



New River Gorge Cliff Line Bat Inventory Survey



Sandstone cliff at New River Gorge National Park.
NPS

New River Gorge cliff line bat inventory survey

Science Report NPS/SR—2024/145

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Abstract

The New River Gorge National River was established by Congress in 1978, the New River Gorge National Park and Preserve (NERI) was established more recently in December 2020. Recreational climbers have been using the Gorge and surrounding areas since the early 1970s. As visitation has increased, NERI has become interested in documenting the presence of bat species and their habitat on and near the cliff face, rim, and base areas to support a park management plan. A total of 51 routes were selected to survey three times throughout the summer of 2022. Cliff line surveys included personnel on-rope rappelling down each selected cliff face to look for bats or bat sign and to collect data on the physical attributes and record habitat information. In addition, a simultaneous acoustic survey for bats was conducted at the base of each survey route. Although no bats or bat sign were documented, analysis of the acoustic data in concert with the environmental factors revealed that bats were detected at more highly climbed walls versus unclimbed walls. Northern long-eared bats (*Myotis septentrionalis*) were more likely to be detected near less vegetated walls and activity of eastern small-footed bats (*Myotis leibii*) was higher as the summer progressed.

Executive Summary

Interactions between humans and wildlife can be beneficial, such as wildlife viewing, but they can also be negative both for the humans and the wildlife, such as people interfering with bison or moose crossing roads. As the human population grows and encroaches farther into wild spaces, a better understanding of how humans can co-exist with and reduce the negative impacts on wildlife becomes more important.

Although the New River Gorge National River was established by Congress in 1978, the New River Gorge National Park and Preserve (NERI) was established more recently in December 2020 (NPS 2023a). However, climbers have been using the Gorge and surrounding areas since the early 1970s (NPS RFQ). As visitation has increased, NERI has become interested in documenting the presence of bat species and their habitat on and near the cliff face, rim, and base areas to support a park management plan.

A total of 51 routes were selected to survey three times throughout the summer of 2022. Cliff line surveys included personnel on-rope rappelling down each selected cliff face to look for bats or bat sign and to collect data on the physical attributes and record habitat information. In addition, a simultaneous acoustic survey for bats was conducted at the base of each survey route. Although no bats or bat sign were documented, analysis of the acoustic data in concert with the environmental factors revealed that bats were detected at more highly climbed walls versus unclimbed walls. Northern long-eared bats (*Myotis septentrionalis*) were more likely to be detected near less vegetated walls and activity of eastern small-footed bats (*Myotis leibii*) was higher as the summer progressed. Bats that roost on rock walls use cracks and crevices, which are also an important feature for climbers. Less vegetation corresponds with better quality acoustic recordings.

Although no bats were seen or heard and no guano or odor were detected, opportunistic conversations with climbers revealed that bats are observed on the cliffs. These climbers generally showed interest and exhibited positive feelings toward the bats. Colorado State University has a Climbers for Bat Conservation group (CSU 2023) that could be a resource for engaging climbers in a citizen science campaign to report and protect bats. Although based in Colorado, people anywhere can submit data on bat sightings. On the observation dashboard, there are currently eight data points within the NERI (ArcGIS 2023). Advertising this site at NERI could provide additional data on bat sighting that would be useful to the Park.

Introduction

New River Gorge National Park and Preserve (NERI) in Fayette and Summers counties in western West Virginia is considered a world-class destination for recreational rock climbing. Climbing has taken place in the New River Gorge and surrounding areas since the early 1970's, with yearly increases in area visitation as the sport has become more popular. In 2022, an estimated 1.6 million people visited New River Gorge (NPS 2023b). To date, there are over 1,600 established rock climbs documented in the New River Gorge area (Mountain Project 2022, Williams 2019). Several bat species in the Eastern United States are known to use cliff line either for foraging or for roosting, including eastern small-footed bats (*Myotis leibii*), little brown bats (*Myotis lucifugus*), big brown bats (*Eptesicus fuscus*), and the federally endangered Virginia big-eared bat (*Corynorhinus townsendii virginianus*) (Burford and Lacki 1995, Neubaum et al. 2006, Johnson et al. 2011, Jung and Slough 2011, Randall et al. 2014). Bat occupancy surveys of these areas are needed if the NPS is to understand the current potential extent and severity of impacts from recreational climbing in the park.

Park Resource Management Issues

Bats have been documented using other cliff areas in the eastern United States and have been encountered in cracks and crevices of the tall sandstone cliffs in the northern part of NERI. As one of the most visited climbing areas in the eastern United States, there is potential for disturbance to bats roosting in the cliffs. Species composition, abundance, distribution, habitat characteristics, and time of year fluctuations in cliff occupancy are unknown at this time. According to information provided in the NPS Request for Proposals (RFP), there have been ten documented bat species at NERI including three species listed as federally endangered (Virginia big-eared bat [*Corynorhinus townsendii virginianus*], Indiana bat [*Myotis sodalis*], and northern long-eared bat [*Myotis septentrionalis*]) and the state-listed species of concern, eastern small-footed bat (*Myotis leibii*). The NPS RFP also states that nine out of ten of the species occurring in the park have a West Virginia state conservation ranking of S1(critically imperiled) – S3 (vulnerable). A sandstone cliff inventory of bat species would assist the park in understanding potential impacts to bats occupying cliffs at NERI and set the framework for making management decisions based on site specific data. Further, this would provide the baseline data for more species-specific studies that may be needed in the future.

Permits

- All biologists that had potential of encountering bats held the following permits:
- West Virginia State Permits: T. Fagin (2022.059), W. Seiter (2022.055)
- NPS permit: Study #: NERI-00063, Permit #: NERI-2022-SCI-0004
- IACUC permit: WV_NERI_ROBY_BATS_2022.A3
- Federal Permit for bat handling: W. Seiter (ES 94849b-2)

Methods

Sample Design

Route Selection

The RFP received from NPS reports that there are over 1,600 climbing routes in the New River Gorge. However, The Mountain Project (2022) records 1,080 for New River Gorge proper (not considered an “official” list), and Williams (2019) lists 1,903 routes. We investigated further into this discrepancy and identified which specific routes to survey. We initially designed a structure that situates a “Climbing Route” within a “Wall” and the “Wall” within a “Crag”. Both acoustic and rappelling-transect survey methods were conducted at the “Wall” level, covering or intersecting several “Routes”. As a result, data collected at the Wall-level yields insights about “Crag”, which could be especially valuable to park management due to their large scope.

Using data from online and published sources as well as individual route information provided by NPS, the Walls were classified as having a use level of “high climber activity”, “low climber activity”, and “no climber activity” via the method described in Appendix A. To determine a statistically sound sample size, a power analysis was performed using a statistical calculator called G*Power (Faul et al. 2009), with Cohen’s f^2 standard for “medium” effect size (Cohen 1988), alpha set to 0.1 (significance), and beta set to 0.8 (power). No prior variance was available to better inform the power analysis. The results suggest that 153 surveys were needed to perform the sampling design. Because occupancy modelling requires replications of surveying the same route, 17 routes of each type (high, low, and unclimbed) were selected throughout the park (spatial replications) and surveyed three times each (temporal replication). Routes were selected from the route pool using a weighted random sampling method, which considered the proximity of the individual route to popular walls and the reliability of the information that the routes were still “unclimbed” (Appendix A).

The data regarding unclimbed areas provided by the NPS were presented at the “Route” level. Out of the total 88 unclimbed routes supplied by the NPS, 75 pertained to walls that were confirmed to have been climbed, as evidenced by reviews of routes on these walls found in NPS-recommended sources.

The study encompasses a comprehensive analysis of 106 walls, distributed across 15 distinct crags (Figure 1). Each of the 106 identified walls on the figure is color-coded to correspond to its specific crag and its size is proportionally scaled based on two key parameters: the Wall Quality Score (Figure 1A) and the Use Category (Figure 1B). These metrics collectively inform the usage patterns of the walls within the scope of this study. In both cases, component variables of these parameters are used in subsequent modeling rather than the scores themselves. This approach was adopted to minimize the number of variables while still providing the model with the necessary information. Appendix A (Score & Threshold Generation Process) details how these parameters were calculated. Summarization of resulting covariates is described in Appendix B (Covariate Summary).

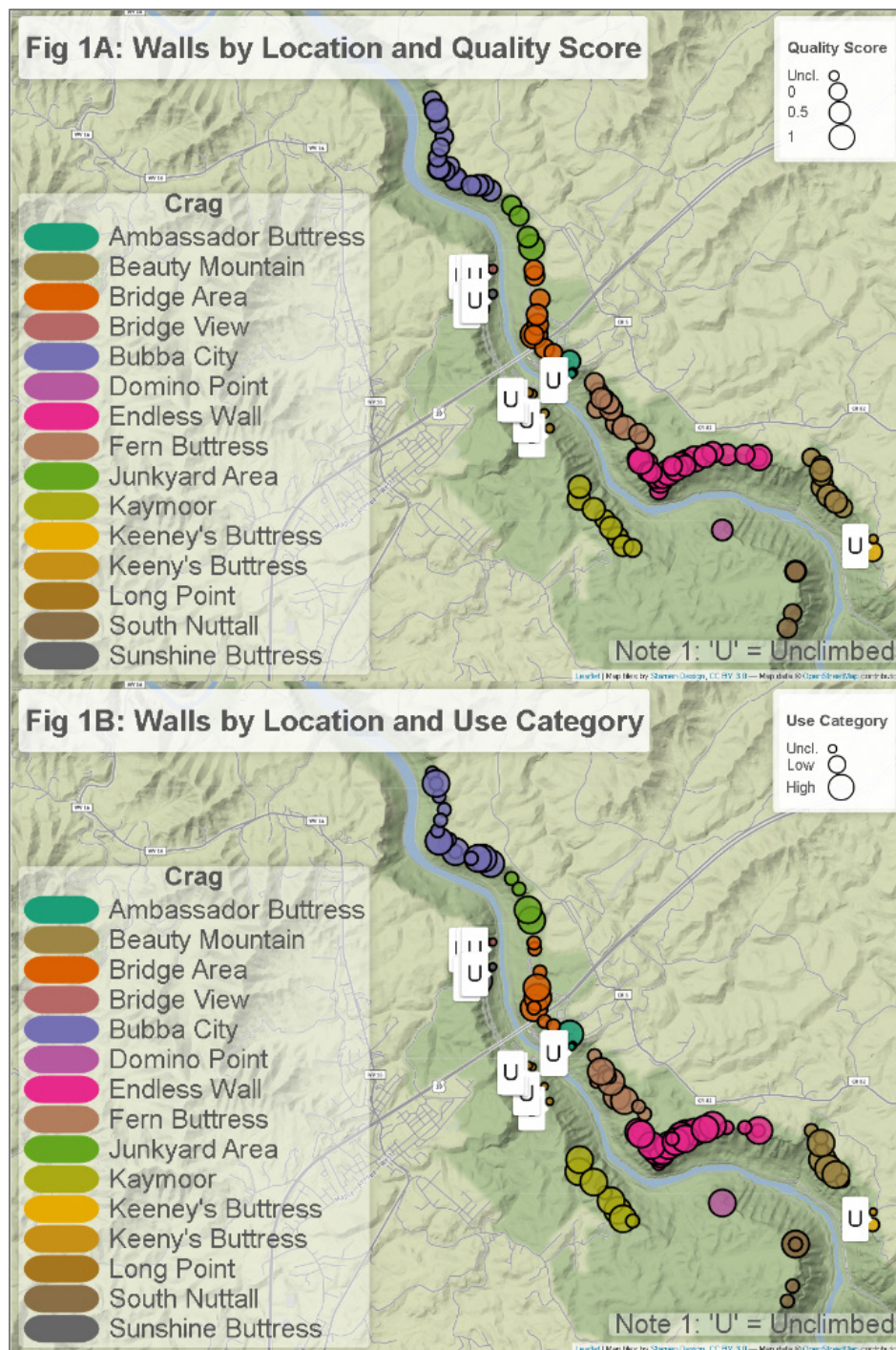


Figure 1. Comprehensive visualization of the 106 identified walls on color-coded crags scaled according to their “Wall Quality Score”, a measure of popularity.

The Wall Use Score is a continuous measure, ranging from 0 to 1, that evaluates the usability of each climbing wall. This score serves as a surrogate for a wall's "use index", "popularity score", or "use impact". It integrates various elements including rating, review count, review source, and the number

of established routes on a wall. For walls that have not been climbed and thus lack this metadata, the Wall Use Score is considered non-existent.

To streamline the reader's understanding, the "wall_routeQualityScore" covariate is created on a scale of [NA (not applicable), 0-4]. This score is a composite of the Williams (2019) and Mountain Project (2022) scores, both of which utilize a 0-4 scale but differ in their treatment of NAs and 0s. This score is the average "Route Quality Score" per wall, which is then multiplied by the number of documented routes on a wall and then normalized (min/max) to form a more useful index. We call this normalized quantity the "Wall Use Score". The median of this index is used to categorize walls into high or low climb. This categorization is included as the covariate "wall_useCategory". If a wall lacks sufficient metadata to generate a "wall_routeQualityScore" (i.e., it is not listed in either source), it is assigned NA, signifying it as an "unclimbed wall".

The Use Category, a tripartite classification system, categorizes the Wall Use Score into "High", "Low", or "Unclimbed" groups. This classification is based on whether the Wall Use Score is above, below, or non-existent in relation to the median score, which in this study was 0.27. This categorical quantity was included in the models as the "wall_useCategory", summarized in Appendix B.

Acoustic Site Selection

In an effort to gather representative data from the unclimbed population, we occasionally deployed two microphone arrays on the same wall within a single night. Owing to the precise route-level coordinates of the unclimbed area, the initial array was positioned in close proximity to the unclimbed route, while the second array was placed in a way that ensured its detection radius did not overlap with the first.

The initial study plan entailed a rappelling team conducting vertical transects along cliff faces to look for bat sign. Upon contract approval, an additional component for full-spectrum acoustic analysis was incorporated. This involved a sensor array utilizing a Titley Scientific™ Anabat Swift detector, outfitted with a US-O V3 omnidirectional ultrasonic microphone at the base of each cliff for data collection. The rappelling team collected covariate data about the cliff face while performing each rappel. While the rappelling team did not find any bat sign, their habitat covariate data was incorporated into the analysis. A standard 9.1 m sampling radius was assumed for microphone detection. Azimuth (also known as dip direction), horizontal distance, and vertical drop measurements were used to determine microphone placement locations. These measurements were gathered by the rappelling teams from their initial positions at the top of the cliffs. To ensure the calculated location was safely distanced from the edge of the cliff, a three-meter buffer was incorporated in the azimuth direction. The median of these estimated positions, grouped by wall, was employed as a single representative microphone placement coordinate for each wall in the study. This methodology was chosen on the basis that, while the microphone was not always placed exactly where the teams descended, it was understood to be in proximity to the wall.

The microphone altitude ($Altitude_{mic}$) was computed as follows:

$$Altitude_{mic} = \text{mean}(Altitude_{cliff} - Drop_{vertical}, Altitude_{3DEP}) + Height_{pole}$$

Here, $Altitude_{cliff}$ is the cliff top altitude recorded by the rappelling team, $Drop_{vertical}$ is the calculated vertical drop from the cliff top, $Height_{pole}$ is the 3.66 m height of the microphone pole, and $Altitude_{3DEP}$ is the returned altitude from the 3DEP Elevation Application hosted by the USGS (USGS 2017). By averaging these two altitude measurements, a more precise estimation was achieved compared to relying on either method individually. The final altitude of the microphone was determined as the median of the three altitude measurements per wall since the exact altitude at the inspection time was uncertain, and the calculated location could potentially place it back on the cliff top. The median altitude of the calculated coordinates more accurately represents the acoustic team's altitude selections, aligning with the statistical modeling objectives, than simply determining the altitude at the microphone location.

“Walls” for the purposes of modeling are centered on their respective microphone coordinate. Each microphone's detection area is modeled as a 30 m radius sphere centered at the computed location and altitude.

Survey Methods

Cliff Line Survey

Field personnel surveyed routes on walls across crags during each of three trips in the summer of 2022. If a route was deemed unsuitable (i.e., inaccessible or unsafe to survey), the field team chose a replacement from a list of back up sites until 51 routes were surveyed. The list of replacement routes was created using the same methods as the initial selection. When a replacement was needed, the first route from the list was chosen. If that route was not suitable the next route on the list was chosen. This process was repeated until a suitable route was found.

The field team consisted of permitted biologists who were current on rabies and COVID-19 vaccines. Both were well trained in rope techniques. Surveys consisted of a two-person crew securing a rope at the rim of a climbing route so that it was oriented approximately down the middle of the route. One person surveyed while rappelling down the cliff face, and the second person recorded data and was available for safety rescue. Personnel were equipped with 2-way radios to communicate efficiently and quietly. The rappelling team collected covariate data about the cliff face while performing each rappel. The person on-rope searched cracks and crevices of the cliff face along the entire rappel route and within arm's reach (i.e., approximately a 2-m wide survey area) of the route for individual bats or bat sign (i.e., guano, staining, odor). Detection aids used were flashlights/headlamps, spotting scopes, and binoculars. Pre-printed data sheets and tablets were used that have fields defined by the “Simple FY2021 project deliverable standard for NPS Inventory 2.0 Species projects” to record data efficiently and to reduce data omission.

Covariate data collected for each route included:

- Aspect of cliff face 1-360°
- GPS location in NAD 83
- Cliff face angle categorized as “Slab,” “Vertical,” or “Overhung”
- Temperature (°C)

- Humidity (%)
- Precipitation in last 24 hrs (cm)
- Current weather conditions (sunny, cloudy, rain, fog, etc.)
- Sun rise/set
- Moon rise/set and phase
- Cliff feature complexity: number of cracks and crevices suitable for bat use
- One random 1-meter vegetation plot was conducted for every 10 meters of the route's length (Route length = 33 m, Random plots = 3; Route length = 35 m, Random plots = 4): % make up of Moss, Lichen, and Leafy.

All data were recorded on physical data sheets as well as electronically. Pictures were not taken due to the lack of dexterity when wearing rappel gloves.

Acoustic Monitoring

A two-person team deployed an AnaBat Swift (Titley Electronics Pty Ltd, Ballina, NSW Australia) acoustic detector at the base of cliffs near the same 51 routes that were surveyed by the cliff line team (Table 1, Appendix C). Detectors were set an average of 44.2 m from the base of the route (range: 9.6 m – 216 m). Detectors were deployed for one night at each site during each of the three trips (16 May - 3 June, 13 - 22 June, and 11 - 19 July 2022). Detectors were fitted with 5-250kHz omnidirectional microphones (Titley US-0 V1-3) vertically oriented at 0° with no weather proofing. Microphones were installed on 3.5-meter poles to increase the sample area and reduce distortion from the ground and surrounding vegetation. To increase the likelihood of recording high-quality calls, acoustic detectors were deployed in the least cluttered environment that biologists could find near the route. Detectors were set to a sensitivity level of 15, a data division of 8, recorded in full spectrum mode, and were programed to record from 20:30 to 06:00 each night. Biologists conducted finger rubs in front of microphones to record ultrasound prior to deployment and after pickup to ensure the detectors were functioning properly. In the event that a detector did not record for the full night or if weather conditions did not allow for a complete survey (rain, fog, wind, temperature <50°), the detector remained deployed for an additional night.

Table 1. Cliff line locations collected from the top of the route and acoustic survey locations located at the bottom of the cliff and dates for the New River Gorge cliff line bat inventory survey, 2022.

Use Category	Crag	Wall	Site/Route Name	Cliff Line Survey Latitude	Cliff Line Survey Longitude	Survey Dates for Cliff Line Survey	Acoustic Survey Latitude	Acoustic Survey Longitude	Survey Dates for Acoustic Survey
Unclimbed	Ambassador Buttress	Ambassador Buttress #2	NERI.521*	38.06728	-81.07233	31 May, 13 Jun, 11 Jul	38.06727	-81.07236	31 May, 13-14 Jun, 11 Jul
	Long Point	Long Point #3	NERI.525*	38.06329	-81.08047	1 Jun, 21 Jun, 17 Jul	38.06330	-81.08050	1 Jun, 14 Jun,12 Jul
	Long Point	Long Point #4	NERI.526	38.06403	-81.08047	1 Jun, 21 Jun, 17 Jul	38.06404	-81.08050	1 Jun, 14 Jun,12 Jul
	Sunshine Buttress	Sunshine Buttress #2	NERI.517*	38.07642	-81.08817	31 May, 13 Jun, 11 Jul	38.07645	-81.08816	31 May, 13-14 Jun, 14 Jul
	Sunshine Buttress	Sunshine Buttress #3	NERI.518*	38.07629	-81.08811	31 May, 13 Jun, 11 Jul	38.07629	-81.08808	31 May, 13-14 Jun, 14 Jul
	Fern Buttress	Thieves Area	NERI.484*	38.06149	-81.06744	2 Jun, 17 Jun, 17 Jul	38.06199	-81.06751	24 May,16 Jun, 14 Jul
	Fern Buttress	Fern Creek Falls	Endless Wall 1b	38.05653	-81.06354	21 May, 16 Jun, 14 Jul	38.05659	-81.06377	21 May, 16 Jun, 14 Jul
	Endless Wall	Fern Point Slabs	NERI.531	38.05620	-81.06325	21 May, 16 Jun, 14 Jul	38.05618	-81.06328	21 May, 16 Jun, 14 Jul
	Endless Wall	Kaymoor Slabs	Endless Wall 2a*	38.05435	-81.06095	21 May, 16 Jun, 14 Jul	38.05433	-81.06098	24 May,17 Jun, 13 Jul
	Endless Wall	Diamond Point	NERI.535	38.05345	-81.05964	21 May, 16 Jun, 14 Jul	38.05333	-81.05978	24 May,17 Jun, 13 Jul
	Endless Wall	Jacob's Ladder	NERI.489	38.05658	-81.04898	24 May, 15 Jun, 13 Jul	38.05636	-81.04825	20 May, 17 Jun, 13 Jul
	Endless Wall	Upper Endless	NERI.488	38.05473	-81.03889	20 May, 21 Jun, 12 Jul	38.05483	-81.03857	20 May, 14 Jun,12 Jul
	Keeney's Buttress	Keeney's Buttress	NERI.496*	38.04571	-81.02484	19 May, 22 Jun, 16 Jul	38.04569	-81.02483	19 May, 15 Jun, 16 Jul
	Kaymoor	Seven-Eleven	Kaymoor 8	38.05231	-81.07268	18 May, 18 Jun, 15 Jul	38.05231	-81.07265	18-19 May, 19 Jun,18 Jul
	Kaymoor	White Wall	Kaymoor 6a	38.04938	-81.07002	18 May, 18 Jun, 15 Jul	38.04939	-81.06999	18-19 May, 19 Jun,18 Jul
	South Nuttall	The Bitch	NERI.502	38.03595	-81.03840	17 May, 19 Jun, 16 Jul	38.03595	-81.03837	17 May, 20 Jun, 17-18 Jul
	Bubba City	Ameless Wall	NERI.491*	38.09620	-81.09437	1 Jun, 20 Jun, 19 Jul	38.09618	-81.09440	1 Jun, 18 Jun, 15 Jul
Low	Junkyard Area	Zealous Area	Zealous Area	38.08389	-81.08035	1 Jun, 14 Jun, 12 Jul	38.08389	-81.08038	1 Jun, 14 Jun,13 Jul
	Junkyard Area	Junkyard Wall	Junkyard Wall	38.08276	-81.08036	1 Jun, 14 Jun, 12 Jul	38.08276	-81.08039	1 Jun, 14 Jun,12 Jul
	Keeney's Buttress	Keeney's Buttress	Keeney's Buttress	38.04427	-81.02491	19 May, 22 Jun, 16 Jul	38.04428	-81.02494	19 May, 15 Jun, 16 Jul
	Domino Point	Domino Point	Domino Point	38.04691	-81.04954	17 May, 19 Jun, 16 Jul	38.04692	-81.04957	17 May, 20 Jun, 17-18 Jul
	South Nuttall	Hueco Pillar	Hueco Pillar	38.04035	-81.03699	17 May, 19 Jun, 16 Jul	38.04035	-81.03696	17 May, 20 Jun, 17-18 Jul
	South Nuttall	The White Wall	The White Wall	38.03820	-81.03707	17 May, 19 Jun, 16 Jul	38.03819	-81.03704	17 May, 20 Jun, 17-18 Jul
	South Nuttall	Toxic Jesus Wall	Toxic Jesus Wall	38.03426	-81.03903	17 May, 19 Jun, 16 Jul	38.03424	-81.03904	17 May, 20 Jun, 17-18 Jul
High	Bridge Area	Overlook Buttress	Overlook Buttress	38.07006	-81.07854	16 May, 14 Jun, 12 Jul	38.07006	-81.07857	16 May, 14 Jun,12 Jul
	Bridge Area	Rock Shelter Cave	Rock Shelter Cave	38.07153	-81.07986	16 May, 14 Jun, 12 Jul	38.07153	-81.07989	16 May, 13-14 Jun, 14 Jul
	Bridge Area	The Pinnacle	The Pinnacle	38.07988	-81.07980	16 May, 14 Jun, 12 Jul	38.07988	-81.07983	16 May, 14 Jun,12 Jul
	Fern Buttress	Theives Area	Thieves Area*	38.06126	-81.06738	2 Jun, 17 Jun, 17 Jul	38.06138	-81.06744	24 May,16 Jun, 14 Jul
	Fern Buttress	Ritz Cracker Area	Ritz Cracker Area	38.05966	-81.06440	2 Jun, 17 Jun, 17 Jul	38.05966	-81.06443	24 May,16 Jun, 14 Jul
	Fern Buttress	Star Trek Wall	Star Trek Wall*	38.05922	-81.06300	2 Jun, 17 Jun, 17 Jul	38.05919	-81.06299	24 May,16 Jun, 14 Jul
	Fern Buttress	Fern Creek Falls	Fern Creek Falls	38.05850	-81.06193	2 Jun, 17 Jun, 17 Jul	38.05752	-81.06283	21 May, 16 Jun, 16 Jul
	Endless Wall	Fern Cirque	Fern Cirque	38.05545	-81.06142	21 May, 16 Jun, 14 Jul	38.05543	-81.06145	21 May, 16 Jun, 14 Jul
	Endless Wall	Idol Point	Idol Point	38.05473	-81.06153	21 May, 16 Jun, 14 Jul	38.05474	-81.06156	21 May, 16 Jun, 14 Jul
	Endless Wall	Diamond Point	Diamond Point	38.05350	-81.05929	24 May, 15 Jun, 13 Jul	38.05345	-81.05963	24 May,17 Jun, 13 Jul
	Endless Wall	Hellbound Area	Hellbound Area	38.05375	-81.05920	24 May, 15 Jun, 13 Jul	38.05373	-81.05918	24 May,17 Jun, 13 Jul
	Endless Wall	Fantasy Area	Fantasy Area	38.05602	-81.05408	24 May, 15 Jun, 13 Jul	38.05599	-81.05409	24 May,17 Jun, 13 Jul
	Endless Wall	The Undeserved Area	The Undeserved Area	38.05644	-81.05231	24 May, 15 Jun, 13 Jul	38.05644	-81.05228	20 May, 17 Jun, 13 Jul
	Endless Wall	Jacob's Ladder Area	Jacob's Ladder Area	38.05677	-81.04913	24 May, 15 Jun, 13 Jul	38.05666	-81.04908	20 May, 17 Jun, 13 Jul
	Endless Wall	Upper Endless	Upper Endless	38.05493	-81.03823	20 May, 21 Jun, 12 Jul	38.05475	-81.03982	20 May, 14 Jun,12 Jul
	Beauty Mountain	The Brain	The Brain	38.05455	-81.03349	19 May, 22 Jun, 18 Jul	38.05453	-81.03352	19 May, 21 Jun, 16 Jul

*Route surveyed replaced the original route due to safety concerns or inaccessibility.

Table 1 (continued). Cliff line locations collected from the top of the route and acoustic survey locations located at the bottom of the cliff and dates for the New River Gorge cliff line bat inventory survey, 2022.

Use Category	Crag	Wall	Site/Route Name	Cliff Line Survey Latitude	Cliff Line Survey Longitude	Survey Dates for Cliff Line Survey	Acoustic Survey Latitude	Acoustic Survey Longitude	Survey Dates for Acoustic Survey
High (continued)	Beauty Mountain	Middle Beauty	Middle Beauty	38.05129	-81.03202	19 May, 22 Jun, 18 Jul	38.05129	-81.03205	19 May, 21 Jun, 16 Jul
	Beauty Mountain	Ram's Head	Ram's Head	38.05007	-81.03005	19 May, 22 Jun, 18 Jul	38.05007	-81.03008	19 May, 21 Jun, 16 Jul
	Kaymoor	Butcher's Branch	Butcher's Branch	38.05034	-81.07366	18 May, 18 Jun, 15 Jul	38.05033	-81.07363	18-19 May, 19 Jun,18 Jul
	Kaymoor	Fire and Ice Buttress	Fire and Ice Buttress	38.04817	-81.06853	18 May, 18 Jun, 15 Jul	38.04818	-81.06850	18-19 May, 19 Jun,18 Jul
	Kaymoor	The Hole	The Hole*	38.04470	-81.06597	18 May, 18 Jun, 15 Jul	38.04472	-81.06599	18-19 May, 19 Jun,18 Jul
	Bubba City	Sandstonia - Decameron Area	Sandstonia - Decameron Area	38.10036	-81.09571	22 May, 20 Jun, 19 Jul	38.10038	-81.09573	22 May, 18 Jun, 15 Jul
	Bubba City	Little Head Wall	Little Head Wall	38.09602	-81.09538	22 May, 20 Jun, 19 Jul	38.09601	-81.09535	22 May, 18 Jun, 15 Jul
	Bubba City	Headless Wall	Headless Wall	38.09439	-81.09540	22 May, 20 Jun, 19 Jul	38.09436	-81.09539	24 May, 18 Jun, 15 Jul
	Bubba City	French Wall	French Wall*	38.09248	-81.09460	22 May, 20 Jun, 19 Jul	38.09246	-81.09463	22 May, 18 Jun, 15 Jul
	Bubba City	Ames Wall	Ames Wall	38.09168	-81.09338	22 May, 20 Jun, 19 Jul	38.09166	-81.09337	22 May, 18 Jun, 15 Jul
	Bubba City	Rainbow Ledge	Rainbow Ledge*	38.09134	-81.09084	1 Jun, 20 Jun, 19 Jul	38.09133	-81.09087	1 Jun, 18 Jun, 15 Jul

*Route surveyed replaced the original route due to safety concerns or inaccessibility.

Analysis Methods

Bat identification

The presence of bat species was determined using the manufacturer recommended settings in Kaleidoscope Pro (KPro) version 5.4.7 (Wildlife Acoustics, Inc. Maynard, MA). KPro analysis settings are provided in Appendix D. Based on species known to occur within NERI and the state of West Virginia, the species listed in Table 2 were selected in the KPro 5.4.0 classifier using the -1-sensitivity setting. On a site per night basis, if the presence of state or federally listed bat species was considered unlikely (i.e., Maximum Likelihood Estimation [MLE] $p > 0.05$), no further analysis was performed. If presence of a state or federally listed bat species was considered likely (MLE $p \leq 0.05$), files from that site per night were visually examined by qualified acoustics analysis expert, Gregg Janos, until the species was confirmed or rejected as likely present. Call characteristics reviewed during manual vetting included, but were not limited to, minimum frequency, slope, and overall call sequence pattern.

Table 2. Bat species included in the Kaleidoscope Pro classifier for autoclassifying bat acoustic recordings.

Common name (Latin name)	KPro Identifier ^A	Listing Status	WV Conservation Ranking ^B
Virginia big-eared bat (<i>Corynorhinus townsendii virginianus</i>)	COTO	Federally endangered	S2
Big brown bat (<i>Eptesicus fuscus</i>)	EPFU	Not Listed	S5
Eastern red bat (<i>Lasiurus borealis</i>)	LABO	Not Listed	S3
Hoary bat (<i>Lasiurus cinereus</i>)	LACI	Not Listed	S3
Silver-haired bat (<i>Lasionycteris noctivagans</i>)	LANO	Not Listed	S2
Eastern small-footed bat (<i>Myotis leibii</i>)	MYLE	WV species of concern	S1
Little brown bat (<i>Myotis lucifugus</i>)	MYLU	Under Review	S2
Northern long-eared bat (<i>Myotis septentrionalis</i>)	MYSE	Federally endangered	S1S2
Indiana bat (<i>Myotis sodalis</i>)	MYSO	Federally endangered	S1
Evening bat (<i>Nycticeius humeralis</i>)	NYHU	Not Listed	S1
Tricolored bat (<i>Perimyotis subflavus</i>)	PESU	Under Review	S2

^A KPro uses a 6-letter identifier, but a 4-letter identifier was used for consistency throughout this document

^B NatureServe State Conservation Status Ranks: S1 = Critically Imperiled; S2 = Imperiled; S3 = Vulnerable; S4 = Apparently Secure; S5 = Secure

Covariate Discussion

Usable Covariate Thresholds

Because of the uncertainty surrounding the exact locations of the microphone arrays, particularly in scenarios involving dual deployments on an unclimbed route, our methodology of utilizing the median of the estimated array positions as the singular microphone placement coordinate for a given wall remains consistent and valid. Removing the variation removes noise from the model. The number of detectors present on a wall each night, the total number of inspections a site received, and temperature within a four-day window centered around the inspection date were added as covariates in the model.

The rappelling team's rope measurements were used to map out the rough profile of each wall. By combining these measurements with their estimate of the wall width, we were able to compute a rough estimate of the area of the exposed cliff face, providing an additional estimate of the level of effort. Vegetative and crevice data were also collected and aggregated at the wall level. Furthermore, we utilized the Yosemite Decimal System (YDS) to gauge route difficulties, as implemented by both Williams (2019) and Mountain Project (2022). However, due to discrepancies between these sources and the large number of categorical levels (31 distinct observed ratings), we chose to synthesize a numerical score to facilitate comparisons and compute an average route difficulty score by wall. This was necessary as Williams (2019) uses an older version of the scale, and the crowd-sourced data from Mountain Project (2022) varies in its incorporation of the YDS "Protection Scale", and it allowed us to remove the categorical variable "wall_avgDifficultyRating_YDS" from the analysis.

A total of 94 unexpanded covariates were collected. "Unexpanded" in this context means "prior to one hot encoding¹ the categorical variables". After performing aggregations accounting for a minimum 85% completeness threshold (minimum of 21 of 142 observations per feature), removing near-zero-variance features, and allowing a selective decision to be made, 88 covariates remained. A summary of the 88 (unexpanded) covariates is provided in Appendix B.

The six covariates removed in the preceding step are "site_Crag", "site_Wall", "wall_avgDifficultyRating_YDS", "rope_dimB_m", "rope_dimC_m", and "veg_sampleStrategy". The decision to remove "wall_avgDifficultyRating_YDS" has been discussed above, its re-encoding into a numerical variable allowing for more accurate comparisons between the two sources.

The categorical variables called "site_Crag" and "site_Wall" are the those defining the locations Crag and Wall respectively. These were removed from the models' consideration due to the relevant information being encoded in the GPS coordinates.

The variable called "rope_dimC_m" is the distance in meters of rope from the cliff edge to the vertical drop, if such a geometry was present. It was removed using the *nearZeroVar* function in the "caret" package in Program R. This function was used with its default settings. The decision to use *nearZeroVar* over a simple zero-variance filter was to reduce complexity. For this the variable, the

¹ One hot encoding is a technique used to represent categorical variables as numerical values in a machine learning model.

most prevalent value was 0 m (a vertical drop) with 144 occurrences, the remaining nine unique values each appeared once out of the total 153 rappels.

The variable called "rope_dimB_m" is the horizontal distance in meters from cliff edge to a point in space directly over the rappel landing point. Similar to "rope_dimC_m", it was removed using the *nearZeroVar* function. In this case, the most prevalent value was 0 m with 144 occurrences, and the second most prevalent value was 0.696 m with two occurrences. The remaining seven unique values each occurred once.

Finally, "veg_sampleStrategy", a categorical variable defining the vegetation sampling method per wall, was removed due to its zero variance.

Variable Reduction

Given the smaller number of observations for a given species ($n = 142$) and relatively large feature set ($p_{max} = 88$), variable reduction was considered. Current approaches to statistical modeling (Harrell 2015) expressly caution against the use of step-wise regression techniques for variable reduction, particularly when working with smaller data, due to their poor ability to handle multicollinearity, solution instability, biased coefficients, arbitrary selection, and overfitting tendencies. These shortcomings are well established in the statistical literature (Whittingham et al. 2006), thus a *dimension reduction*, also known as a variable *compression*, technique was chosen for this analysis over a variable *selection* technique.

To account for the mixed data types in the dataset, i.e., the unexpanded covariates, Factor Analysis of Mixed Data (FAMD) via the PCAmixdata R package (Chavent et al. 2022) was used as a compression method. FAMD extends multiple correspondence analysis (MCA) and principal component analysis (PCA) by utilizing appropriate distance metrics and normalization procedures. Similar to PCA, FAMD aims to capture the maximum variance in the original data through orthogonal “factors” or principal components. Although FAMD implicitly assumes a linear relationship between variables, its interpretability and stability made it preferable to non-linear methods such as t-distributed stochastic neighbor embedding (t-SNE) or Uniform Manifold Approximation and Projection (UMAP) for variable reduction in this study. This technique retains valuable information while providing reliable estimates of model coefficients, with the caveat that interpretation of the resulting factors is required after the final model is selected.

In FAMD and PCA, the first Principal Component (PC) is a construct that captures the primary structure of the dataset by identifying the direction of maximum variance in the feature space. This first PC, called a “factor” or “latent variable” in FAMD literature, often encapsulates the most substantial underlying characteristic or pattern in the data, thus accounting for the greatest proportion of the variance. It essentially operates as an ‘index’ that amalgamates meaningful combinations of original features that embody the main trend in the data, providing a single, comprehensive value summarizing multiple features while retaining the most significant variation in the data.

In other words, FAMD compresses a dataset’s N mixed-type features into N numeric-only “factors”, where each factor represents a different level of information. Each factor’s values are influenced by

the original raw features, which in turn impact the model output. Researchers then select the most informative factors for their model based on data quality and modeling needs. The first factor can often be considered an “index” or “average” when it conveys a meaningful combination of original features that embody the main pattern or trend. Using these factors allows for more confident parameter estimates and allows for maximum use of data information. However, factor interpretation can be complex and dependent on researchers’ subjective interpretations.

At the request of the NPS, we modified the traditional FAMD workflow, adopting a theory-driven approach for factor generation. Rather than analyzing all covariates simultaneously, biologists manually grouped variables into “factors of ecological significance” before using FAMD to generate an “index” for each factor. The NPS further suggested grouping detection variables (variables affecting the “detection” process) into a single index, as understanding the detection phenomena was deemed less important than understanding major patterns or predictors of variation in occupancy. This theory-driven approach was preferred over a purely data-driven approach in order to ensure interpretability of the factors and their corresponding indices. In total three factors were manually generated. The initial factors and variable associations are presented in Appendix B’s “Ecological Factor” column. The factors with the pooling of detection variables applied in shown in the “Model Factor” column.

Key considerations for the NPS-suggested approach include:

- 1) Subjectivity of human opinion in creating initial variable-to-factor associations.
 - a) This is countered by the fact that limited data often benefit from expert opinion or pre-trained models to avoid overfitting to noisy samples.
 - b) Confirmatory Factor Analysis (CFA) can statistically verify variable-factor associations, but was deemed beyond this project’s scope, and the small sample size may limit its utility.
- 2) Utilizing limited data to estimate parameters for N human-generated factors instead of a smaller number of algorithmically generated factors.
 - a) This concern is mitigated by considering this initial inventory as a pilot study. Although accurate standard errors are important, the primary focus lies in exploring “known” factors.
- 3) Separate FAMDs conducted on variable subsets (factors) produce incomparable components due to variations in the distribution of total variance to each factor. Consequently, in the context of the models employed in this project, it is inappropriate to directly compare the first principal component (PC1) of Factor 1 with PC1 of Factor 2. Moreover, the inclusion of multiple principal components per factor introduces complexity, as it hinders the comparability of components within the same factor. In short, the components will be centered, but not scaled to each other.
 - a) In the single-component per factor case, this can be handled by standardizing (scaling) each component before including it in the model.

In order to mitigate coefficient bias during the model building process, a two-step approach was employed. First, FAMD was conducted on each pre-determined factor, and the first principal component was extracted as the respective factor's "index". Second, all indices were standardized prior to model fitting, ensuring consistent and unbiased comparisons between indices. Where standardized (scaled) indices are used will hereafter be denoted by the prefix "i_".

Covariate Aggregation

Single season occupancy models, such as the ones used in this study, can contain representations of several biological processes, of which the two common processes are the "state" or "occupancy" process " $z_i \sim \text{Bernoulli}(\psi_i)$ ", and the "detection" process " $y_{ij}|z_i \sim \text{Bernoulli}(z_i p_{ij})$ ". For all models used, "unmarked" (Fiske and Chandler, 2011) estimates the coefficients dealing with occupancy at the site level, while the coefficients dealing with detection are estimated at the observation level (Fiske and Chandler 2011).

Scaled factor indices were thus aggregated according to their associated biological process. The selected "Site/Occupancy" factor indices were aggregated by taking the mean of each scaled index by site for input into models. The pooled "Observation/Detection" factor could be used as-is. The process grouping of each raw covariate is shown in Appendix B in the "Hierarchy Level/Process" column.

Index Summary

Recall that we have previously aligned our observed variables with ecologically significant constructs, referred to as "factors" (descriptive, physical, environmental, inspection). This method, as opposed to deriving "factors" from technical analysis, facilitates the integration of prior knowledge and human intuition into the interpretation of each index, rather than focusing on factor loadings. This is particularly vital when dealing with smaller datasets. Subsequently, we executed Factor Analysis of Mixed Data (FAMD) on each factor, selecting the first principal component from each FAMD as the representative index for that factor.

Due to the limited sample size, we had to cautiously consider the number of variables to include in the model. In line with our discussions with NPS and the project's main goal of identifying occupancy factors over detection ones, we grouped all detection-related variables into a single factor, "inspection". The variables included in this factor are detailed in Appendix B under the "Model Factor" column. All other factors were assigned to the occupancy aspect of the model.

While these indices are scaled for within-factor comparison, conducting separate FAMDs on variable subsets (factors) results in components that are not directly comparable due to the differential distribution of variance across each manually defined factor. Therefore, it's not appropriate to directly compare the first principal component (PC1) of different factors within the project models. Despite the components being centered, they lack relative scaling. To address this issue, we standardized each factor index before integrating it into the model. The outcomes of this standardization process, which are presented in Table 3, will serve as the covariate inputs for the subsequent occupancy models.

Table 3. Scaled factor index summary.

Factor Index	Scale Value	Scaled Summary
i_descriptive	2.001	Min.: -1.463 1st Qu.: -0.99 Median: -0.063 Mean: 0 3rd Qu.: 0.963 Max.: 2.858
i_environmental	2.530	Min.: -1.35 1st Qu.: -0.564 Median: -0.124 Mean: 0 3rd Qu.: 0.26 Max.: 3.902
i_inspection	1.421	Min.: -1.928 1st Qu.: -0.869 Median: 0.357 Mean: 0 3rd Qu.: 0.833 Max.: 1.328
i_physical	3.176	Min.: -2.168 1st Qu.: -0.777 Median: 0.039 Mean: 0 3rd Qu.: 0.689 Max.: 2.764

Model Fitting Approach

The collection design fits what would likely be described as spatially “multiscaled” (Kéry and Royle 2016) because we have instances of spatial subsampling. More specifically, we have an intrinsically nested structure of “subunits” (inspection areas) within “units” (walls) within “super units” (crag). This nested structure creates a dependency in the state process among the subunits and units which should be addressed in our modeling process. On the other hand, the detection process is relatively invariant and less statistically intriguing. We used the same microphones, installer, and person who vetted the acoustic calls consistently throughout the observations.

The prevalent method for managing nested structures in ecological occupancy and N-mixture modeling is through “multiscale” models, which utilize a random normal effect to represent the spatial site correlation structure. Some software packages support this approach; however, “unmarked” currently does not (Kéry and Royle 2016), despite ongoing experimental work (Kellner 2021). This presents a challenge as we have selected “unmarked” for our project. Nevertheless, a

proposed solution to this issue involves the use of an “overdispersion parameter” ($\hat{c}$) to adjust the model selection criteria and standard errors when there is a suspected lack of independence in the observations (Kéry and Royle 2016, MacKenzie 2018).

Since we chose to use FAMD, we receive as output the *linearly* independent (orthogonal) components of the input. These components are not necessarily *statistically* independent. FAMD does not explicitly assume that the data are independent and identically distributed (i.i.d.). It focuses on identifying the relationships between variables rather than the relationships between observations. Therefore, though applying FAMD to non-independent data may provide useful insights into the underlying structure of the data, it does not replace adding random effects or performing an adjustment to model selection when addressing non-independence between observations is required.

Following the approach used in Chapter 4 of MacKenzie (2018), full (global) models were fit to the data using the *occu* function in the “unmarked” package. A Chi-Square (χ^2) goodness of fit (gof) test was performed on each model, and a p-value for the resulting χ^2 value was estimated using a 1000-sample, parametric bootstrap approach (MacKenzie and Bailey 2004). The covariates for each species were then reduced by permutation with final model selection performed using an appropriate AIC variant. This was done so that any adjustments to standard errors or selection procedures could be made on the basis of the $\hat{c}$ value calculated from the global model (Burnham and Anderson 2010 as cited in MacKenzie 2018). For the purposes of this project, the $\hat{c}$ value was estimated using the $\chi^2_{obs}/mean(\chi^2_{Boot})$ method (MacKenzie and Bailey 2004).

Results

Field Survey

Cliff Line Survey

Field personnel surveyed the 51 selected routes on 46 walls across 14 crags during each of three trips 16 May - 3 June, 13 - 22 June, and 11 - 19 July 2022 (Table 1, Appendix C) resulting in 153 samples. Diamond Point Wall on Endless Wall Crag and Fern Creek Falls Wall on Fern Buttress Crag underwent 5 inspections each, while the rest were inspected thrice. The exact locations for these site inspections were based on the field team's discretion.

No sign of bat use or presence was observed by the rappelling team. A total of 132 potential roosts were identified with an average of 2.4 ± 1.7 (SE) cracks, crevices, or caves found per route (range: 1 – 10 roosts). There was no difference in the aspect (Watson's U^2 Test for circular data: $U^2 = 0.098$, $p > 0.2$) or volume (Student's t-test: $t = -1.7587$, $DF = 125$, $p = 0.08$) between horizontal and vertical cracks/crevices (Table 4). There was a small negative correlation between distance from the top of the route and the amount of leafy vegetation (Pearson's correlation: $r(353) = 0.132$, $p = 0.12$) as well as a small negative correlation between the distance from the top of the route and the amount of moss ($r(353) = 0.188$, $p < 0.001$). However, there was no correlation with the distance from the top of the route to the amount of lichen present ($r(353) = 0.054$, $p = 0.307$).

Table 4. Summary of physical attributes of potential bat roosts along climbed routes.

Crevice type	Metric	Aspect (°)	Width (cm)	Height (cm)	Depth (cm)	Crevice volume (cm ³)	Dist to Top (m)	Dist to Bottom (m)
Horizontal crevices (n = 59)	Mean	252.9	88.2	7.5	8.7	3,132.3	30.0	45.8
	Standard Error	9.5	16.9	2.9	1.0	954.7	3.1	4.1
	Minimum	10.0	1.0	1.0	1.0	10.0	0.0	6.0
	Maximum	317.0	600.0	120.0	36.0	43,200.0	118.0	123.0
Vertical crevices (n = 68)	Mean	240.9	7.7	168.5	28.0	64,172.7	42.9	37.7
	Standard Error	13.1	2.8	30.5	10.2	32,301.5	3.5	3.8
	Minimum	10.0	0.5	1.0	1.0	3.0	0.0	0.0
	Maximum	324.0	180.0	1,400.0	600.0	1,658,880.0	95.0	118.0
Cave-like structures (n = 3)	Mean	201.0	68.0	208.0	184.0	2,952,576.0	62.0	18.0
	Standard Error	45.3	26.2	64.4	89.1	1,455,568.8	28.6	18.0
	Minimum	123.0	36.0	84.0	72.0	217,728.0	6.0	0.0
	Maximum	280.0	120.0	300.0	360.0	5,184,000.0	100.0	54.0

The acoustic team working at the bottom of the cliffs encountered more climbers than the rappel team. Climbers during each of the three trips volunteered information about bats they had seen that summer. Sometimes the encounters they mentioned overlapped with the time of our survey, however most of the routes where they encountered bats were inaccessible from the top of the cliff and were not in our random sample. Climbers will be the best resource moving forward to identify where bats are using climbing routes.

Acoustic Survey

Surveys were canceled on 18 May, 13 June, and 17 July due to rain. The night of 23 May was lost at Headless Wall due to a microphone that failed. A total of 97,335 files were recorded during the project. KPro software classified 45,524 files as bats and identified 44,141 files to species. Across the project, KPro considered all species likely present (Table 5). The number of calls and respective MLE values for each species are listed in Appendix E. Most files were identified as big brown bats (*Eptesicus fuscus*) (n = 14,475 calls) followed by eastern small-footed bat (*Myotis leibii*) (n = 5,800 calls). Sites with the highest number of recorded bat calls were Idol Point (n = 2,840 calls), The White Wall (n = 2,753 calls), and Hueco Pillar (n = 2,665 calls). All these sites were large, open cliffs. The fewest calls were documented at NERI.526 (n = 58 calls) and NERI.491 (n = 64 calls) which were small cliffs cluttered with understory vegetation. Although identified by KPro as being present, manually vetting disagreed and determined that Virginia big-eared bats (*Corynorhinus townsendii virginianus*) were not considered present. Files that were identified as Virginia big-eared bats (*Corynorhinus townsendii virginianus*) by the automated program were either low quality (only a few pulses in the call file or broadband calls) or did not match call characteristics of big-eared bats (i.e., call structure, minimum frequency typically around 20-25kHz, typically contain harmonics). Most of these files appear to be big brown bats (*Eptesicus fuscus*) calling in clutter. Manual vetting confirmed that eastern small-footed bats (*Myotis leibii*) are the most common *Myotis* species within NERI. Northern long-eared bats (*Myotis septentrionalis*) and Indiana bats (*Myotis sodalis*) are also likely present but in lower numbers compared to eastern small-footed bats (*Myotis leibii*). Though not targeted for manual vetting, calls of eastern red bat (*Lasiurus borealis*) and tri-colored bats (*Perimyotis subflavus*) were observed and are considered present. Manual vetting results and comments are in Appendix F.

Based on significant MLE values and after manual vetting, Diamond Point, Hellbound Area, and Ram's Head had the highest diversity of nine species recorded. These three sites were at tall open cliffs. The lowest diversity (n = 3 species) was recorded at the smaller and more cluttered cliffs of NERI.525, NERI.526, Star Trek Wall, and NERI.491. A total of 20 sites recorded all three target *Myotis* species, but Hueco Pillar (n = 2,373 calls) and The White Wall (n = 912 calls) had the most calls. Overlook Buttress, NERI.526, NERI.518, and NERI.491 did not record any target species.

Table 5. Summary of species considered likely present by Kaleidoscope Pro prior to manual vetting. Manual vetting results are in Appendix F. (MLE p-value ≤ 0.05). An “X” indicates that a species was targeted. Species codes are defined in Table 2.

Use category	Site	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Unclimbed	NERI.521 ^B	X	X	X	X	X	X	X	X	–	–	–
	NERI.525 ^B	X	X	–	–	–	X	X	X	X	–	–
	NERI.526	X	X	X	–	X	–	–	X	–	–	–
	NERI.517*	X	X	–	X	X	X	–	X	–	–	X
	NERI.518*	X	X	X	X	X	X	–	X	–	–	X
	NERI.484*	X	X	X	–	–	X	X	X	X	–	–
	Endless Wall 1b	X	X	X	X	X	X	X	X	–	–	–
	NERI.531	X	X	X	X	X	X	X	X	X	–	–
	Endless Wall 2a *	X	X	–	X	X	X	X	X	X	–	X
	NERI.535	X	X	X	–	X	X	–	X	–	–	–
	NERI.489	X	X	X	X	X	X	X	X	X	–	–
	NERI.488	X	X	X	X	X	X	X	X	X	–	–
	NERI.496 *	X	X	X	–	X	X	X	X	–	–	X
	Kaymoor 8	X	X	X	–	X	X	X	X	X	–	X
	Kaymoor 6a	X	X	X	X	X	X	X	X	–	–	–
	NERI.502	X	X	X	–	X	X	X	–	X	X	–
	NERI.491*	X	X	–	X	X	X	–	X	–	–	–
Low	Zealous Area	X	X	–	X	X	X	X	X	–	–	–
	Junkyard Wall	X	X	–	X	–	–	–	X	–	–	X
	Keeney's Buttress	X	X	X	X	X	–	–	X	–	X	X
	Domino Point	X	X	X	–	–	X	X	X	–	–	–
	Hueco Pillar	X	X	–	–	–	X	X	X	X	–	X
	The White Wall	X	X	X	–	–	X	X	X	X	–	–
	Toxic Jesus Wall	X	X	–	X	X	X	X	X	–	–	–

* Route surveyed replaced the original route due to safety concerns or inaccessibility.

Table 5 (continued). Summary of species considered likely present by Kaleidoscope Pro prior to manual vetting. Manual vetting results are in Appendix F. (MLE p-value ≤ 0.05). An “X” indicates that a species was targeted. Species codes are defined in Table 2.

Use category	Site	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Low (continued)	Overlook Buttriss	X	X	–	X	X	–	–	X	–	X	–
	Rock Shelter Cave	X	X	X	X	X	X	–	X	–	–	–
	The Pinnacle	X	X	–	X	–	X	X	X	–	–	–
	Thieves Area*	X	X	X	–	–	–	–	X	X	–	X
	Ritz Cracker Area	X	X	–	X	X	X	–	X	–	X	–
	Star Trek Wall*	X	X	X	–	–	X	–	X	–	–	–
	Fern Creek Falls	X	X	X	–	X	X	X	–	X	–	–
	Fern Cirque	X	X	X	–	X	X	X	X	X	X	–
	Idol Point	X	X	X	X	–	X	X	X	X	–	–
	Diamond Point	X	X	X	X	X	X	X	X	X	–	X
High	Hellbound Area	X	X	X	X	X	X	X	X	X	X	–
	Fantasy Area	X	X	X	X	–	X	X	X	X	–	–
	The Undeserved Area	X	X	–	X	–	X	X	X	X	–	–
	Jacob's Ladder Area	X	X	X	–	–	X	X	X	X	–	–
	Upper Endless	X	X	X	X	X	X	X	X	X	–	–
	The Brain	X	X	X	X	–	X	X	X	X	–	X
	Middle Beauty	X	X	X	X	X	X	–	X	X	X	–
	Ram's Head	X	X	X	X	X	X	X	X	X	X	–
	Butcher's Branch	X	X	X	–	–	X	X	X	X	–	–
	Fire and Ice Buttriss	X	X	X	–	–	X	X	X	X	–	–
	The Hole*	X	X	X	–	X	X	X	X	X	–	–
	Sandstonia - Decameron Area	X	X	X	–	X	X	X	X	X	–	–
	Little Head Wall	X	X	X	–	X	X	X	X	–	–	–

* Route surveyed replaced the original route due to safety concerns or inaccessibility.

Table 5 (continued). Summary of species considered likely present by Kaleidoscope Pro prior to manual vetting. Manual vetting results are in Appendix F. (MLE p-value ≤ 0.05). An “X” indicates that a species was targeted. Species codes are defined in Table 2.

Use category	Site	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
High (continued)	Headless Wall	X	X	X	–	X	X	X	X	–	X	–
	French Wall*	X	X	X	–	–	X	X	X	–	–	–
	Ames Wall	–	X	X	–	X	X	–	X	–	–	–
	Rainbow Ledge*	X	X	X	X	X	X	–	X	–	–	–

* Route surveyed replaced the original route due to safety concerns or inaccessibility.

Table 6 presents the detection histories categorized by crag, wall, species, and observation period. Among the four species monitored (COTO, MYLE, MYSE, MYSO [codes defined in Table 2]), three were detected (MYLE, MYSE, MYSO). Out of the 142 potential detection instances ([46 Walls × 3 Occasions] + [2 Walls × 2 Extra Occasions] = 142), 104 yielded bat detections. Specifically, eastern small-foot bats (*Myotis leibii*) were detected 91 times across 39 walls and 13 crags, northern long-eared bats (*Myotis septentrionalis*) were detected 60 times across 33 walls and 11 crags, and Indiana bats (*Myotis sodalis*) were detected 37 times across 20 walls and five crags.

Table 6. Detection history by species and location (1 = Detected). Species codes defined in Table 2.

Crag / Wall	Species	Period: 1 (14 May - 05 Jun)	Period: 2 (11 Jun - 24 Jun)	Period: 3 (14 Jun - 21 Jul)
Ambassador Buttress / Ambassador Buttress #2	MYLE	0	0	1
	MYSE	0	0	0
	MYSO	0	0	0
Beauty Mountain / Middle Beauty	MYLE	1	1	1
	MYSE	1	1	1
	MYSO	0	1	0
Beauty Mountain / Ram's Head	MYLE	1	1	1
	MYSE	1	0	1
	MYSO	1	1	1
Beauty Mountain / The Brain	MYLE	0	1	1
	MYSE	1	0	1
	MYSO	0	0	0
Bridge Area / Overlook Buttress	MYLE	0	0	0
	MYSE	0	0	0
	MYSO	0	0	0
Bridge Area / Rock Shelter Cave	MYLE	0	0	0
	MYSE	0	0	1
	MYSO	0	0	0
Bridge Area / The Pinnacle	MYLE	0	1	1
	MYSE	0	0	1
	MYSO	0	0	0
Bubba City / Ameless Wall	MYLE	0	0	0
	MYSE	0	0	0
	MYSO	0	0	0
Bubba City / Ames Wall	MYLE	0	0	1
	MYSE	0	0	1
	MYSO	0	0	0
Bubba City / French Wall	MYLE	0	1	1

Table 6 (continued). Detection history by species and location (1 = Detected). Species codes defined in Table 2.

Crag / Wall	Species	Period: 1 (14 May - 05 Jun)	Period: 2 (11 Jun - 24 Jun)	Period: 3 (14 Jun - 21 Jul)
Bubba City / French Wall (continued)	MYSE	0	0	1
	MYSO	0	0	0
Bubba City / Headless Wall	MYLE	1	1	1
	MYSE	0	0	0
	MYSO	0	0	0
Bubba City / Little Head Wall	MYLE	1	1	1
	MYSE	0	0	0
	MYSO	0	0	0
Bubba City / Rainbow Ledge Area	MYLE	0	0	1
	MYSE	1	0	0
	MYSO	0	0	0
Bubba City / Sandstonia - Decameron Area	MYLE	0	0	1
	MYSE	0	0	1
	MYSO	0	0	0
Domino Point / Domino Point	MYLE	0	1	1
	MYSE	0	0	1
	MYSO	0	0	0
Endless Wall / Diamond Point	MYLE	1	1	1
	MYSE	1	0	0
	MYSO	0	1	0
Endless Wall / Fantasy Area	MYLE	0	1	1
	MYSE	0	0	1
	MYSO	0	0	1
Endless Wall / Fern Cirque	MYLE	1	1	1
	MYSE	1	1	0
	MYSO	0	0	1
Endless Wall / Fern Point Slabs	MYLE	0	1	1
	MYSE	0	0	0
	MYSO	0	1	1
Endless Wall / Hellbound Area	MYLE	1	1	1
	MYSE	1	0	1
	MYSO	0	1	1
Endless Wall / Idol Point	MYLE	1	1	1
	MYSE	1	1	1
	MYSO	1	1	1

Table 6 (continued). Detection history by species and location (1 = Detected). Species codes defined in Table 2.

Crag / Wall	Species	Period: 1 (14 May - 05 Jun)	Period: 2 (11 Jun - 24 Jun)	Period: 3 (14 Jun - 21 Jul)
Endless Wall / Jacob's Ladder Area	MYLE	1	1	1
	MYSE	1	1	1
	MYSO	1	1	1
Endless Wall / Kaymoor Slabs	MYLE	1	1	1
	MYSE	0	0	1
	MYSO	0	0	0
Endless Wall / The Undeserved Area	MYLE	1	1	0
	MYSE	1	0	1
	MYSO	1	0	1
Endless Wall / Upper Endless	MYLE	1	1	1
	MYSE	1	1	1
	MYSO	1	1	0
Fern Buttress / Fern Creek Falls	MYLE	1	1	1
	MYSE	1	1	0
	MYSO	1	1	1
Fern Buttress / Ritz Cracker Area	MYLE	1	1	1
	MYSE	1	0	0
	MYSO	0	0	0
Fern Buttress / Star Trek Wall	MYLE	0	1	1
	MYSE	0	0	0
	MYSO	0	0	0
Fern Buttress / Thieves Area	MYLE	0	1	1
	MYSE	1	1	1
	MYSO	1	1	1
Junkyard Area / Junkyard Wall	MYLE	0	0	0
	MYSE	1	0	0
	MYSO	0	0	0
Junkyard Area / Zealous Area	MYLE	1	1	0
	MYSE	1	1	1
	MYSO	0	0	0
Kaymoor / Butcher's Branch	MYLE	1	1	1
	MYSE	1	0	1
	MYSO	0	1	0
Kaymoor / Fire and Ice Buttress	MYLE	1	1	1
	MYSE	0	0	0

Table 6 (continued). Detection history by species and location (1 = Detected). Species codes defined in Table 2.

Crag / Wall	Species	Period: 1 (14 May - 05 Jun)	Period: 2 (11 Jun - 24 Jun)	Period: 3 (14 Jun - 21 Jul)
Kaymoor / Fire and Ice Buttress (continued)	MYSO	0	1	0
Kaymoor / Seven-Eleven Wall	MYLE	1	1	1
	MYSE	0	1	0
	MYSO	1	1	0
Kaymoor / The Hole	MYLE	0	0	1
	MYSE	0	0	1
	MYSO	1	0	0
Kaymoor / White Wall Area	MYLE	0	0	1
	MYSE	1	0	1
	MYSO	0	0	0
Keeney's Buttress / Keeney's Buttress	MYLE	0	0	0
	MYSE	0	0	0
	MYSO	0	0	0
Keeney's Buttress / Keeney's Buttress	MYLE	0	1	0
	MYSE	0	1	0
	MYSO	0	0	0
Long Point / Long Point #3	MYLE	1	1	0
	MYSE	0	0	0
	MYSO	0	0	0
Long Point / Long Point #4	MYLE	0	0	0
	MYSE	0	0	0
	MYSO	0	0	0
South Nuttall / Hueco Pillar	MYLE	1	1	1
	MYSE	1	1	1
	MYSO	0	0	1
South Nuttall / The Bitch	MYLE	0	1	0
	MYSE	0	0	0
	MYSO	0	1	1
South Nuttall / The White Wall	MYLE	0	1	1
	MYSE	0	0	1
	MYSO	1	1	0
South Nuttall / Toxic Jesus Wall	MYLE	1	0	1
	MYSE	1	1	1
	MYSO	0	0	0

Table 6 (continued). Detection history by species and location (1 = Detected). Species codes defined in Table 2.

Crag / Wall	Species	Period: 1 (14 May - 05 Jun)	Period: 2 (11 Jun - 24 Jun)	Period: 3 (14 Jun - 21 Jul)
Sunshine Buttress / Sunshine Buttress #2	MYLE	0	1	1
	MYSE	1	0	0
	MYSO	0	0	0
Sunshine Buttress / Sunshine Buttress #3	MYLE	0	0	0
	MYSE	0	0	0
	MYSO	0	0	0

Occupancy modeling

Eastern Small-Footed Bat (Myotis leibii)

Eastern small-footed bats (*Myotis leibii*) were detected at 39 of the 46 walls for a naive occupancy estimate of 84.78%.

Model Selection

Starting with the full model $[\psi(pc1_{state}), p(pc1_{dte})]^2$, the covariate subsets were permuted and the three lowest-AICc models for eastern small-footed bats (*Myotis leibii*) in the model set were selected (Table 7). AICc model selection was used over AIC to adjust for the smaller sample size. Model averaging was not considered as part of the selection process.

Table 7. Eastern small-footed bat (*Myotis leibii*) – Top 3 models by AICc.

Model	AICc	Δ AICc	Log Likelihood	df	χ^2 GoF p-value
$\Psi(i_descriptive + 1), p(i_inspection + 1)$	163.093	0.000	-77.059	4	0.575
$\Psi(i_physical + 1), p(i_inspection + 1)$	164.557	1.465	-77.791	4	0.574
$\Psi(i_descriptive + i_environmental + 1), p(i_inspection + 1)$	164.590	1.498	-76.545	5	0.572

Best Model - Exploration

Per Table 8, the best model by AICc for this species is:

² Each species has its own model. Each individual "full" model has the same covariates (i_inspection, i_descriptive, i_environmental, i_physical), but they have different coefficients as a result of the different response variables (species). A full model for one species could not be used to predict the occupancy of another.

$$\psi(i_descriptive + intercept), \quad p(i_inspection + intercept)$$

Table 8. Eastern small-footed bat (*Myotis leibii*) – Top model coefficient summary.

Process	Covariate	Estimate	SE	z	P(> z)
ψ	(Intercept)	2.159	0.604	3.575	0.000
	i_descriptive	1.002	0.499	2.008	0.045
p	(Intercept)	1.240	0.258	4.802	0.000
	i_inspection	0.875	0.256	3.421	0.001

Exploring this model in Table 9 shows that the scaled factor index, “Descriptive”, used to estimate occupancy, is significant ($\alpha < 0.05$). The “Inspection” index used to estimate detection probability is also significant ($\alpha < 0.05$).

Table 9. Northern long-eared bat (*Myotis septentrionalis*) – Top 3 models by QAICc.

Model	QAICc	Δ QAICc	Log Likelihood	df	χ^2 GoF p-value
$\Psi(i_descriptive + i_environmental + 1), p(1)$	135.791	0.000	-83.877	4	0.055
$\Psi(i_descriptive + i_environmental + 1), p(i_inspection + 1)$	137.365	1.575	-83.149	5	0.108
$\Psi(i_descriptive + i_environmental + i_physical + 1), p(1)$	138.434	2.643	-83.870	5	0.050

Exploring the significant factors in the best model, the occupancy process (on a logit-link scale) exhibits positive correlation with the “Descriptive” scaled index (1.002). Higher values in this index lead to higher occupancy probability estimates. Similarly, the “inspection” scaled index (0.875) is positively correlated with the detection process (on a logit-link scale), resulting in higher detection probabilities as the index increases.

Northern Long-Eared Bat (*Myotis septentrionalis*)

Northern long-eared bats (*Myotis septentrionalis*) were detected at 33 of the 46 walls for a naive occupancy estimate of 71.74%.

Model Selection

Starting with the full model [$\psi(pc1_{state}), p(pc1_{dte})$], the covariate subsets were permuted and the the three lowest-QAICc models for northern long-eared bats (*Myotis septentrionalis*) in the model set were selected (Table 9). QAICc model selection was used over AIC to adjust for the overdispersion and smaller sample size. Model averaging was not considered as part of the selection process.

Best Model - Exploration

Per Table 9, the best model by QAICc for this species is:

$$\psi(i_descriptive + i_environmental + intercept), \quad p(intercept)$$

Exploring this model further in Table 10 shows that neither the scaled factor index, “Descriptive”, or “Environmental” used to estimate occupancy, are significant ($\alpha \geq 0.05$). The “best model”, per QAICc (Table 9), still recommends the inclusion of these indices for occupancy probability, so they are included for interpretation. Table 10 also shows that an average (constant) detection probability may be assumed as indicated by the fact that there are no covariates.

Table 10. Northern long-eared bat (*Myotis septentrionalis*) – Top model coefficient summary.

Process	Covariate	Estimate	SE adj.	z adj.	P(> z) adj.
ψ	(Intercept)	40.496	91.716	0.442	0.659
	i_descriptive	32.638	72.929	0.448	0.654
	i_environmental	-22.045	69.994	-0.315	0.753
p	(Intercept)	-0.017	0.211	-0.078	0.938

Exploring the factors in the best model, the occupancy process (on a logit-link scale) exhibits positive correlation with the “Descriptive” scaled index (32.638). Higher values in this index lead to higher occupancy probability estimates. Conversely, the occupancy process exhibits a negative correlation with the “Environmental” scaled index (-22.045). Lower values in this index lead to higher occupancy probability estimates.

Based on the model selection process, there are no covariates that affect the detection probability so a constant detection probability across all sites is assumed. The probability along with its $\hat{c}$ -adjusted standard error and 95% confidence interval is reported in Table 11.

Table 11. Northern long-eared bat (*Myotis septentrionalis*) – Detection probability summary.

Pred. Det. Prob.	Adj. SE	Adj. 95% CI
0.496	0.053	[0.392, 0.599]

Indiana Bat (Myotis sodalis)

Indiana bats (*Myotis sodalis*) were detected at 20 of the 46 walls for a naive occupancy estimate of 43.48%.

Model Selection

Starting with the full model [$\psi(pc1_{state}), p(pc1_{dte})$], the covariate subsets were permuted and the three lowest-QAICc models for Indiana bats (*Myotis sodalis*) in the model set were selected (Table 12). QAICc model selection was used over AIC to adjust for the overdispersion and smaller sample size. Model averaging was not considered as part of the selection process.

Table 12. Indiana bat (*Myotis sodalis*) – Top 3 models by QAICc.

Model	QAICc	Δ QAICc	Log Likelihood	df	χ^2 GoF p-value
$\Psi(i_descriptive + 1), p(1)$	108.257	0.000	-62.564	3	0.234
$\Psi(i_descriptive + i_physical + 1), p(1)$	109.192	0.935	-61.562	4	0.136
$\Psi(i_descriptive + 1), p(i_inseption + 1)$	110.509	2.252	-62.392	4	0.352

Best Model - Exploration

Per Table 12, the best model by QAICc for this species is:

$$\psi(i_descriptive + intercept), \quad p(intercept)$$

Exploring this model further in Table 13 shows that neither the scaled factor index, “Descriptive”, or “Environmental” used to estimate occupancy, are significant ($\alpha \geq 0.05$). The “best model”, per QAICc (Table 12), still recommends the inclusion of these indices for occupancy probability, so we will include them for interpretation. Table 13 also shows that an average (constant) detection probability may be assumed as indicated by the fact that there are no covariates.

Table 13. Indiana bat (*Myotis sodalis*) – Top model coefficient summary.

Process	Covariate	Estimate	SE adj.	z adj.	P(> z) adj.
ψ	(Intercept)	-0.188	0.706	-0.266	0.790
	i_descriptive	2.419	1.160	2.085	0.037
p	(Intercept)	-0.011	0.384	-0.029	0.977

Exploring the factors in the best model, the occupancy process (on a logit-link scale) exhibits positive correlation with the “descriptive” scaled index (2.419). Higher values in this index lead to higher occupancy probability estimates.

Based on the model selection process, a constant detection probability across all sites is assumed so there are no covariates that affect the detection probability. The detection probability along with its $\hat{c}$ -adjusted standard error and 95% confidence interval is reported in Table 14.

Table 14. Indiana bat (*Myotis sodalis*) – Detection probability summary.

Pred. Det. Prob.	Adj. SE	Adj. 95% CI
0.497	0.096	[0.309, 0.685]

Interpretation

In the predictive models for all three target species, the "i_descriptive" covariate was consistently present in the top model. It is important to highlight that the "Descriptive" index (i_descriptive) incorporates the key variables associated with climbing use. From Appendix B, these variables are "wall_routeQualityScore", "wall_useCategory", "wall_routeCount", and "wall_routeLength_m", "wall_avgDifficultyRating", "wall_reviewCount". The individual importance of these variables to this index is discussed elsewhere in this report. For Indiana bats (*Myotis sodalis*), "i_descriptive" was the only covariate in the top model. The top model for eastern small-footed bats (*Myotis leibii*) included both "i_descriptive" and "i_inspection" covariates. However, for northern long-eared bats (*Myotis septentrionalis*), the top model comprised of the "i_descriptive" and "i_environmental" covariates, with no association to "i_inspection".

Variables within the "Descriptive" index that were important for all three species were sampling location within the study area and climbing activity. Higher activity of all three species was detected in the southeast portion of the study area where more popular routes (i.e., higher levels of climbing) are located.

The "Inspection" index was important for eastern small-footed bats (*Myotis leibii*), indicating that as the summer progressed, there was a higher likelihood of detecting this species.

The "Environmental" index contained various measurements of vegetation present. As the amount of vegetation increased, the level of northern long-eared bats (*Myotis septentrionalis*) activity decreased.

Conclusions

Higher numbers of bat calls were recorded in the southeast portion of the study area, which corresponds to the highest climbing activity. Similarly, Indiana bat (*Myotis sodalis*) calls and eastern small-footed bat (*Myotis leibii*) calls were detected primarily on highly climbed walls and at low levels on unclimbed walls. If bats are roosting on the walls, they would be found in cracks and crevices, which may also be used by climbers. Northern long-eared bat (*Myotis septentrionalis*) calls were collected near walls with less vegetation. This could be an artifact of the nature of acoustic detection, where more easily identified calls are produced in areas of low clutter, i.e., low vegetation structure. However, bat activity level is not necessarily an indication of roosting habitat nearby; it is more likely identifying foraging and commuting areas for bats. USFWS (2023) states that the capture of an Indiana bat (*Myotis sodalis*) suggests that a roost is located within 5 miles of that capture site. Although that distance encompasses a large area, it could help narrow down roosting availability for the species. Other species may utilize smaller home ranges, e.g., northern long-eared bat (*Myotis septentrionalis*) captures are considered to be within 3 miles of their roosts (USFWS 2023).

Despite no bats or sign of bats being observed during the cliff surveys, there were areas that appeared to have habitat characteristics of rock roosts, e.g., crevices, dark zones, rock shelters, and cave-like overhangs. Biologists talked with many climbers who had encountered bats while climbing within the park. Climbers present a potential avenue for the park to collect citizen science data pertaining to bat use of cliffs. Most of the climbers that biologists interacted with showed interest and positive feelings towards bats, so we recommend continuing to encourage climbers to submit sightings to Climbers for Bat Conservation (CSU 2023).

Due to the cluttered nature of the habitat near the cliffs, confidently identifying calls to species is challenging. Bats alter their echolocation call characteristics when flying in clutter (Broders et al. 2004) which can make species identification difficult. Further compounding species identification is that *Myotis* species produce calls that overlap with one another. As suggested by the acoustic data and given the abundance of rocky habitat which eastern small-footed bats (*Myotis leibii*) heavily utilize for roosting (Erdle and Hobson 2001, Johnson et al. 2011), this species is the most common *Myotis* species within the park. Due to call overlap amongst *Myotis* species, many of the files identified as northern long-eared bat (*Myotis septentrionalis*) and Indiana bat (*Myotis sodalis*) are also likely eastern small-footed bats (*Myotis leibii*), but northern long-eared bats (*Myotis septentrionalis*) and Indiana bats (*Myotis sodalis*) cannot be ruled out as being present. Mist-net surveys, particularly if developed with information from climber data and higher concentrations of bat calls recorded acoustically, will help to confirm the bat species composition within the park. Radio-tracking species of interest to roosts would also help inform NPS of specific roost locations, as well as compiling data on habitat characteristics of roosts used by bats at NERI.

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Appendix A – Classification of Climbing Activity by Wall

Route Pool Generation

To begin analyzing the current “climbing activity” on the Craggs of the New River Gorge, we executed a .csv export from the Mountain Project (2022) on January 18, 2022 pulling all available “Traditional”, “Sport”, and “Toprope” routes documented on the website for the “New River Gorge Proper” area. The export contained an “Average Star Rating” using a (NULL, 0-4)-star continuous ranking system allowing for decimal ratings to represent “Route Quality” where 0 is “not recommended” and NULL is “not reviewed”. It also provides a user-generated Yosemite Decimal System (YDS) climbing grade, route length, and a GPS point location. A total of 874 routes were selected by the field crew from the export’s 950 routes based on their geographic relevance to the project (Cotton Hill and Piney Creek Watershed were removed from consideration). We then manually associated the number of reviews with each relevant route, as “Review Count” was not available in the initial download.

Next we manually cross-referenced the .csv export with Williams (2019), documenting which routes appeared in both sources as well as any additional routes that appeared in the book but not the .csv and vice-versa. This book contains its author’s reputable opinion on “Route Score” utilizing a discrete 4-star system that *does not* allow for decimal ratings and *does not* differentiate between “not recommended” and “not reviewed”. “Review Counts” are not applicable here as it is just a single expert’s opinion on the routes.

A total of 1,959 climbing routes were identified across 93 walls within 12 crags from two distinct sources. This initial dataset was expanded further by including 88 additional areas, classified as “unclimbed”, from the National Park Service (NPS). This enhancement introduced 13 new walls and three previously unconsidered crags, with 75 of these areas situated on already climbed walls. The areas on climbed walls were recognized as distinct routes, with special emphasis given to their unique positions along the wall.

Climbing Activity Indicator

The request to integrate the abstract idea of “climbing activity” into a mathematical model necessitated generating a numerical representation of this concept. Ideally, this would be measured using quantitative metrics such as:

1. The frequency of climber visits to a wall within a specified time frame.
2. The proportion of the wall’s area occupied by climbers within a specified time frame.
3. The percentage of time climbers spend on the wall within a specified time frame.

Regrettably, there is no known source for such precise data. Gathering this data would be both financially burdensome and time-consuming. Therefore, qualitative proxies were used based on the resources recommended by the NPS.

The NPS-recommended resources provided three essential data points: (1) a 4-star “Quality Score” for each route, (2) “Review Counts” indicating the number of reviews each route received from

Mountain Project (2022), and upon aggregating the data to the wall level, (3) “Route Count”, representing the number of routes on a given wall.

Specifically, the “Quality Score” reflects public perception of the routes, with the premise that routes with higher ratings draw more climbers. The “Review Counts” measure the number of reviews per route, suggesting that routes with more reviews have been climbed by more people. Finally, a wall’s (and by extension, a crag’s) “Route Count” indicates that these areas have been visited for route creation and offer increased climbing opportunities, potentially increasing their attractiveness.

We contend that “Review Counts” provides a more accurate measure of realized “climbing activity” than the “Quality Score”. For instance, a remote route with a few 4-star reviews might be less active than a 2-star route with thousands of reviews. Conversely, a remote 2-star route with a few reviews is likely less active than a 4-star route with thousands of reviews. While further study is needed for certainty, we adopt the stance that “Review Counts” are a more reliable indicator of climbing activity in this instance of the “Star Rating” or “Cold Start Problem”. This assumption will be evident in the subsequent steps, most notably in the computation of the Bayesian average.

Score & Threshold Generation Process

To calculate a “Quality Score” and estimate a threshold for binning these scores into “low” and “high” use areas, we performed the steps below.

Step 1: Compute a Bayesian Average of the Mountain Project (2022) route-level scores ($Score_{MP}$) using the formula:

$$Score_{MP} = \frac{v_i}{v_i + m} \cdot R_i + \frac{m}{v_i + m} \cdot C$$

The variables in this formula are defined as follows:

v_i : The quantity of ratings associated with the i_{th} route

C : The “confidence number” determines the minimum count of ratings considered to be reliable. In this instance, we chose C to be the lower quartile. This cautious approach helped to prevent routes with a small number of high ratings from inordinately influencing their final score.

m : The “fallback value” is an estimate of what the average rating would be if there were enough ratings. When an item has fewer ratings than the confidence number (C), the Bayesian average is pulled closer to the fallback value. In this context, we set m to be the arithmetic mean of the scores. This is a prudent measure to deter routes with a limited number of extreme ratings from disproportionately influencing the top rankings.

R_i : The mean rating, or score, supplied by the Mountain Project (2022) for the i_{th} route

Step 2: Standardize and normalize both the Mountain Project (2022) scores ($Score_{MP}$) and the corresponding Williams (2019) scores ($Score_{NRR}$). Subsequently, compute their geometric mean to establish the Route Quality Score ($Score_{RQ}$). The geometric mean is preferred as it provides a

balanced average that is less sensitive to extreme values in these two different scales, making it an ideal choice when integrating diverse rating systems. Should the product of $Score_{MP}$ and $Score_{NRR}$ result in zero, the arithmetic mean (equivalent to halving the non-zero score) should be computed as an alternative:

$$Score_{RQ} = \begin{cases} \frac{Score_{nonzero}}{2} & \text{if } (Score_{MP} \cdot Score_{NRR}) = 0 \\ \sqrt{Score_{MP} \cdot Score_{NRR}} & \text{otherwise} \end{cases}$$

This procedure encapsulates the belief that a route reviewed in both sources tends to be more popular than one reviewed in a single source. Furthermore, it prevents artificial zero-inflation of the rating data by ensuring the assignment of a value even when the geometric mean is zero.

Step 3: Determine the average Route Quality Score ($Score_{RQ}$) for a given climbing wall. Multiply this average by the total number of routes on the wall (n_{routes}) to obtain the Wall Quality Score ($Score_{WQ}$):

$$Score_{WQ} = \frac{1}{n} \sum_{i=1}^n Score_{RQi} \times n_{routes}$$

In this equation, the term $\frac{1}{n} \sum_{i=1}^n Score_{RQi}$ represents the mean $Score_{RQ}$ across all n routes on the wall, and n_{routes} is the total number of routes on the wall. By scaling the quality score with the number of routes, this procedure embodies the notion that a wall with consistently lower scores, but abundant climbing opportunities, could potentially witness the same level of climbing activity as a wall with consistently higher scores but fewer routes.

Step 4: Normalize the Wall Quality Score ($Score_{WQ}$) using min-max normalization. We call this normalized quantity the “Wall Use Score” as it encapsulates everything we know so far (ratings, sources, review counts, and route counts) about a wall’s “popularity”.

Step 5: Lastly, compute the median of these normalized scores. This median serves as the ‘Use Category Threshold’ (UCT):

$$UCT = median(Score_{WQ,normalized})$$

Walls with a “Wall Use Score” exceeding this threshold are classified as ‘High Use’, while those with scores below the threshold are deemed ‘Low Use’.

Wall Selection Summary

We utilized a stratified random sampling technique at the wall level to identify sample locations. The stratification was guided by two factors: the *crag* and the *use category*. Stratifying by *crag*

guaranteed the spatial representation of the sample, while stratifying by use category assured the capture of representative climbing activity.

Exact site locations and final wall selections were not known due to safety concerns prior to deployment. Surveyors endeavored to reach desktop-determined target points. The crews selected final inspection locations based on perceived habitat and safety considerations. The safety considerations were largely guided by the repelling team even though, ultimately no bat sign was detected by that crew. A summary of the sample selection at the crag level is shown in Table 15.

Table 15. Crag-level sample summary.

Crag	Total Walls	High Use Walls	Unclimbed Walls	Total Sampled Walls	Sampled High-Use Walls	Sampled Unclimbed Walls
Ambassador Buttress	3	1	2	1	0	1
Beauty Mountain	9	4	0	3	2	0
Bridge Area	9	3	0	3	0	0
Bridge View	3	0	3	0	0	0
Bubba City	18	7	0	7	0	0
Domino Point	1	1	0	1	1	0
Endless Wall	23	15	0	10	6	0
Fern Buttress	11	4	0	4	2	0
Junkyard Area	4	2	0	2	2	0
Kaymoor	8	6	0	5	4	0
Keeney's Buttress	1	0	0	1	0	0
Keeney's Buttress	1	0	1	1	0	1
Long Point	4	0	4	2	0	2
South Nuttall	7	2	0	4	2	0
Sunshine Buttress	4	1	3	2	0	2

The list of crags in Table 15 were assessed using Fisher's exact test to determine the representativeness of wall sampling across 'High Use', 'Low Use', and 'Unclimbed' categories. Using post Holm correction for multiple comparisons, no significant divergences were noted between the sampled walls and the overall population for any crag. For example, the 'Bubba City' crag yielded adjusted p-values of 0.57, 0.57, and 1.00 for 'Low Use', 'High Use', and 'Unclimbed' categories respectively, indicating effective capture of wall usage distribution in the sampling procedure across all 15 crags. Detailed p-values by crag and use level are presented in Table 16.

Table 16. Crag-level fishers exact test p-value summary.

Crag	p-Value: Low Use	p-Value: High Use	p-Value: Unclimbed
Ambassador Buttress	1.000	1.000	1.00
Beauty Mountain	1.000	1.000	1.00
Bridge Area	1.000	1.000	1.00
Bridge View	1.000	1.000	1.00
Bubba City	0.195	0.195	1.00
Domino Point	1.000	1.000	1.00
Endless Wall	1.000	1.000	1.00
Fern Buttress	1.000	1.000	1.00
Junkyard Area	1.000	1.000	1.00
Kaymoor	1.000	1.000	1.00
Keeney's Buttress	1.000	1.000	1.00
Keeney's Buttress	1.000	1.000	1.00
Long Point	1.000	1.000	1.00
South Nuttall	1.000	1.000	1.00
Sunshine Buttress	1.000	1.000	1.00

Appendix B – Covariate Summary

Table 17 shows a summary of the 88 covariates used in building the model.

Table 17. Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
avg_TAXN	Float	Min.: 15.73 1st Qu.: 18.67 Median: 20.44 Mean: 19.934 3rd Qu.: 21.11 Max.: 23.462	inspection	observation/ occupancy	environmental	environmental	Avg. daily temp (C°) in 4-day window around inspection (NOAA's GHCN-Daily)
avg_moon_dur_hr	Float	Min.: 8.466 1st Qu.: 8.856 Median: 9.477 Mean: 10.174 3rd Qu.: 11.141 Max.: 15.533	inspection	observation/ occupancy	environmental	environmental	Avg moon duration (hr) in 4-day window around inspection
avg_moon_frac	Float	Min.: 0.022 1st Qu.: 0.64 Median: 0.871 Mean: 0.748 3rd Qu.: 0.945 Max.: 0.973	inspection	observation/ occupancy	environmental	environmental	Avg moon illumination (0.0-1.0) in 4-day window around inspection.

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
avg_sun_dur_hr	Float	Min.: 14.256 1st Qu.: 14.468 Median: 14.595 Mean: 14.595 3rd Qu.: 14.792 Max.: 14.809	inspection	observation/ occupancy	environmental	environmental	Avg sun duration (hr) in 4-day window around inspection
crev_count_horizontal	Integer	Min.: 0 1st Qu.: 0 Median: 1 Mean: 1.434 3rd Qu.: 2 Max.: 5 NA's: 6	site	observation/ occupancy	physical	physical	Count of horizontal crevices on wall
crev_count_total	Integer	Min.: 1 1st Qu.: 2 Median: 3 Mean: 3.044 3rd Qu.: 4 Max.: 11 NA's: 6	site	observation/ occupancy	physical	physical	Total count of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_max_aspect	Float	Min.: 10 1st Qu.: 155 Median: 232 Mean: 212.846 3rd Qu.: 278 Max.: 324 NA's: 6	site	observation/ occupancy	physical	physical	Max aspect (deg) of wall crevices
crev_max_depth_cm	Float	Min.: 5.08 1st Qu.: 17.78 Median: 30.48 Mean: 124.441 3rd Qu.: 60.96 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Max depth (cm) of wall crevices
crev_max_height_cm	Float	Min.: 2.54 1st Qu.: 26.67 Median: 182.88 Mean: 476.978 Max.: 3556 NA's: 6	site	observation/ occupancy	physical	physical	Max height (cm) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_max_rrToBottom_m	Float	Min.: 1.829 1st Qu.: 9.144 Median: 16.764 Mean: 17.721 3rd Qu.: 24.384 Max.: 37.49 NA's: 6	site	observation/ occupancy	physical	physical	Max dist. (m) from crevice top to cliff bottom
crev_max_rrToTop_m	Float	Min.: 0 1st Qu.: 7.315 Median: 13.716 Mean: 14.328 3rd Qu.: 19.812 Max.: 35.966 NA's: 6	site	observation/ occupancy	physical	physical	Max dist. (m) from crevice top to cliff top
crev_max_volume_m3	Float	Min.: 0 1st Qu.: 0.009 Median: 0.063 Mean: 4.727 3rd Qu.: 0.354 Max.: 84.966 NA's: 6	site	observation/ occupancy	physical	physical	Max volume (m³) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_max_width_cm	Float	Min.: 2.54 1st Qu.: 12.7 Median: 91.44 Mean: 222.885 3rd Qu.: 243.84 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Max width (cm) of wall crevices
crev_mean_aspect	Float	Min.: 10 1st Qu.: 155 Median: 231 Mean: 209.044 3rd Qu.: 276 Max.: 324 NA's: 6	site	observation/ occupancy	physical	physical	Mean aspect (deg) of wall crevices
crev_mean_depth_cm	Float	Min.: 4.233 1st Qu.: 12.7 Median: 20.637 Mean: 76.034 3rd Qu.: 45.72 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Mean depth (cm) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_mean_height_cm	Float	Min.: 2.54 1st Qu.: 14.605 Median: 81.28 Mean: 225.66 3rd Qu.: 317.5 Max.: 975.36 NA's: 6	site	observation/ occupancy	physical	physical	Mean height (cm) of wall crevices
crev_mean_rrToBottom_m	Float	Min.: 1.829 1st Qu.: 6.553 Median: 10.858 Mean: 12.877 3rd Qu.: 16.764 Max.: 34.138 NA's: 6	site	observation/ occupancy	physical	physical	Mean dist. (m) from crevice top to cliff bottom
crev_mean_rrToTop_m	Float	Min.: 0 1st Qu.: 6.096 Median: 8.23 Mean: 9.892 3rd Qu.: 12.192 Max.: 23.978 NA's: 6	site	observation/ occupancy	physical	physical	Mean dist. (m) from crevice top to cliff top

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_mean_volume_m3	Float	Min.: 0 1st Qu.: 0.008 Median: 0.025 Mean: 2.097 3rd Qu.: 0.142 Max.: 42.577 NA's: 6	site	observation/ occupancy	physical	physical	Mean volume (m³) of wall crevices
crev_mean_width_cm	Float	Min.: 2.54 1st Qu.: 11.43 Median: 41.91 Mean: 112.532 3rd Qu.: 121.92 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Mean width (cm) of wall crevices
crev_median_aspect	Float	Min.: 10 1st Qu.: 155 Median: 229.5 Mean: 209.353 3rd Qu.: 276 Max.: 324 NA's: 6	site	observation/ occupancy	physical	physical	Median aspect (deg) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_median_depth_cm	Float	Min.: 5.08 1st Qu.: 10.16 Median: 20.32 Mean: 71.848 3rd Qu.: 30.48 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Median depth (cm) of wall crevices
crev_median_height_cm	Float	Min.: 2.54 1st Qu.: 6.35 Median: 25.4 Mean: 173.355 3rd Qu.: 243.84 Max.: 914.4 NA's: 6	site	observation/ occupancy	physical	physical	Median height (cm) of wall crevices
crev_median_rrToBottom_m	Float	Min.: 1.829 1st Qu.: 6.096 Median: 10.287 Mean: 12.85 3rd Qu.: 16.764 Max.: 34.138 NA's: 6	site	observation/ occupancy	physical	physical	Median dist. (m) from crevice top to cliff bottom

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_median_rrToTop_m	Float	Min.: 0 1st Qu.: 5.486 Median: 9.144 Mean: 9.783 3rd Qu.: 12.192 Max.: 27.432 NA's: 6	site	observation/ occupancy	physical	physical	Median dist. (m) from crevice top to cliff top
crev_median_volume_m3	Float	Min.: 0 1st Qu.: 0.003 Median: 0.019 Mean: 1.432 3rd Qu.: 0.069 Max.: 42.577 NA's: 6	site	observation/ occupancy	physical	physical	Median volume (m³) of wall crevices
crev_median_width_cm	Float	Min.: 2.54 1st Qu.: 7.62 Median: 20.32 Mean: 86.883 3rd Qu.: 78.74 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Median width (cm) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_min_aspect	Float	Min.: 10 1st Qu.: 155 Median: 228 Mean: 204.103 3rd Qu.: 270 Max.: 324 NA's: 6	site	observation/ occupancy	physical	physical	Min aspect (deg) of wall crevices
crev_min_depth_cm	Float	Min.: 2.54 1st Qu.: 5.08 Median: 10.16 Mean: 45.907 3rd Qu.: 15.24 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Min depth (cm) of wall crevices
crev_min_height_cm	Float	Min.: 2.54 1st Qu.: 2.54 Median: 5.08 Mean: 99.62 3rd Qu.: 60.96 Max.: 914.4 NA's: 6	site	observation/ occupancy	physical	physical	Min height (cm) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_min_rrToBottom_m	Float	Min.: 0 1st Qu.: 3.048 Median: 6.096 Mean: 8.413 3rd Qu.: 10.668 Max.: 34.138 NA's: 6	site	observation/ occupancy	physical	physical	Min dist. (m) from crevice top to cliff bottom
crev_min_rrToTop_m	Float	Min.: 0 1st Qu.: 1.524 Median: 3.353 Mean: 5.412 3rd Qu.: 7.315 Max.: 21.031 NA's: 6	site	observation/ occupancy	physical	physical	Min dist. (m) from crevice top to cliff top
crev_min_volume_m3	Float	Min.: 0 1st Qu.: 0.001 Median: 0.003 Mean: 0.422 3rd Qu.: 0.01 Max.: 17.701 NA's: 6	site	observation/ occupancy	physical	physical	Min volume (m³) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_min_width_cm	Float	Min.: 0 1st Qu.: 2.54 Median: 7.62 Mean: 53.695 3rd Qu.: 15.24 Max.: 1524 NA's: 6	site	observation/ occupancy	physical	physical	Min width (cm) of wall crevices
crev_present	Float	Min.: 0 1st Qu.: 0 Median: 0 Mean: 0.31 3rd Qu.: 1 Max.: 1	inspection	observation/ occupancy	physical	physical	Crevices present on wall (boolean)
crev_sd_depth_cm	Float	Min.: 0 1st Qu.: 0 Median: 10.473 Mean: 41.423 3rd Qu.: 25.145 Max.: 639.394 NA's: 6	site	observation/ occupancy	physical	physical	SD depth (cm) of wall crevices

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_sd_height_cm	Float	Min.: 0 1st Qu.: 0 Median: 48.393 Mean: 184.841 3rd Qu.: 172.421 Max.: 1515.67 NA's: 6	site	observation/ occupancy	physical	physical	SD height (cm) of wall crevices
crev_sd_rrToBottom_m	Float	Min.: 0 1st Qu.: 0 Median: 4.311 Mean: 4.739 3rd Qu.: 8.345 Max.: 17.289 NA's: 6	site	observation/ occupancy	physical	physical	SD dist. (m) from crevice top to cliff bottom
crev_sd_rrToTop_m	Float	Min.: 0 1st Qu.: 0 Median: 3.81 Mean: 4.617 3rd Qu.: 7.148 Max.: 17.289 NA's: 6	site	observation/ occupancy	physical	physical	SD dist. (m) from crevice top to cliff top

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
crev_sd_volume_m3	Float	Min.: 0 1st Qu.: 0 Median: 0.016 Mean: 2.619 3rd Qu.: 0.12 Max.: 59.946 NA's: 6	site	observation/ occupancy	physical	physical	SD volume (m³) of wall crevices
crev_sd_width_cm	Float	Min.: 0 1st Qu.: 1.466 Median: 15.492 Mean: 80.423 3rd Qu.: 84.414 Max.: 534.789 NA's: 6	site	observation/ occupancy	physical	physical	SD width (cm) of wall crevices
inspectionDate_doy	Integer	Min.: 136 1st Qu.: 151 Median: 169 Mean: 169.662 3rd Qu.: 194 Max.: 200	inspection	observation/det ection	descriptive	insp_var	The day of rappelling inspection

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
inspectionDate_month	Integer	Min.: 5 1st Qu.: 5 Median: 6 Mean: 6.077 3rd Qu.: 7 Max.: 7	inspection	observation/ occupancy	descriptive	descriptive	The month of rappelling inspection
inspectionDate_week	Integer	Min.: 20 1st Qu.: 22 Median: 25 Mean: 24.662 3rd Qu.: 28 Max.: 29	inspection	observation/ occupancy	descriptive	descriptive	The week of rappelling inspection
inspection_areaPerMic	Float	Min.: 347.189 1st Qu.: 1156.698 Median: 1766.235 Mean: 1828.556 3rd Qu.: 2578.888 Max.: 3695.069	inspection	observation/det ection	physical	insp_var	Wall Area (sqm) per mic deployments

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
inspection_count	Integer	Min.: 1 1st Qu.: 1 Median: 2 Mean: 2.07 3rd Qu.: 3 Max.: 5	inspection	observation/detection	descriptive	insp_var	Inspection index by wall
inspection_inspector_lastName	Factor w/ 2 levels	Fagin: 67 Seiter: 75	inspection	observation/detection	descriptive	insp_var	Inspector's last name
inspection_totalInspections	Integer	Min.: 3 1st Qu.: 3 Median: 3 Mean: 3.141 3rd Qu.: 3 Max.: 5	site	observation/detection	physical	insp_var	Count of wall inspections during study
mic_altitudeMSL_m	Float	Min.: 318.295 1st Qu.: 455.444 Median: 528.788 Mean: 510.846 3rd Qu.: 562.678 Max.: 595.56	inspection	observation/occupancy	descriptive	descriptive	Estimated microphone altitude (m)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
mic_deployments	Integer	Min.: 1 1st Qu.: 1 Median: 1 Mean: 1.077 3rd Qu.: 1 Max.: 2	inspection	observation/detection	physical	insp_var	Count of mics @ wall during inspection
mic_lat	Float	Min.: 38.034 1st Qu.: 38.051 Median: 38.056 Mean: 38.062 3rd Qu.: 38.075 Max.: 38.1	inspection	observation/occupancy	descriptive	descriptive	Estimated microphone latitude (WGS84)
mic_lon	Float	Min.: -81.096 1st Qu.: -81.08 Median: -81.064 Mean: -81.065 3rd Qu.: -81.05 Max.: -81.025	inspection	observation/occupancy	descriptive	descriptive	Estimated microphone longitude (WGS84)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
rope_dimA_m	Float	Min.: 0 1st Qu.: 0 Median: 0 Mean: 1.215 3rd Qu.: 0 Max.: 9.144	inspection	observation/ occupancy	physical	physical	Distance (m) of rope from anchor to cliff start
rope_dimD_m	Float	Min.: 3.81 1st Qu.: 18.288 Median: 21.336 Mean: 22.485 3rd Qu.: 30.48 Max.: 39.624	inspection	observation/ occupancy	physical	physical	Length (m) of vertical drop
rope_dimE_m	Float	Min.: -15.24 1st Qu.: 0 Median: 0 Mean: 0.357 3rd Qu.: 0 Max.: 15.24	inspection	observation/ occupancy	physical	physical	Lateral distance (m) to landing point

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
rope_run_m	Float	Min.: 9.144 1st Qu.: 18.288 Median: 21.336 Mean: 23.259 3rd Qu.: 30.48 Max.: 39.624	inspection	observation/ occupancy	physical	physical	Total rope distance (m) from cliff start to landing
sd_TAXN	Float	Min.: 0.417 1st Qu.: 1.434 Median: 2.275 Mean: 2.747 3rd Qu.: 3.694 Max.: 7.314	inspection	observation/ occupancy	environmental	environmental	SD of daily temp (C°) in 4-day window around inspection (NOAA's GHCN-Daily)
veg_count_total	Integer	Min.: 3 1st Qu.: 6 Median: 6 Mean: 7.88 3rd Qu.: 9 Max.: 21	site	observation/ occupancy	environmental	environmental	Count of sqm areas with veg. inspection

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_max_leafPct_m2	Float	Min.: 0 1st Qu.: 5 Median: 10 Mean: 11.641 3rd Qu.: 15 Max.: 40	site	observation/ occupancy	environmental	environmental	Max % of sqm area covered by leaves (vis. est.)
veg_max_lichPct_m2	Float	Min.: 20 1st Qu.: 60 Median: 70 Mean: 70.908 3rd Qu.: 90 Max.: 95	site	observation/ occupancy	environmental	environmental	Max % of sqm area covered by lichen (vis. est.)
veg_max_mossPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 5 Mean: 13.577 3rd Qu.: 15 Max.: 95	site	observation/ occupancy	environmental	environmental	Max % of sqm area covered by moss (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_max_totalPct	Float	Min.: 20 1st Qu.: 70 Median: 80 Mean: 77.704 3rd Qu.: 90 Max.: 100	site	observation/ occupancy	environmental	environmental	Max % of sqm area covered by veg. (vis. est.)
veg_mean_leafPct_m2	Float	Min.: 0 1st Qu.: 0.833 Median: 2.333 Mean: 2.929 3rd Qu.: 4.167 Max.: 14.444	site	observation/ occupancy	environmental	environmental	Mean % of sqm area covered by leaves (vis. est.)
veg_mean_lichPct_m2	Float	Min.: 7.778 1st Qu.: 28.333 Median: 41.25 Mean: 39.669 3rd Qu.: 49.167 Max.: 68.333	site	observation/ occupancy	environmental	environmental	Mean % of sqm area covered by lichen (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_mean_mossPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 1.111 Mean: 4.263 3rd Qu.: 4 Max.: 42.5	site	observation/ occupancy	environmental	environmental	Mean % of sqm area covered by moss (vis. est.)
veg_mean_totalPct	Float	Min.: 8.333 1st Qu.: 31.146 Median: 48.819 Mean: 46.72 3rd Qu.: 62.292 Max.: 81.667	site	observation/ occupancy	environmental	environmental	Mean % of sqm area covered by veg. (vis. est.)
veg_median_leafPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 0 Mean: 1.278 3rd Qu.: 2.25 Max.: 10	site	observation/ occupancy	environmental	environmental	Median % of sqm area covered by leaves (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_median_lichPct_m2	Float	Min.: 0 1st Qu.: 24.25 Median: 40 Mean: 38.799 3rd Qu.: 53.75 Max.: 77.5	site	observation/ occupancy	environmental	environmental	Median % of sqm area covered by lichen (vis. est.)
veg_median_mossPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 0 Mean: 2.271 3rd Qu.: 0 Max.: 30	site	observation/ occupancy	environmental	environmental	Median % of sqm area covered by moss (vis. est.)
veg_median_totalPct	Float	Min.: 5 1st Qu.: 29.25 Median: 50 Mean: 46.496 3rd Qu.: 60 Max.: 90	site	observation/ occupancy	environmental	environmental	Median % of sqm area covered by veg. (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_min_lichPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 5 Mean: 9.528 3rd Qu.: 17.75 Max.: 40	site	observation/ occupancy	environmental	environmental	Min % of sqm area covered by lichen (vis. est.)
veg_min_totalPct	Float	Min.: 0 1st Qu.: 0 Median: 5 Mean: 13.648 3rd Qu.: 27.5 Max.: 60	site	observation/ occupancy	environmental	environmental	Min % of sqm area covered by veg. (vis. est.)
veg_sd_leafPct_m2	Float	Min.: 0 1st Qu.: 2.041 Median: 4.082 Mean: 4.517 3rd Qu.: 5.823 Max.: 14.832	site	observation/ occupancy	environmental	environmental	SD % of sqm area covered by leaves (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
veg_sd_lichPct_m2	Float	Min.: 5.774 1st Qu.: 19.408 Median: 24.833 Mean: 23.527 3rd Qu.: 28.723 Max.: 44.814	site	observation/ occupancy	environmental	environmental	SD % of sqm area covered by lichen (vis. est.)
veg_sd_mossPct_m2	Float	Min.: 0 1st Qu.: 0 Median: 2.887 Mean: 5.101 3rd Qu.: 7.407 Max.: 33.429	site	observation/ occupancy	environmental	environmental	SD % of sqm area covered by moss (vis. est.)
veg_sd_totalPct	Float	Min.: 7.36 1st Qu.: 20.493 Median: 25.166 Mean: 24.388 3rd Qu.: 28.431 Max.: 46.556	site	observation/ occupancy	environmental	environmental	SD % of sqm area covered by veg. (vis. est.)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
wall_area_m2	Float	Min.: 357.02 1st Qu.: 1252.165 Median: 1848.321 Mean: 1888.451 3rd Qu.: 2578.888 Max.: 3695.069	site	observation/ occupancy	physical	physical	Area (sqm) of the wall
wall_aspect	Float	Min.: 10 1st Qu.: 155 Median: 232 Mean: 208.898 3rd Qu.: 276 Max.: 324	inspection	observation/ occupancy	physical	physical	Wall direction
wall_avgDifficultyRating	Float	Min.: 18.979 1st Qu.: 20.222 Median: 20.997 Mean: 20.84 3rd Qu.: 21.314 Max.: 22.921 NA's: 18	site	observation/ occupancy	descriptive	descriptive	Avg. climb difficulty (Copperhead's YDS)
wall_cliffAngleCategory	Factor w/ 3 levels	Overhang: 9 Vertical: 74 Slab: 59	inspection	observation/ occupancy	physical	physical	Field crew's general shape description of wall to landing

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
wall_dip_degrees	Float	Min.: 63.435 1st Qu.: 90 Median: 90 Mean: 89.46 3rd Qu.: 90 Max.: 125.538	inspection	observation/ occupancy	physical	physical	Wall slope in degrees (>90 = Overhung)
wall_height_m	Float	Min.: 9.091 1st Qu.: 18.288 Median: 21.336 Mean: 23.179 3rd Qu.: 30.48 Max.: 39.624	inspection	observation/ occupancy	physical	physical	Adjusted vertical distance (m) from cliff edge to wall base
wall_reviewCount	Float	Min.: 0 1st Qu.: 4.75 Median: 59 Mean: 270.852 3rd Qu.: 295 Max.: 2367	site	observation/ occupancy	descriptive	descriptive	Count of wall reviews (MountainProject.com, Jan 24, 2022)

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
wall_routeCount	Float	Min.: 0 1st Qu.: 9.25 Median: 19.5 Mean: 18.296 3rd Qu.: 23.75 Max.: 52	site	observation/ occupancy	descriptive	descriptive	Count of climbing routes on wall (Williams 2019, MountainProject.com, Jan 24, 2022)
wall_routeLength_m	Float	Min.: 0 1st Qu.: 16.679 Median: 19.724 Mean: 18.281 3rd Qu.: 23.308 Max.: 27.867	site	observation/ occupancy	descriptive	descriptive	Mean route length (m) on wall
wall_routeQualityScore	Float	Min.: 0 1st Qu.: 0.832 Median: 1.252 Mean: 1.242 3rd Qu.: 1.518 Max.: 2.439 NA's: 18	site	observation/ occupancy	descriptive	descriptive	Copperhead's score (NA, 0-4), blending Williams 2019 and MountainProject.com, Jan 24, 2022

Table 17 (continued). Covariate Summary – Description of the 88 covariates used in model building. “Record level” describes whether the covariate was recorded once for the site or at each inspection. “Hierarchy Level/Process” describes whether the covariate was used at the site or observation hierarchical level of the model and if it impacted either the occupancy or detection process. The “Ecological Factor” is grouping the variable was initially assigned to by the subject matter expert. The “Model Factor” is the grouping that the variable was ultimately assigned to during modeling because detection covariates were assigned to a single variable group in this project.

Covariate	Class	Summary	Record Level	Hierarchy Level/Process	Ecological Factor	Model Factor	Description
wall_useCategory	Factor w/ 3 levels	Unclimbed: 18 Low: 65 High: 59	site	observation/ occupancy	descriptive	descriptive	"High use" wall boolean (wall_routeQualityScore & park's median score)
wall_width_m	Float	Min.: 29.489 1st Qu.: 59.959 Median: 78.497 Mean: 80.834 3rd Qu.: 100.485 Max.: 136.101	inspection	observation/ occupancy	physical	physical	Vis. est. of wall width (m)

Appendix C – Maps

Figures 2–11 show the locations of the various sampling sites used in the study.

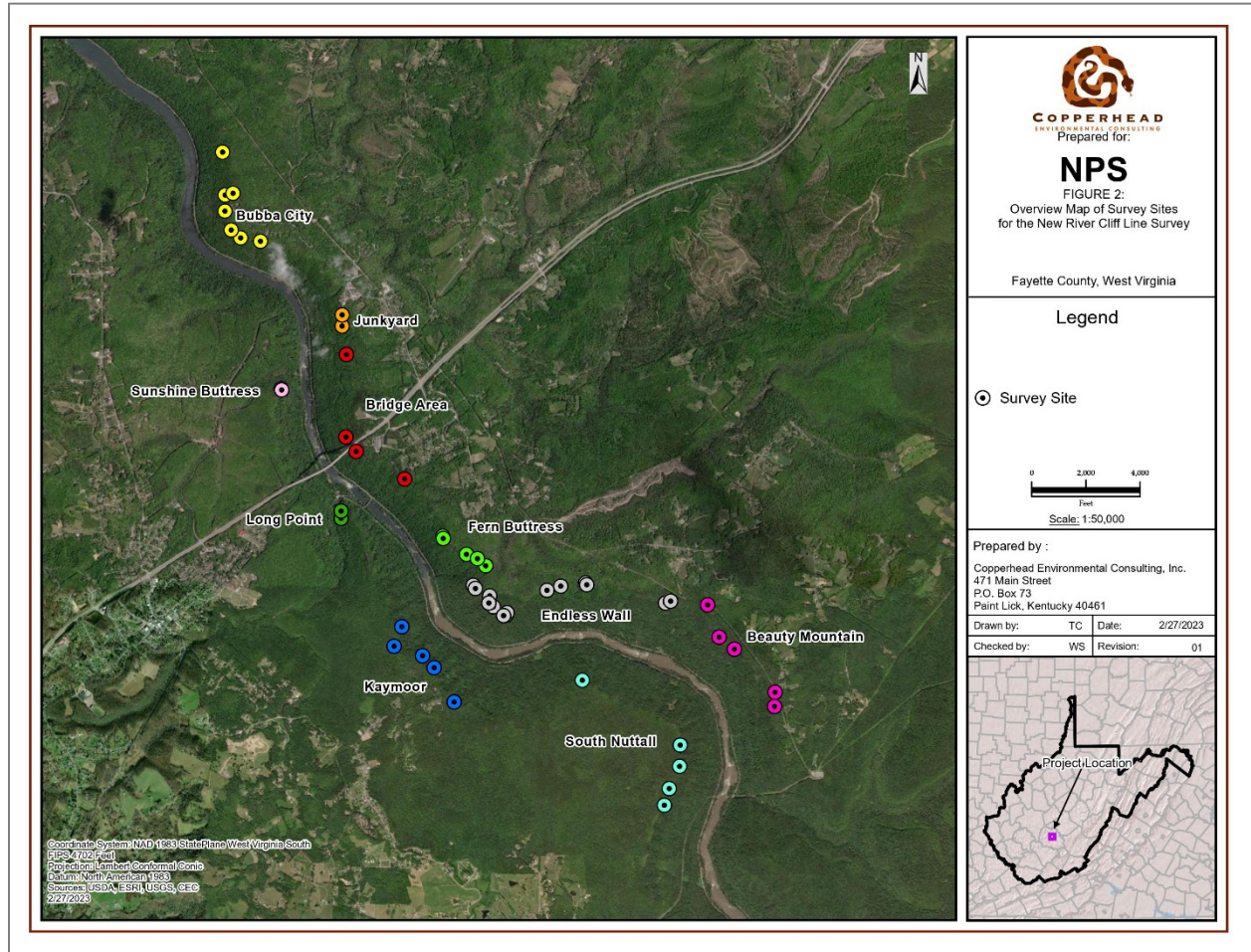


Figure 2. Overview Map of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

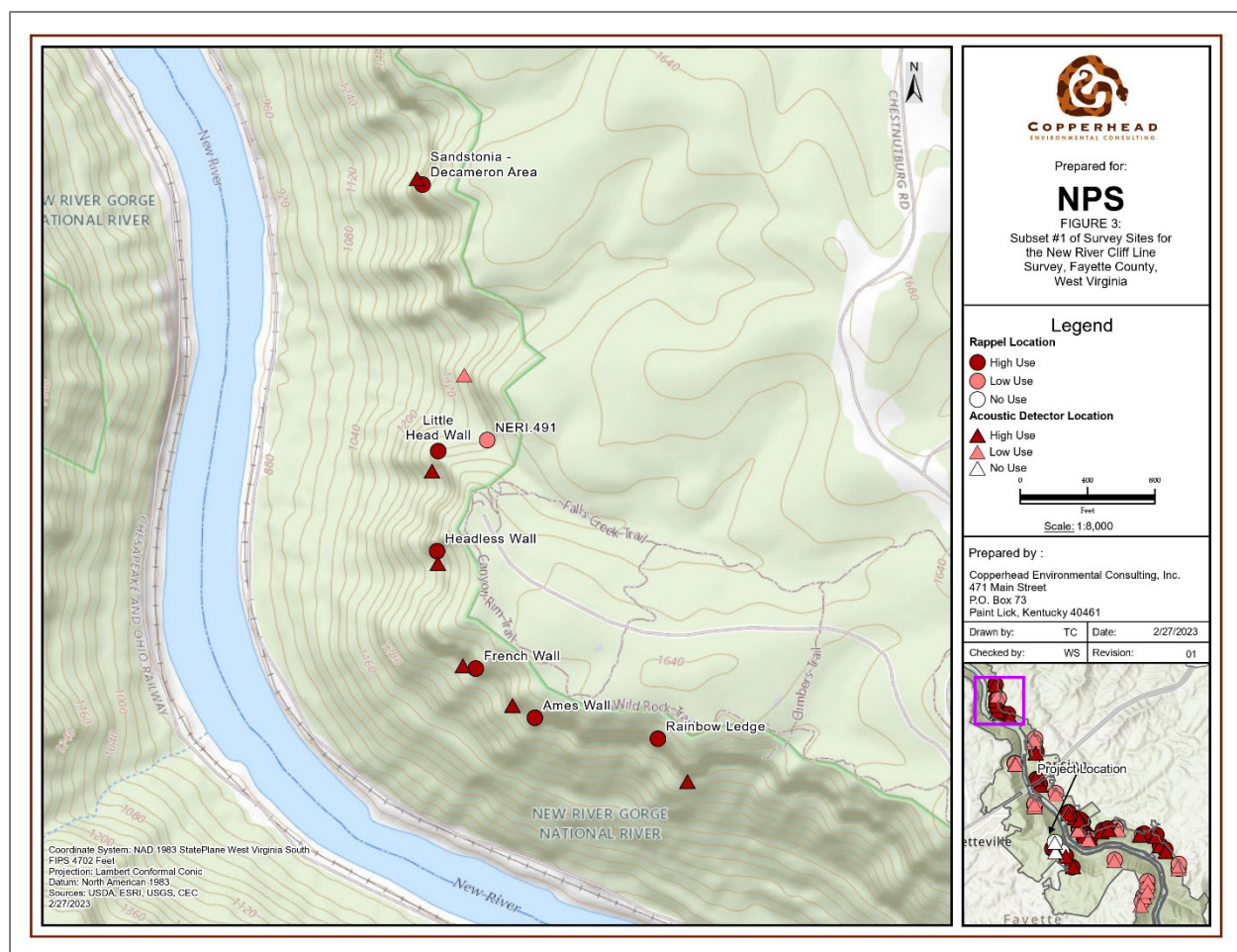


Figure 3. Subset #1 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

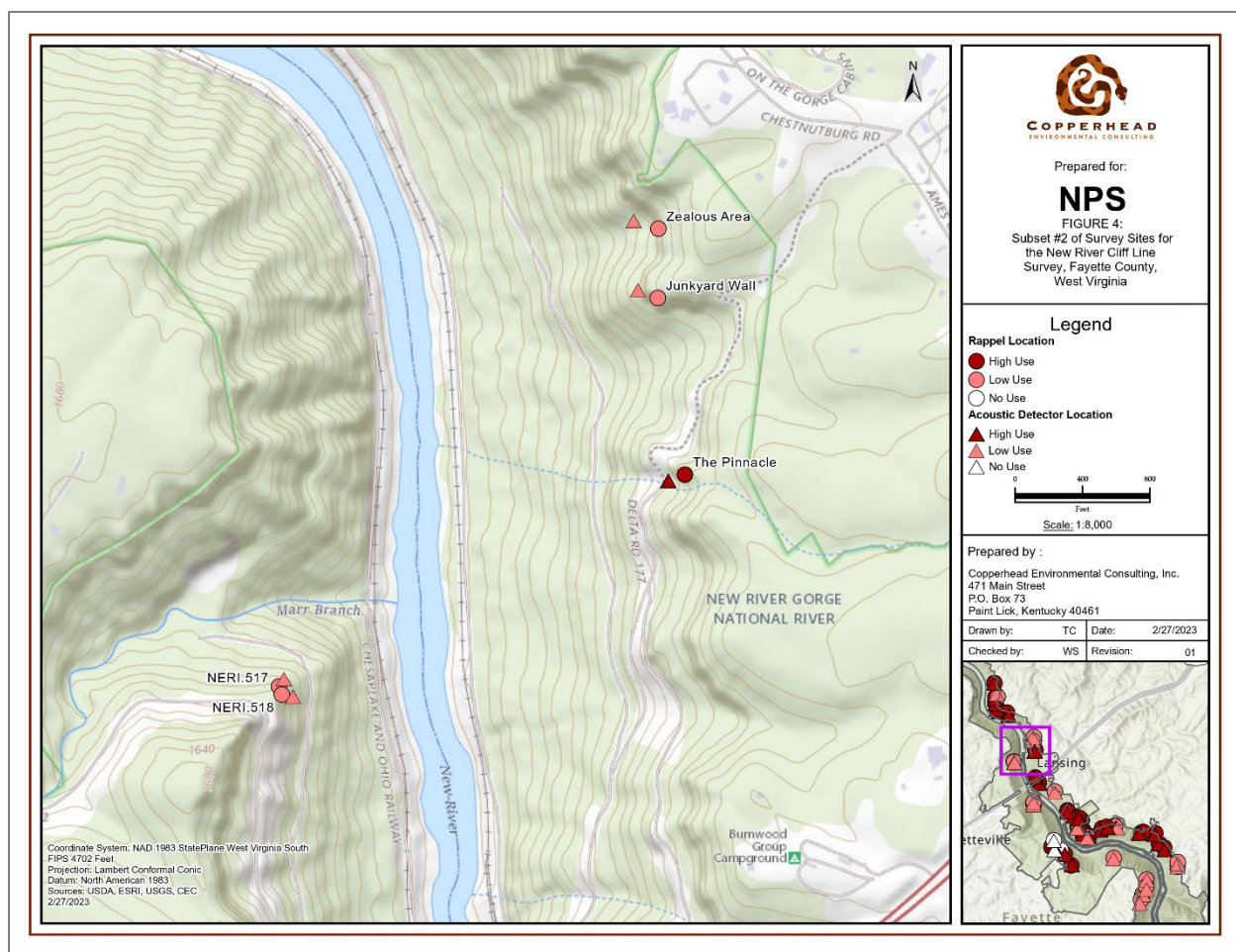


Figure 4. Subset #2 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

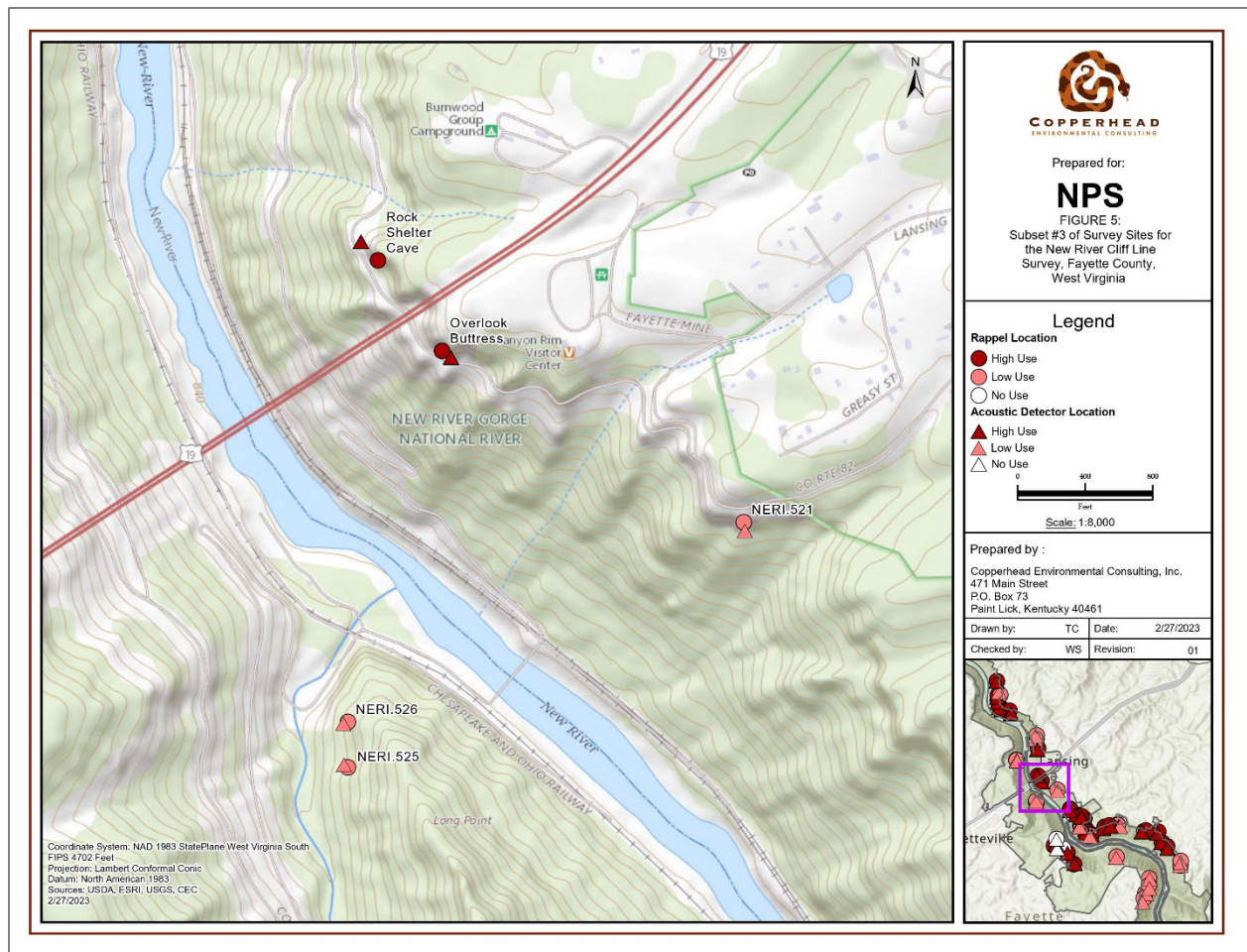


Figure 5. Subset #3 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

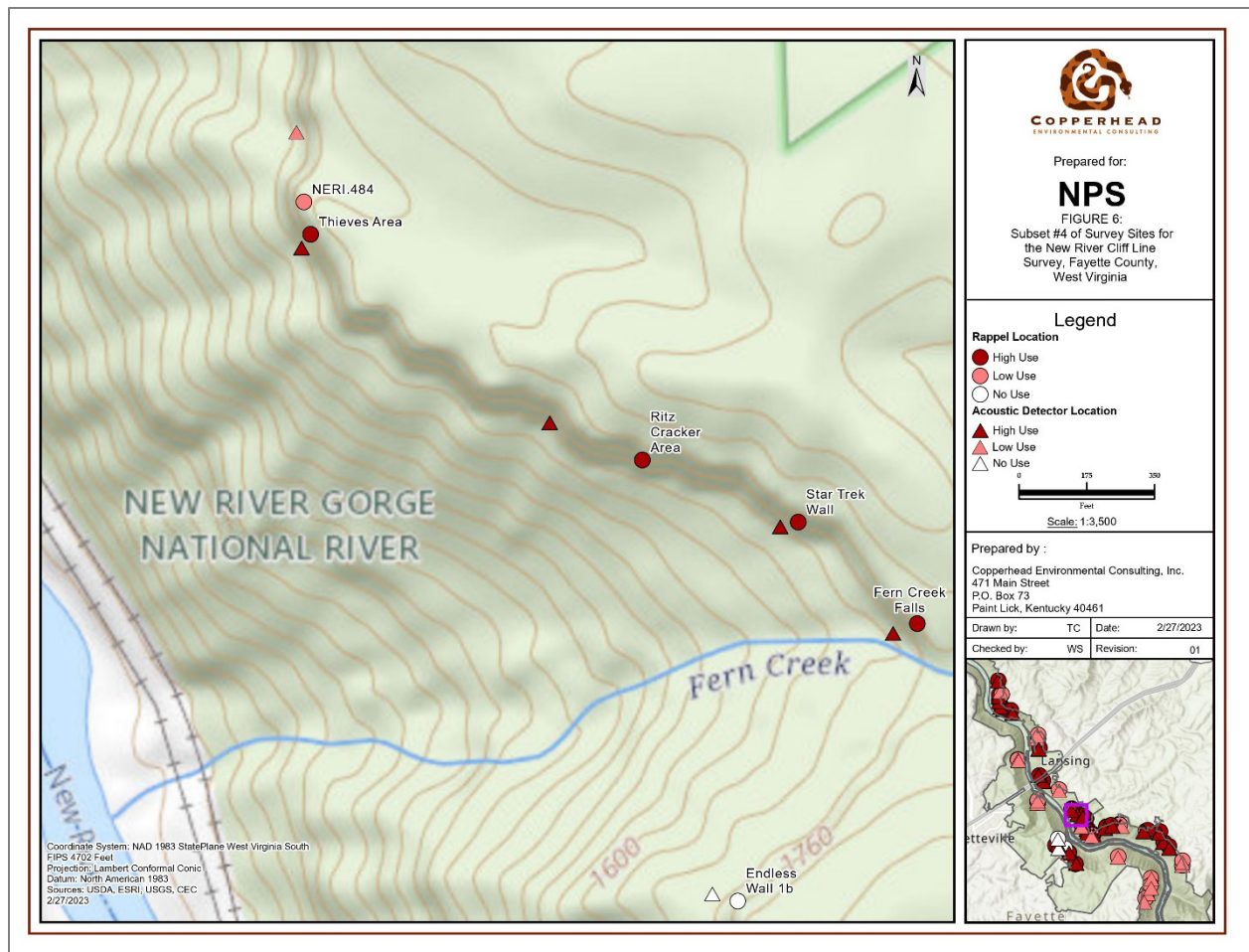


Figure 6. Subset #4 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

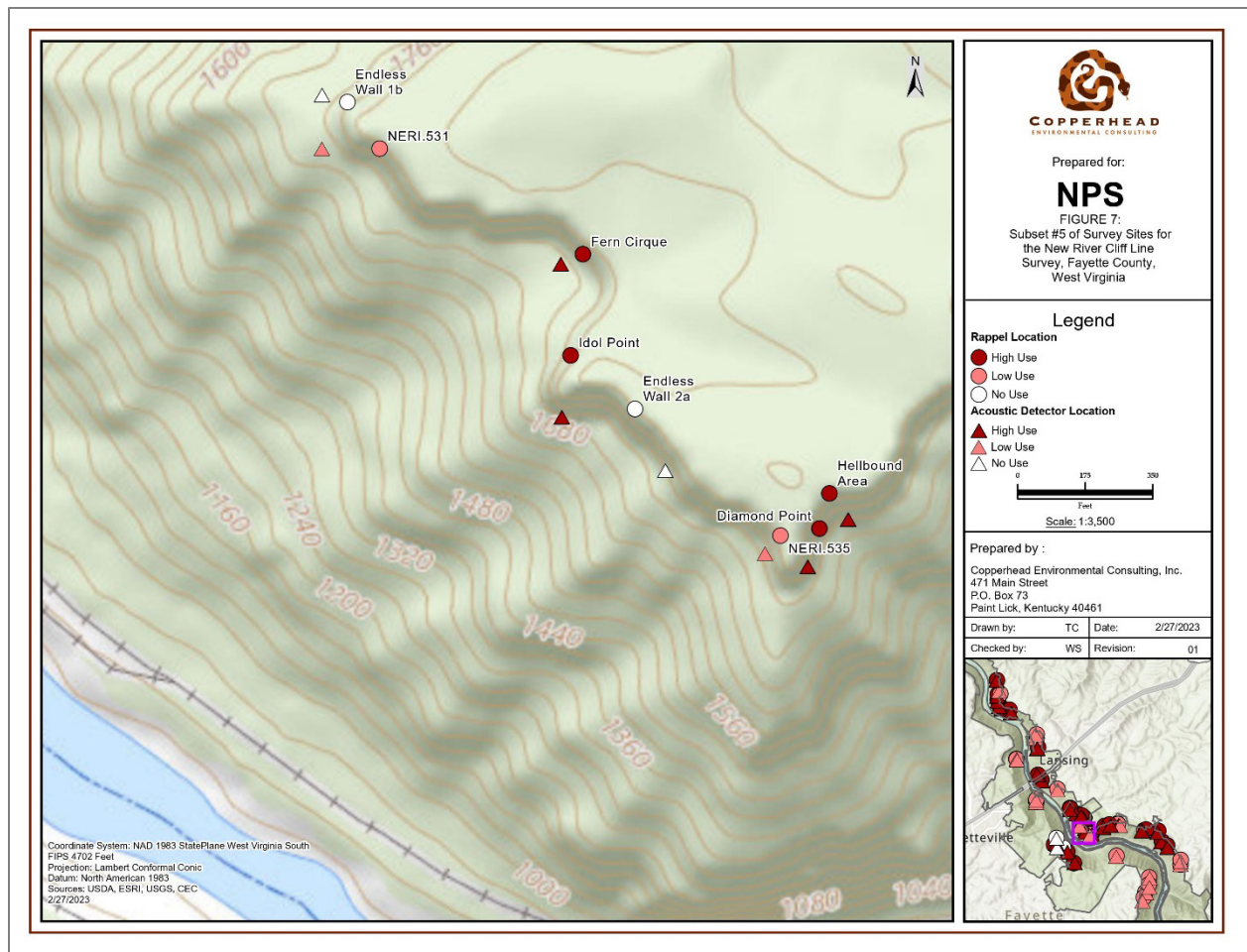


Figure 7. Subset #5 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

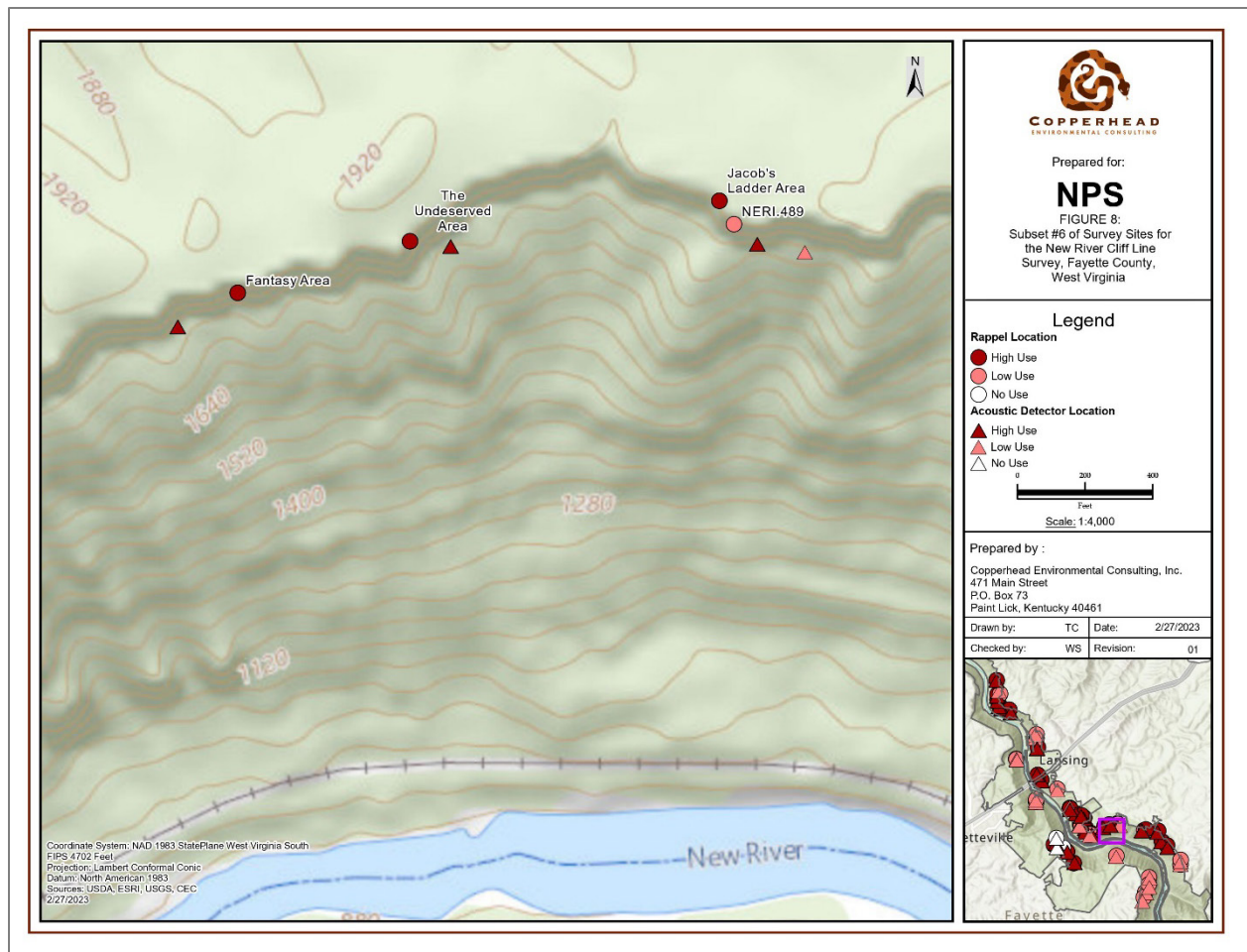


Figure 8. Subset #6 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

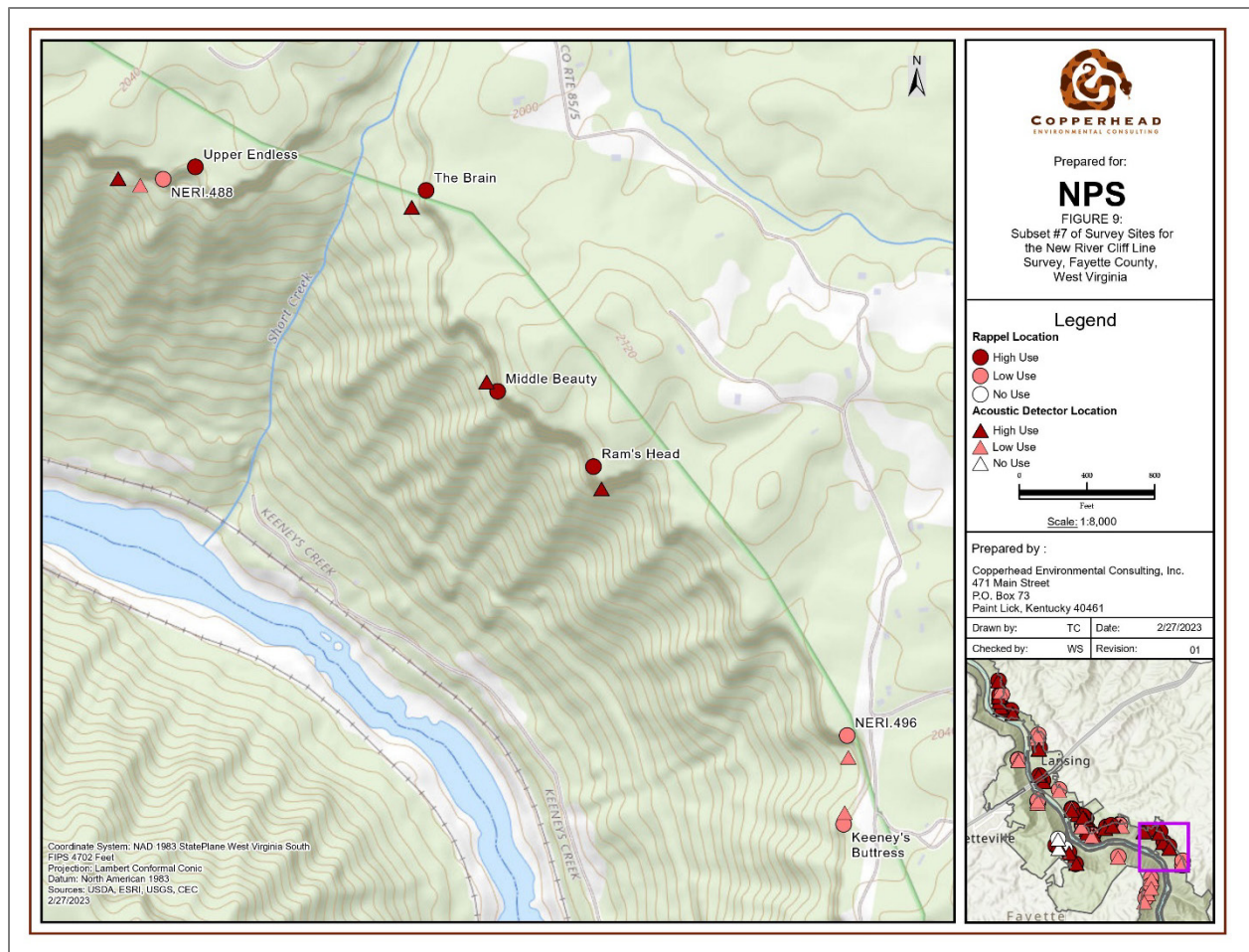


Figure 9. Subset #7 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

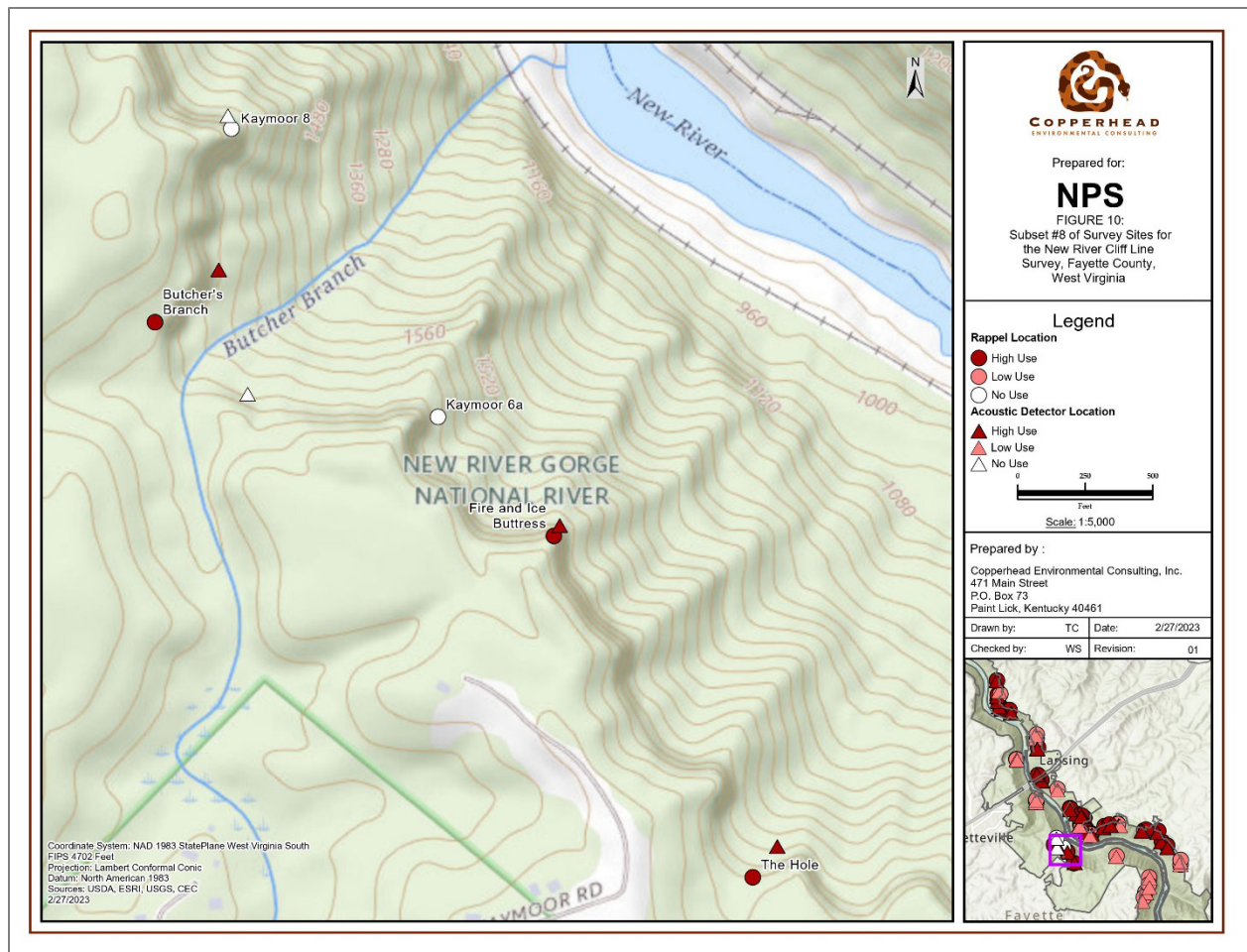


Figure 10. Subset #8 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

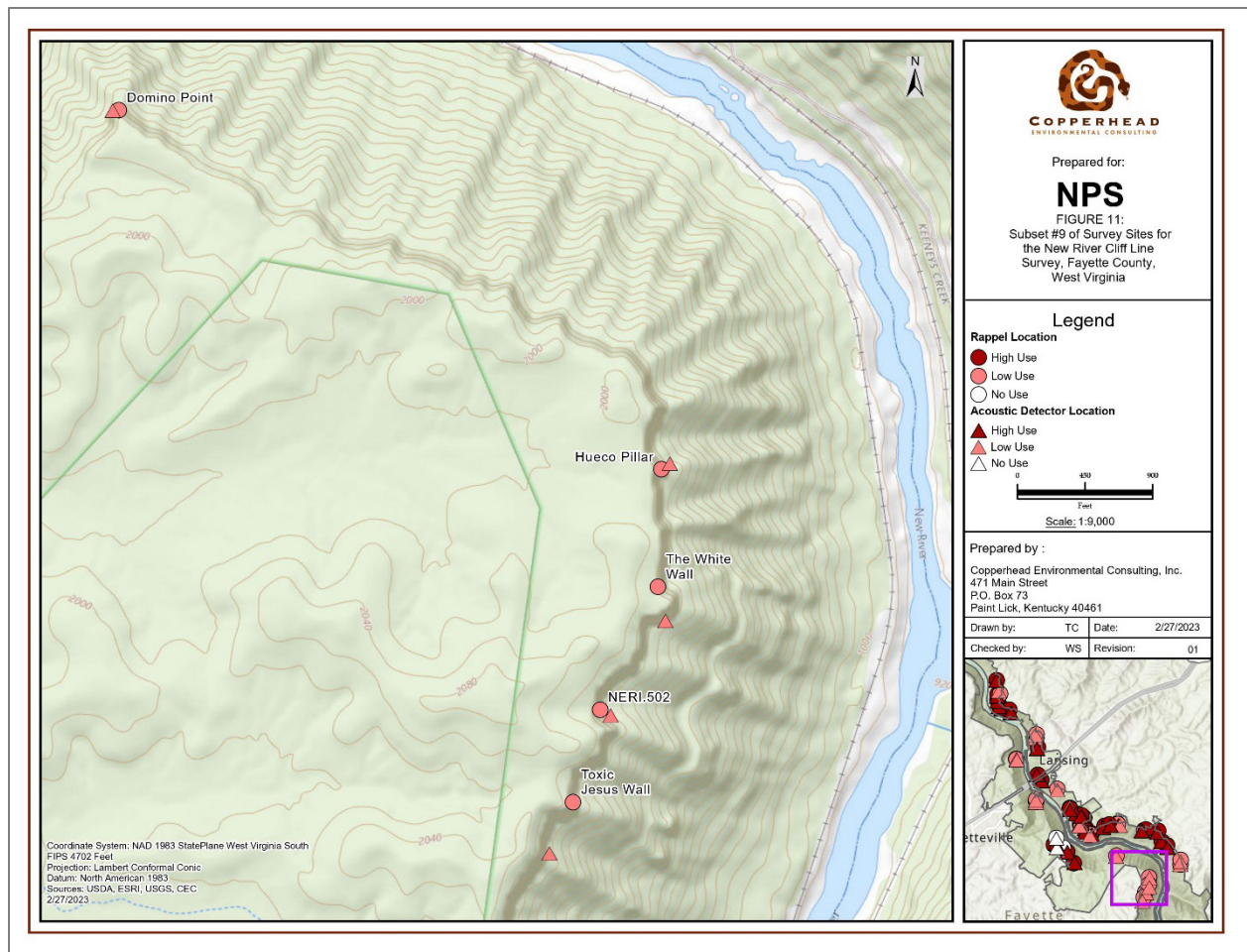


Figure 11. Subset #9 of Survey Sites for the New River Cliff Line Survey, Fayette County, West Virginia.

Appendix D – Kaleidoscope Pro Analysis Settings

version=5.4.7

classifier=classifiers-Bats_of_North_America_5.4.0

[analysis]

freqmin0=8

frequmax0=120

durmin0=2

durmax0=500

maxgap0=500

mincalls=2

filterzc=1

removedc=0

enable=1

divratio=8

Appendix E – Kaleidoscope Pro Results

Table 18 shows the Kaleidoscope Pro results for each species at every site.

Table 18. Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Ames Wall	5/22/2022	1 0.12054	1 1.00000	–	3 0.07682	10 0.00004	–	–	2 0.00592	–	–	–
	6/18/2022	–	1 0.17138	–	–	–	–	1 0.12421	–	–	–	–
	7/15/2022	2 0.76243	51 0.00000	16 0.00000	2 1.00000	7 1.00000	29 0.00000	3 0.95274	14 0.00000	6 0.97901	4 1.00000	2 1.00000
Butcher's Branch	5/19/2022	126 0.00000	242 0.00000	1 0.16372	3 1.00000	1 1.00000	48 0.00000	–	11 0.00531	6 1.00000	–	–
	6/19/2022	1 0.0723	1 0.17212	–	–	–	3 0.01591	–	1 0.66599	4 0.03318	–	–
	7/18/2022	26 0.00000	82 0.00000	69 0.00000	10 0.52163	11 1.00000	39 0.00000	36 0.00000	228 0.00000	5 1.00000	–	2 1.00000
Diamond Point	5/24/2022	5 0.00266	23 0.00057	–	3 1.00000	52 0.00000	7 0.00000	1 0.34839	3 0.10198	2 0.88543	1 0.45092	–
	6/17/2022	53 0.00000	229 0.00000	19 0.00000	21 0.95830	73 0.13572	52 0.00000	56 0.00000	46 0.00000	83 0.00000	10 1.00000	27 0.00000
	7/13/2022	–	8 0.06259	3 0.3359	8 0.00056	15 0.00034	45 0.00000	22 0.00000	65 0.00000	7 1.00000	2 1.00000	3 0.38959
Domino Point	5/17/2022	27 0.00000	161 0.00000	1 0.41205	3 1.00000	30 1.00000	–	2 0.23483	8 0.00000	–	–	1 0.55890
	6/20/2022	23 0.00000	39 0.00000	1 0.17710	8 0.14282	16 0.34465	1 0.29899	–	3 0.00183	–	–	–

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Domino Point (continued)	7/18/2022	26 0.00000	155 0.00000	7 0.00692	9 1	30 1	38 0	16 0	78 0	11 1	9 0.46042	1 1
Endless Wall 1b	5/21/2022	46 0.00000	49 0.00000	–	14 0.03282	62 0.00000	8 0.00000	2 0.21699	16 0.00000	2 1.00000	–	–
	6/16/2022	9 0.00000	12 0.28949	8 0.00037	10 0.00439	43 0.00000	40 0.00000	9 0.03398	48 0.00000	19 0.0605	8 0.84537	2 1.00000
	7/14/2022	52 0.00000	75 0.00000	5 0.00016	5 1.00000	8 1.00000	32 0.00000	2 0.99841	76 0.00000	9 1.00000	–	2 0.72757
Endless Wall 2a	5/24/2022	26 0.00000	39 0.00000	1 0.13086	14 0.00679	52 0.00000	15 0.00000	–	9 0.00006	5 0.60187	–	–
	6/17/2022	12 0.00000	23 0.00000	–	18 0.00000	20 0.01518	6 0.00000	–	3 0.05812	2 0.79626	–	–
	7/13/2022	8 0.00023	47 0.00000	3 1	8 0.31300	23 0.04223	46 0	81 0.00000	42 0.00000	55 0	5 0.67567	13 0.00002
Fantasy	5/24/2022	194 0.00000	137 0.00000	8 1	35 0.00000	4 1.00000	5 0.06484	96 0.00000	8 1.00000	19 0.69274	–	–
	6/17/2022	12 0.00000	26 0.00000	–	4 0.53643	–	6 0.00003	1 0.51510	4 0.01826	3 0.47097	–	–
	7/13/2022	–	4 0.00458	5 0.04105	1 0.66680	1 1.00000	13 0.00071	16 0.00001	43 0.00000	37 0.00000	3 1.00000	–
Fern Cirque	5/21/2022	33 0.00000	61 0.00000	29 0.00000	4 1.00000	80 0.00000	9 0.00000	2 1.00000	16 0.00000	4 0.83265	34 0.01909	–
	6/16/2022	23 0.00000	31 0.00000	1 0.65348	1 1.00000	9 0.86695	31 0.00000	4 0.00905	9 0.00651	3 1.00000	1 0.94642	–
	7/14/2022	8 0.00000	30 0.00000	1 0.96781	3 0.94627	3 1.00000	28 0.00000	10 0.00006	6 0.40411	19 0.00068	4 0.26799	2 0.40153

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Fern Creek Falls	5/21/2022	4 0.00733	19 0.00000	2 1.00000	–	19 0.00009	8 0.73468	38 0.00000	3 1.00000	99 0.00000	–	2 0.42169
	6/16/2022	7 0.00000	21 0.00000	2 0.99271	–	–	15 0.00002	21 0.00000	8 0.35181	51 0.00000	–	–
	7/16/2022	2 0.14724	14 0.00000	3 0.03812	–	3 1.00000	20 0.00000	5 0.01096	3 0.74721	6 0.6539	1 1.00000	1 0.9799
Fire and Ice	5/19/2022	86 0.00000	516 0.00000	15 0.00000	6 1.00000	64 1.00000	31 0.00000	21 0.00000	76 0.00000	2 1.00000	–	4 0.89347
	6/19/2022	1 0.02678	–	5 0.02884	–	1 0.21976	12 0.00000	11 0.00000	–	12 0.00510	–	–
	7/18/2022	45 0.00000	372 0.00000	2 0.97963	15 1.00000	25 1.00000	235 0.00000	6 0.01078	54 0.00000	26 1.00000	–	–
French Wall	5/22/2022	46 0.00000	76 0.00000	–	–	9 1	–	1 0.67844	11 0	–	–	–
	6/18/2022	–	3 0.02542	1 0.17606	1 0.57111	1 0.99029	7 0.00000	–	–	1 1.00000	–	–
	7/15/2022	49 0.00000	64 0.00000	14 0.00000	12 0.05743	13 1.00000	108 0.00000	17 0.00002	124 0.00000	29 0.81912	–	2 1.00000
Headless Wall	5/24/2022	5 0.00001	6 0.29656	2 0.12832	3 0.38109	17 0.00000	36 0.00000	4 0.02895	11 0.00109	2 1.00000	1 1.00000	1 0.91062
	6/18/2022	–	–	–	–	1 0.21650	4 0.00002	–	1 0.55400	–	1 0.39319	–
	7/15/2022	4 0.07013	37 0.00000	20 0.00595	6 0.58029	25 0.00134	58 0.00000	3 1.00000	6 0.60558	5 1.00000	94 0.00000	11 0.90655
Hellbound	5/24/2022	45 0.00000	54 0.00000	–	15 0.00390	31 0.00652	135 0.00000	5 0.05948	26 0.00015	33 0.13078	–	–

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Hellbound (continued)	6/17/2022	46 0.00000	390 0.00000	3 0.45420	143 0.00000	279 0.00000	64 0.00000	11 0.00009	8 0.63889	25 0.00381	12 0.00977	1 1.00000
	7/13/2022	5 0.01962	40 0.00000	11 0.00012	2 1.00000	75 0.00000	63 0.00000	16 0.01014	116 0.00000	51 0.00000	15 0.41423	6 0.73337
Hueco Pillar	5/17/2022	7 0.00000	14 0.00000	2 0.09031	1 1.00000	3 1.00000	24 0.00000	2 0.45081	22 0.00000	7 0.75695	–	–
	6/20/2022	–	14 0.00000	4 0.09309	1 1.00000	–	22 0.00000	12 0.00001	27 0.00000	7 0.98768	5 0.81304	4 0.35713
	7/18/2022	7 0.00366	68 0.00000	3 1.00000	–	1 1.00000	1171 0.00000	83 0.00000	697 0.00000	396 0.00000	4 1.00000	57 0.00000
Idol Point	5/21/2022	160 0.00000	477 0.00000	11 0.00041	9 1.00000	98 1.00000	26 0.00000	23 0.00000	43 0.00000	33 0.00000	14 0.33939	2 1.00000
	6/16/2022	55 0.00000	350 0.00000	18 0.00001	65 0.00000	60 1.00000	59 0.00000	66 0.00000	44 0.00000	74 0.00000	18 0.93853	7 1.00000
	7/14/2022	12 1.00000	550 0.00000	13 0.00004	36 1.00000	108 1.00000	126 0.00000	44 0.00000	149 0.00000	72 0.00000	10 1.00000	8 0.55540
Jacob's Ladder	5/20/2022	79 0.00000	103 0.00000	–	6 1.00000	9 1.00000	25 0.00000	–	23 0.00000	6 0.96967	–	–
	6/17/2022	9 0.00007	55 0.00000	–	4 1.00000	9 1.00000	15 0.00000	1 1.00000	31 0.00000	20 0.00000	–	–
	7/13/2022	1 0.39978	7 0.00010	7 0.04555	1 0.91337	3 0.67944	171 0.00000	50 0.00000	268 0.00000	62 0.17806	11 0.17304	2 1.00000
Junkyard	6/1/2022	88 0.00000	224 0.00000	1 0.29493	64 0.00000	54 1.00000	4 0.33064	–	46 0.00000	–	–	4 0.00660
	6/14/2022	4 0.01664	23 0.00000	2 0.06314	10 0.00186	15 0.07631	–	–	6 0.00000	–	1 1.00000	1 0.88236

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Junkyard (continued)	7/12/2022	–	–	–	4 0.00003	–	–	–	–	–	–	–
Kaymoor 6a	5/19/2022	6 0.00009	15 1.00000	2 0.09251	17 0.00122	110 0.00000	8 0.00256	2 0.74207	45 0.00000	1 1.00000	1 1.00000	–
	6/19/2022	–	4 0.00215	–	2 0.17987	–	1 0.21865		2 0.02104	–	–	–
	7/18/2022	3 0.17302	31 0.00000	26 0.00000	5 0.68551	24 0.00039	161 0.00000	88 0.00000	164 0.00000	13 1.00000	8 1.00000	1 1.00000
Kaymoor 8	5/19/2022	55 0.00000	153 0.00000	9 0.00902	12 1.00000	143 0.00000	14 0.02863	35 0.00000	27 0.00000	92 0.00000	1 1.00000	13 0.00009
	6/19/2022	–	–	2 0.42863	–	–	7 0.33968	10 0.02282	29 0.00000	50 0.00000	–	1 0.79866
	7/18/2022	47 0.00000	161 0.00000	10 0.00371	12 1.00000	30 1.00000	75 0.00000	35 0.00000	42 0.00000	8 1.00000	1 1.00000	13 0.00018
Keeney's Buttress	5/19/2022	9 0.04354	134 0.00000	4 0.00692	11 1.00000	261 0.00000	–	2 0.8022	3 0.01026	–	3 1.00000	3 0.54896
	6/15/2022	19 0.00003	211 0.00000	12 0.00029	64 0.00000	96 0.00067	–	3 1.00000	2 0.08113	–	27 0.00452	8 0.48327
	7/16/2022	6 0.71723	172 0.00000	2 0.08236	33 0.00029	41 1.00000	–	–	1 0.14715	1 0.3318	1 1.00000	4 0.03973
Little Head	5/22/2022	7 0.00023	34 0.00000	1 0.17709	1 1.00000	26 0.00010	5 0.00022	–	8 0.00000	–	–	–
	6/18/2022	1 0.15588	2 0.12628	2 0.03136	1 0.46561	1 0.93475	74 0.00000	–	11 0.04808	–	–	–
	7/15/2022	5 0.13201	69 0.00000	67 0.00000	5 1.00000	74 0.00000	331 0.00000	35 0.00000	39 0.01168	4 1.00000	–	5 1.00000

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Middle Beauty	5/19/2022	98 0.00000	120 0.00000	–	9 1.00000	57 0.00025	36 0.00000	1 0.99932	41 0.00000	6 1.00000	–	–
	6/21/2022	5 0.00586	33 0.00000	2 0.12900	28 0.00000	5 1.00000	21 0.00000	3 0.67032	29 0.00000	15 0.00581	1 1.00000	6 0.00325
	7/16/2022	25 0.00000	119 0.00000	14 0.00000	56 0.00000	282 0.00000	94 0.00000	9 0.12762	81 0.00000	11 1.00000	13 0.69860	1 1.00000
NERI.484	5/24/2022	23 0.00000	126 0.00000	4 0.02153	1 1.00000	11 1.00000	3 0.68003	6 0.04413	28 0.00000	15 0.00003	–	–
	6/16/2022	20 0.00000	26 0.00000	–	–	4 1.00000	14 0.00000	1 0.90454	15 0.00000	7 0.20086	–	1 0.17736
	7/14/2022	81 0.00000	589 0.00000	–	3 1.00000	12 1.00000	8 0.00000	1 1.00000	7 0.00005	3 0.80832	1 0.34639	1 0.33938
NERI.488	5/20/2022	35 0.00000	69 0.00000	6 0.00133	10 0.37691	26 0.23439	11 0.00000	8 0.00698	17 0.00000	16 0.00013	1 1.00000	–
	6/14/2022	5 0.04202	49 0.00000	3 0.00922	23 0.00000	58 0.00000	19 0.00000	2 0.94530	7 0.02292	19 0.00000	1 1.00000	1 0.99681
	7/12/2022	–	–	–	–	–	–	–	–	–	–	–
NERI.489	5/20/2022	80 0.00000	123 0.00000	3 0.53736	24 0.01227	71 0.00000	14 0.00073	26 0.00000	27 0.00000	54 0.00000	1 1.00000	–
	6/17/2022	13 0.00000	39 0.00000	10 0.00552	8 0.26601	31 0.00004	31 0.00000	52 0.00000	43 0.00000	123 0.00000	4 1.00000	1 1.00000
	7/13/2022	8 0.00038	48 0.00000	12 0.00077	15 0.00865	54 0.00000	58 0.00000	64 0.00000	106 0.00000	206 0.00000	3 1.00000	2 1.00000
NERI.491	6/1/2022	3 0.00022	1 1.00000	1 0.17738	3 0.13	13 0.00000	–	–	4 0.00005	–	–	–

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
NERI.491 (continued)	6/18/2022	–	–	–	1 0.07915	–	1 0.06113	–	–	–	–	–
	7/15/2022	8 0.00000	9 0.00056	–	16 0.00000	4 1.00000	–	–	–	–	–	–
NERI.496	5/19/2022	6 0.00000	7 0.00147	1 0.28735	1 0.95394	5 0.22674	–	1 0.43097	1 0.29185	–	–	–
	6/15/2022	14 0.00000	11 0.00268	11 0.00000	3 0.56247	16 0.00007	3 0.01345	3 0.83025	6 0.00025	1 1.00000	–	12 0.00046
	7/16/2022	–	5 0.00014	–	–	–	2 0.12332	2 0.03636	7 0.00000	–	–	–
NERI.502	5/17/2022	101 0.00000	95 0.00000	73 0.00000	6 1.00000	207 0.00000	9 0.00025	14 1.00000	3 1.00000	20 0.00000	40 1.00000	9 1.00000
	6/20/2022	9 0.00001	45 0.00000	37 0.00000	1 1.00000	6 1.00000	25 0.00000	40 0.00000	3 1.00000	79 0.00000	23 1.00000	5 1.00000
	7/18/2022	214 0.00000	142 0.00000	31 0.00158	13 0.90544	3 1.00000	38 0.00000	62 0.00000	12 0.73026	60 0.00000	138 0.00000	21 0.41853
NERI.517	5/31/2022	2 0.04570	6 0.00427	–	3 0.1161	4 0.51746	–	1 0.78163	5 0.00003	–	–	5 0.00015
	6/14/2022	1 0.98325	32 0.00000	1 0.77993	26 0.00000	45 0.00000	6 0.00000	4 0.06376	2 0.49156	1 1.00000	2 0.83369	10 0.00000
	7/11/2022	–	20 0.00008	–	15 0.00000	30 0.00000	107 0.00000	1 0.27807	12 0.17611	–	–	–
NERI.518	5/31/2022	3 0.00291	5 0.81395	–	9 0.00012	21 0.00000	1 0.06114	–	–	–	–	2 0.02625
	6/14/2022	–	34 0.00000	1 0.27731	26 0.00000	38 0.00000	1 0.06288	–	–	–	–	3 0.03092

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
NERI 518 (continued)	7/11/2022	3 0.07354	21 0.00000	4 0.00078	15 0.00000	21 0.00245	29 0.00000	1 0.94532	8 0.00588	–	–	1 0.98010
NERI.521	5/31/2022	6 0.00033	23 0.00000	1 0.17734	5 0.56533	30 0.00000	–	–	2 0.00740	–	–	–
	6/14/2022	3 0.57956	61 0.00000	1 0.17734	12 0.05045	18 0.91178	–	–	7 0.00000	–	–	–
	7/11/2022	5 0.00682	30 0.00000	4 0.00903	13 0.00013	13 0.58507	44 0.00000	5 0.00817	6 0.38172	2 1.00000	–	1 0.98304
NERI.525	6/1/2022	7 0.00001	20 0.00000	3 0.62314	4 0.34257	5 1.00000	29 0.00000	17 0.00000	2 1.00000	12 0.27303	6 0.23211	–
	6/14/2022	6 0.00000	12 0.00000	1 0.50297	2 0.68199	–	1 0.80325	2 0.39204	4 0.01022	6 0.00255	1 0.94913	–
	7/12/2022	–	1 0.17141	–	–	–	–	–	–	–	–	–
NERI.526	6/1/2022	5 0.00002	7 0.01438	2 0.04312	2 0.61817	9 0.00840	–	1 0.62893	–	–	–	–
	6/14/2022	1 0.77263	19 0.00000	–	4 0.30211	3 1.00000	1 0.36840	–	4 0.00012	–	–	–
	7/12/2022	–	–	–	–	–	–	–	–	–	–	–
NERI.531	5/21/2022	47 0.00000	124 0.00000	1 0.59919	7 1.00000	123 0.00000	1 0.27044	3 0.02306	1 0.69741	1 0.92524	–	–
	6/16/2022	15 0.00000	70 0.00000	17 0.00000	233 0.00000	121 0.00000	8 0.00012	13 0.00347	10 0.00056	11 0.01748	18 0.38073	1 1.00000
	7/14/2022	20 0.00000	32 0.00000	2 0.66388	9 0.05724	29 0.00002	14 0.00000	13 0.00007	19 0.00000	31 0.00000	7 0.12033	2 0.66953

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
NERI.535	5/24/2022	111 0.00000	234 0.00000	7 0.00023	9 1.00000	80 0.02295	11 0.00000	4 0.67488	13 0.00000	–	6 0.99554	3 0.95629
	6/17/2022	39 0.00000	298 0.00000	6 0.00021	18 1.00000	69 1.00000	4 0.00613	4 0.14753	9 0.00000	2 1.00000	2 1.00000	1 1.00000
	7/13/2022	7 0.00007	27 0.00000	18 0.00000	6 0.15201	8 0.96831	31 0.00000	10 0.13581	41 0.00000	6 1.00000	14 1.00000	7 0.95194
Overlook Buttrass	5/16/2022	4 0.00522	16 0.01995	1 0.19082	1 1.00000	42 0.00000	–	–	–	–	–	1 0.52864
	6/14/2022	4 0.12849	46 0.00000	15 0.35947	13 0.00810	28 0.00586	2 0.07416	1 1.00000	5 0.00008	–	89 0.00000	3 1.00000
	7/12/2022	–	18 0.00000	–	2 0.91529	3 1.00000	–	–	1 0.07916	–	1 0.39284	–
Rainbow Ledge	6/1/2022	20 0.00000	11 0.05065	–	14 0.00000	24 0.00000	–	1 0.47298	3 0.00396	–	1 0.52155	1 0.31005
	6/18/2022	–	–	1 0.17840	1 0.07916	–	–	–	–	–	–	–
	7/15/2022	3 0.36373	50 0.00000	3 0.00645	5 0.91584	7 1.00000	14 0.00000	1 0.94476	21 0.00000	–	–	–
Rams Head	5/19/2022	16 0.00003	156 0.00000	–	40 0.00001	128 0.00000	20 0.00000	4 0.03923	16 0.00000	12 0.01237	1 0.31859	–
	6/21/2022	10 0.27649	257 0.00000	10 0.00101	21 0.99987	27 1.00000	20 0.00000	5 0.56223	5 0.20818	11 0.02932	21 0.03576	6 0.69417
	7/16/2022	12 0.20539	275 0.00000	17 0.00000	59 0.00000	119 0.00001	275 0.00000	33 0.00000	176 0.00000	135 0.00000	12 1.00000	7 0.92872

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Ritz Cracker	5/24/2022	16 0.00000	5 0.47892	1 0.60982	–	16 0.00000	19 0.00000	–	6 0.01154	–	2 0.53289	–
	6/16/2022	5 0.11599	65 0.00000	1 0.60984	18 0.00172	41 0.00027	6 0.00000	–	4 0.00668	–	2 0.53286	–
	7/14/2022	25 0.00000	79 0.00000	1 0.99178	18 0.00268	23 0.94461	25 0.00000	–	42 0.00000	1 1.00000	8 0.00865	2 0.43578
Rock Shelter Cave	5/16/2022	19 0.00000	32 0.00000	3 0.00557	2 1.00000	62 0.00000	–	–	6 0.00000	–	–	–
	6/14/2022	105 0.00000	341 0.00000	5 0.00147	51 0.00922	170 0.00000	6 0.00002	2 0.99488	9 0.00000	1 1.00000	4 1.00000	5 0.12701
	7/11/2022	11 0.00727	139 0.00000	5 0.00035	15 1.00000	121 0.00000	4 0.01687	1 1.00000	15 0.00000	–	2 1.00000	1 1.00000
Sandstonia	5/22/2022	32 0.00000	20 0.00000	1 0.86286	3 0.89557	19 0.00028	1 0.13626	–	1 0.22438	–	4 0.11666	–
	6/18/2022	1 0.01842	–	8 0.00013	–	–	4 0.00021	7 0.05579	2 0.54466	–	7 0.98860	3 0.99517
	7/15/2022	27 0.00000	149 0.00000	29 0.00000	7 1.00000	42 0.63183	14 0.0047	43 0.00000	40 0.00000	63 0.00000	19 1.00000	6 1.00000
Star Trek	5/24/2022	1 0.63878	15 0.00000	–	1 1.00000	1 1.00000	–	–	23 0.00000	–	–	–
	6/16/2022	2 0.03501	7 0.00000	–	–	–	4 0.03577	–	20 0.00000	–	–	–
	7/14/2022	4 0.00189	12 0.00000	5 0.00016	1 0.99998	3 0.99835	53 0.00000	–	4 0.95347	4 1	–	–

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
The Brain	5/19/2022	121 0.00000	181 0.00000	3 0.11307	12 1.00000	27 1.00000	2 0.01345	3 0.26721	1 0.97887	–	4 0.60404	–
	6/21/2022	35 0.00000	13 0.00000	–	1 1.00000	2 1.00000	4 0.0109	1 0.88759	6 0.00027	5 0.04391	–	2 0.03017
	7/16/2022	24 0.00000	28 0.00000	12 0.00000	10 0.00219	6 1.00000	86 0.00000	13 0.00337	34 0.00000	4 1.00000	13 0.76983	6 0.79931
The Hole	5/19/2022	9 0.00255	83 0.00000	29 0.00000	12 0.67543	74 0.00000	4 0.90973	16 0.01418	14 0.00012	48 0.00000	1 1.00000	7 0.92966
	6/19/2022	5 0.00000	5 0.00251	–	–	2 0.82666	8 0.16224	1 1.00000	22 0.00000	55 0.00000	–	–
	7/18/2022	99 0.00000	639 0.00000	231 0.00000	2 1.00000	38 1.00000	7 0.00084	8 1.00000	15 0.00000	7 0.81781	43 1.00000	15 1.00000
The Pinnacle	5/16/2022	4 0.00279	17 0.00000	–	–	1 1.00000	–	–	3 0.00045	–	–	–
	6/14/2022	29 0.00000	89 0.00000	–	35 0.00000	39 0.14246	4 0.00125	–	4 0.00404	2 0.64227	–	–
	7/12/2022	–	4 0.01278	1 0.88411	–	2 0.69325	46 0.00000	6 0.00006	13 0.00105	6 1.00000	–	–
The Undeserved	5/20/2022	105 0.00000	35 0.00000	1 0.54959	11 0.00240	12 0.81508	11 0.00000	3 0.42304	18 0.00000	12 0.00160	1 0.97885	–
	6/17/2022	29 0.00000	80 0.00000	1 0.88654	8 0.86112	7 1.00000	40 0.00000	6 0.00051	21 0.00000	8 1.00000	–	–
	7/13/2022	–	5 0.0002	1 0.99154	1 0.74692	–	12 0.21132	15 0.02487	18 0.00042	109 0.00000	–	–

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
The White Wall	5/17/2022	238 0.00000	728 0.00000	–	1 1.00000	5 1.00000	5 0.05726	4 0.48504	4 0.16973	20 0.00000	–	–
	6/20/2022	17 0.00000	134 0.00000	7 0.02965	2 1.00000	1 1.00000	19 0.00000	23 0.00000	11 0.0286	29 0.00000	–	4 0.31521
	7/18/2022	286 0.00000	193 0.00000	34 0.00000	–	4 1.00000	532 0.00000	154 0.00000	187 0.00000	105 1.00000	1 1.00000	5 1.00000
Thieves	5/24/2022	38 0.00000	140 0.00000	4 0.00083	1 1.00000	–	2 1.00000	1 1.00000	39 0.00000	33 0.00000	–	–
	6/16/2022	88 0.00000	81 0.00000	2 0.05598	12 0.20346	15 1.00000	9 0.33019	3 1.00000	144 0.00000	15 0.34908	–	4 0.02320
	7/14/2022	71 0.00000	692 0.00000	1 0.18273	4 1.00000	11 1.00000	4 0.24235	–	36 0.00000	15 0.00000	–	–
Toxic Jesus	5/17/2022	4 0.00276	15 0.00000	2 0.84268	–	3 1.00000	15 0.00000	15 0.00000	10 0.00243	4 1.00000	–	2 0.34351
	6/20/2022	2 0.12296	11 0.00364	1 0.42964	7 0.00766	16 0.00041	3 0.00858	2 0.25675	5 0.00089	–	1 0.99058	1 0.76099
	7/18/2022	2 0.13983	12 0.00043	1 0.44239	5 0.09115	14 0.00208	10 0.00000	2 0.26964	23 0.00000	2 1.00000	–	–
Upper Endless	5/20/2022	13 0.00000	58 0.00000	–	17 0.00042	21 0.61167	17 0.0025	5 0.80915	151 0.00000	29 0.00029	–	–
	6/14/2022	44 0.00000	107 0.00000	3 0.02975	42 0.00000	55 0.00056	85 0.00000	16 0.00130	329 0.00000	19 1.00000	1 1.00000	2 0.59622
	7/12/2022	2 0.10244	10 0.00002	6 0.00118	4 0.08525	5 0.65221	23 0.00000	9 0.00444	32 0.00000	16 0.01608	3 1.00000	1 1.00000

Table 18 (continued). Kaleidoscope Pro results for each species at every site across nights. The number of files identified to each species is on top and the corresponding maximum likelihood estimator (MLE) score is below. Nights with a significant MLE score ($p < 0.05$), indicating a species is likely present, are bolded. Target species are in red. Manual vetting determined COTO to be probably absent and MYLE, MYSE, and MYSO to be likely present. Species codes are defined in Table 2.

Site	Date	COTO	EPFU	LABO	LACI	LANO	MYLE	MYLU	MYSE	MYSO	NYHU	PESU
Zealous	6/1/2022	6 0.00001	12 0.00000	–	7 0.00192	5 0.92000	17 0.00000	2 0.17085	17 0.00000	4 0.99159	–	–
	6/14/2022	–	7 0.18034	2 0.37849	9 0.00008	16 0.00011	51 0.00000	7 0.00007	17 0.00002	6 1	–	1 0.79809
	7/13/2022	7 0.00000	16 0.00000	2 0.19921	7 0.00782	7 0.74023	2 0.07731	2 0.52552	5 0.00048	–	3 0.80048	2 0.60116

Appendix F – Manual Vetting Results

Table 19 shows the results of manual vetting of target species.

Table 19. Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Ames Wall	5/22/2022	–	–	x	–	MYSE are not consistent with the species
	6/18/2022	–	–	–	–	–
	7/15/2022	–	xx	xx	–	–
Butcher's Branch	5/19/2022	x	xx	xx	–	COTO calls are likely EPFU. Tough to tell MYLE and MYSE apart. MYSO are low quality or similar to MYLE
	6/19/2022	–	xx	–	xx	Tough to tell <i>Myotis</i> apart
	7/18/2022	x	xx	xx	–	COTO are low quality
Diamond Point	5/24/2022	x	xx	–	–	COTO calls are low quality and should not be identified to species
	6/17/2022	x	xx	x	xx	COTO are low quality or EPFU. MYSE are low quality or EPFU. Due to <i>Myotis</i> call overlap, tough to tell <i>Myotis</i> species apart
	7/13/2022	–	xx	xx	–	–
Domino Point	5/17/2022	x	–	x	–	COTO calls are low quality or EPFU. MYSE are low quality calls
	6/20/2022	x	x	x	–	COTO are low quality or EPFU. MYSE are not very convincing. One file appears to be a MYLE
	7/18/2022	x	xx	xx	–	COTO are low quality or EPFU
Endless Wall 1b	5/21/2022	x	xx	xx	–	COTO are low quality calls or EPFU
	6/16/2022	x	xx	xx	x	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart. Calls similar to all three species are present
	7/14/2022	x	xx	xx	–	COTO are low quality or EPFU

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Endless Wall 2a	5/24/2022	x	xx	x	–	COTO calls low quality or EPFU. MYSE calls are low quality or likely MYLE given the number of MYLE calls
	6/17/2022	x	xx	–	–	COTO are low quality or EPFU
	7/13/2022	x	xx	xx	x	COTO are low quality or EPFU. Most MYSO are low quality and the ones that are better quality likely either MYLE/MYSE
Fantasy	5/24/2022	x	–	–	–	COTO calls are likely EPFU
	6/17/2022	x	xx	x	–	COTO are low quality or EPFU. MYSE are low quality
	7/13/2022	–	xx	xx	xx	Tough to tell <i>Myotis</i> apart
Fern Cirque	5/21/2022	x	xx	xx	–	COTO calls are likely EPFU
	6/16/2022	x	xx	xx	–	COTO are low quality or EPFU
	7/14/2022	x	xx	–	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
Fern Creek Falls	5/21/2022	x	x	–	xx	COTO are likely EPFU. MYSO calls are consistent with those produced by the species
	6/16/2022	x	xx	–	xx	COTO are low quality or EPFU
	7/16/2022	–	xx	–	–	–
Fire and Ice	5/19/2022	x	xx	x	–	COTO calls are of low quality or EPFU. Most MYSE calls are high frequency EPFU
	6/19/2022	x	xx	–	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	7/18/2022	x	xx	x	–	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart but given most files are MYLE, the MYSE files are also likely MYLE
French Wall	5/22/2022	x	–	x	–	COTO are low quality or EPFU. MYSE are low quality or EPFU
	6/18/2022	–	xx	–	–	–

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
French Wall (continued)	7/15/2022	x	xx	xx	–	COTO are low quality or EPFU
Headless Wall	5/24/2022	x	xx	x	–	COTO are low quality or EPFU. MYSE are low quality or likely MYLE
	6/18/2022	–	xx	–	–	–
	7/15/2022	–	xx	–	–	–
Hellbound	5/24/2022	x	xx	xx	–	COTO are poor quality or EPFU. MYSO are likely MYLE. MYSE can't be ruled out but could be MYLE given the number of MYLE
	6/17/2022	x	xx	–	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	7/13/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
Hueco Pillar	5/17/2022	x	xx	xx	–	COTO are likely EPFU
	6/20/2022	–	xx	xx	–	–
	7/18/2022	x	xx	xx	xx	COTO are EPFU. Tough to tell <i>Myotis</i> apart
Idol Point	5/21/2022	x	xx	xx	xx	COTO are likely EPFU. Tough to tell <i>Myotis</i> apart
	6/16/2022	x	xx	xx	xx	COTO are low quality or EPFU
	7/14/2022	–	xx	xx	xx	Tough to tell <i>Myotis</i> apart
Jacob's Ladder	5/20/2022	x	xx	xx	–	COTO are likely EPFU. Most MYSE calls are low quality or MYLE but the last 3 calls are consistent with the species
	6/17/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	7/13/2022	–	xx	xx	–	Tough to tell <i>Myotis</i> apart
Junkyard	6/1/2022	x	–	xx	–	COTO are likely EPFU. Most MYSE calls are low quality or EPFU but a few calls cannot be ruled out

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Junkyard (continued)	6/14/2022	x	–	x	–	Calls are of low quality and cannot be confidently identified to species
	7/12/2022	–	–	–	–	–
Kaymoor 6a	5/19/2022	x	x	xx	–	COTO are likely EPFU. MYLE calls are low quality
	6/19/2022	–	–	x	–	MYSE call is a EPFU
	7/18/2022	–	xx	xx	–	Tough to tell <i>Myotis</i> apart
Kaymoor 8	5/19/2022	x	xx	x	xx	COTO are likely EPFU. Tough to tell <i>Myotis</i> apart but MYSE calls appear more similar to MYLE or LABO. Many MYSO are LABO but can't rule out the others
	6/19/2022	–	x	xx	xx	Some MYSO appear to be MYLI. MYSE and MYSO look very similar and are likely only one species
	7/18/2022	x	xx	x	–	COTO are low quality or EPFU. MYSE are low quality or EPFU
Keeney's Buttress	5/19/2022	x	–	x	–	COTO calls are low quality or EPFU. MYSE are low quality calls
	6/15/2022	x	–	–	–	COTO are low quality or EPFU
	7/16/2022	–	–	–	–	–
Little Head	5/22/2022	x	xx	x	–	COTO are low quality or EPFU. MYSE are low quality or likely MYLE
	6/18/2022	–	xx	x	–	Given the number of MYLE calls, MYSE are likely MYLE
	7/15/2022	x	xx	x	–	COTO are low quality or EPFU. MYSE are low quality, EPFU, or likely MYLE
Middle Beauty	5/19/2022	x	xx	xx	–	COTO are low quality or EPFU
	6/21/2022	x	xx	xx	xx	COTO are low quality or EPFU
	7/16/2022	x	xx	xx	–	COTO are low quality or EPFU

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
NERI.484	5/24/2022	x	—	xx	xx	COTO are low quality or EPFU
	6/16/2022	x	xx	xx	—	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	7/14/2022	x	xx	x	—	COTO are low quality or EPFU. MYSE are low quality, EPFU, or likely MYLE
NERI.488	5/20/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/14/2022	x	xx	x	xx	COTO are low quality or EPFU. MYSE are low quality or another <i>Myotis</i> . Tough to tell <i>Myotis</i> apart
	7/12/2022	—	—	—	—	—
NERI.489	5/20/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/17/2022	x	xx	x	xx	COTO and MYSE are low quality or EPFU
	7/13/2022	x	xx	xx	xx	COTO are low quality or EPFU
NERI.491	6/1/2022	x	—	x	—	COTO calls are low quality or EPFU. MYSE calls are very steep calls that shouldn't be identified
	6/18/2022	—	—	—	—	—
	7/15/2022	x	—	—	—	COTO are low quality
NERI.496	5/19/2022	x	—	—	—	COTO are low quality
	6/15/2022	x	xx	xx	—	COTO are low quality or EPFU
	7/16/2022	—	—	x	—	MYSE are EPFU
NERI.502	5/17/2022	x	—	—	x	COTO calls are low quality or EPFU. Multiple bats calling in most <i>Myotis</i> files making ID unreliable
	6/20/2022	x	xx	—	xx	COTO are low quality or EPFU. Most MYSO are LABO
	7/18/2022	x	x	—	xx	COTO are low quality or EPFU. MYLE are low quality or likely LABO

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO		MYLE	MYSE	MYSO	Comments
NERI.517	5/31/2022	x		–	xx	–	COTO are low quality. Most MYSE calls are low quality but one call is consistent with the species
	6/14/2022	–		xx	–	–	–
	7/11/2022	–		xx	–	–	–
NERI.518	5/31/2022	x		–	–	–	COTO are low quality or EPFU
	6/14/2022	–		–	–	–	–
	7/11/2022	–		x	x	–	Calls are low quality
NERI.521	5/31/2022	x		–	x	–	COTO calls are low quality or EPFU. MYSE are low quality calls
	6/14/2022	–		–	x	–	MYSE are low quality
	7/11/2022	x		xx	–	–	COTO are low quality or EPFU
NERI.525	6/1/2022	x		xx	–	–	COTO are EPFU
	6/14/2022	x		x	x	x	COTO and MYSE are low quality or EPFU. MYSO are likely MYLE
	7/12/2022	–		–	–	–	–
NERI.526	6/1/2022	x		–	–	–	COTO are low quality or EPFU
	6/14/2022	–		–	x	–	MYSE are low quality
	7/12/2022	–		–	–	–	–
NERI.531	5/21/2022	x		–	–	–	COTO are low quality or EPFU
	6/16/2022	x		xx	x	xx	COTO and MYSE are low quality or EPFU
	7/14/2022	x		xx	x	xx	COTO are low quality or EPFU. MYSE are low quality or likely LABO
NERI.535	5/24/2022	x		xx	xx	–	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/17/2022	x		xx	x	–	COTO and MYSE are low quality or EPFU
	7/13/2022	x		xx	xx	–	COTO are low quality or EPFU

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Overlook Buttrass	5/16/2022	x	–	–	–	COTO are low quality or EPFU
	6/14/2022	–	–	x	–	MYSE are low quality or EPFU
	7/12/2022	–	–	–	–	–
Rainbow Ledge	6/1/2022	x	–	xx	–	COTO are low quality or EPFU
	6/18/2022	–	–	–	–	–
	7/15/2022	–	xx	x	–	MYSE are likely EPFU/LABO
Rams Head	5/19/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/21/2022	–	xx	–	xx	–
	7/16/2022	–	xx	xx	xx	Tough to tell <i>Myotis</i> apart
Ritz Cracker	5/24/2022	x	xx	xx	–	COTO are low quality or EPFU. Mostly MYLE but there are a few MYSE that can't be ruled out
	6/16/2022	–	xx	x	–	MYSE are low quality or EPFU
	7/14/2022	x	xx	x	–	COTO are likely EPFU. MYSE calls are very steep but low frequency and shouldn't be ID'd to species
Rock Shelter Cave	5/16/2022	x	–	x	–	COTO are low quality or EPFU. MYSE are low quality or EPFU
	6/14/2022	x	x	x	–	COTO and MYSE are low quality or EPFU. MYLI are low quality
	7/11/2022	x	x	xx	–	COTO are low quality or EPFU. MYLE are low quality
Sandstonia	5/22/2022	x	–	–	–	COTO are low quality or EPFU
	6/18/2022	x	x	–	–	Calls are low quality
	7/15/2022	x	xx	xx	x	COTO are low quality or EPFU. MYSO are low quality or likely LABO
Star Trek	5/24/2022	–	–	x	–	MYSE are low quality calls (super steep calls and at a low frequency)

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Star Trek (continued)	6/16/2022	x	xx	x	–	COTO and MYSE are low quality or EPFU
	7/14/2022	x	xx	–	–	COTO are low quality
The Brain	5/19/2022	x	x	x	–	COTO are low quality or EPFU
	6/21/2022	x	xx	x	x	COTO are low quality or EPFU. MYSE and MYSO are low quality
	7/16/2022	x	xx	xx	–	COTO are low quality or EPFU
The Hole	5/19/2022	x	–	x	xx	COTO are low quality or EPFU. MYSE are low quality
	6/19/2022	x	–	x	x	COTO are low quality or EPFU. MYSE and MYSO are low quality or LABO
	7/18/2022	x	xx	xx	–	COTO are low quality or EPFU
The Pinnacle	5/16/2022	x	–	x	–	Calls are of low quality (i.e. only a few pulses or very steep)
	6/14/2022	x	xx	x	–	COTO are EPFU. MYSE are likely MYLE
	7/12/2022	–	xx	xx	–	Tough to tell <i>Myotis</i> apart
The Undeserved	5/20/2022	x	xx	xx	xx	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/17/2022	x	xx	x	–	COTO are EPFU. MYSE are likely MYLE
	7/13/2022	–	–	xx	xx	–
The White Wall	5/17/2022	x	–	–	xx	COTO are low quality or EPFU
	6/20/2022	x	xx	x	xx	COTO are EPFU. MYSE are likely MYSO
	7/18/2022	x	xx	xx	–	COTO are EPFU. Tough to tell <i>Myotis</i> apart
Thieves	5/24/2022	x	–	xx	xx	COTO are low quality or EPFU. Some good <i>Myotis</i> calls
	6/16/2022	x	–	xx	x	COTO are EPFU. Most MYSE look more like MYSO but there are a few MYSE calls that cannot be ruled out
	7/14/2022	x	–	xx	xx	COTO are EPFU. Tough to tell <i>Myotis</i> apart

Table 19 (continued). Results of manual vetting of target species. Single “x” indicates a species that was considered present by Kaleidoscope Pro (KPro). The “xx” indicates a species that was considered present by KPro and confirmed via manual vetting. Species codes are defined in Table 2.

Site	Date	COTO	MYLE	MYSE	MYSO	Comments
Toxic Jesus	5/17/2022	x	xx	xx	–	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart
	6/20/2022	–	x	xx	–	MYLE are low quality
	7/18/2022	–	xx	xx	–	–
Upper Endless	5/20/2022	x	xx	xx	xx	COTO are low quality or EPFU. MYSO are MYSE. Due to the number of MYSE, MYLE are likely MYSE but can't rule out MYLE for sure
	6/14/2022	x	xx	xx	–	COTO are EPFU. Tough to tell <i>Myotis</i> apart
	7/12/2022	–	xx	xx	x	MYSO are low quality or likely LABO
Zealous	6/1/2022	x	xx	xx	–	COTO are low quality or EPFU. Tough to tell <i>Myotis</i> apart but likely MYLE
	6/14/2022	–	xx	xx	–	<i>Myotis</i> are tough to tell apart but most look like MYLE
	7/13/2022	x	–	xx	–	COTO are low quality or EPFU

Appendix G – Occupancy Modeling

Eastern Small-Footed Bat (*Myotis leibii*)

Goodness of Fit

The results of the goodness of fit for the full model for eastern small-footed bat (*Myotis leibii*) is shown in Table 20. It should be noted that $\hat{c} < 1$, implying “low” or “underdispersion”.

Table 20. Eastern small-footed bat (*Myotis leibii*) – 'Full Model' goodness of fit summary.

Full Model	AIC	χ^2_{obs}	χ^2_{B} Parametric Bootstrap (N=1000)	χ^2_{obs} GOF p-value	Overdispersion Parameter Estimate ($\hat{c}$)
$\Psi(i_{\text{descriptive}} + i_{\text{environmental}} + i_{\text{physical}} + 1), p(i_{\text{inspection}} + 1)$	164.786	8.855	Min: 1.192 1st Qu: 6.237 Median: 9.915 Mean: 23.280 3rd Qu: 17.062 Max: 2202.387	0.562	0.38

Underdispersion is an infrequent occurrence in modeling and analyzing these types of data. This condition manifests when the dispersion parameter, which represents the variance in the response variable unaccounted for by the predictor variables, is particularly low. A low dispersion parameter indicates a high level of homogeneity in the response variable, suggesting that the model is able to explain a substantial portion of the observed variability. Generally, this is not a cause for concern.

However, it is important to recognize that underdispersion may lead to more conservative estimates of uncertainty. Specifically, standard errors may be overestimated, confidence intervals may be narrower, and Type 1 error rates may be deflated. In practical terms, this means that our model leans toward caution, making it less likely to identify true effects unless there is strong evidence for them. Consequently, the effects that the model does detect are those that it can substantiate with high certainty.

While underdispersion might be rare, it is not necessarily problematic. It might merely suggest that the data exhibit less variability than assumed under a Bernoulli distribution, which is often used as a baseline for presence/absence data. Therefore, conventional advice in the face of underdispersion is typically not to overreact but to acknowledge its presence and continue with the analysis (Kéry and Royle 2016). As such, we did not adjust our model selection criteria using quasi-likelihood for this species.

Single Covariate Gradients

To begin to understand how these scaled indices affect occupancy and detection, single variate plots are shown in Figure 12. Recall that the observed numerical range for each scaled index is shown in Table 3.

For Occupancy, recall that the “Descriptive Factor Index” (Figure 12A) is the only index included in this process, so this piece of the model is fully represented here. Estimated occupancy probability does not rise above 0.8 until the scaled index rises above -0.83. For this project, the minimum estimated occupancy probability was 0.57 at a scaled index value of -1.87, the maximum estimated detection probability was 0.97 at a scaled index value of 1.27, and the average estimated detection probability was 0.86 with a standard deviation of 0.12.

For Detection, recall that the “Inspection Factor Index” (Figure 12B) is the only index included in this process, so this piece of the model is fully represented here. Estimated occupancy probability does not rise above 0.8 until the scaled index rises above 0.12. For this project, the minimum estimated occupancy probability was 0.49 at a scaled index value of -1.46, the maximum estimated detection probability was 0.98 at a scaled index value of 2.86, and the average estimated detection probability was 0.74 with a standard deviation of 0.15.

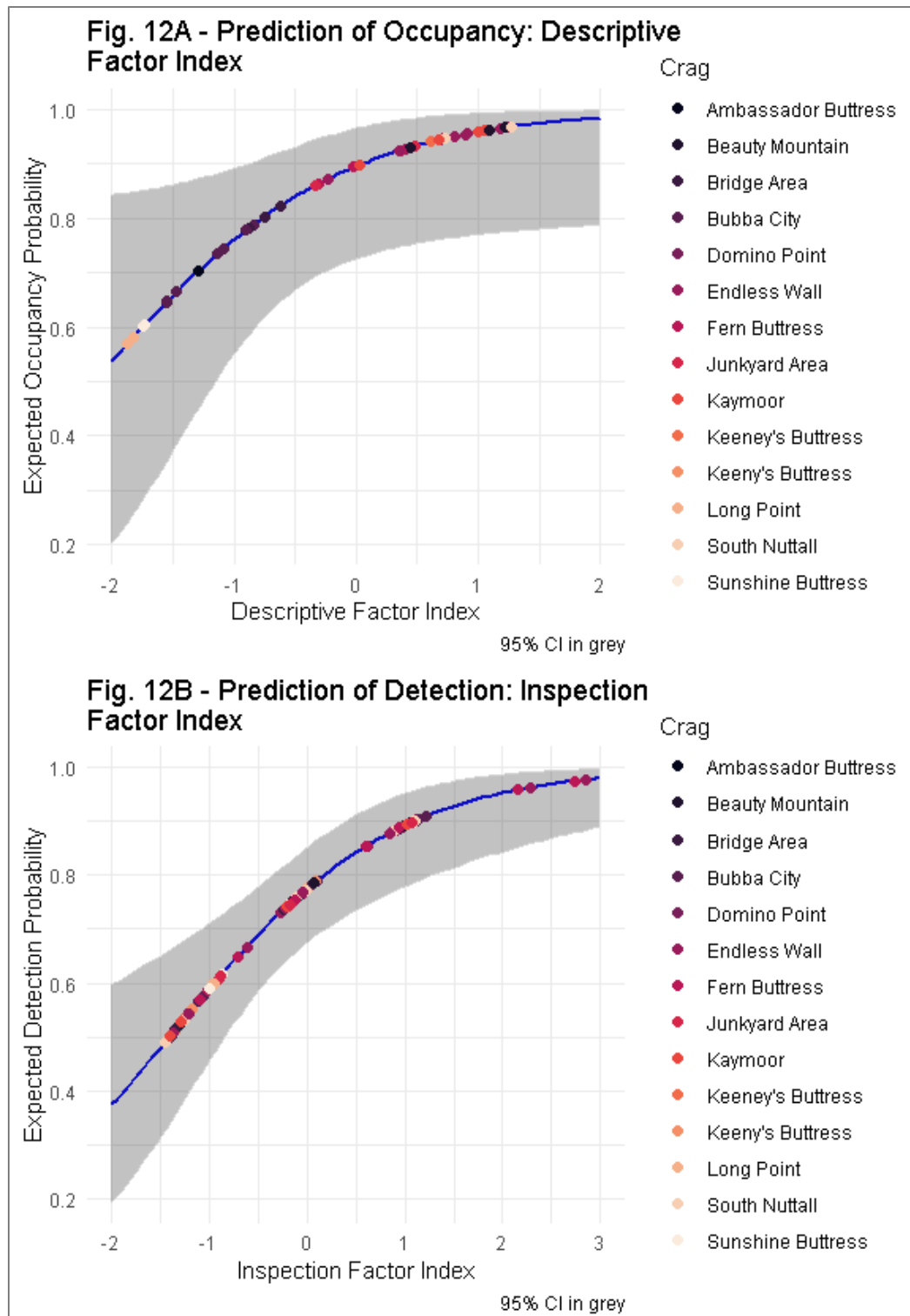


Figure 12. Single variate plots for eastern small-footed bats (*Myotis leibii*).

Spatial Plots

The occupancy predictions and uncertainty (standard error [SE]) are mapped in Figure 13, the detection probability and associated SE are mapped in Figure 14, and the median error for each site is mapped in Figure 15.

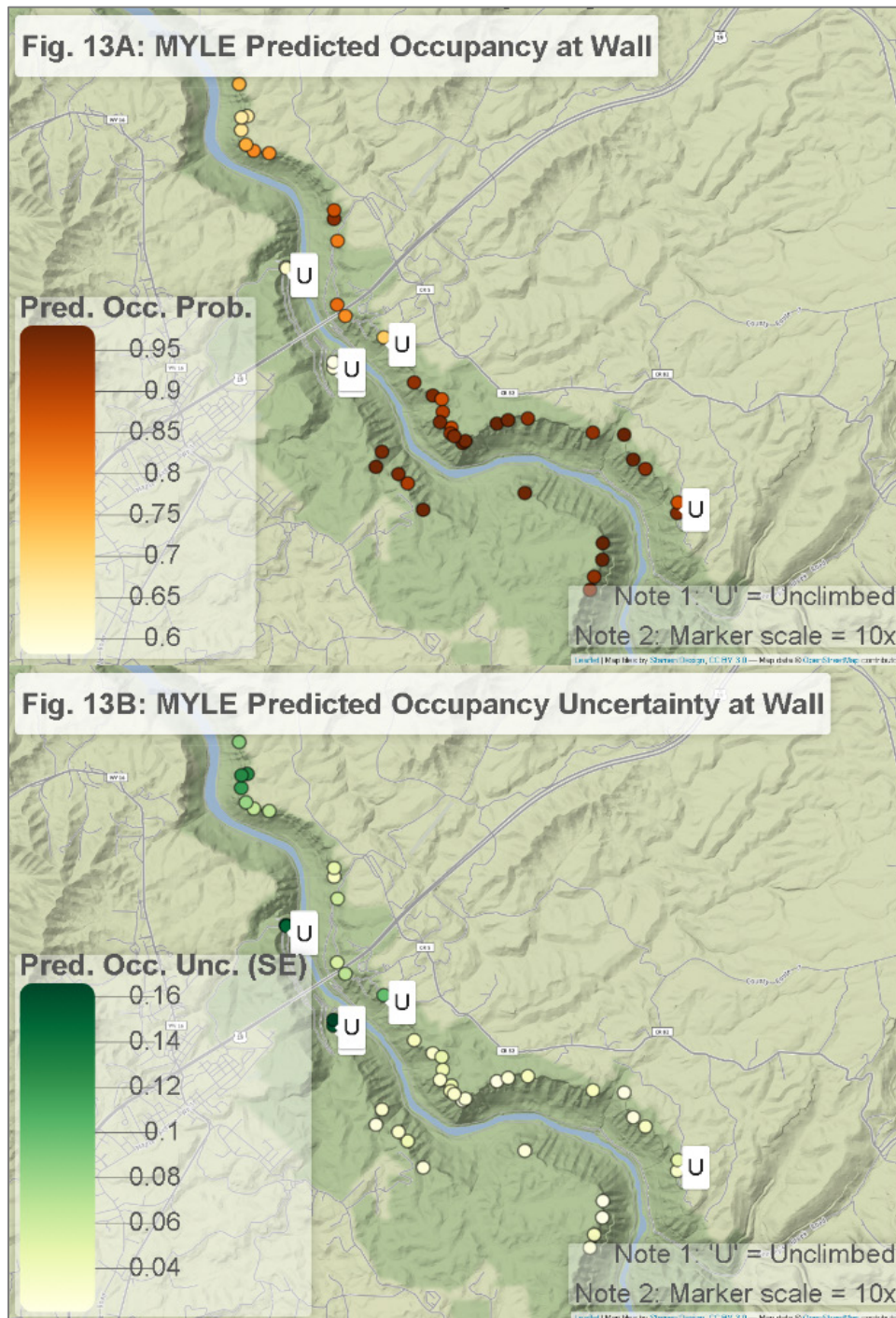


Figure 13. Predicted occupancy of eastern small-footed bats (*Myotis leibii*, MYLE).

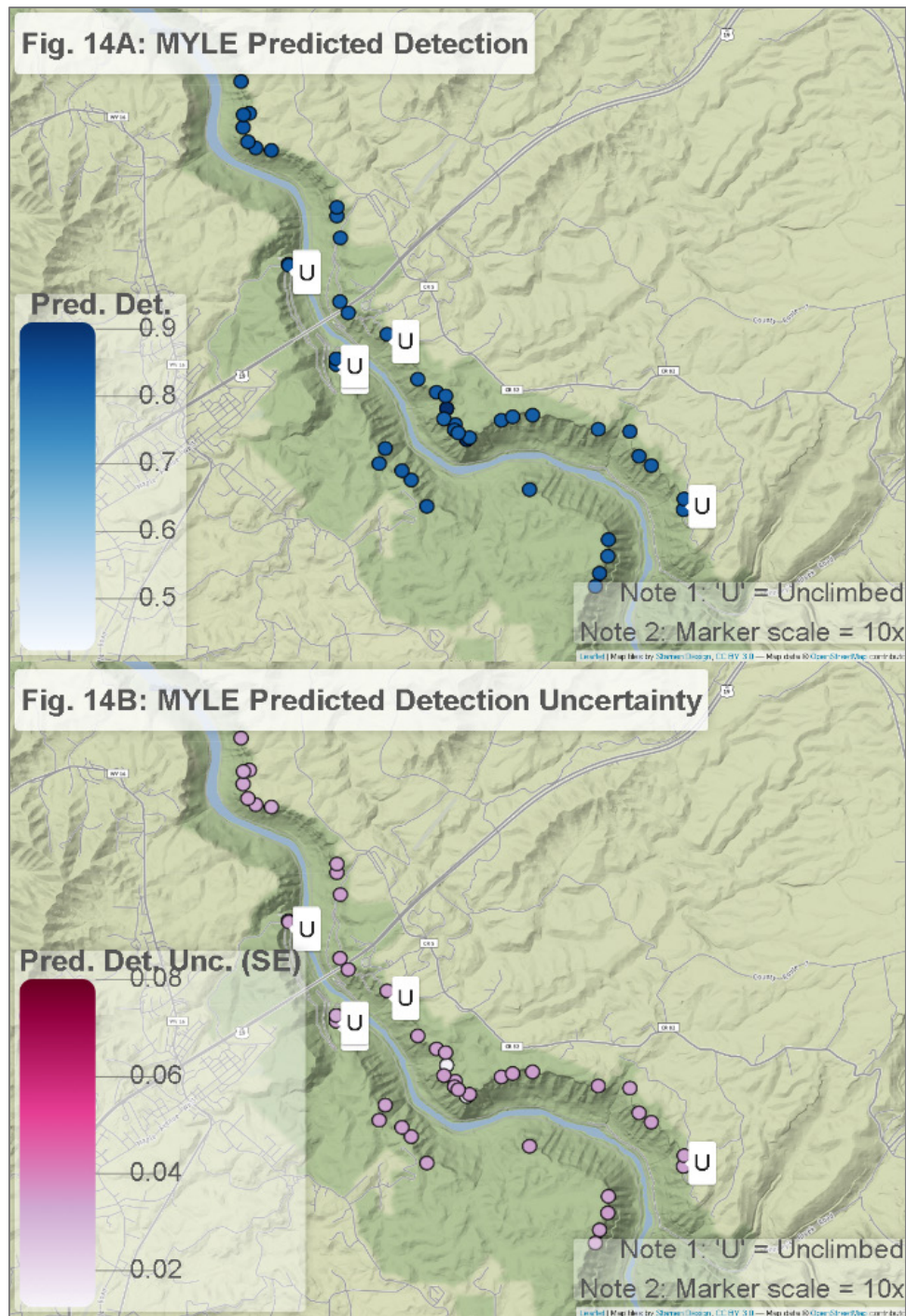


Figure 14. Predicted detection probability for eastern small-footed bats (*Myotis leibii*, MYLE).

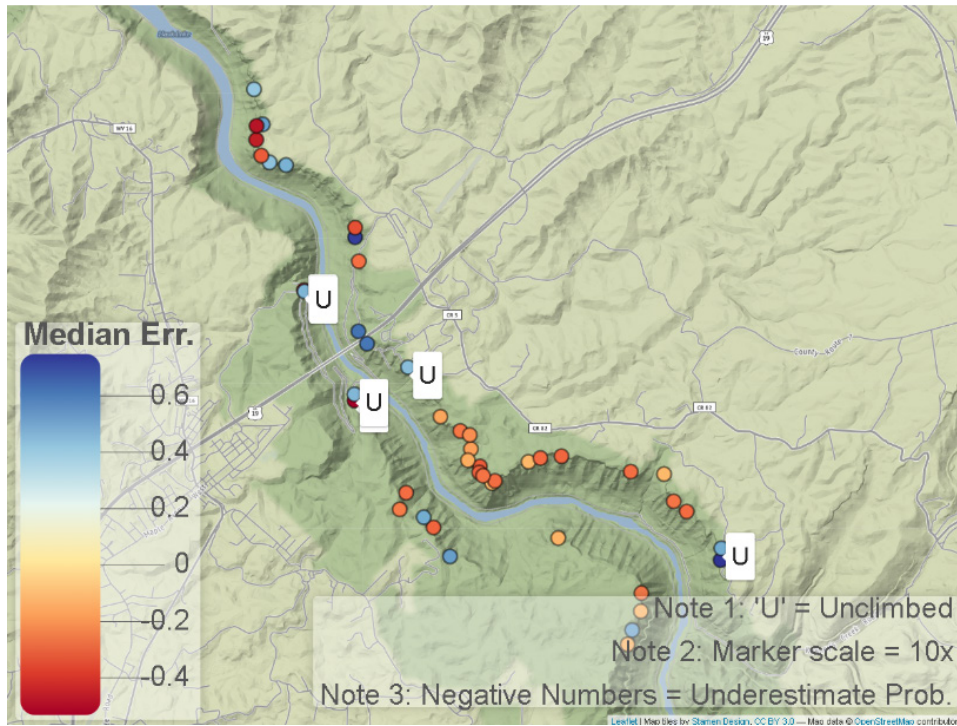


Figure 15. Median occupancy probability error for eastern small-footed bats (*Myotis leibii*).

Model Predictions

Table 21 presents several key estimates related to occupancy modeling. These include the latent occupancy estimates (z_i) for each wall, along with their 95% confidence intervals obtained using the ‘ranef’ function. The table also presents the observed occupancy (denoted as “1” for sites with at least one encounter), and the occupancy probability (ψ) at each wall, complete with its 95% confidence interval. Additionally, the table displays the estimated encounter probability, which is a combination of occupancy and detection probabilities. This encounter probability is symbolized by the Greek letter “ Ω ”.

Table 21. Eastern small-footed bat (*Myotis leibii*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Ambassador Buttress	Ambassador Buttress #2	1 [1, 1]	0	0.7 (0.11) [0.45, 0.87]	0.43	0.52	0.63	–	–
Beauty Mountain	Middle Beauty	1 [1, 1]	1	0.96 (0.04) [0.77, 0.99]	0.50	0.72	0.86	–	–
	Ram's Head	1 [1, 1]	1	0.93 (0.05) [0.75, 0.98]	0.47	0.71	0.83	–	–
	The Brain	1 [1, 1]	1	0.97 (0.03) [0.78, 1]	0.51	0.76	0.87	–	–
Bridge Area	Overlook Buttress	0 [0, 1]	0	0.78 (0.08) [0.58, 0.9]	0.40	0.60	0.69	–	–
	Rock Shelter Cave	0 [0, 1]	0	0.82 (0.07) [0.65, 0.92]	0.41	0.61	0.73	–	–
	The Pinnacle	1 [1, 1]	1	0.8 (0.07) [0.62, 0.91]	0.41	0.61	0.71	–	–
Bubba City	Ameless Wall	0 [0, 0]	0	0.65 (0.14) [0.35, 0.86]	0.38	0.51	0.58	–	–
	Ames Wall	1 [1, 1]	0	0.79 (0.08) [0.6, 0.9]	0.41	0.61	0.71	–	–
	French Wall	1 [1, 1]	1	0.74 (0.1) [0.52, 0.89]	0.42	0.57	0.67	–	–
	Headless Wall	1 [1, 1]	1	0.66 (0.13) [0.38, 0.86]	0.38	0.52	0.60	–	–
	Little Head Wall	1 [1, 1]	1	0.65 (0.14) [0.35, 0.86]	0.35	0.50	0.59	–	–
	Rainbow Ledge Area	1 [1, 1]	0	0.78 (0.08) [0.58, 0.9]	0.46	0.61	0.71	–	–
	Sandstonia - Decameron Area	1 [1, 1]	0	0.73 (0.1) [0.51, 0.88]	0.39	0.55	0.66	–	–

Table 21 (continued). Eastern small-footed bat (*Myotis leibii*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Domino Point	Domino Point	1 [1, 1]	1	0.96 (0.04) [0.77, 0.99]	0.48	0.73	0.85	–	–
Endless Wall	Diamond Point	1 [1, 1]	1	0.97 (0.04) [0.77, 1]	0.65	0.83	0.87	0.93	0.94
	Fantasy Area	1 [1, 1]	1	0.97 (0.03) [0.78, 1]	0.52	0.73	0.86	–	–
	Fern Cirque	1 [1, 1]	1	0.87 (0.06) [0.7, 0.95]	0.47	0.67	0.78	–	–
	Fern Point Slabs	1 [1, 1]	1	0.95 (0.04) [0.77, 0.99]	0.51	0.69	0.84	–	–
	Hellbound Area	1 [1, 1]	1	0.96 (0.04) [0.77, 0.99]	0.57	0.71	0.85	–	–
	Idol Point	1 [1, 1]	1	0.93 (0.05) [0.75, 0.98]	0.50	0.68	0.83	–	–
	Jacob's Ladder Area	1 [1, 1]	1	0.93 (0.05) [0.75, 0.98]	0.47	0.69	0.82	–	–
	Kaymoor Slabs	1 [1, 1]	1	0.95 (0.04) [0.76, 0.99]	0.51	0.72	0.84	–	–
	The Undeserved Area	1 [1, 1]	1	0.96 (0.04) [0.77, 0.99]	0.52	0.71	0.84	–	–
	Upper Endless	1 [1, 1]	1	0.93 (0.05) [0.75, 0.98]	0.47	0.71	0.81	–	–
Fern Buttress	Fern Creek Falls	1 [1, 1]	1	0.89 (0.06) [0.72, 0.96]	0.58	0.76	0.81	0.86	0.87
	Ritz Cracker Area	1 [1, 1]	1	0.95 (0.04) [0.76, 0.99]	0.55	0.73	0.85	–	–
	Star Trek Wall	1 [1, 1]	1	0.86 (0.06) [0.7, 0.95]	0.53	0.66	0.77	–	–

Table 21 (continued). Eastern small-footed bat (*Myotis leibii*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Full Buttress (continued)	Thieves Area	1 [1, 1]	1	0.93 (0.05) [0.75, 0.98]	0.53	0.70	0.82	–	–
Junkyard Area	Junkyard Wall	0 [0, 1]	0	0.93 (0.05) [0.75, 0.98]	0.57	0.71	0.83	–	–
	Zealous Area	1 [1, 1]	1	0.86 (0.06) [0.69, 0.94]	0.53	0.64	0.77	–	–
Kaymoor	Butcher's Branch	1 [1, 1]	1	0.96 (0.04) [0.77, 0.99]	0.49	0.74	0.85	–	–
	Fire and Ice Buttress	1 [1, 1]	1	0.9 (0.06) [0.73, 0.97]	0.46	0.69	0.80	–	–
	Seven-Eleven Wall	1 [1, 1]	1	0.95 (0.04) [0.76, 0.99]	0.51	0.71	0.85	–	–
	The Hole	1 [1, 1]	0	0.96 (0.04) [0.77, 0.99]	0.51	0.71	0.86	–	–
	White Wall Area	1 [1, 1]	0	0.94 (0.04) [0.76, 0.99]	0.47	0.70	0.84	–	–
Keeney's Buttress	Keeney's Buttress	0 [0, 1]	0	0.94 (0.05) [0.76, 0.99]	0.48	0.73	0.84	–	–
Keeny's Buttress	Keeny's Buttress	1 [1, 1]	0	0.86 (0.06) [0.69, 0.94]	0.48	0.68	0.77	–	–
Long Point	Long Point #3	1 [1, 1]	1	0.58 (0.17) [0.26, 0.85]	0.35	0.45	0.52	–	–
	Long Point #4	0 [0, 0]	0	0.57 (0.18) [0.24, 0.85]	0.34	0.44	0.52	–	–
South Nuttall	Hueco Pillar	1 [1, 1]	1	0.97 (0.03) [0.78, 1]	0.52	0.73	0.87	–	–
	The Bitch	1 [1, 1]	0	0.93 (0.05) [0.75, 0.98]	0.49	0.70	0.83	–	–

Table 21 (continued). Eastern small-footed bat (*Myotis leibii*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
South Nuttall (continued)	The White Wall	1 [1, 1]	1	0.97 (0.03) [0.78, 1]	0.47	0.73	0.86	–	–
	Toxic Jesus Wall	1 [1, 1]	1	0.95 (0.04) [0.76, 0.99]	0.48	0.73	0.85	–	–
Sunshine Buttress	Sunshine Buttress #2	1 [1, 1]	1	0.6 (0.16) [0.28, 0.85]	0.37	0.46	0.54	–	–
	Sunshine Buttress #3	0 [0, 0]	0	0.6 (0.16) [0.29, 0.85]	0.36	0.45	0.54	–	–

Best Model – Index Analysis

In the following sections, the scaled indexes were examined within the model to pinpoint the most influential variables on each index. These influences, known as ‘coefficients’ in FAMD (similar to ‘loadings’ in PCA), represent the ‘weight’ of a variable level on a specific factor. Recall that FAMD assumes the observed variables, and associated levels if a categorical variable, are linear combinations of the underlying, unobserved factors, plus some level of error. The coefficients of the variables on this index therefore are used to predict coordinates (scores) of new observations. Understanding the magnitude and direction of these coefficients enables identification of which variables influence the index and, consequently, drive the model’s prediction of occupancy. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of each index’s coefficients were generated. A 95% confidence interval (CI) was then calculated for each variable’s coefficients. Only those variables that had a CI excluding zero were flagged for display, their loadings affirmed as significantly non-zero.

Another important quantity in FAMD is the ‘squared loadings’. These are used to understand the relationship between the original variables and the factors. These help distill the ‘theme’ or ‘essence’ of the index. In this case however, their analysis is of secondary importance due to the initial model-building phase, where variables were deliberately associated with ecologically significant factors. As the thematic interpretation of each index is already determined, the conventional application of squared loading analysis, to identify which variables are most accurately represented by each principal component, becomes less relevant. Instead, the focus shifts to understanding the variable coefficients first. That said, if a variable had a significant coefficient at any level, the entire variable was kept for display.

Though it may seem pedantic, it is important to highlight that each level of a categorical variable is assigned a distinct coefficient, whereas a continuous variable is represented by a single coefficient. This discrepancy arises from the different natures of these variables. The coefficient analysis is conducted at an individual ‘variable level’, while the squared loading analysis occurs at the composite ‘variable’ level. This method ensures uniformity when juxtaposing qualitative and quantitative variables, thereby establishing a unified scale for a given comparison - be it measuring the correlation of an index with a whole variable (encompassing all potential categories) or gauging the influence of the most significant category on the index.

Factor Indices Concerning Occupancy (ψ)

Descriptive Factor Index ($i_{\text{descriptive}}$)

In evaluating the factor “Descriptive”, the first principal component derived from the FAMD was utilized as a representative index. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of this index were generated. The index explains 33.12% of the total variance within the factor. Based on the bootstrap sample, the index explains on average 33.57% of the total variance within the factor with a standard deviation of 1.76% and a 95% confidence interval of [30.21%, 37.02%].

A 95% confidence interval (CI) was calculated for each variable level’s coefficients. Only those variables that had a level with a CI excluding zero were retained for display, implying at least one of

their level coefficients was significantly non-zero. Of the 13 variable levels (11 variables) associated with this factor, 11 levels (9 variables) were retained for display. Collectively these variables account for 99.66% of the index's variance. These variable levels are deemed to be important drivers of the index. The results of this analysis are present in Figure 16 and Table 22.

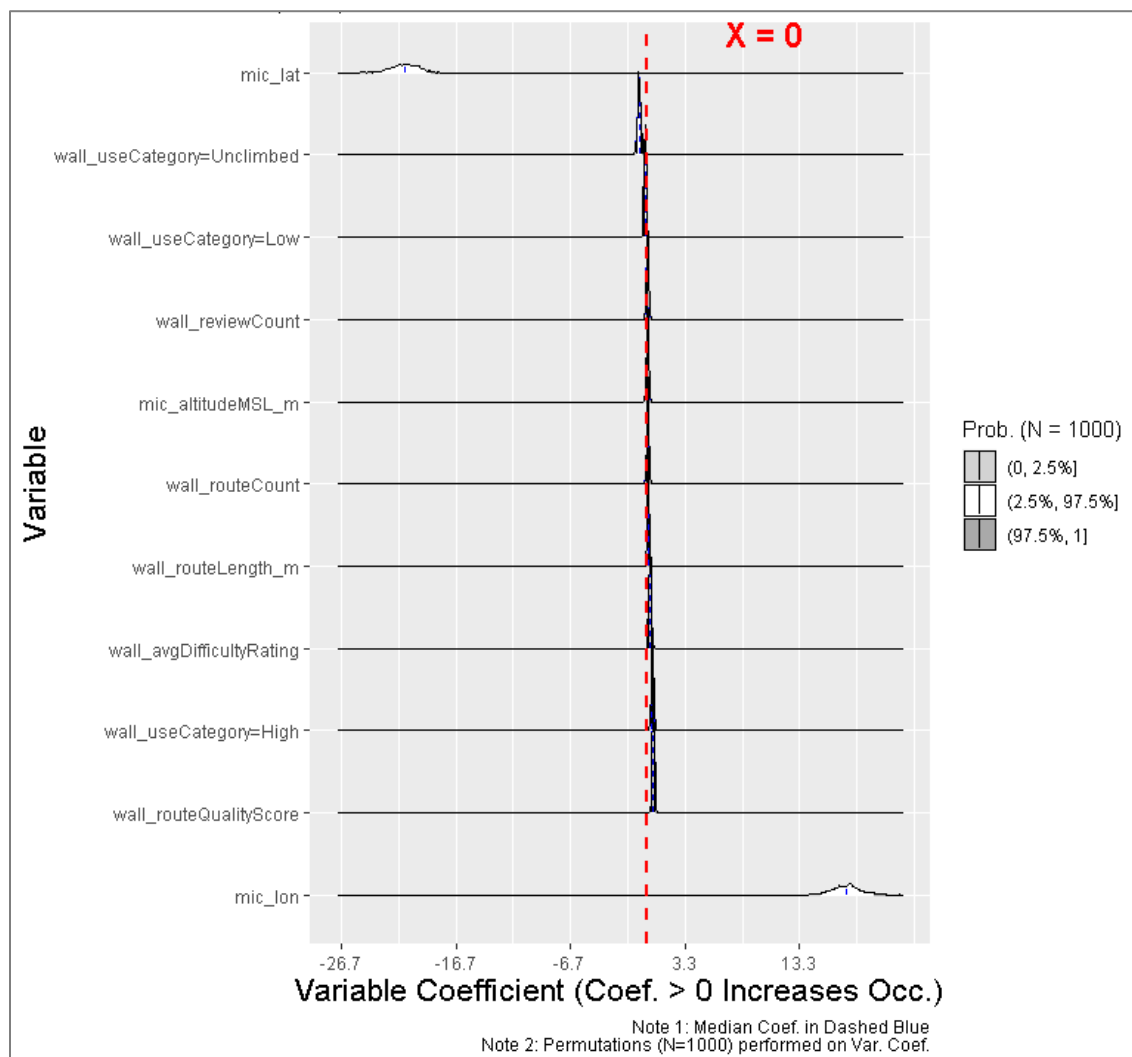


Figure 16. Key features affecting the “Descriptive – Index” for eastern small-footed bats (*Myotis leibii*).

Table 22. Eastern small-footed bat (*Myotis leibii*) – Descriptive factor index summary.

Variable	Pct. Comp. Var.	Mean% (SD) Comp. Var.	95% CI Comp. Var.	Cat. Lvl.	Coef.	Mean (SD) Coef.	95% CI Coef.
mic_altitudeMSL_m	18%	18% (1%)	[16%, 20%]	–	0.01	0.01 (0)	[0.01, 0.01]
wall_routeLength_m	16%	15% (2%)	[11%, 18%]	–	0.05	0.05 (0)	[0.04, 0.06]
wall_useCategory	16%	16% (1%)	[13%, 18%]	High	0.43	0.43 (0.04)	[0.35, 0.51]
	16%	16% (1%)	[13%, 18%]	Low	-0.19	-0.19 (0.05)	[-0.3, -0.08]
	16%	16% (1%)	[13%, 18%]	Unclimbed	-0.74	-0.73 (0.11)	[-0.95, -0.52]
mic_lat	13%	14% (1%)	[11%, 17%]	–	-21.06	-21.2 (1.32)	[-24.09, -18.91]
mic_lon	13%	13% (1%)	[10%, 15%]	–	17.35	17.39 (1.17)	[15.22, 19.77]
wall_routeCount	10%	9% (2%)	[5%, 13%]	–	0.03	0.03 (0)	[0.02, 0.03]
wall_routeQualityScore	7%	7% (2%)	[4%, 11%]	–	0.52	0.52 (0.07)	[0.39, 0.65]
wall_avgDifficultyRating	3%	4% (2%)	[1%, 8%]	–	0.24	0.24 (0.07)	[0.1, 0.38]
wall_reviewCount	3%	3% (1%)	[1%, 6%]	–	0.00	0 (0)	[0, 0]

Interpretation

In Figure 16, the ridgeline plot depicts bootstrapped variable coefficient distributions along the X-axis and significant variable levels on the Y-axis. Due to the positive correlation presented in Table 8 ($i_descriptive = 1.002$) and shown in Figure 16, increasing a quantity or category right of the red dashed line increases the index value, thereby occupancy probability, whereas right of the line diminishes it.

Examining the distributions in Figure 6, the variable “mic_lat” is a quantitative variable. It is located at the top left, with a median coefficient of -21.11 (indicated by the blue dashed line). This negative coefficient is correlated with lower index values and, due to the positive relationship presented in Table 8 and Figure 12, its increase is linked with lower occupancy probabilities. Put simply, decreasing this value is correlated with an increase in occupancy probability.

Conversely, the variable “mic_lon” is another quantitative variable. It is located at the bottom right, with a median coefficient of 17.41 . This positive coefficient is correlated with higher index values and, due to the positive relationship presented in Table 8 and Figure 12, its increase is linked with higher occupancy probabilities. “mic_lat” and “mic_lon” comprise GPS coordinates and their correlations with the Descriptive index and thereby occupancy probabilities imply that it is more likely that MYLE will occupy areas in the southeast of the study area (Figure 13).

The variable “wall_useCategory” is a qualitative (categorical) variable. It has 3 levels (High, Low, Unclimbed). Examining the distributions in Figure 6, the “High” level of the “wall_useCategory” variable is second from the bottom and located to the right of the red dashed line. Its median coefficient is 0.43 . This positive coefficient is correlated with higher index values and, due to the positive relationship presented in Table 8 and Figure 12, its presence is linked with higher occupancy probabilities.

Conversely, the “Unclimbed” level of the “wall_useCategory” variable is second from the top and located to the left of the red dashed line. Its median coefficient is -0.73 . This negative coefficient is correlated with lower index values and, due to the positive relationship presented in Table 8 and Figure 12, its presence is linked with lower occupancy probabilities.

As this is acoustic data, it at first appears that MYLE are more likely to be heard near higher-climbed routes vs unclimbed. A second look at Figure 1 shows that most of the unclimbed walls are not near the southeast quadrant of the study area. Based on their relative distance from the dashed red line vs the latitude and longitude distributions, the presence of one of these categorical climbing levels would not change the Descriptive index as much as a 1-unit change in either latitude or longitude.

Table organizes variables based on their contribution to component variance, indicating how much each accounts for variance within the index. Examining the mean percent of component variation (Mean% (SD) Comp. Var.) reveals that “mic_altitudeMSL_m”, “wall_routeLength_m”, “wall_useCategory”, collectively represent about 50% of the index’s variation. However, the coefficients (Coef.) column shows that, while these variables influence the index’s general

variability, they are not necessarily the most “impactful”, large changes in their values not affecting the Descriptive index result as much as a change in either “mic_lat” or “mic_long” in particular.

In simpler terms, Table 22 may be read one of two ways depending on the goal:

1. To grasp the index’s ‘theme’ or the variables most representative of it, consult the “Comp. Var.” columns. Larger values in these columns imply the variable explains more of the variation in the component. Though in this case, this is a somewhat redundant exercise due to the manual association of variables with ecologically meaningful themes, this step assures comprehensive understanding.
2. To identify which variables (or their categorical levels) statistically impact the ecologically significant index, examine the magnitude and direction of the “Coef.” columns. Changes by 1 unit on these variable levels changes the component output by the respective coefficient. Lower numbers on this index lead to higher abundance for this species per Table 22 ($i_{\text{descriptive}} = 1.002$).

Factor Indices Concerning Detection Probability (p)

Descriptive Factor Index ($i_{\text{inspection}}$)

In evaluating the factor “Inspection”, the first principal component derived from the FAMD was utilized as a representative index. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of this index were generated. The index explains 33.43% of the total variance within the factor. Based on the bootstrap sample, the index explains on average 36.83% of the total variance within the factor with a standard deviation of 3.89% and a 95% confidence interval of [32.89%, 49.08%].

A 95% confidence interval (CI) was calculated for each variable level’s coefficients. Only those variables that had a level with a CI excluding zero were retained for display, implying at least one of their level coefficients was significantly non-zero. Of the 7 variable levels (6 variables) associated with this factor, 2 levels (2 variables) were retained for display. Collectively these variables account for 93% of the index’s variance. These variable levels are deemed to be important drivers of the index. The results of this analysis are present in Figure 17 and Table 23.

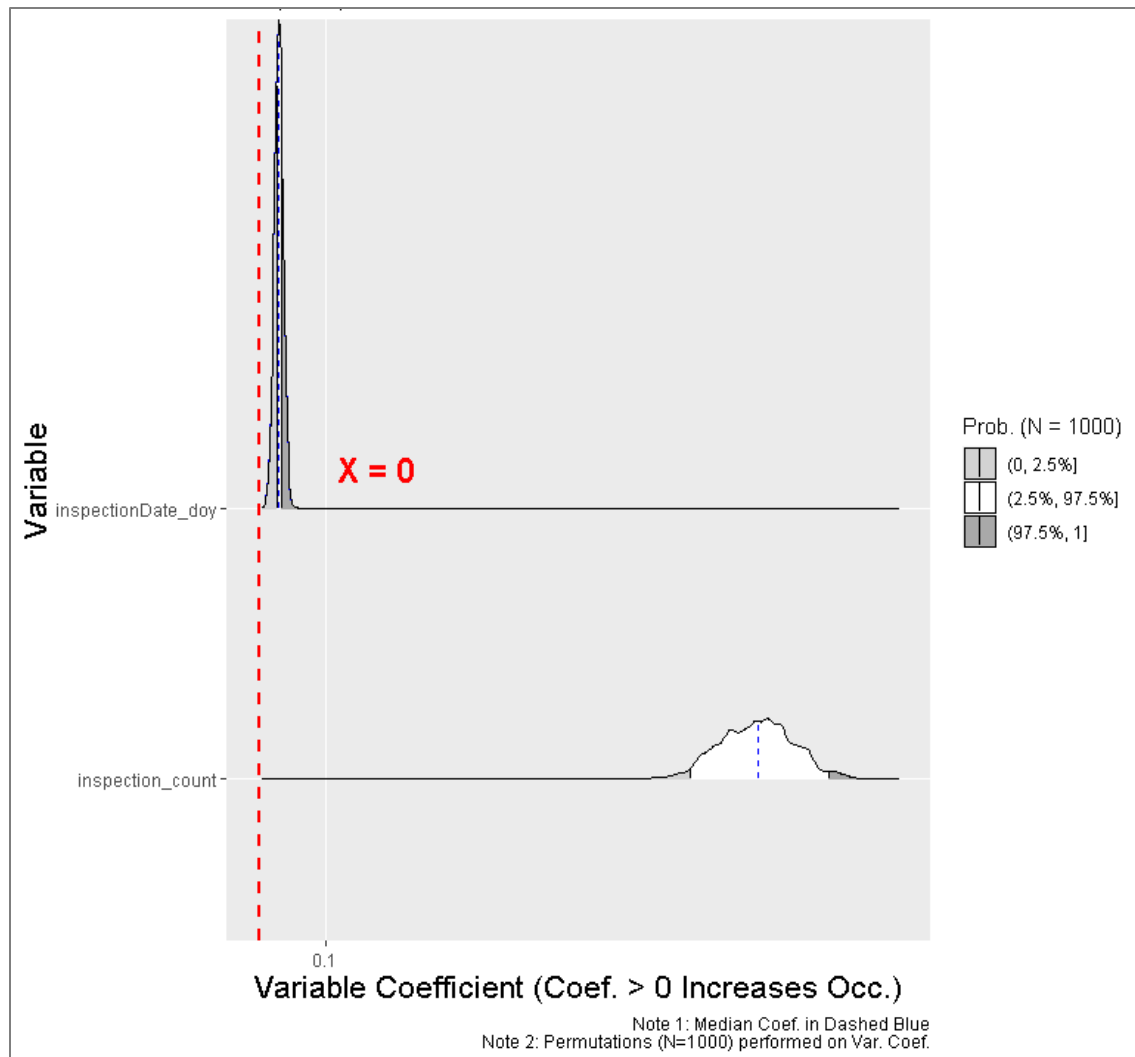


Figure 17. Key features affecting the "Inspection - Index" for eastern small-footed bats (*Myotis leibii*).

Table 23. Eastern small-footed bat (*Myotis leibii*) – Inspection factor index summary.

Variable	Pct. Comp. Var.	Mean% (SD) Comp. Var.	95% CI Comp. Var.	Cat. Lvl.	Coef.	Mean (SD) Coef.	95% CI Coef.
inspection_count	48%	45% (3%)	[39%, 50%]	–	0.77	0.75 (0.05)	[0.65, 0.86]
inspectionDate_doy	45%	43% (4%)	[35%, 49%]	–	0.03	0.03 (0)	[0.03, 0.03]

Interpretation

In Figure 17, the ridgeline plot depicts bootstrapped variable coefficient distributions along the X-axis and significant variable levels on the Y-axis. Due to the positive correlation presented in Table 8 ($i_inspection = 0.875$) and shown in Figure 1, increasing a quantity or category right of the red dashed line increases the index value, thereby occupancy probability, whereas right of the line diminishes it.

Examining the distributions in Figure 17, the variable “inspectionDate_doy” is a quantitative variable. It is located at the top left, with a median coefficient of 0.03 (indicated by the blue dashed line). This positive coefficient is correlated with higher index values and, due to the positive relationship presented in Table 8 and Figure 12, its increase is linked with higher detection probabilities. Put simply, increasing this value is correlated with an increase in detection probability.

Similarly, the variable “inspection_count” is another quantitative variable. It is located at the bottom right, with a median coefficient of 0.75 . This positive coefficient is correlated with higher index values and, due to the positive relationship presented in Table 8 and Figure 12, its increase is linked with higher detection probabilities.

Table 23 organizes variables based on their contribution to component variance, indicating how much each accounts for variance within the index. Examining the mean percent of component variation (Mean% (SD) Comp. Var.) reveals that “inspection_count”, “inspectionDate_doy”, collectively represent about 93% of the index’s variation. The coefficients (Coef.) column shows that “inspection_count” has a larger impact on the index per unit increase than “inspectionDate_doy”.

In simpler terms, Table 23 may be read one of two ways depending on the goal:

1. To grasp the index’s ‘theme’ or the variables most representative of it, consult the “Comp. Var.” columns. Larger values in these columns imply the variable explains more of the variation in the component. Though in this case, this is a somewhat redundant exercise due to the manual association of variables with ecologically meaningful themes, this step assures comprehensive understanding.
2. To identify which variables (or their categorical levels) statistically impact the ecologically significant index, examine the magnitude and direction of the “Coef.” columns. Changes by 1 unit on these variable levels changes the component output by the respective coefficient. Lower numbers on this index lead to higher abundance for this species per Table 8 ($i_inspection = 0.875$).

Northern Long-eared Bat (*Myotis septentrionalis*)

Goodness of Fit

The results of the goodness of fit for the full model for northern long-eared bat (*Myotis septentrionalis*) is shown in Table 24. It should be noted that $\hat{c} > 1$, implying “high” or “overdispersion”.

Table 24. Northern long-eared bat (*Myotis septentrionalis*) – 'Full Model' goodness of fit summary.

Full Model	AIC	χ^2_{obs}	χ^2_{B} Parametric Bootstrap (N=1000)	χ^2_{obs} GOF p-value	Overdispersion Parameter Estimate ($\hat{c}$)
$\Psi(i_{\text{descriptive}} + i_{\text{environmental}} + i_{\text{physical}} + 1), p(i_{\text{inspection}} + 1)$	178.274	47.988	Min.: 8.926 1st Qu.: 27.932 Median : 33.666 Mean : 35.555 3rd Qu.: 39.929 Max. : 179.730	0.109	1.35

Overdispersion is a frequent occurrence in modeling and analyzing this type of data. This condition manifests when the dispersion parameter, which represents the variance in the response variable unaccounted for by the predictor variables, is particularly high. A high dispersion parameter indicates a low level of homogeneity in the response variable, suggesting that the model is not able to explain a substantial portion of the observed variability.

Overdispersion may lead to less conservative estimates of uncertainty. Specifically, standard errors may be underestimated, confidence intervals may be narrower, and Type 1 error rates may be inflated. In practical terms, this means that our model is less cautious, making it more likely to identify effects without strong evidence for them.

A common solution to this problem (MacKenzie 2018) suggests inflating the standard error and adjusting the AIC selection criterion on the basis of the $\hat{c}$ value calculated from the global model [(Burnham and Anderson 2010) as cited in (MacKenzie 2018)]. This particular case is a textbook example and so we will expect to use Quasi-AIC corrected for smaller sample sizes (QAICc) and inflate the reported standard errors accordingly.

Single Covariate Gradients

To begin to understand how these scaled indices affect occupancy, single variate plots are shown in Figure 18. Recall that the observed numerical range for each scaled index is shown in Table 3.

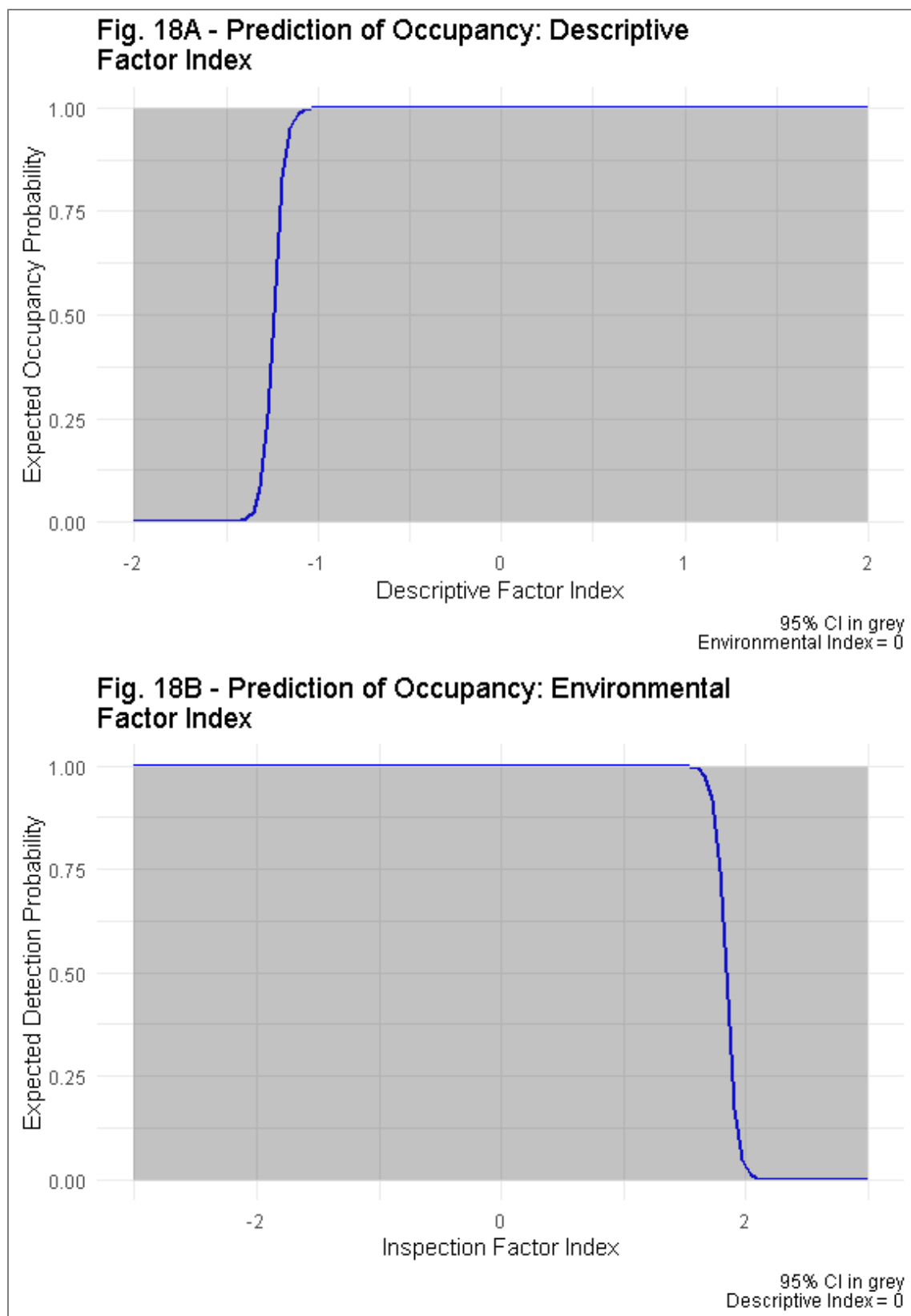


Figure 18. Northern long-eared bat (*Myotis septentrionalis*) Single variate plots.

For Occupancy, the “Environmental” factor index has a larger observed range (-2.18 to 2.76) than the “Descriptive” factor index (-1.93 to 1.33) per Table 3, which defines the X axes used in Figure 18A and Figure 18B. The expected occupancy increases as the “Descriptive” index increases. It decreases as the “Environmental” index increases. The relationship between these indices is discussed further in the dual-variate plots below.

Single variate plots for detection probability were not applicable since detection probability is modeled as a constant (Table 11).

Dual Covariate Plots

Figure 19 presents dual variate plots emphasizing occupancy probability. Dual variate plots for detection probability were not needed since the process was modeled as a constant (Table 24). Estimates of occupancy probability are shown in Figure 19A. Figure 19B plots the $\hat{c}$ -adjusted standard errors for comprehensive analysis. To accommodate the sudden changes in both parameter outputs, a log-scale transformation was used to display the predicted occupancy output. It is important to note that in the log-scale, a point to the right of the 0 contour line denotes a 100% probability of occupancy.

Figure 19A shows that the model is estimating higher northern long-eared bat (*Myotis septentrionalis*) occupancy probabilities for many of the crags (11 Crags with $z = 0$). It also shows that as the occupancy probability increases, the standard errors (uncertainty) around those estimates tend to decrease. Each dot represents the median index value by crag. As in the single variate plots, the occupancy probability sharply increases with an increasing descriptive factor index and sharply decreases with an increasing environmental factor index.

Let’s consider a practical example of a hypothetical site in the study area. Let’s say the scaled “Descriptive” index at this site equals 0, and the scaled “Environmental” index is equal to 1. Referring to Figure 19A, we determine by eye an abundance z -value (contour line) of approximately -5. Using this value in the transform function, we estimate that the abundance at this site is around 99.3%. To ensure accuracy, we calculate the uncertainty of our abundance estimate using Figure 19B. By plugging in the index points of 0 and 1, respectively, we estimate by eye a contour value close to -15. This translates to a standard error of $< 0.01\%$ when applying the transform function.

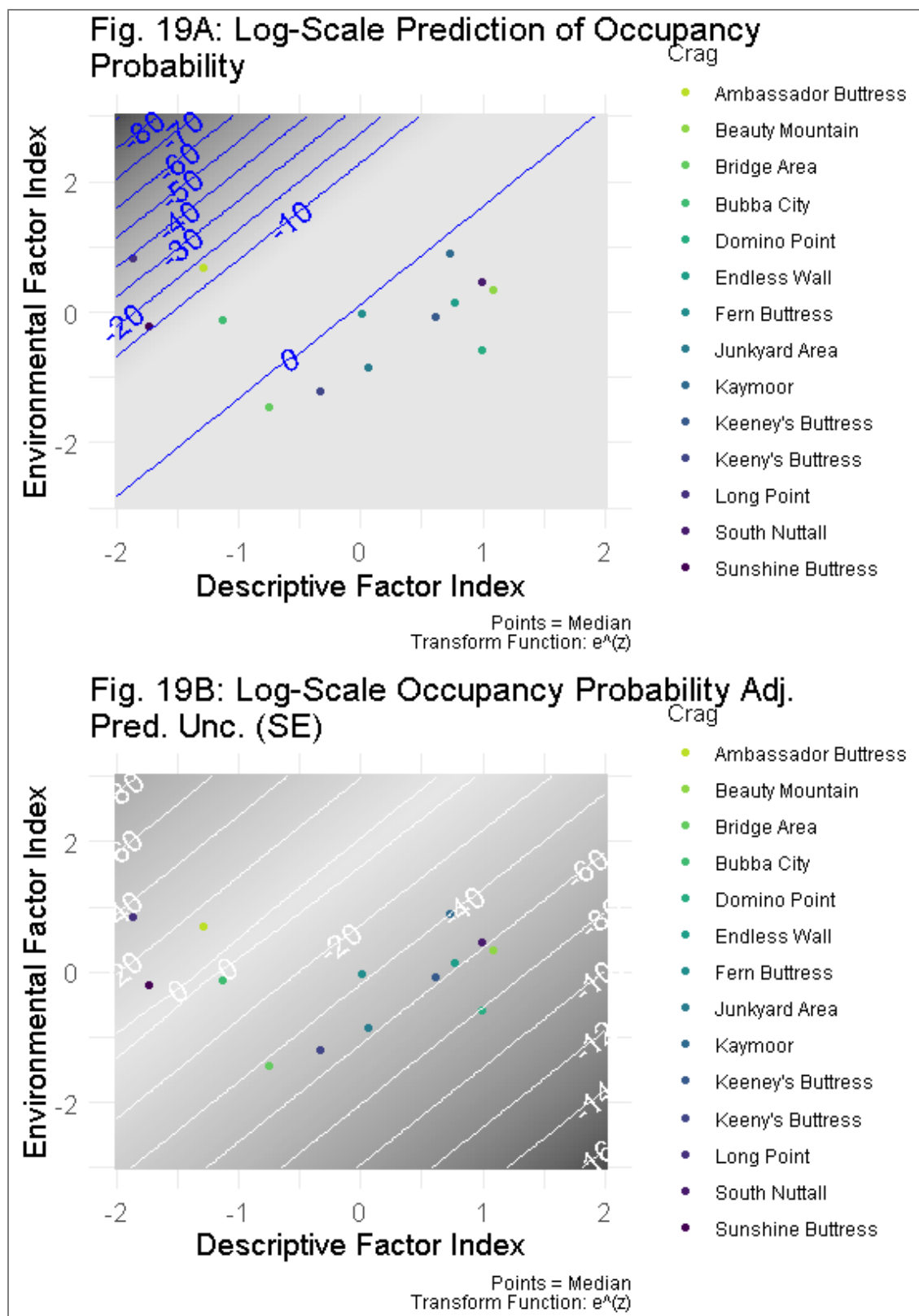


Figure 19. Northern long-eared bat (*Myotis septentrionalis*) dual variate plots.

Spatial Plots

The occupancy predictions and their uncertainty (SE) are mapped in Figure 20 below.

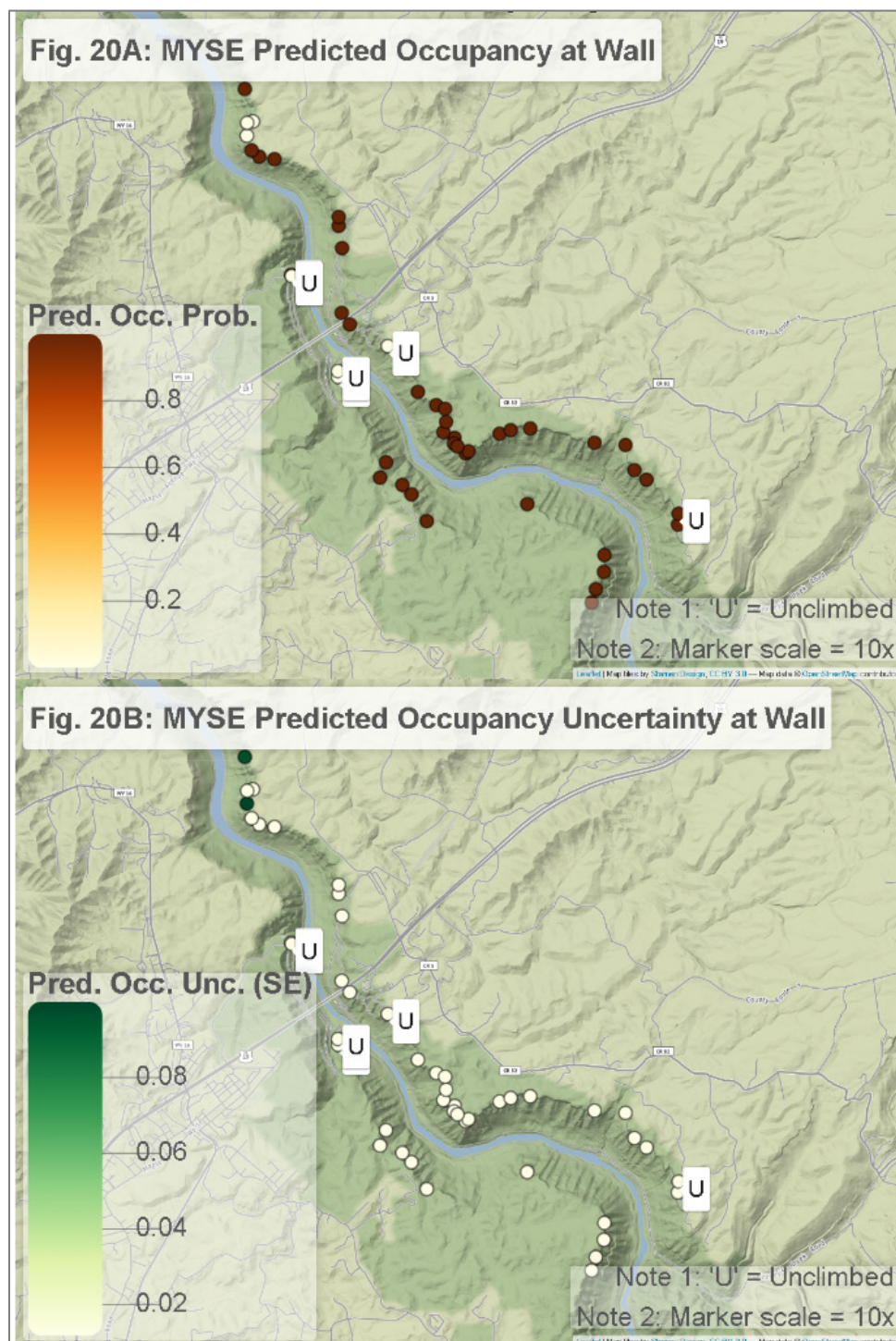


Figure 20. Northern long-eared bat (*Myotis septentrionalis*, MYSE) predicted occupancy.

The detection probability and associated SE are not mapped as they are constant across all sites. Finally, the median error for each site is mapped in Figure 21 below.

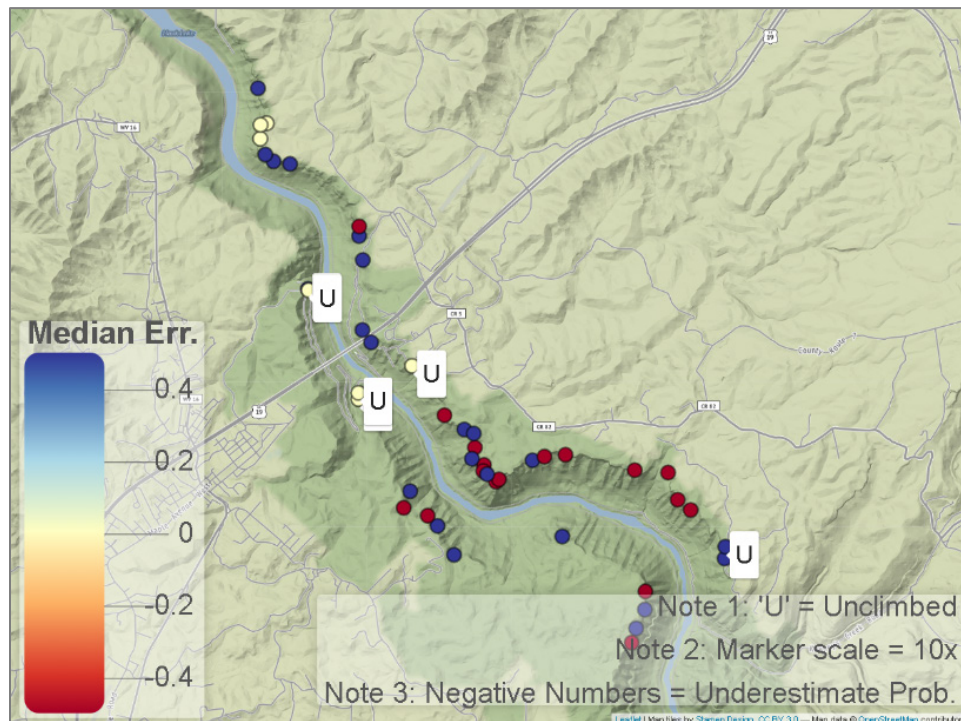


Figure 21. Northern long-eared bat (*Myotis septentrionalis*) median occupancy probability error.

Model Predictions

Table 25 presents several key estimates related to occupancy modeling. These include the latent occupancy estimates (z_i) for each wall, along with their 95% confidence intervals obtained using the ‘ranef’ function. The table also presents the observed occupancy (denoted as “1” for sites with at least one encounter), and the occupancy probability (ψ) at each wall, complete with its 95% adjusted confidence interval. Additionally, the table displays the estimated encounter probability, which is a combination of occupancy and detection probabilities. This encounter probability is symbolized by the Greek letter “ Ω ”.

Table 25. Northern long-eared bat (*Myotis septentrionalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Ambassador Buttress	Ambassador Buttress #2	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00
Beauty Mountain	Middle Beauty	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Ram's Head	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	The Brain	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Bridge Area	Overlook Buttress	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Rock Shelter Cave	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	The Pinnacle	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Bubba City	Ameless Wall	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00
	Ames Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	French Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Headless Wall	0 [0, 0]	0	0.01 (0.09) [1, 0]	0.00	0.00	0.00	0.00	0.00
	Little Head Wall	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00
	Rainbow Ledge Area	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Sandstonia - Decameron Area	1 [1, 1]	0	0.99 (0.08) [1, 0]	0.49	0.49	0.49	0.49	0.49

Table 25 (continued). Northern long-eared bat (*Myotis septentrionalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Domino Point	Domino Point	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Endless Wall	Diamond Point	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Fantasy Area	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Fern Cirque	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Fern Point Slabs	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Hellbound Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Idol Point	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Jacob's Ladder Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Kaymoor Slabs	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	The Undeserved Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Upper Endless	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Fern Buttress	Fern Creek Falls	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Ritz Cracker Area	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Star Trek Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50

Table 25 (continued). Northern long-eared bat (*Myotis septentrionalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Fern Buttress (continued)	Thieves Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Junkyard Area	Junkyard Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Zealous Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Kaymoor	Butcher's Branch	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Fire and Ice Buttress	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Seven-Eleven Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	The Hole	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	White Wall Area	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Keeney's Buttress	Keeney's Buttress	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Keeny's Buttress	Keeny's Buttress	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Long Point	Long Point #3	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00
	Long Point #4	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00
South Nuttall	Hueco Pillar	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	The Bitch	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50

Table 25 (continued). Northern long-eared bat (*Myotis septentrionalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
South Nuttall (continued)	The White Wall	1 [1, 1]	0	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Toxic Jesus Wall	1 [1, 1]	1	1 (0) [1, 0]	0.50	0.50	0.50	0.50	0.50
Sunshine Buttress	Sunshine Buttress #2	1 [1, 1]	0	1 (0.02) [1, 0]	0.50	0.50	0.50	0.50	0.50
	Sunshine Buttress #3	0 [0, 0]	0	0 (0) [1, 0]	0.00	0.00	0.00	0.00	0.00

Best Model – Index Analysis

In the following sections, the scaled indexes were examined within the model to pinpoint the most influential variables on each index. These influences, known as ‘coefficients’ in FAMD (similar to ‘loadings’ in PCA), represent the ‘weight’ of a variable level on a specific factor. Recall that FAMD assumes the observed variables, and associated levels if a categorical single coefficient. This discrepancy arises from the different natures of these variables. The coefficient analysis is conducted at an individual ‘variable level’, while the squared loading analysis occurs at the composite ‘variable’ level. This method ensures uniformity when juxtaposing qualitative and quantitative variables, thereby establishing a unified scale for a given comparison - be it measuring the correlation of an index with a whole variable (encompassing all potential categories) or gauging the influence of the most significant category on the index.

Factor Indices Concerning Occupancy (ψ)

Descriptive Factor Index ($i_{\text{descriptive}}$)

The interpretation of significant variables influencing the Descriptive Factor Index has been previously discussed in the section pertaining to eastern small-footed bats (*Myotis septentrionalis*). As these are independent variables, their characteristics remain constant across different species. Therefore, a single explanation applies universally. For a detailed interpretation, please refer to the aforementioned section.

Environmental Factor Index ($i_{\text{environmental}}$)

In evaluating the factor “Environmental”, the first principal component derived from the FAMD was utilized as a representative index. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of this index were generated. The index explains 26.48% of the total variance within the factor. Based on the bootstrap sample, the index explains on average 27.11% of the total variance within the factor with a standard deviation of 1.41% and a 95% confidence interval of [24.47%, 30%].

A 95% confidence interval (CI) was calculated for each variable level’s coefficients. Only those variables that had a level with a CI excluding zero were retained for display, implying at least one of their level coefficients was significantly non-zero. Of the 24 variable levels (24 variables) associated with this factor, 15 levels (15 variables) were retained for display. Collectively these variables account for 98.32% of the index’s variance. These variable levels are deemed to be important drivers of the index. The results of this analysis are present in Figure 22 and Table 26.

variable, are linear combinations of the underlying, unobserved factors, plus some level of error. The coefficients of the variables on this index therefore are used to predict coordinates (scores) of new observations. Understanding the magnitude and direction of these coefficients enables identification of which variables influence the index and, consequently, drive the model’s prediction of occupancy. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of each index’s coefficients were generated. A 95% confidence interval (CI) was then calculated for each variable’s coefficients. Only those variables that had a CI excluding zero were flagged for display, their loadings affirmed as significantly non-zero.

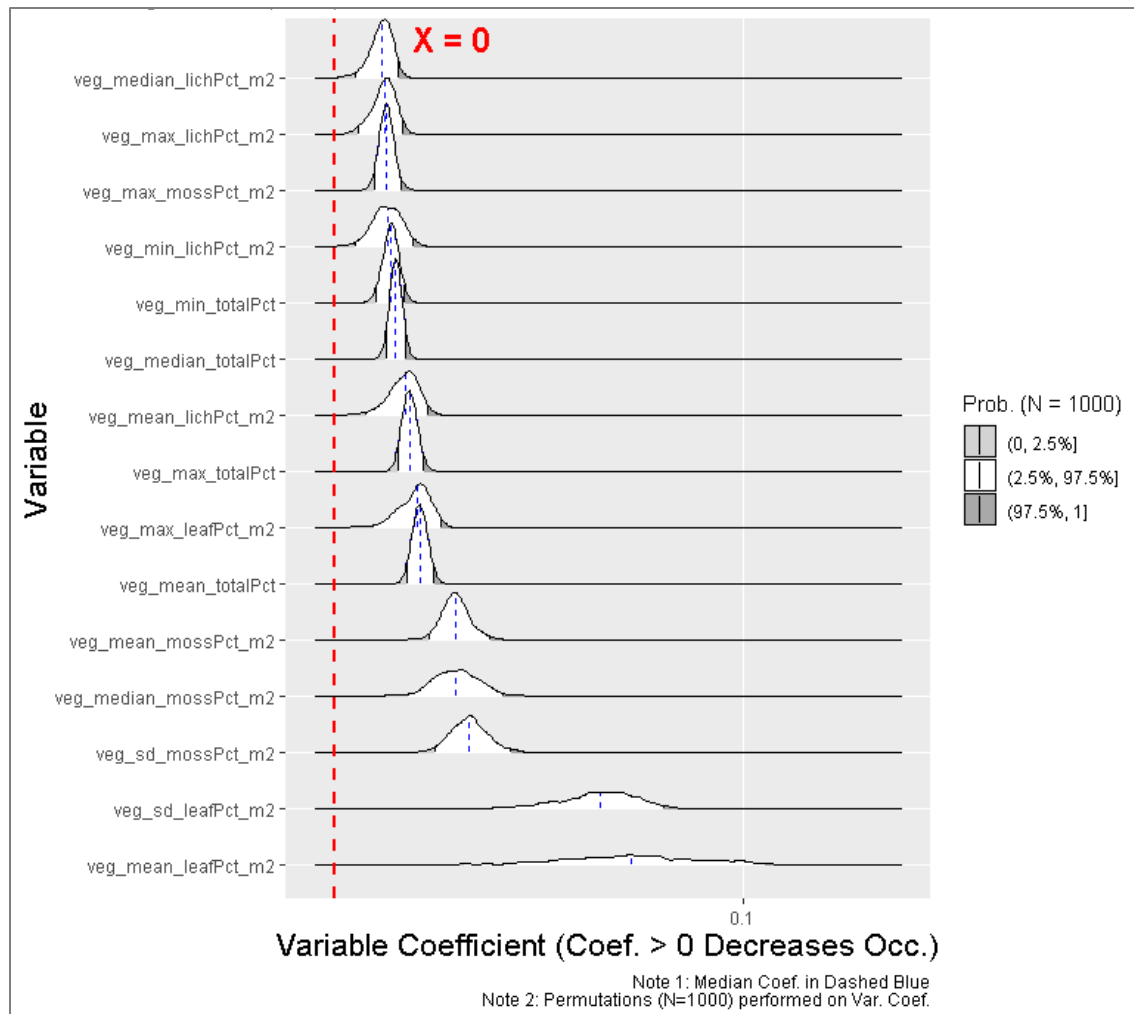


Figure 22. Key features affecting the “Environmental Index” for northern long-eared bats (*Myotis septentrionalis*).

Table 26. Northern long-eared bat (*Myotis septentrionalis*) – Environmental factor index summary.

Variable	Pct. Comp. Var.	Mean% (SD) Comp. Var.	95% CI Comp. Var.	Coef.	Mean (SD) Coef.	95% CI Coef.
veg_mean_totalPct	14%	14% (1%)	[11%, 16%]	0.02	0.02 (0)	[0.02, 0.02]
veg_median_totalPct	12%	12% (1%)	[9%, 14%]	0.02	0.02 (0)	[0.01, 0.02]
veg_max_totalPct	10%	10% (2%)	[6%, 12%]	0.02	0.02 (0)	[0.02, 0.02]
veg_mean_lichPct_m2	7%	7% (3%)	[1%, 12%]	0.02	0.02 (0)	[0.01, 0.02]
veg_max_mossPct_m2	6%	6% (2%)	[3%, 10%]	0.01	0.01 (0)	[0.01, 0.02]
veg_mean_mossPct_m2	6%	6% (2%)	[3%, 10%]	0.03	0.03 (0)	[0.02, 0.04]
veg_median_lichPct_m2	6%	6% (2%)	[1%, 10%]	0.01	0.01 (0)	[0.01, 0.02]
veg_min_totalPct	6%	6% (2%)	[3%, 9%]	0.01	0.01 (0)	[0.01, 0.02]

Table 26 (continued). Northern long-eared bat (*Myotis septentrionalis*) – Environmental factor index summary.

Variable	Pct. Comp. Var.	Mean% (SD) Comp. Var.	95% CI Comp. Var.	Coef.	Mean (SD) Coef.	95% CI Coef.
veg_sd_mossPct_m2	6%	6% (2%)	[3%, 9%]	0.03	0.03 (0)	[0.02, 0.04]
veg_max_lichPct_m2	5%	5% (2%)	[1%, 9%]	0.01	0.01 (0)	[0.01, 0.02]
veg_sd_leafPct_m2	5%	5% (2%)	[2%, 9%]	0.06	0.06 (0.01)	[0.04, 0.08]
veg_max_leafPct_m2	4%	4% (2%)	[1%, 7%]	0.02	0.02 (0)	[0.01, 0.03]
veg_mean_leafPct_m2	4%	4% (2%)	[1%, 8%]	0.07	0.07 (0.02)	[0.03, 0.11]
veg_median_mossPct_m2	4%	4% (2%)	[1%, 8%]	0.03	0.03 (0.01)	[0.02, 0.04]
veg_min_lichPct_m2	3%	3% (1%)	[0%, 6%]	0.01	0.01 (0)	[0.01, 0.02]

Another important quantity in FAMD is the ‘squared loadings’. These are used to understand the relationship between the original variables and the factors. These help distill the ‘theme’ or ‘essence’ of the index. In this case however, their analysis is of secondary importance due to the initial model-building phase, where variables were deliberately associated with ecologically significant factors. As the thematic interpretation of each index is already determined, the conventional application of squared loading analysis, to identify which variables are most accurately represented by each principal component, becomes less relevant. Instead, the focus shifts to understanding the variable coefficients first. That said, if a variable had a significant coefficient at any level, the entire variable was kept for display.

Though it may seem pedantic, it is important to highlight that each level of a categorical variable is assigned a distinct coefficient, whereas a continuous variable is represented by a

Interpretation

In Figure 22, the ridgeline plot depicts bootstrapped variable coefficient distributions along the X-axis and significant variable levels on the Y-axis. Due to the negative correlation presented in Table 11 ($i_{\text{environmental}} = -22.045$) and shown in Figure 18 and Figure 19, increasing a quantity or category right of the red dashed line increases the index value, thereby decreasing occupancy probability, whereas left of the line does the opposite.

Examining the distributions in Figure 22, all distributions are to the right of the red dashed line. The variable “veg_mean_leafPct_m2” is a quantitative variable. It is located at the bottom right, with a median coefficient of 0.07 (indicated by the blue dashed line). This negative coefficient is correlated with higher index values and, due to the negative relationship presented in Table 11, Figure 18, and Figure 19 its increase is linked with lower occupancy probabilities. Put simply, increasing this value is correlated with a decrease in occupancy probability.

As this is acoustic data, it appears that northern long-eared bats (*Myotis septentrionalis*) are more likely to be heard near less-vegetated walls.

Table 26 organizes variables based on their contribution to component variance, indicating how much each accounts for variance within the index. Examining the mean percent of component variation (Mean% (SD) Comp. Var.) reveals that “veg_mean_total_pct” is the variable that explains the most amount of variation in this component. However, the coefficients (Coef.) column shows that “veg_mean_leafPct_m2” is perhaps the most impactful, with changes in its value having a greater affect on the index’s value.

In simpler terms, Table 26 may be read one of two ways depending on the goal:

1. To grasp the index’s ‘theme’ or the variables most representative of it, consult the “Comp. Var.” columns. Larger values in these columns imply the variable explains more of the variation in the component. Though in this case, this is a somewhat redundant exercise due to the manual association of variables with ecologically meaningful themes, this step assures comprehensive understanding.
2. To identify which variables (or their categorical levels) statistically impact the ecologically significant index, examine the magnitude and direction of the “Coef.” columns. Changes by 1 unit on these variable levels changes the component output by the respective coefficient. Lower numbers on this index lead to higher abundance for this species per Table 26. (i_environment = -22.045).

Factor Indices Concerning Detection Probability (p)

A constant detection probability was used in this model, so there are no covariates to interpret.

Indiana Bat (*Myotis sodalis*)

Goodness of Fit

The results of the goodness of fit for the Full model for Indiana bats (*Myotis sodalis*) is shown in Table 27. It should be noted that $\hat{c} > 1$, implying “high” or “overdispersion”.

Table 27. Indiana bat (*Myotis sodalis*) – ‘Full Model’ goodness of fit summary.

Full Model	AIC	χ^2_{obs}	χ^2_{B} Parametric Bootstrap (N=1000)	χ^2_{obs} GOF p-value	Overdispersion Parameter Estimate ($\hat{c}$)
$\Psi(i_{\text{descriptive}} + i_{\text{environmental}} + i_{\text{physical}} + 1), p(i_{\text{inspection}} + 1)$	134.67	43.834	Min.: 1.967 1st Qu.: 20.182 Median: 31.427 Mean: 34.780 3rd Qu.: 44.279 Max.: 188.845	0.254	1.26

Overdispersion is a frequent occurrence in modeling and analyzing this type of data. This condition manifests when the dispersion parameter, which represents the variance in the response variable unaccounted for by the predictor variables, is particularly high. A high dispersion parameter indicates

a low level of homogeneity in the response variable, suggesting that the model is not able to explain a substantial portion of the observed variability.

Overdispersion may lead to less conservative estimates of uncertainty. Specifically, standard errors may be underestimated, confidence intervals may be narrower, and Type 1 error rates may be inflated. In practical terms, this means that our model is less cautious, making it more likely to identify effects without strong evidence for them.

A common solution to this problem (MacKenzie 2018) suggests inflating the standard error and adjusting the AIC selection criterion on the basis of the $\hat{c}$ value calculated from the global model [(Burnham and Anderson 2010) as cited in (MacKenzie 2018)]. This particular case is a textbook example and so we will expect to use Quasi-AIC corrected for smaller sample sizes (QAICc) and inflate the reported standard errors accordingly.

Single Covariate Gradients

To begin to understand how these scaled indices affect occupancy and detection, single variate plots are shown in Figure 23. Recall that the observed numerical range for each scaled index is shown in Table 3.

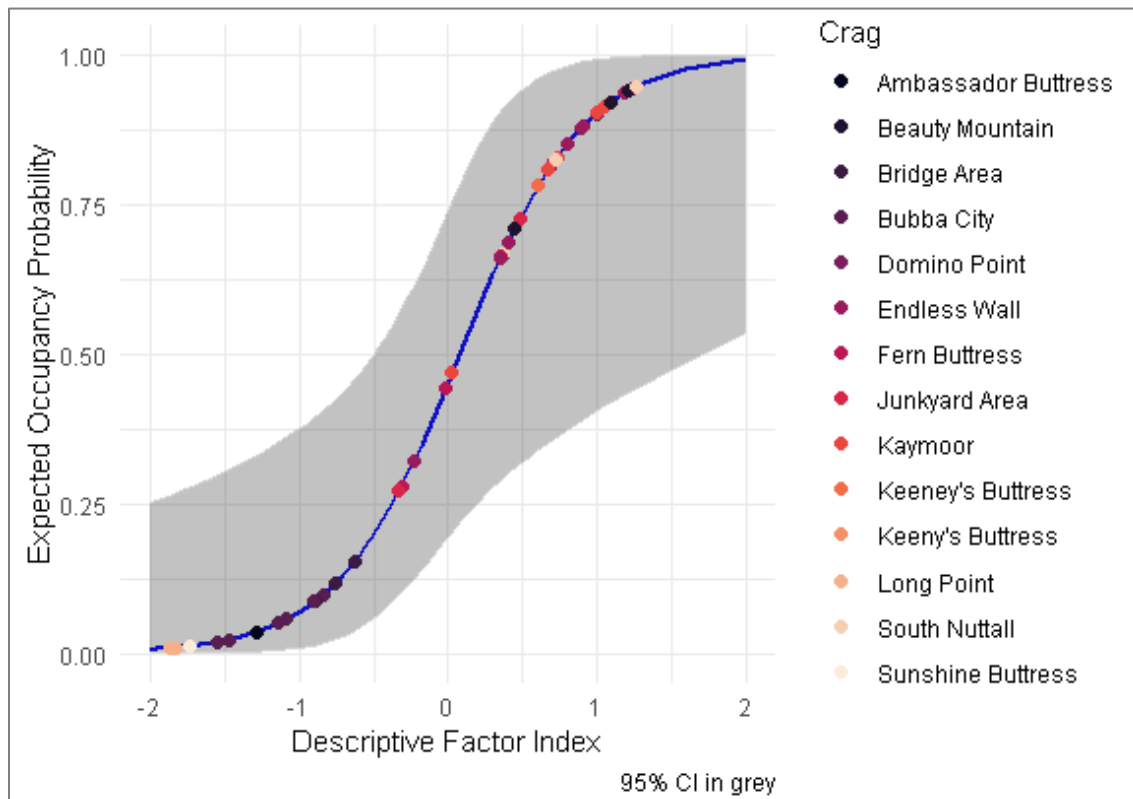


Figure 23. Indiana bat (*Myotis sodalis*) single variate plot, prediction of occupancy: Descriptive factor index.

For Occupancy, recall that the “Descriptive Factor Index” (Figure 23A) is the only index included in this process, so this piece of the model is fully represented here. Estimated occupancy probability does not rise above 0.8 until the scaled index rises above 0.63. For this project, the minimum estimated occupancy probability was 0.01 at a scaled index value of -1.87, the maximum estimated detection probability was 0.95 at a scaled index value of 1.27, and the average estimated detection probability was 0.51 with a standard deviation of 0.37.

Single variate plots for detection probability were not applicable since detection probability is modeled as a constant (Table 14).

Spatial Plots

The occupancy predictions and their uncertainty (SE) are mapped in Figure 24 below.

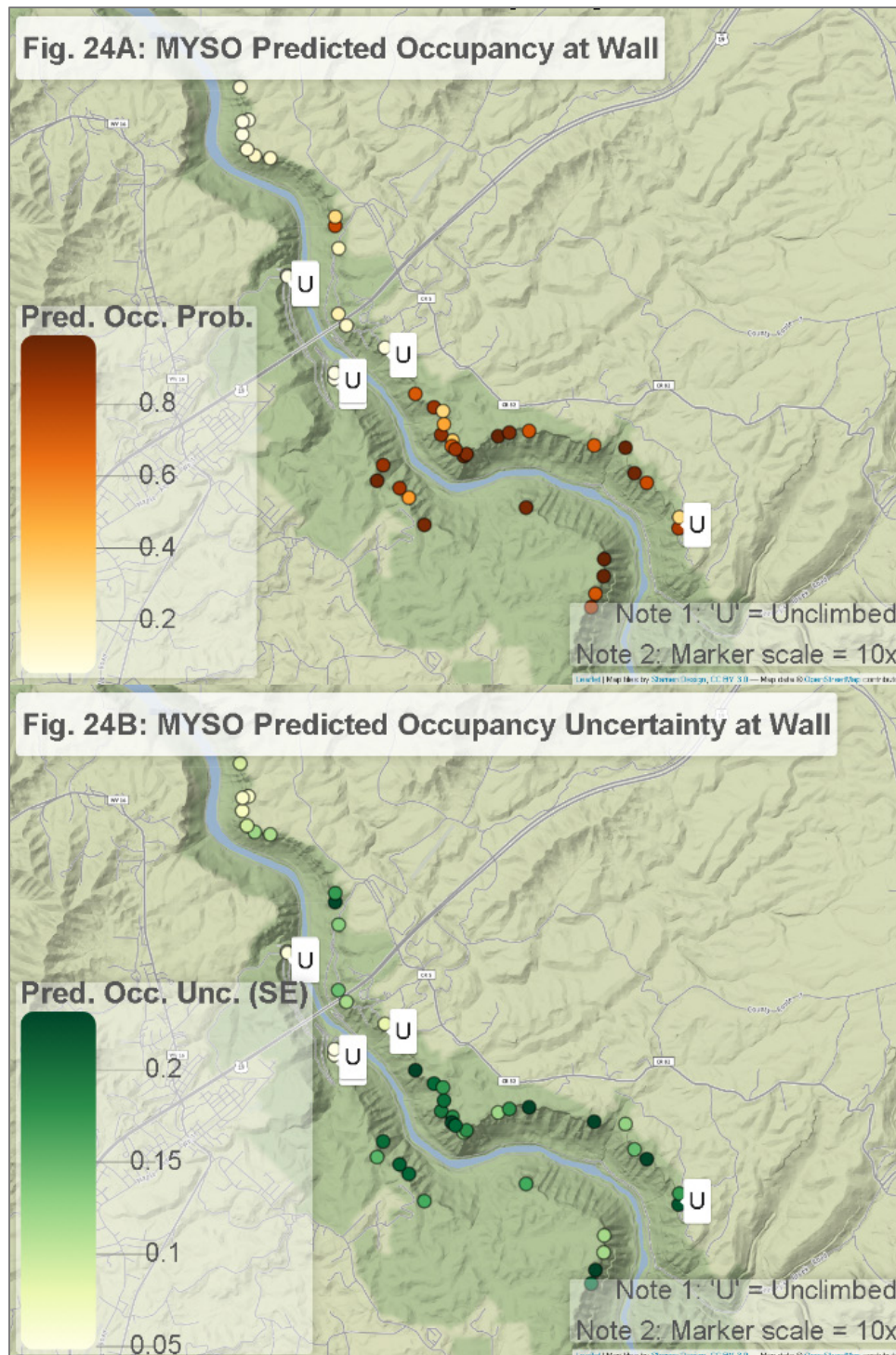


Figure 24. Indiana bat (*Myotis sodalis*, MYSO) predicted occupancy.

The detection probability and associated SE are not mapped as they are constant across all sites. Finally, the median error for each site is mapped in Figure 25 below.

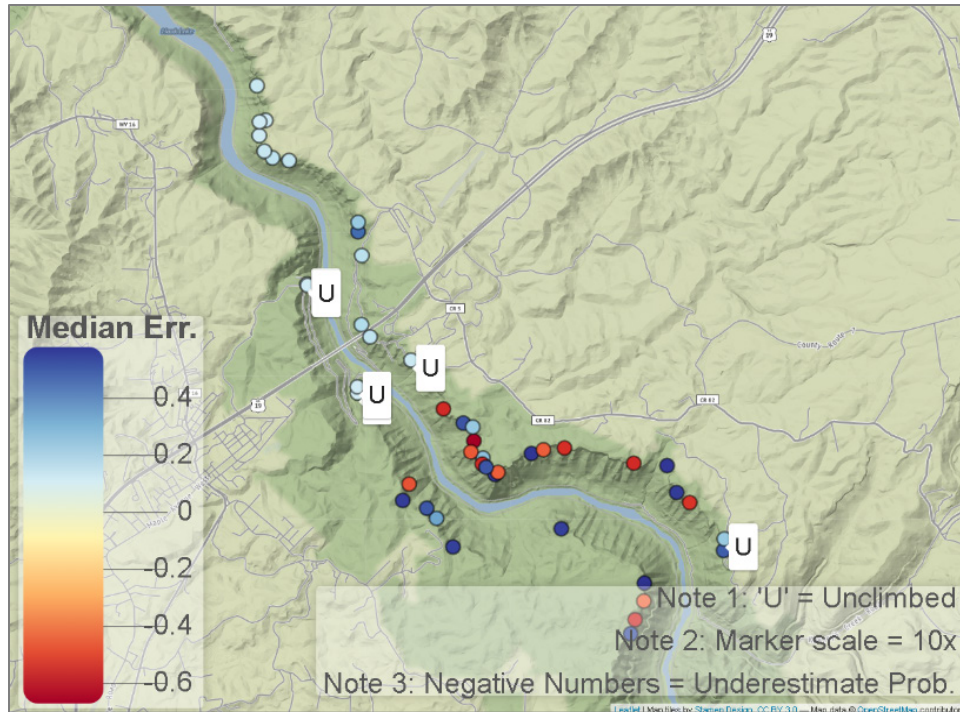


Figure 25. Indiana bat (*Myotis sodalis*) median occupancy probability error.

Model Predictions

Table 28 presents several key estimates related to occupancy modeling. These include the latent occupancy estimates (z_i) for each wall, along with their 95% confidence intervals obtained using the ‘ranef’ function. The table also presents the observed occupancy (denoted as “1” for sites with at least one encounter), and the occupancy probability (ψ) at each wall, complete with its 95% adjusted confidence interval. Additionally, the table displays the estimated encounter probability, which is a combination of occupancy and detection probabilities. This encounter probability is symbolized by the Greek letter “ Ω ”.

Table 28. Indiana bat (*Myotis sodalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Ambassador Buttress	Ambassador Buttress #2	0 [0, 0]	0	0.04 (0.05) [0.77, 0.05]	0.02	0.02	0.02	0.02	0.02
Beauty Mountain	Middle Beauty	1 [1, 1]	0	0.92 (0.12) [0.77, 0.05]	0.46	0.46	0.46	0.46	0.46
	Ram's Head	1 [1, 1]	1	0.71 (0.2) [0.77, 0.05]	0.35	0.35	0.35	0.35	0.35
	The Brain	1 [0, 1]	0	0.94 (0.1) [0.77, 0.05]	0.47	0.47	0.47	0.47	0.47
Bridge Area	Overlook Buttress	0 [0, 0]	0	0.09 (0.09) [0.77, 0.05]	0.04	0.04	0.04	0.04	0.04
	Rock Shelter Cave	0 [0, 0]	0	0.15 (0.11) [0.77, 0.05]	0.08	0.08	0.08	0.08	0.08
	The Pinnacle	0 [0, 0]	0	0.12 (0.1) [0.77, 0.05]	0.06	0.06	0.06	0.06	0.06
Bubba City	Ameless Wall	0 [0, 0]	0	0.02 (0.03) [0.77, 0.05]	0.01	0.01	0.01	0.01	0.01
	Ames Wall	0 [0, 0]	0	0.1 (0.09) [0.77, 0.05]	0.05	0.05	0.05	0.05	0.05
	French Wall	0 [0, 0]	0	0.06 (0.07) [0.77, 0.05]	0.03	0.03	0.03	0.03	0.03
	Headless Wall	0 [0, 0]	0	0.02 (0.04) [0.77, 0.05]	0.01	0.01	0.01	0.01	0.01
	Little Head Wall	0 [0, 0]	0	0.02 (0.03) [0.77, 0.05]	0.01	0.01	0.01	0.01	0.01
	Rainbow Ledge Area	0 [0, 0]	0	0.09 (0.09) [0.77, 0.05]	0.04	0.04	0.04	0.04	0.04
	Sandstonia - Decameron Area	0 [0, 0]	0	0.05 (0.06) [0.77, 0.05]	0.02	0.02	0.02	0.02	0.02

Table 28 (continued). Indiana bat (*Myotis sodalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Domino Point	Domino Point	1 [0, 1]	0	0.9 (0.13) [0.77, 0.05]	0.45	0.45	0.45	0.45	0.45
Endless Wall	Diamond Point	1 [1, 1]	0	0.94 (0.1) [0.77, 0.05]	0.47	0.47	0.47	0.47	0.47
	Fantasy Area	1 [1, 1]	0	0.94 (0.09) [0.77, 0.05]	0.47	0.47	0.47	0.47	0.47
	Fern Cirque	1 [1, 1]	0	0.32 (0.15) [0.77, 0.05]	0.16	0.16	0.16	0.16	0.16
	Fern Point Slabs	1 [1, 1]	1	0.85 (0.16) [0.77, 0.05]	0.42	0.42	0.42	0.42	0.42
	Hellbound Area	1 [1, 1]	1	0.88 (0.15) [0.77, 0.05]	0.44	0.44	0.44	0.44	0.44
	Idol Point	1 [1, 1]	1	0.66 (0.2) [0.77, 0.05]	0.33	0.33	0.33	0.33	0.33
	Jacob's Ladder Area	1 [1, 1]	1	0.69 (0.2) [0.77, 0.05]	0.34	0.34	0.34	0.34	0.34
	Kaymoor Slabs	0 [0, 1]	0	0.81 (0.18) [0.77, 0.05]	0.40	0.40	0.40	0.40	0.40
	The Undeserved Area	1 [1, 1]	1	0.88 (0.15) [0.77, 0.05]	0.44	0.44	0.44	0.44	0.44
	Upper Endless	1 [1, 1]	1	0.66 (0.2) [0.77, 0.05]	0.33	0.33	0.33	0.33	0.33
Fern Buttress	Fern Creek Falls	1 [1, 1]	1	0.44 (0.17) [0.77, 0.05]	0.22	0.22	0.22	0.22	0.22
	Ritz Cracker Area	0 [0, 1]	0	0.82 (0.18) [0.77, 0.05]	0.41	0.41	0.41	0.41	0.41
	Star Trek Wall	0 [0, 1]	0	0.28 (0.14) [0.77, 0.05]	0.14	0.14	0.14	0.14	0.14

Table 28 (continued). Indiana bat (*Myotis sodalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
Fern Buttress (continued)	Thieves Area	1 [1, 1]	1	0.66 (0.2) [0.77, 0.05]	0.33	0.33	0.33	0.33	0.33
Junkyard Area	Junkyard Wall	0 [0, 1]	0	0.73 (0.2) [0.77, 0.05]	0.36	0.36	0.36	0.36	0.36
	Zealous Area	0 [0, 1]	0	0.27 (0.14) [0.77, 0.05]	0.13	0.13	0.13	0.13	0.13
Kaymoor	Butcher's Branch	1 [1, 1]	0	0.91 (0.12) [0.77, 0.05]	0.45	0.45	0.45	0.45	0.45
	Fire and Ice Buttress	1 [1, 1]	0	0.47 (0.18) [0.77, 0.05]	0.23	0.23	0.23	0.23	0.23
	Seven-Eleven Wall	1 [1, 1]	1	0.83 (0.17) [0.77, 0.05]	0.41	0.41	0.41	0.41	0.41
	The Hole	1 [1, 1]	0	0.9 (0.13) [0.77, 0.05]	0.45	0.45	0.45	0.45	0.45
	White Wall Area	0 [0, 1]	0	0.81 (0.18) [0.77, 0.05]	0.40	0.40	0.40	0.40	0.40
Keeney's Buttress	Keeney's Buttress	0 [0, 1]	0	0.78 (0.19) [0.77, 0.05]	0.39	0.39	0.39	0.39	0.39
Keeney's Buttress	Keeney's Buttress	0 [0, 1]	0	0.27 (0.14) [0.77, 0.05]	0.13	0.13	0.13	0.13	0.13
Long Point	Long Point #3	0 [0, 0]	0	0.01 (0.02) [0.77, 0.05]	0.00	0.00	0.00	0.00	0.00
	Long Point #4	0 [0, 0]	0	0.01 (0.02) [0.77, 0.05]	0.00	0.00	0.00	0.00	0.00
South Nuttall	Hueco Pillar	1 [1, 1]	0	0.95 (0.09) [0.77, 0.05]	0.47	0.47	0.47	0.47	0.47
	The Bitch	1 [1, 1]	1	0.67 (0.2) [0.77, 0.05]	0.33	0.33	0.33	0.33	0.33

Table 28 (continued). Indiana bat (*Myotis sodalis*) – Model prediction summary.

Crag	Wall	Latent Occ. [CI]	Obs. Occ. (≥ 1)	Occ. Prob. (SE) [CI]	Ω1	Ω2	Ω3	Ω4	Ω5
South Nuttall (continued)	The White Wall	1 [1, 1]	1	0.95 (0.09) [0.77, 0.05]	0.47	0.47	0.47	0.47	0.47
	Toxic Jesus Wall	0 [0, 1]	0	0.83 (0.18) [0.77, 0.05]	0.41	0.41	0.41	0.41	0.41
Sunshine Buttress	Sunshine Buttress #2	0 [0, 0]	0	0.01 (0.02) [0.77, 0.05]	0.01	0.01	0.01	0.01	0.01
	Sunshine Buttress #3	0 [0, 0]	0	0.01 (0.02) [0.77, 0.05]	0.01	0.01	0.01	0.01	0.01

Best Model – Index Analysis

In the following sections, the scaled indexes were examined within the model to pinpoint the most influential variables on each index. These influences, known as ‘coefficients’ in FAMD (similar to ‘loadings’ in PCA), represent the ‘weight’ of a variable level on a specific factor. Recall that FAMD assumes the observed variables, and associated levels if a categorical variable, are linear combinations of the underlying, unobserved factors, plus some level of error. The coefficients of the variables on this index therefore are used to predict coordinates (scores) of new observations. Understanding the magnitude and direction of these coefficients enables identification of which variables influence the index and, consequently, drive the model’s prediction of occupancy. Using a stratified non-parametric bootstrap method, segmented by crag and presence, 1,000 samples of each index’s coefficients were generated. A 95% confidence interval (CI) was then calculated for each variable’s coefficients. Only those variables that had a CI excluding zero were flagged for display, their loadings affirmed as significantly non-zero.

Another important quantity in FAMD is the ‘squared loadings’. These are used to understand the relationship between the original variables and the factors. These help distill the ‘theme’ or ‘essence’ of the index. In this case however, their analysis is of secondary importance due to the initial model-building phase, where variables were deliberately associated with ecologically significant factors. As the thematic interpretation of each index is already determined, the conventional application of squared loading analysis, to identify which variables are most accurately represented by each principal component, becomes less relevant. Instead, the focus shifts to understanding the variable coefficients first. That said, if a variable had a significant coefficient at any level, the entire variable was kept for display.

Though it may seem pedantic, it is important to highlight that each level of a categorical variable is assigned a distinct coefficient, whereas a continuous variable is represented by a single coefficient. This discrepancy arises from the different natures of these variables. The coefficient analysis is conducted at an individual ‘variable level’, while the squared loading analysis occurs at the composite ‘variable’ level. This method ensures uniformity when juxtaposing qualitative and quantitative variables, thereby establishing a unified scale for a given comparison - be it measuring the correlation of an index with a whole variable (encompassing all potential categories) or gauging the influence of the most significant category on the index.

Factor Indices Concerning Occupancy (ψ)

Descriptive Factor Index (i_descriptive)

The interpretation of significant variables influencing the Descriptive Factor Index has been previously discussed in the section pertaining to eastern small-footed bats (*Myotis leibii*). As these are independent variables, their characteristics remain constant across different species. Therefore, a single explanation applies universally. For a detailed interpretation, please refer to the aforementioned section.

Factor Indices Concerning Detection Probability (p)

A constant detection probability was used in this model, so there are no covariates to interpret.

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