, associated survey dates reflect measurements taken in 2016 (when available) and in 2019 for comparison. An en dash (–) indicates that data were not collected prior to 2019.

Cave	Cave Section	Station Identifier	Year 1 Date	Year 2 Date	Year 1 Elevation (m)	Year 2 Elevation (m)
CRIC [A]	Red Ice Room	CRIC-B	–	3/28/2019	–	1.49
CRIC [A]	Red Ice Room	CRIC-A	3/11/2016	3/28/2019	1.04	0.85
SKIC [A]	Boneless Cavern B	SKIC008a	–	3/27/2019	–	0.29
SKIC [A]	Boneless Cavern A	SKIC006	–	3/27/2019	–	0.16
SKIC [A]	Front Room A	SKIC002	–	3/27/2019	–	1.65
SKIC [A]	Front Room B	SKIC004	3/9/2016	3/27/2019	1.22	1.24

[A] Indicates that this is a frontcountry cave.

BIPA Cave Ice*

BIPA* cave ice was measured in 2016 and 2017. Data in 2017 did not include a tie-in point, preventing the ability to accurately overlap the polygons from the two years. However, the two years are presented in a single figure with correct scaling and manual alignment to facilitate comparison among years (Figure 6). Ice surface area shrank from 18.03 m^2 in 2016 to 10.4 m^2 in 2017 (Table 4).

* Denotes a frontcountry cave.

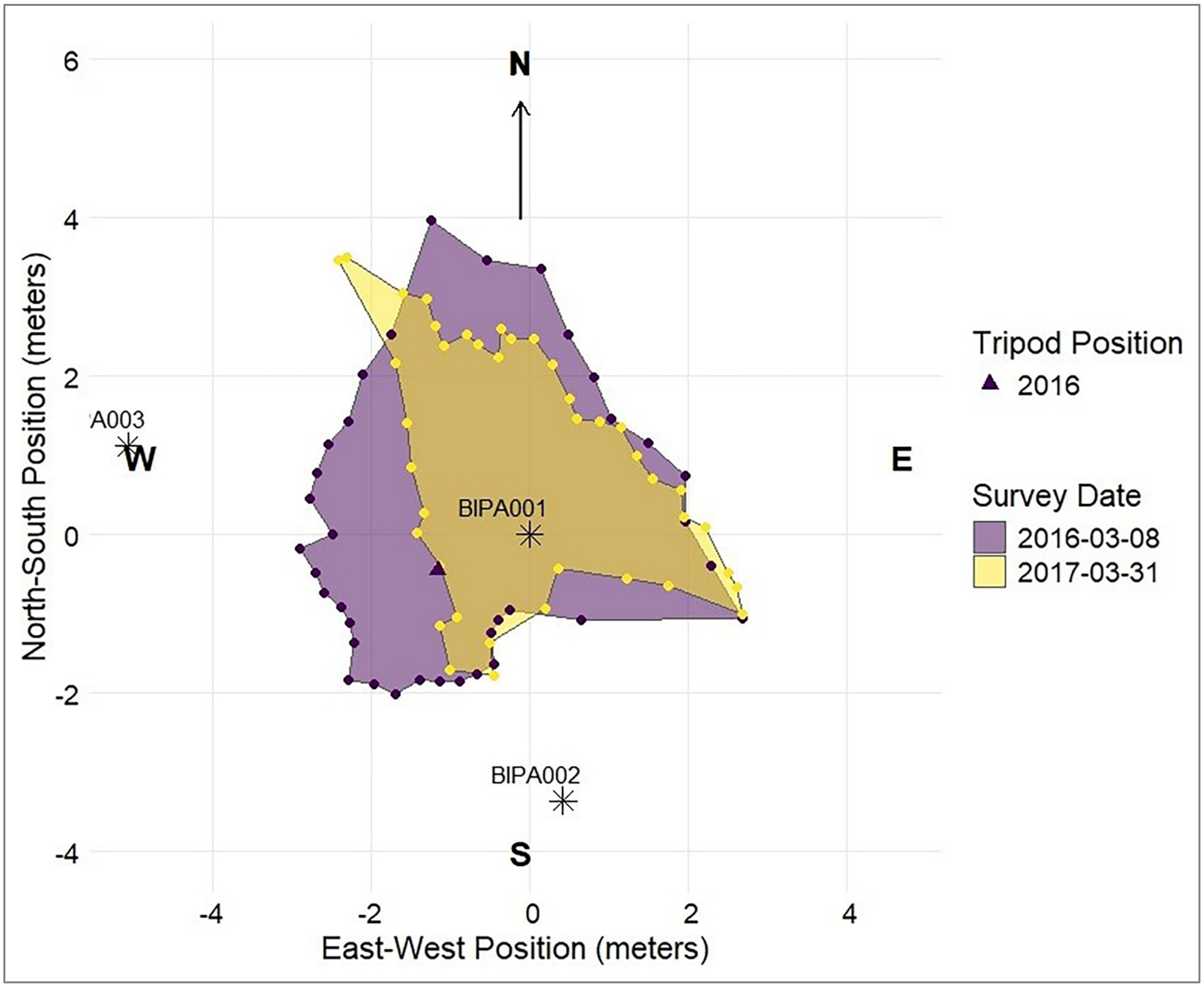

Figure 6. Area and shape of ice at BIPA* in 2016 and 2017 at Lava Beds National Monument. The polygon from 2017 was not spatially aligned due to lack of tie-in data, but has been manually aligned to facilitate comparison. Stars mark the locations of permanent tie-in stations and the triangle shows where the tripod was positioned in 2016.
NPS

CAIC Cave Ice

CAIC cave ice was measured in 2016 and 2017 (Figure 7). The 2016 surface area of 29.66 m^2 shrank to 22.88 m^2 in 2017 (Table 4).

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* Denotes a frontcountry cave.

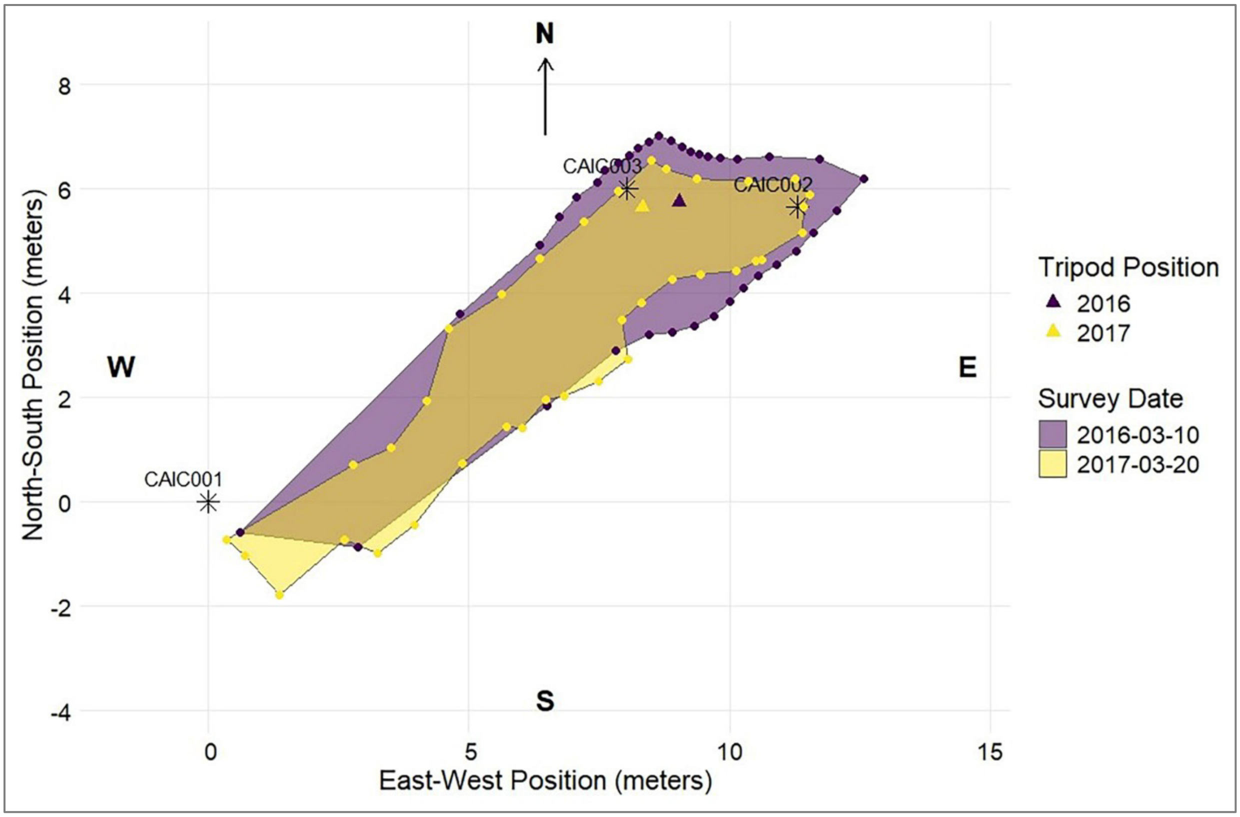

Figure 7. Area and shape of ice at CAIC as measured in 2016 and 2017 at Lava Beds National Monument. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.
NPS

COIC Cave Ice

COIC cave ice was measured in 2016 and 2017 (Figure 8). An example of photo points is given for the entrance image (Figure 9). Ice surface area shrank from 116.20 m^2 in 2016 to 112.68 m^2 in 2017 (Table 4).

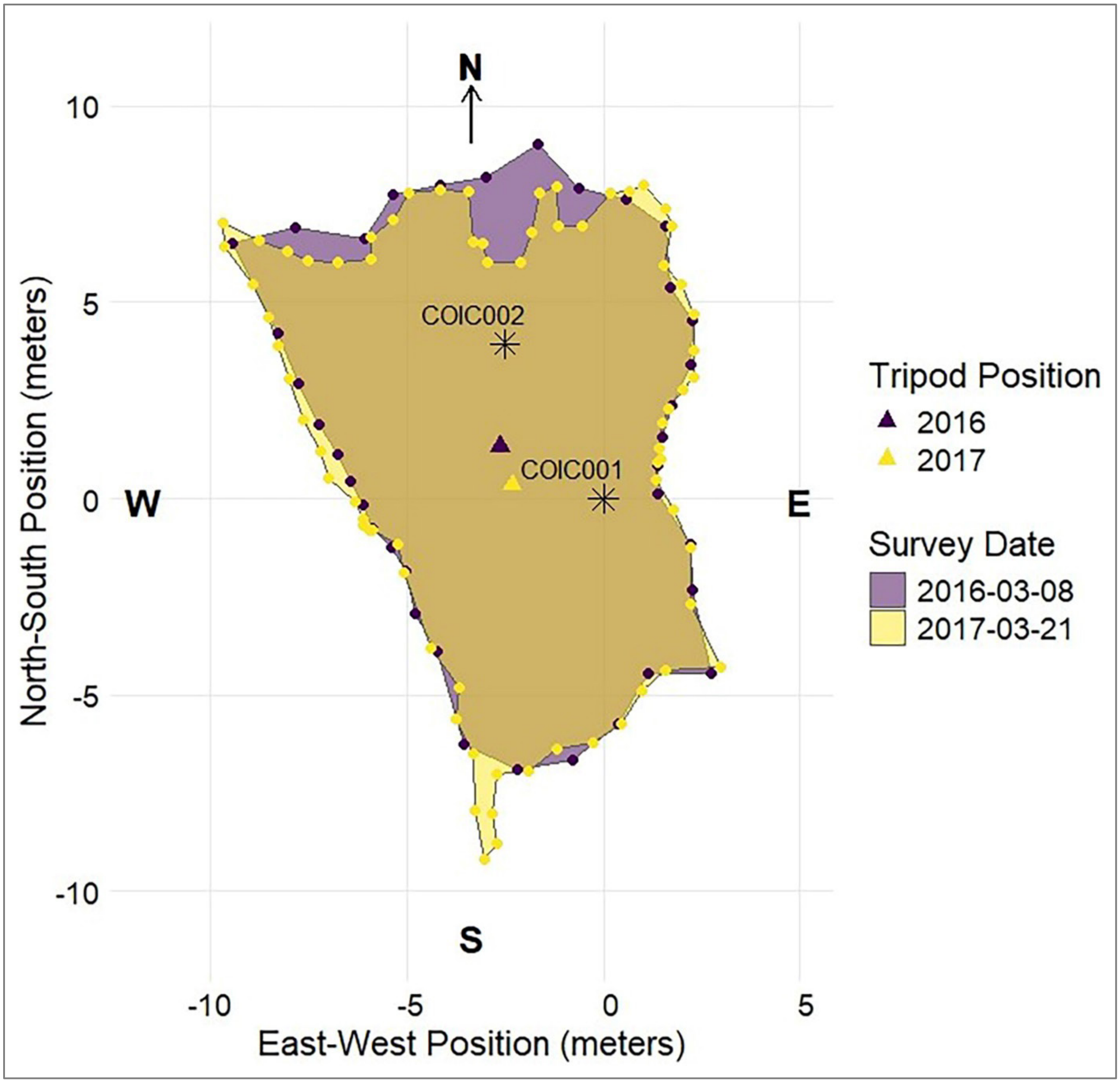

Figure 8. Area and shape of ice at COIC as measured in 2016 and 2017 at Lava Beds National Monument. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.

NPS

Figure 9. Example of ice photos taken in 2016 (A) and 2017 (B) in COIC at Lava Beds National Monument. The alternating bars of black and white on the rod indicate 10 cm increments.
NPS

CRIC Cave Ice*

Blue Glacier Ice

CRIC* ice in the Blue Glacier Room was measured in 2016 and not again until 2019 (Figure 10). Ice surface area grew from 34.75 m^2 in 2016 to 38.45 m^2 in 2019 (Table 4).

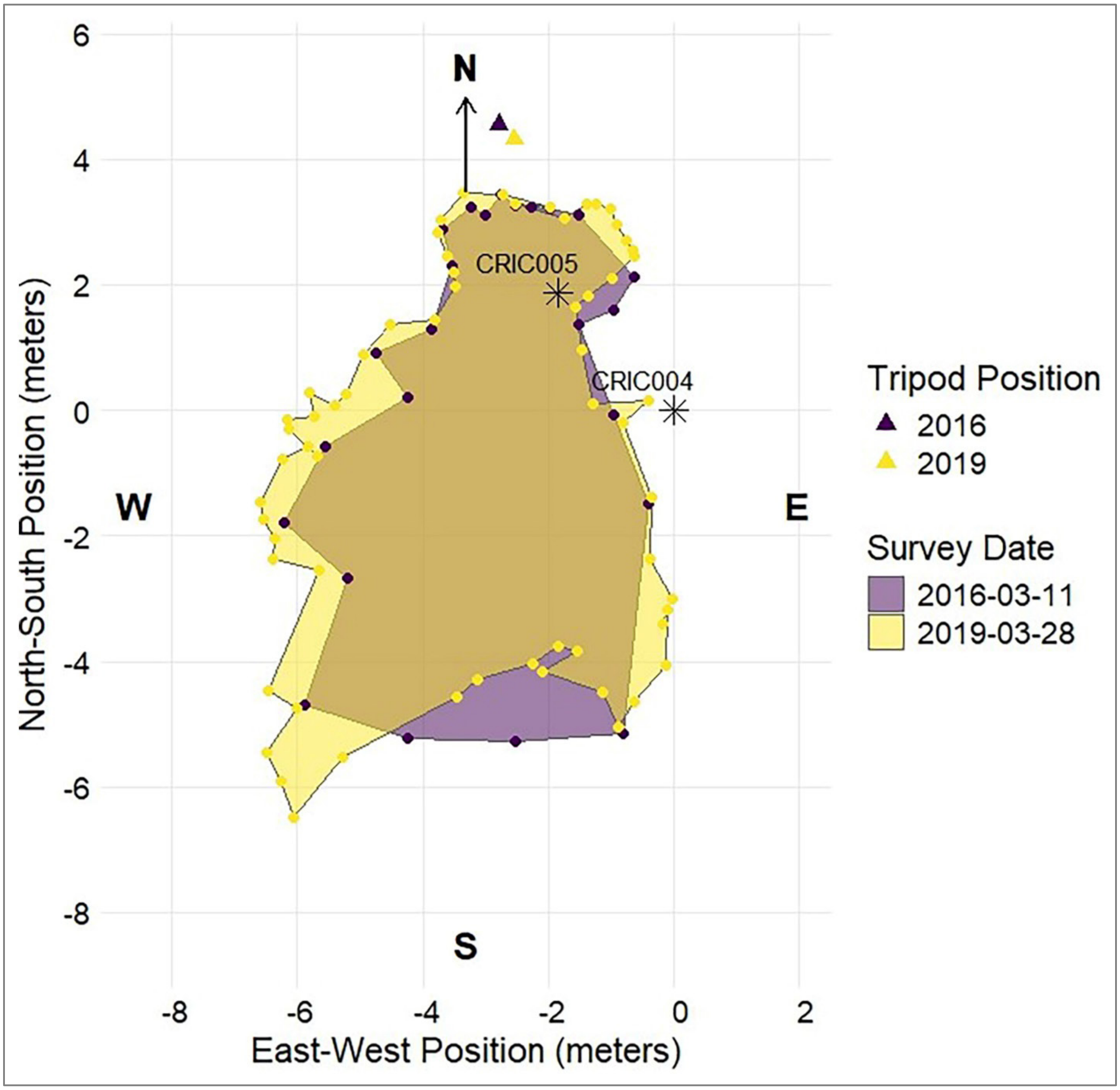

Figure 10. Area and shape of ice at CRIC* Blue Glacier as measured in 2016 and 2019. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.
NPS

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* Denotes a frontcountry cave.

Red Room Ice

CRIC* ice in the Red Room was measured in 2016 and 2017 (Figure 11). Ice surface area shrank from 18.96 m^2 in 2016 to 15.91 m^2 in 2017 (Table 4).

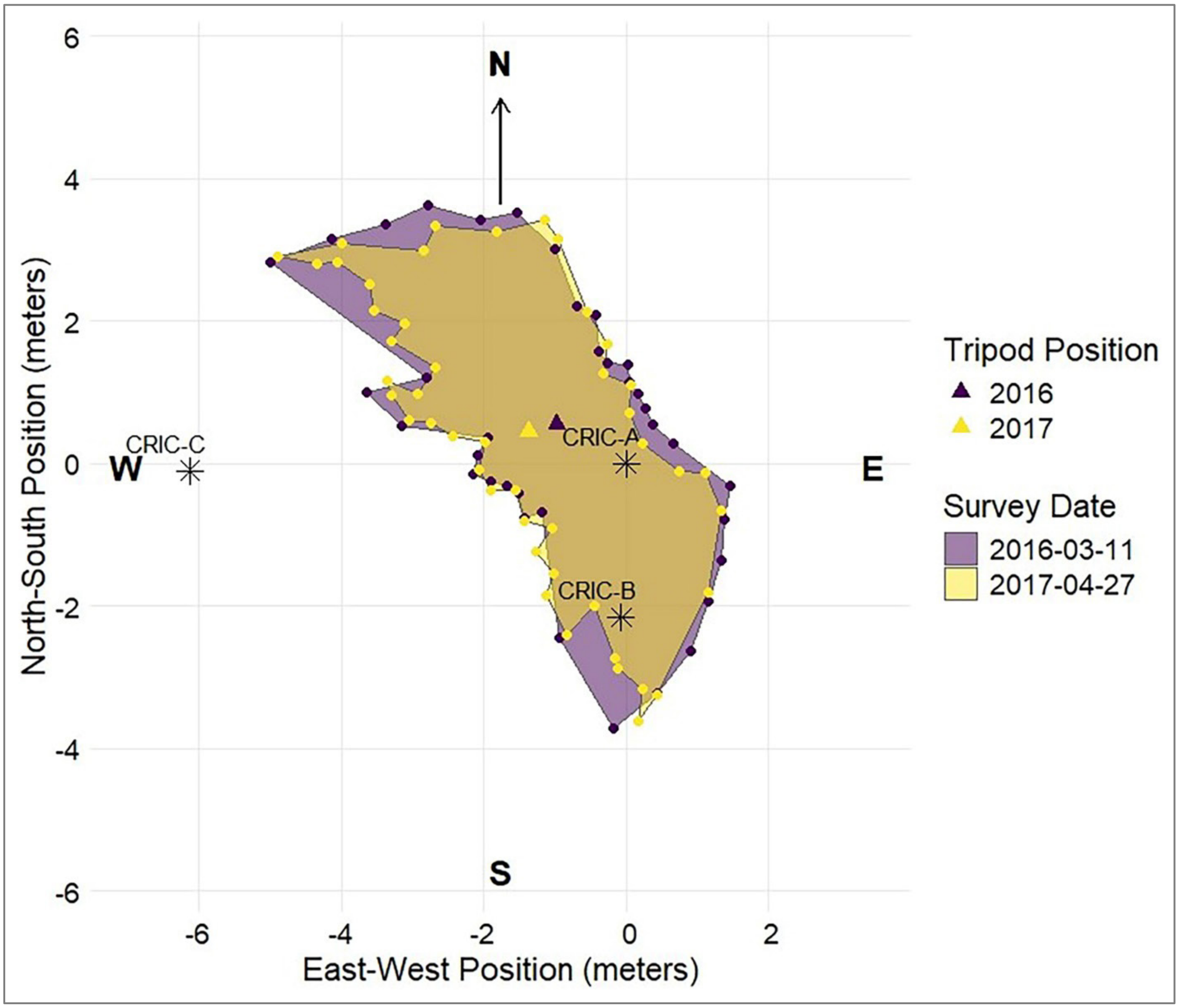

Figure 11. Area and shape of ice at CRIC* Red Room as measured in 2016 and 2017 at Lava Beds National Monument. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.
NPS

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* Denotes a frontcountry cave.

SKIC* Cave Ice

Boneless Cavern Ice

SKIC* Boneless Cavern ice was measured in 2016 and 2017 (Figure 12). Ice surface area shrank from 67.37 m^2 in 2016 to 57.48 m^2 in 2017 (Table 4).

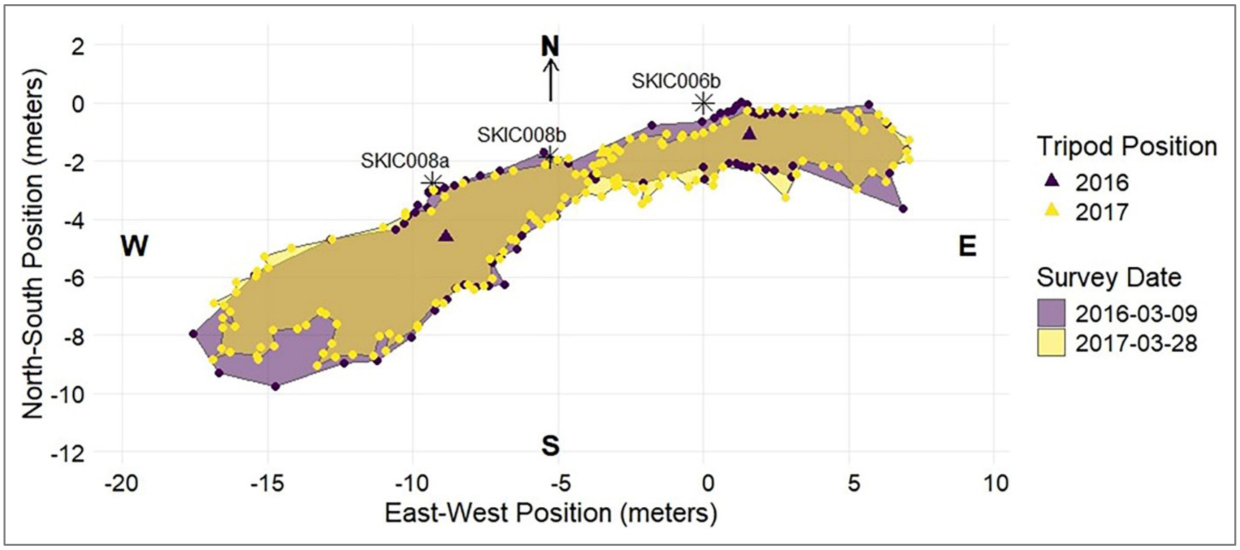

Figure 12. Area and shape of ice at SKIC* Boneless Cavern as measured in 2016 and 2017 at Lava Beds National Monument. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.

NPS

Front Room Ice

SKIC* Front Room ice was measured in 2016 and 2019 (Figure 13). Ice surface area grew from 112.23 m^2 in 2016 to 115.57 m^2 in 2019 (Table 4).

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* Denotes a frontcountry cave.

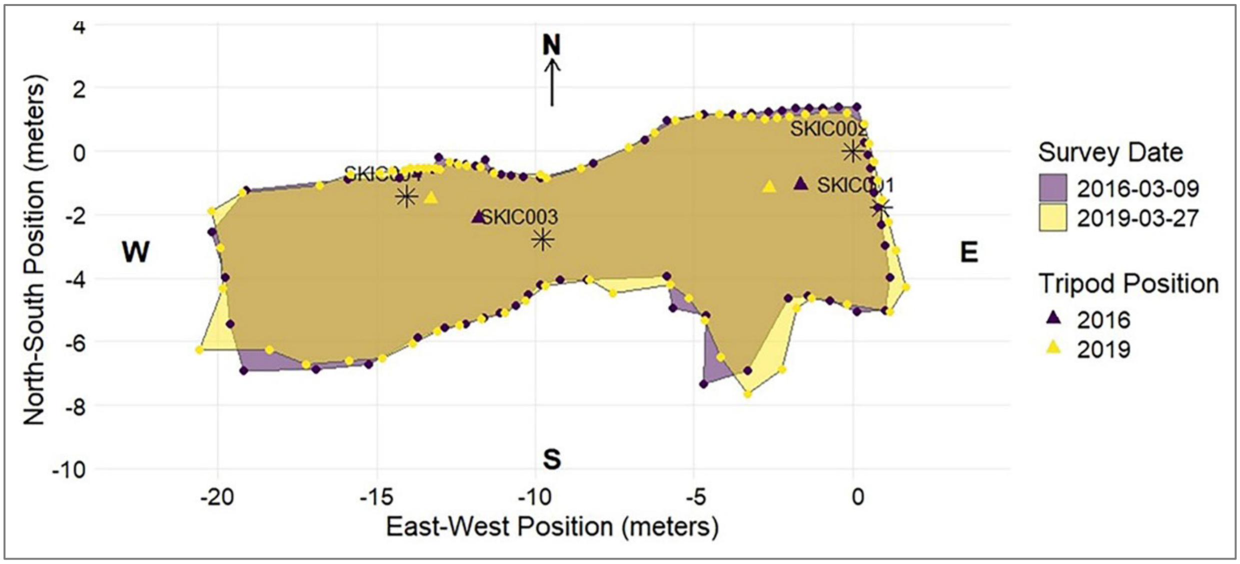

Figure 13. Area and shape of ice at SKIC* Front Room as measured in 2016 and 2019. Stars mark the location of permanent tie-in stations and triangles show where the tripod was positioned during each survey.
NPS

Human Visitation

Three different collection methods provide the best available estimates of human visitation in frontcountry and backcountry caves, as well as for one cave previously accessible through park-led tours and research/monitoring. Data were collected according to the protocol, except where technical equipment failures and limited staff availability resulted in missing records from the TRAFx Infrared Trail Counters. Values from trail counters are corrected (i.e., divided by two) at caves where visitors typically enter and exit from the same location. Values receive no such correction at caves where visitors travel in a single direction through the cave. Register data are imperfect and, in most cases, underestimate true visitation levels since some visitors may not see the register in a cave while others may choose not to sign. Other factors such as poor handwriting and datasheet deterioration can also produce gaps in visitation records. In some cases, most notably with FOCA, registers can also overestimate visitation if the register is visible from nearby trails, since occasional hikers may sign the register despite not entering the cave. Table 6 and Table 7 present estimated average daily visitation rates in 2017 and 2018, respectively. TRAFx data were not recorded from BLGR*, LALA*, and THDB* in 2017. Figure 14 and Figure 15 show heatmaps of visitation in frontcountry and backcountry caves, respectively. Most visitation occurs in the summer months and in frontcountry caves.

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* Denotes a frontcountry cave.

Table 6. Estimated average daily visitation by month in 2017 in caves at Lava Beds National Monument. Visitation was tracked through TRAFx Infrared Trail Counters, cave registers, and NPS visitation logs. TRAFx values have been corrected (i.e., divided by two) for caves where visitors enter and exit from the same location. Missing TRAFx data are due to equipment failures and limited staff availability. An en dash (–) indicates missing or unavailable data.

Cave	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BIPA [A]	TRAFx	0.6	2.9	12.0	14.5	22.6	35.8	45.3	50.9	6.9	–	–	–
IDWL [A]	TRAFx	0.1	0.0	0.1	2.8	52.3	93.0	148.0	133.9	55.7	11.2	0.1	35.1
JUHE [A]	TRAFx	3.9	8.2	26.2	42.8	60.8	95.0	167.5	142.6	72.0	35.2	23.4	17.9
MEIC [A]	TRAFx	2.3	–	–	–	30.5	66.1	66.9	59.7	32.9	15.4	28.8	11.8
SENT [A]	TRAFx	0.6	2.9	12.0	14.5	22.6	35.8	45.3	50.9	6.9	–	–	–
SKIC [A]	TRAFx	6.5	4.4	12.2	15.4	18.9	38.5	59.1	42.8	19.3	12.3	7.6	13.2
VALE [A]	TRAFx	0.1	0.0	0.1	2.5	27.9	45.2	70.5	62.6	34.7	10.3	0.5	0.3
ANGL	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
BEAC	Register	–	–	–	–	–	–	–	–	–	–	–	–
CAIC	Register	0.06	0.00	0.29	0.13	0.13	0.00	0.00	0.00	0.00	0.23	0.07	0.35
CGCA	Register	0.10	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.10	0.00
COIC	Register	0.35	0.14	0.58	0.80	0.29	0.37	0.29	0.39	0.00	0.48	0.60	0.35
DRHE	Register	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
FOCA	Register	0.00	0.00	0.10	0.13	0.00	0.10	0.00	0.00	0.13	0.42	0.00	0.00
INCA	Register	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOPI	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOBE	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ROCO	Register	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEAN	Register	–	–	–	–	–	–	–	–	–	0.06	0.00	0.00
SENT [A]	Register	–	–	–	–	–	0.80	2.10	2.23	0.67	0.10	0.00	0.00
SOLA [A]	Register	0.10	0.00	0.52	0.33	0.00	0.00	0.00	0.00	0.00	0.42	1.37	0.13
YELL	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRIC [A]	Log	0.90	1.89	1.13	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[A] Indicates that this is a frontcountry cave.

Table 7. Estimated average daily visitation by month in 2018 in caves at Lava Beds National Monument. Visitation was tracked through TRAFx Infrared Trail Counters, cave registers, and NPS visitation logs. TRAFx values have been corrected (i.e., divided by two) for caves where visitors enter and exit from the same location. Missing TRAFx data are due to equipment failures and limited staff availability. An en dash (–) indicates missing or unavailable data.

Cave	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
BIPA [A]	TRAFx	–	–	–	–	–	–	–	5.0	29.4	14.2	9.2	2.7
BLGR [A]	TRAFx	–	–	–	–	–	–	–	0.0	0.5	4.0	8.3	1.9
IDWL [A]	TRAFx	–	–	–	–	–	–	7.9	5.2	28.1	9.4	0.3	0.0
JUHE [A]	TRAFx	7.6	6.6	11.0	17.2	36.1	57.2	88.5	9.4	36.0	13.9	10.3	6.3
LALA [A]	TRAFx	–	–	–	–	–	13.4	114.9	72.3	49.4	14.3	0.0	0.1
MEIC [A]	TRAFx	12.6	14.6	19.2	29.9	62.1	80.2	–	4.2	70.8	33.8	24.7	8.3
SENT [A]	TRAFx	–	–	–	–	–	–	6.5	4.3	18.9	6.3	0.3	0.2
SKIC [A]	TRAFx	9.0	11.0	13.6	16.9	42.1	63.5	2.1	19.5	54.3	19.6	19.0	10.5
THDB [A]	TRAFx	–	–	–	–	–	–	–	5.0	29.4	14.2	9.2	2.7
VALE [A]	TRAFx	–	–	–	–	–	–	–	0.00	0.5	4.0	8.3	1.9
ANGL	Register	0.23	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.07	0.00
BEAC	Register	–	–	–	–	–	–	–	–	–	–	–	–
CAIC	Register	0.00	0.00	0.00	0.00	0.48	0.00	0.90	0.32	0.00	0.00	0.43	0.00
CGCA	Register	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.2	0.00	0.00	0.00
COIC	Register	0.13	0.18	0.00	0.13	0.87	2.03	2.06	0.84	0.50	0.16	1.13	0.00
DRHE	Register	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.07	0.16	0.00	0.00
FOCA	Register	0.06	0.00	0.00	0.13	0.00	0.00	0.26	0.00	0.00	0.00	0.13	0.10
INCA	Register	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00
LOPI	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.07	0.00
NOBE	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.19	0.07	0.00	0.00	0.00
ROCO	Register	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00
SEAN	Register	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.19	0.10	0.03	0.00	0.00
SENT [A]	Register	0.10	0.00	0.00	0.17	0.10	0.57	2.61	–	0.90	0.35	0.00	0.00

[A] Indicates that this is a frontcountry cave.

Table 7 (continued). Estimated average daily visitation by month in 2018 in caves at Lava Beds National Monument. Visitation was tracked through TRAFx Infrared Trail Counters, cave registers, and NPS visitation logs. TRAFx values have been corrected (i.e., divided by two) for caves where visitors enter and exit from the same location. Missing TRAFx data are due to equipment failures and limited staff availability. An en dash (–) indicates missing or unavailable data.

Cave	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
SOLA [A]	Register	0.35	0.00	0.10	0.07	0.00	0.00	0.06	–	–	–	–	–
YELL	Register	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.65	0.00	0.00	0.00	0.00
CRIC [A]	Log	0.77	1.07	1.29	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.10	0.19

[A] Indicates that this is a frontcountry cave.

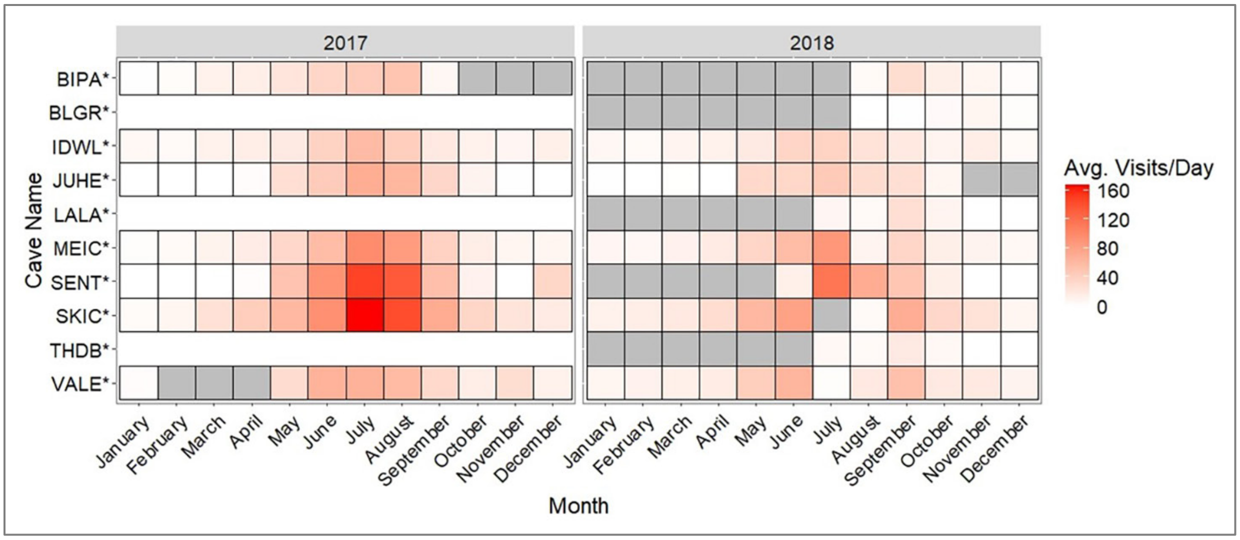

Figure 14. Visitation in frontcountry caves from 2017–2018 in Lava Beds National Monument, measured by TRAFx counters. Dark gray cells indicate missing data for a cave that was monitored for that year. Borderless white rows indicate that no data were collected that year. Visitation rates were generally highest in SENT*, SKIC*, and MEIC* and during the summer months. Note that the color scale differs from Figure 15.

NPS

* Denotes a frontcountry cave.

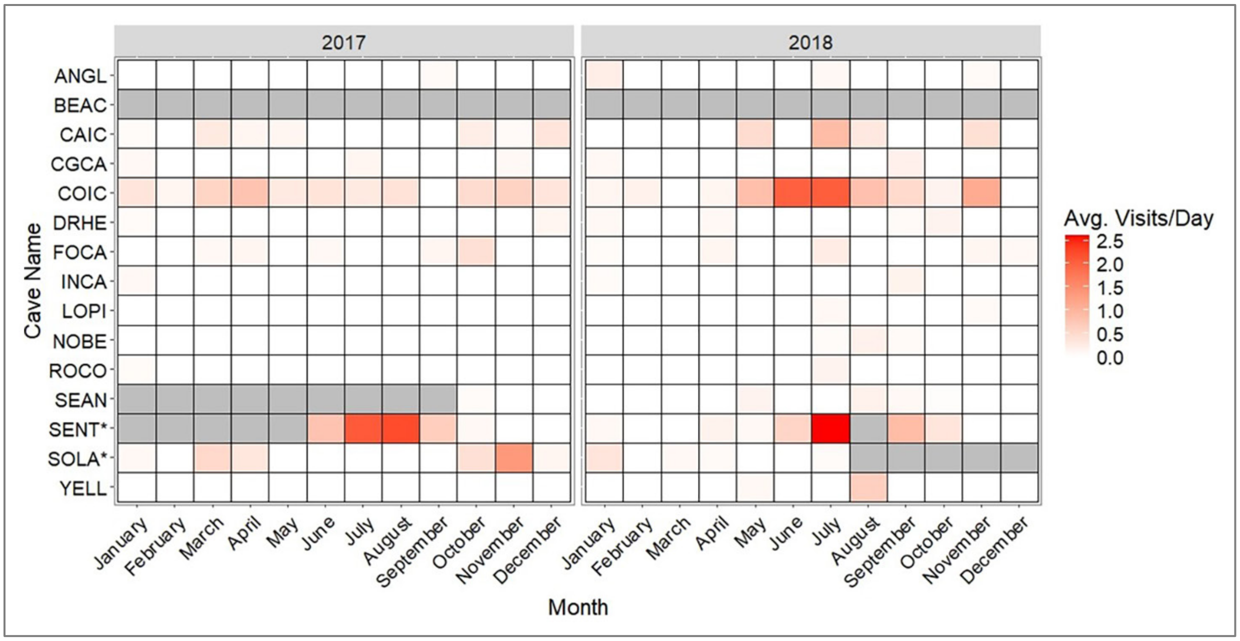

Figure 15. Visitation in backcountry caves from 2017–2018 in Lava Beds National Monument, measured by cave registers. Dark gray cells indicate missing data. Although SENT* is a frontcountry cave, it has been included here because it also contains a cave register. Visitation rates were much lower than in frontcountry caves but were generally highest during the summer months. Note that the color scale differs from Figure 14.

NPS

Cave Entrance Vegetation

Entrance vegetation is monitored biennially in even years. In 2018, entrance vegetation point-intercept transects and photo monitoring were completed at all 34 target sites, including the 30 random caves and the four nonrandom ice caves (Appendix B). Entrance vegetation was also sampled opportunistically at one bat cave (BEAC). Since this site was not required by the protocol, its data are not included here. Monitoring occurred over a five-week period beginning May 23 and ending June 19, except for one cave monitored on July 3. Vegetation was recorded in broad categories; where possible, ferns, graminoid, herbaceous, and woody plants were identified to species using a park-specific photo guide. Due to logistical constraints, cyanobacteria were not differentiated from algae. Where no vegetation was present, bare substrate categories included rock, soil (primarily pumice), and organic (leaves and/or other detritus). Figure 16 provides examples of photos taken during the photo point monitoring; for obvious reasons, this report does not include the numerous photos taken for this monitoring approach. Figure 17 shows the categories of vegetation and/or substrate and their proportional representation across the monitored caves. Table 8 summarizes the proportion of each vegetation or substrate type at each monitored cave.

* Denotes a frontcountry cave.

Figure 16. Examples of vegetation communities in cave entrances at Lava Beds National Monument. Clockwise from top, sites include LOPI, CAIC, and INCA. The image at the top illustrates the placement of an inner and outer transect across a cave entrance. All three images depict photo monitoring points designed to provide a wholistic picture of the vegetation community, which can include vegetation on the cave walls or ceiling that would not be captured by point-intercept transects.

NPS

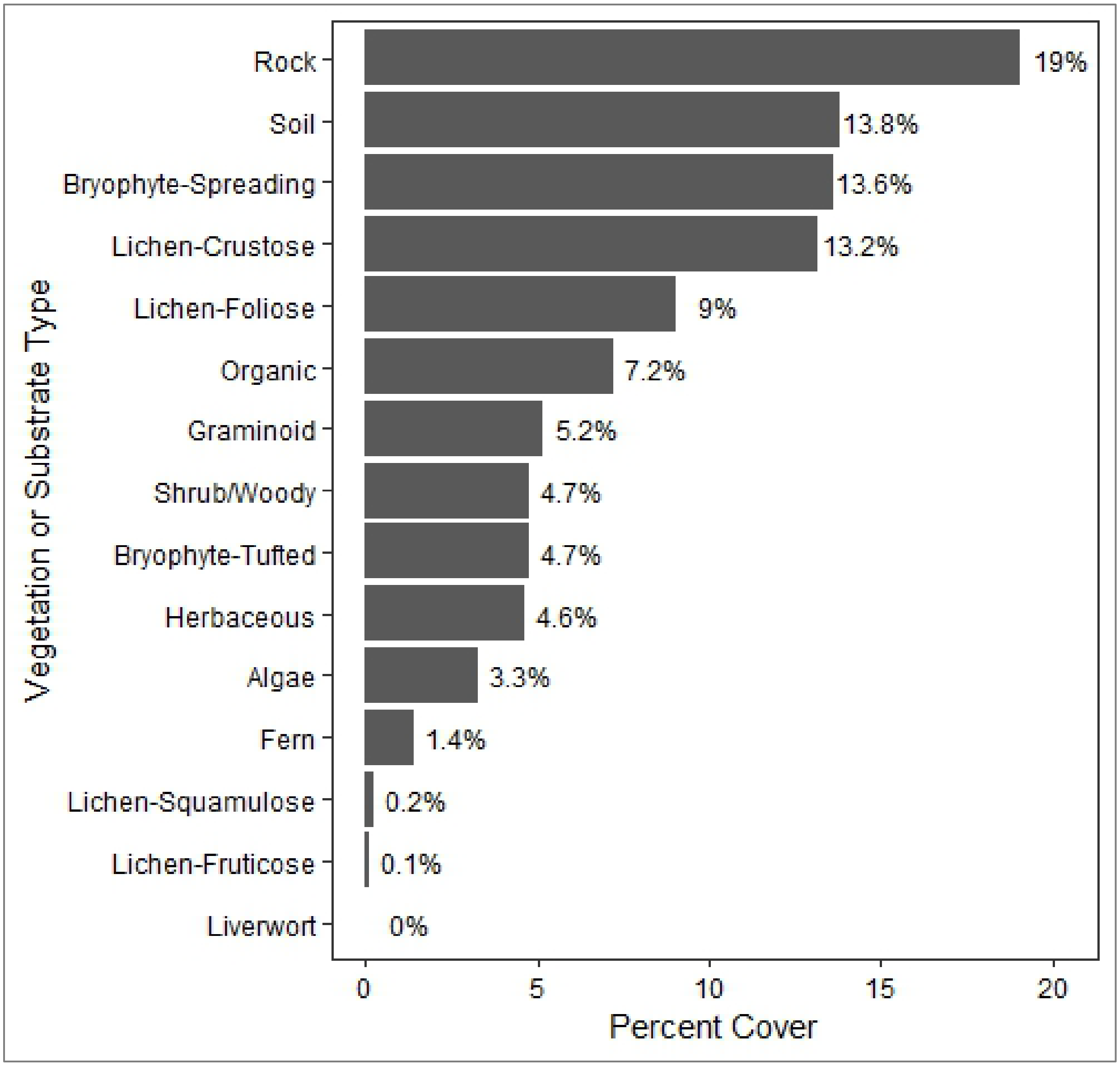

Figure 17. Proportion of vegetation and/or substrate types across 30 randomly sampled cave entrances as monitored using line-transect, point-intercept methods from May 23 to July 3, 2018, in Lava Beds National Monument.

NPS

Table 8. Percent cover of vegetation and substrate types at each of 34 cave entrances in Lava Beds National Monument. Cover types were determined through point intersect transects (2 transects, 40 points per cave) between May 23 and July 3, 2018.

Cave	Algae	Lichen-Crustose	Fern	Lichen-Foliose	Lichen-Fruticose	Graminoid	Herbaceous	Organic	Rock	Shrub/Woody	Soil	Bryophyte-Spreading	Lichen-Squamulose	Bryophyte-Tufted	Liverwort
ANGL	4.4%	15.6%	0.0%	6.7%	0.0%	0.0%	2.2%	11.1%	44.4%	8.9%	2.2%	0.0%	0.0%	4.4%	0.0%
BIPA [A]	2.5%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	2.5%	87.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CGCA	15.2%	26.1%	0.0%	4.3%	0.0%	0.0%	0.0%	8.7%	17.4%	10.9%	4.3%	13.0%	0.0%	0.0%	0.0%
CRIC [A]	28.2%	7.7%	0.0%	2.6%	0.0%	0.0%	0.0%	0.0%	5.1%	0.0%	2.6%	51.3%	2.6%	0.0%	0.0%
DECA	2.5%	15.0%	0.0%	35.0%	0.0%	0.0%	0.0%	0.0%	37.5%	0.0%	2.5%	7.5%	0.0%	0.0%	0.0%
FOCA	13.6%	0.0%	28.8%	0.0%	0.0%	0.0%	0.0%	22.0%	1.7%	0.0%	30.5%	3.4%	0.0%	0.0%	0.0%
HIMM	4.9%	4.9%	0.0%	9.8%	0.0%	0.0%	2.4%	7.3%	24.4%	0.0%	24.4%	9.8%	0.0%	12.2%	0.0%
JUHE [A]	4.7%	11.6%	0.0%	25.6%	0.0%	4.7%	0.0%	0.0%	34.9%	0.0%	2.3%	7.0%	2.3%	7.0%	0.0%
JURI	2.4%	23.8%	0.0%	16.7%	0.0%	4.8%	2.4%	4.8%	16.7%	0.0%	7.1%	16.7%	0.0%	4.8%	0.0%
LALA [A]	4.4%	26.7%	4.4%	6.7%	0.0%	2.2%	8.9%	0.0%	13.3%	0.0%	2.2%	28.9%	0.0%	2.2%	0.0%
LOPI	2.1%	4.3%	0.0%	0.0%	0.0%	6.4%	4.3%	25.5%	17.0%	0.0%	27.7%	8.5%	0.0%	4.3%	0.0%
SKIC [A]	6.7%	17.8%	0.0%	6.7%	0.0%	0.0%	6.7%	8.9%	13.3%	4.4%	8.9%	8.9%	0.0%	17.8%	0.0%
SPID	21.4%	0.0%	0.0%	0.0%	0.0%	2.4%	0.0%	28.6%	16.7%	0.0%	2.4%	28.6%	0.0%	0.0%	0.0%
VALE [A]	2.2%	2.2%	0.0%	4.4%	0.0%	2.2%	8.9%	8.9%	22.2%	0.0%	35.6%	6.7%	0.0%	6.7%	0.0%
BLGR [A]	0.0%	2.3%	0.0%	0.0%	0.0%	6.8%	2.3%	13.6%	11.4%	0.0%	13.6%	50.0%	0.0%	0.0%	0.0%
CAIC	0.0%	13.3%	0.0%	8.9%	0.0%	0.0%	2.2%	15.6%	26.7%	8.9%	11.1%	6.7%	0.0%	6.7%	0.0%
COIC	0.0%	17.5%	0.0%	20.0%	0.0%	0.0%	0.0%	7.5%	50.0%	0.0%	2.5%	2.5%	0.0%	0.0%	0.0%
CRCA	0.0%	1.8%	0.0%	7.3%	0.0%	1.8%	10.9%	5.5%	10.9%	16.4%	30.9%	10.9%	0.0%	3.6%	0.0%
EMST	0.0%	21.2%	0.0%	7.7%	0.0%	1.9%	5.8%	5.8%	7.7%	15.4%	5.8%	21.2%	1.9%	5.8%	0.0%
ICEB	0.0%	27.1%	0.0%	16.7%	0.0%	0.0%	0.0%	6.2%	14.6%	18.8%	2.1%	6.2%	0.0%	8.3%	0.0%
IDWL [A]	0.0%	12.1%	0.0%	5.2%	0.0%	19.0%	3.4%	1.7%	20.7%	8.6%	15.5%	12.1%	0.0%	1.7%	0.0%
INCA	0.0%	19.0%	0.0%	26.2%	0.0%	0.0%	2.4%	0.0%	45.2%	0.0%	0.0%	2.4%	0.0%	4.8%	0.0%
JUPO	0.0%	2.4%	0.0%	2.4%	2.4%	0.0%	2.4%	0.0%	23.8%	0.0%	59.5%	4.8%	0.0%	2.4%	0.0%
MEIC [A]	0.0%	1.9%	0.0%	3.8%	0.0%	7.5%	11.3%	1.9%	13.2%	5.7%	22.6%	22.6%	0.0%	9.4%	0.0%
NOBE	0.0%	31.7%	0.0%	7.3%	0.0%	0.0%	2.4%	0.0%	31.7%	0.0%	2.4%	4.9%	0.0%	19.5%	0.0%
PEAR	0.0%	20.8%	0.0%	8.3%	0.0%	0.0%	4.2%	16.7%	16.7%	16.7%	0.0%	8.3%	0.0%	8.3%	0.0%
RALO	0.0%	19.0%	0.0%	9.5%	0.0%	0.0%	4.8%	7.1%	33.3%	0.0%	14.3%	4.8%	0.0%	7.1%	0.0%
ROCO	0.0%	15.4%	0.0%	19.2%	0.0%	15.4%	1.9%	0.0%	11.5%	5.8%	17.3%	11.5%	0.0%	1.9%	0.0%
SEAN	0.0%	4.6%	1.5%	3.1%	0.0%	12.3%	6.2%	15.4%	10.8%	12.3%	13.8%	10.8%	0.0%	9.2%	0.0%
SKYL	0.0%	42.5%	0.0%	20.0%	0.0%	0.0%	0.0%	5.0%	12.5%	0.0%	5.0%	0.0%	0.0%	15.0%	0.0%
SOLA [A]	0.0%	9.8%	0.0%	12.2%	0.0%	0.0%	0.0%	7.3%	46.3%	0.0%	14.6%	4.9%	0.0%	4.9%	0.0%
SYMB	0.0%	34.8%	0.0%	8.7%	0.0%	6.5%	2.2%	6.5%	23.9%	2.2%	10.9%	4.3%	0.0%	0.0%	0.0%
THDB [A]	0.0%	11.7%	0.0%	13.3%	0.0%	11.7%	13.3%	3.3%	16.7%	8.3%	11.7%	6.7%	0.0%	3.3%	0.0%
YELL	0.0%	0.0%	0.0%	1.4%	0.0%	25.4%	19.7%	0.0%	1.4%	0.0%	16.9%	35.2%	0.0%	0.0%	0.0%

[A] Indicates that this is a frontcountry cave.

Bat Populations

In-cave visual encounter surveys were conducted from January 10 to 13, 2017, (Table 9) and January 8 to 12, 2018, (Table 10) at each of the six bat caves. Survey teams consisted of 2–3 members, all team members had extensive caving experience, and at least one team member had bat species identification expertise. The same methods are also used to survey additional caves as part of an ongoing study to estimate and detect trends in hibernating bat populations at the park, but those data are not included in this report. While conducting hibernacula surveys at the six bat caves, park staff may also have conducted white-nose syndrome (WNS) disease surveillance by swabbing the nose and forearm of hibernating bats to detect the presence of the fungus that causes WNS (*Pseudogymnoascus destructans*). During both years, WNS surveillance returned negative results from swabbed bats (*Corynorhinus townsendii* and *Myotis* spp.) using National Wildlife Health Center diagnostics.

Table 9. Total number of bats observed during 2017 hibernacula surveys, including summary statistics on clusters of two or more bats. For cluster counts, we report the number of bats in the cluster followed by the number of clusters of that size in parentheses. For example, 3(4) indicates that there were four clusters with three bats each.

Cave	Species	Total Individuals	Number of Clusters	Median Cluster Size	Cluster Size Range	Average Cluster Size (SD)	Cluster Counts
ANGL	*Corynorhinus townsendii*	40	4	6	3–13	7 (4.5)	1(12), 8(1), 4(1), 3(1), 13(1)
BEAC	*Corynorhinus townsendii*	81	12	3	2–6	3.8 (1.6)	1(36), 2(3), 3(4), 4(1), 5(1), 6(3)
BEAC	*Myotis* spp.	2	0	N/A	Only Singles	N/A	1(2)
CGCA	*Corynorhinus townsendii*	548	51	3	2–60	7 (9.4)	1(192), 60(1), 9(1), 5(2), 12(1), 23(1), 11(2), 18(1), 7(1), 16(2), 2(20), 10(2), 4(4), 3(8), 8(1), 19(1), 13(1), 17(1), 6(1)
CGCA	*Myotis* spp.	4	0	N/A	Only Singles	N/A	1(4)
DRHE	*Corynorhinus townsendii*	190	17	4	2–41	10.1 (11.8)	1(18), 2(6), 3(2), 4(2), 10(1), 12(1), 13(2), 27(1), 30(1), 41(1)
DRHE	Unknown Bat	2	0	N/A	Only Singles	N/A	1(2)
INCA	*Corynorhinus townsendii*	110	16	3	2–14	4.9 (3.9)	1(32), 2(7), 3(2), 5(3), 8(1), 9(1), 12(1), 14(1)
SENT [A]	*Corynorhinus townsendii*	35	2	2	2–2	2 (0)	1(31), 2(2)
SENT [A]	*Myotis* spp.	2	0	N/A	Only Singles	N/A	1(2)

[A] Indicates that this is a frontcountry cave.

Table 10. Total number of bats observed during 2018 hibernacula surveys, including summary statistics on clusters of two or more bats at Lava Beds National Monument. For cluster counts, we report the number of bats in the cluster followed by the number of clusters of that size in parentheses. For example, 3(4) indicates that there were four clusters with three bats each.

Cave	Species	Total Individuals	Number of Clusters	Median Cluster Size	Cluster Size Range	Average Cluster Size (SD)	Cluster Counts
ANGL	*Corynorhinus townsendii*	50	4	5	2–7	4.8 (2.1)	1(31), 2(1), 5(2), 7(1)
BEAC	*Corynorhinus townsendii*	85	7	3	2–19	5.4 (6)	1(47), 3(3), 19(1), 4(2), 2(1)
CGCA	*Corynorhinus townsendii*	533	60	3	2–52	6 (8.4)	1(174), 9(1), 2(29), 10(1), 6(2), 11(2), 4(6), 19(3), 23(1), 29(1), 13(1), 3(9), 8(2), 52(1), 7(1)
CGCA	*Eptesicus fuscus*	2	N/A	N/A	Only Singles	N/A	1(2)
CGCA	*Myotis* spp.	1	N/A	N/A	Only Singles	N/A	1(1)
DRHE	*Corynorhinus townsendii*	487	46	5	2–58	8.8 (11.5)	1(80), 2(9), 12(2), 21(1), 53(1), 4(2), 9(2), 6(2), 26(1), 17(1), 5(5), 14(3), 13(1), 11(1), 10(1), 7(3), 3(10), 58(1)
INCA	*Corynorhinus townsendii*	93	15	2	2–28	4.8 (6.7)	1(21), 5(3), 3(1), 28(1), 2(9), 8(1)
SENT [A]	*Corynorhinus townsendii*	74	2	2	2–2	2 (0)	1(70), 2(2)
SENT [A]	*Myotis* spp.	7	N/A	N/A	Only Singles	N/A	1(7)

[A] Indicates that this is a frontcountry cave.

Scat and Organic Material

Scat and visible organics surveys are conducted biennially in even years. In 2018, we conducted these surveys at all 30 randomly selected caves over a nine-week period from the last full week of July through the third full week of September, with the majority of the work done in August. In most cases, these surveys were completed in conjunction with invertebrate surveys. Opportunistic scat surveys were also conducted at the four nonrandom ice caves in 2018, but since those surveys are not required by the protocol the results are not described in this report.

There was a wide range of animal-related scat and organic material in the monitored caves. Bat guano and moth wings/cricket legs (bat prey detritus) were observed in 25 and 26 of the 30 randomly selected caves, respectively (Table 11, Figure 18). Bat guano was not identified to species but may include those known to use caves at Lava Beds for day or night roosting (*Corynorhinus townsendii, Antrozous pallidus, Tadarida brasiliensis*) or others less well studied (*Eptesicus fuscus, Myotis* spp., *Parastrellus hesperus*). Bird nests were observed at two caves, which also contained owl pellets. Bird species potentially nesting in cave entrances include barn owls (*Tyto alba*), common ravens (*Corvus corax*) and great horned owls (*Bubo virginianus*). Dead invertebrates were present in 19 out of 30 caves, including 11 entrance zones, 7 middle zones, and 10 deep zones. Human-deposited inorganic trash (plastic wrappers, shredded clothing, and shoe remnants, etc.) was present in 21 out of 30 caves, 14 of which are backcountry caves not advertised to the public. Human-deposited organic trash (food waste, human waste, etc.) was present at 10 out of 30 caves, just three of which are backcountry caves. Key materials of interest at all 30 caves are presented in Table 12.

Table 11. Proportion of 30 randomly selected caves and zones that contained different categories of scat and organic matter in 2018 at Lava Beds National Monument.

Source of Material	Type of Material	Total Proportion of Caves	Entrance Zone	Middle Zone	Deep Zone
Animal	Bat Guano	83.3%	70.0%	50.0%	46.7%
Animal	Bird Nest	6.7%	6.7%	0.0%	0.0%
Animal	Bird Scat	53.3%	53.3%	13.3%	0.0%
Animal	Bones	90.0%	70.0%	80.0%	70.0%
Animal	Dead Invertebrates	63.3%	36.7%	23.3%	33.3%
Animal	Feathers/fur/flesh	30.0%	26.7%	3.3%	0.0%
Animal	Moth Wings/Cricket Legs	86.7%	66.7%	56.7%	30.0%
Animal	Owl Pellet	6.7%	6.7%	0.0%	0.0%
Animal	Pika Scat	10.0%	6.7%	3.3%	0.0%
Animal	Rabbit Scat	53.3%	40.0%	23.3%	6.7%
Animal	Raccoon Scat	20.0%	6.7%	6.7%	6.7%
Animal	Rodent Nest, Midden, or Amberrat	30.0%	13.3%	16.7%	3.3%
Animal	Rodent Scat	96.7%	93.3%	83.3%	86.7%
Human	Lint	26.7%	6.7%	10.0%	20.0%

Table 11 (continued). Proportion of 30 randomly selected caves and zones that contained different categories of scat and organic matter in 2018 at Lava Beds National Monument.

Source of Material	Type of Material	Total Proportion of Caves	Entrance Zone	Middle Zone	Deep Zone
Human	Trash—inorganic	70.0%	60.0%	36.7%	33.3%
Human	Trash—organic	33.3%	23.3%	23.3%	13.3%
Plant	Algae	83.3%	83.3%	10.0%	0.0%
Plant	Plant Material	100.0%	100.0%	90.0%	76.7%

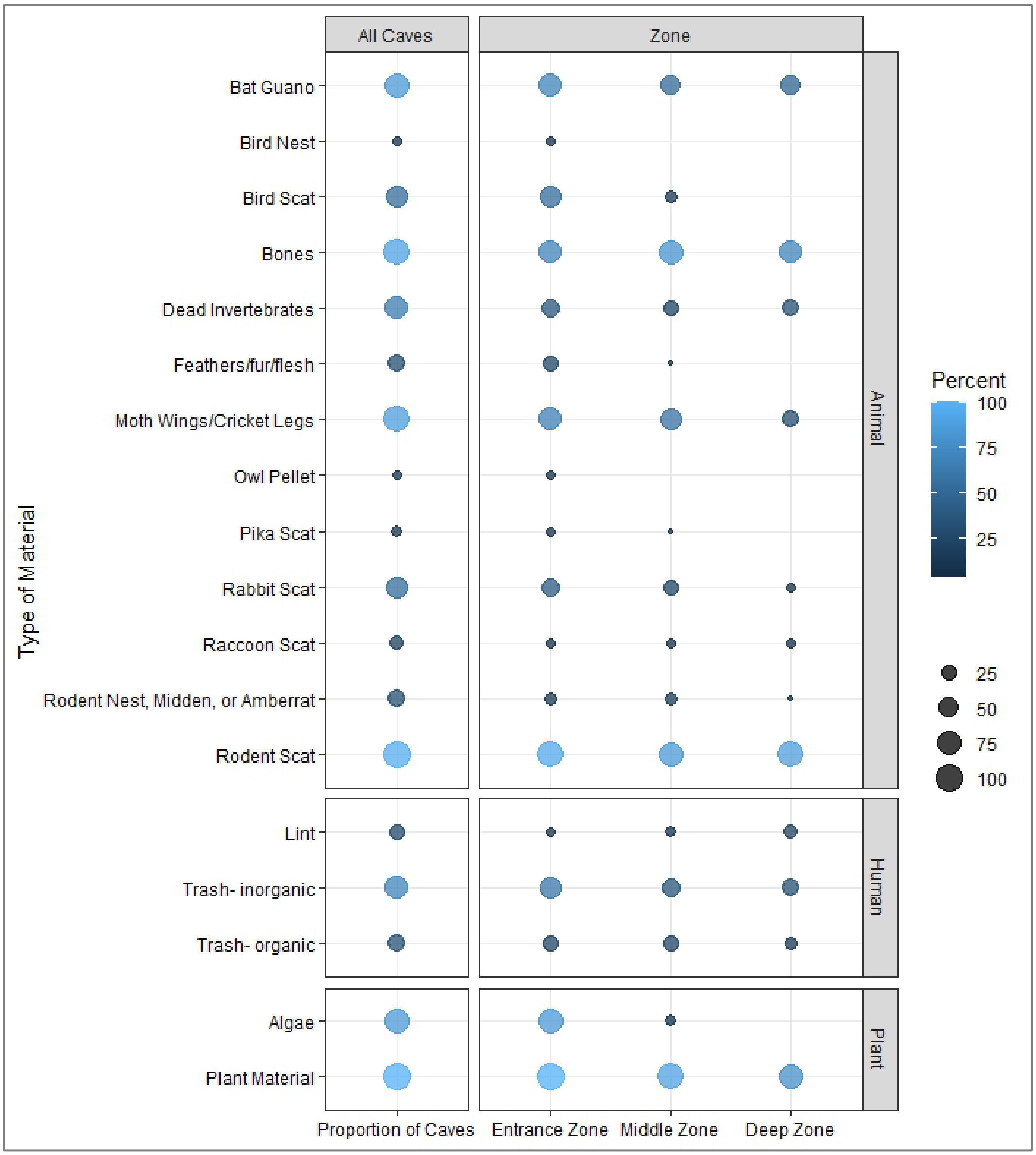

Figure 18. Proportion of caves and cave zones that contained different types of scat and organic matter in 2018 at Lava Beds National Monument.
NPS

Table 12. Presence of “materials of interest” in specific caves (30) and zones in 2018 at Lava Beds National Monument.

Cave	Dead Invertebrates [A]	Bat Guano [A]	Bird Scat [A]	Moth Wings/ Cricket Legs [A]	Trash: Inorganic [A]	Trash: Organic [A]	Rabbit Scat [A]	Feathers/ Fur/Flesh [A]	Raccoon Scat [A]	Bird Nest [A]	Owl Pellet [A]	Pika Scat [A]
ANGL	M	E	E	E	M	–	–	–	–	–	–	–
BLGR [B]	E	MD	E	M	ED	EMD	M	–	–	–	–	–
CGCA	ED	EMD	E	E	E	–	–	E	–	–	–	–
CRCA	E	E	E	EM	–	–	EMD	–	D	–	–	–
CRIC [B]	E	–	–	–	E	–	–	–	–	–	–	–
DECA	–	EMD	–	MD	–	–	–	–	–	–	–	–
EMST	–	EMD	EM	MD	–	–	E	–	–	E	E	M
FOCA	MD	MD	E	EM	EMD	–	–	E	–	–	–	–
HIMM	ED	–	–	–	–	–	–	–	–	–	–	E
ICEB	–	EMD	E	EM	–	–	E	E	E	E	E	–
IDWL [B]	ED	EM	E	M	EMD	E	M	M	–	–	–	–
INCA	M	EMD	E	EM	E	–	E	E	–	–	–	–
JUHE [B]	–	E	–	E	D	EM	EM	–	–	–	–	–
JUPO	M	–	–	E	E	–	–	–	–	–	–	E
JURI	–	EMD	EM	EMD	–	–	EM	–	M	–	–	–
LALA [B]	–	D	–	EM	EMD	EM	–	–	–	–	–	–
LOPI	ED	–	–	–	EMD	–	–	–	–	–	–	–
MEIC [B]	D	E	E	E	EMD	EMD	–	E	–	–	–	–
NOBE	–	EMD	E	EMD	–	–	E	–	E	–	–	–
PEAR	E	E	–	E	EMD	–	E	–	–	–	–	–
RALO	MD	EM	–	EMD	–	M	M	–	–	–	–	–
ROCO	–	EM	–	EMD	E	–	–	–	–	–	–	–

[A] E = Present in entrance zone, M = Present in middle zone, D = Present in deep zone. “–” indicates a material was not observed in a particular cave.

[B] Indicates that this is a frontcountry cave.

Table 12 (continued). Presence of “materials of interest” in specific caves (34) and zones in 2018 at Lava Beds National Monument.

Cave	Dead Invertebrates [A]	Bat Guano [A]	Bird Scat [A]	Moth Wings/ Cricket Legs [A]	Trash: Inorganic [A]	Trash: Organic [A]	Rabbit Scat [A]	Feathers/ Fur/Flesh [A]	Raccoon Scat [A]	Bird Nest [A]	Owl Pellet [A]	Pika Scat [A]
SEAN	ED	E	–	E	EMD	D	–	–	–	–	–	–
SKYL	–	EMD	E	EM	M	–	E	–	–	–	–	–
SOLA [B]	ED	ED	E	ED	E	–	E	E	–	–	–	–
SPID	M	E	EM	D	E	M	EM	–	D	–	–	–
SYMB	–	EMD	EM	EMD	–	–	E	E	M	–	–	–
THDB [B]	MD	ED	–	–	EM	E	D	E	–	–	–	–
VALE [B]	–	M	–	EM	EMD	EMD	–	–	–	–	–	–
YELL	E	–	–	M	E	–	–	–	–	–	–	–

[A] E = Present in entrance zone, M = Present in middle zone, D = Present in deep zone. “–” indicates a material was not observed in a particular cave.

[B] Indicates that this is a frontcountry cave.

Cave Invertebrate Community

Cave invertebrates are monitored biennially in even years. In 2018, we monitored invertebrates over a 10-week period from the second full week of July (July 8–13) through the second week of September (September 9–14). Surveys required two visits to each cave. On the first visit, we set bait stations in each zone; on the second visit (14 to 16 days later), we conducted visual encounter surveys, recording invertebrate fauna within a 1 square meter area around each bait station. After completing surveys, we removed all bait stations from the cave. Cave millipedes and spiders had the highest occupancy rates and were recorded in approximately ¾ of all randomly selected caves (Table 13). The springtail *Tomocerus* sp., followed by the cave millipede, was the most abundant invertebrate overall (Figure 19). Table 14 depicts the cave zones where invertebrates of management concern were recorded within each cave. Figure 19 illustrates the relative abundance of different invertebrate groups aggregated by cave zone. On average, randomly selected caves contained 6.5 invertebrate taxa, with RALO containing the most, at 13, and SYMB and CRIC* containing the least, with only one each.

Table 13. The 20 most widely distributed invertebrate taxa in 2018 across 30 randomly selected caves, by cave zone, at Lava Beds National Monument.

Taxon	Proportion of Caves	Entrance Zone	Middle Zone	Deep Zone
Cave Millipede	73.3%	26.70%	46.70%	66.70%
Spider	73.3%	56.70%	30.00%	30.00%
Springtail-*Tomocerus* sp.	66.7%	36.70%	40.00%	43.30%
Gnat	63.3%	43.30%	23.30%	36.70%
Camel Cricket	53.3%	33.30%	26.70%	30.00%
Dipluran	53.3%	16.70%	6.70%	40.00%
Springtail-*Entomobrya* sp.	50.0%	40.00%	26.70%	20.00%
Rove Beetle	36.7%	16.70%	16.70%	10.00%
Moth	26.7%	13.30%	6.70%	10.00%
Fly	26.7%	16.70%	6.70%	3.30%
Ant	13.3%	3.30%	6.70%	6.70%
Centipede	13.3%	6.70%	3.30%	3.30%
Mite	13.3%	6.70%	0.00%	6.70%
Mosquito	13.3%	10.00%	3.30%	3.30%
Springtail-white	13.3%	10.00%	6.70%	3.30%
Midge	10.0%	6.70%	0.00%	3.30%
Crane Fly	6.7%	6.70%	0.00%	0.00%
Harvestman	6.7%	3.30%	3.30%	0.00%

* Denotes a frontcountry cave.

Table 13 (continued). The 20 most widely distributed invertebrate taxa in 2018 across 30 randomly selected caves, by cave zone, at Lava Beds National Monument.

Taxon	Proportion of Caves	Entrance Zone	Middle Zone	Deep Zone
Pseudoscorpion	6.7%	3.30%	3.30%	0.00%
Springtail-Unidentified	6.7%	0.00%	3.30%	3.30%

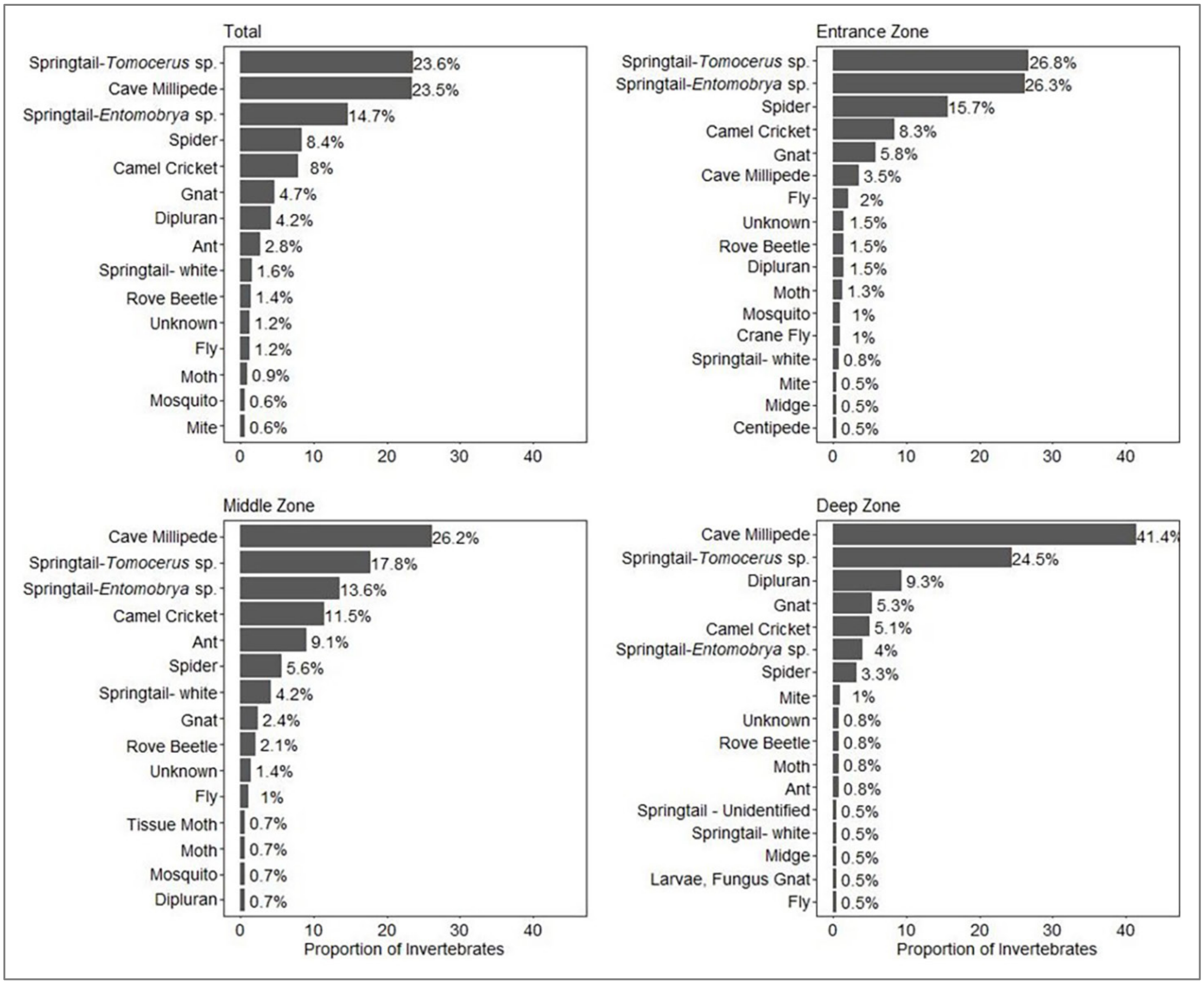

Figure 19. Relative abundance of invertebrates across 30 randomly sampled caves and broken down by cave zone at Lava Beds National Monument. Numbers to the right of each bar reflect the proportional abundance of that taxonomic group. Plots depict taxa whose relative abundance was greater than 0.5%. *NPS*

Table 14. Presence of “invertebrates of management interest” across entrance, middle, and deep zones of 34 caves in 2018 at Lava Beds National Monument. The final column, Richness, reflects the number of different invertebrate groups recorded in each cave.

Cave	Camel Cricket [A]	Cave Millipede [A]	Centipede [A]	Dipluran [A]	Pseudoscorpion [A]	Springtail: *Entomobrya* sp. [A]	Springtail: *Tomocerus* sp. [A]	Springtail: White [A]	Spider [A]	Richness [A]
ANGL	–	EMD	–	E	–	–	–	–	–	4
BIPA [B]	EM	D	–	–	–	EM	–	–	M	6
BLGR [B]	–	–	–	–	–	EM	M	EMD	EMD	5
CAIC	E	D	–	D	–	E	–	–	E	6
CGCA	–	MD	–	D	–	–	M	–	E	8
COIC	–	MD	–	M	–	–	E	–	–	6
CRCA	MD	–	–	–	–	E	EM	–	EM	7
CRIC [B]	–	ED	–	–	–	–	–	–	–	1
DECA	E	MD	M	M	–	–	E	–	E	7
EMST	E	D	–	–	–	–	MD	–	–	3
FOCA	–	D	–	D	E	–	EMD	–	E	9
HIMM	EM	EMD	E	D	–	D	ED	–	EM	11
ICEB	–	MD	–	–	–	–	–	–	–	5
IDWL [B]	–	MD	–	–	–	EMD	EM	M	E	7
INCA	–	MD	–	D	–	D	E	–	–	5
JUHE [B]	EMD	–	–	–	–	EM	D	–	D	6
JUPO	M	D	–	D	–	EM	D	–	MD	7
JURI	EM	D	–	–	–	–	D	–	EM	6
LALA [B]	D	M	–	D	–	E	EMD	E	–	8
LOPI	–	EMD	–	ED	–	M	–	–	D	6
MEIC [B]	–	EMD	–	D	–	–	–	–	–	3
NOBE	–	M	–	M	–	–	–	–	E	5

[A] E = Present in entrance zone, M = Present in middle zone, D = Present in deep zone. “–” indicates an invertebrate was not observed in a particular cave.

[B] Indicates that this is a frontcountry cave.

Table 14 (continued). Presence of "invertebrates of management interest" across entrance, middle, and deep zones of 34 caves in 2018 at Lava Beds National Monument. The final column, Richness, reflects the number of different invertebrate groups recorded in each cave.

Cave	Camel Cricket [A]	Cave Millipede [A]	Centipede [A]	Dipluran [A]	Pseudoscorpion [A]	Springtail: *Entomobrya* sp. [A]	Springtail: *Tomocerus* sp. [A]	Springtail: White [A]	Spider [A]	Richness [A]
PEAR	EMD	–	–	–	–	–	D	–	EMD	6
RALO	MD	ED	D	ED	M	EMD	EMD	–	MD	13
ROCO	D	EMD	–	ED	–	–	EMD	–	D	9
SEAN	–	EMD	–	E	–	–	EM	–	E	8
SKIC [B]	–	–	–	–	–	EM	–	–	–	3
SKYL	–	–	–	–	–	EM	–	E	E	5
SOLA [B]	D	–	E	–	–	ED	–	–	ED	5
SPID	E	D	–	D	–	–	MD	–	EM	11
SYMB	–	–	–	–	–	–	–	–	–	1
THDB [B]	EMD	–	–	–	–	EMD	–	–	ED	6
VALE [B]	ED	MD	–	D	–	E	MD	–	E	8
YELL	E	D	–	–	–	E	ED	–	EM	10

[A] E = Present in entrance zone, M = Present in middle zone, D = Present in deep zone. "–" indicates an invertebrate was not observed in a particular cave.

[B] Indicates that this is a frontcountry cave.

Discussion

Cave Climate

Cave environmental conditions can affect biological and chemical processes, can be altered by human activities and changing surface climate patterns, and are often linked to phenomena such as ice accumulation or the location and behavior of bats. Data presented here show continuous temperature values and 7-day moving averages for the entrance, middle, and deep zones in each of nine caves with substantial ice and bat resources, as well as broad 2-year trends across 30 randomly sampled caves. Overall, temperature tended to be the most variable in entrance zones and most stable in deep zones. Deviations from this general pattern suggest that other factors, like cave morphology and distance to the nearest cave entrance, may also impact patterns and variability in cave climate.

Ice

Comparisons of cave ice through time were made from the two-dimensional areal extent of ice floors. Among sites monitored in 2016 and 2017, the areal extent of ice was less in 2017 than in 2016 and differences ranged from 3.05 m^2 (CRIC* Red Ice Room) to 9.89 m^2 (SKIC* Boneless Cavern). At both sites where data were reported only from 2016 and 2019 due to lack of surveys in 2017 and 2018, the areal extent of ice was greater in 2019 than in 2016 and differences ranged from 3.7 m^2 (CRIC* Blue Glacier) to 3.34 m^2 (SKIC* Front Room). Observer variation and slight differences in the application of field protocols likely contribute to differences in ice polygons between years, so these results—while suggestive—are preliminary. The observation error of these measurements is unknown and may be greater where ice floor edges meet rock breakdown instead of a smooth cave wall. In addition, magnetism due to the bedrock's high iron content can alter compass readings by up to 10 degrees. Park staff strive to minimize this source of error, but at least 2 degrees of variation is inevitable and further complicates our ability to perfectly align ice polygons between years. Further study and/or additional years of monitoring may clarify the accuracy of ice floor measurements. Until then, careful consideration should be given to the differences in areal extent values between years and may be more insightful when paired with photo monitoring and site visits.

Human Visitation

Visitation can serve as a basic indicator of the degree of human impacts on a cave. Here we observed temporal visitation patterns like that of other NPS sites, where visitation is highest in the summer months. We also observed that visitation varies greatly between frontcountry caves popular among public visitors (e.g., SKIC*, SENT*) and those less popular (e.g., JUHE* and IDWL*). For example, during the highest visitation period (July and August) of 2017, JUHE* was visited by approximately 150 people per day, while BIPA* was visited by approximately 50 people per day. In addition, backcountry caves receive substantially less visitation overall and NPS staff visits for monitoring purposes may, in some cases, make up the majority of visitation at those sites. TRAFx Infrared Trail Counters provide useful estimates of visitation at frontcountry sites but require regular staff effort to maintain and replace non-functional equipment. For example, a lapse in staffing resulted in data

* Denotes a frontcountry cave.

collection failures at 7 out of 10 caves with TRAFx Infrared Trail Counters for 6 to 7 months in 2018. Cave registers, in comparison, require very little staff effort to maintain but provide uncertain accuracy, requiring active and voluntary participation from visitors to sign the register and report accurate data. For example, registers in some caves indicate zero human visitation during periods when staff visited to implement monitoring protocols (e.g., NOBE in 2017). One cave, SENT*, contains both methods for tracking visitation, but since the register is located in a remote passage where we expect less frequent visitation, it does not enable a robust comparison between methods. The accuracy of registers in comparison to TRAFx Infrared Trail Counters should be investigated at both frontcountry and backcountry caves.

Cave Entrance Vegetation

Vegetation at cave entrances is sparsely and unevenly distributed across multi-dimensional surfaces on the floor, walls, and ceiling of each entrance. Across the 30 randomly sampled caves, entrance vegetation communities contained an average of 8.3 distinct vegetation and substrate types. On average, cave entrances contained 39% bare ground and 61% vegetation cover. Point-intercept transects alone may not capture the entire vegetation community surrounding a cave entrance; thus, supplementation with photo monitoring provides additional context of vegetation cover and diversity. The 2018 point-intercept transects showed high prevalence of bare rock, soil (i.e., primarily pumice), crustose and foliose lichen, and spreading bryophytes (i.e., moss and liverwort) on the ground in cave entrances. Survey photos captured a variety of other vegetation types of interest surrounding cave entrances that were not represented in point-intercept data, including fragile ferns (*Cystopteris fragilis*), sword ferns (*Polystichum munitum*), *Scrophularia* spp., desert sweet or fernbush (*Chamaebatiaria millefolium*), and young western juniper (*Juniperus occidentalis*).

Bat Populations

At the six bat caves, 68% of Townsend's big-eared bats observed in 2017 and 2018 were clustering (touching), while 32% were roosting individually. Cluster sizes ranged from 2 to 60 bats. Total numbers of Townsend's big-eared bats observed at these sites ranged from 35 to 548 bats. Less than 1% of bats observed were other species (i.e., *Eptesicus fuscus* or *Myotis* spp.). Total number of bats observed per cave was relatively similar between 2017 and 2018 except at DRHE, which historically shows high variation between years (K. Smith, Lava Beds National Monument, pers. obs.). White nose-syndrome (WNS) was not detected during annual disease surveillance in bat hibernacula in Lava Beds National Monument in 2017–2018.

Scat and Organic Material

The most common scat and organic materials observed in over 70% of caves surveyed included plant material, rodent scat, bones, moth wings/cricket legs (bat prey detritus), algae, bat guano, and inorganic trash. Plant material found in entrance zones may have been carried in by rain or wind, but those found in middle and deep zones may have been carried in by rodents and other animals. Rodent scat (primarily *Neotoma* sp.) is distributed throughout many sites and zones. Bones observed were

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* Denotes a frontcountry cave.

not identified to species but may include trogloxene mammals (e.g., rodents and bats). While bat prey detritus is typically deposited during the active foraging season at night roosts where bats consume their prey and rest, guano can be deposited any time of year at both day and night roosts. All algae observed is the result of natural growth at cave entrances; none of the caves in this monitoring protocol have artificial lighting structures that would cause non-natural algae growth. While inorganic trash (plastic wrappers, shredded shoe remnants, headlamp batteries, etc.) was present at 70% of sites and most common in entrance zones, organic trash (food waste, human waste, etc.) was observed at 33% of sites and present more often in entrance and middle zones. Conversely, clothing lint was found most often in deep zones.

Cave Invertebrate Community

The most common invertebrate taxa observed at over 50% of caves included cave millipedes, spiders, springtails (*Tomocerus* sp. and *Entomobrya* sp.), gnats, camel crickets, and diplurans. The springtail *Tomocerus* sp. was common in all cave zones and was the most abundant taxonomic group overall. The springtail *Entomobrya* sp. and spiders were abundant in entrance zones but increasingly scarce in middle and deep zones. By contrast, cave millipedes and diplurans were most abundant in deep zones but not middle or entrance zones. Pseudoscorpions, considered predators among the invertebrate community, were observed at FOCA and RALO during these surveys. Environmental conditions at the bait stations and survey areas varied by substrate and moisture level. In many cases, fungus (mold) grew on the peanut butter bait station between setup and survey dates, and in a few cases, the bait station was removed entirely, presumably by rodents.

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Appendix A. GRTS Site List

Site tracking table containing the Generalized Random Tessellation Stratified (GRTS) draw from the sampling frame of caves ≥91 m long at Lava Beds National Monument. Caves are ordered by their GRTS number, with 30 sites assigned to the main panel and 30 sites assigned to the oversample (Table 15).

Table 15. Results of the GRTS draw defining the main and oversample site list for the sampling frame for caves at Lava Beds National Monument. The GRTS Order shows the sequence for selecting caves to monitor. The Status column shows whether sites were accepted or rejected after screening for additional criteria in 2016.

Cave Code	Cave Name	GRTS Order	GRTS Panel	Status 8/4/2016
SKYL	not available	Site-01	Main	Accepted
PURA	not available	Site-02	Main	Rejected [B]
FOCA	not available	Site-03	Main	Accepted
JURI	not available	Site-04	Main	Accepted
SYMB	not available	Site-05	Main	Accepted
YELL	not available	Site-06	Main	Accepted
JUPO	not available	Site-07	Main	Accepted
MEIC [A]	MERRILL ICE CAVE	Site-08	Main	Accepted
NOBE	not available	Site-09	Main	Accepted
IDWL [A]	INDIAN WELL CAVE	Site-10	Main	Accepted
BLGR [A]	BLUE GROTTO CAVE	Site-11	Main	Accepted
PEAR	not available	Site-12	Main	Accepted
VALE [A]	VALENTINE CAVE	Site-13	Main	Accepted
CGCA	not available	Site-14	Main	Accepted
SEC8	not available	Site-15	Main	Rejected [C]
TOWN	not available	Site-16	Main	Rejected [B]
ANGL	not available	Site-17	Main	Accepted
POBR	not available	Site-18	Main	Rejected [B]
JUHE [A]	JUNIPER - HERCULES LEG CAVE	Site-19	Main	Accepted
INCA	not available	Site-20	Main	Accepted
SKBR	not available	Site-21	Main	Rejected [B]
LALA [A]	LABYRINTH - LAVA BROOK CAVE	Site-22	Main	Accepted
UHBR	not available	Site-23	Main	Rejected [B]

[A] Indicates that this is a frontcountry cave.

[B] Cave was rejected because the deep zone did not meet our criteria.

[C] Cave was rejected due to the presence of fragile resources.

Table 15 (continued). Results of the GRTS draw defining the main and oversample site list for the sampling frame for caves at Lava Beds National Monument. The GRTS Order shows the sequence for selecting caves to monitor. The Status column shows whether sites were accepted or rejected after screening for additional criteria in 2016.

Cave Code	Cave Name	GRTS Order	GRTS Panel	Status 8/4/2016
EMST	not available	Site-24	Main	Accepted
SPIN	not available	Site-25	Main	Rejected [C]
CORE	not available	Site-26	Main	Rejected [C]
COSN	not available	Site-27	Main	Rejected [C]
RALO	not available	Site-28	Main	Accepted
DECA	not available	Site-29	Main	Accepted
CRCA	not available	Site-30	Main	Accepted
FERM	not available	Site-31	OverSamp	Rejected [C]
HIMM	not available	Site-32	OverSamp	Accepted
LOPI	not available	Site-33	OverSamp	Accepted
SEAN	not available	Site-34	OverSamp	Accepted
CRIC [A]	CRYSTAL ICE CAVE	Site-35	OverSamp	Accepted
ROCO	not available	Site-36	OverSamp	Accepted
ICEB	not available	Site-37	OverSamp	Accepted
THDB [A]	THUNDERBOLT CAVE	Site-38	OverSamp	Accepted
SOLA [A]	SOUTH LABYRINTH CAVE	Site-39	OverSamp	Accepted
ELLO	not available	Site-40	OverSamp	Rejected [B]
SPID	not available	Site-41	OverSamp	Accepted
PSYC	not available	Site-42	OverSamp	Unused
SHMO	not available	Site-43	OverSamp	Unused
SNSC	not available	Site-44	OverSamp	Unused
BR02	not available	Site-45	OverSamp	Unused
LOTH	not available	Site-46	OverSamp	Unused
FERN [A]	FERN CAVE	Site-47	OverSamp	Unused
REUN	not available	Site-48	OverSamp	Unused
SHIP	not available	Site-49	OverSamp	Unused
BACH [A]	BALCONY CHAMBER	Site-50	OverSamp	Unused
DWTO	not available	Site-51	OverSamp	Unused
OHIO	not available	Site-52	OverSamp	Unused
LYRO	not available	Site-53	OverSamp	Unused

[A] Indicates that this is a frontcountry cave.

[B] Cave was rejected because the deep zone did not meet our criteria.

[C] Cave was rejected due to the presence of fragile resources.

Table 15 (continued). Results of the GRTS draw defining the main and oversample site list for the sampling frame for caves at Lava Beds National Monument. The GRTS Order shows the sequence for selecting caves to monitor. The Status column shows whether sites were accepted or rejected after screening for additional criteria in 2016.

Cave Code	Cave Name	GRTS Order	GRTS Panel	Status 8/4/2016
MAHO	not available	Site-54	OverSamp	Unused
MAZE	not available	Site-55	OverSamp	Unused
CHRI	not available	Site-56	OverSamp	Unused
SCHO	not available	Site-57	OverSamp	Unused
ADRA	not available	Site-58	OverSamp	Unused
BOUL [A]	BOULEVARD CAVE	Site-59	OverSamp	Unused
ARSE	not available	Site-60	OverSamp	Unused

[A] Indicates that this is a frontcountry cave.

[B] Cave was rejected because the deep zone did not meet our criteria.

[C] Cave was rejected due to the presence of fragile resources.

Appendix B. Monitoring Protocols by Cave

Breakdown of monitoring protocols, along with selection method, region (front or backcountry), and presence of significant ice or bat resources monitored within each cave at Lava Beds National Monument (Table 16).

Table 16. Monitoring protocols by cave at Lava Beds National Monument.

Cave Code	Region	Selection Method	Monitoring Protocol					
			Resource	Climate [A]	Visitation [B]	Scat [A]	Vegetation [A]	Invertebrates [A]
BEAC	Back	Judgement	Bats	X	Register	–	–	–
DRHE	Back	Judgement	Bats	X	Register	–	–	–
SENT [C]	Front	Judgement	Bats	X	Both	–	–	–
BIPA [C]	Front	Judgement	Ice	X	TRAFx	–	X	X
CAIC	Back	Judgement	Ice	X	Register	–	X	X
COIC	Back	Judgement	Ice	X	Register	–	X	X
SKIC [C]	Front	Judgement	Ice	X	TRAFx	–	X	X
ANGL	Back	Random	Bats	X	Register	X	X	X
BLGR [C]	Front	Random	–	X	TRAFx	X	X	X
CGCA	Back	Random	Bats	X	Register	X	X	X
CRCA	Back	Random	–	X	–	X	X	X
CRIC [C]	Front	Random	Ice	X	NPS Log	X	X	X
DECA	Back	Random	–	X	–	X	X	X
EMST	Back	Random	–	X	–	X	X	X
FOCA	Back	Random	–	X	Register	X	X	X

[A] An “X”s indicates that a protocol was conducted in that cave, and an en dash (–) indicates that it was not.

[B] The protocol methods used for that cave are named and an en dash (–) indicates that no protocol method was used for that cave.

[C] Indicates that this is a frontcountry cave.

[D] During the 2017–2018 reporting period, JURI was being monitored for climate, scat, vegetation, and invertebrates, but this cave was removed from the KLMN monitoring program in 2020.

Table 16 (continued). Monitoring protocols by cave at Lava Beds National Monument.

Cave Code	Region	Selection Method	Monitoring Protocol					
			Resource	Climate [A]	Visitation [B]	Scat [A]	Vegetation [A]	Invertebrates [A]
HIMM	Back	Random	–	X	–	X	X	X
ICEB	Back	Random	–	X	–	X	X	X
IDWL [C]	Front	Random	–	X	TRAFx	X	X	X
INCA	Back	Random	Bats	X	Register	X	X	X
JUHE [C]	Front	Random	–	X	TRAFx	X	X	X
JUPO	Back	Random	–	X	–	X	X	X
JURI [D]	Back	Random	–	–	–	–	–	–
LALA [C]	Front	Random	–	X	TRAFx	X	X	X
LOPI	Back	Random	–	X	Register	X	X	X
MEIC [C]	Front	Random	–	X	TRAFx	X	X	X
NOBE	Back	Random	–	X	Register	X	X	X
PEAR	Back	Random	–	X	–	X	X	X
RALO	Back	Random	–	X	–	X	X	X
ROCO	Back	Random	–	X	Register	X	X	X
SEAN	Back	Random	–	X	Register	X	X	X
SKYL	Back	Random	–	X	–	X	X	X
SOLA [C]	Back	Random	–	X	Register	X	X	X
SPID	Back	Random	–	X	–	X	X	X
SYMB	Back	Random	–	X	–	X	X	X
THDB [C]	Front	Random	–	X	TRAFx	X	X	X

[A] An “X”s indicates that a protocol was conducted in that cave, and an en dash (–) indicates that it was not.

[B] The protocol methods used for that cave are named and an en dash (–) indicates that no protocol method was used for that cave.

[C] Indicates that this is a frontcountry cave.

[D] During the 2017–2018 reporting period, JURI was being monitored for climate, scat, vegetation, and invertebrates, but this cave was removed from the KLMN monitoring program in 2020.

Table 16 (continued). Monitoring protocols by cave at Lava Beds National Monument.

Cave Code	Region	Selection Method	Monitoring Protocol					
			Resource	Climate [A]	Visitation [B]	Scat [A]	Vegetation [A]	Invertebrates [A]
VALE [C]	Front	Random	–	X	TRAFx	X	X	X
YELL	Back	Random	–	X	Register	X	X	X

[A] An "X"s indicates that a protocol was conducted in that cave, and an en dash (–) indicates that it was not.

[B] The protocol methods used for that cave are named and an en dash (–) indicates that no protocol method was used for that cave.

[C] Indicates that this is a frontcountry cave.

[D] During the 2017–2018 reporting period, JURI was being monitored for climate, scat, vegetation, and invertebrates, but this cave was removed from the KLMN monitoring program in 2020.

Appendix C. Frontcountry Cave Codes and Associated Names

Due to the sensitive and fragile nature of the resources within, backcountry caves—those located off-trail and not designated for public visitation—are protected and their identities are protected by the use of four-letter cave codes. However, frontcountry caves—those that are well traveled and include NPS-maintained trails—are not protected and their names may be disclosed (Table 17).

Table 17. Frontcountry cave codes at Lava Beds National Monument.

Cave Code	Cave Name
BIPA [A]	Big Painted Cave
BLGR [A]	Blue Grotto Cave
CRIC [A]	Crystal Ice Cave
IDWL [A]	Indian Well Cave
JUHE [A]	Juniper - Hercules Leg Cave
LALA [A]	Labyrinth - Lava Brook Cave
MEIC [A]	Merrill Ice Cave
SENT [A]	Sentinel Cave
SKIC [A]	Skull Ice Cave
SOLA [A]	South Labyrinth Cave
THDB [A]	Thunderbolt Cave
VALE [A]	Valentine Cave

[A] Indicates that this is a frontcountry cave.

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