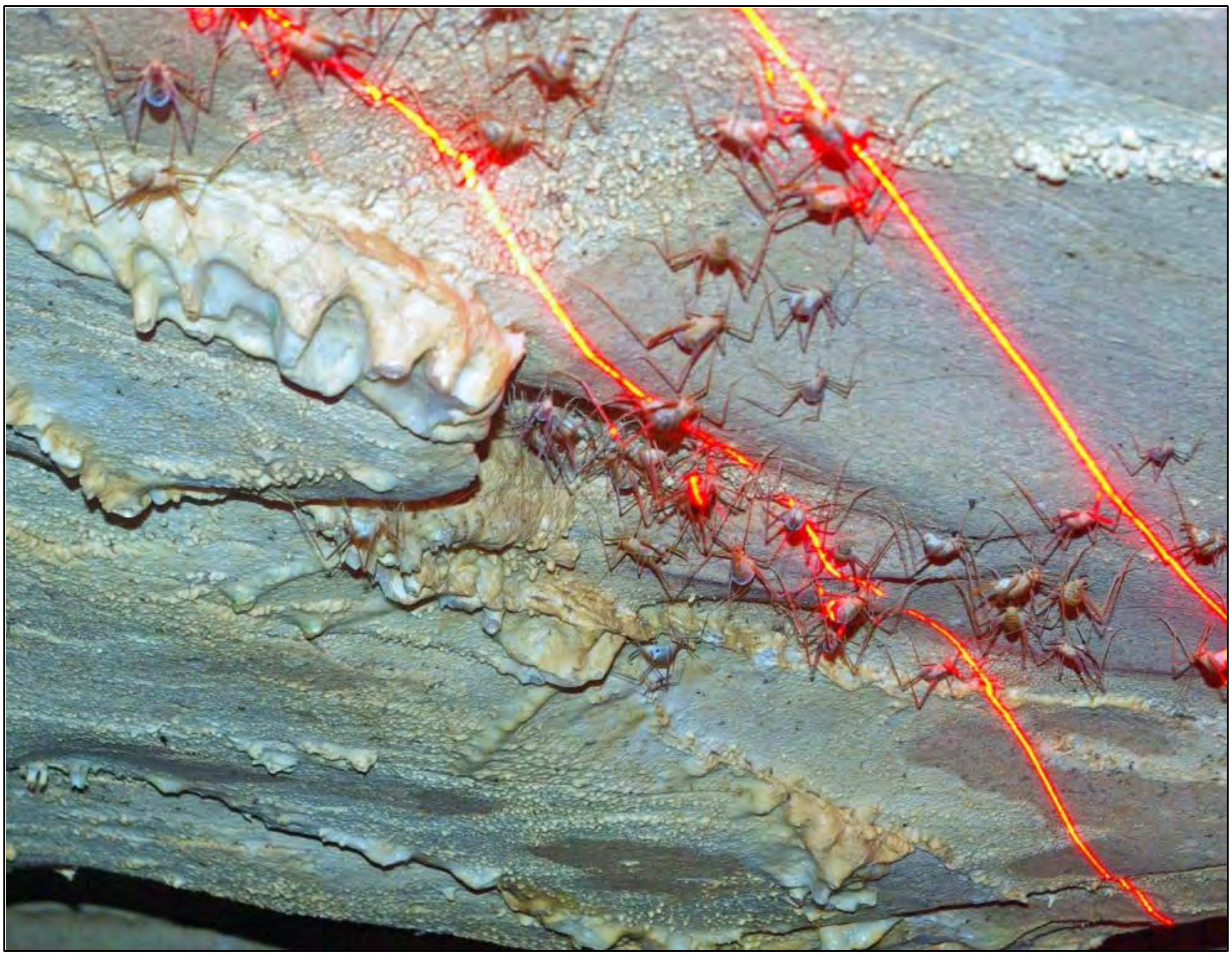
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

A Protocol for Monitoring Cave Crickets (*Hadenoecus subterraneus*) at Mammoth Cave National Park

Version 1.0

Natural Resource Report NPS/CUPN/NRR—2015/934



ON THE COVER
Cluster of cave crickets captured within laser transect during strip adaptive cluster sampling at Mammoth Cave National Park.
NPS photo

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Change History

Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affect requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures for publication in the series.

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

Contents

Contents (continued)

Contents (continued)

Figures

Tables

Standard Operating Procedures (SOPs) Associated with this Protocol Version

Page

Appendices

Page

Executive Summary

The mission of the National Park Service is—to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations‖ (National Park Service 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories, and expanded resource monitoring (National Park Service 1999). Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring networks.

All Inventory and Monitoring networks within the National Park Service have identified high priority park vital signs, indicators of ecosystem health, which represent a broad suite of ecological phenomena operating across multiple temporal and spatial scales. Our intent has been to develop a balanced and integrated suite of vital signs that meets the needs of current park management, and that also will accommodate unanticipated environmental conditions and management questions in the future. Four parks in the Cumberland Piedmont Network (CUPN) selected various vital signs within their cave ecosystems as requiring long-term monitoring. One focal resource selected for long-term monitoring by resource managers at Mammoth Cave National Park (MACA) was cave crickets (*Hadenoecus subterraneus*). Cave crickets ranked first among proposed cave organism populations for monitoring at MACA because they act as a conduit for the transfer of nutrients between the surface and cave communities dependent upon these nutrients (Poulson and Lavoie 2000). Natural stressors that affect foraging cave crickets' ability to access primary productivity on the surface, such as contingent climatic conditions (e.g., extremes in maximum temperature and precipitation events across the Southeast predicted by mid-century), can alter the amount of nutrient subsidies they transfer to dependent subsurface communities. Stressors foreign to the cave ecosystem (e.g., cave entrance configuration altered by management actions) can also affect the flow of organic matter subsidies into caves due to their effects on cave cricket foraging behavior and population structure. Given the importance of cave crickets to subsurface ecosystems monitoring of their entrance populations will provide park managers with an early warning of potential trouble with cave ecosystem health and contribute significantly toward managing and protecting their populations.

Monitoring objectives addressed by this protocol are:

1. To determine the status and trend of cave cricket entrance population size, life stage, and sex ratio among 15 developed and undeveloped cave entrances at Mammoth Cave National Park during biannual visits.

2. To determine effects of management decisions (e.g., tour infrastructure improvement) at Mammoth Cave National Park on cave cricket populations within selected developed caves. Specific monitoring foci will include assessment of the impact of cave-entrance modification on cave cricket population size and structure and localized impacts of infrastructure installation/improvement on cave cricket habitat use.

3. To determine if a correlation exists between cave temperature, relative humidity and air flow trends, surface temperature, relative humidity and precipitation trends and: 1) trends in cave cricket entrance population size, life stage, and sex ratio, and 2) trends in spatial distribution within 15 developed and undeveloped cave entrances in Mammoth Cave National Park using biannual and continuous automated sampling.

This protocol is focused on monitoring cave cricket entrance populations inhabiting 15 selected cave entrances within MACA. Under our sampling design, data are collected twice per year. Our method takes advantage of cave crickets' tendency to roost in clusters, and consists of digital images of clusters intersected by randomly located 10cm wide strips perpendicular to a transect extending the length of the cave entrance. Analysis of the digital images yields count data which enable us to estimate the total cave cricket entrance population size at a given cave entrance (Monitoring Objective 1). Our sampling design automatically partitions cave cricket entrance population size into components of cluster size and numbers of clusters which will be used to assess temporal changes in population size and habitat use within and between developed and undeveloped cave entrances (Monitoring Objective 2). Meteorological data will be collected from local subsurface and surface habitats. Cave meteorological data will be collected using two methods. First, opportunistic grab sampling uses handheld sensors to measure cave air temperature, relative humidity, and air flow at roosting clusters. Second, continuous sampling uses automated dataloggers to continuously collect cave air temperature and relative humidity measurements for a period of time in all 15 sampled cave entrances. Finally, surface temperature, relative humidity, and precipitation are continuously collected by a local automated weather station. These meteorological data will be used to assess whether correlations exist between trends in surface and/or subsurface meteorological conditions and cave cricket entrance populations and habitat use (Monitoring Objective 3).

This protocol details the why, where, how, and when of the MACA cave cricket monitoring program. As recommended by Oakley et al. (2003), it consists of a protocol narrative and a set of standard operating procedures (SOPs) which detail the steps required to collect, manage, and disseminate the data representing the status and trend of cave cricket entrance populations and associated habitat parameters at MACA. The protocol is a living document in the sense that it is continually updated as new information acquired through monitoring and evaluation leads to the refinement of program objectives and methodologies. Changes to the protocol are carefully documented in a revision history log. The intent of the protocol is to ensure that a scientifically credible story about the ecological condition of cave crickets and their responses to contingent climatic conditions, park management actions, land use changes, and other stressors can be told to park visitors and managers alike. These long-term data can contribute to the development of informative models of relationships between cave cricket entrance population dynamics and key environmental factors and management actions by MACA resource managers.

Acknowledgments

Funding for this project was provided through the National Park Service Natural Resource Challenge and the Servicewide Inventory and Monitoring Program. Many people contributed to the development of this protocol. Their assistance and advice improved the document, while any errors or omissions are solely the responsibility of the authors. We thank USGS-Biological Resources Division Ecologist R. Woodman for his lead in the development of the protocol's previous version. We thank Mammoth Cave National Park's Science and Resources Management staff who met with us to discuss, prioritize, and select cave ecosystem vital signs and who provided invaluable feedback on this protocol: B. Carson, R. Olson, and R. Toomey. We thank Mammoth Cave National Park interns C. Dewildt, D. Foster, T. Granke, M. Mahan, A. Nollman, K. O'Neill and, J. Taylor for their hard work and long hours in the field testing the methods we developed. Cumberland Piedmont Network staff J. Jernigan, T. Leibfreid, B. Wells, and R.Woodman provided valuable input throughout protocol development and gave constructive comments that improved the document. Cumberland Piedmont Network intern C. Bledsoe provided valuable input and gave constructive comments that improved the document. Field support from NPS personnel Johnathan Jernigan is greatly appreciated. We acknowledge logistical support from R. Toomey and S. Trimboli. We thank volunteers T. Green, P. Kambesis, A. Tester, and D. West. We are grateful to the anonymous reviewers for their constructive comments that improved the document.

Introduction

Background

Most cave ecosystems do not support primary productivity but rather depend on the transport of organic matter from the surface by both passive (e.g., water) and active (e.g., cave crickets) agents (Culver and Pipan 2009, Schneider 2009). Ecosystems that depend on subsidies, such as caves, are vulnerable to perturbations that affect the production, transfer, and use of those subsidies (Riley and Jefferies 2004). Perturbations on a regional and local scale can affect productivity on the surface and the ability of surface-feeding cave organisms to access it and thus alter the amount of the subsidy being transferred to the subsurface. Important insights into the individual and collective effects of local changes on actively subsidized cave terrestrial ecosystems in the southeast can be gained through assessing the modulation of cave cricket entrance populations.

Cave crickets (*Euhadenoecus* and *Hadenoecus* sp.) are commonly found roosting in high densities just inside cave entrances throughout the southeastern United States (Figure 1). They are omnivores that feed on the surface and transfer nutrients-in the form of guano, eggs, and bodies-into the subsurface habitat. In the Mammoth Cave region cave crickets (*Hadenoecus subterraneus*) are a keystone species in that their entrance populations subsidize up to

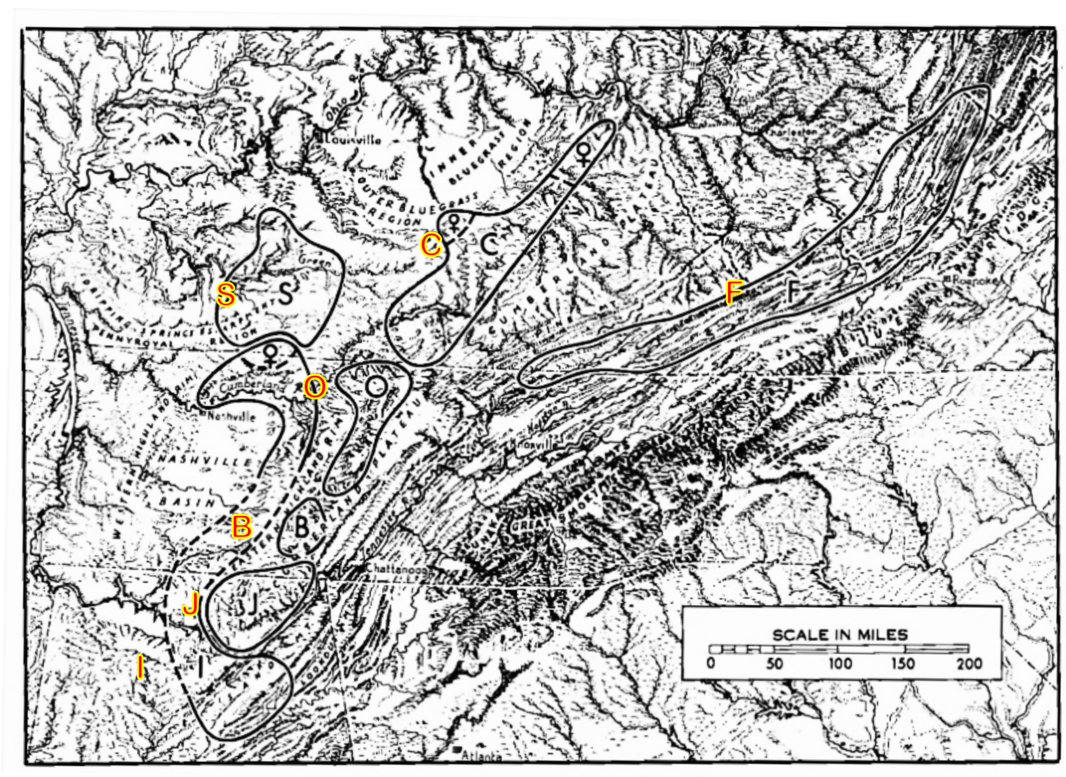


Figure 1. Distribution of southeastern cave-dwelling species of *Euhadenoecus* and *Hadenoecus*. F=*E. fragilis*, I=*E. insolitus*, C=*H. cumberlandicus*, S=*H. subterraneus*¸ O=*H. opilinoides*, B=*H. barri*¸ J=*H. jonesi*. (Hubbell and Norton 1978).

three separate cave invertebrate communities through the active, regular transfer of organic matter from the surface to the subsurface (Poulson and Lavoie 2000, Lavoie et al. 2007). The communities they subsidize can include rare, sometimes endemic, obligate cave-dwelling invertebrates (Culver et al. 2000).

Conceptual Models for Ecosystems

The development of conceptual ecological models is a critical step in the design of a long-term monitoring program the utility of which is well-established (Elzinga et al. 2001, Noon and Dale 2002). Conceptual models are an important heuristic device that aid in the organization and synthesis of information regarding various ecosystem components and their complex interactions. The planning of a monitoring program is also improved through the discussion, evaluation, and refinement engendered during conceptual model's development process of (Maddox et al. 1999). CUPN personnel developed a conceptual model specifically focused on cave crickets (Figure 2) which we used to develop hypotheses regarding important stressors likely to affect their entrance populations at Mammoth Cave National Park (MACA) (Leibfreid et al. 2005).

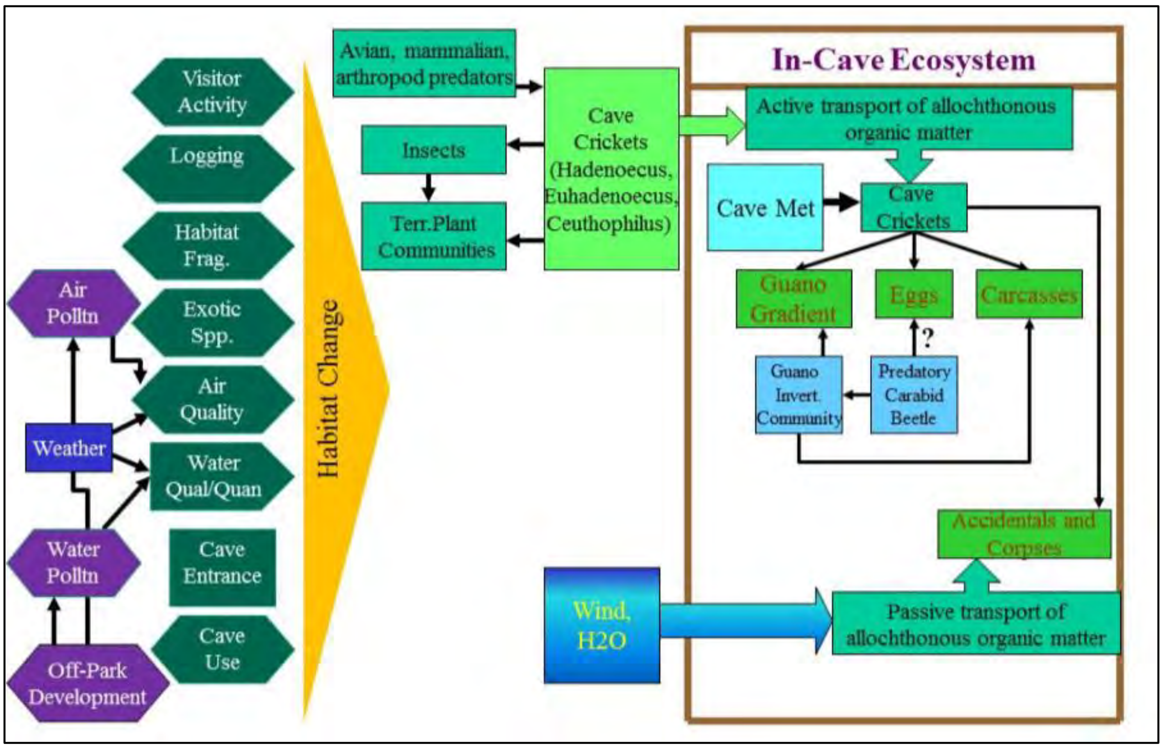


Figure 2. Terrestrial cave invertebrate community conceptual model showing active (cave crickets) and passive (wind and water) transporters of organic subsidies from the surface. Note potential regional (purple/blue) and local (green) influences on surface productivity and its availability for transport and accessibility to cave crickets. Cave Met=Cave Meteorology.

Ecosystem Drivers, Stressors, and Attributes

The CUPN Vital Signs Monitoring Plan (Leibfreid et al. 2005) described the major drivers, stressors, and primary ecosystem attributes associated with cave ecosystems of the Network. We relied on that document, in addition to the literature and personal experience, to determine key ecosystem attributes and stressors of cave terrestrial communities that should be considered during the development of the cave cricket monitoring protocol. Ecosystem *attributes* are any inherent measurable biotic or abiotic factor or environmental process. Ecosystem *drivers* are major natural forces, such as climate and hydrological cycles, and natural disturbances, such as droughts and floods, with large-scale influences on the attributes of monitored systems. *Stressors* are defined as perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive or insufficient level (Barrett et al. 1976). Stressors can include natural disturbances such as flooding but more frequently represent anthropogenic alterations of natural processes or structures [(e.g., water pollution, pesticides, cave development) (Noon and Dale 2002)].

Major ecosystem drivers/attributes in cave ecosystem models include surface weather, in-cave atmospheric conditions ("Cave Met" in Figure 2, *cave meteorology* hereafter), air quality, and water quality/quantity. Ecosystem attributes important to cave crickets include regional and local climate and terrestrial vegetation communities. Key ecosystem stressors include air/water pollution, habitat fragmentation (e.g., land use change), human disturbance such as the development of infrastructure to facilitate cave use (Figure 2).

Some ecosystem drivers, attributes and stressors will be monitored at MACA either under this monitoring protocol (i.e., cave meteorology), or other monitoring programs (i.e., vegetation community, water quality/quantity, air quality, land use change, and weather). When possible, with careful attention to matching temporal and spatial scales, we will examine how trends in these other datasets might correlate with estimates of cave cricket entrance populations and observed changes in their habitat use. Cave crickets co-occur in caves with other vital signs currently monitored (i.e., bats, woodrats) or planned for monitoring (i.e., cave aquatic biota) in MACA. Cave crickets are strongly linked to cave meteorological parameters such as air temperature and relative humidity (Lavoie et al. 2007, Woodman et al. 2012) but weakly linked with the three aforementioned cave vital signs. This reflects the multi-faceted approach for monitoring MACA's resources adopted by the CUPN wherein ecological indicators were chosen from broad categories such as ecosystem drivers, stressors, focal resources of parks, and key properties of ecosystem integrity (Leibfreid et al. 2005). Ecological integration among system drivers, components, structures and functions was considered when CUPN vital signs were selected. Thus, the results obtained from monitoring the selected suite of vital signs should provide a comprehensive understanding of the ecosystem condition of selected park caves, as well as, the status of resources of management interest.

Rationale for Monitoring Cave Crickets

Cave ecosystems were selected as a focal resource during the 2002 scoping process to determine critical ecosystem parameters for monitoring at MACA. In the cave ecosystem components category for the MACA prototype program the abundance and distribution of cave crickets ranked first among the proposed cave organism populations for monitoring (Leibfreid et al. 2005). The Cave Nutrients pathway ranked second in importance among 18 ranked pathways on the park and the status and trends of nutrient inputs ranked fourth in the top ten most significant resource management questions at MACA (Leibfreid et al. 2005). These rankings established the significance of monitoring cave cricket entrance populations and habitat use in MACA caves.

Perturbations affecting the availability of surface resources to cave crickets, such as contingent climatic conditions, can alter the amount of nutrient subsidies they transfer to their dependent subsurface communities. Poulson et al. (1995) showed conditions favorable to cave crickets foraging on the surface (i.e., warm winters, cool summers, and above average precipitation) were correlated with the highest abundance and diversity of the cave invertebrate community dependent on cave cricket guano and declined in years with cold winters, hot summers, and below average precipitation. Helf's (2003) study provided rigorous support for Poulson et al.'s (1995) data in that it showed a significant inverse relationship between cave crickets' use of artificial bait patches and precipitation among growing seasons, strongly suggesting cave crickets fed more on artificial bait patches due to decreased primary productivity on the surface.

Extremes in maximum temperature and precipitation events across the Southeast, predicted by mid-century (Fisichelli 2013, Kunkel et al. 2013), could lead to reduced primary productivity on the surface. While precipitation and primary productivity are often positively correlated the predicted concomitant temperature increases may increase evaporation and so lead to a net loss in moisture available to surface communities (Young et al. 2011). Drier surface conditions may directly reduce the amount of organic material available to cave crickets or indirectly reduce its availability by creating suboptimal foraging conditions that preclude cave cricket foraging bouts (Studier et al. 1987, Poulson et al. 1995, Helf 2003, Lavoie et al. 2007). On the other hand, minimum temperatures below freezing are also predicted to decrease by 20-25 days/year (Fisichelli 2013) which suggests increased foraging opportunities for cave crickets during winter months. Increases in winter foraging opportunities may compensate for decreased foraging opportunities in summer.

Management actions, such as altered cave entrance configuration, can also affect the flow of allochthonous organic matter into caves due to their effects on cave cricket foraging behavior and population structure (Fry 1996, Poulson et al. 2000, Helf 2003). Indeed, from 1993-1996, MACA facilities and resources management personnel retrofitted cave entrance doors with airlocks to mitigate the negative effects of cold, dry winter air on the growth and formation of speleothems and biological communities (Fry 1996). To assess the potential effects of this program MACA funded visual censuses of cave cricket populations at nine cave entrances, six with varying degrees of anthropogenic modification and three without, from 1994-1998. Among all cave entrances overall cave cricket abundance declined significantly from 1994-1997 (Poulson et al. 2000).

Rationale for Monitoring Cave and Surface Meteorology in Connection to Cave Crickets

Meteorological parameters on the surface and in caves (e.g., temperature and relative humidity) are major drivers of cave ecosystems (Tuttle and Stevenson 1977, Poulson et al. 1995). For example, variable climatic conditions over a thirty year period at MACA affected the favorability of surface foraging conditions for cave crickets causing fluctuations in the amount of cricket guano available to the guano community. Reduced availability of guano subsidies resulted in a long-term decline in guano community populations (Poulson et al 1995, Helf 2003). In addition, the density of cave crickets roosting inside cave entrances is affected by temperature, humidity changes, and air flow (Yoder et al. 2002). Further, both anthropogenic stressors (e.g., in-cave or entrance modifications) and natural processes (e.g., rockfall) can effect large-scale changes to cave meteorology. Thus, we decided to collect cave and surface meteorological data as components of this monitoring protocol. Correlations between trends in surface and/or cave meteorological parameters [e.g., cave temperature, relative humidity (RH), air flow, and precipitation] and cave cricket entrance populations and their habitat use should be of particular interest to park managers, speleobiologists, and the broader scientific community.

Monitoring Goal and Objectives

The overall purpose of natural resource monitoring in parks is to develop scientifically rigorous information on the status and trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. Use of monitoring information will increase confidence in manager's decisions and improve their ability to manage park resources, and will allow managers to confront and mitigate threats to the park and operate more effectively in legal and political arenas (National Park Service 2012). Some recent monitoring protocols have identified specific thresholds or trigger points for management actions. While we are not prepared to provide such thresholds in this version of the protocol we intend to work with MACA management personnel, as they complete planning and management documents (e.g., Natural Resource Condition Assessment, State of the Park, and Resource Stewardship Strategy), to develop future thresholds or reference conditions.

Toward that end we developed a primary monitoring goal with three monitoring objectives:

Primary Monitoring Goal:
Assess status and trends of cave cricket entrance populations and their habitat use.

Monitoring Objective 1:

To determine the status and trend of cave cricket entrance population size, life stage, and sex ratio among 15 developed and undeveloped cave entrances at Mammoth Cave National Park during biannual visits.

Monitoring Objective 2:

To determine effects of management decisions (e.g., alteration of cave entrances) at Mammoth Cave National Park on cave cricket populations within selected developed caves. Specific monitoring foci will include assessment of the impact of cave-entrance modification on cave cricket population size and structure and localized impacts of infrastructure installation/improvement on cave cricket habitat use.

Monitoring Objective 3:

To determine if a correlation exists between cave temperature, relative humidity and air flow trends, surface temperature, relative humidity and precipitation trends and: 1) trends in cave cricket entrance population size, life stage, and sex ratio, and 2) trends in spatial distribution within 15 developed and undeveloped cave entrances in Mammoth Cave National Park using biannual and continuous automated sampling.

Sampling Design

There are challenges inherent to monitoring the cave entrances distributed across MACA's large landscape. For example: 1) the accuracy and precision of measurements required to detect meaningful change among cave entrances, 2) the large sample sizes and extensive sampling required to reflect the natural variability found among cave entrances that, while qualitatively similar, present unique sampling spaces with inherent structural complexity and size, and 3) accessing the widely distributed cave entrances across karst landscapes like MACA's present logistical constraints on available time and staff. Our sampling design is an attempt to balance the benefits of extensive monitoring to meet our objectives (i.e., to detect both the status and trends in cave cricket entrance populations) with the logistical constraints of accessibility, safety issues and costs. Our sampling design also reflects our desire to provide substantial information for MACA's resource managers on a limited number of cave cricket entrance populations, including most of MACA's developed entrances. Therefore, we accept the limits to sample size, spatial extent, and subsequent scope of inference that result from this compromise.

Sample Frame

For this protocol the overall statistical population of interest is the set of cave crickets using a set of cave entrances in MACA. Inferences will be made comparing cave cricket entrance populations between developed (i.e., entrances with bat gate or door(s), significant modification to its entrance/passage or significant infrastructure, such as a lighting system, or regular tours) and undeveloped entrances (i.e., entrance with or without bat gate, light or no modification to its entrance/passage or no infrastructure or no tours). Because neither a complete census of cave entrances nor a complete census of cave cricket entrance populations is possible, this monitoring protocol requires two separate sampling frames: the selection of which cave entrances to monitor and defining how to sample within cave entrances. Such multi-stage sampling designs (Thompson 2002) are common for large-scale environmental surveys. At the broad level of entrances, our sample frame consists of 15 cave entrances within MACA's boundary stratified by management status [(i.e., developed or undeveloped) (Figure 3 and Table 1)].

Table 1. Fifteen cave entrances in Mammoth Cave National Park, stratified by development status, selected for monitoring cave cricket entrance populations.

Undeveloped Cave Entrances	Developed Cave Entrances
Crockpot	Austin
Little Beauty	Carmichael
Martin	Floyd Collins Crystal
Salts	Frozen Niagara
Silent Grove Springhouse	Great Onyx
Sloan's Crossing #3	Mammoth Cave (Historic Entrance)
Temple Hill	New Discovery
White	

We did not sample probabilistically among all of MACA's 400+ cave entrances to populate our sample frame because the geology in the MACA region is such that the cave-bearing limestone is on a South-North gradient. North of the Green River the caves become sparse and many are too small, require vertical experience, or have negligible cave cricket populations. To find undeveloped caves for our sample frame we searched through MACA's "Lesser Cave Inventory" database (i.e., a database of cave entrances at MACA) using a rating procedure to eliminate caves that did not meet our sampling frame constraints (Appendix A). We winnowed this list down with a series of field visits wherein we eliminated caves not easily accessed or hazardous. Typically, we sampled the entire passage among these generally shorter undeveloped caves. Most of MACA's few developed cave entrances met the constraints we imposed on sampling sites (e.g., safety, accessibility, and resource sensitivity). Developed cave entrances are typically part of much longer cave systems and, given cave cricket abundance is highest near cave entrances, we sample only a portion of the first 100m of passage. Unfortunately, most of the undeveloped caves in our sample frame were not suitable for a true paired case-control in that they are not near developed entrances and of similar size. Since our sample frame was not chosen probabilistically we cannot use design-based inferences to go from the 15 entrances to the frame of 400+ entrances in MACA. Because neither a complete census of cave entrances nor a complete census of cave cricket entrance populations is possible, our target population requires a multistage, adaptive sampling design (Thompson 2002, Salehi and Seber 2013) for defining how to sample within cave entrances.

Sampling within Cave Entrances

The within-entrance component of cave cricket sampling is designed to provide estimates of the total number of crickets in that entrance, separate estimates of numbers of individuals by life stage and sex, and estimates of counts as a function of distance from the opening to the surface. Entrances are large enough that complete enumeration of crickets is impossible without great risk to personnel safety and damage to resources, so sampling is required. Figure 4 shows a rough sketch of the varying widths of a portion of the Frozen Niagara Entrance to Mammoth Cave, essentially a horizontal slice through the passageway. However, the crickets are found on the walls and ceilings of the passageway. Because the passageways are so irregular, it is difficult to define the surface area to use as a simple area-based sample frame. Further, even if the total surface could be measured, there is no practical way to map equal areas into a grid or array for a sample frame. Therefore, the sample frame must be based on something other than gridded area.

To sample within cave entrances we establish a linear baseline down the center of the passageway, divide that baseline into equal-width finite segments, and define sample units as all areas of the walls and ceilings between imaginary planes perpendicular to the baseline at the start and end of each segment. This approach produces a finite number of sample units. While the sample units would not have equal area because of varying passage height and width, a probability sample could provide unbiased estimates of the total number of crickets.

Because neither the total area nor the area of each sample unit are known, the density of crickets per area could not be estimated. Additional rules would be needed to avoid or minimize double-sampling insides of curves along the passageway (where perpendicular strips would converge and overlap) and undersampling the outsides of curves (where perpendicular strips would diverge and leave gaps).

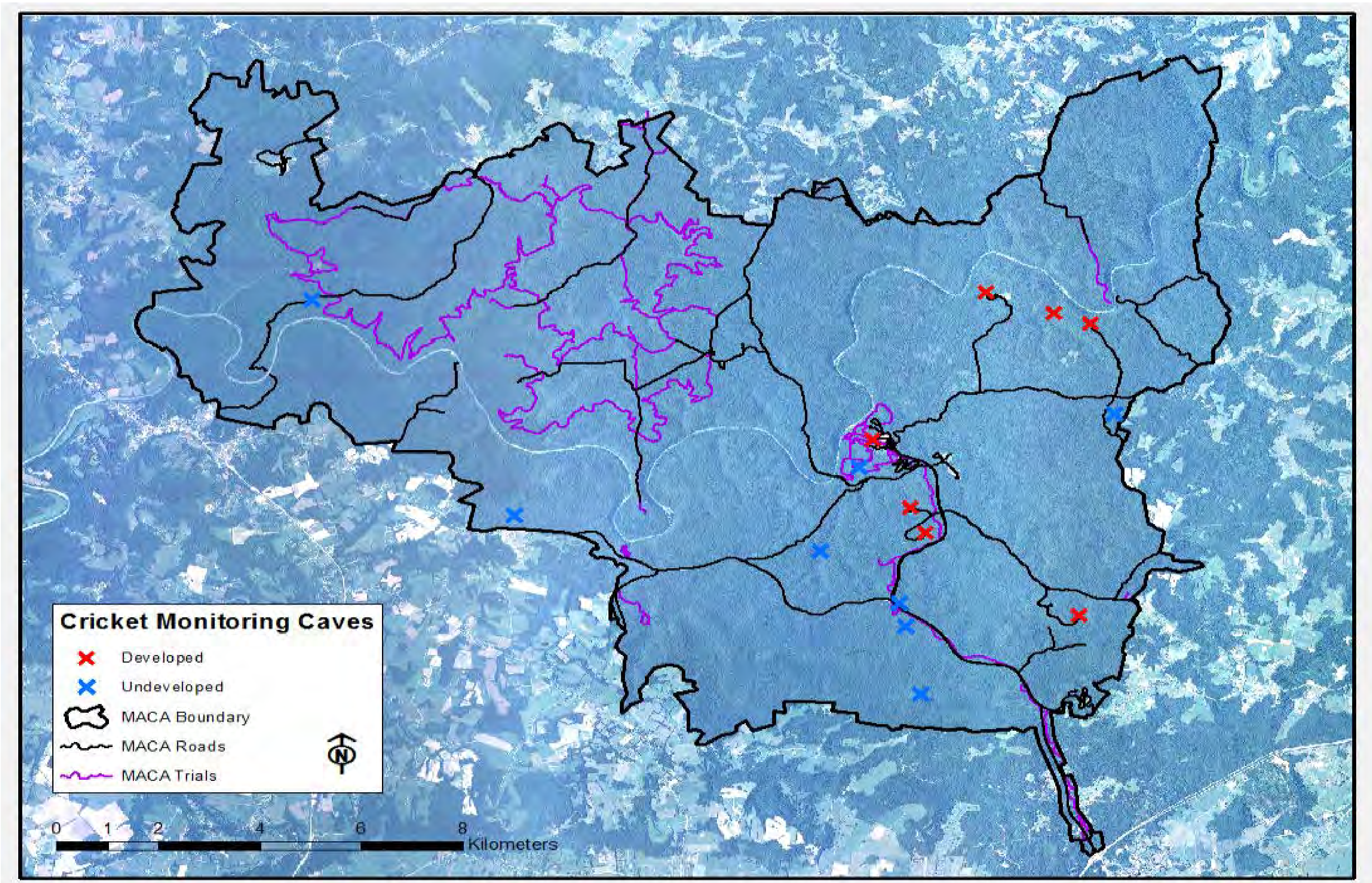


Figure 3. Sample sites (frame) within Mammoth Cave National Park study area. Note mix of developed and undeveloped cave entrances.

A second major complication for the design of the within-entrance sampling is that cave crickets are spatially aggregated, with large areas having few or no crickets. This is likely to be caused by a combination of gregariousness among crickets, and variation. Even if simple random sampling of quadrats were possible, it would be very inefficient, as most quadrats would have no crickets, and the variance of the population estimates would be dominated by the binomial variance of the fraction of quadrats capturing crickets. For sampling rare, clumped distributions adaptive cluster sampling and related methods have the potential to be much more efficient than simple random sampling in that their variance declines with sample size relative to simple random sampling (Thompson 2002). In addition to the estimates of total population size, adaptive cluster sampling automatically partitions the population size into components of cluster size and numbers of clusters, which can be informative for interpreting temporal changes in population size within each entrance.

Because of these two complications, this protocol uses a combination of a linear transect, (i.e., baseline) running down the length of the passageway from the entrance toward the depth of the cave, and strip adaptive cluster sampling (Thompson 2002) with strip locations defined by positions along that baseline. In order to improve the spatial spread of strips along the baseline, Generalized Random Tessellation Stratified (GRTS) sampling rather than simple random sampling is used to select strip locations along the baseline.

Adaptive Cluster Sampling

Adaptive cluster sampling (ACS) (Thompson 1990, Thompson and Seber 1996, Turk and Borkowski 2005) is a form of probability sampling that is especially suited for estimating totals or mean densities of rare, clustered individuals, where most samples in a simple random sample would find zero individuals (Philippi 2005). ACS begins with a probability sample of initial sample units such as quadrats (Figure 5). If a quadrat contains individuals of the species of interest, all adjacent quadrats are also surveyed (the adaptive part of the sampling). Any of those adjacent quadrats that also contain individuals of the species of interest (i.e., red in Figure 5) become part of the cluster, and their neighbors are also surveyed. Adjacent quadrats without crickets are "edge" quadrats (green), and are not counted as part of the cluster that triggered their surveying. The process of surveying adjacent quadrats continues until all clusters are surrounded by a ring of edge quadrats with zero individuals, and all quadrats containing individuals within that cluster have been surveyed.

While this can be a very efficient way to search for and count individuals of a clustered population, the data cannot be summarized as if it came from a simple random sample, because the entire rationale of adaptively measuring adjacent quadrats is that they are more likely to contain individuals of interest than random quadrats. However, as long as the rule for adding adjacent quadrats is symmetric (if quadrat B would be added when quadrat A was included in the initial draw, then quadrat A must be added when quadrat B is included), inclusion of any quadrat in a cluster would lead to measuring all quadrats in that cluster.

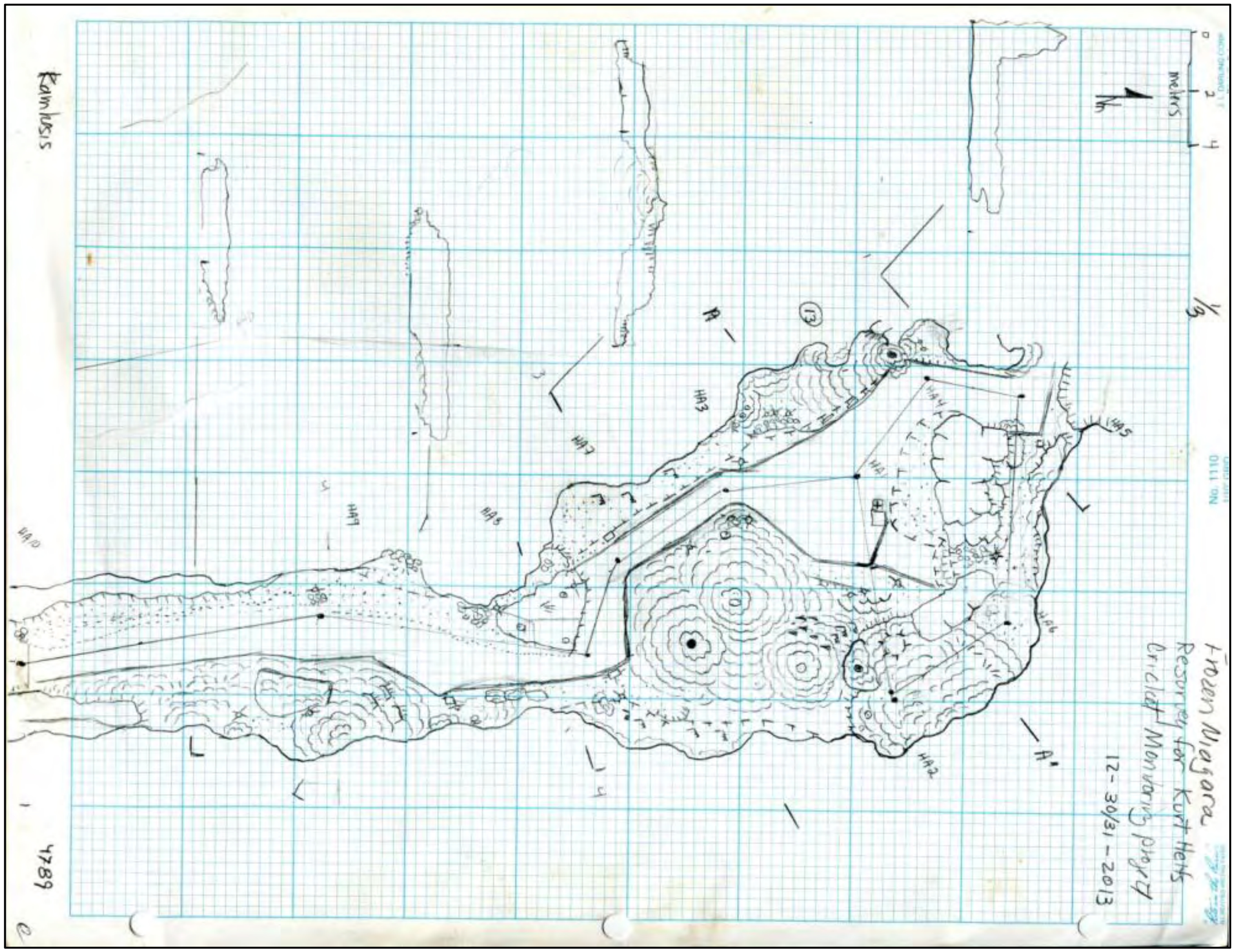


Figure 4. Rough sketch map of the sides of the Frozen Niagara Entrance, illustrating the varying widths of the entrance cylinder. The actual area to be surveyed is the walls and ceiling so it varies even more due to varying ceiling height (note passage cross-sections along top of sketch).

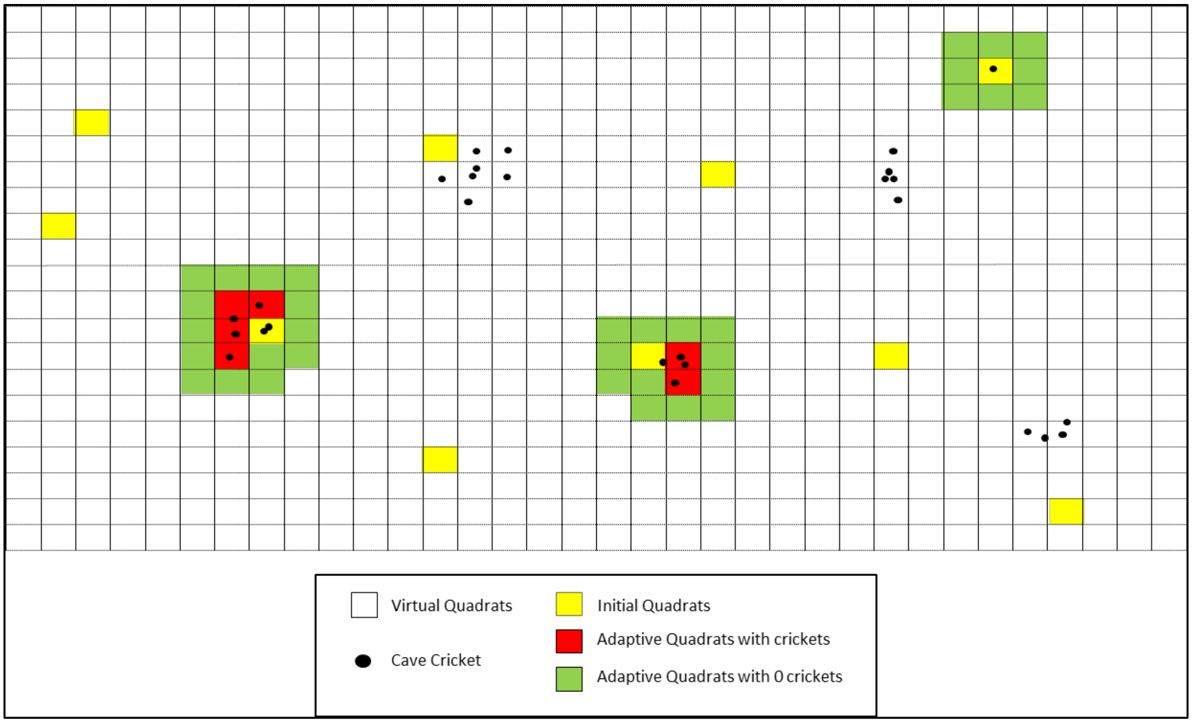


Figure 5. Example of Adaptive Cluster Sampling.

Therefore, the unequal inclusion probability for each cluster can be computed from the cluster's size in quadrats, and unbiased estimates of the population total or mean density can be computed via Horvitz-Thompson (H-T) or Hansen-Hurwitz (H-H) estimators (Thompson 2002). The trick that makes ACS work is that the weighted means are computed across clusters, not individual quadrats, using numbers of individuals counted in each cluster and the inclusion probability of that cluster.

Strip Adaptive Cluster Sampling

Strip Adaptive Cluster Sampling (SACS) is a variant of ACS where the initial probability draw is not a simple random sample of quadrats, but rather a probability draw of belt transects, or strips of quadrats (Figure 6a, Thompson 2002). Once individuals are encountered in a strip, adjacent quadrats are searched as in ACS, until the entire cluster is measured. SACS is especially efficient logistically for sampling rare plant populations over large areas. Using quadrats in the initial sample would require first establishing a grid over the entire target area, while our use of strips as sample units only requires establishing a baseline, and a sighting prism or other tool for running strips perpendicular to that baseline. [For rare but apparent plants, SACS has the additional advantage of searching for individuals while walking from one location to the next (e.g., along a strip).] Because the strips are parallel to each other, the probability that a cluster of crickets is included in the sample is proportional to the width of the cluster perpendicular to the strips, not to the entire area covered by the cluster or the lengths of the strips (Figure 6a). Because the estimates are computed from the intersected clusters, the total number of crickets (but not the density) can be estimated without ever quantifying the lengths of the strips or the total surface area of the passageway. For this protocol, the strips are 10cm wide, defined by two red laser lines separated by 10cm, perpendicular to the baseline, and projected on the walls and ceiling of the passageway. When a cricket is detected within a strip, instead of establishing a 10cm

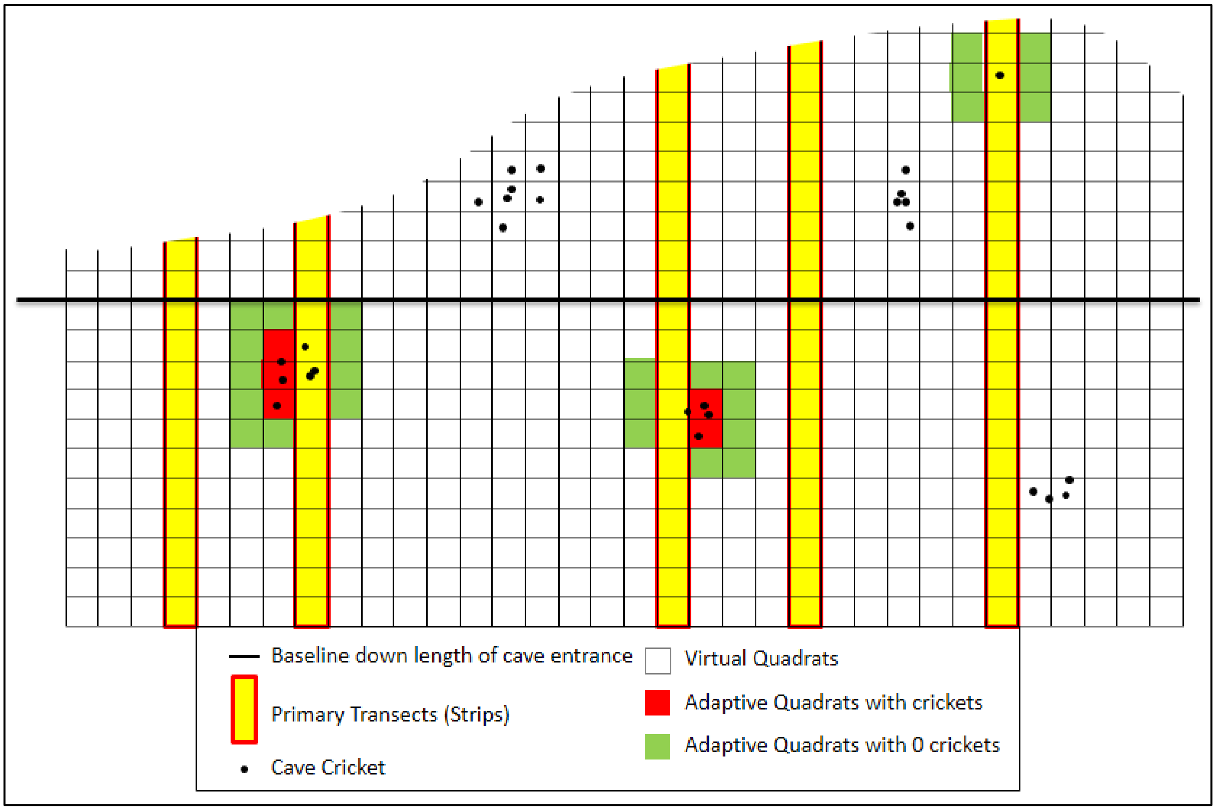


Figure 6a. Schematic diagram of strip adaptive cluster sampling applied to irregular areas. The baseline (black line) bisects the cave passage and anchors the randomly chosen *n* strips (yellow rectangles). Clusters of roosting cave crickets may (black dots inside red and yellow squares) or may not (black dots inside white squares) be intersected by the strips. When crickets are intersected, adjacent quadrats are added to each cluster. Only if the adjacent quadrat contains crickets (red) are neighboring quadrats added. Because the probability a cluster of crickets will be detected is dependent only on the extent of that cluster along the baseline, the grid and virtual quadrats need not exist.

x10cm grid around each cricket and adding adjacent grid cells as in the example above, we use a plotless adaptive cluster sampling design (Mosquin and Thompson 1998). For each cricket in a strip, any other crickets within 10cm are added to that cluster, and any crickets within 10cm of those crickets, recursively, until no additional crickets are within 10cm of any cricket in the cluster (Figure 6b). Therefore, the unequal inclusion probability for each cluster can be computed from the cluster size in sample units, and unbiased estimates of the population total or mean density can be computed via H-T or H-H estimators (Thompson 2002, Salehi and Seber 2013). The fundamental data recorded in the field are recorded by detected cluster. Note that a strip may intersect 0, 1, or multiple clusters, and that more than one strip might intersect the same cluster. A strip that does not contain any crickets is recorded as a cluster with 0 crickets and width 10cm.

The final component of this sampling design concerns the selection of the strip locations. As mentioned above, a baseline is established down the length of each cave entrance passageway, with 0 at the surface or proximal end of the baseline. Because the potential strip units run perpendicular to this baseline and do not overlap, they can be defined as 10cm segments along the baseline. Therefore, the within-cave sample frame for the strip units is the list of locations 10cm apart on the baseline. Prior applications of SACS used a simple random sample without replacement from that list. However, simple random sampling often selects several strips in close proximity and leaves extensive gaps without strips chosen. Such random fluctuations reduce the efficiency of this sampling in two ways. First, because passageway diameters and thus strip areas vary greatly at spatial scales (i.e., from 5m to 20m) along the baseline, groups of nearby strips and extensive gaps falling in narrow or wide sections would produce large visit to visit variance in the estimated population sizes, masking modest changes in abundances. A spatially-balanced approach to selecting strip locations would reduce this error variation by spreading each draw of strips more evenly among narrow and wide regions. Second, data from this protocol will be used to detect changes in the distribution of cricket distances from the entrance (e.g., shifts to roosting further down into the cave). Having strips spread more evenly across the distances during each set of cave sampling events, increases the ability to characterize temporal trends in cave crickets' estimated entrance population size as a function of distance along the baseline.

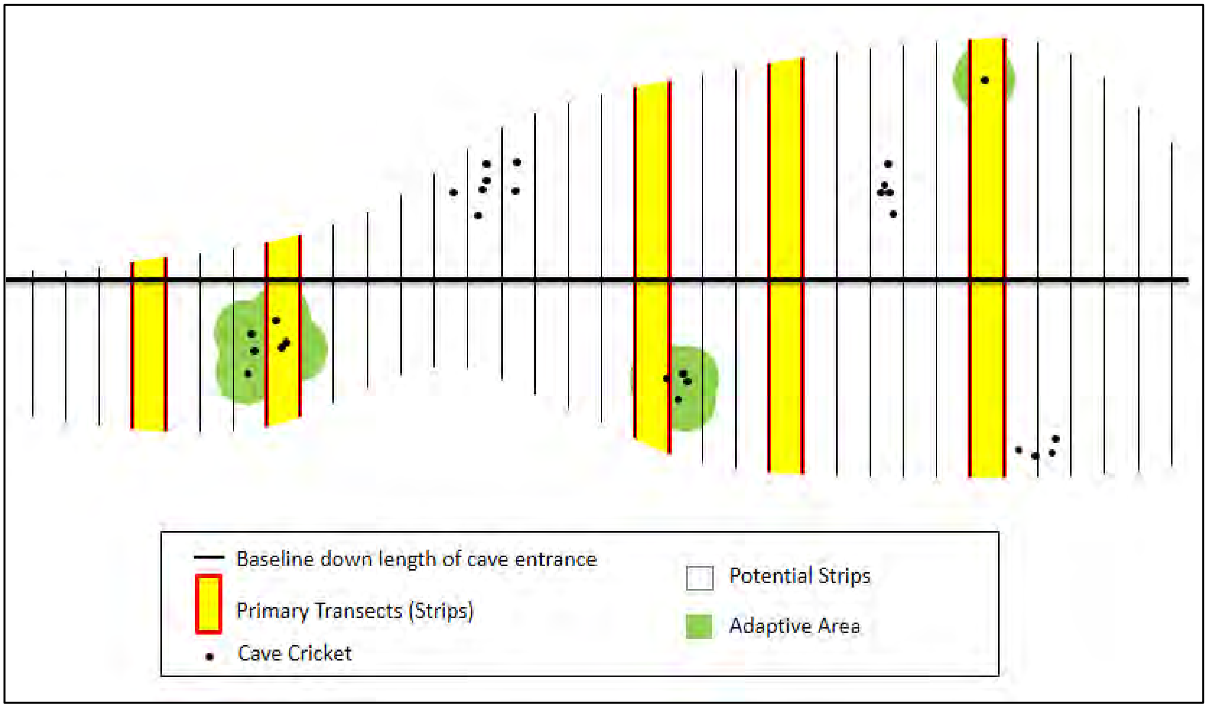


Figure 6b. Schematic diagram of the plotless strip adaptive cluster sampling method used to monitor cave cricket entrance populations at Mammoth Cave National Park. Note that because the probability a cluster of crickets will be detected is dependent only on the extent of that cluster along the baseline, the grid and virtual quadrats need not exist. Any cricket intersected by a strip triggers a cluster; any crickets within 10cm radius of a cricket in a cluster are added to that cluster, and in turn have their 10cm radii searched.

This protocol uses GRTS sampling on the 1-dimensional set of potential strip locations within each cave entrance for each sampling bout. Unlike sampling on a grid or at regularly-spaced locations, GRTS produces a true probability sample. Unlike simple random sampling, GRTS produces approximate spatial balance, reducing the variance in separation distances between adjacent strips. The alternative to GRTS in this situation would be dividing the baseline into N sections 5-10m long, then drawn one random strip location per section, as a one unit per stratum design. However, we expect that some drawn strip locations will be rejected in the field as unsampleable due to such factors as safety or resource damage considerations, and will need to be replaced by oversample strip locations. In one per stratum designs, the replacement strip must occur in the same stratum, which means that the relative inclusion probabilities depend on what fraction of strip locations are unsampleable in each stratum. In GRTS, the replacement sample for a rejected location can occur anywhere in the frame, and so the relative inclusion probabilities are equal and independent of the distribution and extent of unsampleable locations.

GRTS introduces the complication that the strips are not an independent random sample (adjacent strips have a much lower chance of being included than in SRS), so the formulas for computing inclusion probabilities a*i* for clusters and pairwise inclusion probabilities a*ij* based on independence do not apply. However, drawing a GRTS sample from a finite, one-dimensional frame is a very fast process. Therefore, this protocol estimates the inclusion probabilities a*i* and a*ij* by generating 1,000,000 additional GRTS draws, and tabulating how many of those draws would have included each observed cluster *i* and each pair of clusters *i* and *j*.

Finally, as noted above, the curvature in the passageways means that the baseline is not always linear, but rather must bend or curve. Adjacent strips perpendicular to a curved baseline will overlap on the inside wall and leave gaps on the outside wall of the bend. The field procedures in SOP #3a: Field Methods: Strip Adaptive Cluster Sampling includes directions for establishing a baseline with linear segments, abrupt kinks or angles, and rules for truncating strips so that the inside of the corners are not included in multiple strips.

Sampling Frequency and Replication

Sampling events for cave cricket monitoring will be conducted biannually. In a sampling year two sets of sampling events will be conducted at all 15 sampling sites. Sampling events will occur within a two-week period each “shoulder season” (i.e., May-June and October-November), at each of the 15 selected cave entrances at MACA. Previous monitoring efforts show these months are the best times of year to maximize sample size and reduce day to day variability among entrance populations because equable weather creates optimal foraging conditions on the surface and similar proportions of cave cricket entrance populations forage on any given evening (Helf 2003, Lavoie et al. 2007). Due to drought conditions during the mid-summer through late fall months cave cricket abundance on any given day is highly variable and so the potential for substantial sampling noise is greatly increased.

It will take approximately eight to ten days to complete one sampling event focused on SACS activities each “shoulder season”. Opportunistic grab sampling of cave temperature, relative humidity, and air flow at sampled cave cricket clusters is performed in conjunction with SACS. Initial installation of *in situ* dataloggers to continuously sample cave temperature and relative humidity will occur during the first sampling event at each cave and data will be downloaded during each subsequent sampling event. As necessary, datalogger servicing activities will occur during the second sampling event at the end of each cave entrance's sampling event.

Note: In addition to scheduled monitoring additional synoptic sampling can be performed in any area of interest, or as needed, to address a specific management question regarding planned modifications (e.g., management intends to alter a section of cave-lighting system). Management may request “snap-shot” sampling to evaluate local cave cricket populations before and after the planned modification occurs. Synoptic sampling will employ the same design and sampling methodologies, in part or whole, as that in scheduled monitoring. The sampling frequency and duration of this short-term monitoring will be determined by the project leader after consultation with the CUPN program manager and park management.

Adding Sites

There are a number of possibilities that could result in additional cave cricket entrance populations being added to MACA's 15 extant monitoring sites. New caves with substantial cave cricket entrance populations could be discovered on extant park property. Restrictions on previously monitored cave cricket entrance populations (e.g., Saucer Cave) could be lifted. In each case, if the potentially new monitoring site is determined by the project leader to meet or exceed the site selection criteria described in this protocol, the new site will be added providing there are sufficient resources available. Although, beyond the scope of this protocol, occasionally specific research questions or inventory needs may arise related to monitoring cave cricket entrance populations at MACA; participation by the project personnel will be considered on a case-by-case basis in consultation with the Network program manager and any appropriate supervisors.

Detectable Levels of Change

To date no power analysis has been performed on legacy cave cricket data collected at MACA. In this protocol we monitor trends in several parameters for cave entrance cricket populations, such as, total entrance population estimates, life stage ratios, sex ratios, distribution in cluster size, and cluster distance from the surface. These distributions are likely to be poorly estimated by data collected from individual sampling events, but rather will require pooling data from several sampling events to stabilize. Examination of confidence intervals for differences between cave cricket entrance populations at comparable developed and undeveloped cave entrances at the .05 level of significance will be performed after the first sampling year. After 4 or 5 years of data have been collected, unbiased confidence intervals available from the H-T estimates in SACS will be used to examine temporal trends for indicators within and among cave cricket entrance populations.

Field Methods

The CUPN Protocol for Cave Cricket Monitoring is designed to monitor the "cave cricket" vital sign in a rigorous, safe, and cost-effective manner. The goal during this protocol's development was to create a final product that would yield summary data that could be used by MACA resource managers. The SOPs provide detailed instructions for the CUPN cave cricket monitoring protocol. These SOPs include instructions on pre- and post-field sampling activities, safety, sampling site selection, and detailed instructions on all data collection and analysis. We will follow all protocol instructions listed below and will clearly document any changes to protocols so we can fully understand the impacts such changes might have to our final results and data analyses.

Pre-Field Season Preparation

Recurring pre-field season activities include: 1) communication and coordination with MACA staff, 2) permitting and compliance, 3) logistics, 4) job safety review, 5) GPS setup, 6) gathering required supplies and equipment, and 7) training of field crews. The project leader is responsible for pre-field season communication and coordination with park staff as well as logistics. The project leader will email the key MACA contact two weeks prior to each sampling event to provide the proposed dates and locations where cave cricket monitoring field work is scheduled to occur. While weather conditions should not significantly affect the accessibility of subsurface field sites, adjustments to scheduled fieldwork may be necessary due to personnel workloads. Thus, to maintain schedule flexibility, dates of sampling events should be proposed well in advance. Sampling events will be scheduled over multiple days but within a two week time span; thus, the effect of weather and cricket movement within caves on among-cave sample variance should be minimized. Once the specific dates for a sampling event are determined the project leader will secure a vehicle and make other necessary arrangements.

If field crew members have not participated in a sampling event for more than six months they are to thoroughly review SOP #2 Pre-Field Sampling, SOP #3a Field Methods: Strip Adaptive Cluster Sampling, SOP #4 Post-Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry, and SOP# 5 Post-Field Sampling: Decontamination of Gear. All equipment should be checked and readied for field season. All electronic equipment should be checked to make sure it is in working order. Battery charges in all battery-operated equipment should be checked and exhausted batteries replaced. Logistical and equipment checklists are provided in SOP #2 Pre-Field Sampling. Finally, observers should review photographs of cave cricket species to reduce the incidence of misidentification in the field.

Permitting and Compliance

The project leader will be responsible for obtaining and maintaining a current NPS research permit for monitoring cave cricket entrance populations at MACA. The permits should be completed in November of each year (if possible, permits should be requested for two or more years to cut down on the amount of paperwork from year to year) The project leader will ensure that MACA has the current Protocol for Cave Cricket Monitoring and a list of sampling locations so that any compliance issues can be addressed.

Safety

The CUPN considers the occupational health and safety of its employees, cooperators, and volunteers to be of utmost importance, and is committed to ensuring that all field crews receive adequate training on NPS safety procedures, incident reporting, and emergency response prior to field work. Working in a cave environment can present some particular safety hazards, and certain activities (e.g., vertical caving) necessitate specialized training and experience. An important tool used to promote safe conduct is the Job Hazard Analysis (JHA). This approach is consistent with NPS Directors Order 50 and Reference Manual 50B for Occupational Health and Safety. The JHA process is to (1) identify hazards associated with field and laboratory settings, as appropriate, and (2) develop approaches to mitigate those hazards. Prior to conducting the first sampling event all field personnel involved must read and sign the related JHA in SOP #2: Pre-Field Sampling (Table SOP2-5). Prior to each sampling event all participating field personnel must review the JHA and agree to follow all safety guidelines during sampling. In addition to the JHA, all NPS staff must read the entire CUPN Safety Plan (draft/in progress). Prior to participating in field work all NPS staff must complete NPS Operational Leadership training.

Field Information Sheets, Pre-populated Field Data Sheets, and Baseline Maps

Development and maintenance of reference and field data sheets helps orient new crew members, increase efficiency, and greatly improve the consistency among sampling events. Prior to each sampling event the order in which sampled cave entrances are visited is randomized by the project leader, via R code (Appendix G). The order is randomized to ensure estimators generated from the data will not be biased by the order or time of their survey. The *Field Information Sheet* template in SOP #2: Pre-Field Sampling (Figure SOP2-1) provides an outline of the pertinent information describing conditions at each sampled cave. Field Information Sheets are developed for each cave entrance prior to the first sampling event and reviewed by the project leader/field crew leader before each sampling event. The project leader also uses R code to generate a *Pre-populated Field Data Sheet* for each cave entrance which contains the results of the one-dimensional GRTS draw of spatially balanced strips (i.e., primary sampling units), their positions on the baseline, and an additional, doubled oversample (Figure 7). The Pre-populated Field Data Sheet also contains space to record ancillary data on roosting clusters (e.g., their extent and location) and cave meteorological data at the cluster (see below). Both field crew members utilize *Baseline Maps*, generated for each monitored cave entrance, to lay out the baseline (i.e., a fiberglass survey tape) on which the strips are located. The field crew references the baseline map for images of its starting points (landmarks), bearing(s), and length to precisely relocate the baseline(s) in order to ensure continuity among cave cricket monitoring surveys (Figures SOP2-2 and SOP3a-4). Baseline Maps are also used for plotting and labeling the locations of HOBO dataloggers and permanent landmarks during cave meteorological field sampling at all sample units. Metadata recorded during sampling events includes sampling personnel, date, time, and cave entrance name.

Supplies and Equipment

Timing and staff roles for yearly primary tasks are summarized in SOP #2: Pre-Field Sampling (Table SOP2-8). The GIS specialist will upload cave location and parking location coordinates into the CUPN GPS unit(s) or handheld device using DNR Garmin or other similar software. The project leader, or designated field crew member, is responsible for organizing, preparing, repairing, or purchasing supplies and equipment for sampling events. Prior to each sampling event the project leader, or designated field crew member, will assemble all required caving gear and sampling supplies or equipment. This will include instrument calibration (e.g., cave meteorological monitoring devices). The project leader, or designated field crew member, will complete and sign/date a copy of the appropriate checklist in SOP #2: Pre-Field Sampling (Table SOP2-2 and 2-4).

Pre-Field Season Preparation for Data Handling

Well in advance of each field season, the program manager will schedule a meeting with the project leader, data manager, GIS specialist and other relevant staff to communicate problems and suggested changes to procedures implemented during previous sampling events and to also review information management needs for the upcoming field season.

Recurring preseason activities include gathering required supplies and equipment as well as conducting image analysis training. While these tasks are not traditionally viewed as data management tasks, they lay an important foundation in the realm of data quality control. Ensuring that those involved in data acquisition are properly equipped and adequately trained minimizes the need for 'alternative' modes of data collection and reduces the frequency of incorrect or incomplete data sheets. Refer to SOP #1: Training Sampling Crew and SOP #2: Pre-Field Sampling, for additional details.

Strip Adaptive Cluster Sampling Procedure

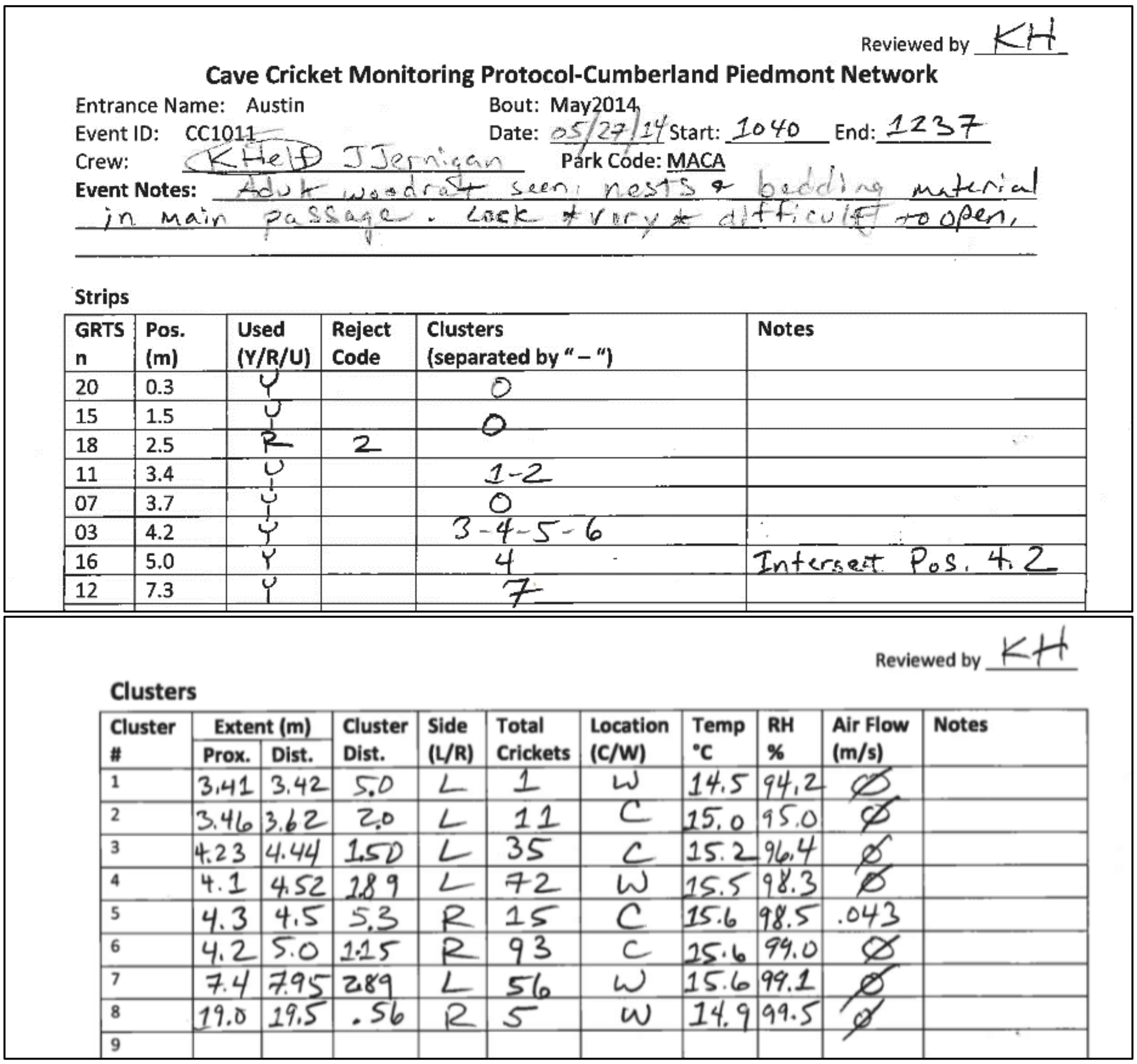
During a sampling event one crew, comprised of two individuals, surveys a randomized selection of two cave entrances per day (see SOP #3a: Field Methods: Strip Adaptive Cluster Sampling for details). A fiberglass measuring tape (i.e., the baseline), placed in approximately the same location each sampling event, serves as the main transect on which randomized, perpendicular strips are positioned. Laser projectors, affixed to a platform mounted on a camera tripod and placed at the randomized locations, project the 10cm wide strips on the caves walls and ceilings. The area within each strip is surveyed and when ≥1 cave cricket is found the area within a 10cm x 10cm proximity is adaptively sampled until no more cave crickets are found in the cluster. Digital images of clusters of cave crickets are recorded from which counts of cave crickets, both inside and outside the strip, are obtained during subsequent image analysis. Ancillary data on clusters include mapping the location of each sampled roosting cluster, the width (i.e., extent) of sampled roosting clusters, and roost site descriptive characteristics (e.g., located on wall or ceiling).

Digital Photography

Once the tripod with the laser assembly is at the correct position on the baseline, and projects the 10cm wide strip perpendicular to the baseline (Figure 4; see SOP #3a: Field Methods: Strip Adaptive Cluster Sampling for details) digital images of roosting clusters are recorded, using a digital camera with flash and zoom lens. The exposure settings on the digital camera are such that the laser lines delineating each transect are visible as a reference point in the image. A detailed summary of digital photographic techniques for use in caves, based on guidance developed by the New York State Department of Environmental Conservation (Hicks et al. 2009), is provided in Step 2 of the "Step-By-Step Instructions" section of SOP #3a Field Methods: Strip Adaptive Cluster Sampling. Data on photographed clusters (e.g., cluster extent, cluster distance from the baseline, side of baseline on which the cluster is located) are written on field data sheets printed on Rite-in-the-Rain™ paper (Figure 7, Figure SOP3a-2). The data levels are roughly arranged in the sequence in which they are collected during a sampling event, that is, by cave entrance level, strip level data, and cluster level data.

Data Recording

Field data sheets, used at each sampled cave entrance during a given sampling event, come in "Strips" and "Clusters" sections (see SOP #3a: Field Methods: Strip Adaptive Cluster Sampling for details). The "Strips" field data sheet generated for each sampled cave is primarily used as a reference for metadata regarding a sampling event at a given cave. The "Strips" field data sheet comes pre-populated with metadata (e.g., Cave Entrance Name) associated with the sampling event (Figure 7, top). Metadata such as field crew members, date, start and end times, and any notes associated with the sampling event are written in the field. The “Strips” field data sheet is also pre-populated with the results of a GRTS draw, including an oversample (Figure 7, middle), for the easy location of the sequential, discrete strip positions on the baseline and their sequence in the GRTS draw (Figure 7, top). Whether a given strip is used or rejected, and a coded reason for any rejected strips, are also recorded in the field (Figure 7, top). A single strip may intercept multiple cave cricket clusters and so each cluster is assigned a unique, sequential number as they are encountered. Strips that do not intercept any clusters are given a “0”. The “Clusters” field data sheet is blank and all data associated with all clusters on the “Strips” data sheet, including their unique number, proximal and distal extents (in meters) along the baseline, and an estimate of the number of crickets in that cluster, are recorded. (Figure 7, bottom). Additional, correlative data used in subsequent statistical analysis, such as roosting location, the temperature (°C), RH (%), and air flow (m/s), are also recorded for each cluster (Figure 7, bottom).



Reviewed by KH

Cave Cricket Monitoring Protocol-Cumberland Piedmont Network

Entrance Name: Austin
Bout: May2014
Event ID: CC1011
Date: 05/27/14 Start: 1040 End: 1237
Crew: KHelf JJernigan
Park Code: MACA
Event Notes: Adult woodrat seen; nests & bedding material in main passage. Lock *very* difficult to open,

Strips

GRTS n	Pos. (m)	Used (Y/R/U)	Reject Code	Clusters (separated by "–")	Notes
20	0.3	Y		0	
15	1.5	U		0	
18	2.5	R	2		
11	3.4	U		1-2	
07	3.7	U		0	
03	4.2	Y		3-4-5-6	
16	5.0	Y		4	Intersect Pos. 4.2
12	7.3	Y		7	

Reviewed by KH

Clusters

Cluster #	Extent (m) Prox.	Extent (m) Dist.	Cluster Dist.	Side (L/R)	Total Crickets	Location (C/W)	Temp °C	RH %	Air Flow (m/s)	Notes
1	3.41	3.42	5.0	L	1	W	14.5	94.2	Ø	
2	3.46	3.62	2.0	L	11	C	15.0	95.0	Ø	
3	4.23	4.44	1.50	L	35	C	15.2	96.4	Ø	
4	4.1	4.52	1.89	L	72	W	15.5	98.3	Ø	
5	4.3	4.5	5.3	R	15	C	15.6	98.5	.043	
6	4.2	5.0	1.15	R	93	C	15.6	99.0	Ø	
7	7.4	7.95	2.89	L	56	W	15.6	99.1	Ø	
8	19.0	19.5	.56	R	5	W	14.9	99.5	Ø	
9										

Figure 7. Truncated strip level data (top) and Cluster level data (bottom) from the “Strips” and “Clusters” field data sheet pages, respectively. The “Strips” field data sheet is pre-populated with some metadata regarding the sampling event, information regarding the location of strips on the

baseline, and sample overdraw (not shown). The “Clusters” field data sheet (bottom) is where ancillary data on each cluster location are recorded in the field.

These data support both non-adaptive estimates based on the counts inside strips and SACS estimates based on the counts by clusters. A cluster is defined as any cricket found inside a strip, plus any crickets within 10cm of that cricket and, recursively, any crickets within 10cm of crickets already in that cluster. Any cricket found inside a strip is a member of one cluster, but crickets adaptively added to the cluster may fall outside a sampled strip. For example, in Figure 8, Strip 11 extends from 3.4m to 3.5m (red lines) and contains two clusters of cave crickets. Cluster #1, entirely inside the strip, is comprised of the cricket at “A” and its proximal and distal extents are recorded on the “Clusters” field data sheet as 3.41m and 3.42m, respectively, (Figure 7, bottom). Cluster #2 is comprised of the 2 crickets inside the strip at “B”, plus the 9 crickets outside the strip: 8 crickets at “C” adaptively added to the cluster because they were within 10cm of the crickets at “B” and the single cricket at “D” recursively added because it was within 10cm of the crickets at “C”. The cricket at “E” is not part of Cluster #2 because there is a >10cm gap between it and any member of the second cluster (Figure 8). Cluster #2’s proximal and distal extents are recorded on the “Clusters” field data sheet as 3.46m and 3.62m, respectively (Figure 7, bottom). Strip 07 extends from 3.7m to 3.8m and no crickets were encountered within the strip; empty strips are assigned a Cluster # of “0” on the “Strips” field data sheet (Figure 7, top). On occasion a given cluster may intersect multiple strips and so include crickets found inside multiple strips.

Subsurface and Surface Meteorological Data

Opportunistic grab samples of temperature (ºC), RH (%), and air flow (m/s) are collected at each sampled cluster with a handheld weather instrument (see SOP #3b: Field Methods: Cave Meteorological Sampling for details). *Continuous sampling* of meteorological data (i.e., temperature and RH) inside all sampled cave entrances, using two *in situ* automated dataloggers (one in the variable temperature zone and one in the constant temperature zone), occurs at a programmed interval (see SOP #3b: Field Methods: Cave Meteorological Sampling for details). A subset of the surface meteorological data continuously collected by the USDA’s Soil Climate Analysis Station (SCAN) at MACA (i.e., temperature, RH, and precipitation) will also be downloaded for the 36 hour period previous to the date of each cave entrance’s sampling event (see SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry for details). Subsurface meteorological data are downloaded from dataloggers at the end of each sampling event at each cave entrance; all dataloggers are serviced at the end of the second sampling event. Surface meteorological data are downloaded from the SCAN station website after the end of the sampling season.

Table 2 outlines the relationship among the sampling categories, raw data, summarized data, and monitoring objectives. Detailed descriptions, instructions on data collection methods, and ancillary measurements (e.g., meteorological data, datalogger location) are included in SOP #3b: Field Methods: Cave Meteorological Sampling as well as the post-field sampling and data analysis SOPs in this monitoring protocol.

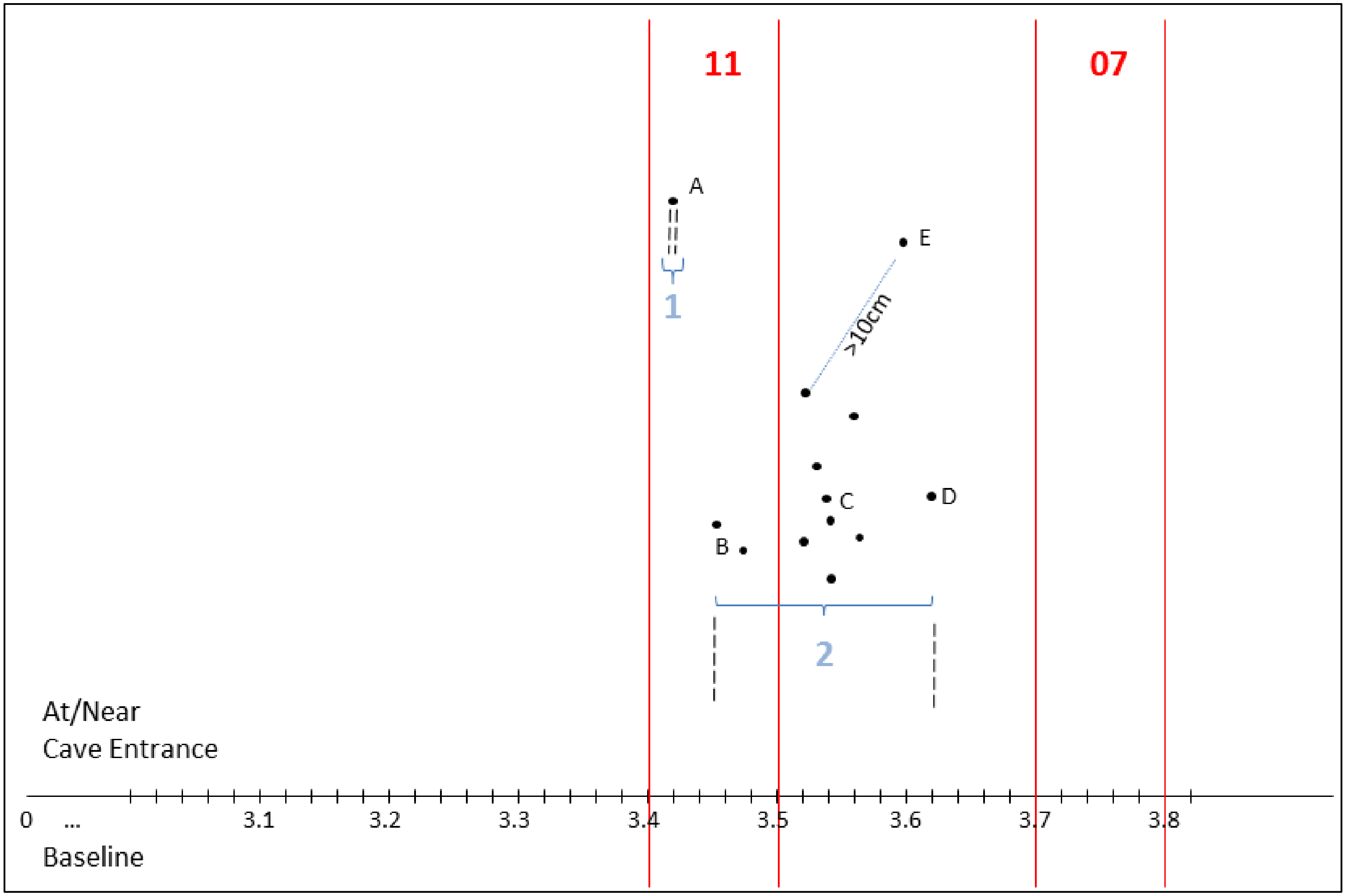


Figure 8. Example of cluster extent with respect to the strip in Strip Adaptive Cluster Sampling used to monitor cave cricket entrance populations at Mammoth Cave National Park.

Variables and Measurements

Table 2 provides a summary of the primary measurements and variables collected during field sampling and post-field sampling analyses. Detailed descriptions of each, collection methods, and secondary measurements (e.g., start time of sampling event, distance from landmark to spot below datalogger) are included in the two field sampling SOPs and the post-field sampling and data analysis SOPs in this monitoring protocol.

Table 2. Sampling categories, raw data, summarized data, and objectives addressed for long-term monitoring of cave cricket entrance populations at Mammoth Cave National Park.

Sampling Category	Raw Data	Summarized Data	Objectives Addressed
Cave Cricket Sampling (SOP #3a: Field Methods: Strip Adaptive Cluster Sampling)	Digital image(counts of roosting clusters of cave crickets)	Total count of cave crickets inside strip/per cluster.	Entrance population size and structure.
		Total count of adult female cave crickets inside strip/per cluster.	Entrance population size and structure.
		Total count of adult male cave crickets inside strip/per cluster.	Entrance population size and structure.
		Cave cricket sex ratios among strips.	Entrance population size and structure.
		Total count of adult cave crickets inside strip/per cluster.	Entrance population size and structure.
		Total count of juvenile cave crickets inside strip/per cluster.	Entrance population size and structure.
		Ratio juvenile to adult cave crickets among strips.	Entrance population size and structure.
		Mean number of clusters of roosting cave crickets among strips.	Entrance population size and structure.
		Mean cluster size among strips.	Entrance population size and structure.
		Mean cave cricket entrance population.	Entrance population size and structure.
	Location of roosting clusters of cave crickets (distance in meters and compass bearing relative to baseline)	Map of sampled roosting clusters of cave crickets among strips.	Habitat use among strips.
Meteorological Sampling (SOP #3b: Field Methods: Cave Meteorological Sampling)	Temp/RH/Air flow at cave cricket roosting sites (ºC/%)	Mean air temp Mean relative humidity Mean air flow (m/s)	Habitat use among strips. Effect of management actions.
	Temp/RH/Air flow in sampling strips (ºC/%)	Mean air temp Mean relative humidity Mean air flow (m/s)	Habitat use among strips. Effect of management actions.
	Temp/RH/Ppt on surface (ºC/%/cm)	Mean air temp Mean relative humidity Mean precipitation	Correlation between surface conditions and cave cricket entrance populations.

Post-Sampling: Disposition of Field Equipment, Disposition of Field Data, Digital Image Analysis

Procedures to follow after completion of a sampling event at sample units can be found in SOP #4: Post- Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry. Recurring post-sampling event activities include the following categories: 1) transit from the field to the office, 2) arrival at the office, 3) logistics (e.g., gate key return), 4) handling field data sheets, 5) processing photos, and 6) processing cave meteorological data files. The tasks detailed in SOP #4 roughly cover the period of time from when field personnel leave the cave entrance after the completion of field work to the point of data analysis; post-field season procedures to follow are also covered. The project leader is responsible for post-field season communication and coordination with park staff as well as logistics. No voucher specimens are planned for collection under this monitoring protocol.

The designated surface contact person will be notified by cell phone or radio when the field crew has left the cave. All field personnel will follow the latest national guidance (available at *www.whitenosesyndrome.org*) (accessed 2 April 2014) regarding the proper decontamination and storage of all gear (including equipment and field data sheets) used in the cave or that entered the cave entrance area to reduce the possibility of transmitting *Pseudogymnoascus destructans* fungal spores (see SOP#4 Post- Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry and SOP #5: Post-Field Sampling: Decontamination of Gear). This fungus is the cause of a novel disease called white-nose syndrome (WNS) that is lethal to most species of cave-hibernating bats in eastern North America. Equipment and caving gear will be checked for damage requiring repairs or replacement, and returned to the appropriate office or person for proper storage. At the end of each sampling year the project leader will inventory the condition of all equipment and prepare a list of required repairs or replacements. Any NPS staff or volunteers injured in a non-emergency incident during field sampling must complete the required Worker's Compensation paperwork within 48 hours of incident. Field crew members should discuss any issues that arose with the monitoring procedures with the project leader. Field data sheets, Field Information Sheets, and Baseline Maps will be scanned and stored to the network server. Photos will be downloaded from cameras, sorted, renamed, and stored to the network server in preparation for analysis and data entry.

Data Handling, Analysis, and Reporting

This and following sections provide an overview of the procedures for data handling, analysis and reporting. Additional detail and context can be found in the CUPN Data Management Plan (Moore et al. 2005), as well as task specific SOPs for this protocol, such as SOP # 4: Post-Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry, SOP #7 Data Analysis, and SOP #8 Reporting.

Data and information are the basic products of scientific research (Michener and Brunt 2000). With this in mind, CUPN's success will ultimately be judged by its ability to provide relevant high-quality data to current and future data users. The goal is not simply to collect data. The goal is to make sure high quality data are available, with appropriate context, so that informed decisions can be made.

Therefore, data handling procedures are in place to ensure data are of an acceptable quality. It is important that data handling procedures not only be documented but also implemented in a consistent manner. To accomplish this, staff must be made aware of their assigned roles and resultant responsibilities and receive the tools and training necessary to accomplish those tasks throughout the life cycle of the project. Thus, data quality is improved by ensuring field crews are properly trained and equipped. Proper training and equipment also minimizes the occurrence of 'alternative' modes of data collection and reduces the frequency of incorrect or incomplete field data sheets; refer to SOP #2: Pre-Field Sampling for additional details.

Data Acquisition and Processing

Cave cricket monitoring data are recorded in the field in digital images and on a set of customized paper field data sheets (Figure 7). The field crew leader designates a data recorder for the sampling event. Crew member(s) call out data and the data recorder repeats the data before/while recording. It is the data recorder's responsibility to accurately and legibly record all data elements. This approach creates a real-time double check in the field and is an important step in the quality assurance and quality control process (QA/QC). However, this approach may not always be possible due to the need for limiting disturbance to the organisms.

Cave meteorological data collected via automated HOBO dataloggers will be uploaded in the field to a storage module (data shuttle) for transport to the office (see SOP #3b: Field Methods: Cave Meteorological Sampling). All digital files will be downloaded from the data shuttle to the CUPN file server, sorted, renamed following the established naming convention. GPS units will be returned to the GIS specialist, who is responsible for stewardship of geospatial data. The field crew leader will alert the GIS specialist if any new waypoints were marked on the GPS units during field sampling.

Prior to leaving each cave, the field crew leader is responsible for ensuring data sheets are reviewed for completeness and legibility. This is a key step in the QA/QC process since the likelihood of correcting errors diminishes greatly once the crew leaves the field. The data sheets include a place for initials to serve as a reminder and document that this review occurred. Upon returning from the field, data sheets will be decontaminated, and scanned. Digital images will be transported to the office on the image cards or hard drive inside the cameras (see SOP #3a Field Methods: Strip Adaptive Cluster Sampling; Step-By-Step Instructions section). Digital images of roosting cave cricket clusters will be renamed following established naming conventions and saved to the appropriate folder on the CUPN file server. The original hard copy field data sheets are then returned to the project leader for storage in a secure location pending data entry. Data on cave cricket entrance populations are derived from a careful analysis of the digital images using ArcMap (see SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry). It is expected that image analysis and the associated data entry will take up to one week per sampling event.

Overview of Database Approach

Development of CUPN's Cave Cricket Protocol database was initiated within Microsoft Access (refer to SOP #6: Data Management) and will continue within this platform for the foreseeable future. Basic structure of this database generally conforms to the I&M developed Natural Resource Database Template, which includes an established set of core tables and fields (National Park Service 2007). Additionally this database application includes a front-end user interface, containing data entry forms, queries and other data manipulation tools. The back-end file, which is linked to the front-end, holds the core data tables.

The approach used by the CUPN for the majority of long-term datasets (and will likely be adopted for this protocol) is to maintain what is referred to as a working copy of the database. This copy is used to enter the current season's data and perform all verification and validation routines. Once those processes are complete then on a scheduled basis (typically at the end of each field season), data are certified and uploaded to a master copy of the data. This master copy, which contains all certified data for a project, is used for data analysis, reporting, etc.

Entry

Prior to each sample event or group of sampling events (a grouping of cave entrances to be visited during a sampling session), the project leader will conduct a GRTS draw to randomize the order in which caves are visited and the order in which locations on the baseline are sampled during in-cave sampling. Unlike simple random sampling, GRTS produces approximate spatial balance, reducing the variance in separation distances between adjacent strips. The R code, which generates these draws, will harvest a list of entrances to be visited, within-cave sample sizes, and the last Event_ID utilized (sequential order). This code will then format and populate field data sheets in Microsoft Word™ (Figure 7).

In addition to generating the primary field data sheets, R code will also be used to create temporary tables in the protocol database. The values in these tables (e.g., event and Location_ID) can then be utilized during the data entry process reducing manual data entry. In addition much of the field data are collected in photographs, which are analyzed in ArcMap. R code will also be utilized to pull and summarize the counts from the various shapefiles generated and append values in the temp_* tables in Access. Refer to SOP #6: Data Management for a more thorough coverage of this process.

In short, the majority of data entry will not be accomplished via the traditional method whereby an individual sits down at their computer with a completed field data sheet and enters each value into a similarly designed form on the computer. Instead much of the data will be populated into temporary tables in the database via R code. Thus the data entry process will include: ensuring data are accurately parsed to the correct location/event combinations in the 'permanent' tables in the database; data records are complete; and finally, entry of remaining data elements from the field data sheets (e.g., notes fields, cricket cluster locational information) is completed. A series of QA/QC checks will be in place to assist in this process. However, the need for properly trained and equipped data entry personnel is still critical to the success of this monitoring effort.

Data entry will be conducted by personnel trained in the use of the specific database application. Preferably this individual participated previously in field data collection and so is familiar with most aspects of the monitoring protocol.

Quality Review

Once entry is complete, the individual conducting data entry will perform various checks and routines to ensure data were accurately and completely transcribed from the field data sheets (i.e., data verification). This is followed by a review by the project leader, who will again check the data for completeness, as well as logical inconsistencies (i.e., data validation). The working database application will facilitate data verification and validation processes via automated queries and reports. In addition, some checks will be incorporated in the R code.

Data Archiving and Curation

All final electronic data sets and material associated with monitoring cave cricket entrance populations at MACA will be archived and curated according to NPS policy and procedures.

Electronic Data Sets

Final data sets for cave cricket monitoring will be archived by the CUPN data manager with all supporting documentation, including documentation of data files, data management procedures, hardcopy field data sheets, and quality assurance data. Multiple copies of datasets will be stored, and care will be taken that all copies are updated simultaneously when additional material is added. Datasets destined for archiving will be stored locally within an object-oriented file structure established on the CUPN file server. Tape backups of all project databases on the server are regularly conducted by the data manager. Backup copies of the data are maintained in a secure alternate location. Working GIS files are maintained by the CUPN GIS specialist. Final GIS files will also be archived on shared network drive.

Archives

Any material (preferably originals, but can be copies) associated with the project (e.g., digital images, maps, Field Information Sheets, field data sheets) will be archived and entered into Interior Collection Management System (ICMS). After these materials are archived and entered into ICMS they will be returned to MACA, or their designated repository, along with their corresponding ICMS records. Refer to the step-by-step instructions in the "Archive" section of SOP #6: Data Management for a more thorough coverage of this process.

Metadata Procedures

All geospatial data will be documented with appropriate Federal Geographic Data Committee and NPS metadata standards.

Sensitive Data

Sensitive information is generally defined as information about protected resources that may reveal the "nature or specific location" of protected resources. Such information must not be shared outside the National Park Service, unless a signed confidentiality agreement is in place. Per Executive Order or resource confidentiality laws, protected resources specific to this project potentially include:

- Endangered, threatened, rare, or commercially valuable resources
- Significant caves

This project will involve the collection and management of cave location data. Metadata development (i.e., Section 1, Constraints on Access) provides one way of documenting or labeling sensitive data to aid in their protection. Additionally procedures will be in place to remove protected information from datasets made available outside of NPS. This may include but is not limited to the removal of location information from externally available datasets and reports. CUPN staff will work with park resource contacts to ensure sensitive data are identified, labeled, and protected from inadvertent release.

Recommendations for Routine Data Summaries and Analysis

Data from the MACA cave cricket monitoring project will be analyzed in multiple ways:

- Annual status summary of cave cricket monitoring highlights,
- Analysis of trends in key measures over time; typically summarized every five years,
- Evaluations of relationships between key ecosystem drivers/attributes/stressors and key measures including cave and surface meteorology and infrastructure installation/maintenance.

Data Analysis

Data from the MACA cave cricket monitoring protocol support both non-adaptive estimates based on the counts inside strips and strip adaptive cluster sampling (SACS) estimates based on the counts by clusters. SACS should be substantially more efficient (i.e., lower uncertainty about estimates for a given sampling effort) than non-adaptive estimates based on just the crickets inside strips (Thompson 2002). However, because the rules for adaptively sampling clusters are based on all crickets, strip adaptive cluster estimates of the total counts for some sub populations (e.g., juveniles) might be less efficient than non-adaptive estimates. Therefore, as is common practice in these applications, we will compute both non-adaptive estimates based on strips and SACS estimates based on clusters, for the total population of crickets, and for the subpopulations based on sex and life stage (Ver Hoef and Boveng 2007).

The non-adaptive estimates of population totals based on counts in strips have a simple form:

$$\frac{N}{n}\sum_{n}^{i=1} Y_i$$

Where the baseline contains $\boldsymbol{N}$ possible strip locations (10cm intervals), $\boldsymbol{n}$ strips were sampled, and $\mathbf{Y}_i$ crickets were counted in strip $\boldsymbol{i}$. This estimator also has a simple variance estimator. However, because the samples of strips were drawn as 1-dimensional finite GRTS draws, the neighborhood variance estimator of Stevens & Olsen (2003) is applicable, and should provide lower variance about the estimated population totals.

The SACS estimators are based on the counts by clusters. The logic of SACS was described above. The computations are relatively straightforward: for a given entrance and event, the Horvitz-Thompson (H-T) estimate of the total number of crickets is the weighted sum of the counts within each cluster, with the weights being the inverse of the inclusion probabilities for each cluster.

$$\widehat{\tau_{HT}} = \sum_{i=1}^{\nu} \frac{y_i}{\pi_i}$$

$\boldsymbol{Y_i}$ is the count of crickets in cluster $\boldsymbol{i}$, $\boldsymbol{\pi_i}$ is the probability that cluster $\boldsymbol{i}$ will be included in a sample draw, and the summation is over clusters. If a cluster is intersected by more than one strip, it is still included only once in this equation.

The inclusion probabilities of clusters are functions of the extent of each cluster in the direction of the baseline: the larger the extent of a cluster, the greater the chances that it is intersected by at least one strip. The standard equations for inclusion probabilities in SACS are based on simple, independent random selection of strip locations. Because our strip locations are generated as a 1-dimensional spatially-balanced GRTS draw, those equations do not apply. Instead, for each cave entrance and sampling event, 1,000,000 additional GRTS draws of $\boldsymbol{n}$ strips are simulated, and the fraction of those simulated draws that have at least one strip intersecting a cluster is taken as the estimate of the inclusion probability of that cluster.

The variance for this H-T estimator is a complex equation (See SOP #7: Data Analysis) involving not only the inclusion probabilities of each cluster, but the probabilities of pairwise inclusion of both clusters $\boldsymbol{i}$ and $\boldsymbol{j}$. Again, the standard equations for pairwise inclusion probabilities are based on independent random samples. The same 1,000,000 simulated GRTS draws used for estimating cluster inclusion probabilities are used to estimate pairwise inclusion probabilities by tallying the number of simulations that included both clusters $\boldsymbol{i}$ and $\boldsymbol{j}$ for all pairs of $\boldsymbol{i \neq j}$.

Given these estimates of the total numbers of crickets at each cave entrance and sampling event, temporal trends will be tested as both generalized linear mixed models (GLMM using function glmer in the lme4 R package) and generalized estimating equations (GEE using function geeglm in the geepack R package). Both of these approaches are appropriate for count data that are likely to be overdispersed relative to the Poisson error distribution expected for counts of independently occurring events. For technical reasons, the glmer approach fits overdispersed Poisson as a two-parameter negative binomial distribution. The geeglm approach adds an overdispersion parameter and treats the error distribution as quasipoisson. These models also support tests for differences in trend among cave entrances or among groups of cave entrances (e.g., between developed and undeveloped entrances). However, because the monitored entrances are not a probability sample of any defined population of entrances, the tests support inferences about only these particular entrances, and not to unsampled developed or undeveloped entrances.

The status of cave cricket entrance populations over time is one of the objectives of this monitoring protocol and is effectively presented by a form of control chart. The estimated population size for the most recent sampling event at each entrance is plotted over a boxplot of the estimates from previous sampling events (Figure 9). This produces a visual representation of which, if any, of the monitored cave entrances have recent population estimates high or low relative to that cave entrance's historic range of variability. If some current values are high and some are low, there is cave entrance-specific fluctuation. If most cave entrances deviate in the same direction that suggests a region-wide driver such as surface weather or food sources (Figure 10).

Estimates of total cave cricket entrance populations, sex, and life stage, are only one aspect of cave cricket status in these entrances. Other aspects may also be informative of impacts of cave entrance management, climate, or other stressors. For instance, the distribution of roosting crickets as functions of distances from the cave entrance to aboveground might shift due to changes in air circulation or meteorological conditions in the first few tens of meters of the passageway. This sampling and data collection scheme supports estimates of several such secondary aspects. Temporal changes in total cave cricket entrance population will be estimated and also partitioned into several components of numbers of clusters and the distribution of the numbers of crickets per cluster (Figure 11). The distribution of crickets as a function of distance from the surface can be characterized as cumulative distribution functions estimated for individual cave entrances and each cave entrance can support tests for shifts in those distributions over time.

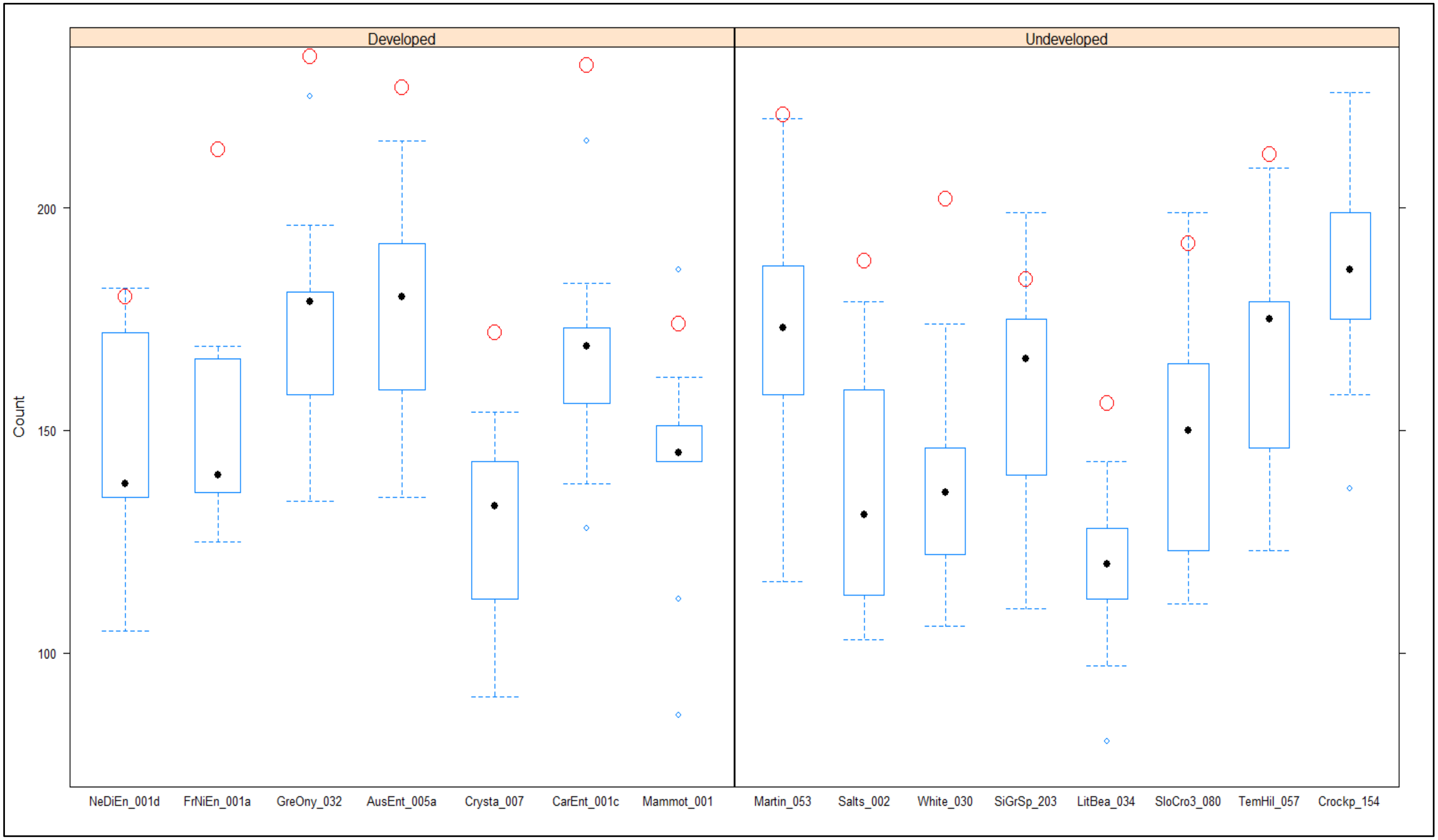


Figure 9. Mockup of control chart depicting ten years of estimates of monitored cave cricket entrance populations. The most recent sampling event (red circles) are plotted over a boxplot of estimates from previous sampling events. Note: black dots indicate the median of the data and blue dots are outliers.

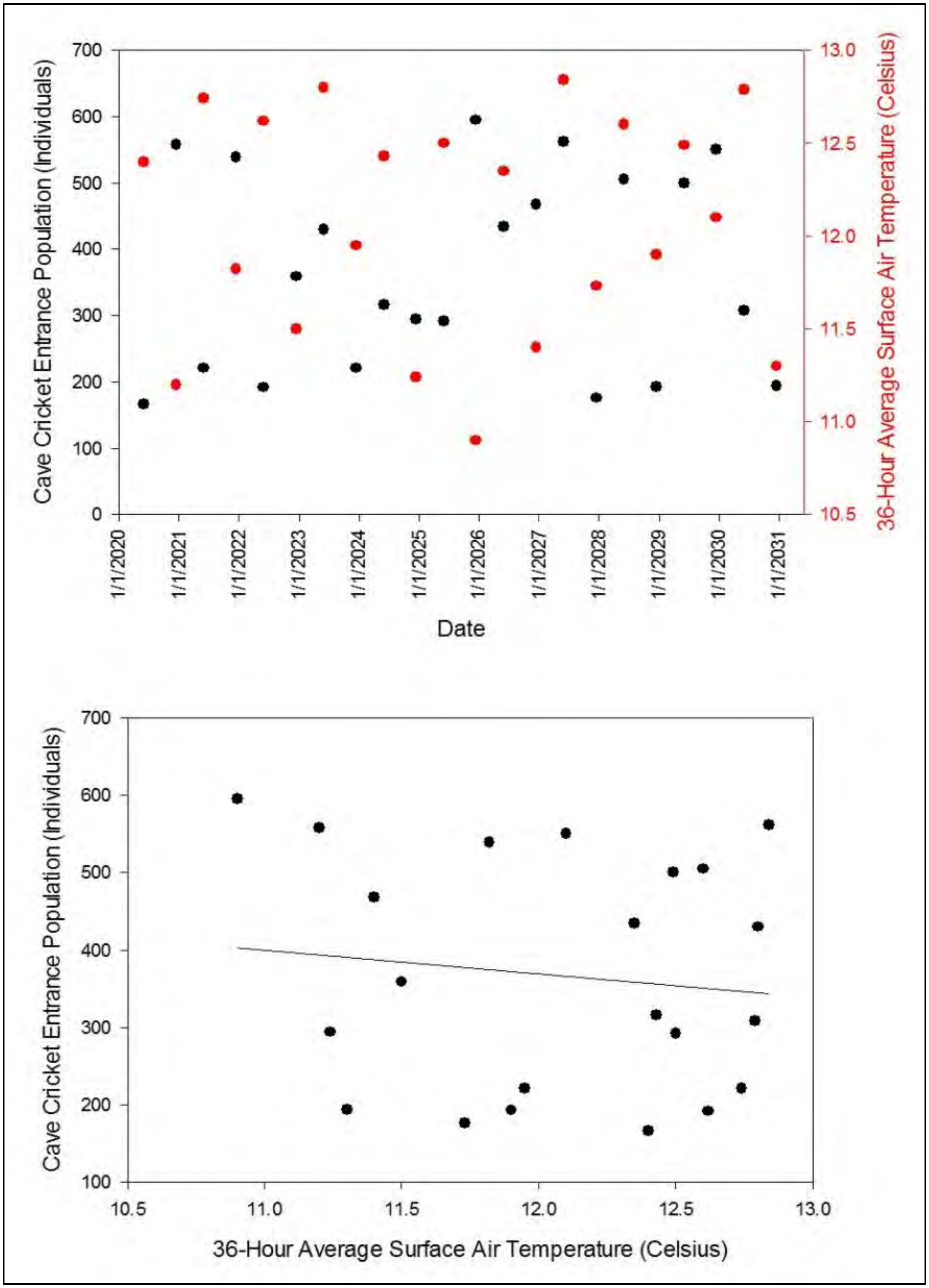


Figure 10. Mockup of plots depicting 36 hour average surface temperature and estimates of monitored cave cricket entrance population at a cave over twelve years. The top plot is a simple time series for both sets of data. The bottom plot explores the relationship between the two sets using a scatterplot and regression line of best fit.

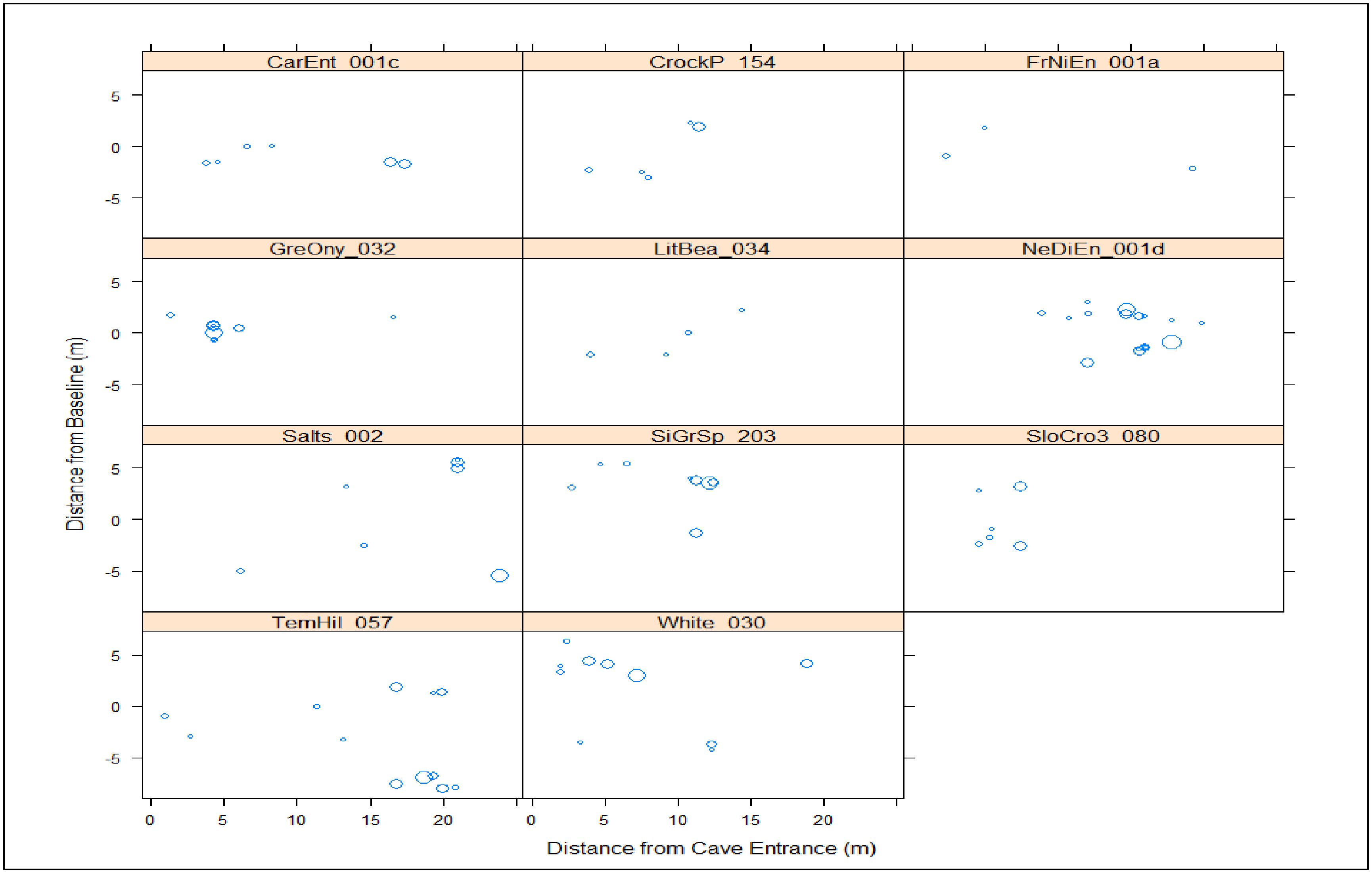


Figure 11. Proportionally sized bubble plot of cave cricket clusters from 2010 Strip Adaptive Cluster Sampling pilot data. The y-axis is the cluster's distance from the baseline and side of the passage on which they were located (positive = left and negative = right). The x-axis is the cluster's distance from the cave entrance. Proportional bubble plots are an informative way to display data on the location, number and size of cave cricket clusters.

Recommended Reporting Format, Schedule, and Delivery

Reports generated by this monitoring project will consist of three major types. Trip Reports will be written to briefly summarize sampling trips for park staff. Brief follow-up trip reports will be completed within two weeks after each sampling trip. Annual Status Reports and Trend Analysis Reports will provide park management and other interested parties technical and interpretive information about the status and trends being detected in the monitored resource. The annual status report may include descriptive statistics, graphic analysis, and correlative statistics on cave cricket entrance populations and will be produced in late winter after the preceding year's monitoring events and subsequent data analyses are completed. This type of report will target MACA's superintendent and resource managers and will provide them with a view of the current status and short-term shifts in any parameter(s) of the resource. Annual status reports will be submitted to the Natural Resources Data Series for publication. The trend analysis report will typically be generated every fifth year, beginning five years after the formal implementation of the monitoring protocol. The trend analysis report will also address patterns in cave cricket population structure and dynamics among developed and undeveloped caves, using similar components as the annual status report, but will do so with cumulative data on a scale spanning multiple years. The Annual Status Reports and 5-Year Trend Analysis Reports will be submitted for publication in the NPS's Natural Resource Publications Management series (accessed 2 April 2014).

To reduce the time and effort normally required to write annual status and trend analysis reports R code, used to access standard databases to produce informative tables and figures, will be added during initial report writing in MS Word™. Thus, when new data are entered into the database the R code run on those data will produce new report components. For consistency between/among report intervals all of the formatting, boilerplate background text, and forms of tables and figures will remain the same year after year. This scripting of the workflow provides both documentation and automation, and makes the work reproducible from one year to the next. For additional details see SOP #8: Reporting.

Several products are also posted to the NPS's Integrated Resource Management Application (IRMA) hosted by the NPS Washington Support Office or National Inventory and Monitoring Program. Formally maintained as separate applications, the IRMA application incorporates:

- The master database for natural resource bibliographic references.
- The master database for biodiversity information including species status on parks (i.e., present in park, probably present, etc.), along with observation and voucher information.
- A centralized data repository, allowing for the download of digital reports and datasets.

Procedure for Revising the Protocol

Over time, revisions to both the Protocol Narrative and to SOPs are to be expected. Careful documentation of changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in SOP #9: Revising the Protocol. Each SOP contains a Revision History Log that will be filled out each time a SOP is revised to briefly document when and why the change was made, and to assign a new

Version Number to the revised SOP. The new version of the SOP or Protocol Narrative will then be archived in the appropriate CUPN Vital Signs Protocol folder on the CUPN network drive.

Personnel Requirements and Training

Roles and responsibilities

Major protocol tasks and staff needed/responsible for each are summarized in SOP 2: Pre-Field Sampling (Table SOP2-6). Additional information on personnel requirements is located in the "Staffing" section of SOP 2: Pre-Field Sampling. The CUPN Network Program Manager and Monitoring Program Leader are responsible for overseeing and coordinating the development and implementation of the cave cricket monitoring project, as well as the other vital sign protocols. They ensure the cave cricket monitoring project is aligned with and contributing towards overall Network goals. The Network Program Manager and Monitoring Program Leader also provide support in budget, personnel, and logistical matters. The project leader is the lead ecologist for implementing this monitoring protocol and is supervised by the Monitoring Program Leader for the CUPN.

Project Leader

A CUPN ecologist functions as the cave cricket monitoring *project leader* at MACA, and is responsible for coordinating all aspects of the project, including communication with MACA resource managers, logistics, field work, data collection and management, and analysis/reporting. The project leader should be knowledgeable in cave invertebrate ecology, experienced with the monitoring techniques contained within this protocol, and experienced in working with R. Specific responsibilities and tasks include:

- Ensuring effective communication between park staff, field crew, and other CUPN staff.
- Developing, reviewing, revising (as needed) and implementing the monitoring protocol, standard procedures and data sheets for field data collection and data handling.
- Developing an annual field schedule and finalizing sampling dates.
- Arranging lodging for field crew.
- Participation in hiring of seasonal field crew.
- Preparing Field Information Sheets for field sampling.
- Preparing pre-populated "Strips" field data sheet and "Clusters" field data sheet.
- Inventorying the condition of all equipment, repairing, or purchasing replacements.
- Ensuring field crews receive pertinent training and briefings.
- Supervising field crew during the field season and participating in field sampling.
- Ensuring field crew work meets the desired standards of quality.
- Ensuring sampling work is done in a way that addresses safety hazards, disturbance to bats, and transmission of WNS.
- Ensuring completed field data sheets, digital images and other data are returned from the field and processed in a timely manner.

- Writing and submitting brief sampling trip reports to park staff.
- Analyzing images of cave cricket clusters (or train/oversee a crew member with image analysis).
- Obtaining and maintaining the required NPS permits, including writing and submitting Investigators Annual Reports to permit reporting system.
- Participating with data manager in QA/QC of data entered into database, and archiving of data (both hard copies of data sheets and electronic formats).
- Acting as the main point of contact concerning data content.
- Once all data are entered, completing final validation and complete summary reports for each park. Analyzing data and writing monitoring reports.

Field Crew Leaders
The cave cricket monitoring *field crew leaders* will be responsible for managing the field crew members as designated by the project leader. The field crew leader will assist the project leader with training the field crew on data collection; will assemble, assess, safety check, and repair equipment; will oversee and review field data collection; and will oversee gear decontamination and storage. The field crew leader must have experience training others, experience leading groups, and particular experience with all field methods used in this protocol, and with conducting field work in caves. This person must also know how to use a GPS unit, including how to mark new points. S/he must also be detail-oriented, organized and meticulous about the collection, analysis, and safeguarding of data.

In addition to the responsibilities of a crew member, the field crew leader will perform the following tasks:

- Coordinating directly with appropriate park resource managers or other personnel when conducting field work in MACA.
- Ensuring that all field crew members are trained in proper data collection and gear decontamination/storage procedures.
- Checking for updates to emergency numbers list and printing copies along with directions to hospitals.
- Acquiring field data sheets and baseline maps from Project Leader for field sampling; the field crew leader may also prepare these if delegated by the project leader.
- Assembling, assessing, and repairing equipment.
- Collecting all data in field accurately, according to established procedures.
- Ensuring sampling work is done in a way that addresses safety hazards, disturbance to bats, and transmission of WNS.

- Accurately identifying cave crickets in the field.

- Supervising field crew member(s) assigned to team and ensure they are collecting data efficiently and correctly.

- Ensuring completed field data sheets, photographs and other data are returned from the field and processed in a timely manner.

- Analyzing images of cave cricket clusters (or train/oversee a crew member with image analysis).

- Writing and submitting brief sampling trip reports to park staff (if delegated by the project leader).

- In cooperation with the Network data manager, ensuring that all data undergo the proper QA/QC procedures (including data verification after data are entered).

Field Crew Members

The *field crew members* will be responsible for assisting with accessing caves, carrying gear, collecting data in the field, handling data, and entering data into the project database. Crew members may be college graduates or students who have strong interest in or experience in ecology, biology, or related natural resource fields. This qualification is relevant because students with a biological career-track, or cavers, are generally less afraid of insects and crew members participating in cave cricket sampling events will be intimately involved with relatively large, long-legged insects. Alternatively, crew members may simply be volunteers who are experienced cavers (if entering caves), or experienced with field work in general. All crew members working in caves must have experience with caving. Crew members involved with data collection or recording must be detail-oriented, and must write legibly. All crew members must be able to work in extreme conditions of heat, humidity, cold, rain, snow, darkness, biting/stinging insects, and venomous snakes, and be capable of making long, off-trail bushwhacking trips into remote caves in rugged terrain. Specific tasks (if assigned) for which the crew members will be responsible include:

- Completing mandatory training and reading pertinent protocols, JHAs, and SOPs.

- Ensuring that all necessary gear and equipment are assembled, clean, and functional prior to each trip.

- Safeguarding equipment during field operations to prevent damage or loss.

- Conducting field work in a way that addresses safety hazards, disturbance to bats, and transmission of WNS.

- Collecting field data accurately, and as described in the SOPs.

- Correctly and legibly recording all data values on the field data sheets.

- Completing timesheets and expense reimbursement sheets accurately and in a timely manner.

- Processing completed field data sheets, images, and other data as described in the SOPs, and in a timely manner.

- Assisting the project leader with analyzing digital images (as deligated).

- Entering data accurately into the project master database from paper data sheets and conducting data verification steps.

- When not in field, assist data manager and project leader in accomplishing other tasks related to the project, as appropriate.

With few exceptions, the project leader or designated field crew leader will be the lead field team member, supervising the work of field crew members. Field crews will consist of CUPN staff, university interns, Student Conservation Associates (SCA), other cooperators, park staff, or volunteers.

Physical Scientist

The CUPN physical scientist will be responsible for coordinating the collection, storage, and analysis of cave meteorological data and equipment related to the cave cricket monitoring project. Tasks include archiving field data sheets, launching/uploading dataloggers, naming and storing data files, analyzing cave meteorological data, and reporting results. Specific tasks for which the physical scientist will be responsible include:

- Ensuring that all field crew leaders are trained in proper collection of cave meteorological data, including proper calibration, use, servicing, and storage of related equipment.

- Launching, servicing, downloading, removing and uploading temperature and relative humidity automated HOBO dataloggers (these subtasks may be delegated to the project leader or a trained field crew leader).

- Naming and storing data files downloaded from automated HOBO dataloggers.

- Participating with data manager in QA/QC of collected cave meteorological data, and archiving of data (both hard copies of data sheets and electronic formats).

- Analyzing data and assisting project leader with writing monitoring reports.

Data Manager

The CUPN data manager will be responsible for maintaining the database for the cave cricket monitoring project and will oversee database management. Data entry will be conducted at the main CUPN office after field data sheets and electronic files have been processed. Along with the project leader, the *data manager* will ensure that all individuals involved in the project are aware of their data management responsibilities. Specific tasks for which the data manager will be responsible include:

- Consultant to all project staff on data management activities.
- Maintain and update database application.
- Provide oversight and training on the use of the database application.
- Coordinating electronic data archival and backup procedures.
- Provide assistance to network program manager and project leader with data summaries and analyses.
- In consultation with project leader, posting of products to IRMA.

GIS Specialist

The CUPN GIS specialist will be responsible for coordinating GPS data/equipment and maintaining all geospatial data and cave maps (including Baseline Maps) related to the cave cricket monitoring project. Tasks include archiving of sampling cave entrance locations and parking locations, and creation of maps for field crews and reports. Geospatial data will be uploaded to the NPS Natural Resource Information Portal (NRInfo), as appropriate, and will be documented with appropriate Federal Geographic Data Committee and NPS metadata standards. Specific tasks for which the GIS specialist will be responsible include:

- Maintaining a full list and coordinates of all cave cricket cave entrances selected for monitoring.
- Maintaining a geodatabase with information about all cave entrance and parking locations, updated yearly.
- Maintaining all working GIS files associated with the protocol, including archiving the files on a shared network drive.
- Creating and maintaining metadata for all geospatial data using appropriate Federal Geographic Data Committee and NPS metadata standards.
- Maintaining and updating the Baseline Maps for each monitored cave entrance.
- Uploading cave entrance location and parking location coordinates into the CUPN GPS unit(s) or handheld device using DNR Garmin or other similar software.
- Obtaining GPS units from field crew leader or project leader, at end of each field season, and downloading GPS coordinates and metadata associated with any newly marked waypoints.

- Assisting with maintenance/troubleshooting of image analysis process.

Curatorial Specialist

Final hard-copy data sets resulting from cave cricket monitoring will be processed by the CUPN *curatorial specialist* according to NPS guidelines. S/he will be responsible for, archival housing, contacting park curators to request accession numbers and catalog numbers for the cave cricket monitoring project, entering information into NPS Interior Collection Management System (ICMS) database, and sending archives to the park (if final repository) or generating loan agreements (if needed) and sending archives to alternate repositories. The curatorial specialist will work with MACA to ensure records are uploaded into their master NPS-ICMS database and that archives are delivered to designated repositories.

Data Intern

This intern's primary task is to enter data into the master database. When available, an intern can serve to assist the data manager, GIS specialist, and curatorial specialist in her/his duties.

Training Procedures

An essential component for the collection of credible, high-quality data on cave crickets and associated meteorological data is well-trained and experienced field crew leaders. Prior to the field season, field crews will require training in order to collect data effectively and efficiently. Training will be conducted by the project leader, or an experienced crew leader designated by the project leader. Training sessions are necessary for <u>all</u> project crew members but particularly crew members new to the project. New crew members must undergo training for each of the field sampling methods and office tasks in which they will participate. Training will include: 1) orientation—which will summarize this protocol, 2) in-office demonstrations of the less intuitive field equipment (e.g., HOBO datalogger servicing), 3) data recording, 4) cave photography, 5) image analysis, data handling, and processing, 6) data entry, 7) sampling dry runs, 8) pre-field sampling event briefings, 9) safety procedures, and 10) WNS decontamination requirements and procedures. A more detailed list of protocol tasks that selected field crew leaders and crew members need to master is provided in SOP #1: Training (Table SOP1-1).

Training will include demonstration and practice of all measurement procedures. The critical importance of careful, accurate, and steady data collection to this long-term monitoring project will be emphasized. Trainers will stress the importance of exact adherence to SOP instructions to prevent bias in measurements among years. Training will emphasize the critical importance of careful behavior to minimize disturbance to cave organisms, and consistent adherence to the latest national decontamination guidance to minimize the risk of spreading the fungus which causes WNS in bats. Training will also include an overview of safety issues that may be encountered by field crews. Prior to conducting the first field sampling event each year, all field personnel involved must <u>read and sign</u> the JHA (Table SOP2-5). Prior to each sampling day, all participating field personnel must <u>review</u> the related JHA (Table SOP2-5) and agree to follow all safety guidelines during sampling.

Operational Requirements

Annual Workload and Field Schedule

Cave cricket monitoring events occur twice during a sampling year. Monitoring events are conducted once per "shoulder season" (i.e., May-June and September-October), at each of our selected monitoring caves at MACA. Monitoring can safely be carried out with a two person crew since at no time are personnel approximately >100m inside sampling caves. The safety of field personnel is discussed in the "Pre-Field Season Preparation" sub-section of the "Field Methods" section of this protocol narrative, and more detail is provided, along with a JHA, in SOP #2: Pre-Field Sampling (Table SOP2-5). Typically, two caves are sampled per day during a sampling event. Eight to nine days are required to complete a cricket sampling event at MACA.

The early spring, late summer and late winter months will be used for equipment inventory/repair/replacement, permit applications, photo analysis, data entry and QA/QC, data analysis, report writing, review and revision (if necessary) of the protocol based on previous field seasons. Preparations for the upcoming sampling events will occur in early spring and late summer. The annual timing of major protocol tasks, including field and administrative needs, is given in SOP #2: Pre-field Sampling (Table SOP2-7).

Facility and Equipment Needs

The nature of cave cricket monitoring work does not require special facilities beyond normal office space and equipment storage needs currently available at the CUPN's MACA Headquarters and MACA's biology laboratory. The logistical and equipment needs of the cave cricket monitoring crew are detailed in the appropriate checklists in SOP #2: Pre-Field Sampling; Tables SOP2-2 to SOP2-4 contain lists of field equipment needs for the crew. The project leader coordinates transportation needs with CUPN and MACA staff. The project leader will first consult the CUPN Vehicle Schedule to reserve a CUPN vehicle or rental vehicle for transport within MACA but, if one is unavailable, may request the use of a MACA vehicle. Sampling at specific caves in MACA may require a 4-wheel drive vehicle.

Startup Costs and Budget Considerations

Legacy cave cricket monitoring efforts at MACA have led to the development of key partnerships with various individuals and institutions. Further, various equipment has been developed and acquired during legacy cave cricket monitoring efforts at MACA.

- One CUPN ecologist has conducted annual censuses of roosting cave crickets in MACA caves since 1994 with faculty and students from Western Kentucky University, the State University of New York-Plattsburgh (SUNY-Plattsburgh) and the University of Illinois at Chicago.

- The CUPN staff have 10 years of experience with cave cricket monitoring equipment (e.g., laser projectors, DSLR camera) developed or acquired during legacy cave cricket monitoring efforts.

- MACA has provided various interns and volunteers to conduct cave cricket censuses since 1994.

- MACA staff have assisted CUPN staff over 20 years developed or acquired during legacy cave cricket monitoring efforts.

Currently, two CUPN ecologists and one CUPN physical scientist have experience with cave cricket monitoring and are listed as field crew members in the MACA permit.

In 2012, a 5-year cooperative agreement was signed between the CUPN and Western Kentucky University (Cooperative Ecosystems Study Unit) for $150,000 to provide student interns in support of vital signs monitoring. These interns will be used as field crew members and will participate in data processing and data entry. Periodically, interns acquired via a cooperative agreement between the CUPN and various organizations that provide youth interns may also assist with field or office tasks in support of this monitoring project.

Future costs associated with the cave cricket monitoring protocol are detailed in Table 3. This estimate includes salary, travel costs, and supplies and equipment. The largest costs involved in monitoring, personnel expenses for field work, are based on one crew of two people: a project leader to oversee the sampling event and photograph cave cricket clusters, and one temporary biological technician to act as a field crew member (Table 3). Estimates of personnel hours are based on two people participating in sampling events at fifteen caves twice per sampling year. A sampling event consists of SACS being performed at two caves per day, for a total of 16 days in the field per sampling year. Field costs may vary from year to year based on scheduling, variety of field crew members (e.g., intern v. volunteer) and the use of synoptic sampling. Additional staff costs involving the project leader and the data intern include renaming and analyzing digital images, data entry, and data validation. Supporting tasks such as answering data requests, database maintenance, map construction, and data/report archiving will be performed by the CUPN's data manager, GIS specialist, and curatorial specialist. Finally, consumable equipment (e.g., batteries, Rite-in-the-Rain™ paper, etc.) will require replacement.

Table 3. Estimated monitoring costs for one year of cave cricket monitoring at Mammoth Cave National Park.

Expense Type	Task Category	% Budget	$ Amount	Estimate Basis
Salary	Field Sampling and Travel Time	62.6%	$7,685.12	Assumes about 150 hours from volunteers or park staff. Assumes 128 hours for 2 sampling events Breakdown: $5,893.12 GS-11 ecologist $1,792.00 CUPN Intern
Salary	Data Mgmt (i.e., Pre-sampling, GIS/Data Processing/Data Entry/Analysis & Reporting)	35.2%	$4,320.58	1/3 budget rule estimate from NPS I&M program Assumes about 60 hours from volunteers or park staff. Breakdown: $1,045.20 GS-12 DM/ecologist (20 hours) $159.96 GIS Specialist (4 hours) $257.20 CUPN Curatorial/biologist (8 hours) $840.00 CUPN intern (60 hrs) $1,841.60 GS-11 Ecologist (40 hours) $176.62 physical scientist (4 hours)
Supplies and Equipment		2.2%	$274.30	After initial equipment purchase this placeholder is for periodic repair/replacement costs and annual supplies.
	TOTAL	100.00%	$12,280.00	

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SOP #1: Training Personnel

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

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SOP 1 – Contents

Page

SOP 1 – Tables

Page

Overview

This Standard Operating Procedure (SOP) discusses the training of personnel involved in all aspects of protocol implementation. Implementation of this protocol requires an overall project leader plus one to two other persons. The project leader, a permanent employee intimately familiar with field sites and years of experience employing sampling techniques, performs monitoring activities and is responsible for training sessions. Field sampling crews will normally be comprised of the project leader (or designated field crew leader) and one field crew member.

Training

Training sessions are necessary for all project crew members but particularly crew members new to the project. New crew members must undergo the entire gamut of training sessions so that they may be proficient in all protocol activities and so able to assist with any task. Training sessions will include: an orientation session which will summarize this protocol, in-office demonstrations of the less intuitive field equipment (e.g., laser assembly), data processing, data entry, sampling dry runs, pre-sampling event briefings, safety procedures, and white-nose syndrome decontamination requirements and procedures. Obviously, on the job training will also be of enormous value toward honing new crew members' skills at various protocol tasks. Experienced crew members absent from the project for six months or more will attend a sampling dry run and re-train at office tasks (e.g., image analysis and data entry) with current crew members. Once the project attains a critical mass of reliable crew members, training sessions will be conducted as needed. Table SOP1-1 below is a more detailed list of protocol tasks that all crew members need to master.

An essential component for the collection of credible, high-quality cave cricket and associated meteorological data is a well-trained and experienced field crew leader. This cannot be overemphasized. Therefore, new crew leaders should be thoroughly familiar with SOP#2: Pre-Field Sampling, SOP #3a: Field Methods: Strip Adaptive Cluster Sampling, SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry, and SOP #5: Post-Field Sampling: Decontamination of Gear, and will be given hands-on training by the project leader, or an experienced crew leader designated by the project leader, for each of the tasks detailed therein. A few crew leaders from among CUPN and park staff should be trained (and should participate in sampling on a regular basis) in case scheduled crew leaders are unavailable for particular sampling events. Proper adherence to SOP #2: Pre-Field Sampling should serve to refresh and "recalibrate" the crew leaders' ability to prepare for sampling; locate sampling sites; and properly record the information and so ensure the integrity of the data being collected. All personnel involved with the handling and processing of equipment or data (i.e., hardcopy and electronic formats) following field sampling must review SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry prior to the first field sampling event each year. Transient personnel (e.g., university interns, Student Conservation Associates, other cooperators, volunteers, short-term or temporary NPS employees) can serve as field crew members and assist with image analysis. Review of SOP #s 2, 3, 4, and 5 is necessary for transient personnel.

Training will include demonstration and practice of all measurement procedures. The critical importance of careful, accurate, and steady data collection to this long-term monitoring project must be emphasized. Trainers must stress the importance of exact adherence to SOP instructions to prevent bias in measurements among years. Lack of strict adherence to protocols will inhibit our ability to detect long-term trends. The crew must never deviate from established protocols or alter data sheets or the database without first consulting with the project leader. Any changes in procedures must be clearly documented in the SOP revision history and the project database by the project leader in conjunction with the data manager.

Training must emphasize the critical importance of careful behavior in the cave and consistent adherence to the latest national decontamination guidance to minimize the risk of spreading the fungus which causes white-nose syndrome in bats. Training will also include an overview of safety issues that may be encountered by field crews. Prior to participating in their first field sampling event each sampling year, **all** field personnel involved must review SOP #2: Pre-Field Sampling, and read/sign the related Job Hazard Analysis (JHA). Prior to each field sampling event, all participating field personnel must review the related JHA and agree to follow all safety guidelines during sampling.

Table SOP1-1. List of protocol tasks in which various project crew members must be proficient and the location for detailed instructions among project SOPs (if any).

Training Location		**Protocol Task**
Field	Office	Use of various checklists and data sheets (SOP #2: Pre-Field Sampling, SOP #3a: Field Methods: Strip Adaptive Cluster Sampling, and SOP #3b: Field Methods: Cave Meteorological Sampling)
Field	Office	Use of laser equipment and tripod (SOP #2: Pre-Field Sampling)
Field	Office	Camera operation and photographic techniques (SOP #2: Pre-Field Sampling and SOP #3a: Field Methods: Strip Adaptive Cluster Sampling)
Field	Office	The use of Field Information Sheets and Baseline Maps (SOP #2: Pre-Field Sampling).
Field		Strip Adaptive Cluster Sampling (SOP #3a: Field Methods: Strip Adaptive Cluster Sampling)
Field	Office	Conducting opportunistic grab sampling with handheld temp/RH sensors (SOP #3a: Field Methods: Strip Adaptive Cluster Sampling)
Field	Office	Installing and servicing a HOBO RH/temperature datalogger (Woodman et al. 2011 and SOP #3b: Field Methods: Cave Meteorological Sampling)
Field	Office	Downloading continuously sampled surface meteorological data from MACA SCAN Station website (SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry)
Field	Office	Taxa recognition and recognition of cave cricket life stage/sex/body parts (Appendix D: Guide to cave cricket morphology)
	Office	Image analysis (SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry)
Field	Office	Decontamination precautions and minimizing disturbance (SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry and SOP # 5: Post-Field Sampling: Decontamination of Gear)
	Office	Data Entry (SOP #4: Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry)
Field	Office	Proper use of the park's two-way radios

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SOP #2: Pre-Field Sampling

Cave Cricket Monitoring Protocol
Cumberland Piedmont Network
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SOP 2 – Contents

Page

SOP 2 – Contents (continued)

Page

SOP 2 – Figures

Page

SOP 2 – Tables

Page

Overview

This SOP describes, along with checklists, general preparations for field work in/at caves, safety (including a Job Hazard Analysis), and scheduling monitoring of cave crickets and associated cave meteorological parameters at fifteen caves in Mammoth Cave National Park (MACA). A sampling design summary is presented first to orient the reader. Additional precautions taken to reduce the spread of white-nose syndrome are described. All field personnel review this SOP by March of each year and the *project leader* revises any sections based on lessons learned from field sampling the previous year.

General Sampling Schedule

Monitoring of cave cricket populations at MACA occurs during biannual sampling bouts in May-June and September-October. A sampling bout consists of seven or eight consecutive days wherein two of fifteen cave entrances (6 developed and 9 undeveloped cave entrances) per eight-hour day are surveyed with a two-person field crew; each visit to a cave entrance constitutes a sampling event. On each day of a sampling bout the field crew performs all steps described in SOP #3a: “Field Methods: Strip Adaptive Cluster Sampling” and in SOP #3b: “Cave Meteorological Sampling” in each of the 15 sampling cave entrances (Table SOP2-1). In most cases all sampling tasks within a cave are expected to be completed within approximately two hours; additional time may be needed if a cave presents unusual conditions or difficulties in

Table SOP2-1. Fifteen cave entrances, stratified by development status, selected for monitoring cave cricket entrance populations in Mammoth Cave National Park.

Undeveloped	Developed
Crockpot	Austin
Little Beauty	Carmichael
Marin	Floyd Collins Crystal
Salts	Frozen Niagara
Silent Grove Springhouse	Great Onyx
Sloan's Crossing #3	Historic Entrance
Temple Hill	New Discovery
White	

performing one or more specific sampling tasks. After a sampling bout concludes image analysis and entry of data associated with clusters (e.g., cluster extent, cluster distance) are entered into the cave cricket monitoring database as described in the SOP #6: Data Management. Initial installation of *in situ* dataloggers to continuously sample cave temperature and relative humidity will occur during the first sampling event at each cave and data will be downloaded during each subsequent sampling event. As necessary, datalogger servicing activities will occur during the second sampling bout at the end of each cave entrance's sampling event. No less than a week following the end of the sampling year (i.e., after the second sampling bout is completed) continuously sampled surface meteorological data are downloaded from MACA's Soil Climate Analysis Network station website.

Communication and Coordination with Park

A current National Park Service (NPS) research permit must be obtained to perform cave cricket monitoring at MACA. The permit application is completed prior to its expiration. MACA allows multi-year permits to cover long-term monitoring projects. The status of cave cricket monitoring research permits is verified and applications for new permits submitted at the Research Permit and Reporting System "Quick Link" on the NPS Integrated Resource Management Application website (accessed April 2014). The project leader ensures that MACA's designated resources management contact has the current, approved, Protocol for Monitoring Cave Crickets and a list of sampling locations so that any compliance issues can be addressed. The project leader is responsible for year-end reporting requirements for each permit.

In addition to permits, the project leader emails MACA's designated resources management contact at least two weeks prior to each sampling bout to provide the planned/proposed dates. Prior to the first sampling event the field crew visits the MACA Science and Resources Management (SRM) office for brief introductions and to meet any logistical needs such as picking up keys, vehicle hang tags, etc. The project leader fills in a cave entrance request form for each cave to be sampled during that sampling bout and obtains an approval signature from appropriate personnel (e.g., Chief of SRM). Brief follow-up trip reports are completed within two weeks of each sampling bout.

Logistics

General Preparation and Review

1. As conditions in caves can change between sampling bouts notes on cave Field Information Sheets (Figure SOP2-1) from previous surveys are reviewed to identify any unique events or hazards that may be encountered. Information from this database may influence how the data are interpreted and reported and so their preservation is important.

2. Prior knowledge of sampling procedures is essential for cohesive and efficient sampling crews. Therefore, new crew members or experienced crew members absent from the project for more than six months review all SOPs referenced in SOP 1.

Cave entrances added to or deleted from the monitoring protocol list have their waypoints loaded on, or removed from, the GPS units by the CUPN GIS specialist prior to the start of a sampling bout. Waypoints are the X and Y coordinates used to navigate to the location of each cave entrance.

Scheduling Field Work

Variable weather and personnel workloads preclude the scheduling of sampling events to specific annual dates. Thus exact sampling dates and field personnel are scheduled and logistics (e.g., vehicles) organized as far in advance of sampling bouts as possible. Backup dates will also be scheduled in advance. To minimize inter-annual variation, sampling dates for each sampling bout will be scheduled as close as possible to the same dates each scheduled year. The project leader is responsible for contacting potential field personnel to schedule specific sampling event (and backup) dates. Once the specific dates (including backup dates) for each sampling event are selected, the project leader reserves a CUPN or SRM vehicle for transport within MACA; traveling to some caves may require a 4-wheel drive vehicle.

Fake Cave: Cave Cricket Monitoring Field Information Sheet

Mammoth Cave National Park   Access Keys Needed:________________
Date (month, year)

Cave Location Map
The cave entrance location should be overlaid on a USGS topographical map, with roads, trails, and park boundaries included. This will aid in navigating to the entrance. [print on back of form, if blank]
GPS coordinates: X=___________ Y=____________

Parking Location
Describe where to park to begin hiking to the cave. This may be a designated trailhead, or a more obscure location, such as a specific spot along a road shoulder.
GPS coordinates: X=_________ Y=__________

Field Crew Size
Indicate the recommended number of personnel based on safety, efficiency, cave size and complexity, number and size of entrance(s), and disturbance considerations, for example:

best = 2, minimum = 2, maximum = 3

Special Equipment
List any non-standard equipment necessary for the survey. For example:

- cave access gear: climb-down on north side of entrance
    - ✓ 20’ webbing for building anchor around oak tree
    - ✓ carabiner to attach 50’ handline to anchor
- camera with zoom lens for photographing high roosting clusters

Overview/Sampling Instructions
Describe the cave and recommended sampling route, method, or equipment/observer placement (provide a sketch). Include obstacles or safety hazards like climbs or drops. Indicate any special considerations that may affect the count.

HOBO Datalogger Information
For each temperature/RH datalogger provide serial #, model, date of initial installation, description of location, landmarks, or plot on baseline map (Figure SOP2-2), date of removal, and applicable date of re-installation.

Figure SOP2-1. Field Information Sheet template for cave cricket monitoring in Mammoth Cave National Park.

Staffing

The cave cricket monitoring protocol is implemented by two persons (typically one field crew leader and one crew member) covering about 7 or 8 days in May-June and another 7 or 8 days in October-November. Field crews consist of CUPN staff, volunteers, park staff, university interns, Student Conservation Associates (SCA), or other cooperators. It is the network program manager's responsibility to obtain field assistants each year through various cooperative agreements available to the CUPN. The project leader may also serve as the field crew leader but there should always be a trained backup as a contingency. The field crew leader possesses good identification skills for cave cricket species, possesses good cave photography skills, and has experience in strip adaptive cluster sampling (SACS) methods. Field personnel also are adept at traveling through caves, including crawling, where necessary. Caving skills are important to ensure that field personnel can safely access caves and maneuver through passages without causing resource damage or sustaining injury. Implementation of the protocol also requires the use of cameras, GPS units, and other field equipment (see equipment checklists in Tables SOP2-2, SOP2-3, SOP2-4, and SOP 2-5).

Organizing Supplies and Equipment

The checklists provided in Tables SOP2-2 through SOP2-5 include a pre-event logistical checklist, a checklist of supplies/equipment needed, and a personal supply checklist for crew members, respectively. These checklists are printed out and read well in advance of each sampling bout. This allows time to prepare documents and organize equipment, such as make needed repairs, check batteries and order equipment, if necessary.

Safety

The CUPN considers the occupational health and safety of its employees, cooperators, and volunteers to be of utmost importance, and are committed to ensuring that all field crews receive adequate training on NPS safety procedures, incident reporting, and emergency response prior to field work. Working in a cave environment can present some particular safety hazards, and certain activities (e.g., vertical caving) necessitate specialized training and experience. All field crew members should read and sign the Job Hazard Analysis form (Table SOP2-6).

Job Safety

An important tool used to promote safe conduct is the Job Hazard Analysis (JHA). This approach is consistent with NPS Directors Order 50 and Reference Manual 50B for Occupational Health and Safety. The JHA process is to (1) identify hazards associated with field and laboratory settings, as appropriate, and (2) develop approaches to mitigate those hazards. Prior to participating in field sampling for the first time in a calendar year all field personnel involved reads and signs the related JHA (Table SOP2-6). Prior to each sampling event, all participating field personnel review the related JHA (Table SOP2-6) and agree to follow all safety guidelines during sampling. In addition to the JHA, all NPS staff read the entire CUPN Safety Plan. Prior to participating in field work all NPS staff complete NPS Operational Leadership training.

Table SOP2-2. Pre-sampling event logistical checklist for cave cricket monitoring in Mammoth Cave National Park. While these tasks are typically performed by the project leader s/he may also assign some of them to others.

Pre-Sampling bout Logistical Checklist	
Task	**Description**
□ 1.	Schedule monitoring crews with cave entrances in advance.
□ 2.	Reserve appropriate vehicle in advance.
□ 3.	Obtain keys to cave gates/doors and road gates in advance (early in the week prior to the sampling bout).
□ 4.	Review supplies/equipment checklist and check for working condition and battery condition—replace as needed. Complete/sign and date checklist.
□ 5.	Inform Director of Mammoth Cave International Center for Science and Learning of dates, times, and cave entrances where sampling will occur. S/he notifies relevant park employees through email.
□ 6.	Project leader or designated crew leader conducts pre-sampling training and briefing for crew member(s), as necessary.
□ 7.	Perform GRTS draws to establish strips for all 15 cave entrances and print out pre-populated field data sheets.
□ 8.	Review appropriate Job Hazard Analysis (JHA) form. Get signatures from field crew member(s) in advance of field sampling.
□ 9.	Print out or copy maps showing locations of cave entrances to be sampled (at appropriate scale). These will be posted on the morning of the event along with the Cave Entrance Request forms.
□ 10.	Establish surface watch.
Checklist the morning of the sampling event(s)	
Task	**Description**
□ 1.	Fill out Cave Entrance Request form for all undeveloped cave entrances & those without regular tours and place a copy, along with location maps, on the SRM office's hallway bulletin board—surface watch is given a copy.
□ 2.	Sign out crew with destination, vehicle, and approximate return time on the dry erase board in the SRM office's hallway.
□ 3.	Project leader or designated field crew leader conducts pre-field sampling briefing for crew member(s), as necessary.

Table SOP2-3. Field equipment checklist for cave cricket monitoring at Mammoth Cave National Park.

No. items Required		Description
□	2	Portable camera tripod
□	6	Laser projector (12 AA batteries)
□	2	Spare laser projectors (Six AA batteries)
□	2	Laser projector platform & hand held laser platform
□	1	Kestrel® 4200 Pocket Air Flow Tracker
□	1	Digital camera with Pelican™ case, battery, and (2) memory card assembly & backup digital point and shoot camera
□	2	Measuring tape ≥100 m (Keson™ preferable) and (1) meter stick
□	8	Pre-printed field data sheets on Rite-in-the-rain™ paper (2 entrances)
□	2	Pre-printed baseline map for scheduled cave entrance on Rite-in-the-rain™ paper
□	2	Clipboard with storage compartment
□	1	Rite-in-the-rain notebook
□	2	Mechanical pencils with extra lead
□	1	Equipment bag (waterproof, as necessary)
□	1	Magnetic compass
□	1	PVC pole (≥1.5m)
□	2	Electronic distance measurer: transmitter and receiver (two 9 volt batteries)
□		Extra batteries for all battery operated equipment (i.e., one digital camera battery, ten AA cells, two 9 volt batteries)
□	1	GPS unit with all cave entrance and parking location waypoints pre-programmed (two AA batteries)
□	1	First Aid kit. Copy of directions to nearest hospitals and emergency #s.
□	1	Two-way radio
□	1	Disinfectant wipes container
□	4	Large plastic garbage bags (for contaminated clothing/gear storage)
□	1	Dry erase board, 2 dry erase pens (black), cloth to wipe/dry
□	1	Laminated copy of “Guide to Cave Cricket Morphology” (Appendix D)
		Crew Leader’s Signature/Date:________________________________

Table SOP2-4. Personal field supply/equipment checklist for a day in the field performing cave cricket monitoring at Mammoth Cave National Park.

No./Sets of items Required		Description
		Personal Supplies/Equipment Checklist (1 Person)
□	1	Helmet with lights
□	2	Pair knee pads
□	2	Pair hiking boots or rubber muckboots (site dependent)
□	1	Water bottle and lunch (as necessary)
□	2	Pair work gloves or disposable rubber gloves (as necessary)
□	1	Hand-held flashlight for back up light source
□	1	Backup headlamp
□	?	Extra batteries (appropriate cells as needed) for all personal battery operated equipment
□	1	Change of clothes (including footwear) for returning to office at end
□	2	Set of field clothing or coveralls
□	2	DuPont Proshield™ (or similar) disposable coveralls with elastic bands
□	1	Snake chaps
□	1	Empty bottle for liquid human waste (site dependent)

Table SOP2-5. Supplies/equipment checklist for installing/servicing/retrieving cave meteorological monitoring equipment in conjunction with cave cricket monitoring at Mammoth Cave National Park.

	No. Items Required	Description – Supplies/Equipment Checklist for Two Sampling Events
		Cave Meteorological Monitoring
□	4	Pre-printed data forms (1 for each HOBO datalogger) on Rite-in-the-rain™ paper (see Field Information Sheet for each cave entrance to determine quantity needed)
□	2	Pre-printed Field Information Sheet for each scheduled cave entrance on Rite-in-the-rain™ paper
□	1	Copy of NPS permit
□	1	Clipboard with storage compartment
□	4	Pre-launched HOBO Pro v2 datalogger (see Field Information Sheet for each cave to be visited to determine quantity needed)
□	≥2	Spare pre-launched HOBO datalogger as backup
□	2	HOBO data shuttle for downloading temp/RH data from dataloggers (1 shuttle for Pro v2 model)
□	1	Block of modeling clay for use as a barrier between cave surface and loggers
□	1	Small clean rag or piece of cloth for cleaning HOBO dataloggers
□	1	Silicone grease for lubricating o-rings on HOBO dataloggers
□	1	Coil of wire for hanging dataloggers on cave wall or ceiling.
□	1	Wire cutters for cutting wire used to hang dataloggers (*optional*—if wire can be cut by hand using a repeated back-and-forth motion)
□	1	Binoculars
□	2	Black ultra-fine point permanent marker ("sharpie")
□	2	Mechanical pencil
□	1	Equipment bag (Waterproof, as necessary)
□	1	Magnetic compass
□	1	50m measuring tape
□	1	Laser range finder or electronic distance measurer
□	1	Watch
□	?	Extra batteries for all battery operated equipment (i.e., one digital camera battery, ten AA cells, two 9 volt batteries, __HOBO temp/RH datalogger batteries, __HOBO shuttle batteries)
□	1	GPS unit with all cave entrance waypoints and parking locations pre-loaded (two AA batteries)
□	1	First Aid kit. Printed copy of directions to nearest hospitals and emergency #s.
□	1	Two-way radio or cell phone
□	1	Disinfectant wipes container
□	4	Large plastic garbage bags (to store contaminated clothing/gear storage)
		Crew Leader's Signature/Date:________________________________

Responding to an Incident

Life-Threatening Medical Emergency

1. Call 9-1-1 or park emergency number. When available, use park radios to contact dispatch. Administer first aid to the best of your knowledge, ability and training. If appropriate, transport to emergency room. Directions to the nearest hospital (i.e., Caverna Memorial Hospital in Horse Cave, KY) and emergency numbers will be updated and printed every January, prior to field sampling, by the project leader or designated field crew leader. Copies of the hospital directions and emergency numbers will be included on the supplies and equipment checklists (Table SOP2-2 through Table SOP2-5) used before each field sampling day.

2. As soon as it is practical to do so, inform your supervisor and the park's emergency contact.

3. For injured NPS staff and volunteers, complete Worker's Compensation paperwork. For contractors and cooperators, follow your organization's procedures for documenting accidents.

Non-Emergency Incidents

1. For a non-emergency incident that may require medical attention, contact your supervisor immediately after incident. If the supervisor cannot be reached, inform the park's emergency contact.

2. Seek medical attention, if needed.

3. For injured NPS staff and volunteers, complete Worker's Compensation paperwork (must be done within 48 hours of incident). For contractors and cooperators, follow your organization's procedures for documenting accidents.

Table SOP2-6. Job Hazard Analysis (JHA) for performing monitoring work in CUPN cave parks.

Cumberland Piedmont Network		**JOB HAZARD ANALYSIS**	
Job Description: *Field Work in Caves*		Date of last update: 2 August, 2013	
NPS Division with primary responsibility for this JHA: **Inventory and Monitoring Division for the Southeast Region**	Last updated by: Rick Toomey	Reviewed by: Teresa Leibfreid, Rickard Olson, Steven Thomas, Rickard Toomey, Kurt Helf	Approved by: Steven Thomas
Required standards & general notes:		Cave entry permits must be obtained and approved prior to any caving activity. Surface watch and call-in time must also be established prior to the trip; surface watch should be informed of party exiting cave ASAP (e.g., via cell phone or radio). Appropriate staff must be informed of trip plan when conducting surveys in remote sections of cave. Trip leaders must be appropriately trained and prepared for the type of trip they are leading. Each team member must be prepared for the type of trip and familiar with first aid kit locations along the nearest travel route (if any). All PPE will be inspected and tested prior to using, and all equipment will be adequate for the type of trip. Always cave with an appropriate party size for activity and cave area, caving alone is usually not appropriate.	
Personal protective equipment:		UIAA approved helmet with four-point suspension chin strap, three reliable independent light sources, knee-pads (as needed), elbow-pads (as needed), gloves, treaded boots with good soles and ankle support, sufficiently warm clothing, chemical heat pack, compact first aid kit.	
Typical tools, equipment & supplies:		Side-mounted pack, adequate drinking water, adequate quick-energy food supply, extra batteries, watch, cave maps, compass, hand-line.	

Activity	**Potential Hazards**	**Recommended (unless otherwise stated) Safe Action or Procedure**
Planning Cave Trip and Communication	Not being prepared and not following plan/itinerary. Lack of leadership and communication. Failing to establish a reliable surface watch and reasonable call-in time. Planning a caving trip that will exceed the abilities of any team member. These abilities include physical condition, technical skills and psychological aspects.	1. One person for each trip will be designated as the trip leader. This person is responsible for providing leadership and clear communication concerning safety, minimizing impact to the cave resource and achieving the trip goals. Ensure that trip plans are within the range of all team members. 2. Discuss trip plans with team members and make sure each member understands the trip plans, is prepared to meet the challenges of the trip in terms of physical condition, technical skills and psychological aspects. 3. Gather appropriate maps, GPS data, and route information so that the team can efficiently find caves they are going to and their objectives within the caves. 4. Establish a reliable surface contact person and reasonable call-in time. 5. Ensure designated surface watch and LE informed when conducting surveys in remote sections of cave. 6. Check expected weather and stream conditions for day and sites.
Emergency Preparedness	Not knowing emergency procedures.	Know who to contact and how to reach them in the event of a life-threatening or non-life-threatening emergency. Have current CPR and first aid certification, and know the certification status of co-workers.
Preparing Equipment	Not bringing proper equipment to achieve the planned objectives.	Trip members will make sure they have the proper personal equipment for the trip. Trip leader will supply protocol-specific checklist of necessary equipment.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
	Equipment worn, broken or inoperable due to lack of proper maintenance.	Each trip member is responsible for regularly checking, cleaning and ensuring their caving equipment is in proper working order.
	Team member not knowing how to properly use caving equipment.	All team members will have the training and knowledge as to proper usage of each piece of equipment used for their specific trip.
Entering Cave	Entrance Zone Animals	While in the entrance area of a cave all team members should be alert and aware that skunks, venomous snakes, spiders, and other potentially hazardous animals may be found. Avoid treading on accumulated guano or middens.
	Rock fall	Due to high fluctuation in temperature and moisture near cave entrances, some entrances areas can be particularly prone to loose rocks. Move carefully and thoughtfully so as not to dislodge rocks.
Horizontal Caving (general)	Getting Lost	Caves can be confusing, and route finding in the cave can be tricky. As you travel to the area(s) where you will be working, pay attention to the route you take. Each person on the party should be able to find his/her way out of the cave. It helps to look back at junctions as you travel through them; doing this gives you a look at what the junction will look like when you come back. If needed, removable flagging can be used to mark junctions; permanent markers, like arrows, should not be placed in the cave without specific permission.
	Exposed climbs	Always use three points of body contact on cave surfaces to minimize risk of falling. Where feasible, use a hand-line or belay.
	Slippery surfaces / Falling	Everyone will wear footwear with good traction and a caving helmet with a chinstrap. Everyone should move in a careful, controlled manner to avoid falling. When climbing, test all holds to ensure that they can withstand the force being placed upon them.
	Low / small areas	Trip leaders should ensure all members are able to negotiate low/small areas on caving route. Remaining calm and thinking through what one must do to get through low/small areas is key. Travelling head-first through low/small areas that slope steeply downward can present challenges and should be undertaken with extreme care.
	Exertion / Exhaustion	Each team member should have adequate knowledge of the length and duration of trip prior to heading into the cave, and should have cave-specific physical conditioning. People in good physical condition need less water and are less prone to injury. Push your endurance limit in gradual increments. Avoid overloading your pack; be creative to reduce weight and bulk. Prior to the trip, the trip leader should inquire about people with known physical conditions and treatment needs. Groups should avoid overexertion, and should stop at least every hour to eat and drink. Group speed should be tailored to the slowest person on the team. Should the trip become too much for one trip member, the whole trip plan will be modified to achieve a safe trip.
	Temperature related issues	Ensure team members are appropriately dressed for continued movement – a lightweight long-sleeved shirt and lightweight, durable pants are usually sufficient and prevent overheating.
		Ensure team members have adequate cold-weather clothing in their packs such as a balaclava and long-sleeved polypropylene shirt. Explain to team members about the colder temps while not moving and the necessity of wearing these items to prevent hypothermia. Keeping clothing dry is important.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
	Overdue party	Trip leaders must always establish a reliable surface watch prior to embarking on a trip. This person must be briefed on what time to expect the team to return (or call-in) and whom to contact in the event the team does not exit on time. Location of the team, number of participants and travel route maps will be made available to the surface watch. Trip leaders will allow a reasonable amount of time for the team to exit the cave. If the team becomes lost, they will remain where they are and wait for the surface watch to notify search & rescue.
	Dehydration	All team members will be properly hydrated before entering the cave and drink sufficient water or electrolyte replacement drinks during the trip to maintain a proper hydration and avoid cramps.
	Minor injuries	Self-rescue using compact first aid kit in pack or in caches.
	Major injuries	When possible, at least one team member stays with injured party while other team member(s) goes for help. In many areas of Mammoth Cave near toured sections, telephones may allow you to notify help without exiting the cave.
	Rock fall	Cavers should locate themselves in places where they will not be exposed to rockfall from team members above them. Cavers will move carefully and thoughtfully so as not to dislodge rocks. Should a team member accidentally dislodge a rock or drop equipment they will clearly yell “Rock!” to inform team members below of the impending danger. Team members below should be alert and step away (not look up). All team members will wear a caving helmet with chinstrap. Helmets should not be removed when in area w/ potential for rockfall
Wading or snorkeling Additional required equipment: *Thermal protection in water (such as wetsuit or drysuit, neoprene shorts, neoprene shirt, neoprene socks, exposure suit as appropriate for specific condition),*	Total submersion	When possible, monitoring in cave streams and rivers should be performed during the dry season so that water levels and flooding potential are low (and visibility high). Always check weather reports before performing monitoring in cave streams or rivers. Be aware of antecedent conditions: consider current soil saturation. If there is a high chance of heavy rain in the surrounding area the trip should be postponed. Always work in areas with adequate air space between the water surface and the cave ceiling. Know alternative exit routes. Personal flotation devices are unnecessary when snorkeling because wetsuits or exposure suits (which are needed due to temperature) make the individual positively buoyant and so they will float on the surface.
mask and snorkel, fins (if snorkeling), *inflatable kayak/boat, paddle (if needed for specific work).*	Hypothermia	When wading use neoprene socks and shorts to keep warmed film of water in contact with skin. For work in deeper water, wetsuits or even drysuits should be used to reduce chance of hypothermia. The thickness of wetsuit (or choice to use a drysuit or exposure suit) will depend on the water temperature, length of potential exposure, and type of exposure (wading chest deep, swimming, etc.). Chemical heaters that last for 8-10 hrs are highly recommended to deal with hypothermia. They can be wrapped in a rag and inserted into the exposure suit to supply heat to the snorkeler’s core. A heat tab stove can be used to heat up a hot meal (e.g., beef stew) for energy and warmth. Performing physical exercise is also a good way to warm someone up.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
Vertical Caving Additional required equipment: *Rope of adequate length, harness outfitted with standard (or preferred) ascending and descending gear, and Quick Attachment Safety*	Miscommunication resulting in someone entering the rockfall zone while another team member is in a position to dislodge rocks or while another team member is still on rope.	Clear signals will be used to avoid miscommunications. "On Rope!" will be clearly shouted when entering the rockfall zone with the intent to rappel or ascend a rope. "Off Rope!" will be clearly shouted after getting off rope and exiting the rockfall zone. A clearly shouted "OK!" from the other team members should acknowledge either of these commands.
	Ropes and or rigging materials worn or damaged.	All ropes and rigging materials will be inspected for wear or damage before use. If necessary damaged or worn materials will be retired.
	Unsafe Rigging.	All rigging will be inspected before use to ensure that it is safe. If determined not to be safe, the rigging will be modified if possible or the trip halted until the rigging can be made safe. During rigging, a figure eight knot will be tied at the end of the rope prior to the first rappel to prevent accidental "short-roping".
	Not conducting a thorough check prior to rappelling.	All vertical caving participants will go through a pre-rappel checklist; often called "Checking the Chain".
	Rope damage encountered while on rope.	A butterfly knot will be used to eliminate the damaged section of rope from the life supporting rope. A note will be left both at the top and bottom of the rope informing cavers of the situation.
	Incident occurs where caver is forced to change over to ascent while descending or to descent while ascending.	Everyone participating in vertical caving will be required to have the equipment, training and knowledge to perform changeovers from ascent to descent and descent to ascent.
	Object becomes jammed in rappel device.	Everyone participating in vertical caving will be required to have the equipment, training and knowledge to safely lock off their rappel device and remove the jammed object without using a knife.
	Difficulty in passing a rebelay, traverse or other complex rigging situation.	All persons traveling to sections of cave with complex riggings will be required to have the equipment, training and knowledge to safely negotiate these complex riggings.
	Caver becomes exhausted, unconscious or injured resulting in immobilization on rope.	When someone becomes immobilized on rope, it is critical to remove that person from rope as soon as possible, usually by talking them through the problem, or lowering them to the ground. Ideally every trip should have at least one person knowledgeable of small-party vertical rescue techniques. Single-rope pickoffs are a last resort.
	Unsafe use of cable ladders	Cable ladders are often convenient for short pitches (<30'); however, they can be tricky to use. People using cable ladders should have knowledge and experience in their use. A belay should be used when either descending or ascending on cable ladders.
	Unsafe use of ladders	Although they are not used very frequently, hard sided ladders (such as extension ladders, step ladders, collapsible ladders, or sectional ladders) may be used for some types of vertical caving. Be sure that ladders are appropriately secured. It may be appropriate to belay climbers on ladders, depending on mounting and exposure. With collapsible ladders, be sure that ladder is locked, to prevent collapse while climbing. For sectional ladders, be sure sections are locked together and that ladder is used with an appropriate rise/run ratio. Be aware of (and clean off) mud on rungs to prevent slipping on the ladder.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
General Foot Travel (on surface)	Falling or tripping due to stream crossings, wading, wet areas, poor footing, uneven terrain, loose/rolling rocks and heavy pack.	Use caution at all times. Walk carefully, watching footing. Wear appropriate boots for conditions, especially stream wading. Stay aware of your feet. Address blisters and hot spots promptly. Avoid carrying excessive weight or unbalanced loads. When walking on a steep slope, lean upslope. Ensure that stems and vines are alive and can support your weight before relying on them. Use extreme caution traversing wet rocks, streams, steep slopes or blowdown areas. Proceed cautiously, test footing carefully, and use a sturdy pole or walking stick for balance.
Working Outdoors During Storms	Being struck by falling trees or branches. Being struck by lightning.	Listen to the weather forecast each morning (park radio and/or internet). Plan or adjust field work to avoid being out in thunderstorms. Postpone work if safety will be compromised by storm conditions. If you see or hear a thunderstorm coming, retreat from high ground and exposed areas. Go inside a sturdy building, vehicle, or cave, if possible. If you can't get inside and if you feel your hair stand on end, lightning is about to strike. Make yourself the smallest target possible & minimize contact with the ground. Crouch down on your pack on the balls of your feet and keep your feet close together. Place your hands on your knees and lower your head. During a thunderstorm members of the crew should stay separated by at least ten feet.
Poisonous Plants (especially poison ivy)	Contamination/toxicity from contact with poisonous plants.	Learn to identify poison ivy in its many growth forms. Wear long sleeves and pants. Be aware of poison ivy and avoid coming in direct contact with it. Thoroughly wash hands, equipment, and clothes with Tecnu or similar specialized soap after working in areas with poison ivy.
Bee, Wasp, or Yellow-jacket Stings	Multiple stings from disturbing or stepping into nest areas.	Be alert to hives in brush, ground holes, or hollow logs. Watch for insects traveling in and out of one location. If you or anyone you are working with is known to have allergic reactions to be stings, tell the rest of the crew and the field crew leader. Make sure you carry emergency medication with you at all times, and that your co-workers know where you keep it. Wear long sleeve shirts and pants, tuck in shirt. Bright colors and metal objects may attract bees or wasps. If you are stung, a cold compress may bring relief. If stinger is left behind, scrape it off of skin. Do not use tweezers as this squeezes the venom sack, worsening the injury. If the victim develops hives, asthmatic breathing, tissue swelling or a drop in blood pressure, seek medical help immediately.
Bites from Mosquitoes, No-see-ums, and Chiggers	Itchy reactions to multiple bites.	Avoid sitting on the ground or on logs, especially in dry sunny grassy areas. Use insect repellants. Do not apply Permethrin, Permanone, or greater than 30% DEET directly to skin, only to clothing. Wear long sleeves and pants. Carry after-bite medication to reduce skin irritation.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
Venomous snakes	Being bitten by a venomous snake.	Wear snake gaiters when in known snake habitat. Be alert for snakes in thick vegetation and rocky habitats. Look **before** putting hands or feet in places out of immediate view. Treat all bites as if evenomation has occurred. Seek medical attention immediately and/or call 911 for help. Keep the person calm & move as little as possible to reduce spread of the venom Immobilize the bitten area and keep it at or below the level of the heart. Remove rings, watches, shoes, etc. before swelling begins in earnest. Monitor the person's vital signs -- temperature, pulse, rate of breathing, and blood pressure -- if possible. If there are signs of shock (such as paleness), lay the person flat, raise the feet about a foot, and cover the person with a blanket. Do NOT use tourniquets or suction devices. Do NOT cut the area around the bite. Do NOT apply ice or flush the wound with water. Do NOT give the person stimulants or pain medications unless a doctor tells you to do so. Do NOT give the person anything by mouth. [compiled from NIH, JAMA, and American College of Emergency Physicians]
Ticks	Contracting diseases transmitted from ticks.	Use tick avoidance precautions, such as pre-treating clothing with permethrin, tucking pants into socks and shirt into pants. Avoid sitting directly on the ground, especially in leaf litter and check packs for ticks before putting them on. Wear clothes (including pants and long-sleeved shirts) that are light colored and check for ticks on clothing periodically throughout the day. Conduct a thorough tick check every evening after completing field work. Know how to identify tick life forms, and the symptoms of tick-borne diseases.
Walking through Thick Vegetation	Cut, scratched, or bruised by vegetation; eye or ear injuries.	Shield your eyes and face with your hands, glasses, or hat when moving through tall thick brush. Keep your head and eyes pointed somewhat downward so your head hits obstacles before your eyes. Wear pants and long-sleeved shirts to protect bare skin. Look before you grab vegetation to avoid grasping thorny stems. Do not follow closely behind other people to avoid having branches snap back at you.
Working in Heat, Humidity, or Cold	Heat exhaustion, sunburn, dehydration, hypothermia.	Evaluate the weather forecast each morning and plan field work accordingly. Carry and drink plenty of water. Take extra breaks during extreme weather events. Adjust the work routine to minimize exposure to extreme heat and humidity. Take adequate garments for all possible weather conditions. Choose clothing that will keep you warm even if it gets wet.
Hazard Trees	Being struck by falling trees or branches.	Look up. Be alert for “widow-makers”, storm-damaged trees with large broken limbs, and unstable standing dead trees. Do not spend extended time in an area with hazard trees. Do not attempt to tag or measure unstable snags.

Activity	Potential Hazards	Recommended (unless otherwise stated) Safe Action or Procedure
High Water Stream Crossings	Injuries from falling and/or drowning.	Thoroughly investigate area to find safest crossings Wear appropriate foot gear for stream crossings. It is safer to wade through high water, rather than rock hop across a stream trying to keep your boots dry. Unbuckle your pack and be prepared to jettison gear should you lose your balance or fall in. Use a sturdy pole or walking stick for balance.
Carrying a Pack and Other Equipment	Injuries from improper packing, adjustment, and lifting of backpacks. Injuries from improper carrying of gear.	Learn how to properly pack, adjust, lift, and carry a pack. When hand-carrying gear, keep one hand free. If carrying long equipment, be aware of other people and never swing around quickly. Avoid allowing a long piece of equipment to project up and behind you, where you cannot see it.
		Perform pre-operational check of vehicle (oil, tire pressure, tire condition, fluids, wipers, brakes, lights, gas, etc.). Report all needed repairs to the crew leader or supervisor promptly. Do not use the vehicle if it is unsafe. Wear seat belts with shoulder harnesses whenever vehicle is in motion. (E.O. 13043 4-16-97) Do not use cell phones or text while driving. Only NPS employees, volunteers, or authorized cooperators and contractors are allowed to operate or ride in a government vehicle. Ensure full visibility from all windows and mirrors. Clean windshield regularly. Always ride inside the vehicle. Properly store and secure all tools, equipment, and cargo so that they will not shift during sudden starts or stops. Plan your travel before you start. Know your route. Practice defensive driving; be alert to potential hazards. Obey all traffic laws and speed limits. Adjust speed to changing weather or traffic conditions. Allow adequate following/stopping distance. Avoid distractions such as eating or adjusting navigation/GPS units while driving. Be alert for pedestrians or bicyclists using roadways. Be watchful for wildlife crossing roads, especially at early morning, dusk, and after dark. Do NOT drive if fatigued. Stay alert! Do NOT exceed the 12 hour limit for driving/work hours.
Driving on Gravel, Dirt, or Un-maintained Roads	Injuries from vehicle accident; damage to vehicle.	Maintain a slow and safe speed for changing road conditions, such as loose gravel, large potholes, washed out road, fallen trees or rocks, etc. Be alert on narrow roads for oncoming vehicles and log trucks. Be prepared to slow down, pull over, or stop with little notice. Many roads require 4-wheel drive and/or high- clearance vehicles for safe passage. Use the appropriate vehicle for the terrain. Do not exceed the capacity of your vehicle or driving ability. When in doubt, turn around or back out. Use spotters to assist in navigating obstacles and assessing water depth at stream crossings.

Table SOP2-6. Job Hazard Analysis (JHA) for performing monitoring work in CUPN cave parks (Cont.).

Please sign your name below to certify that you have read the Job Hazard Analysis and fully understand the Safety Standard Operating Procedures for the Cumberland Piedmont Network protocol for long-term monitoring of cave crickets.

PRINT NAME	SIGNATURE	DATE

Field Information Sheets and Baseline Maps

The development and maintenance of *Field Information Sheets* and *Baseline Maps* describing conditions at each sampling site will help orient new crew members, increase efficiency and consistency of data collection over time. The Field Information Sheet template in Figure SOP2-1 provides an outline of the types of information that are included; additional information can be included (e.g., recommended sampling schedule, gate status, etc.) as needed. Field Information Sheets and Baseline Maps were both developed for each cave prior to their first sampling event. Field Information Sheets are maintained in a Microsoft Access database application and, in addition to Baseline Maps, are also maintained on the CUPN server. If necessary, after a sampling event concludes, but prior to leaving the site, the field crew leader reviews the Field Information Sheet and revises any sections based on lessons learned during the sampling event. The Baseline Map for Frozen Niagara entrance in Figure SOP2-2 provides an example of the types of information to be included in each Baseline Map. Both members of the field crew use the Baseline Map to lay out the baseline with a fiberglass survey tape. The field crew references the map for images of the baseline's landmarks, bearing(s), and length to precisely relocate the baseline(s) and so ensure continuity among cave cricket monitoring surveys. The maps will also be used for plotting and labeling the locations of HOBO dataloggers and corresponding permanent landmarks at all sampling cave entrances. Baseline Maps are also the basis for later generating distribution maps of sampled cave cricket clusters at each cave entrance. The spatial resolution for most roosting sites may be coarse, as areas must be defined by easily recognized cave features (e.g., passage junctions, steep slopes or pits, dramatic changes in ceiling height); however, the systematic collection of these data will allow changes in cave cricket habitat use to be tracked over time. It is critical that data from Field Information Sheets is well-documented and integrated with Baseline Maps.

All data sheets utilized during a sampling bout are printed on waterproof marine paper/Rite-in-the-rain™ paper using pencil or permanent ink (non-permanent ink may smear during decontamination). All sheets will be decontaminated after a sampling event following current national decontamination protocols. While some print cartridges use permanent ink, others do not, so we experiment with locally printed forms prior to field sampling. Because they contain sensitive information (e.g., cave entrance locations), extra copies of Field Information Sheets and Baseline Maps are maintained by the project leader with the secure project files.

GPS Setup

Using DNR Garmin or similar software, the GIS specialist uploads cave entrance location and parking location coordinates into the CUPN GPS unit(s) and/or handheld device. Immediately after uploading the plot coordinates, the GIS specialist checks the GPS unit's map page to ensure that the cave entrance locations are shown correctly and are in the correct projection. One easy way to check that the points loaded properly is to navigate manually to the park in the GPS unit's map function and see if the points line up approximately with where they should be based on each cave location map in the Field Information Sheets.

Communication and Crew Oversight

While most of the sampled cave entrances in MACA are front-country cave entrances (i.e., not in remote areas) the field crew carries a NPS radio when traveling to more remote areas. In all situations, crew members comply with park policies regarding the use of radios while conducting field work. Radios are programmed to the appropriate frequencies for the park. Crew members

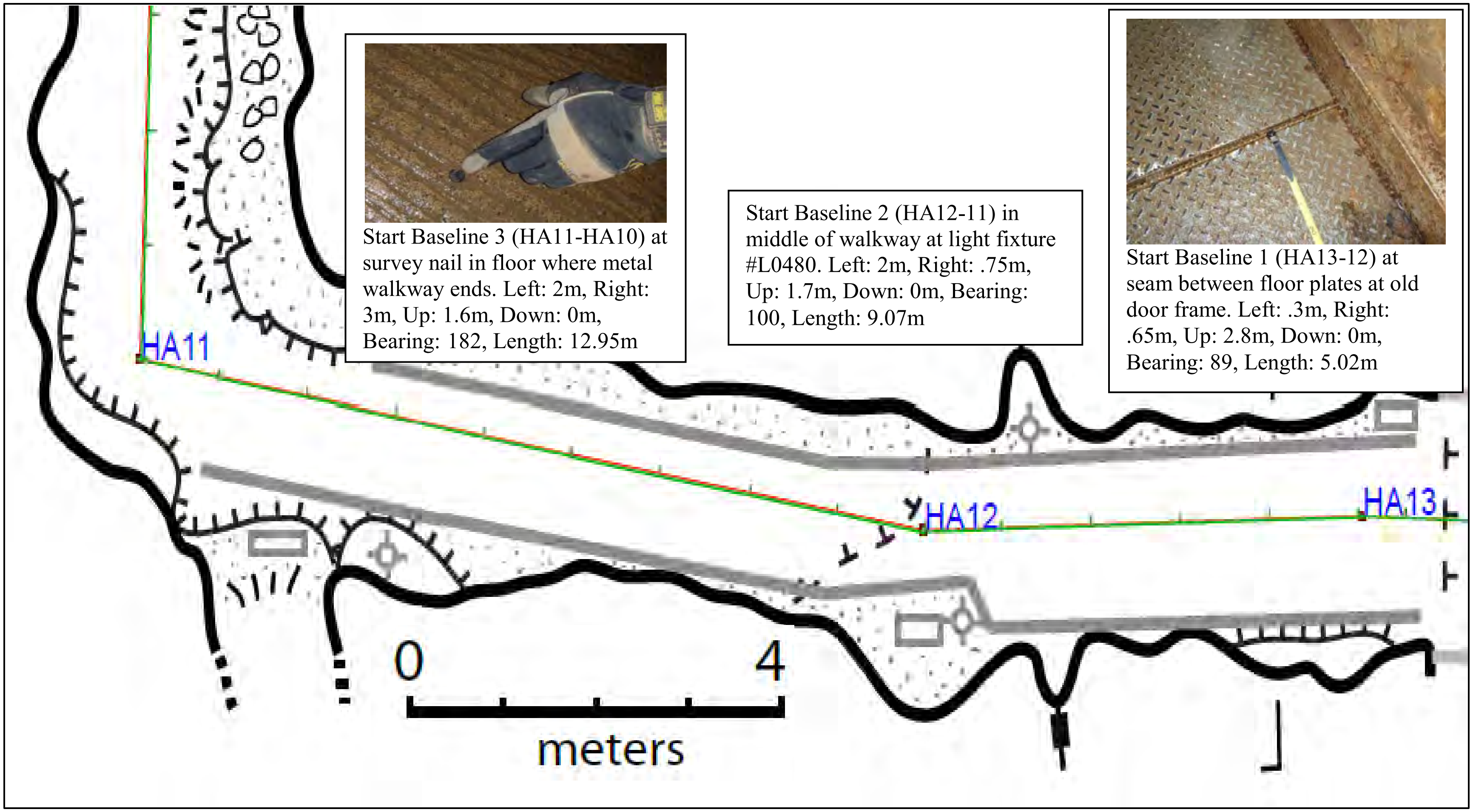

Figure SOP2-2. Section of the baseline map for Frozen Niagara Entrance. Baseline maps for each survey cave contain inset photographs and/or instructions to accomplish their accurate relocation among sampling events. Baseline maps are used for the precise relocation of baselines among sampling events, relocation of dataloggers for servicing, depictions of cave cricket habitat use and to record locations of unusual phenomena. Note this example shows separate, but continuous, baseline segments are necessary in caves with meandering passages.

know which frequencies to use, how to contact park radio dispatch, and are familiar with proper radio etiquette. Further, crew members remember that radios and cell phones do not work inside caves. In areas with cell phone coverage, crew members are encouraged to carry a cell phone in the field for safety.

Generating Field Data Sheets Pre-populated With Sample Draws

Randomizing the order in which caves are sampled between each sampling event ensures estimators generated from the data will not be biased by the order and/or time of their survey. In this SOP the randomization process is performed using R code to draw a random sample of cave names from a predetermined list in a ".csv" file.

R is a language and environment for statistical computing and graphics, runs on Windows, Unix, and Mac computers, and is freely available at http://www.r-project.org/index.html (accessed April 2014). The R Wiki provides an online forum at http://wiki.rproject.org/rwiki/doku.php (accessed April 2014) and documentation. R is a necessary part of choosing sampling points and data analysis in this protocol and is rapidly becoming the analytical environment of choice for ecologists.

Before each bout of sampling, the R code named "CaveSampleGen.R" is run by the project leader (Appendix F). This code performs two tasks: randomizing the order of visits to entrances for that bout, and generating Generalized Random Tessellation Stratified (GRTS) sample draws of strip positions along the baseline for each cave entrance to be visited. This code reads the table of entrance names, baseline lengths, and sample sizes, and asks for a bout name (e.g., May 2014). "Function DoOrder()" generates a random order for visiting entrances, subject to the constraint that the Austin and Floyd Collins Crystal cave entrances are always sampled together on the same day (Appendix F). This order nominally assumes that two cave entrances are visited each day, so that Austin and Floyd Collins Crystal always occur as an odd-even pair. "Function DoDraw()" is then called for each cave entrance which generates a field data sheet file for each cave entrance. The first page of the field data sheet file is pre-populated with some metadata relevant to the sampling event and bout, unique identifiers for each strip generated by the GRTS draw, the strip's sequential position (in meters) on the baseline, and an additional doubled oversample (See the Protocol Narrative and SOP #3a: Field Methods: Strip Adaptive Cluster Sampling). The second page of the field data sheet is not pre-populated with any values, rather it contains spaces to record ancillary data on all cave cricket clusters associated with the strips (e.g., their extent and location) and cave meteorological data at each cluster. The resulting field data sheet file should be printed on waterproof paper using a laser printer

Equipment Preparation for Strip Adaptive Cluster Sampling of Roosting Cave Crickets Using Photography and Laser Transects

In this protocol, the fundamental data recorded in the field are images of clusters of roosting cave crickets. Sampling of clusters occurs within 10cm strips, perpendicular to a baseline (i.e., fiberglass measuring tape) bisecting the cave passage, projected by lasers on the walls and ceiling of the passage. When an individual cricket is detected in a strip other crickets within 10cm are added to that cluster, and any crickets within 10cm of those crickets are also added until no additional crickets are found. A strip may intersect 0, 1, or multiple clusters, and more than one strip might intersect the same cluster. Images of clusters intersected by the strips are recorded using a digital camera.

Digital Cameras

The ideal field camera is a rugged, high-resolution, auto-focusing, multi-function digital camera with integral strobe flash, optical and electronic zoom, and macro-mode capabilities. The camera utilizes a standard removable memory card for image recording, and an interchangeable, rechargeable battery. While digital cameras may be impact and moisture-sensitive they are carried and stored in a padded, hardened camera case when not in use (Figure SOP2-3). Expensive digital SLR cameras have their lens fitted with a threaded ultraviolet filter to protect the lens from accidental scratching; the filter does not affect photographic images. The camera comes with an attached lens cap. The cap is secured on the lens face at all times when the camera is not in use. A spare battery and a spare memory card are carried into the field on all sampling events. Field crew members consult the Camera Operator's Manual available in the CUPN project office for technical details and instructions on setting camera features. Digital cameras are both essential field instruments and expensive assets and so personnel handle them with care.

Figure SOP2-3. Rugged, "Pelican™" type camera case.

Preparation and Operation of the Tripod and Laser Assembly

The 10cm strips are "virtual" transects projected onto cave ceilings by a set of two low-power red-light laser projectors mounted on a portable camera tripod. The laser projectors are magnetically attached to a rigid mounting frame to form a "laser assembly" (Figure SOP2-4). This assembly serves to position and hold the lasers so that they can project two effectively parallel lines or beams, while allowing for small amounts of adjustment to be made in the alignment and positioning of each laser unit. The laser assembly unit is also expressly designed to allow quick, easy, and reliable in-the-field assembly and disassembly to facilitate ease of transport into and out of caves. The laser assembly is positioned on and attached to the "pan-head" of a portable camera tripod using the integral "quick-release" mounting feature of the tripod.

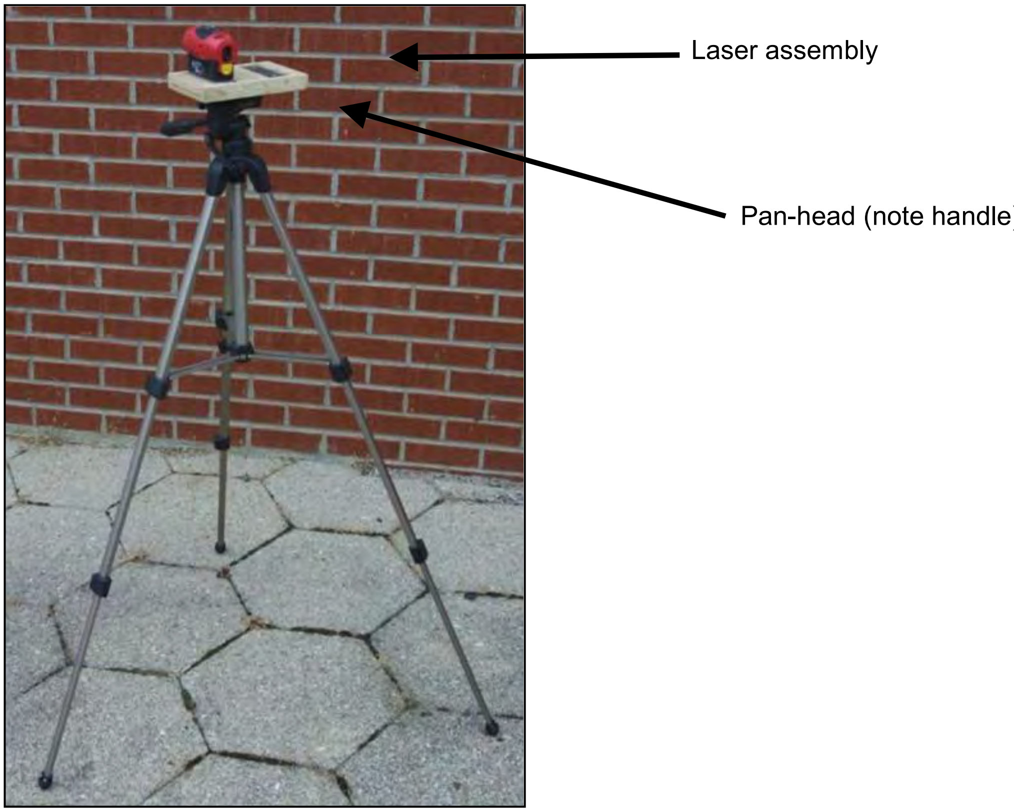

Figure SOP2-4. Photograph of laser assembly on tripod. The assembly is used for projecting 10cm strips onto cave walls and ceilings.

The laser unit used for this protocol is the Sears-Craftsman™ "4-in-1 Level with Laser-Trac, Model No. 320.48251", a commercial "laser plane and level" device used to project leveling lines during house construction (Figure SOP2-4 and Figure SOP2-5). The unit includes two integral spirit levels and a set of detachable magnetic and screw-mount bases for attachment to standard tripods, etc. This unit is a compact, battery-powered, low-power, red-light (650 nm wavelength) diode laser emitter which will project a "plane" or fan of focused red light that covers or spreads out over approximately 100 degrees of arc from the unit face. When used in a cave, the laser plane is visible as a bright, red line "drawn" across the cave substrate in the area at which the laser is aimed (see photo on cover of this protocol). The projected plane is visible across distances of over 40 meters in a dark cave environment. The laser plane may be rotated up to 90 degrees, allowing users to tilt or position the plane as needed (Figure SOP2-5).

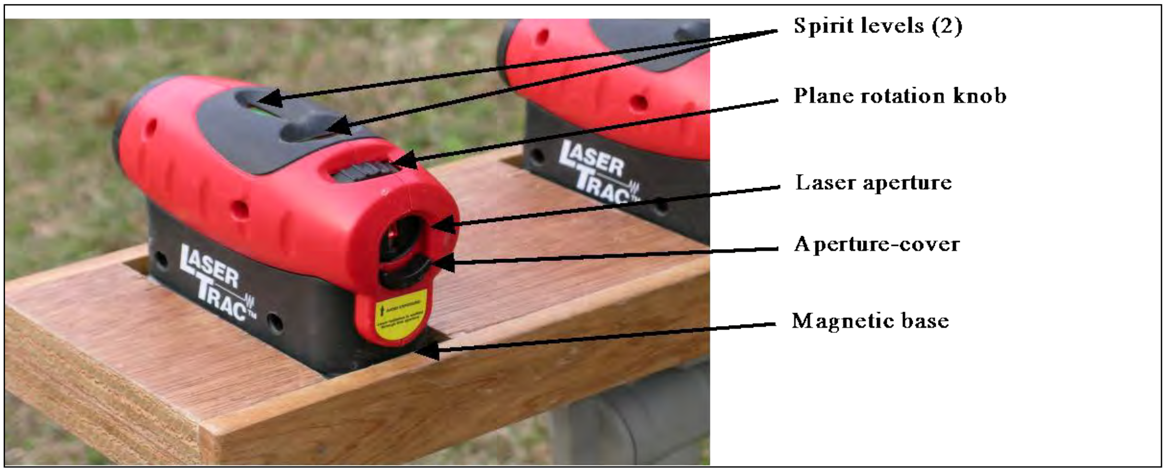

Figure SOP2-5. Laser units in laser assembly mounting frame.

Laser levels are moderately impact and moisture sensitive, and should be carried and stored in a padded case or field bag when not in actual use. Spare batteries (2 “AA” cells per laser unit) should be carried into the field to provide ready replacements. **Note**: Looking directly at or into the laser emission aperture of the device while the laser is active is to be avoided. All field crew members should review the laser device Operator’s Manual, available in the MACA Biology Laboratory, paying specific attention to safety information and guidance.

The laser assembly is mounted on a frame attached to a compact, light-weight collapsible camera or video tripod for use in the field (Figures SOP2-4 through SOP2-7). Any model tripod may be used, providing that the tripod has a full-function “pan-head” with a standard size and threaded captive mounting screw (1/4-20 SAE thread) for attaching a camera or other device to the head platform. The tripod used in this protocol is the SunPak™ Model 5800D “PlatinumPlus” medium-duty tripod. This tripod includes a pan-head that provides axial head rotation, platform “pitch” and “yaw” (tilting on the y and z axis in xyz coordinates), pan-head post extension ability

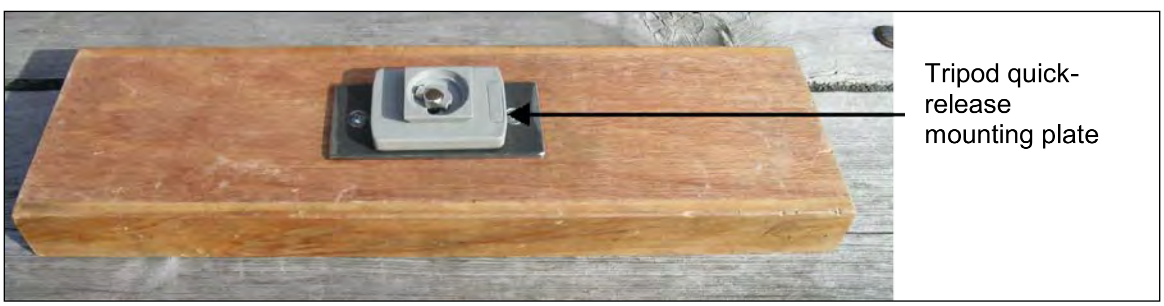

Figure SOP2-6. Bottom side of the laser assembly mounting frame showing the tripod quick-release mounting plate fastened to and aligned on the mounting frame. This quick-release mount allows for easy attachment of the laser assembly in the field without tools.

Figure SOP2-7. Tripod "pan-head" with laser assembly mounting frame. The frame is attached to the tripod's quick release mounting plate, showing the 2 laser seats with steel floor-plates for magnetic attachment of laser units. Note tripod leveling bubble to the left of the "pan-head" handle.

and an integral spirit-level for leveling the tripod (Figure SOP2-7). A key feature is the integral "quick-release" mount and clamp feature that allows for equipment to be easily installed on and removed from the tripod without tools (Figures SOP2-6 and SOP2-7). Tripods used are constructed of anodized Aluminum and plastic; an important consideration in caves where exposure to moisture is frequent and corrosion may become an issue. An additional handheld strip generator is used to determine the size of cave cricket clusters by measuring distances among neighboring cave crickets in a cluster (Figure SOP2-8).

Pre-Departure Equipment Setup and Preparation

The project leader or designated personnel performs the following equipment checks and preparation steps one week prior to a sampling bout.

1. Laser units function is ensured by aiming the unit at a safe "target" (away from people and towards a wall or ceiling to allow adequate viewing of the laser plane) and sliding the power switch (emission aperture cover) "down" to activate the laser (Figure SOP2-5, note position of the aperture cover "switch"). If the laser does not function, the power switch is turned to the "off" position and the batteries checked. Depleted or low batteries are replaced with new batteries as necessary. At least eight lasers per sampling event, two for each laser assemblies, two for the handheld strip generator and two spares, should be in working order.

2. The laser assembly is assembled by placing the mounting frame seats-side-up on a table or other flat surface and inserting the 2 lasers into the slots magnet side down (Figure SOP2-5). The lasers are positioned so they face the same direction. The lasers magnetically attach to the steel plates located in each slot and their firm, snug attachment is to be ensured. The quick-release mounting plate, located on the underside of the laser assembly frame, is to be checked for tightness and proper alignment with the frame (Figure SOP2-6). The mounting plate should be aligned with the frame edge and the mounting screw firmly hand-tightened to ensure that the laser assembly remains stable and attached to the mounting plate when clamped to the tripod. The lasers are removed from the frame for transport.

Figure SOP2-8. Handheld strip generator. This is used to determine cave cricket cluster size by measuring distances among neighboring cave crickets in a cluster.

3. The tripod is checked for general condition and all movement functions: the tripod's legs are unfolded and extended; the pan-head's extension, rotation and tilt functions are tested; and all movement locks that operate by twisting or rotating the control handles to clamp down on and immobilize a moving part or component are checked. All functional parts appear in good working order and are free from distortion or significant damage beyond minor surface wear or abrasion. The tripod is repaired or replaced if its legs or pan-head components are damaged and do not work; since the tripod is essential to the successful performance of SACS.

4. All equipment is to be readied for transport to the field (Tables SOP2-2 and SOP2-4).

Summary of Yearly Staff Roles

Timing and staff roles for primary tasks are presented in Table SOP2-7

Table SOP2-7. List of major protocol tasks, responsible staff, and schedule for monitoring cave crickets in Mammoth Cave National Park.

Task	Staff	Timing
Acquire the appropriate permits (i.e., NPS) as necessary.	Project Leader	February
Upload cave entrance location and parking location coordinates into CUPN GPS unit(s) as needed. Print maps, if necessary.	GIS Specialist	Late April
Launch automated HOBO dataloggers.	Project Leader/Physical Scientist/Field Crew Leader	Late April
Prepare field data sheets, Field Information Sheets, pre-populated field data sheets, baseline maps, and equipment for sampling.	Project Leader/Field Crew Leader	Late April
Finalize sampling and backup dates for field crews.	Project Leader	Late April
Coordinate directly with MACA resources management contact when conducting field sampling [email at least two weeks in advance to confirm field work dates and to arrange logistical support (e.g., keys, unlocking gates)].	Project Leader	Late April
Arrange and conduct field crew training for sampling as needed (i.e., if new crew members or refresher for experienced crew members absent from field sampling for more than six months).	Project Leader/Field Crew Leader	Mid-Late April
Participate in May/June field sampling. Project Leader oversees field crew during field season and provides logistic and administrative support.	Project Leader/Field Crew Member(s)	May and June
Install, download, remove, or replace temperature and relative humidity automated HOBO dataloggers in each cave entrance.	Project Leader/Physical Scientist/Field Crew Leader	May and June
After spring sampling bout: download, sort, and rename camera image files; and file decontaminated field data sheets, and updated Field Information Sheets.	Field Crew Leader/Field Crew Member	May and June
Conduct image analysis.	Project Leader/Field Crew Member/Data Intern	Late June-early July
Ensure sampling work meets quality standards.	Project Leader/Field Crew Leader	Ongoing
Ensure effective communication between park staff, field crew, and other CUPN staff.	Project Leader/Field Crew Leader	Ongoing
Submit brief sampling trip report to MACA resources management contact within two weeks after spring sampling bout.	Project Leader	Late May-early July
Enter all May-June sampling data into master database as soon as practicable after data are collected. Update Field Information Sheets in database, as necessary.	Crew Member(s)/Data Intern	July – August
Conduct data verification on 10% of field data sheets once data from hardcopy sheets are entered into database.	Data Manager/Field Crew Member/Data Intern	August
Conduct data validation after records are entered into database. Scan and name field data sheets and save on server.	Project Leader/Field Crew Member/Data Intern	August
Inventory the condition of all equipment and prepare a list of required repairs or replacements.	Field Crew Member/Data Intern	August
Upload cave entrance location and parking location coordinates into CUPN GPS unit(s) as needed. Print maps, if necessary.	GIS Specialist	Late August
Prepare field data sheets, Field Information Sheets, pre-populated field data sheets, baseline maps, and equipment for sampling.	Project Leader/Field Crew Leader	Late August
Finalize sampling and backup dates for field crews.	Project Leader	Late August

Task	Staff	Timing
Coordinate directly with MACA resources management contact when conducting field sampling [email at least two weeks in advance to confirm field work dates and to arrange logistical support (e.g., keys, unlocking gates)].	Project Leader	Late August
Arrange and conduct field crew training for sampling as needed (i.e., if new crew members or refresher for experienced crew members absent from field sampling for more than six months).	Project Leader/Field Crew Leader	Mid to Late August
Participate in October/November field sampling. Project Leader oversees field crew during field season and provides logistic and admin. support.	Project Leader /Field Crew Member(s)	October and November
Service, download, remove, or replace temperature and relative humidity automated HOBO dataloggers in each cave entrance.	Project Leader/Physical Scientist/Field Crew Leader	October and November
After each sampling bout: download, sort, and rename camera image files; and file decontaminated field data sheets & updated Field Information Sheets.	Field Crew Leader/Field Crew Member	October and November
Conduct image analysis.	Project Leader/Field Crew Member/Data Intern	Mid-Late November and December
Submit brief sampling trip report to MACA resources management contact within two weeks after fall sampling bout.	Project Leader	Mid-Late November and December
Enter all October/November sampling data into master database as soon as practicable after data are collected. Update Field Information Sheets in database, as necessary.	Crew Member(s)/Data Intern	Late November and December
Conduct data verification on 10% of sheets once data from hardcopy forms are entered into database.	Data Manager/Crew Member(s)/Data Intern	December
Conduct data validation after records are entered into database. Scan/name data sheets & save on server.	Project Leader/Field Crew Member/Data Intern	December
Data analysis and report writing.	Project Leader/Physical Scientist/Data Manager	January-February
Assure final electronic data sets are archived and backed-up following NPS guidelines.	Data Manager/Physical Scientist	January-February
Assure archives are processed according to NPS guidelines.	Curatorial Specialist	January-February
Review and revise monitoring protocol and standard operating procedures on a yearly basis.	Project Leader	February-March
Prepare, repair, or purchase supplies and equipment for upcoming sampling year.	Project Leader/Field Crew Leader	January-February
Establish and refine annual and seasonal budgets.	Project Leader/Network Program Manager	March

SOP #3a: Field Methods: Strip Adaptive Cluster Sampling

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 3a – Contents

Page

SOP 3a – Figures

Page

SOP 3a – Figures (continued)

Page

SOP 3a – Tables

Page

Overview

This Standard Operating Procedure (SOP) gives an overview of strip adaptive cluster sampling (SACS) and step-by-step instructions for the field crew leader and field crew member to follow to perform SACS at Mammoth Cave National Park (MACA) including: (1) laying out the baseline on which strips are located, (2) laying out the strip within which the field crew surveys for cave cricket clusters, (3) photographing cave cricket clusters in a strip, and (4) filling in the field data sheet.

Prior to conducting a cave cricket sampling event, all personnel involved should review SOP #2: Pre-Field Sampling, this SOP, and follow all safety guidelines (Figure SOP2-5).

Strip Adaptive Cluster Sampling

While cave crickets are the most abundant large subsurface organism found in MACA sampling their populations in a statistically valid manner can be challenging. Indeed, while the bulk of cave cricket entrance populations roost in clusters (generally within 100m of cave entrances) they are rare relative to the surface area of cave ceilings and walls on which they roost. Further, their propensity to roost in clusters reduces the probability any one cluster would be detected by randomly located sampling units. As a result, the majority of randomly sampled units would likely contain no individuals and result in large variances of estimates of population size. The use of SACS takes advantage of cave crickets' tendency to roost in clusters to obtain more precise estimates of entrance population size and so increase the effectiveness of our sampling efforts (Thompson 2002). For the purposes of this SOP, the probability that sampling units adjacent to clusters of roosting cave crickets are occupied is higher than that of sampling units not adjacent to clusters, so sampling effort is increased in the vicinity of roosting clusters (Figure SOP3a-1). For example, if a given strip intersects a cluster of cave crickets with ≥1 cave crickets inside its 10cm boundary, then all cave crickets within 10cm of the initially encountered individual(s), whether inside or outside the strip, are included in the cluster. This process of adaptively sampling the cluster continues until no more individuals are found within 10cm of one another (Figure SOP3a-1).

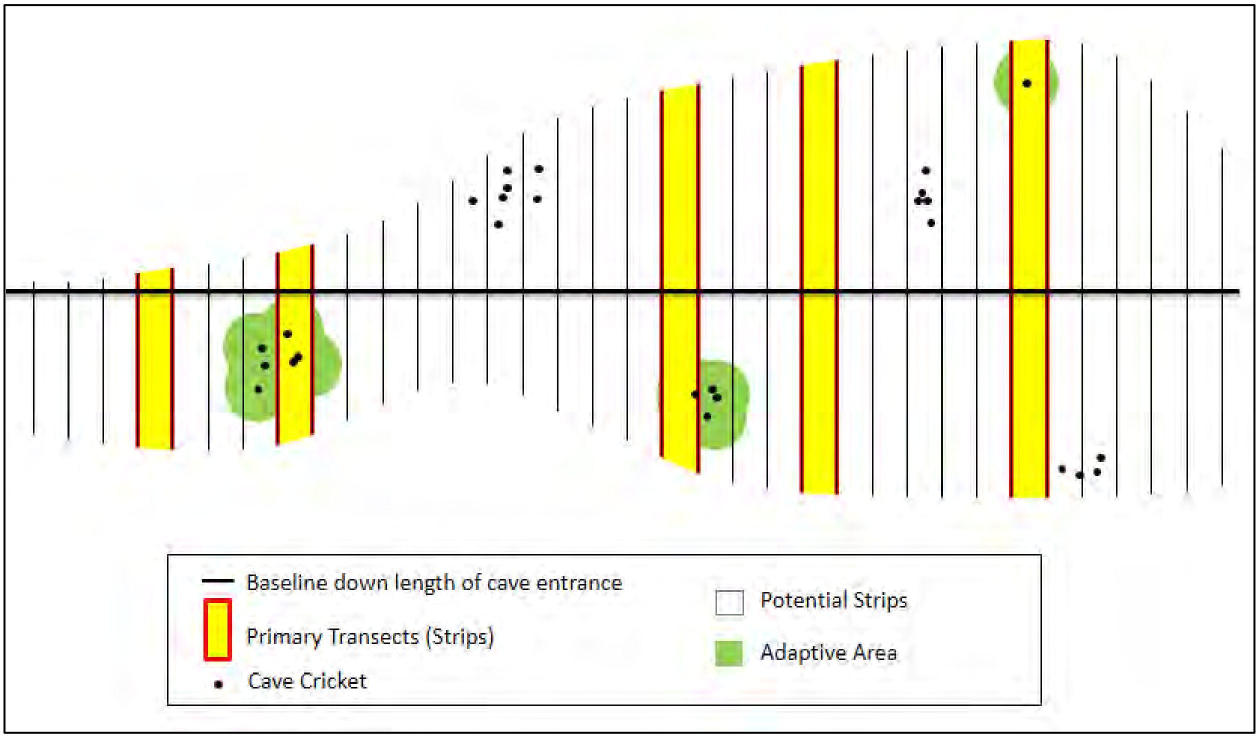

Figure SOP3a-1. Diagram of the strip adaptive cluster sampling method used to monitor cave crickets entrance populations at Mammoth Cave National Park. Randomly selected strips are searched for crickets with search area expanded around detected crickets.

Step By Step Instructions

1. Prior to each sampling event the field crew leader randomizes, via R code, the order in which sampled cave entrances are visited. The field crew leader also generates the Pre-populated Field Data Sheet, which contains the results of the 1-dimensional GRTS draw of spatially balanced strips, their positions on the baseline, and an additional, doubled oversample. The oversample is included in case there is a valid reason a few strips must be discarded and to maintain spatial balance (Table SOP3a-1). The Pre-populated Field Data Sheet also contains space to record ancillary data on roosting clusters (e.g., their extent and location) and cave meteorological data at the cluster (Figure SOP3a-2). Further, before leaving the office on a sampling bout, the field crew leader will review the Field Information Sheet, which provides an outline of the pertinent information describing conditions at each sampled cave, and equipment checklists for both cave entrances to reduce any confusion in the field. The field crew leader also ensures ample blank copies of field data sheets (with at least two additional pages per cave) are stored in the covered clipboard.

Reviewed by KH

Cave Cricket Monitoring Protocol-Cumberland Piedmont Network

Entrance Name: Austin Bout: May2014

Event ID: CC1011 Date: 05/27/14 Start: 1040 End: 1237

Crew: KHeld JJernigan Park Code: MACA

Event Notes: Adult woodrat seen; nests & bedding material in main passage. Lock *very* difficult to open.

Strips

GRTS n	Pos. (m)	Used (Y/R/U)	Reject Code	Clusters (separated by "–")	Notes
20	0.3	Y		0	
15	1.5	Y		0	
18	2.5	R	2		
11	3.4	Y		1-2	
07	3.7	Y		0	
03	4.2	Y		3-4-5-6	
16	5.0	Y		4	Intersect Pos. 4.2
12	7.3	Y		7	
21	19.8	Y		8	Replace Strip Pos. 2.5
22	0.9				
23	10.8				
24	8.3				

Reviewed by KH

Clusters

Cluster #	Extent (m) Prox.	Extent (m) Dist.	Cluster Dist.	Side (L/R)	Total Crickets	Location (C/W)	Temp °C	RH %	Air Flow (m/s)	Notes
1	3.41	3.42	5.0	L	1	W	14.5	94.2	Ø	
2	3.46	3.62	2.0	L	11	C	15.0	95.0	Ø	
3	4.23	4.44	1.50	L	35	C	15.2	96.4	Ø	
4	4.1	4.52	1.89	L	72	W	15.5	98.3	Ø	
5	4.3	4.5	5.3	R	15	C	15.6	98.5	.043	
6	4.2	5.0	1.15	R	93	C	15.6	99.0	Ø	
7	7.4	7.95	2.89	L	56	W	15.6	99.1	Ø	
8	19.0	19.5	.56	R	5	W	14.9	99.5	Ø	
9										

Figure SOP3a-2. Truncated Strip level data table (top and middle) and Cluster level data table (bottom) from the "Strips" and "Clusters" field data sheets, respectively. Prior to the sampling bout the "Strips" field data sheet is pre-populated, via R code, with Strip IDs from the GRTS draw, the Strip's (sequential) Position on the baseline, an additional, doubled oversample, Entrance name, Bout, Event ID, and park code. Strip level data (e.g., which strips and/or oversample strips are used and sequentially numbered clusters within a strip) are recorded in the field. The "Clusters" field data sheet is where all ancillary data associated with cave cricket clusters (e.g., each cluster's extent and cave meteorological data) are recorded in the field.

2. Prior to each sampling event the project leader, who acts as the field crew leader, ensures camera readiness. This is the protocol's main source of data, so preparation is crucial for obtaining adequate pictures.

    a. The field crew leader is to be cognizant of the potential for mud, dust, trauma, and contamination of both the camera and the case by the fungus that causes white-nose syndrome (WNS) in bats. A hard case that is easily cleaned/decontaminated is used to house the camera. The field crew leader wears latex or nitrile gloves when handling the camera and replace gloves, as needed, to help keep it clean.

    b. When changing lenses minimize exposure to dust and dirt. If possible, the field crew leader uses one camera with a zoom lens for high ceiling areas and another camera with a smaller or fixed lens for low ceiling areas.

    c. The field crew leader is to be exceedingly familiar with the camera gear before starting surveys. The field crew leader may create an abbreviated manual or "cheat sheet" including the essential functions of the camera and the flash (e.g., changing mode, shutter speed, IS0, aperture, image format, reviewing images); the list is kept with the camera to ensure continuity of settings among sampling events and event groups (Hicks et al. 2009). The following are recommended settings:

        i. Image format: "jpg" format.

        ii. ISO setting: ISO-800.

        iii. Mode: TAv-Automatic shutter and aperture priority where shutter speed and aperture will give proper exposure based on the brightness of the subject (Pentax K10D).

        iv. Metering: Use center-point metering when possible, center-weighted when not.

        v. Focus: Set to auto focus.

3. Once at the survey cave entrance the field crew member fills in the pertinent cave and sampling event data (i.e., Cave Name, Crew, Date, and Start Time) at the top of the field data sheet. The field crew member is the designated data recorder for sampling events. The data recorder performs verbal verification checks for data quality as data are received from the field crew leader and ensures that data are legibly entered into correct fields on the field data sheet. The field crew member retains the field data sheets in the covered clipboard at all times while in the cave so that their loss or damage (and potential loss of data) can be avoided. Data collected during the survey are entered onto a common field data sheet printed on Rite-in-the-Rain™ paper (Figure SOP3a-2). The data fields are roughly arranged in the sequence in which the data are acquired in the field, analyzed at the office, and entered into the database: (1) Cave level and sampling event data, (2) Strip level data, and (3) Cluster level data.

a. Repeated monitoring visits increase the possibility of damage to fragile cave resources and so best management practices should be observed to prevent damage; these include:

   i. Maintain a relatively small field crew size to minimize the impact on cave resources caused by repeated visits.

   ii. Travel should generally proceed in a single-file line to confine impact to a narrow path.

   iii. In general, but particularly through fragile cave sections, traveling slowly and deliberately is necessary to minimize the chances of impact such as breaking cave formations.

   iv. Only the field crew leader should move outside the immediate vicinity of the baseline.

4. Both members of the field crew use a baseline map (Figure SOP3a-3), generated during the cave entrance mapping survey for each monitored cave, to lay out the baseline using a fiberglass survey tape. The field crew references the baseline map for images of its starting point(s) (landmarks), bearing(s), and length to precisely relocate the baseline(s) in order to ensure continuity among cave cricket monitoring surveys. If the starting point is not tied to obvious landmarks, instructions indicate their distance (facing into the cave) from the left and right walls and the ceiling (up) and floor (down). A cave's baseline may have multiple segments if the cave passage meanders. However, multiple baselines must still be laid out continuously (i.e., with a single survey tape) so that all useable strip positions generated in the GRTS draw can be easily located.

5. The field crew member consults the Pre-populated Field Data Sheet (Figure SOP3a-2) of entrance-specific strip positions from the GRTS draw (see step 1) and brings the tripod to the appropriate sequential strip position on the baseline. Facing into the cave the field crew member turns on the lasers to project the 10cm wide strip, ensures the tripod is leveled, and pans the assembly to the left and then down and moves the tripod as necessary to assure that the strip's proximal (i.e., closer to the cave entrance) edge is projected onto its correct position on the baseline and it is perpendicular to the baseline while the tripod is level. The field crew member then pans the assembly up so that the strip is projected onto wall of the cave passage.

6. If the strip is not rejected (see sub-step c below) the field crew member records a "Y" in the "Used" column in the "Strips" table on the "Strips" page. (Figure SOP3a-2). Facing into the cave the field crew leader visually scans the strip, systematically from the left side to the right side of the baseline, for intersected clusters of cave crickets. The search always begins at floor level on the left cave wall, continues up the wall, onto the cave ceiling, and down the right cave wall to floor level. The field crew leader coordinates the search with the field crew member, who pans the laser assembly to move the strip as needed. Panning the laser assembly keeps the strip perpendicular to the plane of the baseline and reduces problems with changing its width.

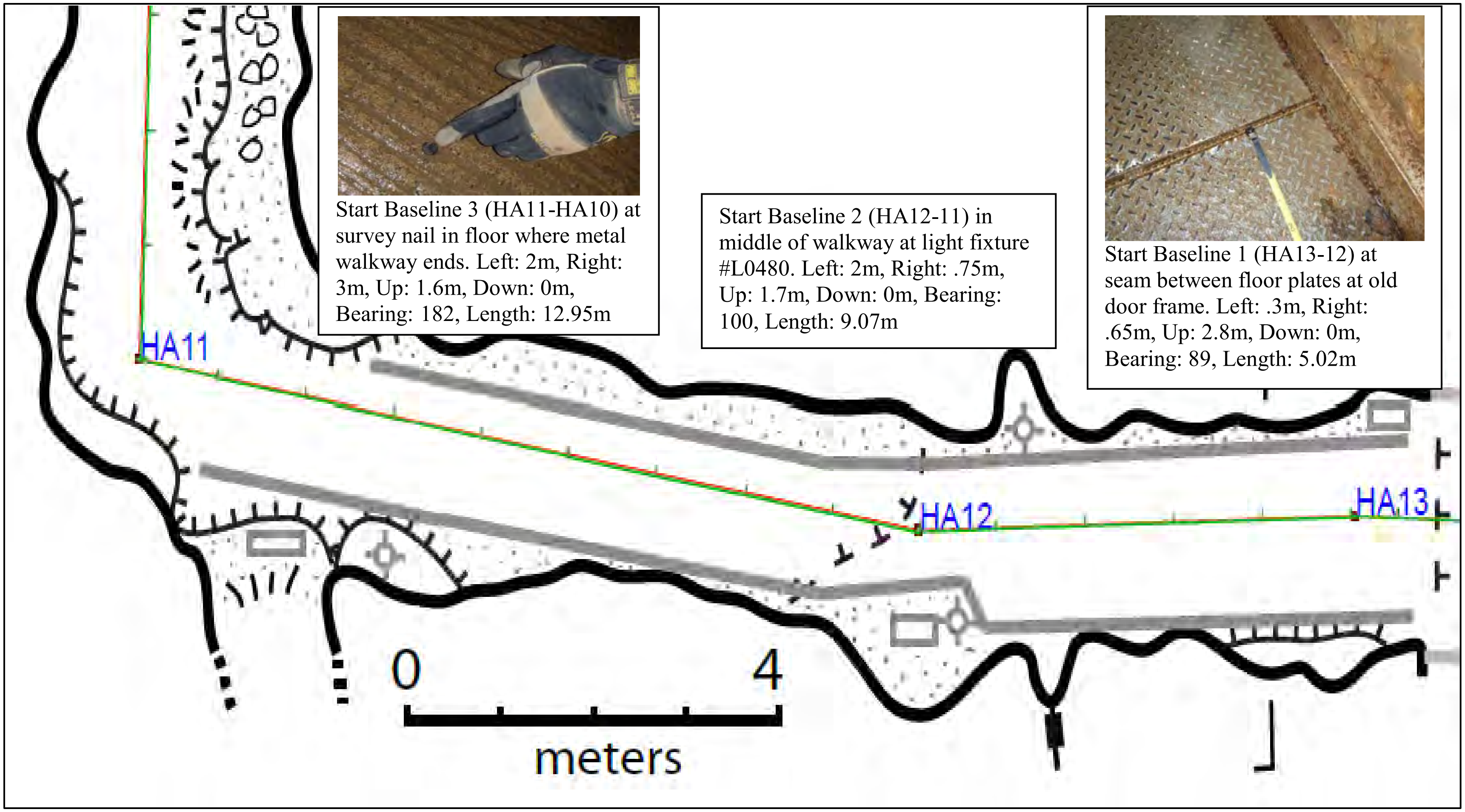

Figure SOP3a-3. Section of the baseline map for Frozen Niagara Entrance. Baseline maps for each survey cave contain inset photographs or instructions to accomplish their accurate relocation among sampling events. Note: this example shows separate, but continuous, baseline segments are necessary in caves with meandering passages.

a. If the field crew leader does not find any cave cricket(s) in the strip, the field crew member records “0” in the “Clusters” cell on the appropriate page of the “Strips” table. “Proximal”, “Distal”, and “Total Crickets” cells on the appropriate sequential “Cluster #” row on the appropriate page of the “Clusters” table

b. The first cave cricket found with at least 50% of its body within the strip is used by the field crew leader to determine whether other cave crickets in close proximity, if any, are included in the cluster (Figure SOP 3a-4). The ≤10cm proximity necessary for other crickets’ inclusion in the cluster is determined using the handheld strip generator (Figure SOP3a-5, left). A strip may intersect more than one cave cricket cluster (Figure SOP3a-4).

   i. The field crew leader expands the cluster iteratively, using the handheld laser strip generator, to include cave crickets within 10cm of any cave cricket already within the cluster, until there are no more cave crickets within 10cm of any other in the cluster (Figure SOP3a-4).

   ii. The handheld laser strip generator projects a 10cm wide strip and so, using it as a guide, the field crew leader estimates the locations along the baseline, in meters, to which the cluster extends from the strip’s proximal and distal edges and calls these two values out to the field crew member who records them on the appropriate page of the “Clusters” table (Figure SOP3a-2). Because clusters can extend **outside or inside** either edge of a strip, in either case the field crew leader estimates a positive or negative distance, respectively, and adds it to the original strip positions. For example, in Figure SOP3a-4 the position of Strip #11 on the baseline is at 3.4m and extends to 3.5m. Cluster #1 is the single cricket at “A” and its proximal and distal cluster extents are recorded as “3.41” and “3.42m”, respectively (dashed and blue lines). Cluster #2 starts with the two crickets inside the strip at “B”, 5cm inside the strip’s proximal edge, plus nine adaptively added crickets outside its distal edge: eight crickets at “C” are added as they are ≤10cm of those at “B” and the one at “D” is added as it is ≤10cm of those at “C”. Thus, Cluster #2’s distal margin is 12cm outside the strip’s distal edge. Cluster #2’s proximal and distal cluster extents are recorded as “3.45” and “3.62m”, respectively (dashed and blue lines).

   iii. The field crew member records the cluster’s sequential number in the “Clusters” column in the appropriate “Strips” table (Figure SOP3a-2).

   iv. Every fifth cluster the field crew leader confirms the estimates of cave cricket cluster extents using a meter stick or some other graduated device.

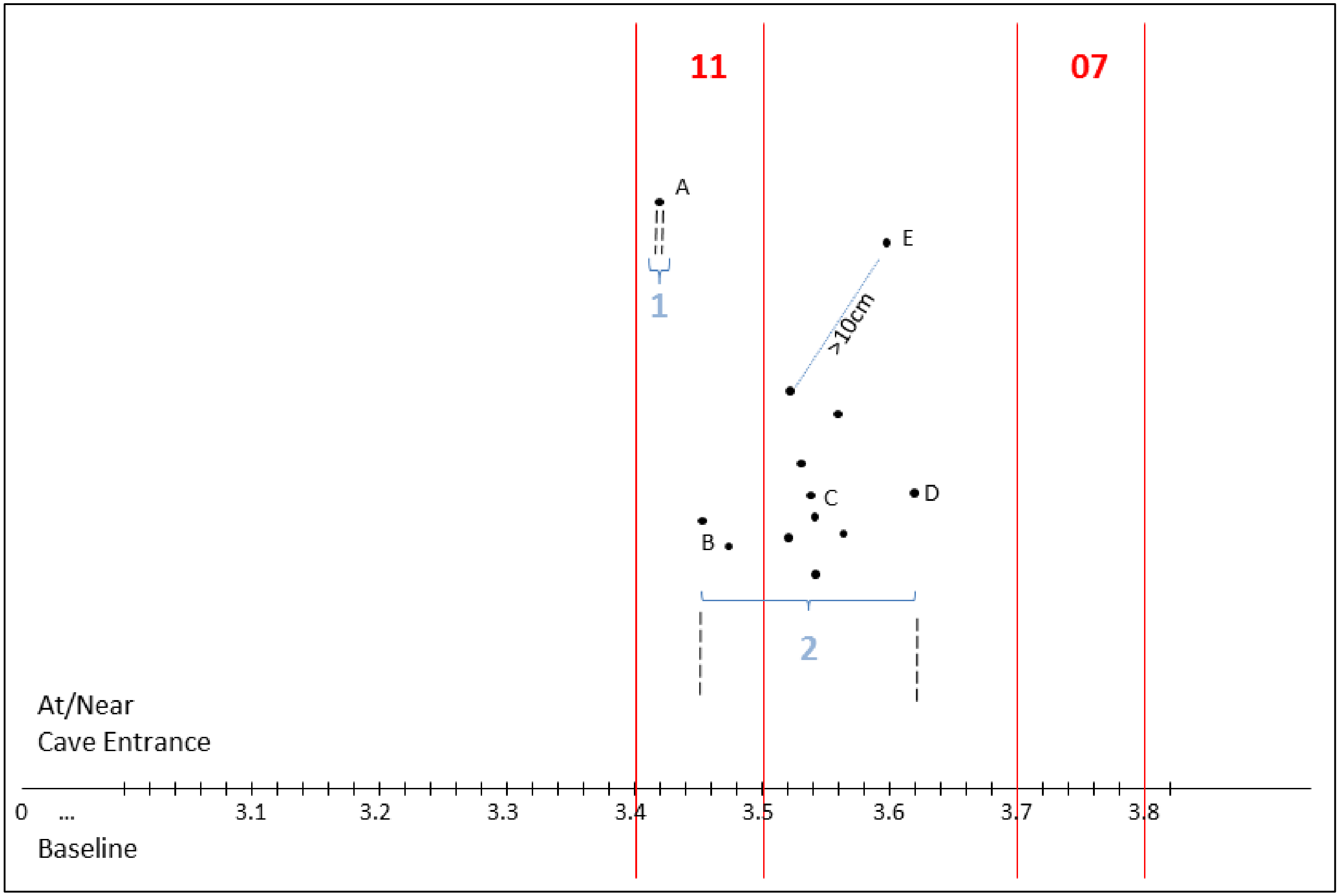

Figure SOP3a-4. Example of cluster extent with respect to the surveyed strip in Strip Adaptive Cluster Sampling used to monitor cave crickets at Mammoth Cave National Park. Note: strip #07 extends from 3.7 to 3.8m (red lines), and one row of data with 0 cave crickets is recorded in the Strips Table on page 1 of the field data sheet (Figure SOP3a-2).

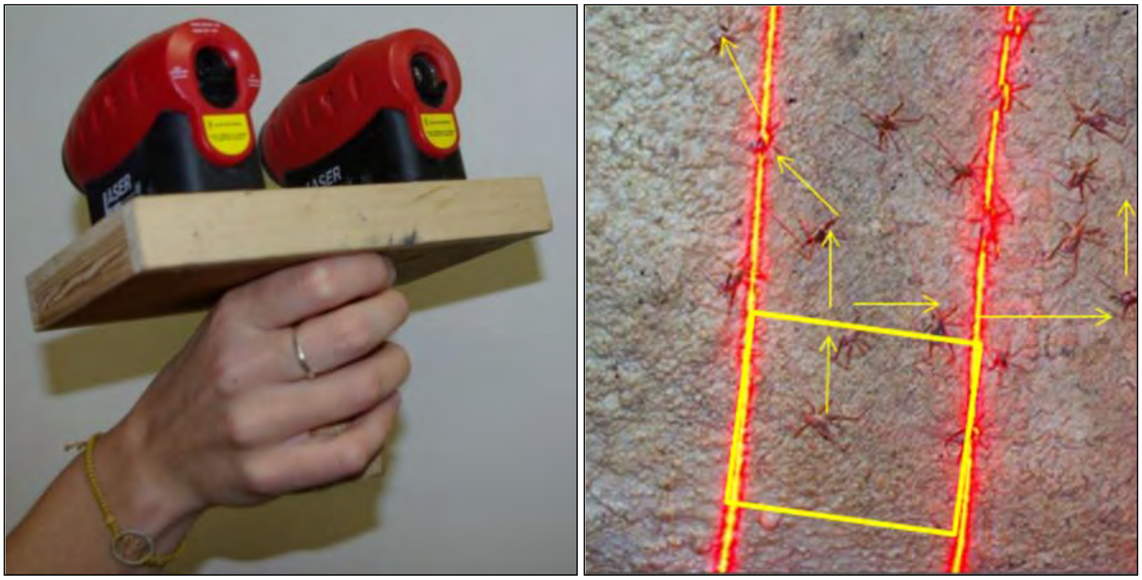

Figure SOP3a-5. Handheld laser strip generator (left). It is primarily used to iteratively expand a cave cricket cluster intercepted by the strip projected by the tripod laser assembly (right). The first cave cricket found with ≥50% of its body within the lines of the strip (centered in yellow box) is used to begin expanding the cluster. Beginning with this first individual, the generator is used to determine if the cave crickets adjacent to it, if any, are within 10cm. If so, the cluster is expanded iteratively by 10cm (yellow arrows) until no more cave crickets are found within 10cm of another.

c. If the field crew leader rejects the strip the field crew member writes “R” in the “Used” column on the field data sheet and records only one numbered rejection code in the “Rejection Code” column (Table SOP3a-1).

Table SOP3a-1. Valid reasons for rejecting strip positions during a sampling bout and their associated numbered code to be recorded on the field data sheet.

Rejection Code	Rejection Reason
1	Safety concern (e.g., pit)
2	Significant obstruction to strip
3	Avoid infrastructure damage
4	Avoid resource damage
5	Unsampleable/Inaccessible
6	Misc. Temporary Unsampleable

i. Reasons for discarding a strip position include situations where photography may be too difficult to attempt or data obtained are unreliable. For example, the strip may contain cave cricket clusters located too high on ceilings. Further, the field crew leader must always consider the potential for damage to sensitive cave features, such as speleothems or artifacts, and take all care possible if they are nearby. However, **do not compromise the crew’s safety or cave features**. The field crew leader is to remember the mnemonic “If in doubt, throw it out.”

ii. After finishing all the strips from the initial GRTS draw, any rejected strips are replaced by selecting, **sequentially by Strip ID**, a replacement from the oversample list (Figure SOP3a-2). S/he also records a “Y” in the oversample “Used” cell in the “Strips” table on the appropriate page in addition to the requisite cells the field crew member must fill in (e.g., “Cluster #s”). A “U” is recorded in the cells of any unused oversample strip positions. If the oversample is rejected follow the same procedure as in step 6c and select the next Strip ID in the oversample sequence.

7. Before the field crew leader begins recording image(s) of a specific cave cricket cluster intersected by the strip the field crew member records information pertinent to their identity on a small dry erase board (Figure SOP3a-6). The information includes the name of the cave entrance being sampled, the sampling event date, the Strip Position, and Cluster Number of the images to follow. The field crew leader records a digital image of the filled-in dry erase board; this image immediately precedes the sequence of cave cricket cluster images to which the information on the dry erase board applies (Figure SOP3a-6). Not only does the image mark the beginning of the specific cave cricket cluster’s image sequence but, critically, connects the data contained therein to the ancillary data on the “Clusters” field data sheet all of which are essential to subsequent analysis.

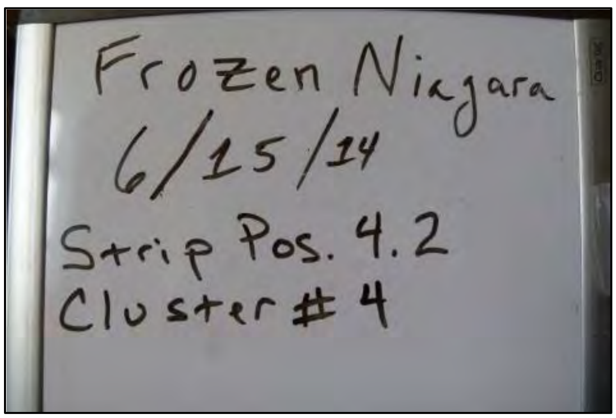

Figure SOP3a-6. Image of dry erase board with pertinent information identifying the sequence of cluster images following it. These data include (from top to bottom) cave entrance name (i.e., Frozen Niagara), sampling date, Strip Position, and Cluster Number.

8. The field crew leader captures images of cave cricket clusters as expeditiously as possible, limits their movement, and avoids shining light directly on the target cluster.

   a. The field crew leader rotates the camera body and adjusts the zoom. Thus, the larger dimension of the image just includes the largest dimension of the cluster, so the frame is filled with cave crickets to the extent possible. When the image cannot be filled (e.g., distant clusters) flash power is increased or augmented to obtain a properly exposed image of the cluster. Note: the laser line delineating the strip’s proximal side (i.e., the side closest to the entrance) is **always** on the left hand side of the image.

   b. The field crew leader **always** attempts to shoot on a line perpendicular to the plane of the cluster. This avoids depth-of-field issues and minimizes the number of hidden cave crickets. The smallest aperture possible, generally f-8, is used to maximize depth of field to compensate for uneven surfaces of clusters.

c. If a cluster is not arrayed in a single plane the field crew leader shoots multiple images, if possible, with each perpendicular to the ceiling or wall of interest and clearly overlapping adjacent shots.

d. For large clusters a single image providing both accurate data and coverage of the entire cluster is the best case scenario. However, if necessary, the field crew leader records multiple, overlapping tiled shots at a longer focal length so that individual cave crickets can still be counted. The tile shots include the unique edge characteristics to show places where images overlap. All tiled images are taken from the same spot, to keep perspective in each image the same. The tiled images are "stitched" together back at the office using image processing software typically included with the camera.

   i. When large clusters (i.e., clusters that extend outside the strip) are encountered the field crew leader alerts the field crew member to check the next strip position on the field data sheet to determine (i.e., "eyeball") if it is close enough to intersect with the cluster. If so, the field crew member sets up the second tripod and laser assembly there per Step 5.

   The field crew leader <u>**must**</u> record multiple tiled images of clusters that intersect more than one strip. The initial whiteboard must show the intersected strip position (Figure SOP3a-7, left). This alerts the image analyzer to look for a separate image sequence, with its own whiteboard image (Figure SOP3a-7, right), of the cave crickets inside the laser boundaries of the subsequent intersected strip position (see SOP #4 Post-Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry).

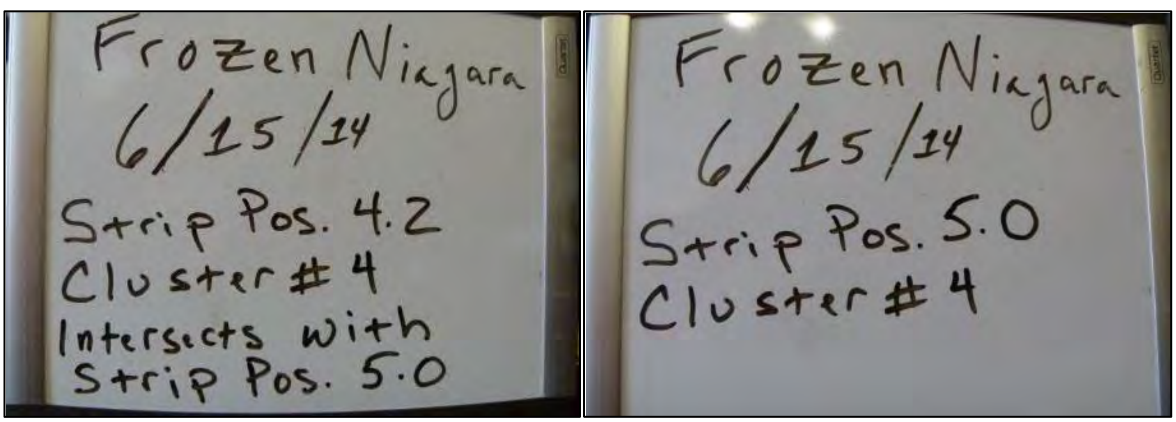

Figure SOP3a-7. A cluster that intersects more than one strip has at least two whiteboards associated with its image sequence. The first whiteboard in the image sequence contains an additional fifth line indicating the subsequent strip position with which the cluster intersects (left). The next whiteboard indicates that the subsequent image sequence contains <u>only crickets inside the boundary of the intersected strip</u> (right). Note: the strip position on the second whiteboard is that of the intersected strip.

1. The field crew leader records images capturing all cave crickets in the cluster from the initial strip position with which it intersected including all crickets in the cluster that intersect the second strip and beyond (if any).

2. The field crew member changes the Strip Position on the whiteboard to that of the subsequent intersected strip; however the cluster number stays the same (Figure SOP3a-7, right).

3. The field crew leader records an image of the whiteboard with the new information for the following image sequence of the subsequent intersected strip position.

4. The field crew leader records images of the of the cave crickets within the laser lines of the subsequent intersected strip position. Substep ii continues in the unlikely event the cluster intersects a third strip.

e. If the field crew leader wishes to capture images of an unusual feature or cave organisms other than cave crickets:

i. The field crew leader maximizes the depth of field (f-20 or f-22).

ii. The field crew leader ensures the ISO setting is 100.

iii. The field crew leader uses a reflective object (e.g., aluminum clipboard, or field data sheet) to soften shadows. The reflector is set as close as possible to the feature or organism without including it in the image, nearly on the opposite side of the feature or organism from the flash, and angled so the reflected light will fill in the shadow areas created by the flash.

9. The distance of the cluster's centroid from the baseline is determined using an electronic rangefinder (Figure SOP3a-8). Of necessity this step is performed by both field crew members. Both rangefinder units are turned on prior to step "a" below. The switch on the right side of the transmitter is moved to the bottom position (this position shows a diagram of both the transmitter and receiver).

a. Using the electronic rangefinder the cluster distance is measured perpendicular to the baseline and parallel with the edge of the strip. The field crew member holds the electronic rangefinder's transmitter level at, but just above, the back edge of the pan head assembly so that the back of the transmitter lines up with the baseline. The field crew leader holds the receiver at the same height as the transmitter and below the cluster's centroid. Note: if the centroid of the cluster is far outside the strip's boundary the field crew member can place the second tripod and laser assembly at a location on the baseline where the cluster's centroid is in a line perpendicular from the baseline and measure from there.

Figure SOP3a-8. The Sonin Combo Pro™ electronic rangefinder includes a transmitter (left) and a receiver (right).

b. The field crew member presses the large button on the lower right side of the transmitter (i.e., the triangle with the line segment beneath it; Figure SOP3a-8) so the distance is measured from the baseline. The measurement is repeated three times to ensure accuracy; if they are different the field crew member records the average of all three measurements. The field crew member records the distance to the nearest centimeter in the "Cluster Dist." cell in the appropriate "Cluster #" row on the appropriate page of the "Clusters" table (Figure 3a-2).

10. The field crew member notes on which side of the baseline (facing into the cave) the cluster is located, i.e., left or right side, and records it in the "Side (L/R)" cell in the appropriate "Cluster #" row on the appropriate page of the "Clusters" table (Figure 3a-2). Note: if the cluster straddles the baseline the side on which the majority of the cluster is roosting is chosen.

11. The field crew leader calls out the total number of cave crickets in the cluster (either the exact number or, in the case of large clusters, estimated) and the field crew member records it in the "Total Crickets" cell in the appropriate "Cluster #" row on the appropriate page of the "Clusters" table (Figure 3a-2).

12. field crew member records whether the cluster is roosting on the wall or ceiling in the "Location" cell in the appropriate "Cluster #" row on the appropriate page of the "Clusters" table (Figure 3a-2). Note: if the cluster includes the wall and the ceiling the location on which the majority of the cluster is roosting is chosen.

13. The field crew leader holds the thermohygrometer (e.g., Kestrel® 4200 Pocket Air Flow Tracker) at the densest portion (if applicable) of the cave cricket cluster; otherwise, it is held in the centroid of the roosting cluster and calls out the values obtained for temperature (ºC), relative humidity (%RH), and air flow (m/s) to the field crew member who records them in the "Temp", "RH", and "Air Flow" cells in the appropriate "Cluster #" row on the appropriate page of the "Clusters" table. Note: if the cluster is too high to safely reach the

thermohygrometer may be attached to a telescoping painting pole with a rubber band or a Velcro® strap. The rubber band or strap should be wrapped around the bottom of the unit so as not to obscure the unit's sensors or display.

14. Once all relevant data are recorded the field crew leader searches for another cluster in the current strip. If the strip intercepts another cave cricket cluster steps 6.b.i. to13 in "Step By Step Instructions" and all data on the "Strips" and "Clusters" field data sheets are recorded (Figure SOP3a-9 and Table SOP3a-2). If the strip does not intercept another cave cricket cluster, the field crew performs steps 5 to 13 in "Step By Step Instructions" until the last Strip Position on the baseline from the GRTS draw has been sampled and any necessary replacement strips (due to rejected strips) have been sampled.

15. Prior to pulling up the baseline the field crew leader reviews all field data sheet pages for completeness and legibility, resolves any ambiguities with the data recorder, and initials them.

16. When the work is complete, the field crew exits the cave quickly, and moves cautiously (in a safe manner).

17. The field crew leader secures all cave gates and locks as required.

18. The field crew leader informs the surface watch of the field crew exiting cave ASAP (e.g., via cell phone or radio).

19. The field crew follows all applicable gear decontamination procedures as described in the White-nose Syndrome section of SOP #2: Pre-Field Sampling.

Reviewed by______

Cave Cricket Monitoring Protocol-Cumberland Piedmont Network

Entrance Name: ________________________________ Bout: ___________________________

Event ID: ___________________ Date: ___________ Start: __________ End:___________

Crew: __________________________________ Park Code: MACA

Event Notes:

____

____

____

Strips

Strip ID	Pos. (m)	Used (Y/R/U)	Reject Code	Clusters (separated by " – ")	Notes

Page __ of __ Data Entry_________

Figure SOP3a-9. Blank copy of "Strips" page on pre-populated field data sheet for cave cricket monitoring protocol.

Reviewed by______

Clusters

Cluster #	Extent (m)		Cluster Dist.	Side (L/R)	Total Crickets	Location (C/W)	Temp °C	RH %	Air Flow (m/s)	Notes
	Prox.	Dist.								
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
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Page __ of __ Data Entry_________

Figure SOP3a-9 (continued). Blank copy of “Clusters” page on pre-populated field data sheet for cave cricket monitoring protocol.

Data Dictionary for Field Data Sheet

A detailed list of descriptions for the field data sheet (Figure SOP3a-2) is provided in Table SOP3a-2 below.

Table SOP3a-2: Field data sheet field descriptions for cave cricket monitoring protocol.

Sampling Event Data	Field Description
Entrance Name (pre-populated)	MACA's unique cave entrance name being sampled. Example: "Frozen Niagara".
Bout (pre-populated)	Set of cave sampling events, analogous to event group (i.e., May2014). If a bout spans two months the month the bout started is used.
Event ID (pre-populated)	Unique event identifier—event defined as a single visit to a single cave entrance, of form "CC" & unique randomized sequence number.
Date	Starting date for the event in mm/dd/yyyy format. Example "06/15/2014".
Start	Starting time for the event (i.e., arrival at the cave entrance); recorded in 24-hour clock in hhmm format. Example: "1040".
End	Ending time for the event (i.e., exit from the cave entrance); recorded in 24-hour clock in hhmm format. Example: "1237".
Crew	Names of all field crew members participating in a given sampling event; first initial and spelled out last name. The crew leader's name is circled. Example: "KHelf, JJernigan".
Park Code (pre-populated)	"MACA"
Event Notes	Any phenomena pertinent to the sampling bout, the data, or the cave's resources. Example: "Adult woodrat seen".
Strips Table Data	**Field Description**
Strip ID (pre-populated)	Strip sequential order generated during the GRTS draw. Listed out of sequence on the pre-populated data sheet (Figure SOP3a-2). Because more than one cluster may be intersected by a strip this row may contain many Cluster numbers.
Pos. (m) (pre-populated)	Position (m) is the one-dimensional, discrete position on the baseline to the nearest tenth of a meter where strip is initiated. Strip positions are listed sequentially on the field data sheet and each is given one row. The proximal edge of the strip is projected perpendicular to its position on the baseline and its (parallel) distal edge is projected 10cm farther down the baseline. Strip positions intersecting more than one cluster will have several Cluster #s associated with their row on the field data sheet. Example of Position: "3.4" (See Figure SOP3a-2).
Used (Y/R/U)	Refers to whether initial Strip or Oversample is used (Y) or rejected (R) and Oversample that go unused (U) during the sampling event "U" is exclusively recorded in "Used" cells associated with unused oversample strip positions.
Reject Code	Numbered code refers to whether strip is rejected or used during the sampling event. Record only one number per strip. 1 = Safety concern, 2 = Significant obstruction to projecting a strip, 3 = Avoid infrastructure damage, 4 = Avoid resource damage, 5 = Position is unsampleable/inaccessible, 6 = Misc. Temporary Unsampleable.
Clusters	Sequential number assigned to each cave cricket cluster detected within a cave entrance during a sampling event. Multiple clusters detected in the same strip are separated by a "-". Typically, cluster numbers are assigned unique sequential numbers without regard to Strip ID or Strip Position. However, there are a few exceptions: a "0" is recorded in the cluster # column whenever a strip does not intersect any cave cricket clusters. Also, large cave cricket clusters are occasionally intersected by >1 Strip Positions. In this case, the first Strip ID to intersect such a cluster is assigned that cluster's sequential number in its "Clusters" cell. Subsequent Strip IDs with which the cluster intersects are also assigned that "Clusters" number (Figure SOP3a-2). No other data are recorded in these rows on the "Clusters" table except a Note indicating the initial Strip Position with which it intersected. Example: "Intersection Strip Pos 4.2".
Notes	Any information pertinent to a specific Strip Position associated with that row.

Sampling Event Data	Field Description
Cluster # (pre-populated)	Sequential number assigned to each cave cricket cluster detected within a cave entrance; sequence begins with "1" (See Figures SOP3a-2 and SOP3a-9 for examples).
Extent (Prox./Dist.)	An estimate, in meters, of the distance a cave cricket cluster extends from the proximal and distal edges of the strip. Clusters can extend outside or inside either edge of a strip, in which case the field crew leader estimates a positive or negative distance, respectively, and adds it to the strip position. For example, in Figure SOP3a-4 the position of Strip ID 11 on the baseline is at 3.4m and extends to 3.5m. The proximal margin of the second cave cricket cluster with which it intersects, starting at "B", is five cm inside the strip's proximal edge. Thus, the strip's proximal extent is recorded, in the "Proximal" column, as "3.45" (see Strip ID 15 in Figure SOP3a-2). Further, the cluster's distal margin is 12cm outside the strip's distal edge, so the cluster's distal extent is recorded, in the "Distal" column, as "3.62". (See Figure SOP3a-2).
Cluster Dist.	Distance in meters from baseline to a point directly below the cluster centroid measured parallel with the strip and perpendicular to the baseline. Recorded to the nearest centimeter. Example: "1.92".
Side (L/R)	The side of the baseline, facing into the cave, on which the cave cricket cluster is located. If the cluster straddles the baseline the side on which the majority of the cluster is roosting is chosen. Recorded as "L" for left or "R" for right.
Total Crickets	Total number of crickets within the cluster (either the exact number or, in the case of large clusters, estimated). Used as a reference for image analysis.
Location (C/W)	Location of the roosting cave cricket cluster, recorded as "C" for ceiling or "W" for wall. If the cluster includes the wall and the ceiling the location on which the majority of the cluster is roosting is chosen.
Temp ^{0}C	Temperature at the densest portion (if applicable) of the cave cricket cluster; otherwise, taken at the cluster's centroid (see SOP #3b: Cave Meteorological Sampling). Recorded to the nearest tenth of a degree. Example: "15.5".
RH%	Relative humidity at the densest portion (if applicable) of the cave cricket cluster; otherwise, taken at the cluster's centroid (see SOP #3b: Cave Meteorological Sampling). Recorded to the nearest tenth of a percent. Example: "94.7".
Air Flow (m/s)	Air flow in meters per second at the densest portion (if applicable) of the cave cricket cluster; otherwise, taken at the cluster's centroid (see SOP #3b: Cave Meteorological Sampling). Recorded to the nearest thousandth. Example: "0.043".
Notes	Any information pertinent to the specific Cluster Number associated with that row.
Reviewed by	Initials of field crew leader who reviewed field data sheet for completeness prior to pulling up the baseline tape.
Page _of_	Number of pages in the field data sheets associated with a specific sampling event. Example "Page 1 of 2".
Data Entry	Date on which data from field data sheet were entered into the cave cricket monitoring protocol database.

Literature Cited

Hicks, A. C., C. Herzog, A. Ballmann, and A. King. 2009. Protocol for 2008-2009 hibernacula surveys of cave bats. New York State Department of Environmental Conservation, Albany, New York.

Thompson, S. K. 2002. Sampling. Second edition. John Wiley & Sons, Inc., New York, NY.

SOP #3b: Field Methods: Cave Meteorological Sampling

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 3b – Contents

Page

SOP 3b – Figures

Page

SOP 3b – Tables

Overview

This SOP provides step-by-step instructions for field crew leaders and crew member(s) to follow when collecting cave meteorological data (i.e., temperature, relative humidity (RH), airflow) during biannual sampling bouts and/or continuous automated sampling. These data will be used to determine if a correlation exists among cave meteorological trends and: 1) cave cricket entrance populations and 2) habitat use within monitored cave entrances in MACA.

Two methods will be used to collect cave meteorological data: 1) opportunistic grab sampling in which field personnel utilize a handheld weather instrument to measure cave temperature, RH, and air flow in association with clusters of roosting cave crickets and 2) continuous sampling wherein field personnel rely on automated dataloggers to gather data on cave temperature and RH; continuous sampling methods follow those outlined in Woodman et al. 2011. In addition, meteorological data on the surface (e.g., temperature, RH, and precipitation) are continuously collected by the USDA's Soil Climate Analysis Station. Continuously collected surface and subsurface meteorological data are downloaded from their respective sources at the end of the sampling year. Additional details related to this method are available in SOP #4: Post- Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry.

Opportunistic Grab Sampling

Opportunistic grab sampling involves the use of handheld sensors to measure cave temperature, relative humidity, and air flow at cave cricket clusters and is performed in conjunction with Strip Adaptive Cluster Sampling (SACS). The timing of opportunistic grab sampling during SACS is described in the step-by-step instructions in SOP #3a: Field Methods: Strip Adaptive Cluster Sampling. Cave meteorological data are "Cluster Level Data" and are recorded at each cave cricket cluster on the field data sheet. Since opportunistic grab sampling is performed in conjunction with SACS of cave cricket clusters see the step-by-step instructions and descriptions of fields on the data form provided in SOP #3a: Field Methods: Strip Adaptive Cluster Sampling.

Equipment

Air temperature (ºC), RH (%), and air flow (m/s) data are obtained at each photographed cave cricket cluster via thermohygrometer. Some roosting clusters will be out of reach of handheld meteorological instruments and so the instrument is mounted to an extensible paint handle with a Velcro® strap or rubber band. To measure air temperature at a cave cricket cluster, the field crew leader attempts to avoid disturbing the cluster and carefully inserts the instrument into the centroid of the cave cricket cluster without touching the rock surface. The remaining parameters (i.e., RH and air flow) are sampled simultaneously and so the field crew leader recites the readings to the field crew member; the field crew member records them on the field data sheet. All instrument sensors should be calibrated per the manufacturer's recommendations prior to each sampling bout.

Continuous Sampling

Meteorological data are sampled continuously in monitored cave entrances. Continuous sampling of cave temperature and relative humidity measurements follows methods outlined in Woodman et al. 2011; data collection is automated and datalogger driven. This approach streamlines data collection, largely eliminates the need for data entry from data forms to a database, and improves data quality since human error is essentially removed. However, associated metadata are recorded on a field data form.

Equipment

The dataloggers used in this protocol are the HOBO® Pro v2 (U23-001) Temperature/RH systems by Onset Computer Corporation. These dataloggers include integrated air temperature and relative humidity sensors. Prior to each use, dataloggers should be calibrated per the manufacturer's recommendations.

Site Selection, Sampling Frequency/Interval, and Replication

In each sampled cave two HOBO dataloggers are installed such that they yield meteorological data generally representative of the twilight zone (i.e., proximal to the entrance) and the constant temperature zone (i.e., distal to the entrance), respectively. Placement is determined by the project leader (or designated field crew leader) or CUPN physical scientist based on written or photographic documentation from past inventory, monitoring or research efforts. The location of each datalogger is clearly marked on the specific cave's baseline map. The field crew member records a detailed written description, including azimuth, inclination, and distance from an obvious permanent landmark (e.g., a distinct rock formation) of the specific location of each datalogger on the HOBO RH/Temp Datalogger field data form. The field crew leader records digital images of the installed datalogger and the corresponding permanent landmark and image numbers are recorded on the field data form. No other means of marking these locations in sample caves are used in this protocol.

The following guidance on installation of HOBO dataloggers, permanently stationed in the cave passage of interest, is taken from Woodman et al. (2011). Installation is performed by the field crew leader in one of three ways. The easiest way is to place the datalogger on the floor, turned upside-down (to avoid having water collect on the logger's humidity sensor), and suspended between two small rocks or boards to avoid contact with the cave floor. Direct contact with a cave surface may conduct heat into or out of the datalogger and distort air temperature measurement. Note: in caves with packrats or other opportunistic biota, this location is not optimal as the datalogger may be damaged or removed. A purchased or constructed mounting stand must be thermally isolated; particularly if the stand is a good conductor of heat (e.g., metal). The third, and preferred, option for mounting the datalogger is direct attachment to a cave wall or the ceiling. This option uses toggle bolts or nails through appropriately sized crevices in the cave surface of choice. Note: this method can damage the cave surface and is to be avoided, particularly in areas with delicate formations, if possible. If this option is chosen, the datalogger will be thermally isolated from the cave surface so that no conduction occurs. Thermal isolation of the HOBO is accomplished by putting spacers between the back of the unit and the cave surface. The toggle bolts or nails should pass through the spacers.

Each HOBO datalogger collects temperature and relative humidity data at a particular sampling unit. Initial installation for each datalogger will occur during the first sampling event at each cave and data will be downloaded at the end of each subsequent sampling event (i.e., after cricket sampling is finished but before exiting the cave). As necessary, datalogger servicing activities (e.g., changing batteries, cleaning o-rings) will occur during the second sampling bout at the end of each cave entrance's sampling event. Data for the 36 hour period previous to the date of each cave entrance’s sampling event are used in subsequent analyses. A datalogger is replaced if there is evidence it ceased collecting data during the sampling year (e.g., the LED in the communications window is not blinking, the download indicator LED flashes for only a few seconds during download) or if the datalogger is not able to relaunch after replacing the battery. The datalogger’s specific location will be monitored for two consecutive years out of every five years to determine whether it is truly representative of the meteorology in the sampled cave entrances’s respective zones. HOBO dataloggers are programed to continuously collect temperature and relative humidity measurements once every hour.

Step by Step Instructions

The status of continuous cave meteorological information and recommended sampling schedule are provided in the Field Information Sheet for each sample cave. Activities involved in obtaining continuously sampled cave meteorological data in the field broadly include datalogger installation, service, replacement, and removal. Instructions for launching, programming, downloading, and battery replacement for the datalogger (and its corresponding data shuttle) used in this protocol can be found in Appendix E. Below is a sequential list of major tasks the field crew should follow with respect to continuous sampling of cave meteorological data during each sampling event. Some tasks, however, are dependent upon whether the sampling cave has extant dataloggers and their status:

1. Before leaving the office on a sampling bout, the field crew leader should review the Field Information Sheet and checklists for both cave entrances to reduce any confusion in the field.

2. If necessary, the field crew uses the GPS unit and field map included with Field Information Sheet to navigate to the entrance of the cave to be monitored.

3. Near the entrance, the field crew suits up with caving gear and prepares the monitoring equipment Field Information Sheet, the pre-populated field data sheet, and specific baseline map.

4. The field crew refers to the Field Information Sheet and baseline map to navigate through the cave to the datalogger.

5. Typically, the field crew leader handles dataloggers and data shuttles. However, the field crew member may serve as data recorder, datalogger/shuttle handler, datalogger spotter, measurer, or photographer (of dataloggers and landmarks). It is important the field crew leader establish roles in advance and maintain good communication in the cave to ensure efficient and accurate work.

6. The field crew member completes the fields “Cave Name”, and “Datalogger Location Name” on the HOBO RH/Temp Datalogger Monitoring Data Form.

7. In sampled cave entrances <u>without</u> initial HOBO RH/Temp dataloggers the field crew leader *installs* initial pre-launched (in the office) units. Installation should follow the guidance provided in the Continuous Sampling section above (Woodman et al. 2011). The field crew member records required metadata on the HOBO RH/Temp datalogger field data form (Figure SOP3b-2 and Table SOP3b-1). After a datalogger has been initially installed, the field crew leader selects a permanent landmark (e.g., a distinct cave rock formation) to use as a reference point for relocating the datalogger or datalogger location. On the field data form

the field crew member records siting information from the landmark (i.e., azimuth, inclination, and distance from the baseline); the field crew member assigns it a unique name; the field crew member describes its location relative to the datalogger; and the field crew leader photographs both the landmark and the datalogger *in situ*. The field crew member plots and labels the approximate location of each datalogger and corresponding landmark on the field copy of the baseline map. For more detail see the "Continuous Sampling" section of this SOP above.

8. In sampled cave entrances with previously installed HOBO RH/Temp dataloggers the field crew leader s*ervices* both dataloggers during the second sampling bout of each sampling year. This includes battery changing, data downloading, relaunching (i.e., restarting automatic data collection), examining, cleaning, and reinstalling. The field crew member records required metadata on the HOBO RH/Temp datalogger field data form (Figure SOP3b-2 and Table SOP3b-1). Location information for previously installed dataloggers is included on the cave's Field Information Sheet and field copy of the baseline map. For more detail see the "Continuous Sampling" section of this SOP above.

9. When there is some doubt about the reliability of a previously installed HOBO RH/Temp datalogger (e.g., data transfer was not successful, datalogger did not relaunch, LED not blinking after replacing battery, evidence of datalogger having been submerged in flood, signs of external damage to the datalogger) the field crew leader r*eplaces* it with a pre-launched datalogger. The field crew member records required metadata on the HOBO RH/Temp datalogger field data form (Figure SOP3b-2 and Table SOP3b-1). For more detail see the "Continuous Sampling" section of this SOP above.

10. The field crew leader r*emoves* (and does NOT replace) each previously installed HOBO RH/Temp datalogger located in the cave in which at least two years (total) of cave temperature/RH data have likely been collected based on length of time since initial installation, success of previous data downloads, and condition of indicator LED and download speed that day. The actual number of days a datalogger successfully recorded data since it was last downloaded will not be known until data are transferred from the data shuttle to a computer in the office. The field crew leader refers to the Field Information Sheet for datalogger history at each monitored location within a cave. The field crew member records required metadata on the HOBO RH/Temp datalogger field data form (Figure SOP3b-2 and Table SOP3b-1).

11. When the work is complete, the field crew exits the cave quickly, and moves cautiously (in a safe manner).

12. The field crew leader secures all cave gates and locks as required.

13. The field crew leader informs the surface watch of the field crew exiting cave ASAP (e.g., via cell phone or radio).

14. Before leaving cave entrance area, the field crew leader reviews and signs all data forms. The field crew reviews the Field Information Sheet and suggests any changes to be considered by the project leader.

15. The field crew follows all applicable gear decontamination procedures as described in the White-nose Syndrome section of SOP #2: Pre-Field Sampling.

16. Cave meteorological data files are processed per the instructions in SOP #4: Post- Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry.

Filling in the Field Observer Form

Detailed descriptions of each field in the HOBO RH/Temp Datalogger field observer form (Figure SOP3b-2) are provided in Table SOP3b-1 below

Office Only: scan made by______ on___/___/______ MACA_Cave_Cricket_HOBO_Data_Form_20140408
entered by______ on___/___/______ validated by______ on___/___/______

HOBO RH/Temp Datalogger – Site Setup and Maintenance Field Observer Form

General Information

Cave Name ____

Datalogger Location Name ______

Siting information:

Azimuth ____________

Inclination __________

Distance ____________

Datalogger Location Description ____________________________

____

Datalogger Photos ______________________________________

Landmark Name _______

Landmark Description ____________________________________

____

Landmark Photos ____

HOBO Serial Number ______________________ Model ______________

Crew Member _____________________________

Date ____ ____ ____ Time_________
mm dd yy

Datalogger installation status and accompanying notes (check one):

____ Installed datalogger today. There was no datalogger at this location before today.

LED blinking on departure? Y N

____ Servicing existing datalogger.

LED blinking on arrival? Y N

Datalogger undisturbed? Y N

Changed battery? Y N

If Y:

Cleaned o-ring? Y N

Greased o-ring? Y N

Cleaned o-ring groove? Y N

Replaced dessicant? Y N

Data transfer successful? Y N

Datalogger relaunched? Y N

LED blinking on departure? Y N

_____ This datalogger is being replaced today by:

HOBO Serial Number _____________________

Model _____________

LED blinking on departure? Y N

____ This datalogger is being removed, but **NOT** replaced today.

Notes: ____

____

____

Data recorder initials _____ Reviewed by: ______

Figure SOP3b-1. Field data form for HOBO relative humidity and temperature automated datalogger installation and maintenance for MACA caves (based on Woodman et al. 2011).

Table SOP3b-1: Data form field descriptions for HOBO RH/Temp datalogger installation and maintenance.

Field Name	Field Description
General Information	
Cave Name	The unique cave name, and entrance name (if more than one), being sampled.
Datalogger Location Name	Unique name assigned (in the field) to a permanent location where a datalogger was initially installed. Within a cave, each specific HOBO datalogger location will be assigned a name beginning with "H1", followed by "H2", and so forth.
Siting information: Azimuth	Record the compass bearing in degrees (0^0 - 360^0) from the permanent landmark to the datalogger.
Siting information: Inclination	Record the inclination (% slope) obtained by a clinometer or disto from the permanent landmark to the datalogger. Record as a positive or negative whole integer.
Siting information: Distance	Record the distance in meters obtained by a measuring tape or laser range finder from the permanent landmark to the datalogger.
Datalogger Location Description	A detailed description of the location where the newly installed HOBO datalogger is placed.
Datalogger Photos	Record i.e., image number(s) of photos taken of newly installed HOBO datalogger *in situ*. Note camera used to obtain images, if different from camera used for cave cricket cluster sampling.
Landmark Name	Unique name assigned (in the field) to a permanent landmark that will be used as a reference point in the cave for relocating the specific location where a datalogger was initially installed. Within a cave, each landmark will be assigned a name beginning with "L1", followed by "L2", and so forth.
Landmark Description	A detailed description of the permanent landmark that will be used as a reference point in the cave for finding the specific location where the datalogger was initially installed.
Landmark Photos	Record image number(s) of landmark. Note camera used to obtain images, if different from camera used for cave cricket cluster sampling.
HOBO Serial Number	Record the serial number printed on the side of datalogger.
Model	Record the HOBO datalogger model type. The current model is the **HOBO Pro v2** (the general shape of a toilet paper roll cylinder).
Crew Member	First and last name of the primary crew member who carries out the datalogger installation or maintenance.
Date	Date on which data are collected in mm/dd/yy format (e.g., 05/17/11 for May 17, 2011).
Time	The time, to the nearest minute, when the existing datalogger was relaunched, removed, or the new datalogger was installed/replaced. Use 24-hours format. All four digits should be filled in. Examples: 0630 (6:30 am) and 1350 (1:50 pm).
Datalogger installation status and accompanying notes (check one):	
Installed datalogger today	Place an "X" or "√" on this line if there was no datalogger at this location before today.
LED blinking upon departure?	Circle Y if the red LED in communications window (HOBO Pro v2) was blinking when finished. Circle N if the LED was <u>not</u> blinking when finished.
Servicing existing datalogger	Place an "X" or "√" on this line if an existing datalogger is being serviced today (e.g., battery changed, data offloaded).
LED blinking upon arrival?	Circle Y if the red LED in communications window (HOBO Pro v2) is blinking when field crew arrived. Circle N if the LED was <u>not</u> blinking when field crew arrived.
Datalogger undisturbed?	Circle Y if the datalogger was undisturbed when the crew arrived today. Circle N if the datalogger was disturbed when the crew arrived today.

Field Name	Field Description
Changed battery?	Circle Y if the datalogger was changed today. Circle N if the datalogger was **not** changed today, and skip the next 4 questions.
Cleaned o-ring?	Circle Y if the o-ring in the datalogger was cleaned today. Circle N if the o-ring in the datalogger was **not** cleaned today.
Greased o-ring?	Circle Y if the o-ring in the datalogger was greased today. Circle N if the o-ring in the datalogger was **not** greased today.
Cleaned o-ring groove?	Circle Y if the o-ring groove in the datalogger was cleaned today. Circle N if the o-ring groove in the datalogger was **not** cleaned today.
Replaced desiccant?	Circle Y if the desiccant in the datalogger was replaced today. Circle N if the desiccant in the datalogger was **not** replaced today.
Data transfer successful?	Circle Y if the data transfer was successful today. Circle N if the data transfer was **not** successful today.
Data logger relaunched?	Circle Y if the datalogger successfully relaunched today. Circle N if the datalogger did **not** successfully relaunch today.
LED blinking upon departure?	Circle Y if the red LED in communications window (HOBO Pro v2) was blinking when finished. Circle N if the LED was not blinking when finished.
This datalogger is being replaced today	Place an “X” or “√” on this line if an existing datalogger is being replaced today. Record the serial number of the datalogger being installed today.
LED blinking upon departure?	Circle Y if the red LED in communications window (HOBO Pro v2) was blinking when finished. Circle N if the LED was not blinking when finished.
This datalogger is being removed, but NOT replaced today	Place an “X” or “√” on this line if an existing datalogger is being removed from the permanent datalogger location and not being replaced by another datalogger today (it may be replaced in the future).
Notes:	Record notes related to the datalogger installation and maintenance event. May include: damage to datalogger, shuttle problems, missing or moved datalogger, evidence of recent flooding near datalogger, proximity of datalogger to roosting cave crickets (including estimated distance and numbers).
Data recorder initials	Initials of individual filling-out the data form in the field. Occasionally, one (or more) persons will call out data, while another records.
Reviewed by	Initials of individual who reviewed completed data form for HOBO RH/Temp datalogger installation and maintenance elements. Ideally this should be someone other than individual who filled-out the data form.

Literature Cited

Woodman, R. L., J. W. Jernigan, B. C. Carson and B. J. Moore. 2011. A protocol on sampling designs and methodologies for selective and adaptive monitoring in caves of air temperature, relative humidity, and cross-sectional air velocity throughout the Cumberland Piedmont Network. Natural Resource Report NPS/CUPN/NRR—2012/491. National Park Service, Fort Collins, Colorado.

SOP #4: Post- Field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

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SOP 4 – Contents

Page

SOP 4 – Contents (continued)

Page

SOP 4 – Figures

Page

Overview

This SOP describes procedures to follow after completion of a sampling bout of cave cricket monitoring in Mammoth Cave National Park (MACA). This SOP gives step-by-step instructions that designated personnel should follow for: (1) processing field data sheets, (2) downloading, sorting and labeling of cluster image files, (3) performing image analysis to collect data on cave cricket clusters, (4) processing cave and surface meteorological data files, and (5) post-analysis image archiving.

Prior to performing cluster image analysis for a cave cricket sampling event all personnel involved in image analysis will review this SOP and Appendix D, the Guide to Cave Cricket Morphology. Image analysts should participate in at least one cave sampling event as part of their training to perform the tasks described herein. Personnel who may serve as image analysts include Cumberland Piedmont Network (CUPN) staff, student interns, and volunteers. Image analysis tasks will be performed under the supervision of the project leader, who is responsible for ensuring that all image analysis and data entry is performed in a timely manner after completion of a sampling bout.

General Sampling Approach

Monitoring of cave cricket entrance populations involves photography of roosting clusters of cave crickets intersecting randomly located transects called “strips”. Analysis of the digital images and the image data entry element, as described in this SOP, will be performed in the CUPN office after completion of all field sampling elements described in SOP #3a: “Field Methods: Strip Adaptive Cluster Sampling” and SOP#3b: “Cave Meteorological Sampling”. Resultant data from analyzed photographs will be used to determine estimates of cave cricket entrance populations, their structure, and correlations with cave and surface meteorology.

Logistics

The project leader is responsible for post-field sampling communication and coordination with MACA staff, as well as logistics. At the end of a sampling bout (i.e., group of sampling events—visits to sampled cave entrances) the sampling crew must return keys, vehicle hang tags, borrowed equipment, etc. to the MACA Science and Resources Management office. Brief follow-up trip reports are to be completed and submitted to MACA’s designated resources management contact within two weeks after each sampling bout.

Transit from Field to Office

- Upon exiting the cave contact the designated surface contact person via cell phone or radio.
- If necessary, use the GPS unit to navigate to the vehicle.
- Secure any road gates used to access cave entrances.
- Prior to entering the vehicle, follow the latest national guidance (available at www.whitenosesyndrome.org and stored on the CUPN server) regarding the proper storage of all gear used in the cave or that entered the cave entrance area to reduce the possibility of transmitting *Pseudogymnoascus destructans* fungal spores.

Arrival at Office

1. Sign in field crew at MACA’s Science and Resources Management office message board.
2. Remove gear and refuse from field vehicles.

3. Carefully clean and decontaminate gear following the latest national WNS decontamination guidance (see link above or obtain from the CUPN server). Field forms, notebooks, and maps filled out in pencil or permanent ink and printed on Rite-in-the-rain™ paper that were exposed to a cave will be disinfected following current national decontamination protocols.

4. Check for damage to equipment and caving gear, perform required repairs or replacement, and return equipment and gear to the appropriate office or person for proper storage.

5. For NPS staff or volunteers injured in a non-emergency incident during the field trip, Worker's Compensation paperwork must be completed within 48 hours of incident.

6. The field crew leader or crew member should discuss any issues that arose with the monitoring procedures with the project leader.

Processing Field Data Sheets

Upon returning from the field to CUPN headquarters at MACA the data chain of custody should be closely controlled so data are not lost during processing. Transferring field data sheets and images to archival CDs can all be accomplished at a later date (see "Archives" in SOP #6: Data Management). However, this process should be completed before the next sampling bout. These tasks are all performed by the project leader or designated project personnel.

After disinfected field data sheets or maps have thoroughly dried (SOP #5: Post-Field Sampling: Decontamination of Gear) they are returned to the project leader where they are retained in a physical file folder labeled with the unique cave entrance location ID, and the month and year of the sampling bout ("<Location_ID> <sampling bout>"). When the project leader confirms all field data sheets are present, manual entry of data recorded on the "Strips" and "Clusters" field data sheet is performed and the field data sheets are scanned and saved, typically these steps are performed by the field crew member or the data intern, to folders with unique cave entrance and sampling bout identifiers on the CUPN network server in the following folder structure: Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Data\Working_Data\Scanned_Field_Forms\<Location_ID>\<sampling bout>.

Example: Z:\Vital_Signs\...\Working_Data\Scanned_Field_Forms\FrNiEn_001a\May2014

There are two different field data forms onto which data are recorded during cave cricket monitoring sampling events: field data sheets, and HOBO RH/Temp Datalogger – Site Setup and Maintenance Field Observer Form. Baseline Maps may be marked on during field sampling and should be scanned as needed. Follow the instructions below for the file naming convention of the two data forms being scanned:

Cave Cricket Monitoring Field Data Sheet

Files of scanned field data sheets will be saved utilizing a naming convention similar to that of image files <Event_ID>_DB_Entry.pdf. "<Event_ID>" is an identifier which defines the place of a sampling event at a cave entrance in the sequence of all cave entrances sampled during a specific sampling bout. "DB_Entry" indicates this version of the field data sheet will be entered in the database.

Example: "CC1011_ DB_Entry.pdf"

HOBO RH/Temp Datalogger – Site Setup and Maintenance Field Observer Form
Files of scanned HOBO data forms will be saved utilizing a naming convention similar to that of image files <Event_ID>_<HOBO location name>.pdf where the HOBO location name is the unique name assigned to the permanent location where the datalogger was initially installed.

Example: "CC1011_H1.pdf"

Scanning Field Data Forms and Maps Directly to Gmail Account
All CUPN staff are assigned email buttons under the "Address" tab on CUPN's Konica-Minolta Printer. Here are the steps that must be taken to scan an item and send it directly to both the CUPN data intern's and the project leader's gmail addresses. These steps must be followed whether using the scanning feeder or the scanning bed.

- Place the field data form on the scanning bed or in the feeder.
- Press the "Scan" button.
- Select the email buttons of the project leader and the data intern gmail accounts (more than one may be selected at once) under the "Address" tab.
- Select "Full Color" under the "Color" setting; no other color options will work.
- Under "Scan Settings" select "Compact pdf".
- The "Resolution" setting is automatically set at 300 dpi and cannot be changed.
- Press "File Name" and use the keypad to rename the file according to this protcol's naming convention (see above):
- Example: "CC1011_ DB_Entry.pdf"
- Press the "Start" button to scan and send the pdf to the desired gmail address.
- The pdf(s) are received as an attachment to an email from "CUPN_Konnica" (it's spelled that way in the email).
- Download the file and save it in the appropriate folder on the network server.
- **Note**: File size should be less than 250 KB. Also, it is important to review the scans to make sure all pages scanned correctly and are legible.
- Files to be saved/copied in a park specific folder on the CUPN network file server at
- Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Data\Working_Data\Scanned_Field_Forms\< Location_ID>\ <sampling bout>.
- The original hard copy field data sheets should be returned to the project leader for storage and eventual archiving.

Processing Digital Images

A single sampling bout will yield many digital images of cave cricket clusters. Each image is stored as a "jpg" image file (ca. 1.0 MB) in the camera's memory card. At the conclusion of the day's sampling events the images are stored, for later sorting and labeling, in a dedicated temporary folder on the CUPN server. After the completion of the sampling bout the project leader (or designated personnel) sorts through the cave cricket cluster images, discarding unsuitable images (e.g., indistinguishable images, images of nothing, etc.), and renames them. The designated image analyst reviews the remaining images, chooses one suitable image within each sequence for analysis, enhances the image (if necessary), analyzes the images from each cave using ArcMap, and stores them in the dedicated network folder for modified images labeled to represent the cave entrance, month and year of the sampling bout (Figure SOP4-1). These folders and the images contained therein are later copied onto archival CDs. Downloading, sorting, labeling, and storing of images onto archival CDs is performed by a designated project team member. The data from the modified images are later imported into the cave cricket monitoring database as described in SOP #6: Data Management.

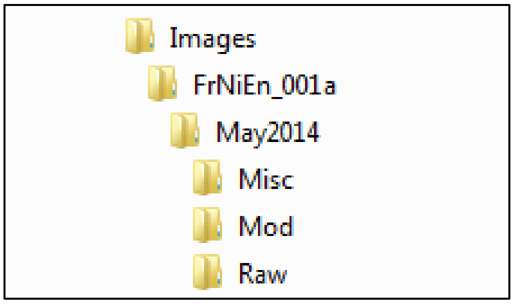

Figure SOP4-1. Image storage folders for images of cave cricket clusters from individual monitoring cave entrances. Note the sampling bout (i.e., May2014) has three folders: one "Raw" folder into which all unprocessed cave cricket images are uploaded from the camera's memory card, a "Mod" folder in which renamed and modified images ready for analysis are stored, and a "Misc" folder in which images of other cave organisms, formations, personnel, etc. are stored.

Prior to Downloading Images from the Memory Card

1. Sorting and renaming of cave cricket cluster images can be performed using Windows Photo Viewer, but not image enhancement.

2. ArcMap can perform any basic functions of image enhancement needed (e.g., alter contrast, brightness, image inversion).

3. The designated computer should have an available secure digital (SD) card slot or a USB port and adapter with an SD card slot. Uploading of image files from the memory card is performed by inserting the memory card into the computer's SD card slot.

4. The computer on which image analysis will be performed must be connected to the MACA local area network (LAN) to provide for image transfer to the CUPN server via the LAN.

Upload the image files from the camera to the appropriate image folder on the CUPN drive.

Image transfer can take a substantial amount of time and it is best performed as soon as the project leader arrives at the office. The SD card from the digital camera is removed and plugged into the SD card slot on the project leader's computer. The "Computer" window is opened and the "SD Disk" icon double clicked to access the cave cricket cluster images. In a separate window, the "Raw" folder with the appropriate cave entrance name into which the images will be dragged and dropped (Figure SOP4-1) is accessed via the following folder structure: Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Images\<Location_ID>\<sampling bout>\Raw.

A window with the title "Copying…" opens automatically; indicating the image files are being transferred from the SD card to the folder. A bar graph and time remaining clock indicates the progress of the image transfer. Once all the images are transferred the "Copying…" window will automatically close. When the process is finished the number of images in the cave entrance folder window is compared to that of the "SD Disk" folder to ensure the integrity of the transfer. In addition, several of the transferred photos in the cave entrance folder window are randomly examined to ensure the images were not corrupted during transfer. The images are stored as ".jpg" files with annotation for date, time, and exposure parameters automatically provided by the camera. Once all raw images have been transferred the images on the SD card are to be deleted. **Even if the memory card has a large amount of space it is best to delete the images each day to avoid later confusion and/or having to pause during field work to delete old images in order to free space on the memory card.**

Performing Image Analysis

Image analysis can be effectively performed by any trained project and program personnel. Image analysis is an easily learned skill that should be developed by practicing using sample images under the guidance of the project leader. Primary skills needed include: recognition of the cricket genera (i.e., *Hadenoecus* and *Ceuthophilus*) recognition of secondary sexual characteristics of adults, and recognition of individual *Hadenoecus* life stages. Reference standards and materials, such as photographs showing sexual anatomy and features that help distinguish among life stages, are provided in Appendix D "Guide to Cave Cricket Morphology"of this protocol.

The computer being used for image analysis must have an image editor application (e.g., Picasa) that permits the adjustment of contrast and brightness of an image to help distinguish among cave cricket life stages. The computer must also have ArcMap so that all cave cricket demographic data may be automatically obtained. ArcMap 10.1 was used to create the shapefile images and layers at the time this section of the SOP was written.

In general, all tasks involved in both image analysis and the associated entry of image data into the data forms may be performed by a single individual. If experienced personnel are available image analysis can begin as soon as image files from a monitored cave are available and need not wait until the sampling bout is finished. It is expected that image analysis and the associated data entry will take one work-week per sampling bout. The following steps provide a chronological sequence of the major components of the image analysis process: examine and label images, open images in ArcMap, analyze images for cave cricket cluster and strip data, and save marked images for archiving. Manual entry of ancillary/metadata into the cave cricket database is covered in SOP #6: Data Analysis.

Step By Step Instructions

1. **Cluster image sequences are viewed in "Filmstrip" mode in Windows Photo Viewer.** Viewing the sequence this way makes it easier to compare among cluster images.

2. **The image icons are displayed in sequential order automatically numbered by the camera.** The image of the dry erase board containing the metadata on that specific cluster indicates the start of the sequence and is deleted after images are renamed. All adequate

cluster images are renamed for eventual archiving and inadequate images (e.g., too blurry for analysis, no discernible clusters, etc.) are deleted.

3. **All remaining cluster image(s) are labeled with the appropriate file name using the format <Event ID>_<cluster number> (Example: "CC1001_1.JPG").** Changing the image's file name is performed using the "slow double-click" on the file's name or selecting the file name and pressing F2. The file name "CC1001_1. JPG" is a concatenation of the unique "Event ID" found at the top of the pre-populated field data sheet's first page and the cave cricket cluster number. The file name is used to uniquely identify each image with the sampling bout, the cave entrance in which it was taken, and its order in the sequence of cluster images taken there. In the example above, the file name indicates the image was taken at Frozen Niagara Cave Entrance during the May sampling bout of 2014 and is an image of the first cave cricket cluster. Multiple images of a particular cluster are labeled sequentially, such as "CC1001_1a. JPG", "CC1001_1b. JPG", "CC1001_1c. JPG", etc.

    a. Occasionally a large cluster intersects more than one strip along the baseline (see step 19). These clusters will have at least two image sequences associated with them (see "Step By Step Instructions" in SOP #3a: Field Methods: Strip Adaptive Cluster Sampling). The second sequence of image(s) captures crickets found inside the subsequent strip's laser lines and is sorted as in step 2 above. Multiple images of crickets found inside the subsequent strip's laser lines are labeled accordingly (e.g., "CC1001_1_Intersect. JPG") and, as necessary, sequentially as in step 3 above (e.g., "CC1001_1_Instersecta", "CC1001_1_Intersectb.JPG", "CC1001_1_Intersectc. JPG", etc.).

    b. After all cluster images from a sampling event are renamed they are examined to determine which ones should be used for analysis.

4. **There will be at least one image, more likely several, for a given cluster but only one image is analyzed.** The analyst selects the image that provides the best data (i.e., a clear view of all individuals in a cluster). Clusters intersecting more than one strip will have at least two images associated with the cluster's image file: the image of the original cluster and an image of the crickets found inside each of the subsequent strips' laser lines (see step 19).

5. **The analyst saves the image determined to be best for analysis to the "Mod" folder (Figure SOP4-1) at:**
   Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Images\<Location_ID>\<sampling bout>\Mod.

   This will be the image subsequently analyzed and stamped in ArcMap. Steps 1-5 are repeated until all images from a cave's sampling event are renamed and the best image, or images in the rare case when a large cluster intersects more than one strip, for each cluster captured during that cave entrance's sampling event are transferred to the "Mod" folder.

6. **Images of other cave organisms, formations, personnel, etc. are renamed with appropriate location, date, and content information (e.g., FroNia_May2014_Stalactite) and stored in a separate "Misc" folder for that sampling event**. The project leader reviews these photos to ascertain their value and processes appropriately. These images are

stored at: Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\ Images\<Location_ID>\<sampling bout>\Misc.

7. **The analyst opens ArcMap, selects "File", "New", and "Blank Map", clicks on the "Add Data" button and the "Connect to Folder" button.** The analyst connects to the "…\<Location_ID>\<sampling bout>\Mod" folder (see Step 5): this is the folder from which modified image files are selected, processed into shapefiles, and the folder in which they are subsequently saved.

8. **The first image from the cave sampling event being analyzed is selected (Figure SOP4-2).**

    a. The analyst clicks on the "Add Data" button, clicks on the appropriate cave sampling bout "Mod" folder containing the jpeg files, selects the desired cluster image from among the others to be analyzed, and clicks the "Add" button <u>once</u>.

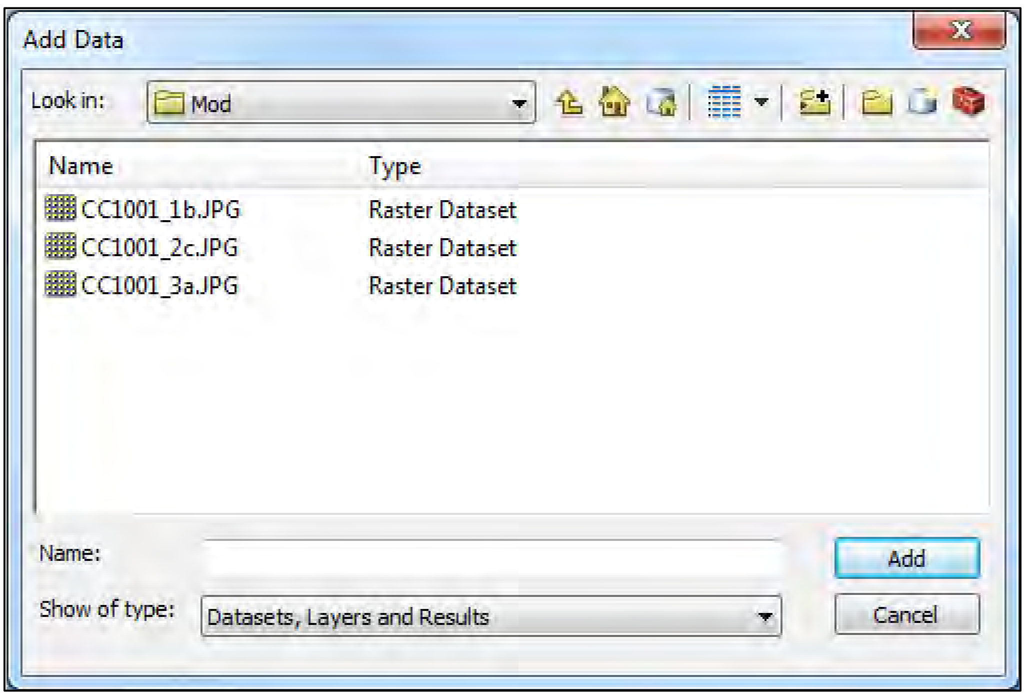

Figure SOP4-2. Connecting to the "Mod" folder from which jpeg files (i.e., Raster Dataset) will be selected for processing in ArcMap. The "Mod" folder is also where the ".mxd" project files containing the processed jpegs, and the subsequent shapefiles and layers associated with them, will be saved.

    b. A window opens requesting to create pyramids for the image file and the analyst clicks "Yes" (Figure SOP4-3). The cluster's jpeg file is now visible, displayed in ArcMap's Table of Contents (TOC) pane on the left.

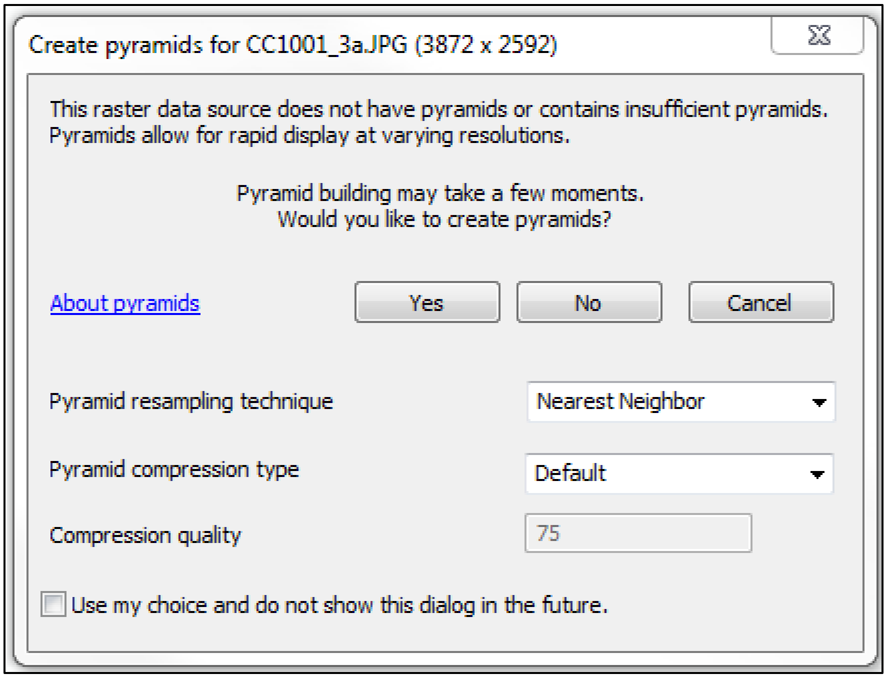

Figure SOP4-3. Pop up window displayed by ArcMap once the image to be analyzed is selected.

c. The ArcMap or ".mxd" project file is given the appropriate file name, based on the image's file name "Event_ID_Cluster Number" (e.g., "CC1001_1"), and is saved in the appropriate cave sampling bout "Mod" folder (Figure SOP4-1 and SOP4-2). This ".mxd" project file is where all data associated with individual images of cave cricket clusters recorded at a cave entrance's sampling event, along with the shapefiles and template layers subsequently created from them, will be stored.

d. The analyst clicks "OK" if a window appears referring to an "Unknown Spatial Reference" (Figure SOP4-4).

9. The analyst clicks on the "Add Data" button and adds the pre-made "cricket_symbology_template.lyr" file to the ".mxd" project file.

a. The file is located in the "cricket_symbology_template" folder at: Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Images.

b. Once the layer is added to the ".mxd" project file it will appear in the TOC and the appropriate symbology will appear in the data view.

c. Note the symbology does not line up with the image file being analyzed.

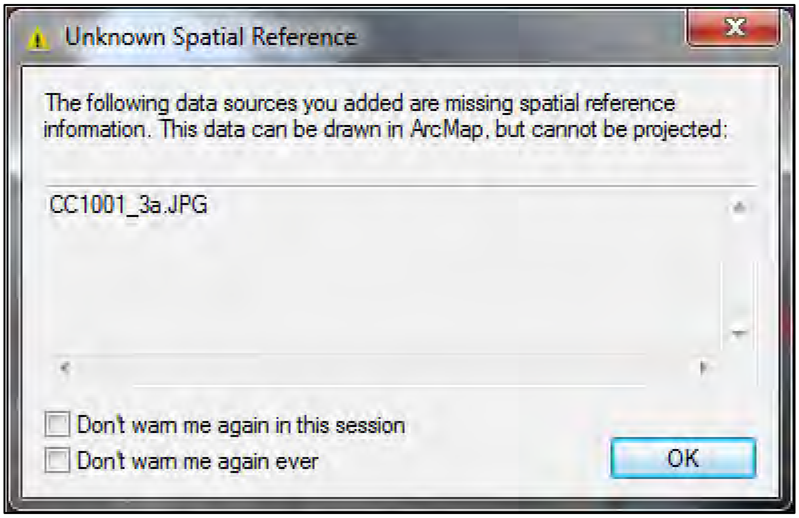

Figure SOP4-4. Click "OK" if a popup referring to "Unknown Spatial Reference" appears.

10. A new shapefile must be created by right clicking on the newly added "cricket_symbology_template.lyr", going to "Data", and "Export Data".

a. The analyst clicks the folder icon on the right of the "Export Data" pop-up window, navigate to the appropriate "Mod" folder for the cave sampling bout where the shapefile needs to be saved, names the shapefile to match the name of the cluster image being analyzed (see step 8), clicks "Save", and clicks "OK".

b. The analyst clicks "Yes" when a pop-up window appears asking the question "Do you want to add the exported data to the map as a layer?".

c. Once added, the newly added layer appears at the top of the TOC above the layer template.

11. The analyst imports the template's symbology to the layer just created.

a. The analyst right clicks on the newly added layer, goes down to "Properties", and left clicks.

b. The "Layer Properties" dialog box appears. The analyst clicks on the "Symbology" tab, clicks on the "Import" button at the top right of the "Symbology" tab, and clicks "Import".

c. The "Import Symbology" pop-up window appears. The "Import symbology definition from another layer in the map or from a layer file" button and the "Complete symbology definition" button are both highlighted. The "Layer" pull down menu shows "cricket_symbology_template". The analyst clicks "OK".

d. When the "Import Symbology Matching Dialogue" box appears the analyst selects "Sex" in the first "Value Field" and clicks "OK".

e. The analyst observes the "Layer Properties" now resemble the "cricket_symbology_template" from which they were created (but still does not line up with the image file being analyzed) and clicks "OK". If the image sequence is of a cluster that spans >1 strip the original "cricket_symbology_template" is retained in the TOC to create a layer for the next image of the crickets found inside the subsequent strip's laser lines, as necessary (see step 17).

12. The analyst begins editing the newly created layer.

a. The analyst clicks on the "Start Editing" tab, selects the name of the current layer being edited in the "Start Editing" pop-up window, and clicks "OK". The analyst right clicks on the layer and selects "Open Attribute Table".

b. The analyst selects the contents of the table, which are not correct at the moment, with "Ctrl + A". Alternatively, the analyst accomplishes this by highlighting the left-most cell in the table's top row, holding the "Shift" key, and clicking the bottom right cell on the table. The data are deleted by clicking the "X" symbol on the toolbar (Figure SOP4-5).

c. To avoid confusion the analyst ensures the "cricket_symbology_template" layer is unchecked in the TOC (Figure SOP4-5).

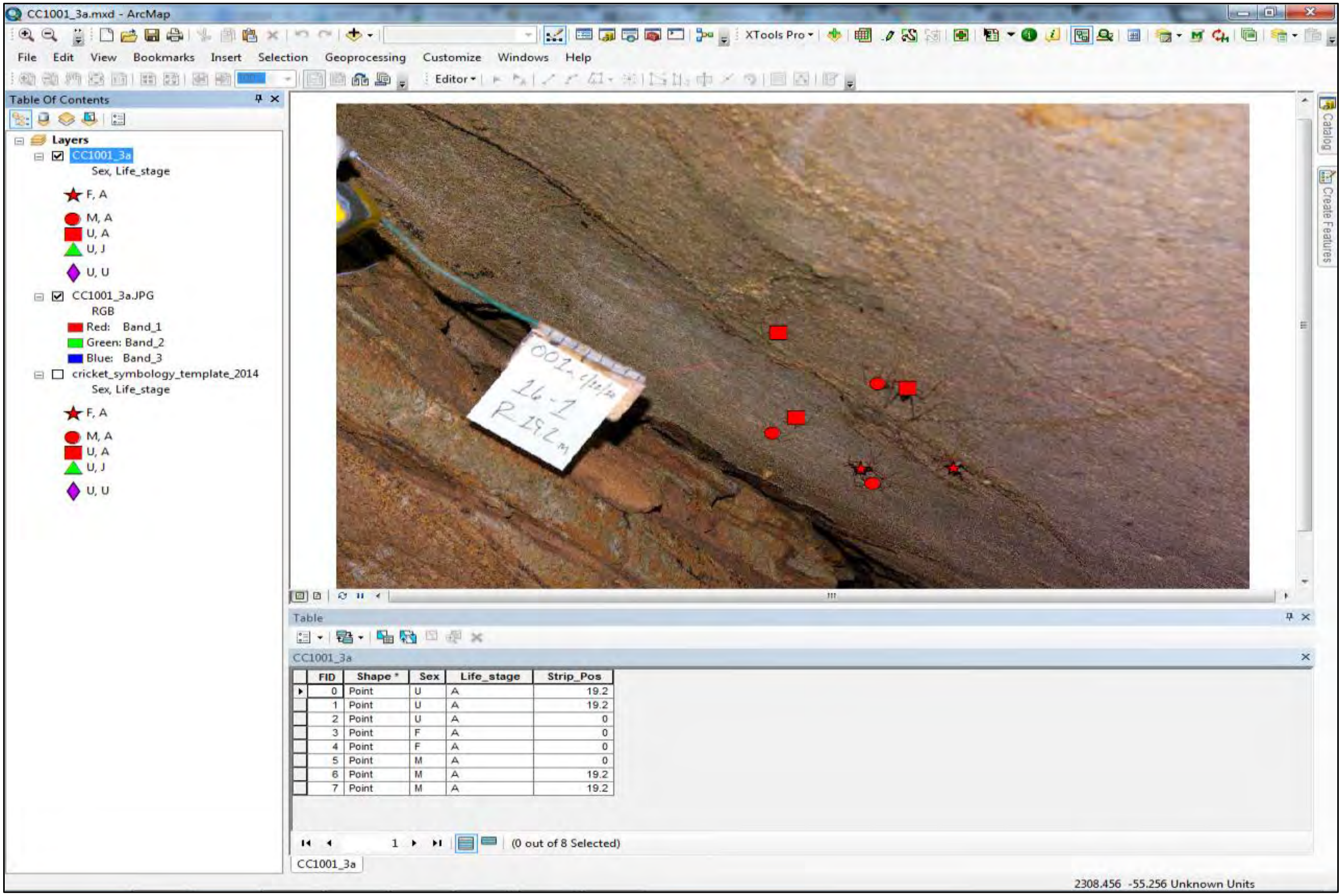

Figure SOP4-5. Image analysis on a newly created layer. Note: the "Sex" and "Life Stage" columns are automatically populated in the attribute table at the bottom when crickets are stamped; "Strip_Pos" is added manually and only crickets inside the strip's laser lines have the "Strip_Pos" field populated.

13. **The analyst begins adding data to the attribute table by clicking on the "Create Features" tab in the "Editor" toolbar on the right hand margin of the screen (Figure SOP4-5).**

    a. A pop-up window appears with the symbology template for cave cricket life stage and sex.

    b. To add the window to the right hand margin of the screen the analyst clicks on the pushpin icon in the window's top right-hand toolbar.

    c. Once the image is open the analyst uses the toolbar "zoom" and "invert" features to look at cave crickets as needed. The "invert" feature, accessed by clicking "Invert" in the "Symbology" tab in the image's "Properties", temporarily changes the color of the image, which may help reveal smaller and less "contrasting" individuals or sexual characteristics, such as the presence of an ovipositor (Figure SOP4-6). If necessary, the analyst alters the image using any automatic enhance features. This is often useful for better image analysis. The analyst adjusts contrast and brightness of the image as necessary. To achieve efficiency, the image analyst systematically "stamps" all individuals in one life stage and sex combination with their symbology combination. For example, the analyst, intending to start with adult female cave crickets, clicks on the red star in the "Create Features" pop-up window, examines vertical or horizontal "slices" of the image for adult female cave crickets, and clicks each to "stamp" them with a red star. If necessary, the mouse wheel is used to zoom in and out to examine individuals for secondary sexual characteristics. The image is analyzed for the next life stage and sex combination by mousing over the "Create Features" pop-up window with the symbology template and clicking on the appropriate symbol (e.g., red circle for adult males).

Figure SOP4-6. The 'Invert' feature in photoprocessing software is useful for confirming sex when a cave cricket's secondary sexual characteristics are in doubt (left). Note the ovipositor on this female is clearly visible when the image is inverted (right).

    d. The analyst clicks the symbol in the "Create Features" pop-up window to select the appropriate life stage and sex combination for which the image will be stamped; this is done systematically from left to right. The symbology adopted for this protocol uses <u>red for adults</u> and <u>green for juveniles</u>. Sexes are distinguished by the following shapes: stars for female cave crickets, circles for males, and squares for cave crickets of indeterminate sex (Figures SOP4-5). Distinguishing among sexes and life stage (and between genera) is a learned skill and is taught by experienced analysts and referencing the "Guide to Cave Cricket Morphology" in Appendix E.

14. **After all crickets in the image are stamped the analyst reviews the entire image once more to ensure all individuals were found and stamped.** It is possible the analyst missed some individuals, particularly small juveniles; missed individuals are stamped with the correct symbology, as necessary.

15. **The analyst fills the empty fields in the "Strip_Pos" column only for crickets <u>inside the strip's laser lines</u> by typing in the strip's position (meters) from the "Pos." column on the "Strips" field data sheet associated with the appropriate cluster number (Figure SOP4-5).**

16. **When finished, the analyst saves the edits by clicking "Stop Editing". A window appears asking if the analyst wants to save edits and, if satisfied, the analyst clicks "Yes".**

17. **The analyst determines the total number of stamped cave crickets in the shapefile image.**

    a. The analyst accesses the "Layer Properties" by right clicking on the data layer in the TOC and selecting "Properties" at the bottom of the window (Figure SOP4-7). The "Symbology" tab needs to be selected to access the appropriate field.

    b. The analyst clicks the "Count" column header to access a total of all sexes and life stages in the shapefile image. The total number of cave crickets stamped on the shapefile image appears at the end of each "Symbol" row for sex and life stage (Figure SOP4-7). Each individual layer's symbols, such as adult female cave crickets, are tallied. The total "Count" is cross-checked with the filled-in "Total Crickets" cell on the "Clusters" field data sheet associated with the appropriate cluster number. If they are different the count from the analyzed image takes precedence. **Note:** These data illustrate the excellent quality control inherent in this process versus the potential for human error in a manual count of cave crickets *in situ*.

    c. The analyst clicks the "Save" icon on the top menu bar after analyzing each shapefile image in the ".mxd" project file.

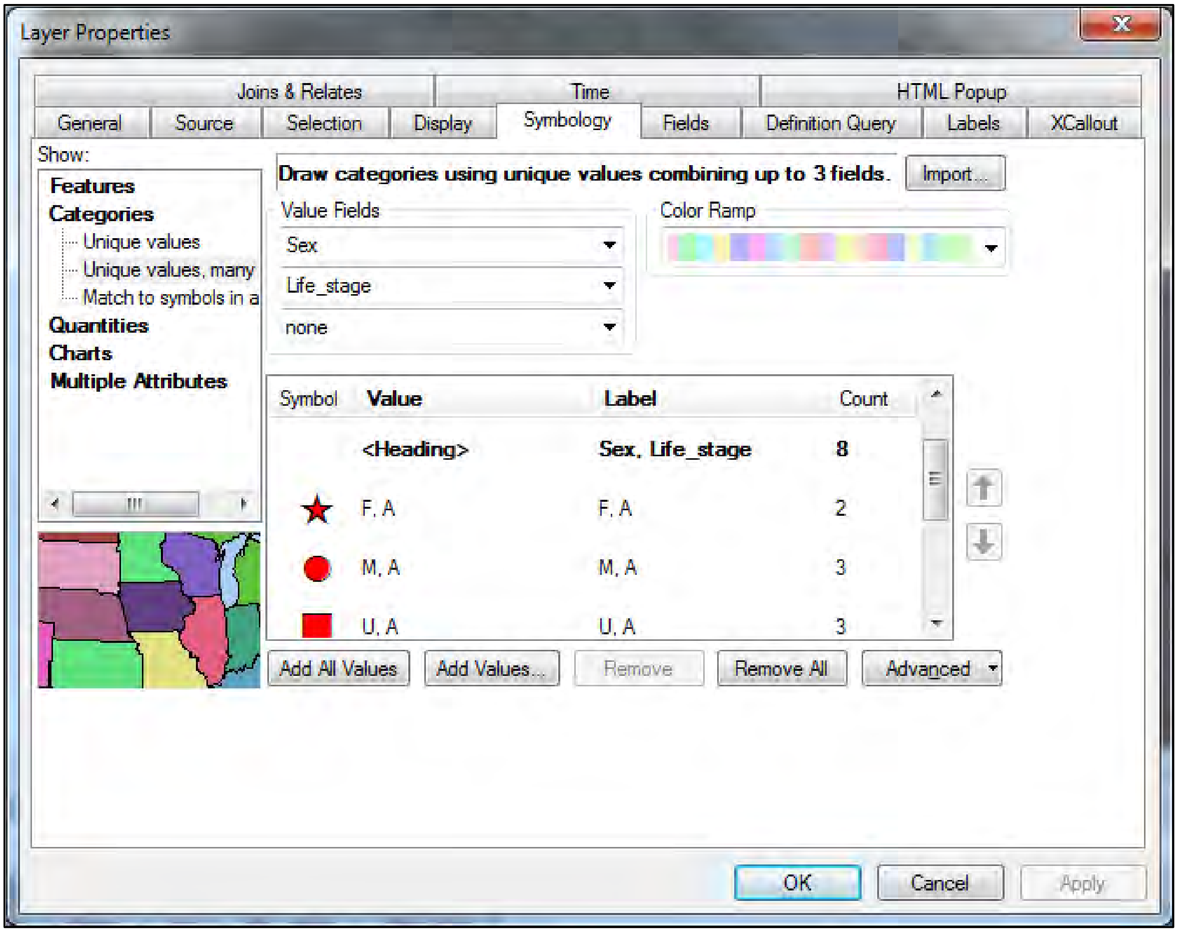

Figure SOP4-7. Layer Properties window with totals and symbology for each category of cave cricket stamped on the shapefile image.

18. **The analyst creates an image file to save the analyzed shapefile image in an archiveable form requiring less storage space.**

    a. The analyst clicks on the "Layout View" tab on the bottom left hand side of the screen, turns on the "Layout View" toolbar by right clicking anywhere in the top toolbar, selects "Layout" in the drop-down list, and the "Layout View" toolbar appears on the top or bottom of the screen. The "Layer" toolbar is dragged to a preferred location using the mouse.

    b. The analyst changes the orientation of the image, as necessary, by clicking the "Change Layout" button in the "Layout View" toolbar, clicking the "North American (ANSI) Page Sizes" tab, and choosing either "Letter (ANSI A) Landscape.mxd" or "Letter (ANSI A) Portrait.mxd".

    c. To automatically populate the legend for the image file the analyst clicks on the "Insert" drop-down menu, and clicks "Legend".

        i. When the "Legend" wizard pop-up window appears *N* number of items (i.e., the number of items the analyst has open) will populate the "Legend Items" box. The analyst highlights (e.g., Ctrl click) all items in the "Legend Items" box on the right with which they are currently <u>not</u> working and moves them to the "Map Layers" box on the left by clicking the single, left-pointing arrow, and then clicks "Next". **Note:** If the analyst keeps the current image with which they are working at the top of the TOC it will appear at the top of the list in the "Legend Items" box. Then the analyst selects all items below it and moves them to the "Map Layers" box.

ii. The analyst deletes the word "Legend" from the "Legend Title" box, ensures the font size is of a visible size (i.e., at least 26 points) and clicks "Next".

iii. The following settings are chosen for the "Legend Frame":

1. "Border" = 2.0

2. "Background" = White

3. Ignore "Drop Shadow"

4. "Gap" = 10

5. Ignore "Rounding"

The analyst clicks "Next", continues clicking through the remaining boxes, reaches the "Finish" button, and clicks "Finish". The legend appears in front of the image file (Figure SOP4-8).

iv. The analyst adds the automatically tallied life stage and sex combinations (from Step 18) to the legend:

1. The analyst double clicks inside the legend to bring up the "Legend Properties" pop-up box (Figure SOP4-8).

2. The analyst clicks on the "Items" tab, checks the "Show feature count" under "Map Extent Options", checks "Place item(s) in a new column" under "Item columns" (Figure SOP4-8), and clicks "OK". The analyst clicks "Only include classes that are visible in the current map extent" to exclude unrepresented categories.

3. The analyst inserts a text box into the shapefile image by clicking the "Insert" pull down menu and clicks "Text". The text box is populated with their first initial and last name, and the date on which the image was analyzed [(i.e., First Initial Last name_MMDDYYYY) (Figure SOP4-9)]. Text is entered by double clicking the text box, the "Text" tab, and typing into the "Text" window; text may be edited (e.g., text size and color) by clicking the "Change Symbol" button. This step identifies the analyst and date associated with the analysis of the cluster's image.

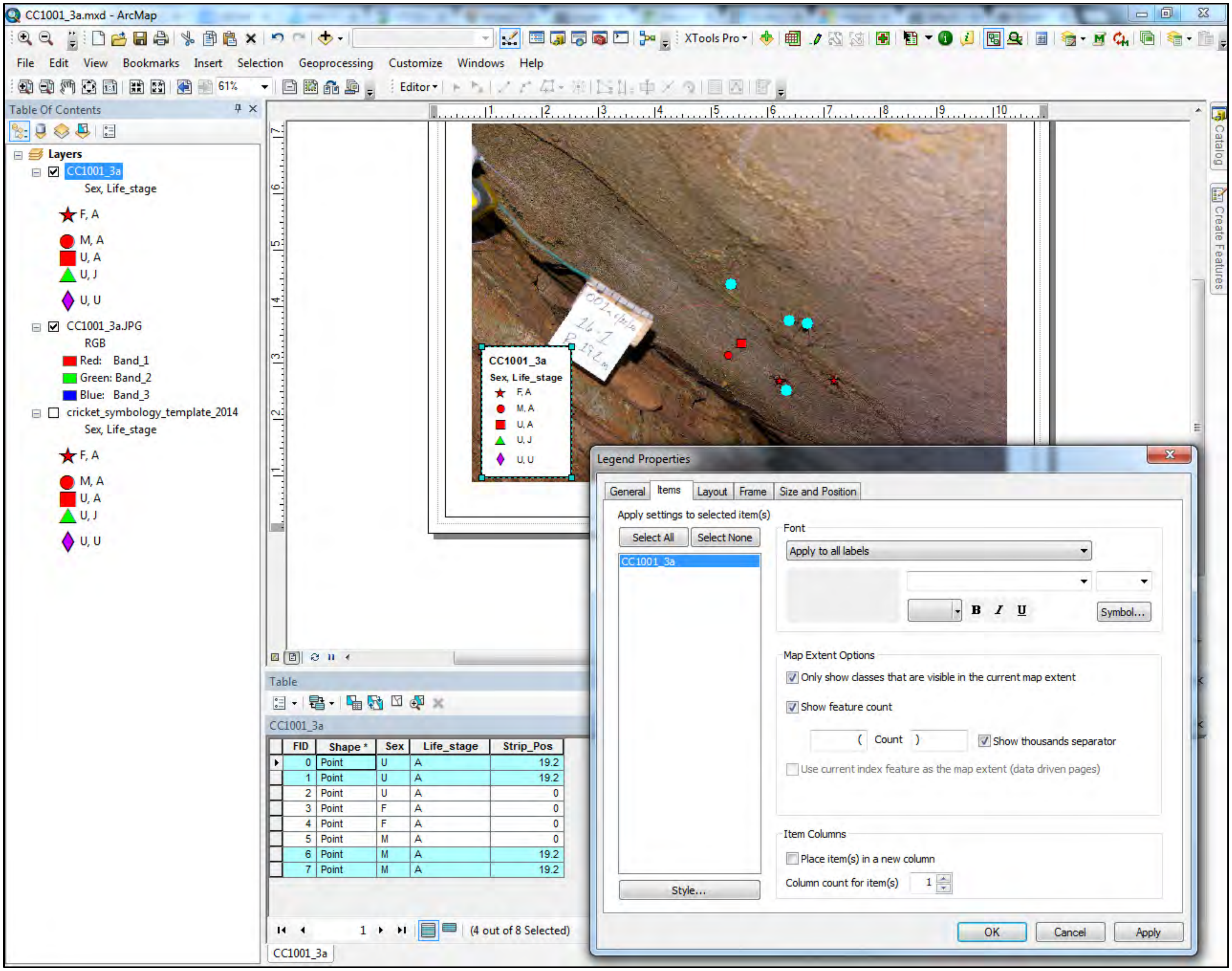

Figure SOP4-8. Creating a legend for the image file with an automatic tally of all cave cricket life stage and sex combinations.

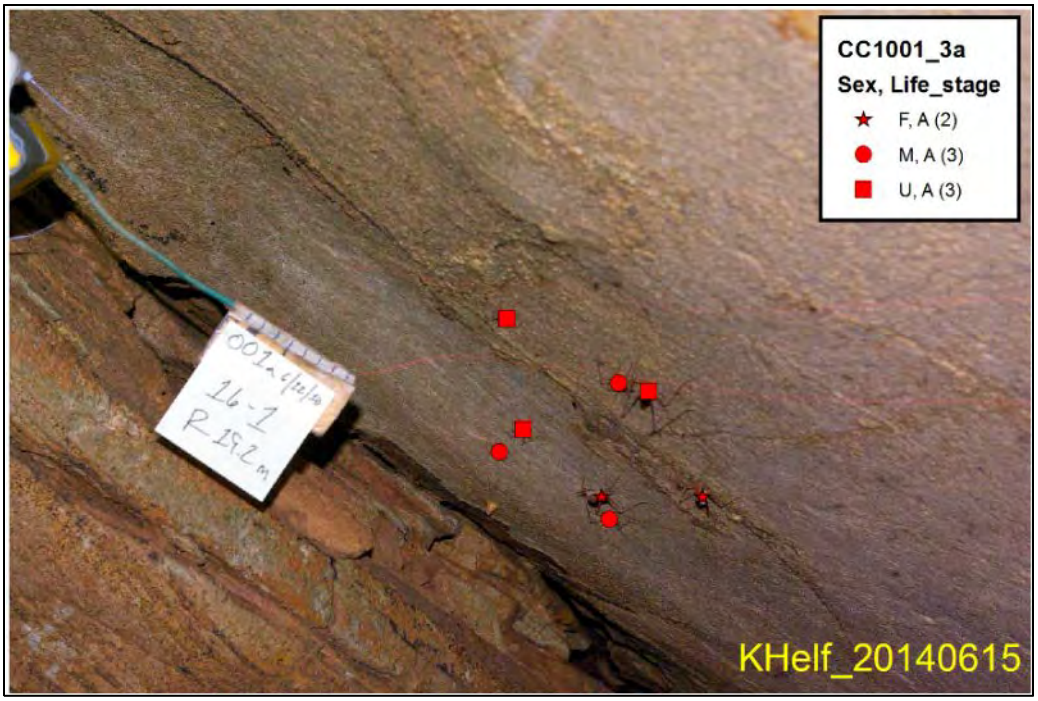

Figure SOP4-9. Example of a shapefile image file with an automatically populated legend that is saved in an archiveable format (e.g., ".pdf") requiring less storage space.

4. To export the image file to ".pdf", a more compact file format, the analyst clicks "File", clicks "Export Map", clicks the "Save as type" pull down menu and selects "PDF". Next, the analyst assigns the same name to this ".pdf" file as the cluster shapefile from which it was created (e.g., "CC1001_3a"), sets the resolution to 200dpi, and saves the file in the appropriate "Mod" folder.

19. **On rare occasions a large cluster intersects more than one strip along the baseline.** This cluster will have at least two image sequences associated with it: the first sequence captures all cave crickets in the original cluster and the next sequence captures the crickets from the original cluster only found inside the subsequent strip's laser lines (see "Step By Step Instructions" in SOP #3a: Field Methods: Strip Adaptive Cluster Sampling). Thus, these project files will contain two analyzed images rather than one:

    a. The image of the original cluster as analyzed via steps 8-18.

    b. The specially labeled image of the crickets inside the subsequent strip's laser lines (see step 3a) is added to the original cluster's project file by repeating steps 8-18.

20. **The analyst repeats steps 7-18 until all images from the cave entrance's sampling event are analyzed and saves their work after processing each image.**

21. **The project leaders runs the "PhotoHarvest.R" R code which extracts data from the shapefiles, sums crickets by cluster and strip, tabulates strip by cluster intersections, and checks for discrepancies among the data. Additional consistency checks are performed and data are validated by the project leader. The data manager appends**

these validated records to data tables in the database (see SOP #6: Data Management and SOP #7: Data Analysis).

Processing Cave Meteorological Data Files

Cave temperature and relative humidity data files downloaded from automated HOBO dataloggers are processed in the following way. The physical scientist, project leader, or designated field crew member or data intern downloads all automated data files from the data shuttles and renames the files using the standard naming convention. The data files will be checked for completeness. Instructions for downloading data to the data shuttles (storage modules) for use with HOBO dataloggers used in this protocol are provided in Appendix F. Copies of these manuals will be maintained on the network's server and in the project files.

Upload HOBO data files in MACA's "raw HOBO files" directory folder on the network's server located at one of three paths:

1. If the meteorological data are from HOBOs located in the Historic entrance of Mammoth Cave use the following path:
   Z:\Vital_Signs\Vital_Signs_Prj\Cave_Air_Quality\Data\Working_Data\Historic Mammoth Cave and Frozen Niagara\Raw_HOBO_Files

2. If the meteorological data are from HOBOs located in Frozen Niagara Entrance use the following path:
   Z:\Vital_Signs\Vital_Signs_Prj\Cave_Air_Quality\Data\Working_Data\Historic Mammoth Cave and Frozen Niagara\Frozen Niagara\Raw_HOBO_Files

3. If the meteorological data are from HOBOs located in one of the lesser caves use the following path:
   Z:\Vital_Signs\Vital_Signs_Prj\Cave_Air_Quality\Data\Working_Data\HOBO Lesser Caves\MACA\Raw_HOBO_Files

Field crews will have maintained a record associated with each handling of a HOBO datalogger at a cave on the field data form including the datalogger serial number, the date and time the datalogger was either installed or serviced or replaced, the unique datalogger location name, whether the data transfer in the field was successful, etc. Therefore, **do not continue with processing of HOBO data files, beyond copying them to the network server as described above, unless you have the HOBO RH/Temp Datalogger field data form(s) at hand.**

All HOBO data files in Z:\....|Raw_HOBO_Files should be copied and, depending on the three paths above, pasted up to its cave level in the "working data" directory before renaming. For example, HOBO data files from Frozen Niagara Entrance in the Raw_HOBO_Files folder should be **copied** and pasted into:

Z:\Vital_Signs\Vital_Signs_Prj\Cave_Air_Quality\Data\Working_Data\Historic Mammoth Cave and Frozen Niagara\Frozen Niagara

Data files should be renamed as "<Location_ID>_<HOBO location name>_<serial number>_<date>.dat" where the HOBO location name is the unique name assigned to the permanent location where a datalogger was initially installed, the serial number is the number printed on the side of the datalogger, and the date is the date recorded on the field data form when the datalogger was downloaded inside- or removed from- the cave in YYYYMMDD format. These unique names will distinguish them from other meteorological data files from other protocols (e.g., cave bat monitoring).

Example: “FrNiEn_001a_H1_675503_20140527.dat”.

Processing Surface Meteorological Data Files

Surface temperature, relative humidity, and precipitation data files downloaded from MACA’s SCAN station are processed in the following way. The physical scientist, project leader or designated field crew member downloads separate temperature, RH, and precipitation data files from MACA’s SCAN station website (Figure SOP4-10), renames the files using the standard naming convention, checks the files for completeness, and merges them into one file.

Step by Step Instructions

1. Surface meteorological data are accessed at the SCAN station website (accessed 29 January 2014). These data are to be accessed no earlier than December of the sampling year.

2. The first column, “Select Report Content”, is where the surface meteorological parameters to be downloaded are selected; these are accessed by scrolling down past the “Individual elements” divider and clicking on either “Air Temperature (2003-08-28)”, “Precipitation Increment (2003-08-28)”, or “Relative Humidity (2003-08-28)” (Figure SOP4-10).

3. The second column, “Select Time Series”, is where the desired time interval is selected; in this case it is “Hourly”.

4. The third column, “Select Format”, gives three choices of data format which, in this case, is “csv”.

5. The fourth column “View Current” can be ignored.

6. The fifth column, “View Historic”, is where the desired year, month, and days corresponding to the 36 hour period prior to the date of the sampling events associated with specific sampled cave entrance pairs are selected. Thus, the number of time periods downloaded for each parameter in a given sampling bout depends on the number of days taken to complete the sampling bout. Once the time period is selected the data are downloaded by clicking the “View Historic” button.

7. A pop up window will appear and the data are copied to the folder associated with the month of the sampling bout: Z:\Vital_Signs\Vital_Signs_Prj\Cave_Crickets\Data\Working _Data\Surface_Met_Data\<Location_ID>\<sampling bout>.

8. After each surface meteorological parameter is (i.e., temperature, RH, and precipitation) downloaded as a separate “.csv” file they are merged into one file. Because all three parameter values are summarized on an hourly basis merging the disparate parameter measurements into one file is simply a matter of cutting and pasting the individual columns to match the other rows and columns’ time and date stamp. Parameters are merged so that their order is always temperature, RH, and precipitation.

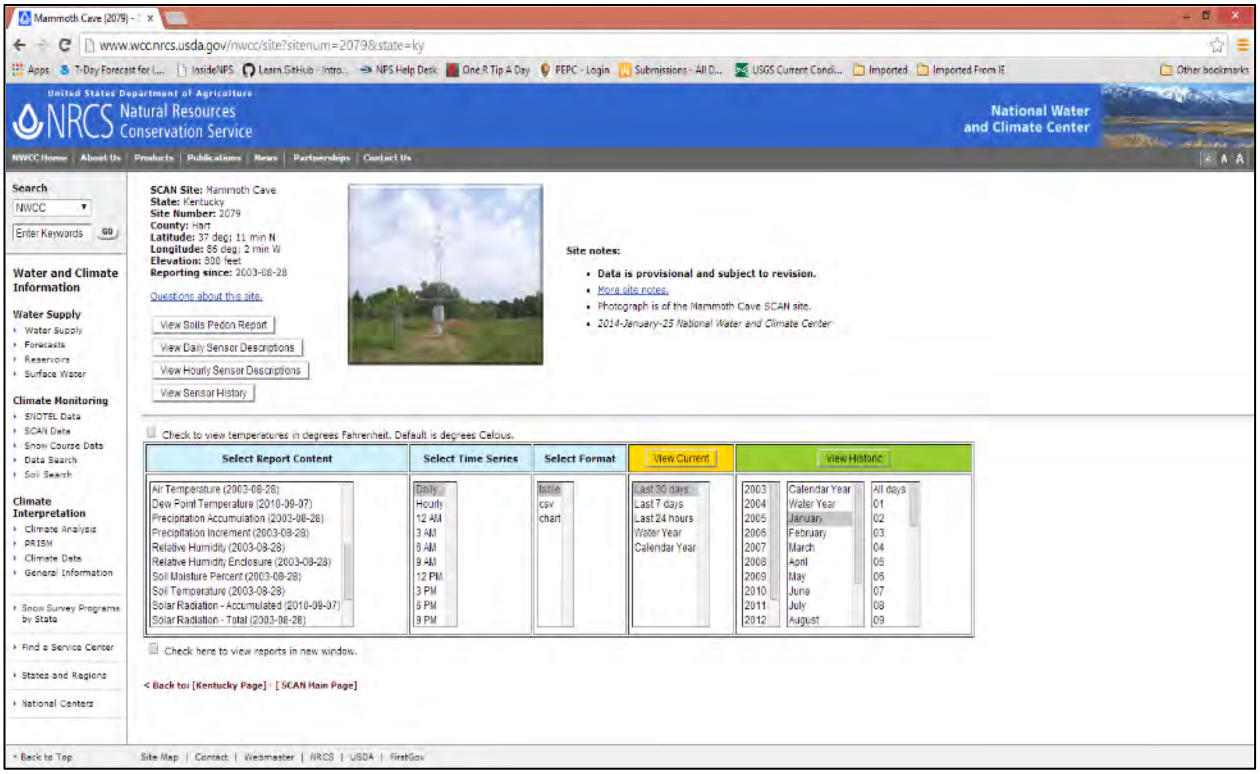

Figure SOP4-10. Soil Climate Analysis Network (SCAN) website from which validated surface meteorological data (i.e., surface temperature, RH, and precipitation), collected by MACA's SCAN station, are downloaded.

9. The merged data file is renamed as "<Location_ID1_Location_ID2>_SCAN2079_<date>.csv" where "Location_ID#" are the Location_IDs of the two caves in the sampling day, "SCAN2079" is the unique site number assigned to MACA's SCAN station location, and "date" is the date of the specific sampling event on which the two cave entrances were sampled as recorded on the field data sheet. The date format used is YYYYMMDD.
   Example: "FrNiEn_001a_GreOny_032_ SCAN2079_20140527.csv".

10. These data are deleted after being imported into R data analysis files since they are archived at the National Water & Climate Center and are readily accessible from the MACA's SCAN station website.

Saving Data to an archival CD for Long-Term Storage

All data produced by sampling bouts and their subsequent processing and analysis will be collected by the project leader who ensures they are archived for permanent storage. All scanned field data sheets, HOBO RH/Temp Datalogger – Site Setup and Maintenance Field Observer Forms, labeled cluster image files, and ArcMap files are saved onto archival DVD memory media for archiving in the CUPN offices. Once all materials from a sampling bout have been labeled, analyzed, and saved on the CUPN server they are transferred to archival DVDs using an available CD "burner" utility. The general steps below are used to save files onto the DVD memory.

Step by Step Instructions

1. The computer on which data are transferred to archival DVDs must be connected to the MACA LAN to provide for data transfer from the CUPN server to the archival DVD.

2. The project leader opens the CD "burner" utility on the host PC and follows the commands to start creation of a "data" or "image" CD. The "create" process requires the project leader to select the files(s) and/or folder(s) to be saved onto the archival DVD. The CD "burner" permits browsing through the various CUPN directories on the server to select specific files to be copied to the archival DVD.

3. The project leader follows the commands for copying the file(s) and/or folder(s) onto an archival DVD. The transfer process should take several seconds to a few minutes, depending on the number of file(s) and/or folder(s) to be transferred.

4. The CD/DVD "burner" will indicate when photo transfer is complete and should query the project leader as to their next command (e.g., label archival DVD, add notes, etc.). The project leader clicks "Close" and saves the archival DVD using the appropriate commands. The archival DVD memory has been created and should be retrieved from the computer and stored in a DVD jewel box.

5. The project leader checks the final DVDs to ensure the files copied correctly.

The project leader continues saving image files to DVD memory by following steps 1-4 above, until all files for the sampling bout have been recorded. The labeled DVDs are delivered to the CUPN curatorial specialist who will ensure they are properly stored for archiving.

SOP #5: Post-Field Sampling: Decontamination of Gear

Cave Cricket Monitoring Protocol
Cumberland Piedmont Network
Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 5 – Contents

Page

Overview

This SOP explains decontamination procedures to follow between caves during a field sampling day or completion of a field sampling day or field sampling bout at Mammoth Cave National Park (MACA). The tasks detailed in this SOP roughly cover the period of time from when field personnel have left the cave after a sampling event (or datalogger installation) has been completed to the point of arrival at the second sampling cave entrance, the Cumberland Piedmont Network (CUPN) headquarters office, or Science and Resources Management laboratory at MACA. This SOP also covers procedures to follow at the end of a sampling year. All field personnel will review this SOP by December of each year and the project leader should revise any sections based on lessons learned from the previous field sampling that year.

Since the initial discovery of a northern long-eared bat (*Myotis septentrionalis*) with white-nose syndrome (WNS) in MACA in January, 2013 multiple additional species have been found with the disease and multiple hibernacula are known to be contaminated with the fungus that causes the disease. Despite this fact the decontamination procedures adopted by the park will continue in order to minimize the risk of inadvertent human-assisted transmission among caves inside and outside of the park. These procedures include cave-level equipment dedication and decontamination of cave gear (including everything worn or taken into a cave), as detailed below.

Under no circumstances are clothing, footwear, or equipment, that have been used in a confirmed or suspected WNS-affected state or region, to be used in a WNS-unaffected state or region. Gear (includes clothes, footwear, caving gear, and monitoring equipment, hereafter) that has had substantial contact (i.e., more intimate contact than normal walking tours on trails) with the sediments of a park cave **must** be decontaminated before use in any other park cave. Footwear must be decontaminated even if it comes into only minimal contact with the cave.

Criteria for Decontamination When Caving In Mammoth Cave National Park

1. Gear will require decontamination between all caves within the Park, with the following exceptions (cave cricket monitoring caves bolded):

   - Mammoth Cave System entrances on Mammoth Cave Ridge (**Historic**, Violet City, New, **Frozen Niagara, Carmichael**, Elevator, Cox, **New Discovery**, Echo River Spring, and the Ventilator Shaft) are considered as one cave.

   - Mammoth Cave System entrances on Flint Ridge (**Salts, Crystal, Austin,** Unknown, Woodson-Adair, Bedquilt, and Hazen) are considered as one cave. Note: Colossal Entrance is not considered as the same cave, due to its further restrictions as a hibernaculum.

   - Mammoth Cave System entrances on Joppa Ridge (Procter, Doyle Valley, Morrison, and Ferguson) are considered as one cave.

   - Mammoth Cave System entrances on Toohey Ridge (Historic Roppel, Daleo, Weller, Kahn, and Hoover) are considered as one cave.

   - **Great Onyx Cave** is considered its own system.

2. Monitoring activities between small, disjunct caves (e.g., **Silent Grove Springhouse** and **Little Beauty**) and the above large cave systems require decontamination and/or change of equipment.

Decontamination Procedures

The minimal acceptable decontamination standards for cave work at MACA follow the current national decontamination protocol available from the US Fish and Wildlife Service (USFWS).

At the time of the preparation of this protocol, standards for cave work are available at the USFWS's main WNS website at:

http://whitenosesyndrome.org/sites/default/files/resource/national_wns_revise_final_6.25.12.pdf (accessed 1 April 2014)

The procedures can be summarized as follows:

1. Contaminated submersible gear should be scrubbed to remove mud and other dirt.

2. Scrubbed, contaminated submersible gear should be immersed in hot water [i.e., ≥ 50°C (122°F)] for 20 minutes, thoroughly rinsed, and air dried.

3. Decontamination procedures for non-submersible gear, such as electronic equipment and field notebooks (as well as hard, non-porous surfaces), can involve the use of a number of different commercially available cleaning products. Consult the Applications/Products chart on page one of the linked pdf above. Alternatively, some electronics can be placed in sealed plastic bags (or wrapped) and the plastic bags can be discarded between caves. Follow manufacturer's recommendations pertaining to Personal Protective Equipment for use with all decontamination chemicals. Material Safety Data Sheets for each product are available in the MACA Science and Resources Management office and at the park Visitor Center.

Approaches to Reducing Decontamination Needs

There are several approaches available which will reduce the amount of gear that needs to be decontaminated and reduce the risk of transmission by error. They are as follows:

1. Reduce the amount of gear being taken into the cave/field to that needed for safe and effective work.

2. Gear (such as extra lights) which may not be used during a cave trip can be bagged in sealed plastic bags. If the bags are not opened in the cave, the gear inside will not require decontamination. However, the outside of the bags themselves will be considered contaminated and will require disposal or decontamination.

3. Clothing coverings, such as disposable rubber booties and disposable coveralls (made of tyvek® or similar fabrics), may be used to reduce the risk of contamination of clothing and shoes (and thus also the need for decontamination). However, it is important to be sure that coverings do not tear or otherwise allow clothing to be exposed to the cave sediments. Also, boot coverings can affect footing and should only be used when it is clear that they will not compromise safety.

4. Some gear (especially less expensive or difficult to decontaminate gear) could be dedicated for use in only one cave system entrance or cave (such as Mammoth Cave Ridge system entrances, or Little Beauty Cave). Dedicated gear should be stored in labeled containers to reduce confusion and cross-contamination among gear.

5. The use of submersible rubber boots, such as wellies or muckboots, may simplify decontamination of footwear.

6. Remove outer clothing/footwear, place in a sealed plastic bag, and change into clean clothing/footwear prior to entering a vehicle.

Transport and Storage

Careful double bagging of potentially contaminated gear after exiting the cave but before placing it in vehicles is essential to reduce the potential for contaminating vehicles and other gear. Vehicles that have been used to haul dirty gear not properly stored should also be decontaminated. After gear is decontaminated, personnel must take care not to let it come in contact with gear that has not been decontaminated or placed in storage containers, car trunks, etc. that have been used to haul dirty cave gear.

Equipment Organizing/Cleaning

Clean the insides of all vehicles used in the field. Clean and repair all equipment, per the above standards, prior to returning them to their designated storage space. All references manuals should be re-shelved on their appropriate bookshelf. Other reference materials and extra data sheets need to be filed in their appropriate filing cabinet. These documents are currently stored in the project leader's office at the CUPN headquarters, in MACA.

SOP #6: Data Management

Cave Cricket Monitoring Protocol
Cumberland Piedmont Network
Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 6 – Contents

Page

SOP 6 – Contents (continued)

Page

SOP 6 – Figures

Page

Overview

This SOP provides documentation for the Cumberland Piedmont Network (CUPN) Cave Cricket Monitoring Protocol database, CUPN_Cave_Cricket_be.mdb. It also provides guidance for the processing, maintenance, and archival of the data contained within the aforementioned database. For step by step procedures related to data entry, verification and validation, individuals are referred to the CUPN Cave Cricket DB user manual (*in prep*).

Archival procedures for data products produced as a result of this project are also discussed within this SOP. For additional details related to the processing of other data elements (i.e., photos, cave maps, and datalogger files), users are referred to SOP #4: Post-Field Sampling.

Database Model

Development of CUPN's Cave Cricket database was initiated within Microsoft Access and will continue within this platform for the foreseeable future. Basic structure of this database conforms to the National Park Service's (NPS) Inventory and Monitoring (I&M) developed Natural Resource Database Template (NRDT), which includes an established set of core tables and fields (NPS 2007). Existing I&M Network databases were also reviewed in the development of this application, as well as consultations with NPS I&M Division Staff.

The core or primary tables within the NRDT, and ultimately the CUPN Cave Cricket database, are tbl_Locations and tbl_Events. Within tbl_Locations all fixed location sampling units (i.e., cave entrances) are stored. As its name implies, tbl_Events contains information about the sampling event such as date and time of sampling, protocol being implemented, etc. These tables are linked within the NRDT structure via a one to many relationship where each sampling location can accommodate multiple sampling events (Figure SOP6-1). Additional tables within the database can be summarized as:

- tbl_Strips – The primary sampling units within this protocol are randomly located (via GRTS) 10cm wide strips leading off a permanently referenced baseline.

- tbl_Clusters – In addition to strips, data are collected on cave cricket clusters which can span multiple strips.

- xref_CC_Strips_Clusters – A cluster will intersect one or more strips. A strip can intersect zero to many clusters. This results in a many to many relationship between strips and clusters.

- tbl_CC_Design – Within cave sampling and the order in which caves (i.e., cave entrances) are sampled is randomized prior to each bout. This randomization is generated via R code which pulls the list of caves, the baseline length within each cave, and pre-determined sample size (i.e., # strips per cave) from the protocol database.

- tbl_Landmark, tbl_Hobo_Location, and tbl_Hobo – location and servicing history of within-cave continuous monitoring environmental dataloggers.

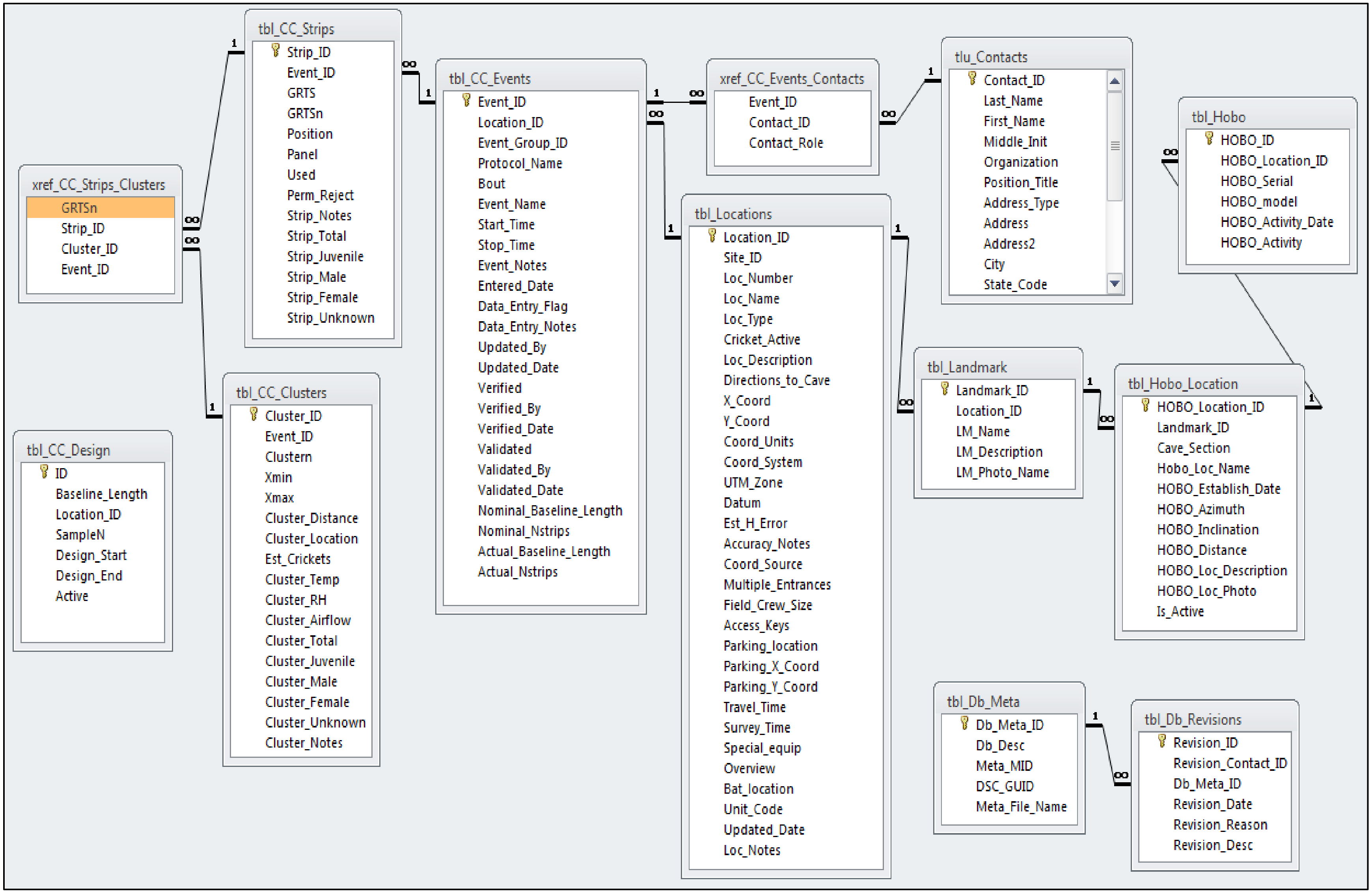

Figure SOP6-1. The Cumberland Piedmont Network (CUPN) Cave Cricket Monitoring Protocol database model.

Database Dictionary

With the exception of look up tables (i.e., tlu_ prefix), the following data dictionary contains names, type, size, and descriptions of fields within the CUPN Cave Cricket database back-end file. Note, this information was excerpted from the most recent working draft of this database, CUPN_Cave_Cricket_be_20140425.

Table SOP 6-1. Data dictionary for fields in the CUPN Cave Cricket database, containing field name, type, size, and description

Field Name	Field Type	Field Size	Field Description
tbl_CC_Clusters — Cave Cricket Cluster level data			
Cluster_ID	Text	50	Unique row identifier comprised of [Event_ID]&"_"&[ClusterN]
Cluster_Airflow	Long Integer	4	Airflow (meters/second) at densest portion of cricket cluster, recorded to nearest thousandth (e.g., 0.043 m/s)
Cluster_Distance	Integer	2	Distance in meters from baseline to cluster centroid measured parallel with strip (e.g., 1.92)
Cluster_Female	Integer	2	Total number of adult female crickets within cluster
Cluster_Juvenile	Integer	2	Total number of juvenile crickets within cluster
Cluster_Location	Text	1	Location of the cluster, recorded as "c" for ceiling or "w" for wall
Cluster_Male	Integer	2	Total number of adult (large)male crickets within cluster
Cluster_Notes	Text	255	Field notes pertinent to specific cluster
Cluster_RH	Integer	2	Relative humidity at densest portion of cricket cluster recorded to nearest tenth percent (e.g., 94.7%)
Cluster_Temp	Integer	2	Temperature at densest portion of cluster, recorded to nearest tenth degree Celsius (e.g., 15.5)
Cluster_Total	Integer	2	Total number of crickets within cluster
Cluster_Unknown	Integer	2	Total number of adult (large) crickets with indeterminate sex within cluster
Clustern	Long Integer	4	Sequential number assigned to each cricket cluster detected within a cave (1,2,...)
Est_Crickets	Integer	2	Field estimate of the number of crickets within the cluster (primarily an aid in image analysis)
Event_ID	Text	50	Foreign Key: Link to tbl_Events
Xmax	Integer	2	Estimate in m of the distal (furthest from cave entrance) extent of cave cricket cluster along the baseline.
Xmin	Integer	2	Estimate in m of the proximal (nearest cave entrance) extent of cave cricket cluster along the baseline.
tbl_CC_Design — Utilized in R sample draw process to generate a set of strip values for each bout			
ID	Long Integer	4	unique row identifier
Active	Boolean	1	Is this record currently active (has start but no end date is empty or Null)
Baseline_Length	Integer	2	Baseline length in meters
Design_End	Date/Time	8	When this record was dropped from the sample design (e.g., superseded by another record or that entrance dropped from sampling)
Design_Start	Date/Time	8	When this record became effective in the sample design (set to 1/1/2014 for all records at start)

Field Name	Field Type	Field Size	Field Description
tbl_CC_Design — Utilized in R sample draw process to generate a set of strip values for each bout (cont.)			
Location_ID	Text	255	Foreign key link to tbl_Locations
SampleN	Integer	2	Design number of strips to be sampled (R code generates 2x this # to have oversample replacement locations)
tbl_CC_Events — Cave Cricket Event level data, where event equals one visit to one cave.			
Event_ID	Text	50	Event identifier-event defined as one visit to one cave (location) comprised of "CC"&SequenceNumber
Actual_Baseline_Length	Long Integer	4	Actual baseline length in meters
Actual_Nstrips	Long Integer	4	Actual sample size (number of strips) including rejections & replacements
Bout	Text	25	Set of cave sampling events, analogous to event group (e.g., May2014)
Data_Entry_Flag	Boolean	1	Option for data entry to flag this event for closer examination by project leader during future QA/QC steps
Data_Entry_Notes	Memo	0	Justification for data entry flag or general notes related to anomaly discovered during data entry
Entered_Date	Date/Time	8	Date on which data entry occurred
Event_Group_ID	Text	50	Foreign Key: Link to tbl_Event_Group (likely not used for Cave Cricket protocol)
Event_Name	Text	64	Concat of Location_ ID & Bout (to aid in future data discovery)
Event_Notes	Memo	0	General notes on the event
Location_ID	Text	50	Foreign Key: Link to tbl_Locations
Nominal_Baseline_Length	Long Integer	4	Intended or planned baseline length in m
Nominal_Nstrips	Long Integer	4	Intended or planned sample size (number of strips)
Protocol_Name	Text	100	The name or code of the protocol governing the event ("CUPN Cave Cricket")
Start_Time	Date/Time	8	Starting time for the event (i.e, arrival at cave)
Stop_Time	Date/Time	8	Stopping time for the event (i.e., recorded when crew exits cave)
Updated_By	Text	50	Person who made the most recent updates
Updated_Date	Date/Time	8	Date of the most recent edits (i.e., mm/dd/yyyy)
Validated	Boolean	1	Whether the data has been validated
Validated_By	Text	50	Person who validated data for accuracy and completeness
Validated_Date	Date/Time	8	Date on which data were certified (i.e., mm/dd/yyyy)
Verified	Boolean	1	Whether the data has been verified
Verified_By	Text	50	Person who verified accurate data transcription
Verified_Date	Date/Time	8	Date on which data were verified (i.e., mm/dd/yyyy)
tbl_CC_Strips — Cave Cricket strip (i.e., primary sampling unit) level data			
Strip_ID	Text	50	Unique identifier for Strip (where strip is the 10cm primary sampling unit or transect) comprised of [Event_ID]&"_"&[GRTSn]
Event_ID	Text	50	Foreign Key: Link to tbl_Events
GRTS	Text	100	Site label generated by spsurvey during GRTS draw
GRTSn	Long Integer	4	Strip sequential order (1,2,3...) within an Event generated during GRTS draw

Field Name	Field Type	Field Size	Field Description
tbl_CC_Strips — Cave Cricket strip (i.e., primary sampling unit) level data (cont.)			
Panel	Text	15	Refers to whether Strip is within initial draw (i.e., Panel) or oversample (i.e., Replacement)
Perm_Reject	Integer	2	Numbered code indicating one of five valid reasons for rejecting a strip position in the field
Position	Integer	2	one dimensional position on baseline to nearest tenth meter (e.g., 10.1) where Strip is initiated
Used	Text	10	Refers to whether initial Strip or Oversample is used (Y) or rejected (R) and Oversample that goes unused (U) during the sampling event. “U” is recorded exclusively in cells associated with unused Oversample strip positions.
Strip_Female	Integer	2	Total number of adult female crickets within strip
Strip_Juvenile	Integer	2	Total number of juvenile crickets within strip
Strip_Male	Integer	2	Total number of adult male crickets within strip
Strip_Notes	Text	255	Field notes related to a specific strip
Strip_Total	Integer	2	Total number of crickets within strip
Strip_Unknown	Integer	2	Total number of adult crickets of indeterminate sex within strip
tbl_Hobo — HOBO data logger information			
HOBO_ID	Text	50	HOBO identifier
HOBO_Activity	Text	100	Type of HOBO Activity taking place (i.e., install, service, replace, remove)
HOBO_Activity_Date	Date/Time	8	Date HOBO activity (e.g., install, service, replace) is taking place
HOBO_Location_ID	Text	255	Foreign Key: Link to tbl_Hobo_Location
HOBO_model	Text	255	HOBO datalogger model type (e.g., H8 Pro or Pro v2)
HOBO_Serial	Text	255	Serial # printed on side of the datalogger
tbl_Hobo_Location — Information on HOBO datalogger locations (in cave)			
HOBO_Location_ID	Text	50	Location identifier
Cave_Section	Text	10	Section within cave where HOBO location is located (S1, S2, ...)
HOBO_Azimuth	Long Integer	4	Compass bearing in degrees from permanent landmark to datalogger
HOBO_Distance	Long Integer	4	Distance in meters via tape or orange finder from permanent landmark to the HOBO
HOBO_Establish_Date	Date/Time	8	Date Hobo Location was first established (mm/dd/yyyy)
HOBO_Inclination	Integer	2	Record the inclination (% slope) obtained by a clinometer or disto from the permanent landmark to the datalogger
HOBO_Loc_Description	Text	255	HOBO Location Description, a detailed description of the location where the installed HOBO datalogger is placed
Hobo_Loc_Name	Text	255	Unique identifier within cave for HOBO Location (H1, H2,...)
HOBO_Loc_Photo	Text	50	Photo Name (as stored on network server) of datalogger in situ
Is_Active	Boolean	1	Is this particular HOBO location in use (i.e., a datalogger is currently deployed in this location)?
Landmark_ID	Text	50	Foreign Key: Link to tbl_Landmark

Field Name	Field Type	Field Size	Field Description
tbl_Landmark — In cave landmarks to aid in finding locations where dataloggers are or have been deployed			
Landmark_ID	Text	255	Unique Location Identifier
LM_Description	Text	255	Physical description of landmark
LM_Name	Text	4	Land Mark Name (ex. L1, L2... or NONE)
LM_Photo_Name	Text	50	Photo Name of Landmark (as stored on network server)
Location_ID	Text	50	Foreign Key; Link to tbl_Locations
tbl_Locations — Cave location information			
Location_ID	Text	50	Location identifier
Access_Keys	Text	255	List keys needed for access to cave (road gate, cave gate, etc.)
Accuracy_Notes	Text	255	Positional accuracy notes
Coord_Source	Text	255	The source of the GIS X and Y coordinates (i.e., shapefile, Lesser Cave Inventory database, field coordinates)
Coord_System	Text	50	Coordinate system
Coord_Units	Text	50	Coordinate distance units
Cricket_Active	Boolean	1	Active Cave Cricket Monitoring Cave?
Datum	Text	50	Datum of mapping ellipsoid
Directions_to_Cave	Memo	0	Directions to cave
Est_H_Error	Single	4	Estimated horizontal accuracy
Field_Crew_Size	Text	255	The ideal recommended number of personnel based on safety, efficiency, cave size, and disturbance considerations
Loc_Description	Text	255	In cave description
Loc_Name	Text	100	Cave Name
Loc_Notes	Memo	0	General notes on the location
Loc_Number	Text	5	Lesser Cave DB unique identifier (MACA only)
Loc_Type	Text	12	Cave entrance developed or undeveloped?
Multiple_Entrances	Boolean	1	Does this cave have multiple entrances requiring multiple, simultaneous survey efforts?
Overview	Memo	0	Cave description and recommended survey route, including obstacles such as crawls and climbs
Parking_location	Text	255	Where to park to begin hiking to the site. May be a designated trailhead, or a more obscure location, such as a specific spot along a road shoulder
Parking_X_Coord	Double	8	X coordinate of the parking location
Parking_Y_Coord	Double	8	Y coordinate of the parking location
Site_ID	Text	50	Foreign Key: Link to tbl_Sites
Special_equip	Text	255	Non-standard equipment necessary for the survey
Survey_Time	Text	255	The approximate time needed to complete survey (does not include travel time and set-up)
Travel_Time	Text	255	The approximate time required to complete round-trip travel only
Unit_Code	Text	12	Park, Monument or Network code
Updated_Date	Text	50	Date of entry or last change
UTM_Zone	Text	50	UTM Zone

Field Name	Field Type	Field Size	Field Description
tbl_Locations — Cave location information (cont.)			
X_Coord	Double	8	X coordinate of the cave entrance
Y_Coord	Double	8	Y coordinate of the cave entrance
xref_CC_Strips_Clusters — Cross reference table between tbl_clusters and tbl_strips			
Cluster_ID	Text	50	Foreign Key: Link to tbl_cCC_Clusters
Event_ID	Text	255	Foreign Field: link to tbl_CC_Events tbl_CC_Strips tbl_CC_Clusters (duplication aid for R imports)
GRTSn	Text	255	Foreign Field: Link to tbl_CC_Strips (duplication aid for R imports)
Strip_ID	Text	50	Foreign Key: Link to tbl_CC_Strips

Data Entry

Prior to each sample bout, or grouping of cave entrances to be visited during a sampling session (sometimes referred to as a sampling event group), a Generalized Random Tessellation Stratified (GRTS) draw will occur to randomize the order in which in-cave sampling occurs and the order in which caves are visited. The R code, which generates these draws, will harvest a list of entrances to be visited, within cave sample sizes, and the last Event_ID utilized (sequential order). This code will then format and populate field data sheets (MS Word). Examples of blank and pre-populated field data sheets and a field sheet data dictionary can be found within SOP #3a: Field Methods: Strip Adaptive Cluster Sampling. Fields pre-populated on the data sheet include: Loc_Name (referred to as Entrance name on field data sheet), bout, Event_ID, GRTSn, and position (i.e., strip position). More detail on the completion of this data sheet is outlined below.

A second field data sheet will be utilized for this protocol to capture metadata on automated data loggers deployed for continuous monitoring of cave meteorological conditions. An example of this field form can be found in SOP #3b: Field Methods: Cave Meteorological Sampling. The data logger field form will be produced with a laser copier/printer in the office and all values entered manually into the protocol database.

Data entry for this protocol into the protocol database relies on some automated data entry (generated primarily by customized R code) and some manual data entry. Following is a step by step guide of the process.

1. R code (i.e., "CaveSampleGen.R" in Appendix F) run by the project leader to randomize the order in which cave entrances will be visited for each bout as well as generate a GRTS draw for randomizing within cave sampling. The code will prompt the project leader for a bout name (e.g., May2014). Cave list (Location_ID), baseline length, and sample size are pulled by the R code from tbl_CC_Design in the protocol database. In addition the R code will look for tables of the name temp_Events_* (see below) as well as tbl_CC_Events to check for the last Event_ID sequence number. The first event within this bout will be assigned the next highest sequence.

    a. Preprinted field data sheets are produced with entrance name, bout, unique event identifier, sampling strip order and position (i.e., the order and locations of where sampling takes place in the cave).

b. A pair of temporary tables is created in the protocol database via the pre-sampling R code.

temp_Events _May2014	
Event_ID	
Bout	
Location_ID	
Event_Name	
Nominal_Baseline_Length	
Nominal_Nstrips	

temp_strips_May2014	
Event_ID	
GRTS	
GRTSn	
Position	
Panel	

2. In the order specified by the pre-sampling code, field crews will utilize the pre-populated field data sheets to conduct field sampling at each cave entrance in the bout. In addition to the field data sheets, data are collected via photographs (taken in the field) of cave crickets within strips and clusters.

3. Upon returning from the field, manual data entry commences in the protocol database. A field crew member (or project leader) will enter metadata fields pertaining to the event (e.g., crew members, time, date, etc.) from the field data sheets into the appropriate temporary tables.

   a. The cover or first sheet info is entered into the existing temp_Events_Bout table:

Note shaded fields indicate previously populated items. →

temp_Events _May2014	
Event_ID	
Bout	
Location_ID	
Event_Name	
Nominal_Baseline_Length	
Nominal_Nstrips	
Crew members & roles	
Start_Time	
Stop_Time	
Event_Notes	
Actual_Baseline_Length	
Actual_Nstrips	
Data_Entry_Flag	
Data_Entry_Notes	

   b. Utilizing values stored in temp_strips_May2014 (i.e., Event_ID and GRTSn) the protocol database generates temp_QAQC_R_Compare and cluster/strip combinations are manually entered from the top portion of the field data sheet. This table will be used as a later consistency check (looking for potentially missing or misnamed shapefiles retrieved by R code, see below), as well as to populate xref_CC_Strips_Clusters.

temp_QAQC_R_Compare	
Event_ID	
GRTSn	
ClusterN	

c. Utilizing values stored in temp_QAQC_R_Compare (i.e., Event_ID and ClusterN) the protocol database generates temp_Clusters_May2014 and manual entry of the remaining field data sheet portion commences.

temp_Clusters_May2014	
Event_ID	
ClusterN	
Xmin	
Xmax	
Cluster_Distance	
Cluster_Location	
Est_Crickets	
Cluster_Temp	
Cluster_RH	
Cluster_Airflow	
Cluster_Notes	

4. Cave cricket photographs are copied from the camera's memory card into a "Raw" directory for that entrance name (i.e., Location_ID) and bout. The images are reviewed by the protocol leader (or their designee), protocol lead, who selects the best one or more (if tiling is necessary) images for each cluster, and saves those selected images into the "Mod" directory with file names encoding Event_ID and Cluster Number (i.e., ClusterN)

5. The selected images are analyzed in ArcMap. All crickets are assigned to a cluster, strip (where appropriate), sexed, and life stage determined (i.e., adult or juvenile). These values are stored in the attribute tables of individual shapefiles (one shapefile per cricket cluster, one record per cricket).

6. R code (PhotoHarvest.R) run by the project leader will extract data from the shapefiles.

   a. It will sum crickets by cluster, and put those counts into temp_Clusters_May2014, and sum crickets by Strip, adding those numbers to the appropriate fields of temp_Strips_May2014.

temp_strips_May2014	
Strip_ID	
Event_ID	
GRTS	
GRTSn	
Position	
Panel	
Strip_Total	
Strip_Juvenile	
Strip_Male	
Strip_Female	
Strip_Unknown	

temp_Clusters_May2014	
Event_ID	
ClusterN	
Xmin	
Xmax	
Cluster_Distance	
Cluster_Location	
Est_Crickets	
Cluster_Temp	
Cluster_RH	
Cluster_Airflow	
Cluster_Notes	
Cluster_Total	
Cluster_Juvenile	
Cluster_Male	
Cluster_Female	
Cluster_Unknown	

b. As part of QA/QC steps it will tabulate which pairs of GRTSn and ClusterN have at least one cricket in common (but keep that as a table in R, not in the database).

c. Finally, it will use the ClusterN, Xmin and Xmax values in temp_Clusters(_Bout) and the GRTSn and Position values in temp_Strips_May2014 to create another table in R (not the protocol database) of strips and clusters that should intersect for that Event_ID. If there are any discrepancies among the 3 versions of strip by cluster intersections, the R code will write out a report highlighting the discrepancies, and writing out all 3 tables.

7. Additional consistency checks are performed and data are validated by the project leader. At least part will be R code. One check will be printing out a table of Est_Crickets and Cluster_Total for each cluster. The project leader can look at these and check for any obvious large discrepancies.

8. The data manager appends validated records to the non-temporary tables in the database (listed below). This process will include creating sensical Cluster_ID and Strip_ID values (from combinations of Event_ID, ClusterN and GRTSn as appropriate).

   tbl_CC_Events
   tbl_CC_Strips
   tbl_CC_Clusters
   xref_CC_Strips_Clusters

9. The data manager deletes that set of temp_* tables.

In short, much of the data entry will <u>not</u> be accomplished via the traditional method whereby an individual sits down at their computer with a completed field data sheet and enters each value into a similarly designed form on the computer. Instead much of the data will be populated into temporary tables in the database via R code. Thus the data entry process will include ensuring: data are accurately parsed to the correct locations and events in permanent database tables; data records are complete; and entry of remaining data elements from the field data sheets (e.g., notes fields, cricket cluster locational information, etc.) is completed. A series of QA/QC checks will be in place to assist in this process. However, the need for properly trained and equipped data entry personnel is still critical to the success of this monitoring effort.

Prior to initiating data entry for a sampling bout the project leader will coordinate with the data manager to ensure database versions are current and the correct files are accessible for use on appropriate computers. Data entry will be completed as soon as possible following field data collection and should be done by someone familiar with data collection efforts; preferably someone who participated in collection of the data to be entered.

Prior to commencement of database use, a user (e.g., field crew leader, crew member, and data intern) will have reviewed this SOP and received hands-on training from the project leader and data manager in the use of this database and demonstrated a level of competency and understanding of the data entry steps.

Correct data entry is an integral step in ensuring the overall success of this long-term monitoring effort. As such, when in doubt as to what is written on a data sheet due to poor hand writing or any other reason, do not guess! Data sheets should have been reviewed and initialed in the field. Thus, begin by checking with the crew leader who initialed it to determine what is printed on the form. If confusion remains, flag the record in the database and make a note (also in the database) for the project leader to review during later data processing steps. After each field data sheet is entered, the person entering the data will print their initials and date in the reserved space on the field data sheets.

Quality Review

The success of this monitoring effort relies heavily on accurate sex/life stage classifications from photographs. Some steps (noted above in data entry section) will be automated to ensure imported records are complete and linked the appropriate event. Despite image analysis training and the inclusion of a field guide for identifying cave cricket species, sexes, and life stages (see Appendix D: Guide to Cave Cricket Morphology) a potential source for error is incorrect determination of sex and life stage of cave crickets during image analysis. Thus, to ensure photo analysis is of an acceptable quality, the project leader (in cooperation with the data manger) will perform a blind review of images. In summary, the data manager will periodically select a cluster that has been analyzed with the # or level of review being determined by the overall experience of the analyst. Without knowing the results of this analysis (i.e., blind) the project leader will perform his own analysis. The results of the two independent analyses will then be compared by the data manager to ensure a predetermined level of precision is obtained. If the results are not of an acceptable quality, the initial analyst will be retrained by the project leader and additional quality reviews will be conducted. Note, this quality review will be conducted and an acceptable level of precision achieved before any image analysis data are imported into the protocol database.

As part of data entry, database entries will be reviewed against the original data sheets to ensure data have been copied from the paper forms accurately (i.e., verification). In addition to manual checks, some basic queries summarizing sex/stage counts, date ranges, max and min values, etc. will also be utilized by the data entry technician to further verify data are accurate and complete.

If data verification reveals significant problems with the data entry for a particular method, cave or park, this will trigger a full review of all data entered for that method, cave or park. In addition, steps will be reviewed by the data manager or project leader to correct deficiencies and avoid a repeat of past errors. Once all routines are complete the data intern will mark the events as "verification complete" in the database. Once verification is complete field data forms will be returned to the location designated by the project leader. The project leader will also be informed that data verification is complete.

After data verification is finished, the data will be reviewed by the project leader, who will again check the data for completeness and logical inconsistencies. The primary question throughout the validation process should be "Do these data make sense?" Although data may be correctly transcribed from the original field forms, they may not be accurate or logical. For example, a cave temperature of 60 °C may have been recorded on a data sheet and entered 'correctly' in the database. However, the value is obviously in error. Certain components of data validation are built into data entry forms and R commands. Data validation will also be extended into the database via automated queries and reports.

During the entry, verification, and validation phases, the project leader is responsible for the data. The project leader must assure consistency between field data sheets and the database by noting how and why any changes were made to the data on the original field sheets. In general, changes made to the field sheets should not be made via erasure, but rather through marginal notes (preferred) or attached explanations.

Once the computerized data are verified as accurately reflecting the original field data and validation is complete, the project leader can submit original field data sheets to the curatorial specialist for archival. The electronic version of the data can be turned over to the data manager for archiving and storage. This version of the data is used for all subsequent data activities.

Other Data Types

In addition to paper forms (including the R code automation), data will be collected in various media. These are listed below. Their mention within this SOP is not to provide step-by-step instruction (refer to the overview section of this SOP), but rather to simply make readers seeking an overview of data management aware of these 'other' data. Many of the steps for processing and cataloging these other forms of data can be found in SOP #4: Post- field Sampling: Disposition of Field Data, Digital Image Analysis and Image Data Entry.

Digital photos –These include photographs to accomplish accurate determination of sex and life stage of cave crickets (core data included in the flow above), as well as ancillary photographs of unique cave formations, to document other species, etc. Another 'category' of photographs will be taken to aid in documenting the location of HOBO dataloggers deployed in-cave. This will entail a photograph of the data logger *in situ*, as well as photographs of landmarks within caves.

Field paper – In addition to the field data forms found within the field methods SOPs for this protocol (i.e., SOPs 3a and 3b), other paper field forms include cave baseline maps and cave field information sheets. In addition to maintaining copies accessible for field crews, these items will also need occasional updating. Examples include adding new data logger locations on cave maps or updating the equipment list needed within a cave. These updated products will need to be properly versioned and made available to field crews.

GPS data – Incidental observations (e.g., rare plants or animals), coordinates for cave locations or access points.

Datalogger files – Digital files comprised of cave meteorological data. These are periodically downloaded from dataloggers in the field and transported to the office via a data shuttle.

Database Administration

Data Updates

Data sets are rarely static. They often change through additions, corrections, and improvements made following the archival of a data set. There are three main caveats to this process:

- Only make changes that improve or update the data while maintaining data integrity.
- Be prepared to recover from mistakes made during editing.
- Document changes

Any editing of archived data is accomplished jointly by the project leader and data manager. Every change must be documented and accompanied by an explanation that includes pre- and post-edit data descriptions.

Version Control

Prior to any major changes of a data set or protocol, a copy is stored with the appropriate version number. This allows for the tracking of changes over time. With proper controls and communication, versioning ensures that only the most current version is used in any analysis. Versioning of archived datasets is handled by adding a floating-point number to the file name, with the first version being numbered 1.00. Each major version is assigned a sequentially higher whole number. Each minor version is assigned a sequentially higher .01 number. Major version changes include migrations across Access versions and complete rebuilds of front-ends and analysis tools. Minor version changes include bug fixes in front-end and analysis tools. Frequent users of the data are notified of the updates and provided with a copy of the most recent archived version.

In addition to maintaining version numbers, dataset file names (i.e., backend database files) should also be appended with date of last update, utilizing a YYYYMMDD format. This is done to aid the user in knowing when that particular file was last updated. The data manager will also add the word "archive" to the file name for files archived at the end of each field season. As an example: Cave_Cricket_Archive_v1.0_be_20121113

This file is a backend database file (indicated by the "be") for the Cave Cricket protocol. It was last updated on November 13, 2012 and archived by the data manager. The version of this particular file is 1.0.

It is also highly recommended that reports, presentations, etc. be appended with date at the end of the file name. This will aid other users by making it clear as to which file is the last report or the most recent presentation given.

Data Backups

Tape backups of all project data stored on CUPN's server are regularly conducted. A full backup is conducted at the end of each work week (i.e., every Friday night), and incremental backups each night, Saturday through Thursday. With this approach data are backed up every night and the tape is changed on Friday, giving a full weeks backup on each tape. Utilizing 12 tapes provides 12 weeks' worth of daily backups before tapes are recycled (i.e., put back in the rotation). In addition, to these short-term backups an historical backup is also made and retained by the data manager at least once annually. All tape backups are conducted by Mammoth Cave National Park (MACA) information technology (IT) staff.

Directory Structure

The various databases, images, reports, GIS coverages, etc. used and generated by the CUPN monitoring program create a large number of files and folders to manage. Poor file organization will lead to confusion and potentially to data corruption. Figure SOP6-2 depicts the file organization structure for a typical monitoring project.

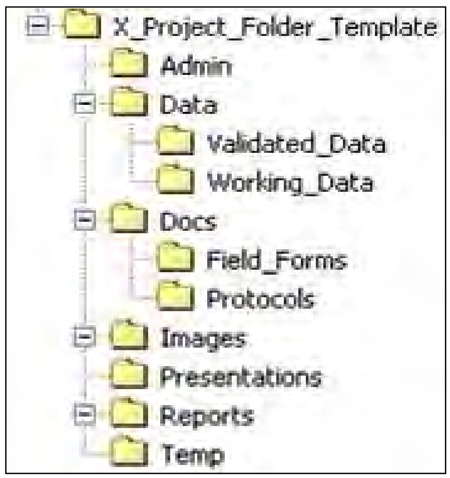

Figure SOP6-2. Project folder structure for the Cumberland Piedmont Network.

CUPN has established this template directory structure for each vital sign monitoring project to serve as a basic starting point and provide consistency across projects. A similar directory structure contains archived files (\CUPN_Archive\). Both the working and archive directories are accessible via the MACA Local Area Network (LAN), with access permissions maintained by the data manager and MACA IT staff.

Because this project includes multiple visits to multiple cave entrances over the course of a calendar year, attention to organization becomes much more important. The basic foundation or folder tree utilized to maintain organization within a park is presented below. Currently this protocol is scheduled for implementation on MACA only.

\Location_ID\bout

While there are schema that could be utilized, it was determined by the project leader that this basic structure is intuitive and will aid staff in maintaining park specific data, such as completed field forms (scanned) and images in a logical, retrievable fashion. One type of data briefly noted earlier in this SOP that will not be stored within the Cave Cricket Vital Sign folder structure is the cave meteorology datalogger files. This is because cave meteorology data are collected in support of multiple vital signs. As such, Cave Met data are stored within a folder structure established specifically for that project on the MACA LAN.

Without due diligence file folders will become bloated over time with draft documents, multiple copies of the same files, etc. As such a review of archive and temporary files, backups etc., will be undertaken by the project leader and data manager on an annual basis. A good time for this review to take place is at the end of each sampling year once annual reporting requirements have been completed and disseminated.

Metadata

Metadata has been defined as structured information about the content, quality, and condition of data. It can provide information about the 'core data' such as when and where they were collected and/or provide end users some level of confidence in the quality of the data, if for example they were collected via documented field methodologies. All CUPN projects are required to conform to Federal Geographic Data Committee (FGDC) guidelines. NPS also has its own guidance within the confines of FGDC guidelines. The ultimate goal of metadata is to make data available and inform users of its usability. With this in mind, CUPN staff will make every reasonable effort to fully document and make data available.

Sensitive Data

Sensitive information is generally defined as information about protected resources that may reveal the "nature or specific location" of protected resources. Such information must not be shared outside the National Park Service, unless a signed confidentiality agreement is in place. Per Executive Order or resource confidentiality laws, protected resources specific to this project potentially include:

- Endangered, threatened, rare, or commercially valuable resources
- Significant caves

This project will involve the collection and management of cave location data. Metadata development (i.e., Section 1, Constraints on Access) provides one way of documenting or labeling sensitive data to aid in their protection. Additionally procedures will be in place to remove protected information from datasets made available outside of NPS. This may include but is not limited to the removal of location information from externally available datasets and reports. CUPN staff will work with park resource contacts to ensure sensitive data are identified, labeled, and protected from inadvertent release.

Natural History Collections

Natural history collections consist of specimens taken from the living and non-living components of the natural world. Often these items are collected as part of a scientific research project in order to: 1) serve as vouchers documenting research; 2) document an area's natural features; 3) provide a better understanding of a natural process; 4) document changes in the environment over time.

The NPS maintains natural history collections primarily to voucher, or document, the presence of plants, animals, fossils, rocks, minerals, and other resources in a park at a particular place and time. Researchers and resource managers use this information for science and resource management decisions. Parks use research results and specimens in exhibits and as the basis for education and interpretive programs. Natural history collections and their associated records, which are managed as archival collections document the park's natural environment, geological history, current conditions and changes over time.

ICMS

Field data, objects, specimens and features obtained for preservation during inventory, monitoring, research and study projects, together with associated records and reports, will be managed over the long term within the museum collection and catalogued into the Interior Collection Management System (ICMS). It should be noted information on specimens (i.e., species vouchers) will also be entered into the Integrated Resource Management Application's (IRMA) voucher application.

ICMS is a collection management system for museum collections in all bureaus and 150 units of the U.S. Department of the Interior. It is used to catalog objects, specimens, and archival materials. This is the NPS museum standard and will be followed according to guidelines established by that program. Specimens, digital photographs, and archival material will be handled according to procedures established in the NPS museum handbook (Polk 2011). Final storage location will be in designated repositories decided by the collection park using loan agreements where needed.

Archives

Administrative histories, collections documentation, exhibits, publications, interpretation, cultural and natural resource management studies, and scholarly research are all dependent upon having well organized and accessible archives and manuscript collections. Without these documents, park interpretation, administrative histories, structural and vegetative preservation, scientific research, and resource management would be greatly diminished, and staff, visitors and scholars could only speculate upon the history of the parks as well as their management.

The preservation of archival and manuscript collections is dependent upon providing appropriate resources, including suitably trained staff, a proper environment, and appropriate storage equipment and supplies. Once a document is damaged, it can never be fully repaired, even through the most costly restorative procedures. Under appropriate conditions, most agents of deterioration that affect collections can be greatly reduced. The design and long-term maintenance of archival conditions is, therefore, a crucial part of a park's collections management program. Further, it is essential to develop basic procedures on access, usage, duplication, and conservation, as well as to complete the archival processing work of arrangement and description.

Any material (preferably originals, but can be copies) associated with the project (photos, maps, field notes, recordings, etc.) will be archived and entered into ICMS. After these materials are archived and entered into ICMS they will be returned to the park or a repository requested by the park along with their corresponding ICMS records. All final electronic data sets and material associated with monitoring bats at cave roosts in the CUPN will be archived and curated according to NPS policy and procedures.

Curatorial Procedures

Once a project is complete, the project leader (PL) is responsible for turning over any and all material related to that project to the CUPN curatorial specialist. Projects have two main components: Archives and Specimens.

Step By Step Instructions

1. Project Lead turns over all project materials and specimens to the CUPN curatorial contact.

2. All archival materials are transferred to archival housing by the CUPN curatorial contact or a designated student intern.

3. Specimens are counted by the CUPN curatorial contact.

4. The park curator is contacted by the CUPN curatorial contact to request an accession number and the amount of catalog number(s) determined from step 2.

5. For specimens only: the CUPN curatorial contact either curates specimens or arranges for professional curation.

6. The CUPN curatorial contact enters all information connected with each specimen or archival material(s) into ICMS.

7. For specimens only: labels are printed and placed with specimen.

8. If applicable, photos are taken of specimens.

9. If park is final repository, archives or specimens will be sent to park with associated ICMS records and DI-105 (i.e., receipt for property form) by CUPN curatorial contact.

10. If park is unable to store items, the park will choose a repository that abides by NPS standards. The CUPN curatorial contact will create a loan agreement between park and repository, and will deliver final archives and specimens to repository.

<u>Archives</u>
Every project will have materials to be archived. Once the project leader has turned over all materials related to the project, not including actual specimens, they are placed in archival housing (stable acid-free papers, folders, boxes, etc.) for conservation by the CUPN curatorial specialist or an appointed student intern. The CUPN curatorial specialist will then notify the park curator to request one accession number and catalog number(s) for that project. The information is then entered into ICMS by the CUPN curatorial specialist. If the park will be final repository, the archives will be sent to the park with the associated ICMS records and a DI-105 (receipt for property form). If the park is unable to store the archives, the park will choose a repository that abides by NPS standards. The CUPN curatorial specialist will then be responsible for creating a loan agreement between the park and the repository, as well as the final delivery of the archives.

<u>Specimens</u>
In addition to archives, if there are specimens, they will need to be curated (prepared for long-term storage). For inventory projects, the amount of specimens will be tallied to obtain the same number of catalog numbers and one accession number from the park. For ongoing monitoring projects, the new specimens are tallied every time they are turned in to the PL to receive the same number of catalog numbers, keeping the same accession number for the duration of the project. The CUPN curatorial specialist will be responsible for either curating the specimens or finding a professional to do so. Once the specimens have been curated, all information connected with each specimen will be entered into ICMS by the curatorial specialist. A standard NPS label will be created from this information through ICMS and then attached to the specimen. If applicable, photos will be taken of the labeled specimen and digitally attached to the respective ICMS record. If the park is final repository, the specimens will be sent to the park with the associated ICMS records and a DI-105 (receipt for property form). If the park is unable to store the specimens, the park will choose a repository that abides by NPS standards. The CUPN curatorial specialist will then be responsible for

creating a loan agreement between the park and the repository as well as the final delivery of the specimens.

Literature Cited

National Park Service. 2007. Natural Resource Database Template Version 3.2 documentation. Natural Resource Program Center, Office of Inventory, Monitoring, and Evaluation, Fort Collins, CO.

Polk, R. 2011. NPS Museum Handbook, Part II. Archive Assesment: Vicksburg National Military Park. National Park Service Unpublished Report, Vicksburg, Mississippi.

SOP #7: Data Analysis

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 7 – Contents

Page

SOP 7 – Figures

Page

Overview

This SOP outlines the process for conducting analyses of cave cricket monitoring data collected during sampling bouts (i.e., one round of sampling at all 15 sampled cave entrances) at Mammoth Cave National Park (MACA). The data analyses can be broken into two steps. The first step is generating estimates of the total population size, and the population sizes of subsets such as by life stage or sex, for each entrance at each bout. These estimates can be calculated from the numbers of crickets intersected by each 10cm wide strip and by the more complicated computations based on the numbers of crickets in each cluster from strip adaptive cluster sampling (SACS). The second step of the analyses involves extracting information relevant to park planning and management from those the estimates of population sizes. This step includes presenting each sampling bout's estimates in the context of previous observations, environmental covariates (e.g., meteorology), infrequent tests for temporal trends in estimated population sizes, and comparisons of population sizes among entrances (e.g., between developed and undeveloped entrances) or temporal trends. Additional questions such as the distribution of cricket abundances as a function of their distance from the cave entrance (i.e., the surface) and differences in those distances between sexes or life stages, are part of this second step, but require accumulation of several years of data.

The computation of unbiased estimates of population size from these SACS designs is complex. Thus, it is implemented as R code that fetches the required data from the Access or SQL Server database, performs the several estimates, and writes out those results. The R code also produces simple figures appropriate for annual reports, illustrating the current bouts estimates in the context of previous estimates for each entrance.

R is an open source implementation of the S language for computing with data, available from the R Project for Statistical Computing. R can run on almost any computer architecture, with binaries available for MSwindows, Mac osX, and several flavors of linux and unix, but the source code is available for compiling for other systems. The core data manipulation, graphics, and statistical components were developed by a small group of academic statisticians. However, the power and utility of R is that it is designed to be extensible: additional functionality can be provided as add-on packages containing libraries of additional functions. When applied statisticians publish new techniques, they tend to provide implementations of their techniques as packages, so new techniques are often available in R long before they are implemented in commercial statistical packages. In addition, data analysts in many fields, from climatology, water quality, ecology and evolution, and agronomy, to finance, econometrics, machine learning, social sciences, and molecular and biomedical analyses, have all found the core data handling and graphics useful, built their field-specific applications in R to leverage that core and the ecosystem of other packages, and then made their field expertise and computational skills freely available as further packages (Smith 2010, McKinney et al. 2013).

For now, the R code used in this protocol is specific enough that it is included in the protocol but not provided as a full package (see Appendix G). If this protocol is implemented in other Inventory and Monitoring (I&M) networks, I&M networks implement strip adaptive cluster sampling in other protocols, and especially if unbiased bootstrap-based confidence intervals are developed for strip adaptive cluster sampling, this code may be developed into a full package.

General Workflow

Once the digital photographs have been analyzed, and the data entered into the Access database and run through QA/QC checks the project leader runs the R code that fetches the necessary data from the Access database, computes the estimates of population sizes, appends the estimates to a table in the Access database, and writes the estimates along with simple graphs into an MSword document template for use as the basis of annual reports. The project leader adds to the boilerplate information already incorporated into the template, inspects the tabular and graphical results, and writes the brief expert interpretation and summary.

When more than one year of data are available, a second set of R code will be added to perform the second step of analyses and reporting. This SOP includes descriptions of several of the envisioned analyses, to give an indication of the forms of status and trends that may be characterized, and to prevent changes to implementation of this protocol that might break the ability to perform those envisioned analyses before sufficient data are collected. These analyses will require somewhat more hands-on work by the project leader and perhaps collaboration with additional expertise.

Background

The data collected under this protocol's sampling design support both non-adaptive and adaptive estimates of the population totals. The non-adaptive estimates are based on only the number of crickets within each 10cm strip, not counting any nearby crickets that were included in the clusters but outside of that intersecting strip. The adaptive estimates are based on all crickets identified in each cluster, with corrections for the increased probability of the sample intersecting larger clusters. The SACS was designed to obtain more efficient estimates (narrower confidence intervals for a given effort) of the total entrance populations of cave crickets based on pilot data on their aggregations. However, while adaptive estimates are available for subpopulation totals (e.g., by life stage and sex), it is possible that those adaptive estimates will be less efficient (i.e., lower uncertainty about estimates for a given sampling effort) for some or all subpopulations than the non-adaptive estimates. Given that the only cost is separate tallying of individuals within the 10cm strip in each photograph, population totals are estimated via both methods.

Required Data Tables

These analyses are based on three data tables: one table with records for each strip, a second table with one record for each cluster intersected, and one table of which strips intersected which clusters. Because of the structure of the database, these tables are actually stored queries in Access or SQL server, combining data recorded on the field data sheets with data from analyzed digital photographs taken of each cluster.

The simple (non-adaptive) analyses based only on crickets within each 10cm strip requires a table of Entrance Name, Bout, GRTSn, Strip Position, Strip Status ("Used" or "Rejected"), and the total number of crickets found within that 10cm wide strip, with one row or record for each strip in each entrance and bout. Strips that are rejected in the field should also have records in this table, but with Status = "Rejected" and missing values for all dependent variables. This table may also have additional variables (columns) with counts within the 10cm strip separately by life stage, sex, species, or other subset. Strips that do not intersect any crickets also have records in this table, with 0s for the total number of crickets and for any additional subset counts.

The SACS estimates use the first 5 variables in the strip table, but also use a second separate table with one row for each cluster. This second table includes the variable columns Entrance Name, Bout, Cluster, proximal and distal extent [min and max coordinates (in meters) projected along the baseline], the total number of crickets detected in that cluster, and additional variables giving counts of crickets in the different subpopulations of interest (i.e., life stage and sex).

Non-adaptive Estimates of Population Size

The simplest estimates are based on only crickets found within the 10cm strips. Given that the sample frame had *N* possible 10cm wide strips, of which *n* were sampled, the naïve estimate of the population total is:

$$\frac{N}{n}\sum_{n}^{i=1} Y_i$$

This estimator has a simple variance estimator. But, because the strips were drawn as GRTS, there is also a neighborhood variance estimator (Stevens and Olsen 2003). If nearby strips tend to have more similar numbers of crickets than random pairs of strips (e.g., unimodal or declining abundances with distance from entrance), the neighborhood variance estimator will give a smaller variance and produce smaller confidence intervals about the estimated total. The local (neighborhood) variance estimates require the original R objects produced as part of the sample draw by the CaveSampleGen.R code, and written as shapefiles to a subdirectory given the Bout Name, e.g., May2014 (Appendix F). These non-adaptive estimates and their variances are computed by function strip_est() in CaveCricketAnalysis.R (Appendix F).

Adaptive Cluster Sampling Estimates

Estimators for the population total based on adaptive sampling must account for the bias introduced by the adaptive process, which explicitly increases sampling where larger numbers of targets are likely to be. The key for adaptive cluster sampling (ACS) is that as long as those unequal probabilities can be calculated then unbiased estimates for the population total can be computed. Several estimators of the population total can be applied to data from SACS designs, including Hansen-Hurwitz, Horvitz-Thompson, and Murthy estimators (Seber and Salehi 2012). Recent work on improved unbiased confidence intervals for ACS has utilized Murthy estimators but their logic is harder to grasp. While the applicability of Murthy estimators to ACS designs with other than simple random sampling of the initial units is recognized the actual computations for this design with GRTS draws of strips would be complicated. Therefore, this version of this protocol uses Horvitz-Thompson (H-T) estimators, which empirically have equal or greater efficiencies than Hansen-Hurwitz estimators.

H-T estimators of the population total are based on summing the values of the observed sample units, each weighted by dividing by the probability of that individual sample unit being included in the sample draw.

$$\widehat{\tau_{HT}} = \sum_{i=1}^{\nu} \frac{y_i}{\pi_i}$$

Where π_i is the inclusion probability for the *i*th sample unit. Note that if all units are included, π_i=1 for all units, and the estimate of the total is the sum of the *y* values. Similarly, for equal-probability sampling where all π_i are equal, this reduces to the sum of the observed values divided by the fraction of the population sampled.

For this SACS design, π_i is the probability that at least one strip would intersect the *i*th cluster of crickets, which is a function of the cluster's width along the baseline. If strips are drawn as a simple random sample this probability is a simple computation based on combinations of drawing *n* out of *N* possible strips without replacement, as each of the strip's inclusion is independent of that of the other strips. However, in this protocol, we use one dimensional GRTS to draw the strip locations to improve the spatial spread of the strips, so adjacent strips have a slightly lower probability of being included. The solution is to generate 1000000 draws by the same GRTS procedure, and estimate the inclusion probability π_i as the fraction of those random draws that included strip *i*.

The variance of the H-T estimator requires not only inclusion probabilities for each individual cluster π_i, but also joint inclusion probabilities π_{ij} for all pairs of clusters *i* and *j*. With independent random sample draws of strips, calculating π_{ij} is a rather complex calculation. However, we can use the same 1,000,000 additional GRTS draws required to estimate π_i to tally the fraction that include both *i* and *j* to estimate π_{ij}.

$$\widehat{Var(\tau_{HT})} = \sum_{i=1}^{\nu} \left(\frac{1-\pi_i}{\pi_i^2}\right) + \sum_{i=1}^{\nu} \sum_{j \neq i}^{\nu} \left(\frac{\pi_{ij} - \pi_i \pi_j}{\pi_i \pi_j}\right) \frac{y_i y_j}{\pi_{ij}}$$

Unfortunately, neither the normal approximation based on the variance of the estimator nor simple bootstrap estimates produce unbiased confidence intervals for the estimated total counts. This is an area of active research, with unbiased bootstrap estimators developed for simple ACS (Salehi et al. 2010, Mohammadi et al. 2014). We expect that one or both of these approaches will be extended to the case of SACS in the near future, at which time it will be added to the R code. These computations are performed in the function stripACS_est(), (Appendix F).

Estimates for Subpopulations

This protocol is designed to be informative about changes in the total numbers of cave crickets. However, the sampling allows for both non-adaptive and SACS estimates of counts of subsets of crickets. When the photographs are analyzed individuals that fall within each strip are counted by life stage and sex and these become the additional variables in the strip table. Further, counts of individuals that fall within each cluster are counted by life stage and sex and these become additional variables in the cluster table. While the SACS estimates of the total number of crickets are almost certain to have smaller variances than the non-adaptive estimates it is less likely to be the case for the life stage and sex subpopulations. For instance, if juveniles only occur as isolated individuals or in small clusters but not in (spatially) large clusters of crickets, the SACS estimates for juveniles could have larger variances than the non-adaptive estimates.

Analyses and Reporting

The biggest limitation for analyses of these data is that neither the developed nor undeveloped cave entrances selected for monitoring are a probability or otherwise explicitly representative sample from the set of all cave entrances at MACA. Therefore, no quantitative inferences can be made from the set of monitored cave entrances to the set of all cave entrances. Hypothesis or significance tests comparing cave entrances will be used judiciously. While a simple test of estimated cave cricket entrance population sizes between developed and undeveloped cave entrances might seem an obvious comparison, any such test is only about these particular cave entrances, not developed and undeveloped cave entrances in general in MACA. Rather, the logic is that if a pattern is observed in this set of monitored cave entrances, it may be worth managing resources as if that pattern is pervasive across many or all cave entrances.

The simplest presentation of the status of cave crickets in these cave entrances is a form of control chart. For each entrance, the estimated population size for the most recent sampling bout is plotted over a boxplot of the estimates from previous sampling bouts. This produces a visual representation of which, if any, of the monitored cave entrances have recent population estimates high or low relative to that cave entrance's historic range of variability. If some current values are high and some are low, there is cave entrance-specific fluctuation. If most cave entrances deviate in the same direction that suggests a region-wide driver such as surface weather or food sources (Figure SOP7-1). Rather than listing cave entrances in alphabetical order, they should be ordered by developed/undeveloped status and then size or geography (e.g., N versus S side of the river) within management status, so that horizontal patterns across cave entrances are informative. This control chart will be extended by stacking the same figure built for total crickets, juveniles, adults, males, females, and any other subsets, with the entrances aligned across charts. Additionally, if after several years there are clear seasonal patterns, the control charts can be generated separately by season (i.e., May-June, and October-November).

Once at least 4 or 5 years of data have been collected, the trend over time within each cave entrance is an appropriate context for the most recent estimates. For these figures, each cave entrance will be a separate panel on the page, with estimated count (Y) as a function of date (X) plotted within panels, and colors and symbols used to indicate season within year. If by then unbiased confidence intervals are available for the H-T estimates from SACS, those confidence intervals will be included in these figures.

Inferences about Population Estimates

The above caveats about nonrandom cave entrances notwithstanding, some analyses of the population estimates from the monitored cave entrances will be appropriate, notably estimates about temporal trends in cave entrance population sizes. There are two major issues to get right for such analyses, the proper structure of the model, and the appropriate error distribution to assume for the cave entrance population estimates. The difficulties with the structure of the model are due to the overall sampling design of repeated measures within a purpose-selected (i.e., nonprobabilistic) set of cave entrances. The difficulties with the appropriate error distribution would exist for complete census counts within each cave entrance (i.e., potential overdispersion, or the variance is larger than the mean, of Poisson distribution), but are complicated by the form of the cave entrance population estimates from SACS.

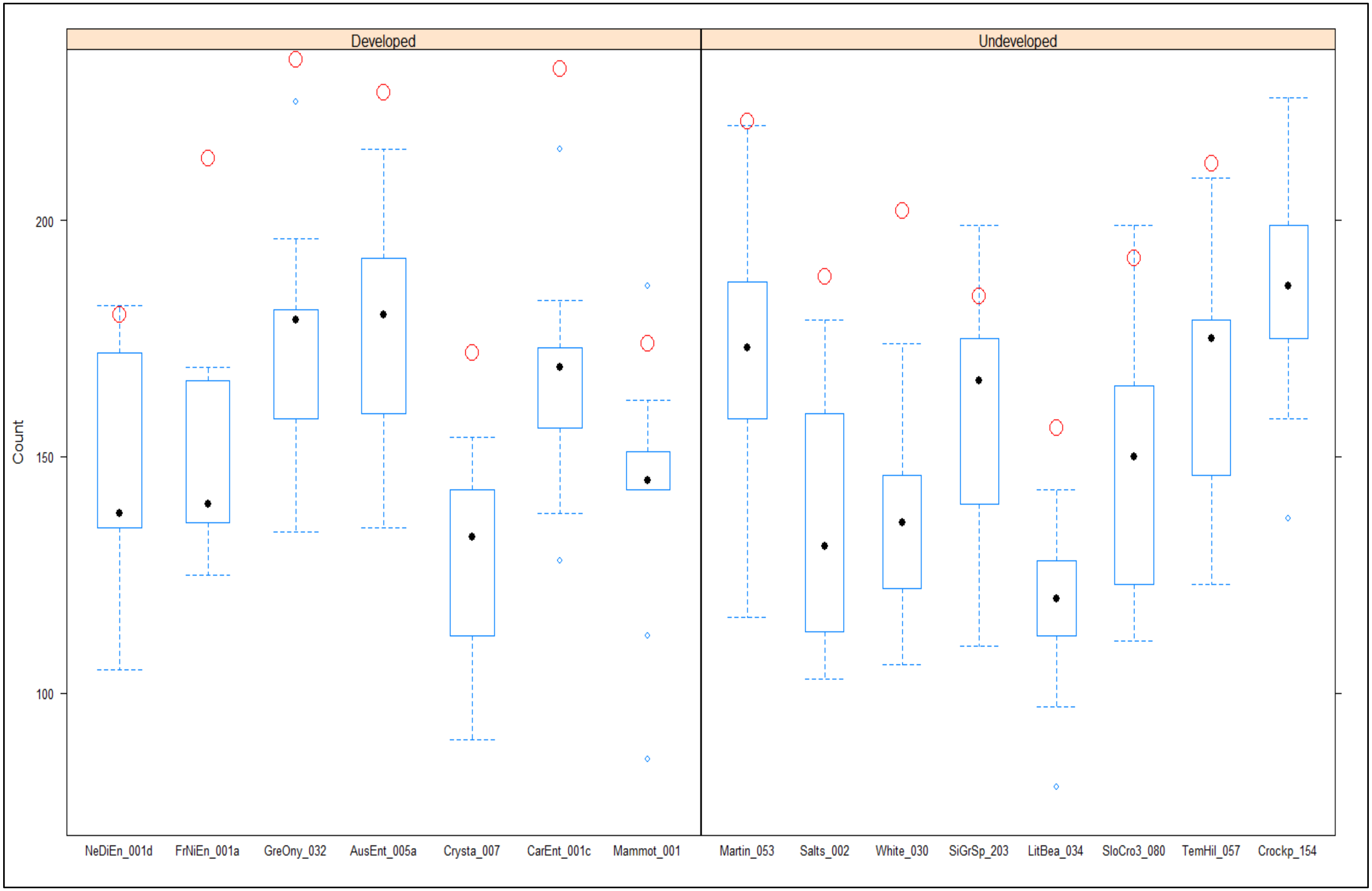

Figure SOP7-1. Mockup of control chart depicting ten years of estimates of monitored cave cricket entrance populations. The most recent sampling bout (red circles) are plotted over a boxplot of estimates from previous sampling bouts. Note: black dots indicate the median of the data and blue dots are outliers.

For almost any statistical models, the independent subjects are the 15 cave entrances. Developed versus undeveloped, location, size, adjacent vegetation, etc., are all among-subject effects or predictors. Dates (and strip positions) are repeated within-subject effects. Temperatures, recent precipitation, and other time-varying covariates may be either single measures across all cave entrances (e.g., previous week's precipitation) at each time or measured individually at each cave entrance (e.g., cave air temperature) at each time. The open question is whether cave entrances should be treated as fixed or random effects. Logically, cave entrances are fixed effects, as they are not random samples from a population of entrances, and inferences can only be made to the specific measured cave entrances, not to a larger population. However, in terms of the generalized linear mixed models (GLMM) approach to temporal trends in repeated measures, cave entrances would be random effects.

The lme4 approach to GLMM testing for trends in such a repeated measure design treats cave entrances as random effects: a sample from a larger population of entrances (Bates 2010, Bates et al. 2013). This approach fits an intercept and slope with time within each cave entrance then asks questions about the distribution of those slopes: is the mean of the distribution significantly different than 0? Do the distributions of slopes differ significantly between developed and undeveloped cave entrances? This approach makes inferences about the distributions of slopes (trends) for cave cricket entrance populations based on the sample. Time-varying covariates such as temperature or recent precipitation can be included in the model as fixed effects. The structure of the within-subject error covariance is irrelevant, as a linear slope is fit, and inferences are made about the (assumed normal) distributions of the slope estimates. The nlme approach (Pinheiro and Bates 2000, Pinheiro et al. 2013) allows specification of error covariance structure, but will not support specification of non-normal error distributions. According to Stroup (2014), PROC GLMMIX in SAS can fit a GLMM with structured error covariance and non-normal data. However, we do not have access to SAS, and thus do not know what the resulting output contains, nor what additional assumptions are required for their model. SAS is prohibitively expensive for I&M networks without academic affiliations (and of questionable legality for using an academic license for NPS I&M production work).

Given that entrances are fixed rather than random effects generalized estimating equations (GEE), which do not incorporate random effects, are applicable alternatives to GLMM, and may be the best option (Stroup 2014). Function geeglm() in package geepack can fit repeated measures models with structured error covariance within subjects (Højsgaard et al. 2006).

Below is the R code for each of the above approaches (untested as of this writing):

```
# lme4 approach with lmer/glmer
Mod4.1 <- lmer(PopEst ~ Season + Developed + Year + Developed:Year +

     (1+as.numeric(Bout)|Entrance), data=dsn)
# nlme approach with lme
ModL.1 <- lme(PopEst ~ Season + Developed + Year + Developed:Year,
data=dsn,
     Random=~Date|Entrance, correlation=corAR1(form=~
as.numeric(Bout)| Entrance))
# GEE approach with geeglm from package geepack
```

```
ModG.1 <- geeglm(PopEst ~ Season + Developed + Year + Developed:Year,
                                                  data=dsn,
id=Entrance, corstr='ar1')
```

The appropriate error distribution for the statistical analyses of cave entrance population sizes, requires careful consideration. Counts of crickets in the strips, the basis for the non-adaptive population estimates, follows an overdispersed Poisson distribution, with the overdispersion coming from the clumpiness or aggregation of the crickets, whether that aggregation is behavioral or due to good and bad roost habitat within entrances; varying area (length) of the strips will introduce even more overdispersion. Similarly, counts of crickets in clusters are likely to be overdispersed (i.e., variance across clusters > mean of clusters). While weighted sums of these counts should approach normality via the Central Limit Theorem it is not clear the resulting population estimates for each cave entrance and sampling bout will have normally-distributed errors. The asymmetry of true confidence intervals about those estimates, and difficulty in creating unbiased confidence intervals imply the estimates do not have fully normal error distributions. The question is whether the estimates are normal enough for GLMM or GEE. While it is plausible that the estimates of total population size may be normal enough, it is likely that estimates for subpopulations, with fewer non-zero observations and much lower means, will not be normal.

The two plausible distribution families to fit overdispersed count data are quasi-Poisson and negative binomial (Ver Hoef and Boveng 2007). While cave entrance population estimates may include fractional crickets, for the purpose of fitting non-normal error terms, they can be rounded to the nearest whole number of crickets, as these are estimates of population totals, not population densities. The third approach to GLMM for overdispersed counts, individual-level random effects, might work, but it is not clear how that would apply when the variation among entrances cannot be assumed to be normal.

For complicated reasons, the negative binomial distribution is available in the lme4 approach to GLMM via glmer.nb(), and the quasiPoisson approach is available in GEE in geeglm():

```
# lme4 approach with glmer version for negative binomial
Mod4.nb <- glmer.nb(PopEst ~ Season + Developed + Year +
Developed:Year +
      (1+as.numeric(Bout)|Entrance), data=dsn, verbose=TRUE)
# GEE approach with geeglm from package geepack and quasiPoisson
ModG.qp <- geeglm(PopEst ~ Season + Developed + Year + Developed:Year,
                                                  data=dsn,
family=quasipoisson, id=Entrance, corstr='ar1')
```

Note from the secondary analyses below that temporal trends in the SACS estimates of cave entrance population sizes can be partitioned into components of numbers of clusters and the size distribution of clusters. The above repeated measures analyses of the population estimates may be repeated separately for trends in counts of clusters (Poisson counts, possibly not overdispersed) and in numbers of crickets per cluster (also Poisson but likely to be overdispersed). Note that analyses of the numbers of crickets per cluster require weighting of clusters by InvWidth (see below).

Secondary Analyses of Estimates

Cave cricket entrance population size, even subdivided by sex or life stage, is only one aspect of the status of cave crickets. Other aspects of the crickets may also be important, and might potentially provide earlier warning of changes or impacts than pure numeric responses. Other metrics may have little or no direct management relevance, but are unknown aspects of cave cricket ecology. Care was taken to ensure that data from this sampling design can be used to estimate these other aspects, even though the design was optimized for estimates of total population size. However, because the cluster data are from an unequal probability design, most of these analyses require inclusion of weightings to account for the unequal inclusion probabilities.

Distribution of Cluster Sizes

ACS naturally partitions variation or change in total cave entrance population into components of the number of clusters and the numbers of crickets per cluster. In other situations that partitioning is informative about recruitment and mortality processes driving trends. In the case of cave crickets, where factors affecting population dynamics are likely to occur at locations other than roosting areas, this partitioning is more likely to reflect cricket responses to roosting density than any causal factors. The only complication is that clusters do not have equal probabilities of being included in the sample but rather inclusion probabilities proportional to their broadest width along the baseline. Therefore, any characterization of the distribution of numbers of crickets in clusters (e.g., mean number, variance in numbers, kernel density estimate of the probability distribution) must include weighting by the reciprocal of the cluster widths. These distributions can be characterized from data pooled across entrances and dates, or characterized separately by season or entrances, and then compared:

```
ClusterSizeDist <- density(~ Count, data=Clusters, weights=InvWidth)
```

Differences in estimated total cave entrance population sizes can be partitioned into differences in numbers of clusters versus differences in crickets per cluster.

Distribution of Crickets with Distance from the Surface

Because crickets leave the cave to forage and temperature fluctuations are greater near the opening to the surface than deeper into the cave, the roosting distance from the opening to aboveground is likely to be important for cricket ecology. Further, these distances may vary with changing cave meteorology or entrance management. Therefore, the distribution of cave cricket cluster sizes as functions of distances from the surface are worth estimating and testing for shifts over time (Figure SOP7-2). Each entrance will have a different distribution of surface area or roosting habitat as functions of distance from the opening, so data cannot be pooled or compared across entrances.

Using SACS, not all distances on the baseline are sampled, so many distances have no crickets recorded because no strips were sampled at that distance. Therefore, these distributions cannot be computed as kernel density functions. Instead, they need to be estimates as loess or other smooth functions through the observed counts of crickets at the sampled distances. However, non-adaptive counts within the 10cm strips can be fit as simple loess functions separately for each entrance:

```
for (E in EntranceList) assign(paste("CricketDistances.",E ,sep=''),
                loess(Count ~ BaselineDistance, data=Strips))
```

Confidence bands for these distributions will be obtained from bootstrapping the strips, and optimal smoothing will be determined by boostrap crossvalidation. These distributions are likely to be poorly estimated by data from individual bouts, but rather will require pooling data from on the order of 4-5 bouts to stabilize. That implies that after 5 or so years, separate estimates can be made for spring versus fall sampling for each entrance, and compared to test for a systematic seasonal shift in how deep into the cave the crickets roost. As with other measures these distributions can also be estimated for each subpopulation: juveniles, adults, males, females, etc. To test for differences in these distributions they will be compared as paired tests within each entrance.

Unfortunately, the counts of crickets by clusters cannot produce unbiased estimates of the distribution of crickets with distance. The additional information from the crickets not in the original strip but adaptively added to the cluster only sets minimum values for the numbers of crickets at those distances, as there could be other crickets elsewhere in those unsampled distances offset far enough to not be included in the cluster and thus not counted. The strength of this bias will be assessed by the fraction of strips that intersect more than one cluster: the lower that fraction, the smaller this bias would be. If few strips intersect crickets, so that the strip-only estimates are poorly characterized, this bias will also be small and so biased estimates might prove useful. In this case, care will be taken to both spread the count out over the width of the cluster, and also correct for the increased inclusion probability of wider clusters. For a cluster of *N* crickets and width *X* (in m), the count can be spread over the *n*Strip <- ceiling(*X*/10) overlapped strips by creating a value of *N*10 <- *N*/*n*Strip for each of the *n*Strip 10cm distances. These are still more likely to be included in the adaptive sample than individual crickets or small clusters, which must be accounted for via weights. For each cluster, compute InvWidth <- 1/nStrip, then include it in the loess model:

```
for (E in EntranceList) assign(paste(“CricketDistances.”,E ,sep=’’),
                loess(N10~ BaselineDistance,
                weights=InvWidth,data=Clusters))
```

Segregation among Subpopulations

The data from this sampling design will also address questions about segregation among subpopulations of cave crickets. Not just location of cluster, but cluster size, positive or negative associations across clusters of counts of different subpopulations. The sex ratio or demographic composition of clusters can be tested as functions of cluster sizes or cluster distance from the surface, as binomial (or multinomial) responses predicted by cluster size or distance. In this case, because different entrances may have different sex ratios or life stage structure, entrance should be included in the model as a fixed effect, with contrasts used to compare between developed and undeveloped entrances:

```
glm(cbind(Males,Females)~Count*Entrance,data=Clusters,weights=InvWidth
)
glm(cbind(Males,Females)~BaselineDistance*Entrance,data=Clusters,weigh
ts=InvWidth)
```

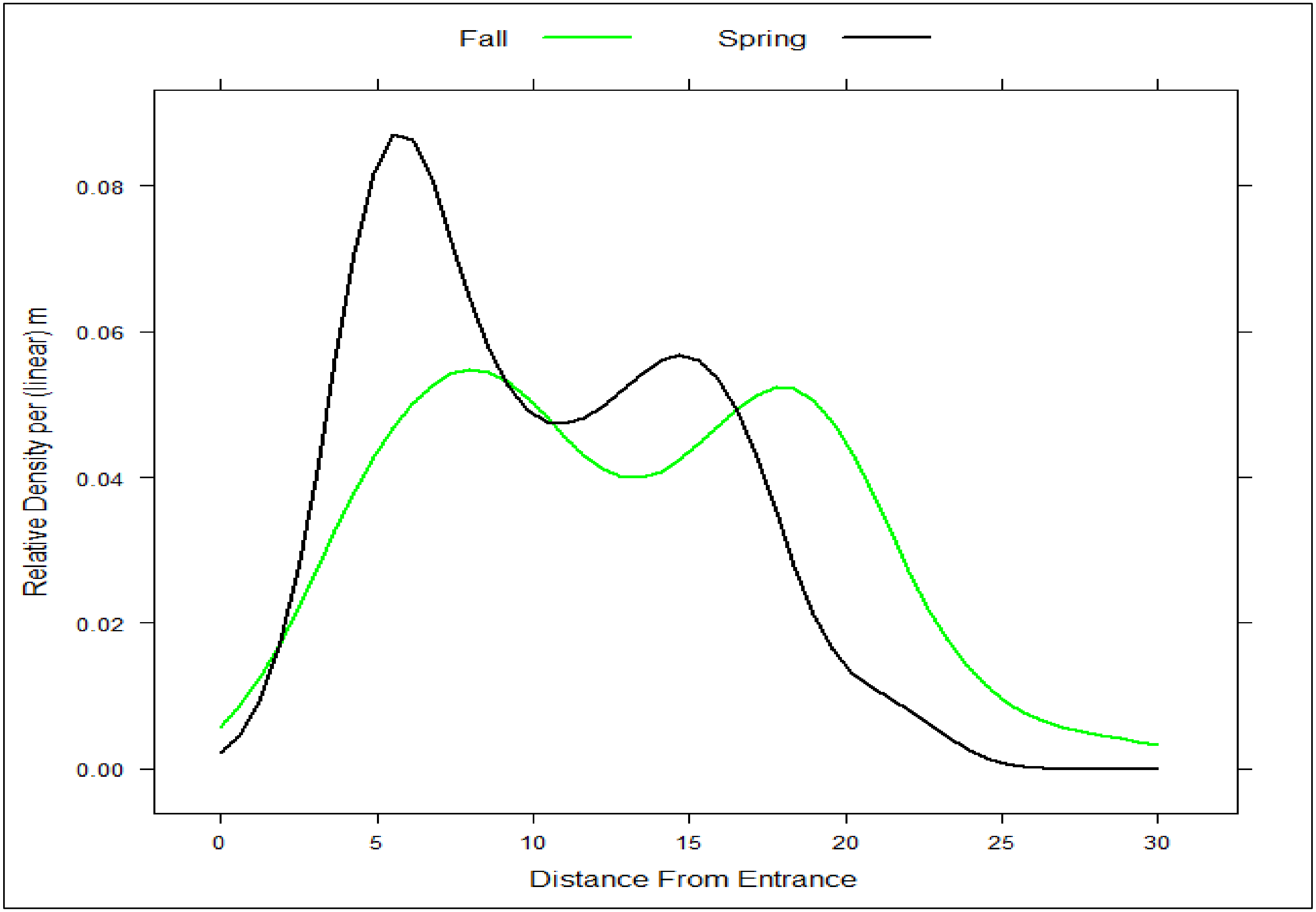

Figure SOP7-2. Mockup of density plot showing the proportion of cave cricket entrance population as a function of distance from the cave entrance over five years of sampling. Note the change in bimodal distribution from spring (black curve) to fall (green curve).

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SOP #8: Reporting

Cave Cricket Monitoring Protocol
Cumberland Piedmont Network
Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

SOP 8 – Contents

Page

SOP 8 – Figures

Page

SOP 8 – Tables

Page

Overview

This SOP gives step-by-step instructions for reporting on cave cricket population structure and dynamics monitoring data collected among developed and undeveloped caves at Mammoth Cave National Park (MACA). The SOP describes the process for generating the three types of reports which will be produced from this monitoring protocol: 1) Trip Reports, 2) Annual Status Reports, and 3) Trend Analysis Reports. Trip reports will be written to briefly summarize sampling trips for MACA staff. The annual status reports and trend analysis reports will be generated to provide MACA management and other interested parties technical and interpretive information about the status and trends being detected in cave cricket entrance populations and associated cave meteorological parameters. The schedule and format for each report type, as well as reporting responsibilities is discussed below. Efficient reporting on monitoring results is critical in assisting park resource managers in management decisions. Therefore, a reporting schedule is given with critical dates identified. Timely production of appropriate reports is the responsibility of the project leader. Further, timely reporting will be made considerably easier through the use of 'reproducible reporting' (i.e., automated reporting), using the R statistical and graphical environment, to produce annual status reports and trend reports. While data, analyses, and interpretation resulting from the implementation of this monitoring protocol will be circulated among many different venues [e.g., Cumberland Piedmont Network (CUPN) Annual Administrative Report, oral presentations, journal articles, website, etc.] only trip reports and Natural Resource Publications are covered hereafter in this SOP.

Publications Generated

Brief Trip Reports will be written to summarize sampling trips for MACA staff and will include important observations such as signs of human disturbance in/at caves. These reports should be completed within two weeks after each sampling trip. Trip reports will be sent directly to the official MACA resources management contact. The two Natural Resource Publications will be generated to provide technical and interpretive information regarding the status and trends detected in the monitored resource to park management among other interested parties. First, the Natural Resource Data Series (NRDS) is basically an annual status report which is intended for a quick release of accurate, raw data without a thorough statistical analysis and interpretive component. NRDS will present cumulative data in a graphic format reflecting observed trends in data. The purpose of this component is to provide park managers and other viewers with a visual portrayal of resource status over time; where inspection of trends graphics will support easy detection of large and rapid changes in resource condition.

Table SOP8-1. Proposed reporting schedule for the Natural Resource Publications report series to be generated as a result of cave cricket monitoring.

Report Element	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural Resource Data Series	X	X	X	X	X	X	X	X	X
Natural Resource Technical Report						X			

Second, the Natural Resource Technical Report (NRTR) will be produced on a 5-year schedule and are the comprehensive series in which current and all previous multiple year analyses, in both graphic and tabular statistical test summary formats, interpretive discussion, and, if appropriate, management recommendations for action by park management are included (Table SOP8-1).

Regular reporting will be the responsibility of the project leader, working in collaboration with the physical scientist and data manager. Preparation of the quantitative elements for all reports will be the responsibility of the project leader working in collaboration with appropriate staff. Interpretative and explanatory content for all reports will be provided by the project leader, who is also responsible for the final assembly, formatting, and disposition of reports. According to the "SER Guidance and Standards for Inventory & Monitoring Peer Review Management" plan, implemented in August 2012, the CUPN Program Manager will oversee internal review, follow the procedure described below, and is responsible for forwarding reports to the official MACA resources management contact and other stakeholders.

Review guidance requires the following:

1. Annual or periodic monitoring reports submitted to the NRDS may be internally reviewed and submitted for publication directly by the network, regardless of authorship, if the reports meet the following criteria:

    a. The monitoring report must be based on an approved peer reviewed protocol.

    b. The report should include enough content on purpose and methods so it is not necessary to read the monitoring protocol (or other primary documentation) to understand how or why the data were collected.

    c. Highlighting of data is encouraged, especially in summary sections. Highlights and reported results should be limited to statements of fact and presentation of data, and not include explanations or interpretations of trends, relationships to factors not measured as part of the protocol, or explanations of observations based on speculation or interpretation of factors beyond the scope of the protocol.

    d. Implementation recommendations may be suitable for the NRDS but more likely will be published in an NRTR report accompanied by additional discussion.

2. Peer review for periodic monitoring reports with greater analysis, interpretation, and/or management implications, such as the NRTR series, require additional review but can be developed by the Network Program Manager (NPM) as long as the NPM is not an author. Further, the following guidance is also associated with the NRTR series report:

a. Report organization generally follows the "Introduction-Methods-Results-Discussion-Conclusion" model.

b. Monitoring reports should follow recommendations in the protocol regarding the scope and content for status and trends data analysis and reporting.

c. The report should include enough content on purpose and methods so it is not necessary to read the monitoring protocol (or other primary documentation) to understand how or why the data were collected.

d. While these are typically longer documents than data series reports, strive for readability and succinct summarization. Use appendices when appropriate.

e. Analyses related to implementation of field work and subsequent recommendations may be discussed.

f. Interpretation of data is valuable and management implications may be appropriate; however, these will require an appropriate level of scientific, administrative, policy, and possibly legal review (e.g., by parks, T&E specialists, the DOI Solicitor, and other appropriate reviewers at the regional or national levels).

3. A brief (2-3 paragraphs) summary of sampling activities, preliminary results, and any public interest highlights that occurred during each federal fiscal year will be written for inclusion in the CUPN monitoring program's Annual Administrative Report.

Report Format and Construction

Periodical reports on the results of monitoring activities will be drafted following the guidelines provided on the "Natural Resource Publications Management Report Submission Procedures" website:

http://www.nature.nps.gov/publications/nrpm/procedure.cfm (accessed 1 April 2014)

Reports should be direct and concise, avoid superfluous wording. Refer to CBE Style Manual (1994) or Writing with Precision, Clarity and Economy (Mack 1986) for aids in writing. Also see Strunk and White (1999) and "Notes on Writing Papers and Theses" (Lertzman 1995) for help in structuring sentences and paragraphs for clarity.

Reproducible Reporting Using R

With some initial time investment writing MS Word™ report templates and inserting R code the automated generation of Natural Resource Publications in both series is possible (i.e., 'Reproducible Reporting'). Following the creation of template master reports within the Natural Resource Publication Management (NRPM) series, format updated annual NRDS reports and 5-year NRTR reports for this protocol will be produced using the R package "R2wd" (Ritter 2012). In "R2wd" the R code specifying objects produced with R (e.g., figures and dates) are inserted as bookmarks into the master report. This master report will consist of a document with headers, formatting, boilerplate text (e.g., background, methods, etc.) and bookmarked R code to produce the desired tables and figures (Figure SOP8-1). For consistency between/among report intervals all of the formatting, boilerplate background text, and types of tables and figures will remain the same year after year. The R code will be able to fetch the required data from the MS Access™ or SQL Server database to produce informative tables and figures. In subsequent years, as new monitoring data are appended to the database, previous versions of the R objects embedded in the old report are replaced in favor of the new, re-computed versions, and the core of the updated report is generated. The final step in the production of updated reports is to include revised or augmented interpretation and summary based on the new results. Thus, the use of 'Reproducible Reporting' will greatly reduce the time and effort normally dedicated to report writing. This scripting of workflow will provide documentation, automation, and make the work reproducible from one year to the next. 'Reproducible Reporting' is covered in greater depth in the "Using R Statistical and Graphics Tools for Natural Resource Stewardship Science" series of web pages written by Tom Philippi under "Advanced R Topics" here:

http://science.nature.nps.gov/im/datamgmt/statistics/r/advanced/ReproducibleReporting.cfm (accessed 1 April 2014)

More information on "R2wd" can be found here:

http://cran.r-project.org/web/packages/R2wd/R2wd.pdf (accessed 1 April 2014)

```
#####################################################
# BubblePlot Code
Fig1<-xyplot(Y~BaselineDistm,groups=Cave,data=SACS.Clusters,
          aspect="iso",
          ylab="Distance from Baseline (m)",
          xlab="Distance from Cave Entrance (m)",
          cex=sqrt(SACS.Clusters$ClusterSize)/4,
          auto.key=list(space="bottom",columns=3))

# Insert Figure 1
wdGoToBookmark("Fig1")
wdPlot(Fig1)
```

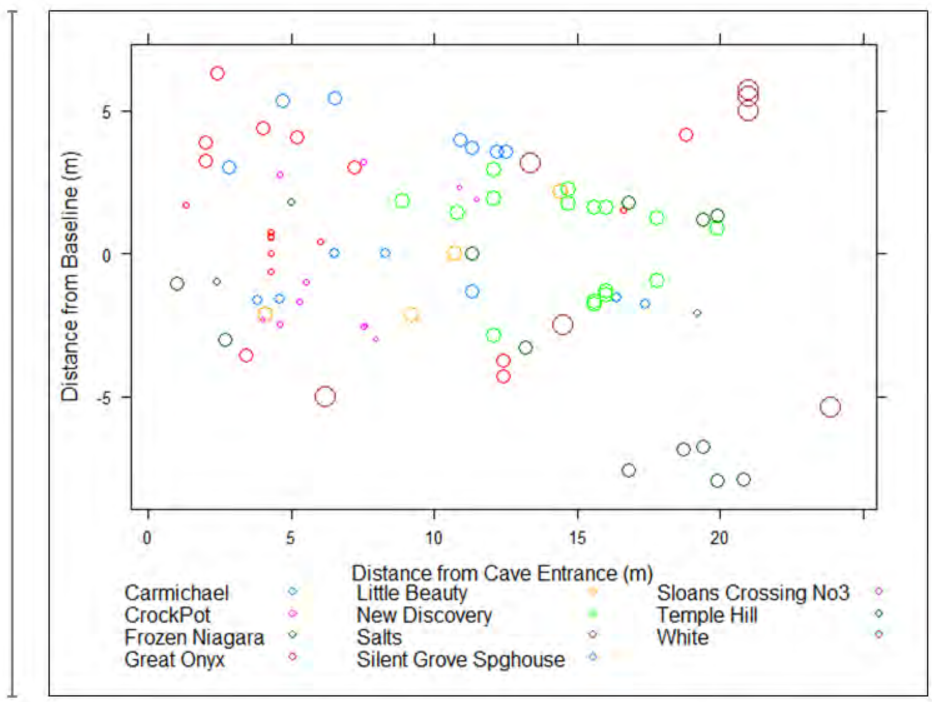


Figure 1. Proportionally sized bubble plot of cave cricket clusters. The y-axis is the cluster's distance from the baseline and side of the passage on which they were located (positive = left and negative = right). The x-axis is the cluster's distance from the cave entrance. The R code was written by Tom Philippi.

Figure SOP8-1. Example of R code (top) used to generate a bubbleplot and insert it at its designated bookmark in the master report (bottom). Note graph is offset slightly to show bookmark to left.

Natural Resource Condition Summary Table

The Annual Status Report will contain a Natural Resource Condition Summary Table intended to provide a snapshot assessment of the status and trend in the condition of MACA's cave cricket entrance population. Reference conditions that represent "healthy" ecosystem parameters, and regulatory standards (such as those related to air or water quality) provide the rationale to describe current resource status. In the absence of regulatory standards for cave cricket entrance populations we will use a combination of collected data, models, and expert opinion from literature and personnel to interpret key measures and choose reference conditions for each measure that assign ratings for cave cricket entrance populations at MACA. We will follow the three ratings used by the NPS national Vital Signs rating system, Good, Caution, and Significant Concern. "Good" represents acceptable or desired conditions; "Caution" indicates a problem may exist; "Significant concern" indicates undesired conditions in need of management correction.

The Status and Trend symbols used in the summary table below (Table SOP8-2) are summarized in the following key. The background color represents the current condition status, the direction of the arrow summarizes the trend in condition, and the thickness of the outside line represents the degree of confidence in the assessment. Table SOP8-3 contains an example (at MACA) of what the Natural Resource Condition Summary Table might look like in an annual summary report for this monitoring protocol. The number of rows could be expanded to add more species for which data are available.

Table SOP8-2. Symbols used in the National Park Service's Natural Resource Condition Summary Table.

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low

Report Preparation, Review, and Submission Procedure

Most of the following, current at the writing of this protocol, was copied from the Natural Resource Publication Management web page:

http://www.nature.nps.gov/publications/nrpm/procedure.cfm (accessed 1 April, 2014)

Some amendments were added to reflect CUPN-specific information.

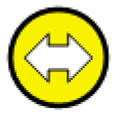
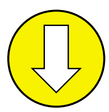
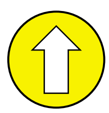
1. The national report series is recommended given the utility of reporting on the results of monitoring cave organisms to other cave and karst parks in the national park system.

2. The point at which the protocol leader finds themselves in the reporting schedule they should, in most cases, determine whether the manuscript is better suited for the NRTR, NRR, or NRDS report series.

3. Select the format to use to publish the report (basic MS Word™ or the more polished Adobe InDesign format). Click here for help

4. Click here to download the appropriate document template and the mandatory NRPM Manuscript Submittal Form and Checklist (MSF).

Table SOP8-3. Example of a Natural Resource Condition Summary Table to include in an annual summary report for monitoring cave crickets at Mammoth Cave National Park.

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Wildlife Communities	Cave Crickets	Entrance Population Size Estimate		Nonexceedance of the +/- 2 S.D. control limits suggests the increase in New Discovery's entrance population is not significantly large relative to previously observed natural variation.	Maintain current entrance population size.	
Wildlife Communities	Cave Crickets	Ratio of adult to juvenile cave crickets.		Ratio of adult to juvenile cave crickets in New Discovery decreased to 0.95 relative to previous sampling seasons.	Ratio of 1.0 or lower indicative of source population; New Discovery typically classified as source population (Poulson et al. 2001).	
Wildlife Communities	Cave Crickets	Mean cluster size		Mean size of clusters of roosting cave crickets increased to 55.2 over previous sampling seasons suggests entrance population increased.	35.5 cave crickets per cluster (mean cluster size from 2008-2012)	

a. The document templates provide software-specific manuscript format examples and user guidance in accordance with NRPM policy as outlined in the Instructions to Authors Manual Version 3.1. A vast majority of authors and editors do not need to download the manual.

b. The MSF includes all of the instructions needed to peer review and submit your report for final publication.

5. Prepare the manuscript using the style standards provided in the template.

6. As of 8/12/2012, the Peer Review Manager for the CUPN is Southeast Regional Inventory and Monitoring Division Chief.

7. Fill in the first section of the MSF form, and submit it and the draft manuscript to the Peer Review Manger to begin the final peer review of your report.

8. The Peer Review Manager works with the person submitting the report to edit and update the report to meet the Peer Review Manager's standards.

a. The end product of the final peer review should be an absolute final draft of the report that is ready for immediate publication. The only edits that should take place after this point are:

i. Minor edits to correct things like typos and minor grammar issues.

ii. The changes required by the Fort Collins Natural Resource Stewardship and Science (NRSS) office during the final publication policy review outlined in the steps below

b. The Peer Review Manager also makes sure that the first and second sections of the MSF form are filled out correctly.

c. Click here to see a list of NPS Peer Review Manager responsibilities.

9. After the peer review comments have been addressed, the person submitting the report, in this case the Peer Review Manager, sends the final draft of the peer-reviewed report (in either MS Word™ or Adobe PDF format), along with the MSF form, to the Fort Collins NRSS office for the final publication policy review.

a. If the final draft was created using:

i. MS Word™ - the actual file(s) that make up the final draft is preferred (vast majority of reports). This will save everyone involved time and effort during the final review. Publishing in MS Word™ can be tricky, and we often need to see the actual files to figure out what may be wrong, and the best/fastest way to fix things.

ii. Adobe InDesign™ - the PDF version is preferred. Adobe InDesign™ files are much more stable and predictable than MS Word™ files, and we almost never need to see the actual Adobe InDesign™ files to explain how to fix something.

b. The final draft of the report and MSF can be sent to the Fort Collins office by:

i. Using an online file sharing site (FTP, SharePoint, etc.). This is the preferred method, especially if the final draft of the report is more than 5 MB in size.

ii. Attached to an email.

- There is a 20 MB file size limit for NPS employees and a 10 MB limit for everyone else.

- Sending files by email sometimes requires multiple attempts.

10. The NRSS office reviews the final report for policy issues and software bugs, assigns new NRPM and NPS Technical Information Center (TIC) numbers to the report, handles all of the NPS-mandated records keeping tasks, and sends all pertinent information back to the person submitting the report to finish it and upload it to the IRMA online library (NPS Data Store) for online distribution digital archiving.

a. Reviews the final draft for publication policy issues (official NPS disclaimer and copyright language, report series and NPS graphic identity standards, NPS-approved fonts, etc.)

   i. Identifies and fixes any known software bugs that would cause MS Word™ files to export incorrectly to Adobe PDF format.

   ii. Looks for and notes any publication policy elements that still need to be fixed (both MS Word™ and PDF reports) (only policy issues - not main report language, graphics, etc.).

b. Assigns the next available NRTR, NRR, or NRDS report number in that series to the new report.

c. Creates a draft reference in the NPS Data Store.

d. Obtains the TIC reference number for that report (a new NRTR, NRR, or NRDS report number is required to obtain a new TIC number, and the number that we give them is permanently archived in the TIC system).

e. Sends all pertinent information back to the person submitting the report to finish and upload the final PDF to the NPS Data Store.

11. The person submitting the report works with the Fort Collins office to incorporate any **absolute final** updates to the report.

12. The person submitting the report activates (makes public) the draft NPS Data Store record created for them by the Fort Collins office, and uploads the final Adobe PDF to that same NPS Data Store record (mandatory for all NRPM reports).

Literature Cited

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SOP #9: Revising the Protocol

Cave Cricket Monitoring Protocol

Cumberland Piedmont Network

Version 1.0 (May 2014)

Revision History Log:

Previous Version #	Date	Revised by	Changes	New Version #
1.0				

Overview

This Standard Operating Procedure explains how to make changes to the Cave Cricket monitoring Protocol Narrative for Mammoth Cave National Park (MACA) and accompanying SOPs, and how to track these changes. Any changes in the Cave Cricket monitoring protocol will adhere to the guidelines contained in this SOP. Reviewers tasked with editing the Protocol Narrative or any one of the SOPs need to follow this outlined procedure in order to eliminate confusion in how data are collected and analyzed. All observers should be familiar with this SOP in order to identify and use the most current methodologies, and should see the revision history log attached to each SOP.

1. The Cave Cricket Monitoring Protocol Narrative for Mammoth Cave National Park and accompanying SOPs have attempted to incorporate the soundest methodologies for collecting and analyzing data. However, all protocols, regardless of how sound, require editing as new and different information becomes available. Required edits should be made in a timely manner and appropriate reviews undertaken.

2. All edits require review for clarity and technical soundness. Oversight of the revision process for all protocols is the responsibility of the I&M Regional Program Manager (RPM). When a potential modification to a protocol is identified, the project leader consults with the CUPN Monitoring Program Leader (MPL), who then decides whether the change should be considered “small” or “significant”. Small changes or additions to existing methods will be reviewed in-house by CUPN staff designated by the MPL. However, if a substantial change is sought, such as a significant change in data collection methods, then the RPM coordinates the outside review that may be required. Reviewers will be selected based on the type of change (i.e., changes in sampling sites versus changes in sampling design or sampling analysis). Regional and national staff of the National Park Service, as well as the U.S. Geological Survey-Biological Resource Discipline, with familiarity in ecological research and data analysis could be utilized as reviewers. Also, experts in cave invertebrate monitoring, research, and statistical methodologies outside of the National Park Service will be utilized in the review process, as needed.

3. Edits and protocol versioning must be documented in the Revision History Log that accompanies the Protocol Narrative and each SOP. Log changes in the Protocol Narrative or

SOP being edited only. Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures included in the protocol.

4. Proposed changes, depending upon their magnitude and nature, could have significant implications for data management. The database may have to be edited by the data manager to accompany changes in the Protocol Narrative and SOPs. Thus the data manager must be consulted prior to implementing changes to protocols. Immediately after the changes to the Protocol Narrative or SOPs have been made, the data manager will be notified, so the new version number can be incorporated in the metadata of the project database.

5. New versions will be posted on the Internet and in the “Narratives” or “SOP” subfolder for the project. Copies will be forwarded to all individuals with a previous version of the effected Protocol Narrative or SOP. A copy of each previous version will be archived in the MACA curatorial facility.

Appendix A: Vetting potential monitoring caves

Data mining

MACA possesses an extant, searchable computer database with information on the caves within its boundaries (Figure 1). Were the data contained in paper files the process would be slowed somewhat but the search criteria still apply. The following criteria may be considered more or less a sequential winnowing process to produce a short list of potential monitoring caves prior to field vetting.

1. We performed an initial keyword search for files that contained the word “cave crickets” which greatly reduced the number of files we examined closely. We examined the resultant files for any description of relative abundance of cave crickets and used this as part of our decision matrix as to whether or not a particular cave would be included in monitoring.

2. We examined the file’s notes regarding ease of access to the cave. If getting to the cave is particularly arduous it was included only if there is no alternative. Further, caves requiring technical caving skills (e.g., rope climbing) or tight spots that would complicate rescue were rejected.

3. We consulted park maps to determine cave location with respect to the starting point of the monitoring team (i.e., office). Location of the cave with respect to the CUPN office was an important criterion we considered beforehand because it determines driving and/or walking distance. Travel time to and from the caves have a large effect on the amount of time monitoring crews spend in the field. GPS coordinates, if available from the file, were downloaded into a GPS unit to facilitate finding the cave.

Field vetting potential monitoring caves

While this section assumes some information was gained from data mining, many of the same criteria used in the pre-vetting process are mentioned below. Often field notes on a cave’s file were vague and so there was value to field confirmation of the information we gained during the data mining process. Field vetting at MACA was particularly useful when notes from the database suggested a cave was marginally promising. We used the following criteria as more or less a sequential winnowing process to produce a short list of potential of caves to monitor at MACA and subsequently include in the scoring process. We created standardized data sheets for the field vetting process (Appendix B).

1. We recorded travel times from base, including drive time/walking time on the field data sheet. Walking time was an important criterion due to its potential to significantly increase time in the field. Potential monitoring caves were scored accordingly if walking time added significantly to travel time. While determining what constitutes a long walk can be subjective, the rule of thumb we used at MACA was a walk >15 min, all things being equal, often resulted in rejection of a potential monitoring cave.

2. We noted ease of access, safety hazards, and sensitive resources on the field data sheet. Safety was an especially important criterion and any major safety concerns about a potential monitoring cave at MACA resulted in its rejection from the list.

3. Cave morphology such as ceiling height and relief was also carefully noted and measured where possible. We considered ceiling height and relief during field vetting because high and/or complex ceilings can significantly reduce accuracy and precision of monitoring data.

Ceiling height was an important criterion we considered in ease of discerning cricket abundance, sex, and life stage. Low ceiling relief was also an important criterion because crickets may hide in pockets of complex cave ceilings. We noted areas of high and/or low ceiling relief on the cave data sheet and also consulted profiles contained in extant cave maps when possible.

4. The relative abundance of cave crickets in a potential monitoring cave was a significant criterion we noted in the field vetting process. We recorded notes on relative abundance of clusters and ratios of juvenile to adult crickets on field vetting data sheets and cave maps. Cave maps were a useful part of field equipment in this part of the field vetting process. We annotated cave maps, in pencil, where clusters of cave crickets and their guano deposits were found. Guano deposits are particularly informative in determining where cave crickets regularly roost because roosts must be used over time to build guano deposits whereas clusters of cave crickets can be transient as they cycle to and from the cave entrance. We used a qualitative/quantitative method to indicate relative abundance of cricket clusters on the map (i.e., circles of increasing size and/or abundance count) to facilitate scoring among caves during the Monitoring Cave Rating Process.

5. Extant monitoring occurring at cave.

Monitoring Cave Rating Process:

We ranked prospective monitoring caves at MACA from best to worst according to the criteria evaluated in the field vetting process. The ranking process involved assigning each criterion a weighted numerical value and using the sums of these values to rank the caves. The weights assigned to each criterion in the rating process reflected their importance in obtaining adequate data during the sampling process. The semi-quantitative data on cave cricket abundance/population structure and cave ceiling height/relief obtained during the vetting process was weighted more heavily in the rating process than trip time and ease of access; this is because we eliminated the farthest, most difficult to access caves during the field vetting process. The cave entrance with the highest summed value was ranked the best prospective monitoring cave and the rankings decrease sequentially from there. The list we generated from the rating process provided us with defensible reasons why lower ranked caves were excluded from our proposed sampling plan.

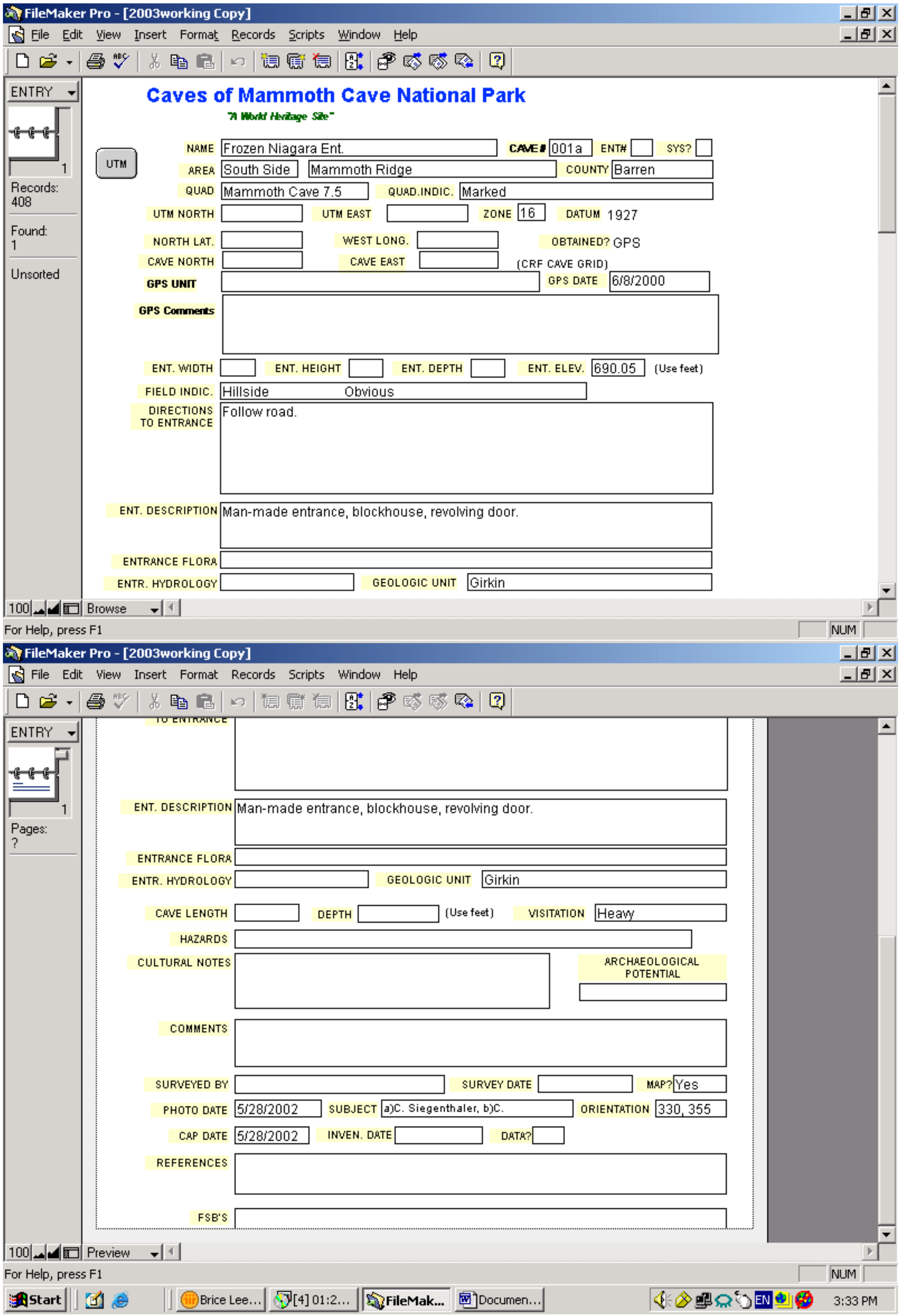


Figure A-1. Example of Cave File Data Form. Note searchable categories pertinent to sampling frame constraints (e.g., Hazards) and Field Information Sheets (e.g., Directions to Entrance).

Appendix B. Example of Cave Vetting Field Data Sheet

Cave Characteristics for Cave Cricket Monitoring

Cave name and GPS coordinates:
Travel time: Drive______ Hike______
Ease of access:

SURFACE HABITAT:
Cave entrance aspect:

Vegetation notes (e.g., common names and/or types)

Forest characteristics: (e.g., open or thick undergrowth)

SUBSURFACE HABITAT:
Estimate relative # crickets:

Estimate mix of adults v. juveniles:

Evident clusters of crickets? Guano deposits in places with/without clusters? Shoot photos and record image numbers.

Cave Ceiling Width/Height (measure or estimate) in cricket cluster areas. Give estimation of ease of sampling in this cave. Draw rough x-section or shoot photos and record image numbers.

Cave Length (if easily measurable)

Notes:

Appendix C. Cave Rating Example

Rating system for MACA field vetted caves: Points awarded on best-worst scale

1. Cricket numbers: 10-5 points
2. Ceiling morphology: 10-5 points
3. Trip time: 5-1 points
4. Ease of access: 5-0 points
5. Extant monitoring occurring at cave: yes=5 points, no=0 points

Wildcat Hollow Sink

1.	7
2.	9
3.	2
4.	4
5.	5
∑	**27**

Temple Hill Cave

1.	6
2.	8
3.	2
4.	5
5.	5
∑	**26**

Salts Cave

1.	8
2.	7
3.	4
4.	4
5.	5
∑	**28**

Currie Cave

1.	8
2.	8
3.	2
4.	3
5.	5
∑	**25**

Paw Paw Cave

1.	5
2.	8
3.	2
4.	3
5.	0
∑	**18**

Dennison Cave

1.	6
2.	9
3.	2
4.	2
5.	0
∑	**19**

Silent Grove Springhouse Cave

1.	8
2.	9
3.	4
4.	3
5.	5
∑	**29**

Martin Cave

1.	7
2.	7
3.	3
4.	3
5.	0
∑	**20**

Ice Cave

1.	5
2.	8
3.	4
4.	0
5.	0
∑	**17**

White Cave

1.	9
2.	8
3.	3
4.	5
5.	5
∑	**30**

Little Beauty Cave

1.	7
2.	7
3.	3
4.	2
5.	5
∑	**24**

Ranked Undeveloped Caves from Best-Worst

1. White
2. Silent Grove Springhouse
3. Salts Cave
4. Wildcat Hollow Sink
5. Temple Hill Cave
6. Currie Cave
7. Little Beauty Cave
8. Martin Cave
9. Dennison Cave
10. Paw Paw Cave
11. Ice Cave

Appendix D. Guide to Cave Cricket Morphology

Appendix D – Contents

Appendix D – Figures

Appendix D – Tables

Overview

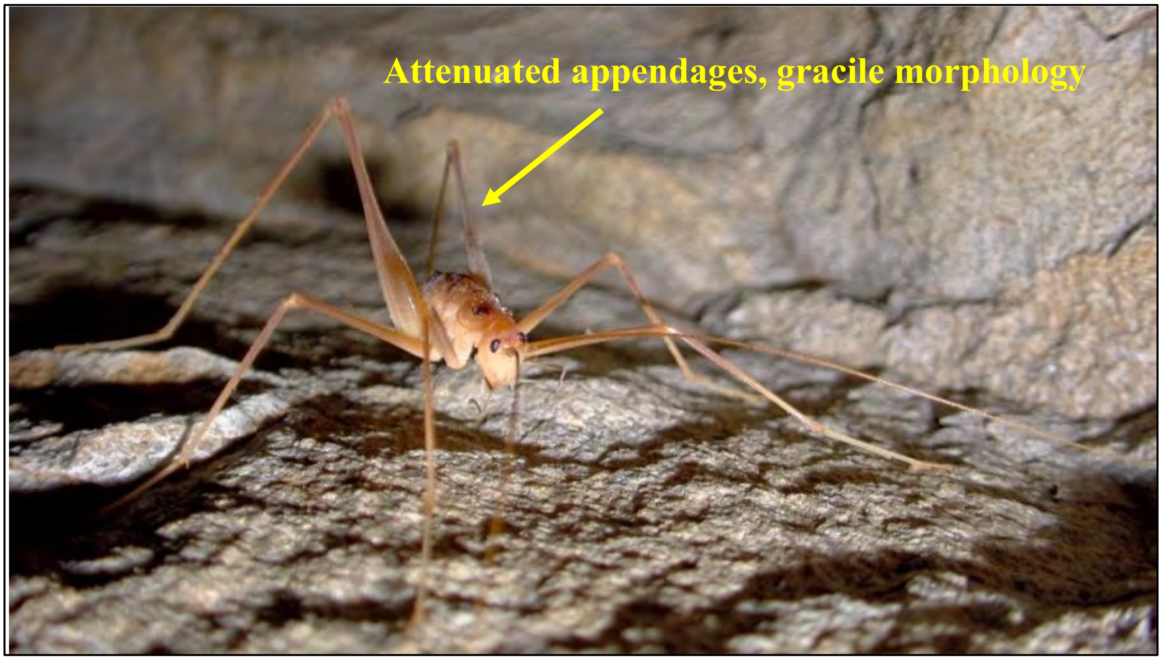
This guide explains what all field crew members should observe and note to learn (1) how to identify cave inhabiting cricket species by sight; (2) how to differentiate between *H. subterraneus* sexes; and (3) how to differentiate among *H. subterraneus* life stages. Field crews will include temporary personnel that exhibit some turnover rate (e.g., student interns). Thus, training new field assistants on sampling tasks (e.g., image analysis) will be performed by the project leader or experienced field crew. Learning to distinguish among cricket species and cave cricket size classes is essential and so will be covered in this appendix. While there are only three species of crickets that utilize caves in

Mammoth Cave National Park it is important to review cricket species and identification of *H. subterraneus* size classes by sight because misidentification of a species or size class is one of the most serious potential errors to be made both in the field and during image analysis.

Identification of Crickets by Sight

The most crucial component for the collection of credible, high-quality cricket data is well-trained and experienced observers. This cannot be overemphasized. While new field assistnats should pay particular attention to this appendix even seasoned observers should periodically review to "recalibrate" their ability to identify cricket species, sex, and life stage ensures the integrity of the data. While identifying cricket species, sex, and life stage is also useful for field work it is likely these skills will be used mostly during image analysis.

Upon observing cave crickets in the wild or opening images from a previous sampling bout the differences between the two genera should be immediately apparent. *Hadenoecus subterraneus* exhibits troglomorphic, or cave-adapted, morphology such as attenuated appendages (e.g., long legs giving them a 'spidery' appearance) and reduced pigmentation whereas *Ceuthophilus* spp have shorter, more robust appendages and strongly colored with dark mottling and stripes on the abdomen, (Figure Appendix D-1). Regardless of life stage *H. subterraneus* exoskeleton appears dull whereas *Ceuthophilus* spp appear shiny due to a waxy covering that retards evaporative water loss (Figures Appendix D-1 and Appendix D-2). In addition, *H. subterraneus* roosts in loose clusters which typically exhibit a wide range of life stages. *Ceuthophilus* spp. tend to gather in tight clusters and exhibit little to no size variation (Figure Appendix D-2). Two species of *Ceuthophilus* spp. are found in Mammoth Cave: *C. stygius* and *C. latens* (Figure Appendix D-3). The characteristic that most distinguishes these species from one another are the multiple transverse stripes on *C. stygius* dorsum and the single sagittal stripe on *C. latens* dorsum. Though these species are usually found within 20 meters of cave entrances C. stygius can be found inside the cave throughout the year whereas C latens is typically found using the cave as a hibernaculum in winter. Juvenile and adult H. subterraneus life stages are discernible as a gestalt between hind femur length and body size (Table Appendix D-1). Juvenile life stages are small relative to adults. First instar nymphs are tiny, about the size of a grain of rice, and known as 'whiteys' due to their virtual lack of pigmentation. The smallest pigmented nymphs have limbs that appear relatively proportionate to the rest of their body (Figure Appendix D-4). Later small instars show accelerated hind femur growth out of proportion to the rest of their body and they begin to take on a 'leggy' appearance (Figure Appendix D-5). While in twos sexes can be distinguished in the field by presence of a budding ovipositor in females this is unlikely to be noticeable in a digital images. Sexes usually cannot be distinguished in juveniles. Subadults are nearly as large as adult crickets and exhibit a distinct gray coloration, especially on the pronotum, abdomen, and hind femurs, which distinguishes them from juveniles and adults (Figure Appendix D-6). Female subadults are further discernible from small instars and adult males by their large ovipositor which has not yet fully sclerotized and so appears a dull whitish gray (Figure Appendix D-7). Large adult *H. subterraneus* are distinguished from immature subadults by their tawny color. In addition, female adults have fully sclerotized ovipositors that appear shiny and reddish brown in color.



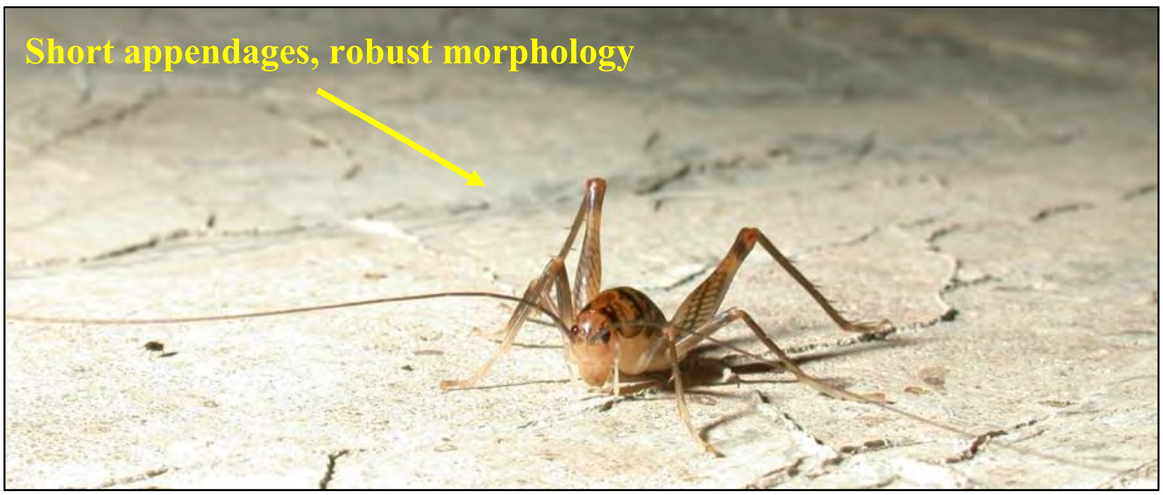


Figure Appendix D-1. Photographs showing morphological differences between Hadenoecus subterraneus and Ceuthophilus sp. Note length and delicacy of H. subterraneus (top) limbs relative to Ceuthophilus (bottom) relatively short, more robust limbs.

Figure Appendix D-2. Aggregative habits of Ceuthophilus spp. (top) and H. subterraneus (bottom). Note loose clusters of H. subterraneus versus tight clusters of Ceuthophilus spp. Further, note how Ceuthophilus spp. exoskeleton shines in the camera flash whereas H. subterraneus appears dull.

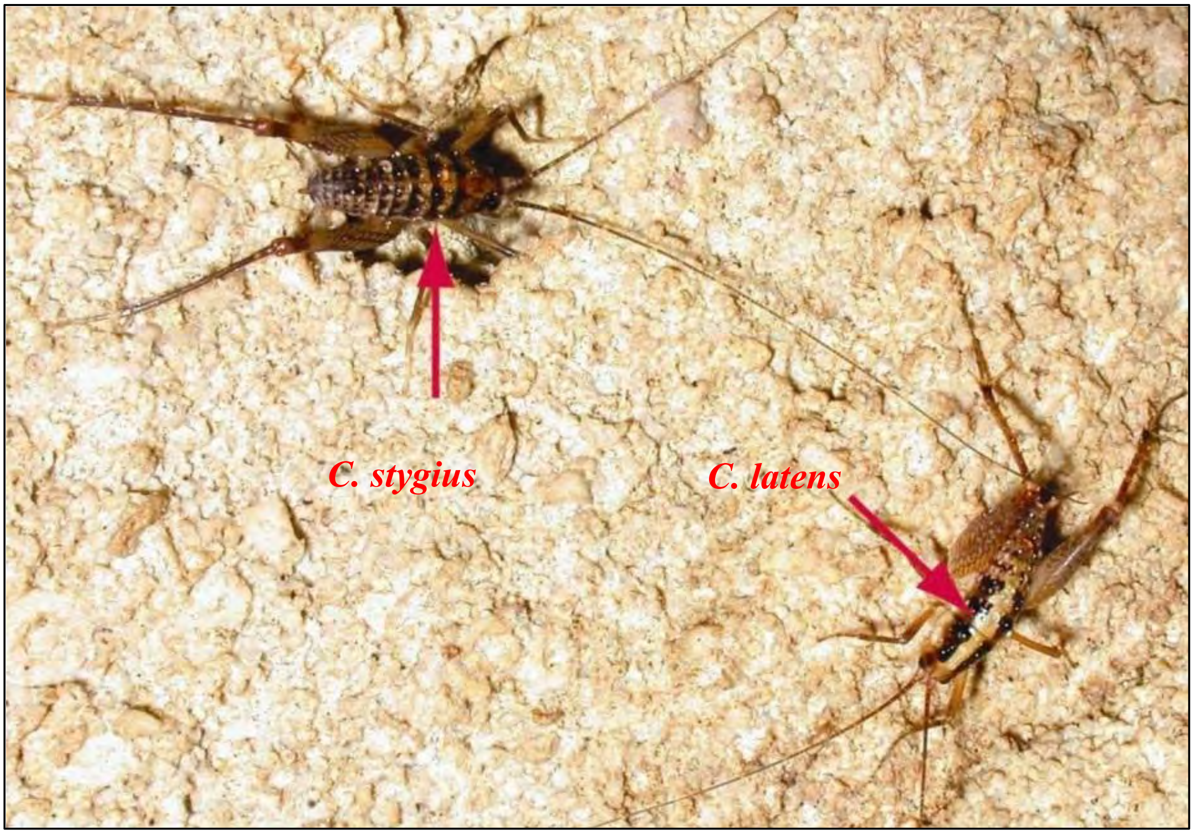


Figure Appendix D-3. The two non-cave adapted species of *Ceuthophilus* are easy to distinguish from one another due to their dorsal coloration. *C. stygius* (left) has multiple transverse stripes on its dorsum and *C. latens* (right) has a prominent sagittal stripe on its dorsum.

Table Appendix D-1. Division among cricket size classes based on hind femur length and field characters.

Life Stage	Distinguishing Characteristics
Juvenile	Very small appendages proportionate or hind femurs disproportionate from other appendages that give 'leggy' appearance
Subadult and Adult	Grayish or Tawny color, large

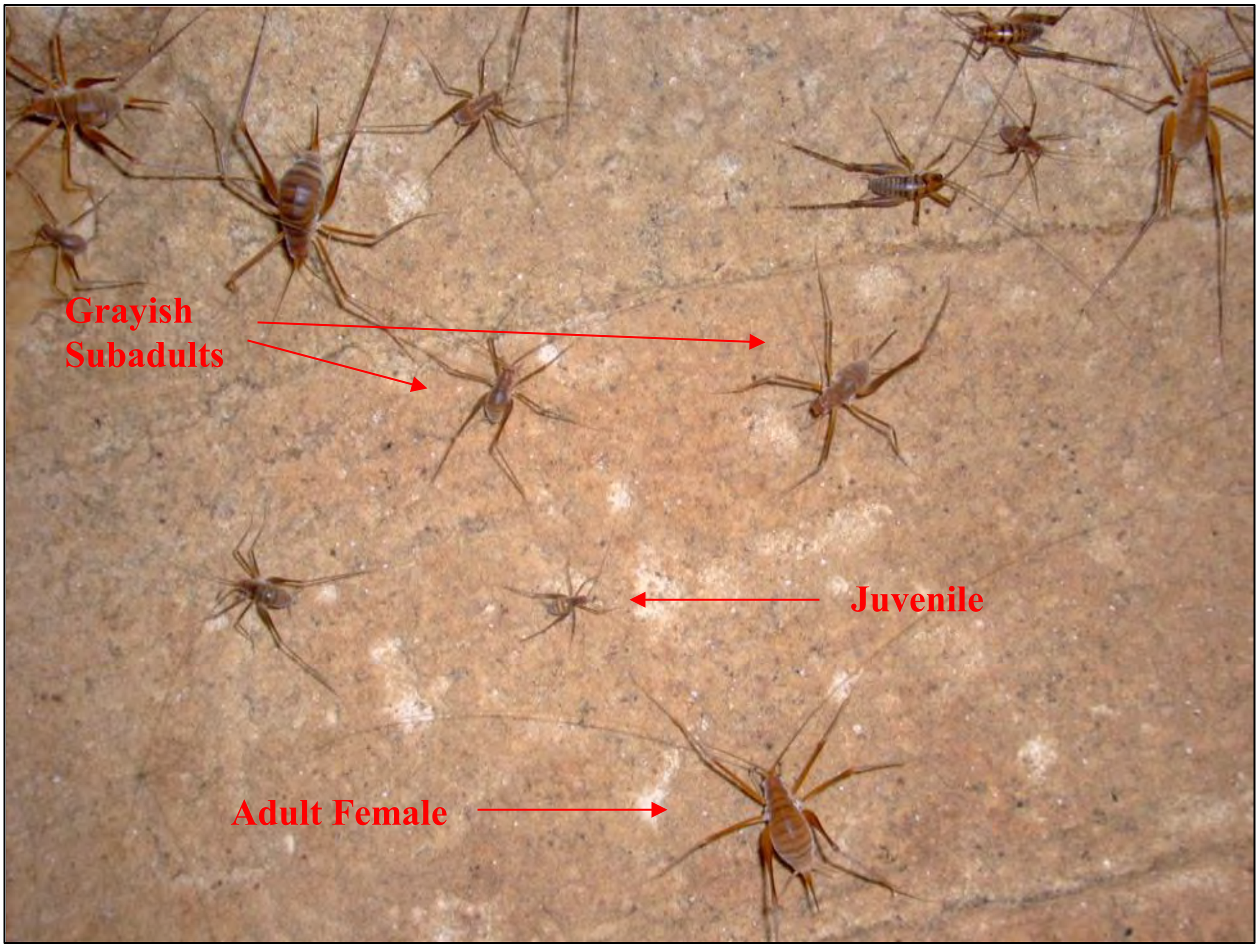


Figure Appendix D-4. Gross size difference between adult and juvenile *H. subterraneus*. Note also the color differences between the unsclerotized ovipositor of the subadults (middle) and the fully sclerotized ovipositor in the adult female (bottom).

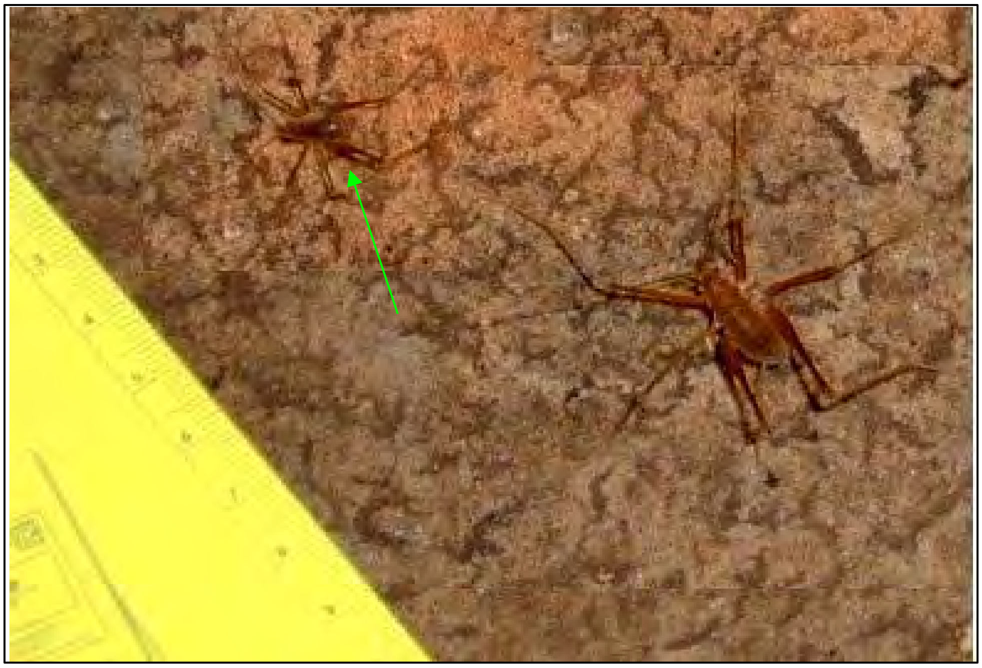


Figure Appendix D-5. Large nymph categorized as juvenile. Note ‘legginess’ compared to small nymph in Figure Appendix D-4.

Figure Appendix D-6. Characteristics of large subadult cave crickets categorized as adults. Note grayish color and size relative to adult at bottom right.

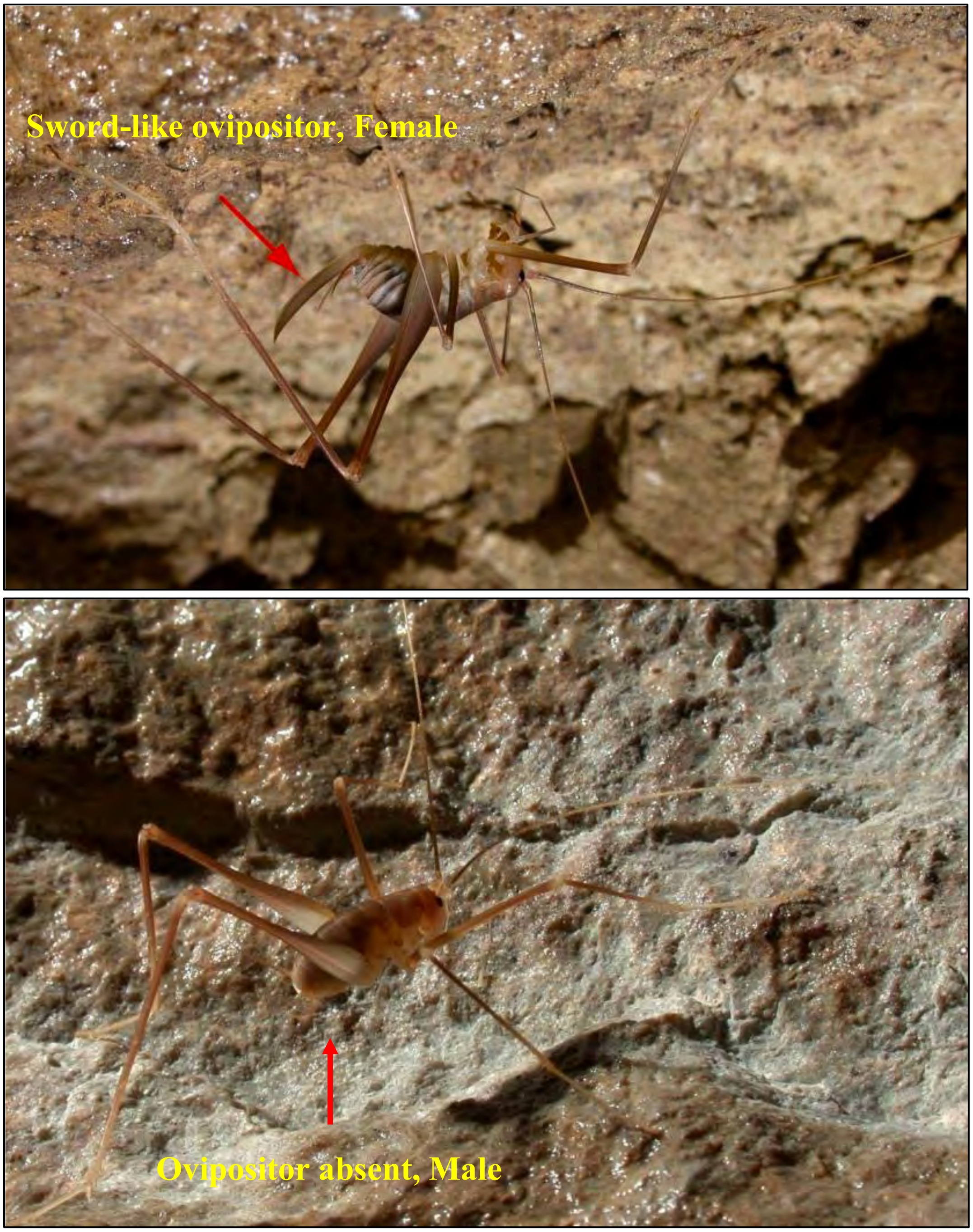


Figure Appendix D-7. Anatomical differences between sexes. Note large ovipositor on female *H. subterraneus* (top) which is absent in males (bottom). Note also that the pictured female's ovipositor is unsclerotized and its grayish color which, while it is still categorized as adult, indicates it is sexually immature. Finally, note male's tawny color which distinguishes it as a sexually mature adult.

Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park

The following pages contain instructions for launching, programming, downloading, and battery replacement for the two models of dataloggers (and their corresponding data shuttles) used in this protocol. The files are available at: http://www.onsetcomp.com/products/data-loggers/u23-001 (accessed 24 March 2014). Electronic copies of these manuals will be maintained on the Network's server and in the project files.

The above times are intended only as guidelines. For critical field applications of long duration we recommend installing a fresh battery before each deployment. We recommend replacing the HOBO's battery and O-rings simultaneously (Onset battery/service kit part #HP-BK includes battery, O-ring, stainless steel self-sealing screw with O-ring, O-ring lubricant and jack cap.)

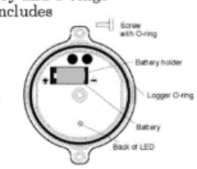


Diagram B- HOBO Pro Series back with cover removed

Changing or Accessing the Battery

If you can, offload the logger before changing the battery. This will ensure that no data will be lost (See Non-Volatile Memory below). To change the battery, open the case by removing the Phillips screw in the center of the back of the logger and removing the stainless steel back plate. Remove the old battery and install the new one. Be careful to put the battery in the battery holder with the correct polarity (Diagram B). The logger's red LED will blink three times after the battery has been installed. If you have difficulty seeing the LED flash, use the battery check in the Launch dialog box of the logger software to verify the battery status. **Warning: Do not cut open, incinerate, heat above +185°F (+85°C) or recharge the removed lithium battery. Dispose per local regulations.**

Note: Before replacing the back plate, check that the logger seals (O-ring, screw, jack cap) are not contaminated by dust, dirt or other materials. All components must be cleaned of any contaminants to ensure a weathertight seal. Make sure the back plate O-ring has a light film of lubricant (Dow Corning DC 111 or Nye Lubricants NYOGEL). Insert the O-ring in the groove and replace the back plate using the screw with O-ring. The screw should be tightened until it is snug (10 inch-pounds). Do not use lubricant on jack cap.

Non-Volatile Memory

The HOBO Pro uses a high-capacity Flash EEPROM to store data. This storage is non-volatile and will retain the data even if the battery is removed. To save power and maximize the life of the flash memory device, 32 bytes of data are buffered in RAM prior to writing to the flash memory. In the case of a dead battery, or the unlikely event that power is interrupted during logging, the data in this RAM buffer will be lost. For example, if the sample interval was set to one half hour and one channel with low resolution, then up to 16 hours of data could be lost.

Service and Support

HOBO® products are easy to use and reliable. In the unlikely event that you have a problem with the hardware or software, please read the following.

Who do I contact?

Contact the company that you bought the loggers from: Onset Computer Corporation or an Onset Authorized Dealer.

Before calling, you can evaluate and often solve your problem if you try the following:

1. Read this manual and the ReadMe file on the software disk. It may only take a few moments to get the answers you need.

2. Write down the events that led to the problem. Have you changed anything in your computer recently? Are you doing anything differently?

When contacting Onset Computer Corporation, please indicate that you need Technical Support for HOBO® products.

Be prepared to:
1. Provide the product number which is found on the side of the logger, the software version and serial number if present on the disk.
2. Provide details on the hardware and software configuration of your computer including: manufacturer, model number, peripherals, and version of operating system.
3. Completely describe the problem or question. The more information you provide, the faster and more accurately we will be able to respond.

NOTE: Onset provides technical support to one person for each software license.

Onset Technical Support
Onset Computer Corporation
470 MacArthur Blvd.
Bourne, MA 02532
Mailing: PO Box 3450
Pocasset, MA 02559-3450
1-800-LOGGERS (1-800-564-4377)
Phone: (508) 759-9500
Fax: (508) 759-9100
E-mail: loggerhelp@onsetcomp.com
www.onsetcomp.com

Warranty

The HOBO® products are warranted to be free from defects in material and workmanship for a period of one year from the date of original purchase. During the warranty period Onset will, at its option, either repair or replace products that prove to be defective. This warranty is void if the Onset products have been damaged by customer error or negligence or if there has been an unauthorized modification.

Returning Products to Onset

Direct all warranty claims to place of purchase. Before returning a failed unit, you must obtain a Return Merchandise Authorization (RMA) number from Onset. You must provide proof that you purchased the Onset product(s) directly from Onset (purchase order number or Onset invoice number). Onset will issue an RMA number that is valid for 30 days. You must ship the product(s), properly packaged against further damage, to Onset (at your expense) with the RMA number marked clearly on the outside of the package. Onset is not responsible for any package that is returned without a valid RMA number or for the loss of the package by any shipping company. Loggers must be clean and free of any toxins before they are sent back to Onset or they may be returned to you.

Repair Policy

Products that are returned after the warranty period or that are damaged by the customer as specified in the warranty provisions can be returned to Onset with a valid RMA number for evaluation.

Please contact Onset for more information and prices on:

ASAP Repair Policy

Onset will expedite the repair of a returned product.

Data-back™ Service

HOBO® data loggers store data in nonvolatile EEPROM memory. Onset will, if possible, recover your data to a disk.

Tune Up™ Service

Onset will examine and retest any HOBO® data logger.

2869-J MAN-HO8-03x-08

HOBO® H8 Pro Series User's Manual

Requires Onset Computer Corporation's BoxCar® Pro 3.5 or BoxCar® 3.6 or later software and PC interface cable for operation.

The CE mark identifies this product as complying with all relevant directives in the European Union (EU).

Inside this package

The HOBO H8 Pro Series is shipped with:

1. One HOBO H8 Pro Series logger (part numbers H08-030-08, H08-031-08, or H08-032-08)

2. Mounting Accessories: Two self-tapping screws Hook and loop tape

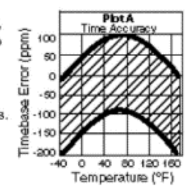
Thank you for buying a HOBO H8 Pro Series data logger. With proper care it will give you years of accurate and reliable measurements.

This manual covers all of the HOBO H8 Pro Series products. All products share a common feature set, store up to 65,291 time-stamped measurements, and are compatible with the HOBO Shuttle (Part number H09-002-08) and HandCar software for Palm™ handhelds allowing for convenient retrieval of data. The measurements available on each model are:

Model	Part Number	Temp	RH	External Temp
HOBO Pro Temp	H08-030-08	✓		
HOBO Pro Temp/External Temp	H08-031-08	✓		✓
HOBO Pro RH/Temp	H08-032-08	✓	✓	

Unlike most other HOBOs, the HOBO Pro does not have the wrap-around-when-full option for storing data; its large memory capacity eliminates the need for this function in most cases.

Common Specifications



Operating range (logger): -30°C to +50°C (-22°F to +122°F), 0 - 100% RH, HOBO Pro RH/Temp should be mounted so that water does not impact or collect in the RH sensor.
RH Sensor operating environment: 0°C to +50°C (+32°F to +122°F) in intermittent condensing environments up to +30°C; and above +30°C in non-condensing environments. Sensor requires protection from rain, splashing, mist, dust, and airborne chemicals such as salt and ammonia.
Time accuracy: approx. ±1 minute per week (±100 ppm at +20°C or +68°F), full dependance shown in Plot A.
Measurement capacity: 65,291 standard-resolution (8-bit) measurements, 32,645 high-resolution (12-bit) measurements or 21,763 measurements if one channel uses standard-resolution and the other channel uses high-resolution. RH measurements use standard resolution only. All measurements are stored in nonvolatile memory, with seven levels of data archiving (See Non-Volatile Memory).
Data offload time: 1 minute typical
Size: 4.0" H x 3.2" W x 2.0" D
Weight: Temp and RH/Temp are approx. 3.7 oz. and Temp/Temp External is 5.1 oz.
Battery: ½ AA, lithium, 3.6V, user-replaceable (Use only Onset part # HP-B)
Battery life (continuous use): 3 years
Storage temperature: -30°C to +75°C (-22°F to +167°F)

NOTE: The logger software's absolute humidity calculation does not use an actual pressure measurement but assumes an ambient pressure of 1 atmosphere (14.7 PSI.)

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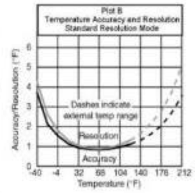
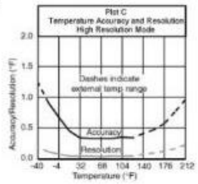
Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park.

Measurement Specifications

Temperature - Each HOBO Pro Series logger has an internal temperature sensor mounted inside the front of the logger's case (Diagram A). The sensor measures ambient air temperature over the operating range of the logger, -30°C to +50°C (-22°F to +122°F) with a response time of less than thirty-five minutes (typical to 90%) in still air. The HOBO Pro Series loggers have a standard and a high-resolution mode which are selectable in the logger's software. For temperature accuracy and resolution specifications, please refer to Plot B for standard-resolution mode and Plot C for high-resolution mode. See "Selecting Channels and Resolutions" for more information.





External Temperature - The HOBO Pro Temp/Ext Temp is equipped with a 6' external temperature sensor which measures temperature from -40°C to +100°C (-40°F to +212°F) with a response time of less than 3 minutes typical to 90% in air moving 1 m/sec (2.2 mph). See plot B and C for accuracy and resolution specifications in the two resolution modes. For loggers with serial numbers greater than 593938 the sensor tip and cable can be buried in soil or immersed in fresh water up to +50°C (+122°F) for up to one year.

Relative Humidity - The HOBO's relative humidity sensor has an accuracy of ±3% over the range of 0 to 50°C (32° to 122°F). The relative humidity sensor range is 0 to 100% RH. It can read up to 104.1% in a condensing environment. While the sensor is saturated, you will not get accurate readings. In general, the RH response time is less than 5 minutes typical to a 90% change (independent of temp). Drift is less than 1% per year in normal operating conditions (non-corrosive, non-condensing). An additional temporary drift of up to 3% can occur when the average humidity is above 70%. Factory verification and tune-up service available. White RH sensor case may yellow with exposure to light. This is not a problem.

Connecting the Communications Cable and Launching

A Starter Kit, which includes the appropriate PC interface cable and software, is required to operate your logger. Unscrew the jack cap from the logger. You can store it temporarily by pushing it onto the cap holder (Diagram A). Connect the interface cable into the 3.5 mm jack on the logger and into a working serial port on your computer. Install and start the logger's software. Select **Launch...** under **Logger** on the menu bar and a launch dialog box will be provided. For a complete explanation on installing the software and launching your logger, please refer to the logger software manual.

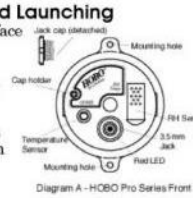


Diagram A - HOBO Pro Series Front

When launching a logger, the software defaults to the parameters specified the last time the logger was launched. The factory default is to select all channels with high-resolution mode for temperature measurements. See "Selecting Channels and Resolutions" for details.

Operation Indicator

The HOBO data loggers have a red LED that blinks while they are logging. The blinking LED is located inside the 3.5 mm jack and is only visible when the PC interface cable and jack cap are removed (Diagram A). The LED blinks brightly at every measurement, and weakly every two seconds if the interval between measurements is longer than two seconds. Once you have verified the operation of the logger, rescrew the jack cap, making sure there is no dust or dirt on the cap that might compromise the integrity of the weatherproof seal. Hand tighten lightly. The cap only needs to be snug. If it is overtightened it may require a pair of pliers to unscrew.

Operation on Computers Equipped with a Power Conservation Mode

Many newer computers, especially laptops, have a power conservation feature which shuts the serial port off after a short period of time. If a HOBO or StowAway logger is still connected to the serial port when this happens, the logger will shut off. To resolve power conservation shut off of the serial port, BoxCar Pro 4.0, 4.1, and 4.2.x customers should download the BoxCar Pro 4.2.10.1 or later upgrade patch. Similarly, BoxCar 3.6 and 3.7.1 customers should download the BoxCar 3.7.3 or later upgrade patch. Both are available for free on our website under Support and Upgrades, Software Upgrades and Utilities. If you have an earlier version of BoxCar and you would like to test to see if you will be affected by the power conservation feature do the following. Using BoxCar, launch your logger from the computer that you are testing. If you are using a laptop, it may behave differently when running off battery versus running off the power plug; please test both. After launch, leave the logger attached to the PC interface cable and watch the LED to see if it remains blinking. When a logger is actively logging, the LED will blink faintly every 2 seconds. If the power conservation is causing a problem, the LED will stop blinking within one minute.

When you are using a HOBO Pro logger, the LED is located under the PC interface cable, and is not visible when the cable is plugged in. To test a HOBO Pro, launch the logger to take readings at 10 second intervals. Leave the logger attached to the interface cable for one minute. You can either remove the interface cable at this point and check the LED status, or download the datafile to see how many points were collected. If power conservation is causing the logger to shut off, you will only see one data point in the file. If your computer has the power conservation feature, you should download an upgrade patch as noted above.

Mounting Options

The HOBO Pro Series data loggers have mounting tabs. Be careful not to stress the case when using the screws to mount the logger to an uneven surface, as this may crack the tabs. The supplied hook and loop tape can be stuck on the back of your HOBO for mounting. Do not use double sided tape on the back of the logger for mounting, as this could disturb the weatherproof seal when the logger is removed.

HOBO Pro RH Sensor Should not get Saturated

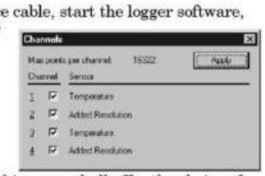
The RH sensor used on the HOBO Pro is among the best in its price range. It is designed for normal outdoor environments with cyclical high and low humidity levels. Saturation of the sensor is evident when the logger reads values of 100% RH or greater. Like all RH sensors, repeated saturation from exposure to condensing environments will lead to irreversible drift and eventually destroy the RH sensor. If this happens, the logger will need to be returned to Onset Computer Corp. for sensor replacement. The rate at which this degradation of the sensor occurs depends on the harshness of the environment to which the sensor is exposed. Condensing environments with temperatures above 30°C (86°F), exposure to salt spray, ammonia vapor, or some other chemicals will accelerate the sensor degradation.

Mounting considerations in wet environments

The RH/Temp version should be mounted so that the RH sensor is protected from water saturation. To prolong the life of your RH sensor, Onset strongly recommends mounting the HOBO Pro logger (H08-032-08) face down in a protective housing such as the Solar Radiation Shield (Onset part # RS1) or the Rain Shield (Onset part # RS2).

Readout

Reconnect the HOBO data logger to the interface cable, start the logger software, select **Readout** under **Logger** on the menu bar and the data will be displayed in a graphical or tabular form. For a complete explanation on reading out your logger, please refer to the logger software manual. The optional HOBO Shuttle can also be used to readout and relaunch the HOBO Pro loggers.



Selecting Channels and Resolutions

The three HOBO Pro Series loggers covered by this manual all offer the choice of standard-resolution (8-bit) or high-resolution (12-bit) operation for their temperature channel(s). High-resolution mode doubles the amount of memory required by each measurement, reducing the deployment time for each interval setting, but dramatically improving the temperature resolution and accuracy. The high-resolution mode is not available for the RH channel. For high-resolution mode select the sensor and "Added Resolution" on the channel that follows it. For standard-resolution select only the temperature channel. *"Added Resolution" should not be enabled unless the corresponding temperature channel is enabled, otherwise the data will be invalid.* If you are using the Temp/Ext Temp version, the internal temperature sensor is Channel 1 and the external temperature probe is Channel 3.

Data Archiving

HOBO Pro Series loggers preserve the data from up to seven deployments preceding the current deployment. You will be able to retrieve data from all eight deployments by using the archive reader function in the logger software. (In some versions of the software it is a separate utility for windows 95/98/NT on the installation disk.) The reader will contact your logger, readout the last eight deployments, display information such as the deployment number, start time, end time, number of points and the description, and then allow you to select which file(s) you would like to save. For more information on the archive reader function, consult your logger software manual or the Archive Reader Utility readme.txt file. This archiving feature provides backup of your measurements in the logger, giving you another level of protection from accidental data loss.

Battery Life Specifications and Battery Level Indication

The battery level is displayed on the host computer during Launch. For the HOBO Pro Logger this will display one of two states: 98% or 20%. The lowest battery level that will be shown is 20%. Thus if the battery status indicates 20%, the battery is effectively dead and should be replaced immediately. **Launching the logger when the battery level reads 20% risks data corruption and/or data loss.**

In normal usage the HOBO Pro's battery can last up to three years when used with an interval of 1 minute or greater. Battery life is very dependent upon the sample interval and service temperature. See Table 1 for approximate run times at various intervals and service temperatures.

Table 1. Approximate Operational Battery Life for the HOBO Pro

	Logging Interval		
Operating Temperature	< 10 seconds	10 secs - 1 minute	1 minute – 1 hour
+104 - +122°F (+40 - +50°C)	~ 3 - 6 months	1/2 - 1 1/2 years	1 1/2 - 2 years
+77 - +102°F (+25 - +39°C)	~ 3 - 6 months	1/2 - 2 years	2 - 3 years
< +77°F (< +25°C)	~ 3 - 6 months	1/2 - 2 1/2 years	2 1/2 - 3+ years

Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park (cont.)

HOBO® Pro v2 (U23-00x) Manual

HOBO Pro v2 U23-001 shown

The HOBO Pro v2 logger's environmentally rugged case is designed for years of reliable use in outdoor applications. It has enough memory to record over 42,000 12-bit measurements. The U23-001 and U23-002 models also feature user-replaceable RH sensors.

The logger uses an optical USB communications interface (via a compatible shuttle or base station) for launching and reading out the logger. The optical interface allows the logger to be offloaded without compromising the electronics. The USB compatibility allows for easy setup and fast downloads.

HOBO Pro v2 Logger

Models: U23-001
U23-002
U23-003
U23-004

Included Items:

- Clamp and mounting screws
- UV protective cap

Required Items:

- Coupler (COUPLER2-E) with USB Optic Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1)
- HOBOware Pro 2.2.1 or later

Accessories:

- RH sensor replacement kit for U23-001 (HUM-RHPCB-1)
- RH sensor replacement kit for U23-002 (HUM-RHPCB-2)
- Replacement cable/sensor for U23-002 (CABLE-U23-002)
- Replacement UV protective caps (U23-CAP)

Specifications

Temperature Sensor

Operation Range	Internal sensor: -40 to 70°C (-40 to 158°F) U23-002 external temperature sensor: -40 to 70°C (-40 to 158°F) U23-003 and U23-004 external sensors: -40 to 100°C (-40 to 212°F), with tip and cable immersion in fresh water up to 50°C (122°F) for one year
Accuracy	±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F), see Plot A
Resolution	0.02°C at 25°C (0.04°F at 77°F); see Plot A
Response Time (Typical to 90%)	U23-001 internal sensor: 40 minutes in air moving 1 m/sec U23-002 external temperature sensor: 5 minutes in air moving 1 m/sec U23-003 and U23-004 external sensors: 3 minutes in air moving 1 m/sec; 30 seconds in stirred water
Stability (Drift)	< 0.1°C (0.18°F) per year

Relative Humidity Sensor (U23-001, U23-002 only)

Operation Range	0 to 100% RH, -40° to 70°C (-40° to 158°F) Exposure to conditions below -20°C (-4°F) or above 95% RH may temporarily increase the maximum RH sensor error by an additional 1%
Accuracy	±2.5% from 10% to 90% RH (typical), to a maximum of ±3.5% including hysteresis. See Plot B for full range.
Resolution	0.03%
Response Time (Typical to 90%)	U23-001: 40 minute in air moving 1 m/sec with protective cap U23-002: 5 minutes in air moving 1 m/sec with protective cap
Stability (Drift)	<1% per year typical

Logger

Operation Range	-40° to 70°C (-40° to 158°F)
Real-time Clock	±1 minute per month 0° to 50°C (32° to 122°F)
Battery	1/2 AA, 3.6 Volt lithium, user-replaceable (HP-B)
Battery Life (Typical Use)	3 years with 1 minute or greater logging interval
Memory (Non-Volatile)	64K bytes memory (approx. 21,000 temperature and RH measurements)
Materials	All models: ASA styrene polymer housing and mounting clamp; polypropylene protective cap; Buna-N o-ring(s); U23-001, U23-002 only: ASA styrene polymer RH sensor cap; modified hydrophobic polyethersulfone membrane

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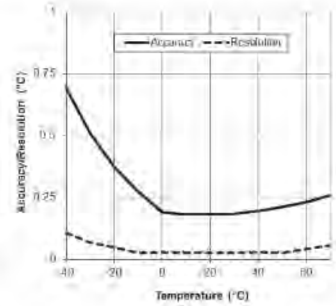
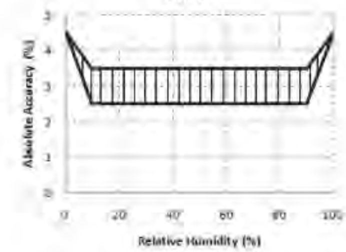
Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park (cont.)

Specifications (continued)

Cables	U23-001: No cables U23-002: One 184 cm (6 ft) PVC cable; sensor diameter 1 cm (0.38 in.) U23-003: Two 184 cm (6 ft) PVC cables; sensor diameter 0.5 cm (0.20 in.) U23-004: One 184 cm (6 ft) PVC cable; sensor diameter 0.5 cm (0.20 in.)
Environmental Rating	Electronics housing is NEMA 6P equivalent (tolerant of brief submergence); Units with RH sensors are NEMA 4 equivalent (splash-resistant)
Launch Modes	Immediate start; delayed start
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
Weight	U23-001: 57 g (1.5 oz); U23-002: 118 g (3.1 oz); U23-003: 138 g (3.7 oz); U23-004: 102 g (2.7 oz)
Dimensions	Housing measures 10.2 × 3.8 cm (4.0 × 1.5 in.)
NIST Certificate	Temperature certificate available for additional charge
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).



Plot A



Plot B

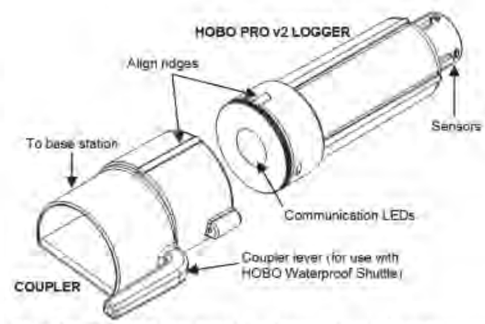
Connecting the Logger

The HOBO Pro v2 requires a coupler (COUPLER2-E) and USB-Optic Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1) to connect to the computer.

> **IMPORTANT**: USB 2.0 specifications do not guarantee operation outside the range of 0°C (32°F) to 50°C (122°F).

1. Install the HOBOware logger software on your computer before proceeding.
2. Follow the instructions that came with your base station or shuttle to attach the base station or shuttle to a USB port on the computer.
3. Make sure the logger's communications window is clean and dry. (Use a clean, nonabrasive cloth, if necessary.) If the logger is damp, wipe off excess moisture.
4. Attach the coupler to the base station or shuttle, then insert the logger into the coupler with the ridge on the logger aligned with the ridge on the coupler.
5. If you are using the HOBO Waterproof Shuttle, briefly press the coupler lever to put the shuttle into base station mode.
6. If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.
7. Use the logger software to launch the logger, check the logger's status, read it out, stop it manually with the software, or let it continue to record data until the memory is full. Or, use the HOBO Waterproof Shuttle to read out and relaunch the logger in the field.

Refer to the software user's guide for complete details on launching, reading out, and viewing data from the logger.



Note: The first time you launch the logger, the deployment number will be greater than zero. Onset launches the loggers to test them prior to shipping.

Operation

A light (LED) in the communications window of the logger confirms logger operation. (In brightly lit areas, it may be necessary to shade the logger to see the LED blink.) This table explains when the light blinks during logger operation:

When:	The OK Light Does This:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample.
The logger is awaiting a start because it was launched in Start At Interval or Delayed Start mode	Blinks once every eight seconds until logging begins

Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park (cont.)

Sample and Event Logging

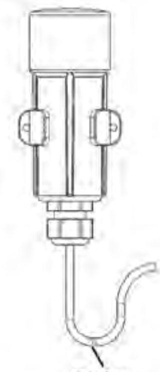
The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval (for example, temperature every minute). Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

The logger stores 64K of data, and can record over 42,000 12-bit measurements.

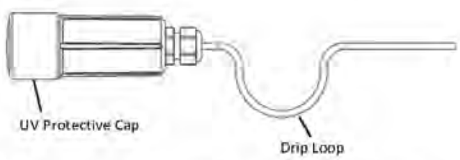
Deploying and Protecting the Logger

- To clean the logger's case, use a sponge with warm, soapy water.
- Use the included clamp to mount the logger to a surface. The clamp has two holes for the screws, 44 mm (1.7 inches) apart.

  The clamp is slightly tapered to accommodate the logger. Install the clamp so the logger is oriented with the communication window facing up or to the side. This will prevent condensation from pooling on the sensor or cable grommet.
- A solar radiation shield is recommended if the logger or its sensors will be exposed to sunshine.



- If the logger housing will be in sunlight, slide the included protective cap over the logger communication window to protect the window against UV light.



- When mounting the logger, be sure to attach the logger so the logger cable is not being pulled. Also leave about 5 cm (2 inch) of drip loop in the cable where it comes out of the logger (as shown in the above diagrams) to prevent water from entering the logger housing.
- Periodically inspect the three desiccant packs located in the logger cap. If they are not bright blue, dry them following the instructions below.

  To dry a desiccant pack, remove it from the logger cap and leave in a warm (≤70°C (158°F)), dry location until the bright blue color is restored. (Refer to the "Battery" section for instructions on removing and replacing the logger cap.).

  If a desiccant pack remains pink and will not turn blue, replace it with a new desiccant pack (DESICCANT1)

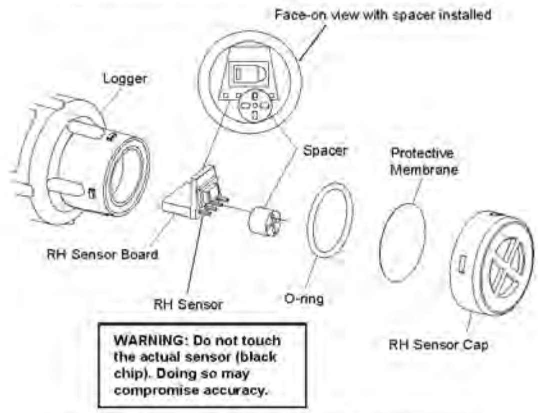
Replacing the RH Sensor

The RH sensor (on models U23-001 and U23-002) is protected by an ASA styrene polymer cap and a modified hydrophobic polyethersulfone fluid barrier membrane that allows vapor to penetrate while protecting the sensor from condensation.

RH sensor performance may degrade over time. To replace the RH sensor in your logger, refer to the diagram and instructions for your logger.

U23-001 RH Sensor Replacement Steps

1. Turn the RH sensor cap counter-clockwise slightly and pull to remove it. Discard the sensor cap, membrane, and o-ring. Clean the sensor end of the logger.

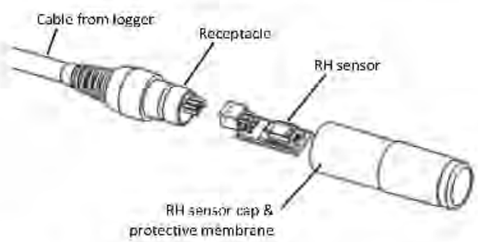


2. There may be a spacer installed on the RH Sensor Board. Remove and discard the spacer.
3. Note the orientation of the small circuit board containing the RH sensor. With a pair of needle-nose pliers, grip the sensor board pins. Pull out and discard the board.
4. Use needle-nose pliers to hold the pins on the new sensor board, push the board gently but firmly and install it in the same orientation as the old board. Make sure it engages with the pins inside the logger housing. Do not touch the sensor itself; only touch the sides of the board.
5. Install the new spacer on the sensor board by placing the spacer onto the third pin from the left (use the topmost hole on the spacer instead of the center hole).
6. Make sure the o-ring is clean and seated properly, and set the protective membrane on top (either side can face up).
7. Put the sensor cap back on. Push down and turn it slightly clockwise to close it securely. Do not force it. If the cap does not go on easily, the sensor may be installed incorrectly. Check the sensor orientation and try again.
8. Check logger status in HOBOware to verify the RH reading.

Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park (cont.)

U23-002 RH Sensor Replacement Steps

1. Grasp the cap and membrane and pull firmly. Discard them.
2. Note the orientation of the small circuit board containing the RH sensor. Pull it out and discard it.



3. Holding the sides of the board only, push gently but firmly to install the new sensor (HUM-RHPCB-2) in the same orientation. **WARNING:** Do not touch the actual sensor (black chip) itself; doing so may compromise accuracy.
4. Put the new sensor cap and membrane on. Do not force the cap. If it does not go on easily, the sensor may be installed backwards. Reverse the sensor and try again.

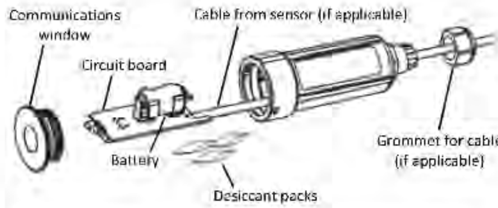
Battery

Typical battery life is about three years. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. To obtain a three-year battery life, use a logging interval of one minute or greater, and operate and store the logger at temperatures between 0° and 40°C (32° and 104°F).

Frequent deployments with logging intervals of less than one minute, and continuous storage/operation at temperatures above 40°C, will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

The logger can report and log its own battery voltage. If the battery falls below 3.1 V, the logger will record a "bad battery" event in the datafile. If the datafile contains "bad battery" events, or if logged battery voltage repeatedly falls below 3.3 V, the battery is failing and should be replaced before the next deployment. To change the battery:

1. Turn slightly counter-clockwise and pull to remove the protective cap. Loosen the cable grommet on the opposite end, if the logger has an external sensor.
2. Carefully pull out the circuit board containing the battery. (If the logger has an external sensor, you will probably find it easier to push the cable(s) into the case to push the circuit board out.)
3. Examine the desiccant packs that were packed into the case. If the desiccant is not bright blue, put the desiccant packs in a warm, dry place until the blue color is restored.



4. Install a new 1/2 AA, 3.6 Volt lithium battery (part # HP-B). The negative end of the battery must face towards the communication LEDs.
5. Use a clean, dry cloth to wipe away any moisture inside the case.
6. Push the board and the desiccant packs back into the case, taking care not to bend the communication LEDs. Align the board with the grooves inside the case. (If you try to put the board in upside-down, the battery will get in the way.)
7. Make sure O-ring on the protective cap is still in place. It should not be pinched, twisted, or trapping dirt or lint, which could interfere with the protective cap. If you are replacing it with a new O-ring from an RH sensor replacement kit, discard the old O-ring and place the new one into the same groove on the communications window. Apply a small dot of lubricant from the grease packet included in the kit on the O-ring. Spread the lubricant around the O-ring just enough to moisten it while avoiding getting it on the communications window.
8. Line up the bumps on the protective cap with the notches in the logger's case. Push and turn the cap slightly clockwise. Pull the slack in the sensor cable(s) if applicable. Hand-tighten the grommet and then turn an additional half turn with a wrench (do not force).

> ⚠ **WARNING:** Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

Appendix E. Instruction Manuals for HOBO Temperature and Relative Humidity Dataloggers Used to Collect Cave Meteorological Data in Mammoth Cave National Park (cont.)

Appendix F. R code for randomizing order of cave entrances visited between sampling bouts, GRTS draws, and obtaining cave cricket entrance population estimates from SACS data (File names/locations will vary).

Preliminary R code

```
# The following line needs to be run once in R (select everything
#after the # sign and submit)
#
install.packages(c('spsurvey','lattice','R2wd','RDCOMClient','rgdal'),
dep=TRUE)
setWindowTitle("Sample Draws StripACS Cave Crickets")
library(sp)
library(spsurvey)
library(lattice)
library(R2wd)
library(rgdal)
library(RODBC)
library(NCmisc)  # for wait() function, not needed if slow grts draws

# Edit the following line to point to the directory with the cave
#entrances csv file
setwd("f:\\networks\\05_CUPN_CumberlandPiedmont\\crickets")
#setwd("l:/crickets/sops")

Bout <- 'May2014'  # edit this here
if (!exists('Bout')) {
    cat('Please enter the name of the sample Bout (e.g., May2014,
Oct2016):')
    Bout <- scan(what='character')
}

# create subdirectory for this bouts draw files
if (!file.exists(Bout)) dir.create(Bout)

# grab last Event_ID and entrance sample sizes from Access database
mdb <- odbcConnectAccess2007('CC.accdb')


# grab last Event_ID from database
tbl_Events <-
sqlFetch(mdb,'tbl_Events',as.is=TRUE,stringsAsFactors=FALSE)
EventNum <-
as.numeric(substr(tbl_Events$Event_ID,3,nchar(tbl_Events$Event_ID)))
```

```
StartEventN <- max(EventNum)
rm(tbl_Events) # remove R copy of table, doesn't touch CC.accdb
rm(EventNum)

Entrances <-
sqlFetch(mdb,'tblEntranceSampleSizes',as.is=TRUE,stringsAsFactors=FALS
E)

OutName <- paste('CaveSamples_',Bout,'.docx',sep='')
```

R code to generate an equal probability order of sampled cave entrances, a 1-dimensional finite GRTS draws for a given cave entrance, length of baseline, desired number of strips, and a 2*n* oversample

```
######################################################################
##
# CaveCrickets_unified.R
# This code is part of the "Protocol for Monitoring Cave Crickets at
# Mammoth Cave National Park".
#
# It contains ancillary functions to generate an equal-probability
order of the cave entrances
#   SampleOrder(Entrances)
# and a function to generate a GRTS draw for a given entrance, length
of baseline,
# desired number of perpendicular transects, and desired number of
oversample perpendicular transects
# DoDraw(Entrance,Transectlength,Npoints,OverSample)
#
#################################################
# Functions
#       DoOrder to draw random order of cave entrances
#       DoDraw to draw GRTS locations of transects within an entrance
#       stripACS.ht4 to generate estimates of population sizes from
resulting data

DoOrder <- function(Entrances) {
    # Separate offAustin & Floyd Collins
    AFC <- Entrances[Entrances$Entrance%in%c('Floyd
Collins','Austin'),]
    # random order of AFC
    AFC <- AFC[order(sample.int(2,2)),]

    # random order for all but Austin & Floyd Collins
```

```
    notAFC <- Entrances[!Entrances$Entrance%in%c('Floyd
Collins','Austin'),]
    nEnt <- nrow(notAFC)
    SampleOrder <- notAFC[order(sample.int(nEnt,nEnt,replace=FALSE)),]

    # add spacer if necessary to have even number of entrances for 2
per day
     if (nrow(SampleOrder)%%2==1) {
         Spacer <- SampleOrder[1,]
         Spacer$Entrance <- 'Makeup'
         Spacer$Baseline <- NA
         Spacer$nTransects <- NA
         SampleOrder <- rbind(SampleOrder,Spacer)
     }
    # which day to insert them?  2 entrances per day
    nDays <- nEnt/2
    Insert <- (sample(nDays+1,1) -1) *2
    if (Insert==0) SampleOrder <- rbind(AFC,SampleOrder) else {
              if (Insert==nrow(SampleOrder)) SampleOrder <-
rbind(SampleOrder,AFC) else {
                   SampleOrder <-
rbind(SampleOrder[1:Insert,],AFC,SampleOrder[(Insert+1):nrow(SampleOrd
er),])
              }
        }
     print(SampleOrder)
    return(SampleOrder)
    } # Bottom DoOrder

#####################
# Function to generate a 1-dimensional finite GRTS draw
# Entrance: character label
# Baseline: the length of the baseline in units of transect widths
# Npoints: the desired number of points in the sample draw
# OverSample: the number of oversample or replacement points desired
#require(spsurvey)
DoDraw <- function(Entrance="Cave",Baseline,Npoints,OverSample=0) {
    x <- seq(1,Baseline*10)/10 # positions of the outer end of each
10cm interval)
    y <- rep(1,length(x))
    Baseline <- data.frame(x,y) #new object old name
    Baseline$I <- 1:length(x)
    Baseline$Xpos <- x
    coordinates(Baseline) <- ~x+y
    # fake projection to keep spsurvey happy
```

```
    proj4string(Baseline) <- CRS(" +proj=utm +zone=11 +ellps=GRS80
+datum=NAD83 +units=m")
    if (OverSample>0) { Design <-
list(None=list(panel=c(panel1=Npoints),seltype="Equal",over=OverSample
))
                                   } else Design <-
list(None=list(panel=c(panel1=Npoints),seltype="Equal"))
    #sink(file="grts_notes.txt",append=TRUE)
    DoDraw <- grts(design=Design,DesignID=gsub(' ','_',Entrance),
                              type.frame="finite",
                              src.frame="sp.object",
                              sp.object=Baseline,
                              shapefile=FALSE,
                              shift.grid=TRUE,
                              do.sample=TRUE)
 } # bottom DoDraw

####################################################
# Order of Visiting Entrances for sampling Bout
  BoutOrder <- DoOrder(Entrances)
  BoutOrder <- BoutOrder[BoutOrder$Entrance!='Makeup',]
  EventIDs <- paste('CC',StartEventN+1:nrow(BoutOrder),sep='')
  # OT is for Access Database, OrderTable is for .docx datasheets
  OT <- data.frame(
                   Event_ID=EventIDs,
                   Bout=Bout,
                   Entrance=BoutOrder$Entrance,
                   Event_Name=paste(Bout,BoutOrder$Entrance,sep='_'),
                   Leader=character(length=nrow(BoutOrder)),
                   Crew1=character(length=nrow(BoutOrder)),
                   Crew2=character(length=nrow(BoutOrder)),
                   Var1=character(length=nrow(BoutOrder))
                   )

  sqlSave(mdb,OT,paste('temp_Events_',Bout,sep=''),rownames=FALSE)

  OrderTable <- data.frame(Entrance=BoutOrder$Entrance,
                           Event_ID=EventIDs,
                           Date=rep('
',nrow(BoutOrder)))


# open blank word document
wdGet(method="RDCOMClient")
# wdNewDoc() # method="RDCOMClient")
```

```
# Cover Page
#
wdTitle(paste('Cave Cricket Sampling Bout: ',Bout))


  wdTable(OrderTable,row.names=FALSE,autoformat=16)

#  wdPageBreak()

wdSave(Name=paste(getwd(),'/',Bout,'/',Bout,'_EntranceOrder.docx',sep=
''))
  wdQuit()
```

R code to generate pre-populated Field Data Sheets

```
#################################
# Each datasheet is its own file

  if (exists('BigStrip')) rm(BigStrip)

for (E in 1:nrow(BoutOrder)) {
# do the draws first, as R2wd can go too fast for MSword

    Samples <- DoDraw(BoutOrder$Entrance[E],BoutOrder$Baseline[E],

BoutOrder$nTransects[E],ceiling(BoutOrder$nTransects[E]/2))
    Oname <- paste(gsub('
','_',BoutOrder$Entrance[E]),'.',Bout,sep='')
    Oname <- gsub("\\'","_",Oname)
    Oname <- gsub("\\'","",x)

    if (exists('Olist')) Olist <- rbind(Olist,Oname) else Olist <-
Oname
    assign(Oname,Samples)
    BS <- Samples@data
    BS$Entrance <- OrderTable$Entrance[E]
    BS$Event_ID <- OrderTable$Event_ID[E]

    if (exists('BigStrip')) BigStrip <- rbind(BigStrip,BS) else
BigStrip <- BS


write.csv(Samples@data,paste(Bout,'/',Oname,'.csv',sep=''),row.names=F
ALSE)
    writeOGR(get(Oname),Bout,Oname,driver="ESRI
Shapefile",overwrite_layer=TRUE)
```

```
    # wack for datasheet
    ST1 <- Samples@data[Samples$panel!='OverSamp',c('siteID','Xpos')]
    ST1$StripID <- substr(ST1$siteID,regexpr('-
',ST1$siteID)+1,nchar(ST1$siteID))
    ST1 <- ST1[order(ST1$Xpos),]
    ST1$Xpos <- formatC(ST1$Xpos,format='f',digits=1)
    # add a blank line
    Spacer <- ST1[1,]
    Spacer$siteID <- '-'
    Spacer$StripID <- ''
    Spacer$Xpos <- ' '

    ST2 <- Samples@data[Samples$panel=='OverSamp',c('siteID','Xpos')]
    ST2$StripID <- substr(ST2$siteID,regexpr('-
',ST2$siteID)+1,nchar(ST2$siteID))
    ST2$Xpos <- formatC(ST2$Xpos,format='f',digits=1)
    SampTable <- rbind(ST1,Spacer,ST2)

    #############
    # grab a clean copy of the page

wdGet(filename='CUPN_Cricket_fieldform_20140320bm.docx',method="RDCOMC
lient")

    # Populate Header
    wdGoToBookmark('Entrance')
    wdWrite(OrderTable$Entrance[E])
    wdGoToBookmark('Bout')
    wdWrite(Bout)
    wdGoToBookmark('EventID')
    wdWrite(OrderTable$Event_ID[E])  # will be pulled from database

#    wdTitle(paste('Cave Cricket Sampling\nEntrance:
',BoutOrder$Entrance[E],'    Bout:',Bout,'\n'))
    for(X in 1:nrow(SampTable)) {
        # GRTSn
        BM <- paste('SID',X,sep='')
        wdGoToBookmark(BM)
        wdWrite(SampTable$StripID[X])

        # Position
        BM <- paste('P',X,sep='')
        wdGoToBookmark(BM)
        wdWrite(SampTable$Xpos[X])
    } # bottom for X
```

```
    # write out that datasheet

wdSave(Name=paste(getwd(),'/',Bout,'/',Bout,'_',BoutOrder$Entrance[E],
'_datasheet.docx',sep=''))
    wdQuit()
#    wait(10) # from NCmisc  not neeted if grts draws take long enough
for MSword to close
#    wdTable(SampTable,row.names=FALSE,autoformat=2)
#    wdPageBreak()
} # loop over E Entrances

# now build temp_Strips_Bout table for uploading
str(BigStrip)
Flag <- regexpr('-',BigStrip$siteID) # positon of dash for parsing

BigStrip$Strip_ID <- ''
BigStrip$GRTS <- BigStrip$siteID
BigStrip$GRTSn <-
as.numeric(substr(BigStrip$siteID,Flag+1,nchar(BigStrip$siteID)))

tmp_Strips <-
BigStrip[,c('Strip_ID','Event_ID','GRTS','GRTSn','Xpos','panel')]
names(tmp_Strips) <-
c('Strip_ID','Event_ID','GRTS','GRTSn','Position','Panel')
tmp_Strips$Event_ID <- as.character(tmp_Strips$Event_ID)
tmp_Strips$Rejected <- ''
tmp_Strips$RejectReason <- ''
tmp_Strips$Total <- numeric(length=nrow(tmp_Strips))
tmp_Strips$Juvenile <- numeric(length=nrow(tmp_Strips))
tmp_Strips$Female <- numeric(length=nrow(tmp_Strips))
tmp_Strips$Male <- numeric(length=nrow(tmp_Strips))
tmp_Strips$Comments <- ''

sqlSave(mdb,tmp_Strips,paste('temp_Strip_',Bout,sep=''),rownames=FALSE
)
```

STRIP_EST(): R function to estimate totals from strip adaptive cluster sampling data

```
##################
R function to estimate totals from strip adaptive cluster sampling
data
# stripACS_est.R
# Parameters
# N: the number of possible transect locations (length of baseline in
units of transect widths)
```

```
# n: the number of transects selected and sampled
# X: a dataframe of results with 1 row per cluster and the following 
variables:
#       Distal the location (position along the baseline) of the edge 
of the cluster
#              nearest the entrance, in units of transect widths
#       Proximal the location (position along the baseline) of the 
edge of the cluster
#       Counts
#              furthest from the entrance, in units of transect widths
#       note that for transects Counts==0, Distal==Proximal
# simlnc: how many simulations of GRTS draws to use to estimate 
pairwise inclusion probabilities
#     0 means do not run simulations; 100000 is default
stripACS_est <- function(N=N,n=n,X=X,simInc=100000) {
  # Test that all rows of X have clusters with >0 counts
  Count <- X$Counts[X$Counts>0]
  Nclusters <- length(Count)
  vDistal <- X$Distal[X$Counts>0]
  vProximal <- X$Proximal[X$Counts>0]
  # Check that Proximal - Distal are in right order; if not, reverse
  Distal <- ifelse(vDistal>=vProximal,vDistal,vProximal)
  Proximal <- ifelse(vDistal>=vProximal,vProximal,vDistal)
  # Compute widths for each cluster
  cluster.widths <- Distal - Proximal +1
  # speed things up by computing choose(N,n) only once
  ChooseNn <- choose(N,n)
  NotAlpha <-(choose(N-cluster.widths,n) / ChooseNn) # used for first 
2 terms of Pjk eqn 6
  IncProb <- 1- NotAlpha
  # First generate H-T estimate of total
  estHT <- sum(Count/IncProb)
  # Compute variance of the H-T estimate of total
  # compute pairwise inclusion probabilities
  # stick IncProb along diagonal of pairwise inclusion probabilities
  Pjk <- diag(IncProb) # odd 4th usage of diag() see ?diag
  # compute off diagonal terms only need to do one traingle
  Overlap <- matrix(nrow=Nclusters,ncol=Nclusters)
  Vsum <- 0 # running sum for estimate of variance
  for (j in 1:(Nclusters-1)) {
    for (k in (j+1):Nclusters) {
      Overlap[j,k] <- max(0,min(Distal[j],Distal[k])-
max(Proximal[j],Proximal[k]))
      Pjk[j,k] <- 1 - (NotAlpha[j] + NotAlpha[k] - choose(N-
cluster.widths[j]-
```

```
            cluster.widths[k]+Overlap[j,k],n)/ChooseNn)
      Vsum <- Vsum + 2 * (Count[j]*Count[k] / Pjk[j,k]) *
(Pjk[j,k]/(Pjk[j,j]*Pjk[k,k]) -1)
    } # bottom of k loop
  } # bottom of j loop
  # still need to add in diagonal terms to Vsum (could have been in j
loop but faster outside as vectorized)
  DiagSumTerms <- (Count^2/IncProb)*(1/IncProb - 1)
  Vsum <- Vsum + sum(DiagSumTerms)
  sdEst <-sqrt(Vsum)
  # approximate confidence intervals based on standard deviations
  upperCI <- estHT + 1.645*sqrt(Vsum)
  lowerCI <- estHT - 1.645*sqrt(Vsum)
  # simulation inclusion probabilities
  # Compute Simulation-based IncProb
    if (simInc>0) {
      StartTime <- Sys.time()
      print(StartTime)
      hits <- rep(0,nrow(X))
#      s.Pjk <- matrix(0,nrow=nrow(X),ncol=nrow(X))
      Transects <- rep(0,N)
      for (ss in 1:simInc) {
        # x coords for n transects
        sx <- DoDraw(Baseline=N,Npoints=n)@data$xcoord
        Transects[sx] <- Transects[sx] + 1
        sHits <- rep(0,nrow(X))
        for (sss in 1:n) {
          sHits <- sHits + (sx[sss]>=Proximal&sx[sss]<=Distal)
        }
        hits <- hits + (sHits>0)
        # now joint occurrences
#        lhits <- as.numeric(sHits>0)
#        s.Pjk <- s.Pjk + crossprod(lhits)
      } # for ss
      print(Sys.time())
      cat(Sys.time()-StartTime)
      s.IncProb <- hits/simInc
      s.NotAlpha <- 1 - s.IncProb
      # First generate H-T estimate of total
      s.estHT <- sum(Count/s.IncProb)

  } # bottom if simInc

  ######## finally, format output
  results <- data.frame(estHT,s.estHT,Vsum,sdEst,lowerCI,upperCI)
```

```
  names(results) <-
c("EstTotal","SimEstTotal","varEstTotal","sdEstTotal","lowerCI","upper
CI")
  InclusionProbs <- data.frame(IncProb,s.IncProb)
  names(InclusionProbs) <- c("Computed","Simulated")

return(list("results"=results,"InclusionProbabilities"=InclusionProbs)
)
} # bottom of function stripACS_est
```

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior

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