Rapid Resource Inventory & Assessment of Horseshoe Bay Cave (2014)

A Baseline Inventory and Analysis of Cave Resources Focusing on Rare Biota and Sensitive Features of the Horseshoe Bay Cave System in Preparation for Development of and Updates to the Cave Management Plan

DRAFT 5/14/2014 **Prepared by:**

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Wisconsin Coastal Management Program

The Wisconsin Coastal Management Program (WCMP) was established in 1978 under the Federal Coastal Zone Management Act to preserve and improve Wisconsin's Great Lakes resources for present and future generations. WCMP is a voluntary state-federal partnership that works through a Governor-appointed Council to provide policy coordination among state agencies and award federal funds from the Office of Ocean and Coastal Resource Management and U.S. Department of Commerce, to state,

local, and tribal governments, universities and non-profit organizations, for innovative coastal initiatives. WCMP supports projects focusing on wetland protection, habitat restoration, nonpoint pollution control, land use planning, great lakes education, public access, and historic preservation.

Established in 1985 by the Wisconsin legislature, Wisconsin's Natural Heritage Inventory program (NHI) is part of an international network of inventory programs. The program is responsible for maintaining data on the locations and status of rare species, natural communities, and natural features throughout the state. Species and natural communities tracked by the Wisconsin NHI Program can be found on the NHI Working List.

Door County Government, established in 1851, provides services to the County's 30,000 year round residents as well as a seasonal population whose size fluctuates throughout the year. The county seat is the City of Sturgeon Bay. The county consists of the city, fourteen towns and four villages covering the 492 square miles of the Door Peninsula.

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- Robert Boszhardt—UW-LaCrosse (retired), archaeology

Cover photo by J. Redell of hibernating bats in the HSB Cave Cloak Room

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CHAPTER 1: PURPOSE & BACKGROUND

Purpose and objectives

Management of cave resources is complex, often involving multiple landowners and a variety of scientific, cultural, financial and political considerations. Land use, geology, hydrology, climate, biology and sociology interact to influence management, and thus it is best to be informed by collecting as much objective data as feasible. This report provides managers with consolidated information about the known geological, biological, and cultural resources that comprise the Horseshoe Bay (HSB) Cave system. It addresses issues specifically related to the conservation of HSB Cave resources and is intended to be used in conjunction with other sources of information, including the best available science for making management decisions related to HSB Cave.

The primary objectives of this assessment were to:

- Compile geologic, biotic, and cultural inventory information relevant to the development of a management plan for HSB Cave and to analyze, synthesize and interpret this information for use by the Science Advisory Committee and Project Oversight Committee.
- Focus on assessing the cave system for rare species, identifying natural community management opportunities.
- Recommend general and site-specific resource management strategies that protect or enhance habitat for these species.

- Provide a tool for cave managers to use for interdisciplinary team work on projects that impact the cave system.

Survey efforts for HSB Cave were limited to a "rapid assessment" for 1) identifying and evaluating Cave resources, 2) documenting rare species occurrences, and 3) documenting occurrences of sensitive features. This document is an internal document used for management planning and decision making. The information collected was the result of numerous survey efforts in and around HSB cave but much work remains to be done. There will undoubtedly be gaps in our knowledge of the resources of this cave, especially for certain biota taxa groups and hydrogeologic activity; some of these have been identified in the future needs section.

Background on previous efforts at HSB Cave

Cave History

Cave exploration efforts in HSB Cave have been increasingly well documented through time. Documentation efforts began with geologist J. Harlan Bretz and include:

- J. Harlan Bretz created the first map of the cave in 1939 illustrating the area from the entrance to the Wall Room.
- By 1963 cavers had explored and mapped the "Old Section" of the cave (1740ft.), which in cluded the Big Rooom.
- Subsequent maps and inventory efforts identified a number of locations where the cave is geomophologically or ecologically significant. (Appendix XX)
- Gary K. Soule has compiled a number of trip reports and historical notes which provide specific dates and details related to the cave exploration and mapping timeline, anecdotal observations, notable geologic features, and hydrogeological events (Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986)
- Norb Kox compiled information and wrote a description of HSB Cave in 1986. In it he offers theories about speleogenesis and predicts hydrogeological activity within the cave.

Cartographic maps

Past efforts by individual members of the Wisconsin Speleological Society (WSS) have resulted in several useful maps of HSB Cave (listed below andprovided in Appendix XX). Maps used in this document are derived directly or modified from maps supplied from the WSS (maps can be found in Appendix A). **Error! Reference source not found.** illustrates the approximate cave ap in relation to surface features.

- 1939—J. Harlan Bretz produces the first map of "Tecumseh" Cave

Geological & hydrogeological mapping

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Photograph by H. L. Bartlett
29. Tecumseh's Cave

Figure 1 Earliest known photo taken inside the cave (Cloak Room) in 1933. (Soule 2014- WI Cave Archives)

Figure 2 Photo of high school teachers in the Wall Room, October 16, 1968 (Soule- WI Cave Archives)

Horseshoe Bay Cave map superimposed over surface image

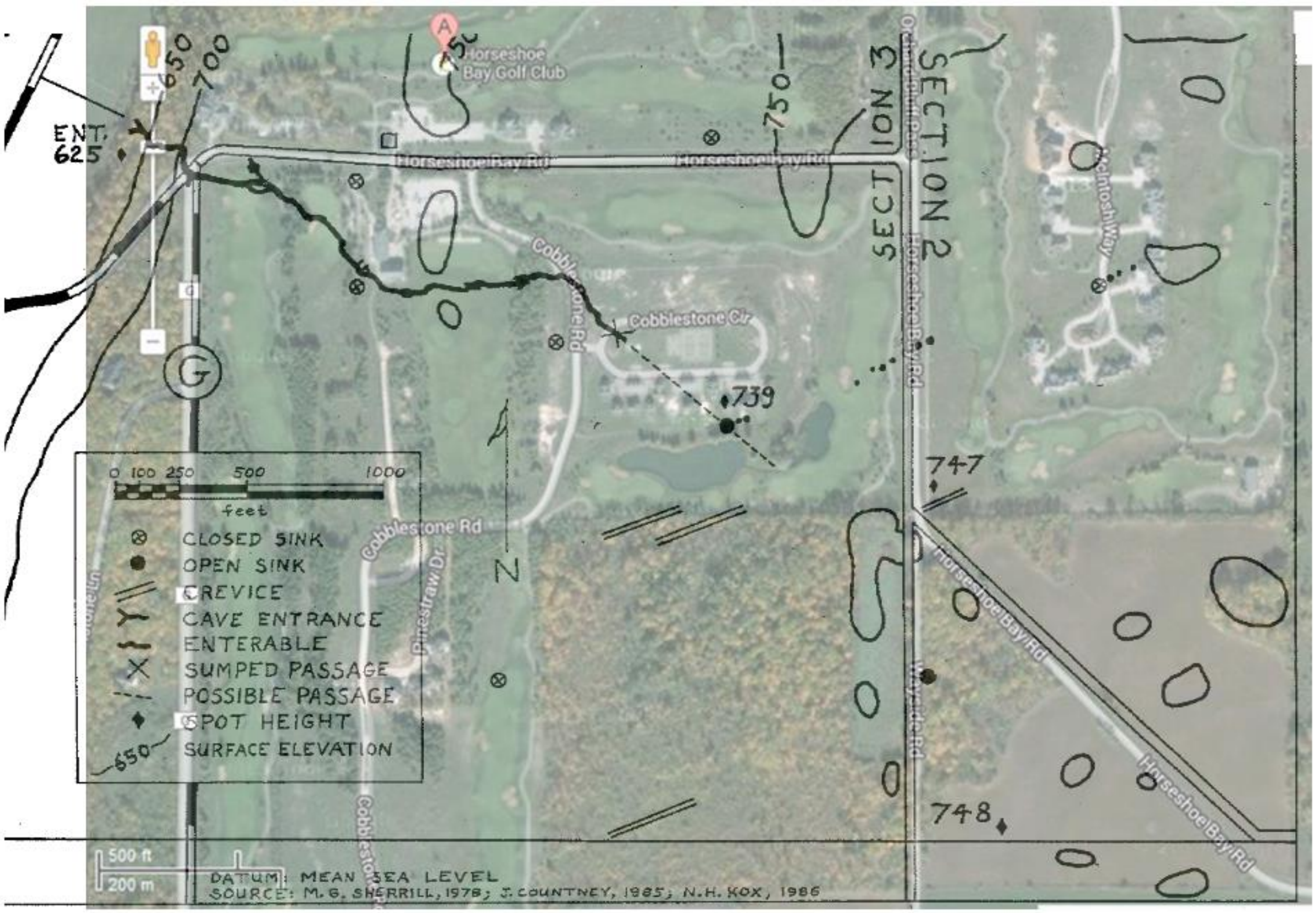
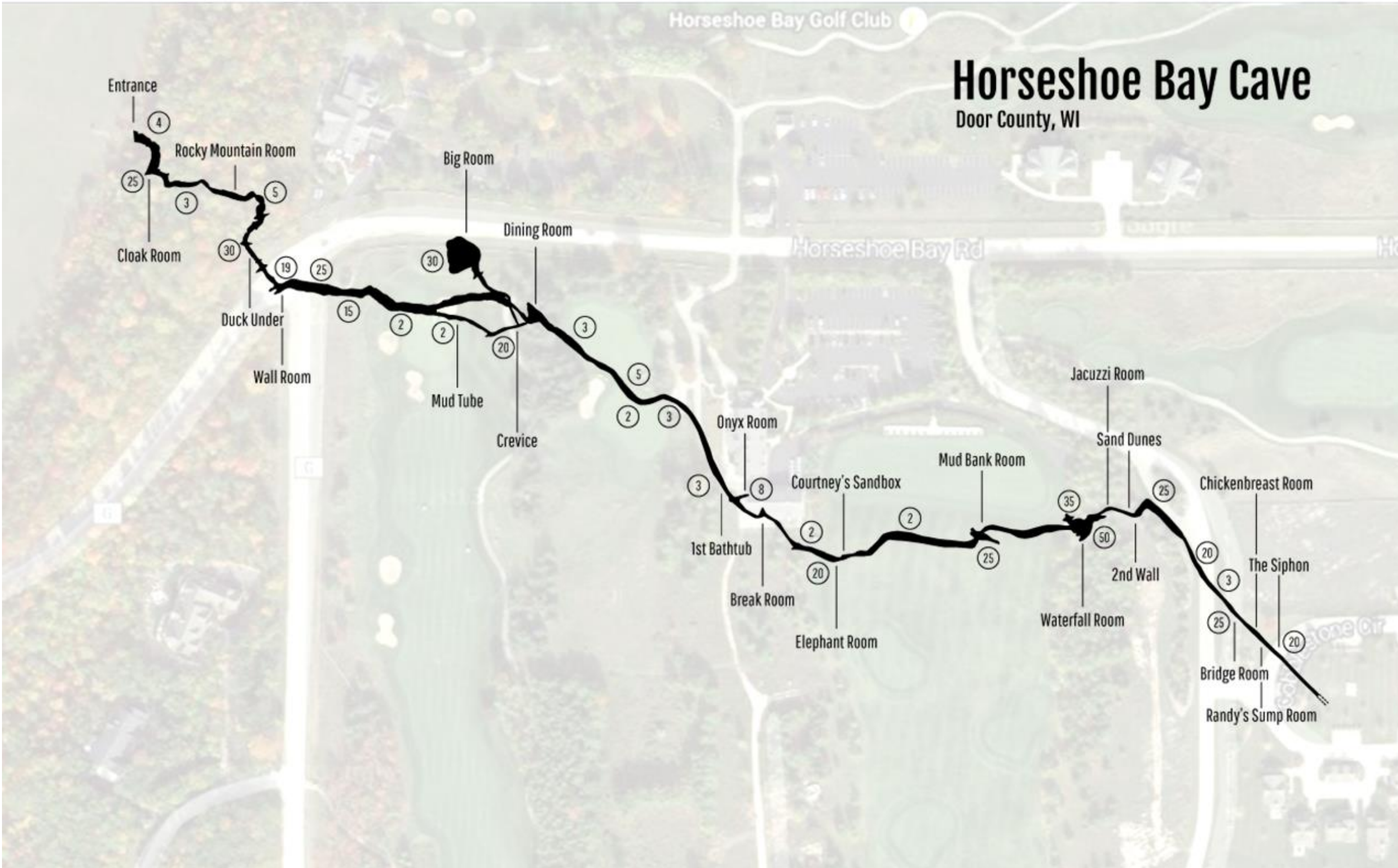


Figure 3 ***In 1988 a 5watt, 23 channel DB radio, a tone encoder, and a one-second time delay circuit were used inside the cave to send signals to the surface where a field-strength meter and loop antenna were used to verify the locations of the Wall Room, Crevice Room, and Big Room.*** **(Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986)**


Horseshoe Bay Cave
Door County, WI
Horseshoe Bay Golf Club
Horseshoe Bay Rd
Entrance
Rocky Mountain Room
Cloak Room
Duck Under
Wall Room
Big Room
Dining Room
Mud Tube
Crevice
Onyx Room
1st Bathtub
Break Room
Courtney's Sandbox
Elephant Room
Mud Bank Room
Jacuzzi Room
Sand Dunes
Waterfall Room
2nd Wall
Chickenbreast Room
The Siphon
Bridge Room
Randy's Sump Room
4
25
3
5
30
19
25
15
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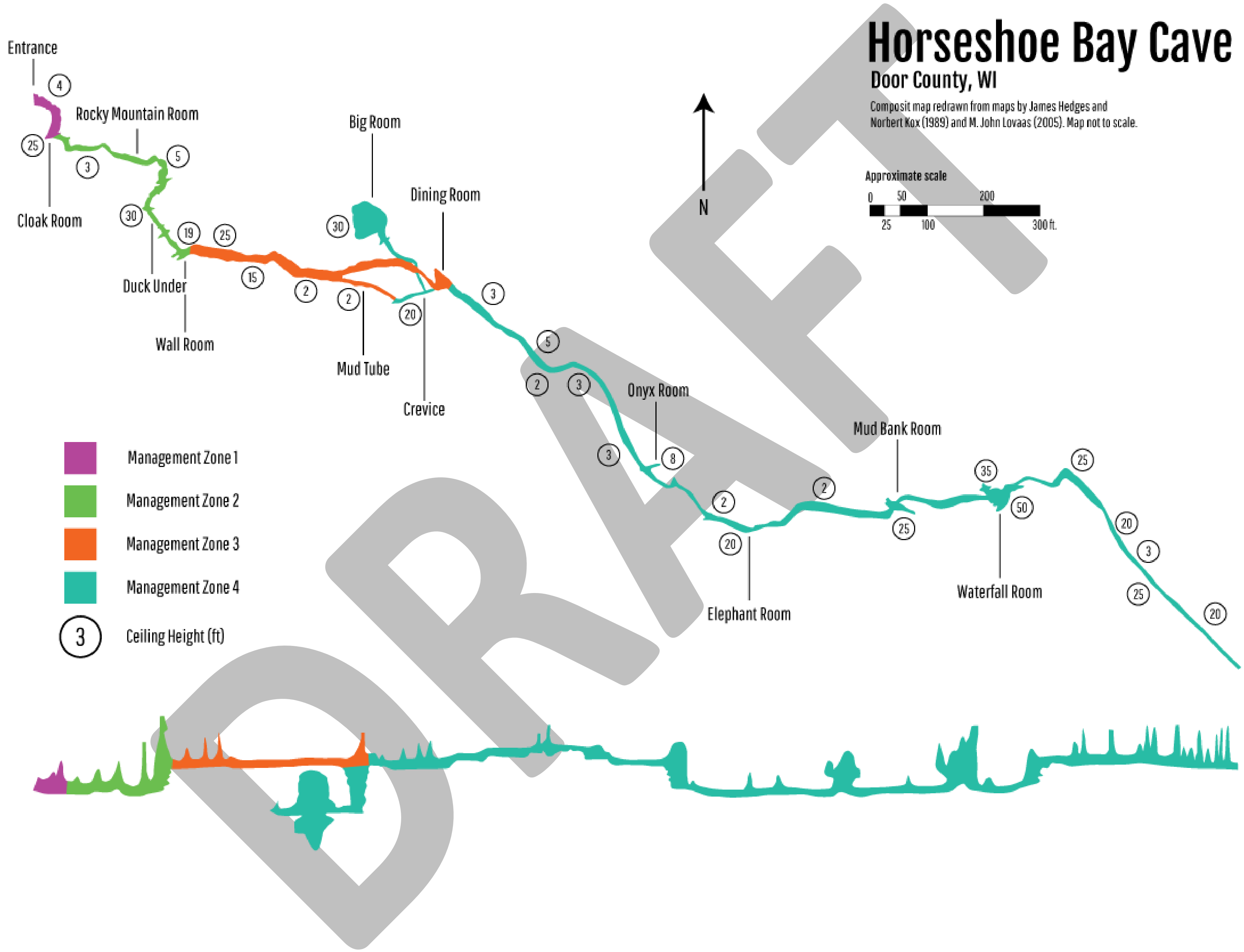

Horseshoe Bay Cave
Door County, WI
Composit map redrawn from maps by James Hedges and Norbert Kox (1989) and M. John Lovaas (2005). Map not to scale.
Approximate scale
0 50 200
25 100 300 ft.
N
Entrance
Rocky Mountain Room
Cloak Room
Duck Under
Wall Room
Big Room
Dining Room
Mud Tube
Crevice
Onyx Room
Mud Bank Room
Elephant Room
Waterfall Room
Management Zone 1
Management Zone 2
Management Zone 3
Management Zone 4
3
Ceiling Height (ft)
DRAFT

Methods

Inventory work was coordinated and, in some cases conducted, by the Wisconsin DNR's Bureau of Natural Heritage Conservation (NHC) and Door County's Soil & Water Conservation Department. (The Wisconsin Natural Heritage Inventory (NHI) Program is a member of an international network of natural heritage programs representing all 50 states, as well as portions of Canada, Latin America, and the Caribbean). Natural heritage programs track certain *elements* of biological diversity: rare plants, rare animals, high quality examples of natural communities, and other selected natural features.

The Wisconsin NHI program uses standard methods for biotic inventory to support guidance and planning. Our general approach involves collecting relevant background information, planning and conducting surveys, compiling and analyzing data, mapping rare species and high quality natural community locations into the NHI database, identifying ecologically important areas, and providing interpretation of the findings through reports and other means.

The NHI methodology for organizing and storing data is actually a system of three inter-related data storage techniques: structured manual information files, topographic map files, and a computer database that integrates the various information. The computer component, known as Biotics, is a sophisticated relational database management application with both tabular and spatial components. The following describe standard NHI methods for conducting inventories.

Exceptional characteristics of HSB Cave

The following are ecologically important characteristics and management opportunities for HSB Cave that contribute to the region's biodiversity.

Cave- naturally occurring voids in bedrock, caves are rare in Wisconsin. There are approximately 90 known caves (not rock crevices or shelters, but naturally occurring voids in bedrock, generally containing a zone of total darkness) in Wisconsin (**Error! Reference source ot found.**). Caves provide subterranean habitat for many species, some of which are wholly dependent on caves to survive.The unique characteristics of cave environments offer the specific conditions required by many animals, as well as some plants that utilize cave entrances. At first, these habitats may appear to be isolated from the outside world, with a layer of rock separating the underground from sunlight, precipitation, and wind. However, a closer look finds that the surface and subsurface are connected in a variety of ways. (Baker) Many of these caves contain cave-obligate biota, and without caves, these species would cease to exist. In North America there are over 1,100 known troglobites and stygobites (Culver et al. 2003), with many more likely present in other subterranean environments, like aquifers and the epikarst. Most cave species are largely unknown; they have small populations and low rates of reproduction, making field studies difficult, and few can be raised successfully in the lab.

Bat hibernaculum- (normally) underground location with stable, buffered temperatures, free from disturbance and predation that bats may use year round, but is critical for mating & winter survival from mid-August through mid-May. There are approximately 145 known bat hibernacula in Wisconsin. They include natural caves, mines, tunnels, and cellars Table 1. Most hibernacula in Wisconsin host relatively few individuals (Table 2) while approximately one quarter of known hibernacula host all four species of cave bats (Table 3).

Overview of the Wisconsin Cave & Mine Catalogue (bat hibernacula)

Based on the rapid expansion of WNS on the landscape (USFWS 2013), the last substantial winter colonies of little brown bats (*Myotis lucifugus)* in the United States, located in Michigan and Wisconsin, are expected to become infected within the next few years. Nearly all large winter colonies of little brown bats in the Northeast have suffered 85 percent to 99 percent losses (Turner et al. 2011). WNS could result in the extinction or large-scale extirpation of this and other bat species (Frick et al. 2010; Thogmartin et al. 2013).

Establishing WNS surveillance and (later) disease management priorities can be achieved with a complete understanding of Wisconsin caves and mines used by bats. Knowing where hibernacula exist, what species and how many bats use them, proximity to one another, bat movement patterns among sites, site accessibility, and survey resources available allow managers to make the most informed decisions when setting priorities in WNS surveillance and (later) disease management actions.

Some of the larger and well known Wisconsin hibernacula have been monitored for years; however, in 2009 many sites were unknown and rarely visited to determine bat usage. To fill the existing gaps, WDNR created a Cave & Mine Catalogue, which will be used to establish priorities for surveillance. While bats had been observed by cavers in the past, HSB Cave was not formally surveyed for bat use prior to 2010.

Gathering data about cave and mine conditions

The process of identifying all hibernacula began by layering existing geo-referenced databases from the Natural Heritage Inventory (NHI) and the Wisconsin Geological & Natural History Survey (WI GNHS) and incorporating paper records from the Wisconsin Speleological Society (WSS) to identify locations of all known and possible bat hibernacula within the state (spring 2010). The resulting list of potential cave and mine hibernation sites included 779 known or previously known underground locations.

Owners of all potential hibernacula locations were contacted by letter and by phone in order to receive permission for WDNR field crews to visit and assess potential sites (spring, summer, and fall 2010). Over 90 percent of landowners in the initial group voluntarily permitted access to their property. Field crews visited these potential sites to ground-truth both current and sealed entrances and assess whether sites offered environmental conditions suitable for bat use (summer & fall 2010). These initial assessments reduced the number of potential hibernation sites from 779 to approximately 145 suitable locations Table 1.

Almost all locations were visited to establish baseline data due to the almost total lack of information related to bat use at the majority of the sites (winter 2011). Again, over 90% of private landowners voluntarily agreed to allow disease surveillance and bat monitoring activities on their property. The only sites not visited were those at which the landowner refused permission to visit or could not be contacted. However, since the initial surveillance winter many of the landowners who refused an initial visit have voluntarily allowed visitation. During the winter visits, bat species, numbers, and environmental conditions were recorded while WNS surveillance were, and continue to be conducted. Data collected from these field efforts were entered into a GIS database and will aid in the prioritization of future surveillance efforts, response strategies, and recovery efforts.

Cave and mine assessment for WNS surveillance and conservation efforts

WDNR has now compiled multiple years of population data to determine where the largest concentrations of bats reside over the hibernation period. Three mines (2 active, 1 abandoned) comprise the top tier of hibernacula by population alone (Tier 1). HSB Cave falls into Tier 2 according to its winter population of over 1000 individuals, however, it has the largest concentration of bats out of all Wisconsin caves Table 2.

WDNR has prioritized sites for follow-up monitoring, management, and conservation efforts such as for sites that contain the largest or most diverse populations and the most threatened or endangered species. Cave and mine hibernacula are categorized for prioritization according to 1) Distance to nearest contaminated site, 2) total number of bats, 3) number of species(Table 3), 4) level of human visitation, 5) apparent value of the site in meeting bat needs, 6) known threats if not protected, and 7) status of the species involved. Due to its high numbers, high diversity, and other factors HSB Cave was identified as a Priority 1 (highest priority) hibernaculum.

Table 1 Since 2010 approximately 800 potential underground sites (caves and mines) were assessed by the WDNR and 145 sites were found to be open and suitable as bat hibernacula.

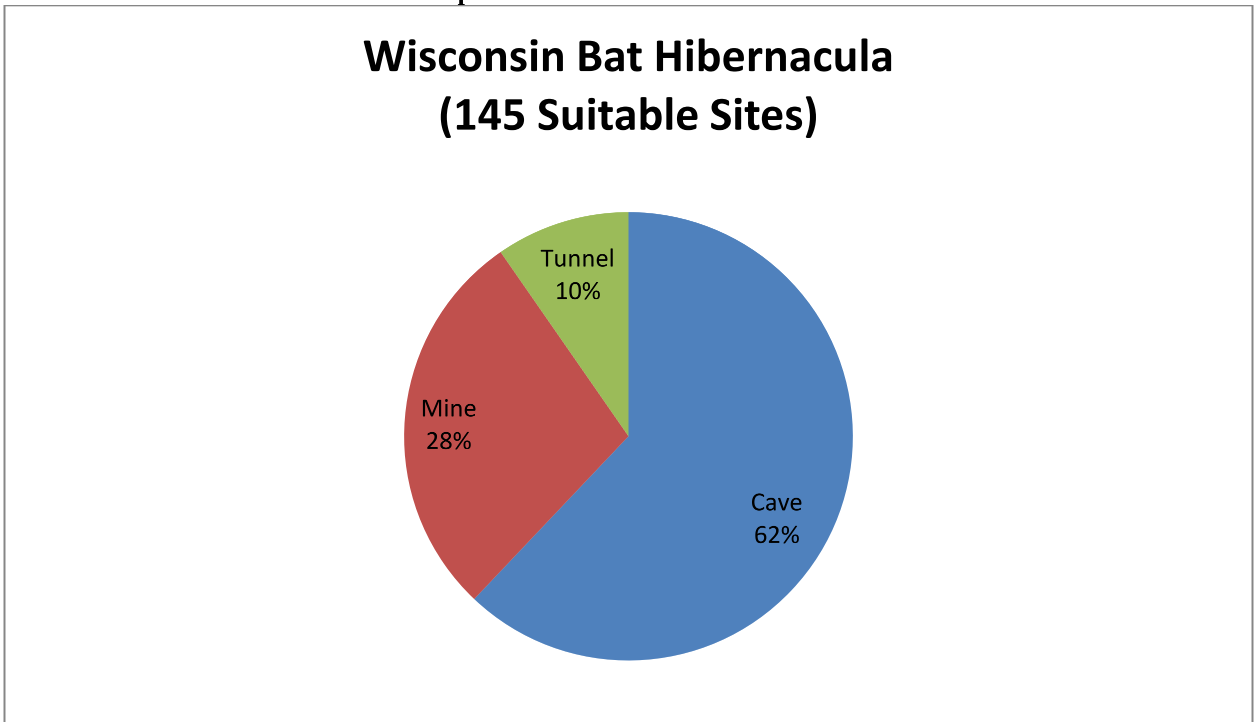


Table 2 Three mines (2 active, 1 abandoned) comprise the top tier of hibernacula by population alone. HSB Cave falls into Tier 2 according to its winter population of over 1000 individuals, however, it is the highest bat numbers of all Wisconsin caves.

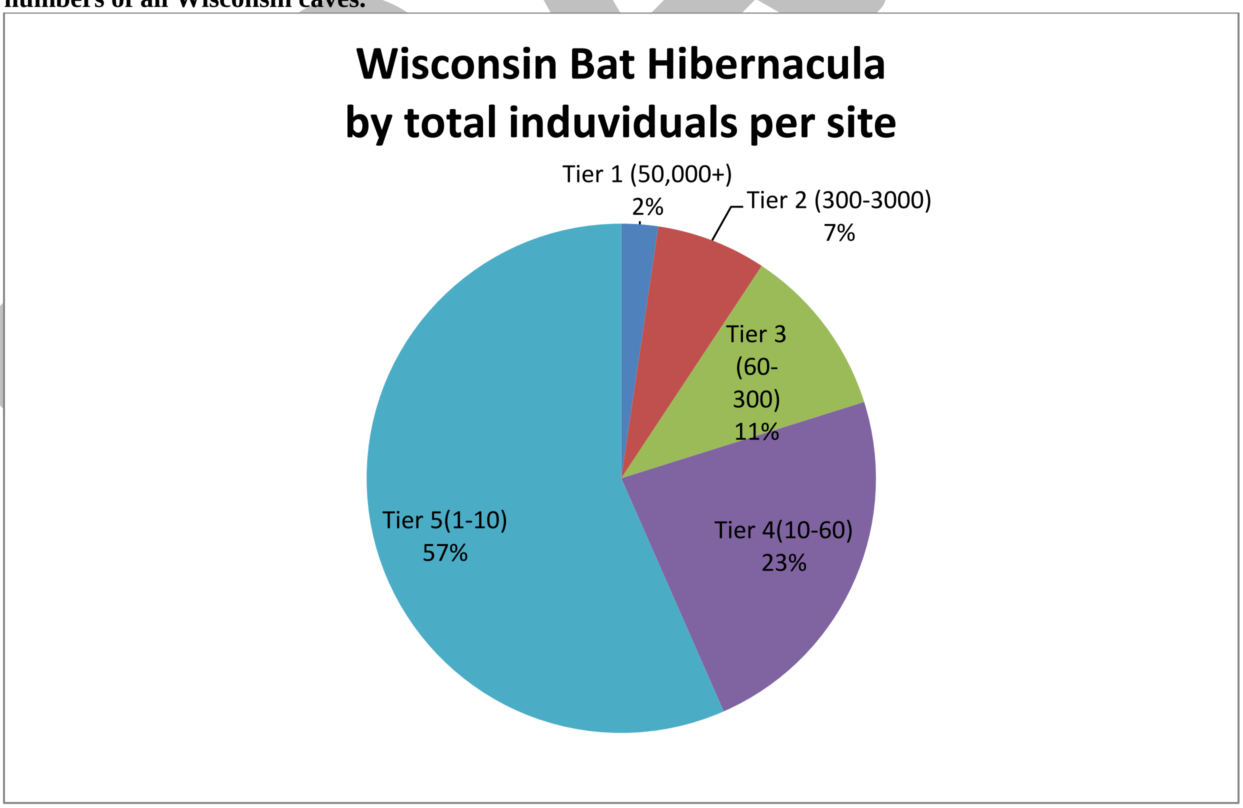
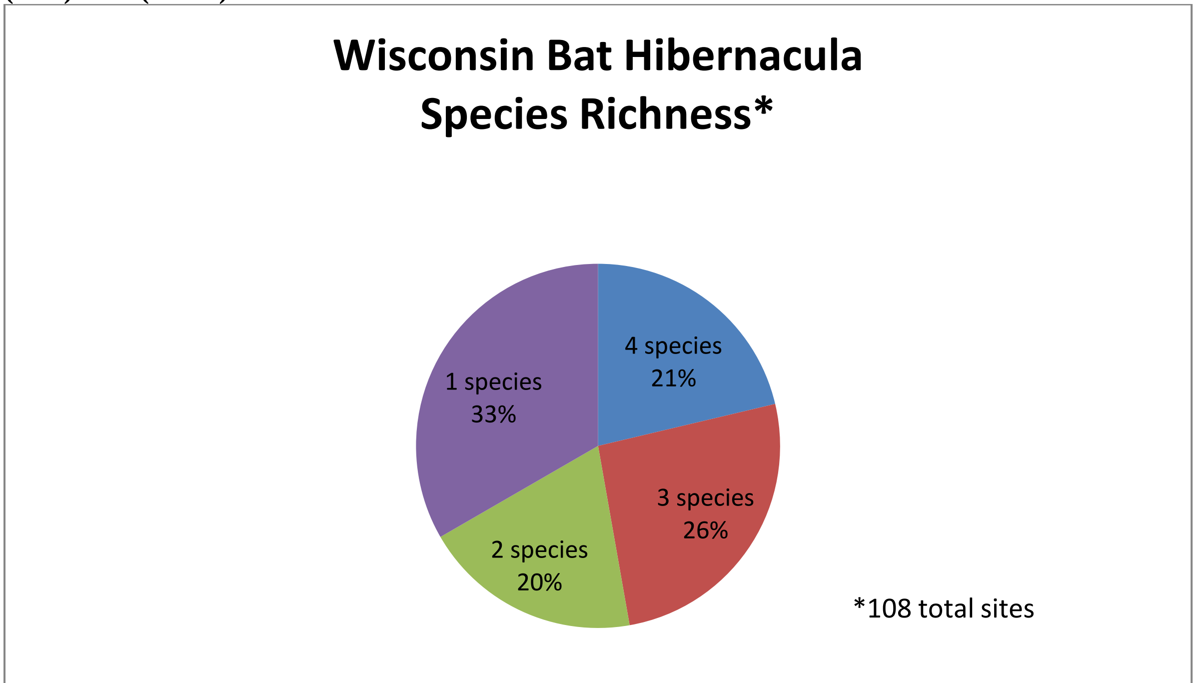


Table 3 HSB Cave has the highest possible bat diversity in Wisconsin, hosting all four species of hibernating (cave) bats. (n=108)



Ecological context

The study area falls within the Northern Lake Michigan Coastal region of Wisconsin's 16 ecological landscapes, based on a system of land classification developed by the WDNR and described as having Lake Michigan climate influence; gently rolling to flat topography with clay and loam soils; land cover now dominated by agriculture in the south and mixed conifer-hardwood forest in the north. The cave itself is a geologic feature contained within the Niagara Escarpment, a known sensitive biologic community and landform subject to the processes of karstification.

Figure 4 The Niagara Escarpment (red) and location of HSB Cave (yellow dot)

Figure 5 The forested entrance of HSB Cave (center of photo, half way up slope) near the base of the exposed Escarpment "ledge".

The Niagara Escarpment is the exposed portion of a 650 mile sickle-shaped bedrock ridge that runs from the northeastern United States south of Rochester, New York, across portions of southeastern Canada, and then southward north and west of Lake Michigan to southeastern

Wisconsin (Anderson, 2002). The portion of the Escarpment occurring in Ontario Canada has been designated as a World Biosphere Reserve by the United Nations Education, Scientific and Cultural Organization (UNESCO).

In Wisconsin, the Escarpment extends for over 230 miles (Martin, 1965), from Rock Island, off the northern tip of the Door Peninsula, south to northern Waukesha and Milwaukee counties (Watermolen 1997 (Watermolen, 1997). The Niagara Escarpment (hereafter “Niagara Escarpment” refers to both the escarpment and cuesta of the formation commonly known as the Niagara Escarpment. See the Glossary for detailed definitions of these terms and others throughout the document.) characterizes the Door Peninsula from the majestic bluffs on the west side of the peninsula to the broad horizontal bedrock “beaches” well developed on the east side of the peninsula. Sand dunes and beaches are found along the Lake Michigan shoreline, as are several areas of complex ridge and swale topography. Embayment lakes and freshwater estuaries are other physical features of the easternmost part of the Landscape. The entrance to HSB Cave is near the base of one of these western bluffs, directly adjacent to the shoreline of Green Bay. It is a documented groundwater resurgence point which has implications for water runoff conditions and impacts on the coastal region.

Neighboring natural communities of HSB Cave

See Appendix F

Existing conditions & altered ecological processes at HSB Cave

The biota that historically occurred in HSB Cave developed within a complex environment comprised of both elements that are relatively static over ecological time (e.g., soils, underlying landforms) and dynamic (e.g., hydrological cycles, nutrient cycles). Some of the dynamic ecological processes that shaped the cave have been altered by humans. At the time of the first recorded discovery of HSB Cave and since its discovery the cave entrance, sediment fill, and hydrology of the cave have been modified by humans for various purposes (Kox) (Soule G. K.).

Entrance modification

Kox’s report on “Tecumseh Cave” notes hunters “discovered” the cave in 1879 when they noticed water flowing from the entrance and needed to clear debris from the area in order to enter the cave (Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986). Assessment of the cave by regional cave art expert Ernie Boszhardt (as part o this project) did not find any signs of pre-

European/settlement use of the cave. No concrete documentation exists for the nature of the cave entrance prior to human modification. Because almost none of the known caves of the Niagara Escarpment exist in their natural state (all have been modified by explorers searching for continuing cave passages) comparing the entrance of HSB Cave to other natural, unmodified entrances in the area is not possible (Society, 1965- 2013) & Redell, personal observations). A result of ice-wedging and shattering of dolomite (Stieglitz R. M., 1980), the presence of talus along most western bluffs of the escarpment and the nature of the talus along the ledge at Murphy County Park indicate that a significant amount of rock and sediment were likely present at the entrance at the time of the cave's discovery. The opening and enlargement of cave entrances can have dramatic effects on both the environmental conditions of the cave and microclimates near the cave entrance.

Figure 6 Many of the rocks stacked in the left of the photo were cleared from the cave entrance area (right) to make the cave more accessible for humans. The curving channel leading downslope from the cave entrance carries water toward Green Bay during periods when the entrance acts as a resurgance point.

Figure 7 This view looking northwest from the cave entrance show the stacked talus rocks and sloping channel along the base of the stack that carries water away from the entrance during times of flooding. The open canopy around the cave allows filtered sunlight to fall on the cave entrance.

In 1986 volunteers from the WSS constructed an iron gate just inside the drip line of the cave entrance Figure 8 (Zachariasen, 1990). The gate was designed to prevent unauthorized human access and was constructed of I-beam iron bars and a solid iron door in the center of the gate. The gate was also designed to exlude most raccoons, opossum, porcupines, and other larger mammals that frequent caves. 4-5 inches of space were left between the iron bars to allow for the entry of bats which were known to use the site. Multiple signs were hung in the center of the cave passage just inside the gate indicating that people interested in accessing the cave should contact the WSS (Figure 10).

Figure 8 The historic gate at HSB Cave did not reflect current bat-friendly gating standards.

Figure 9 The new gate, installed in 2012, reflects current bat-friendly gate standards.

Figure 10 Signs hanging just inside the entrance directly in the flight path for bats.

Passage modification

The presence of (relative to floor height) high sediment banks along passage walls and exposed strata, though potentially the result of flooding, seem more likely to be the result of digging to lower the floor of the passage for human access. No records exisit in the consulted literature to provide further information about when this may have occurred.

Historical caving trip reports indicate that sediment was dug out or moved from the main passage between the entrance and Big Room at various points during the cave's recent history. Sediment was dug out of the "Top Shelf" passage off the Big Room in 1985 and deposited in a large pile on the floor of the Big Room (Kox, A General History of Horseshoe Bay Cave (Tecumseh Cave), 1990). When a sand-choked passage closing the far end of the Elephant Room (Countney's Sandbox) was discovered in 1963 cavers dug it open in order to continue exploration. Subsequent trips to the Sandbox found it washed closed again and digging was required to pass through, eventually leading to the discovery of the "Waterfall" and "Bat" rooms in 1978. In 1986 a wooden dike and dam of sand bags and boards was installed to permanently open the Mississippi River section of the cave. (Kox, A General History of Horseshoe Bay Cave (Tecumseh Cave), 1990)

Surface & drainage basin land use

Farming, golf course, housing, tree cutting, road/pavement blocking recharge, excavating sinkholes, filling sinkholes and other karst features such as grikes, high capacity wells

High capacity wells may contribute to a lowered local water table that results in the more frequent opening of airspace in otherwise sumped (flooded) cave passages beyond Countney's Sandbox.

Nutrient enrichment

Fertilizer application, septic systems, and human activity in caves may all lead to increased nutrient input into the cave ecosystem. Almost all natural communities derive energy directly from sunlight on vegetation which is in turn consumed by animals that transmit that energy up the food chain to top predators. Cave ecosystems derive energy from indirect sources such as debris washed or carried into the cave, animal waste deposited in the cave, meteoric waters infiltrating the cave system through a variety of entry points, or from the chemistry of the rock itself Figure 11. As a result cave systems and flora & fauna within them are starved for energy but adapted to living on little. Cave ecosystems such as HSB Cave are frequently unbalanced as a result of flooding (which may remove nutrient sources and inhabitants) and the input of nutrients from human visitors (who may bring food debris, lint, leaf litter, skin, hair, or other wastes far beyond the cave entrance—where high nutrient levels from incidental input on the surface is expected). Although specific cases have not been studied, both frequent flooding and human derived nutrient input are known factors affecting the ecosystem of HSB Cave.

Figure 11 An abandoned mouse nest on a rocky shelf beyond the Cloak Room illustrates how nutrient material in cave ecosystems must be washed, blown, or carried in from the cave entrance.

CHAPTER 2: UNIQUE COMPONANTS & RESOURCES

These results from the biotic inventory and other surveys are not listed in order of importance or priority. Effective management of the Horseshoe Bay Cave system provides the opportunity to support high-quality habitat for a large number of rare and declining species and can help reduce impacts from habitat fragmentation and ecological simplification of landscapes.

Geological & geomorphological component

Geological setting

One of the most obvious features shared by both karst and non-karst caves, including caverns, fissures, fractures, shelters, tubes, and other rock cavities, is that they all provide windows into rock units. In some cases, a cave may provide the best or only exposure of a subsurface geologic unit. Likewise, fossils preserved in a cave-forming rock unit may in turn become exposed through cave-forming processes.

HSB Cave is located in the Door Peninsula, which extends some 100 km into Lake Michigan and ranges from 5-30km wide, a cuesta developed on the Silurian-aged Niagaran dolomite. The Niagaran Series is approximately 107-m thick and consists dominantly of light gray, medium to coarse-grained, thin-bedded, fossiliferous dolomites and includes, from oldest to youngest, the Burnt Bluff Group, the Manistique Dolomite, and the Engadine Dolomite (Sherrill, 1978) (Stieglitz R. , 1990). Horseshoe Bay Cave formed in the Burnt Bluff Group, along with many other notable karst features of the Escarpment. Joints in Door County follow two prominent sets with azimuths of about 72° and 155° (Schneider, 1989; Carson and others, 2013). The precipitation of Paleozoic Mississippi Valley-type minerals along planar surfaces, as well as a late episode of dolomitization (sometimes present only along joints and bedding plane fractures) serves as evidence for a Middle to Late Paleozoic age for bedrock joints and rarely observed faults (Luczaj, 2006).

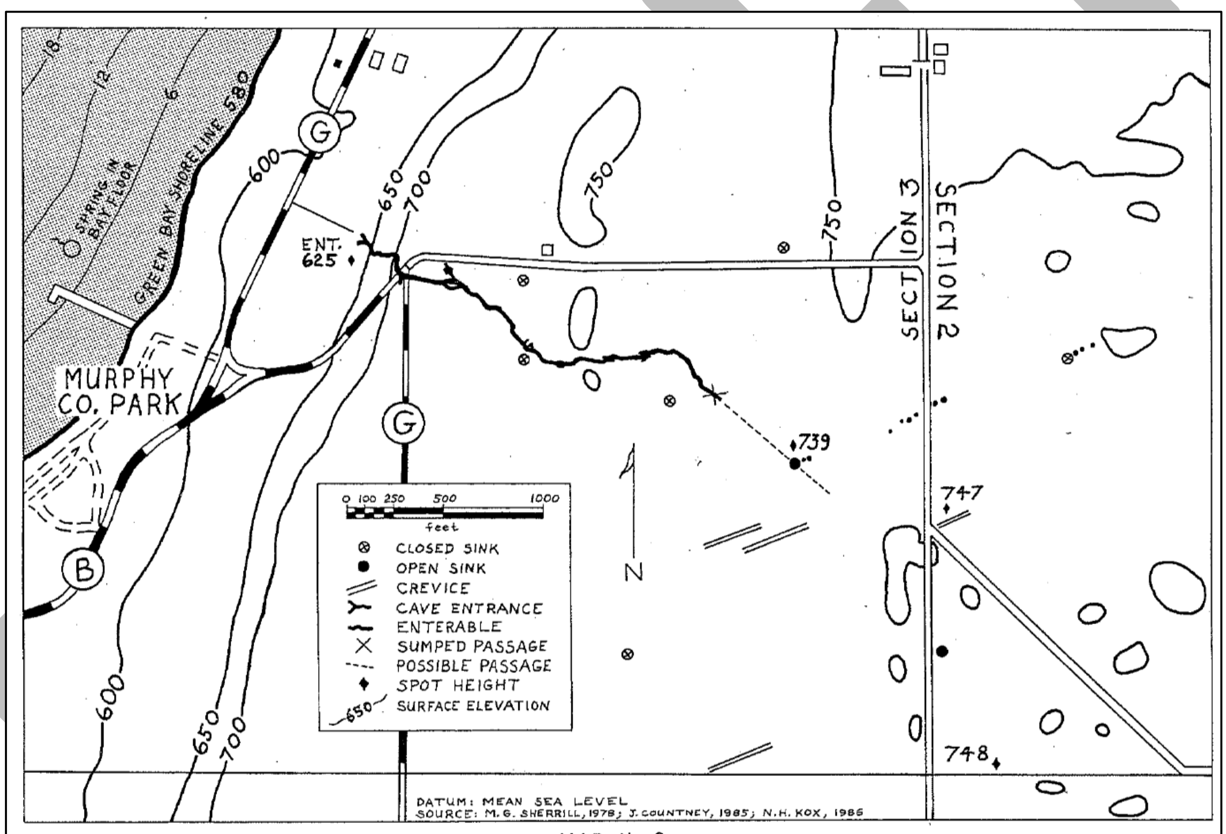


Figure 12 Map illustrating visible surface karst features overlying the HSB Cave area (Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986).

Geomorphology of HSB Cave

Wisconsin caves have formed through an interaction of geology, vegetation, and rainfall. Caves in Wisconsin can be found in two distinct karst regions: in the Ordovician dolostone of the Driftless Area in the southwest and western part of the state, and in the Silurian dolostone of the Niagara Escarpment along the eastern part of the state.   The dolomite bedrock of the Door Peninusula has extensive karst development (Johnson & Stieglitz, 1990).

Continental glaciation has influenced both distribution and surface morphology of preexisting karst features in Wisconsin and may have contributed to some new ones. The Door Peninsula was covered by ice periodically during the (at least) three major stages of Pleistocene glaciation in Wisconsin, though it is not known how frequently and for what duration (Schneider, Late Wisconsin glaciation of Door County, Wisconsin, 1981) (Schneider, Till stratigraphy of the northern Door Peninsula, Wisconsin, 1986) (Schneider, Geomorphology and Quaternary Geology of Wisconsin's Door Peninsula, 1989). As a result the peninsula is characterized by glaciokarst landforms, including staircases and pavements, postglacial crevices and sinkholes, and caves (Rosen, 1990). Joints (vertical fractures) and bedding planes (horizontal contacts) in bedrock have a strong influence on the orientation and character of most karst features, particularly HSB Cave and other caves in the Escarpment. Close to the escarpment, joints are dilated as a result of glacial unloading or ice wedging (Stieglitz R. M., 1980).

Karst forming processes include mildly acidic meteoric waters enlarging vertical joints and horizontal bedding planes over time, creating conduits for groundwater flow. Later, as groundwater levels drop, air-filled passages emerge, occasionally intersecting with the surface as they are exposed by erosional forces. Unfortunately, because the very nature of speleogenesis is erosional in nature, most evidence for events leading to the formation of caves is absent from surface landscapes as well as the karst feature itself. Geologists are left with only the use of cross-cutting relationships and the presence of secondary sedimentary deposits for relative age determination. Some caves in Door County contain mammal bones that have been radiometrically dated to be several thousand years old indicating that cave formation and some of the sediments in these caves are even older than the fossil record they hold (Brozowski and Day, 1994; Luczaj and Stieglitz, 2008, ongoing research).

Horseshoe Bay Cave is one of the longest known caves in Wisconsin, with approximately 740 m of explored passageway and 49 rooms (Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986). The cave developed along dissolution-widened bedding planes, forming domes where vertical dissolution-widened joints intersect the passageways (Johnson & Stieglitz, 1990) Figure 13. It is considered to have formed by a combination of phreatic and water table influences (Ford & Williams, 1978). The domed rooms are oriented parallel to other elongated sinkholes and crevices present at the surface and following a N70-80E joint trend (Johnson & Stieglitz, 1990). A detailed description of the cave’s passage and rooms can be found in Kox’s report (1986).

It is likely that HSB Cave formed prior to the Pleistocene glaciations of N. Eastern Wisconsin, which took place within the last 2 million years in this part of North America. This is due to the observed presence of glacial gravels in HSB Cave (often found beneath vertical joint-controlled domes) and other caves in the region. According to Rosen and Day (1990) speleogenesis Door County's caves may have been initiated prior to the last glaciation but Brozowski and Day (1994) have hypothesized karstiglacial cave formation of nearby Brussels Hill Pit Cave after glacial loading and unloading accentuated bedrock jointing that were subsequently enlarged by dissolution. Clastic sedimentary deposits and flowstone, that must be younger than the cave itself, could help determine the age of HSB Cave and are recommended for future study. Other hypotheses propose the development of the cave during or after the glacial period **Error! Reference source not found.**.

A lack of collapsed areas, bones clearly from the surface, and organic soils point to the liklihood the cave remained largely "closed" to the surface until gravity induced mass wasting during the formation of talus slopes exposed it at the present day Escarpment entrance. A bedrock channel extends from the modern entrance in a sinuous path to the northwest, following the same trend as the cave, however the walls and ceiling of the cave are missing in this area.

It is possible that wave erosion from glacial Lake Algonquin (6,000 ybp) may have played a role in opening the cave. As many as a dozen different late-glacial and post-glacial shorelines of higher lake levels can be seen along the Door Peninsula, with good records of terraces, wave-cut cliffs, sea caves, dune ridges, and gravelly beach ridges (Schneider, 1989). These ancient shorelines are remnants of higher lake levels recorded during Algonquin and Nipissing stages, approximately 11,000 and 5,500 14C years ago, respectively. (Schneider 1989; Larson and Schaetzl 2001)

The cave entrance faces west from the base of a steep-sided bluff formed where the escarpment rises up to 79m above present lake level and is located near Horseshoe Bay. The base of the bluff is talus-strewn while the top, relatively flat surface, reflects the less than one degree dip of the southeast sloping side of the cuesta. Characteristic of karst landscapes, the upland area above the cave is covered by a thin veneer (mostly less than 1m thick, of unstratified sandy till, much of which contains more than 25% calcium carbonate. (Thwaites, 1957) Numerous karst features are present above the cave Figure 12.

Figure 13 The Wall Room is the transition point from low level cave passage to upper level passage . Domed rooms like these are some of the only places where a human can stand up in HSB Cave.

Non-biotic HSB cave resource table

Numerous unique and sensitive features have been documented in HSB Cave.

Table 4 *Documented features. More than one element occurrence of a particular feature may be at each location.*

Bedrock geological/Hydro	Secondary geomorphological	Tertiary geomorphological	Classification/type	Detail/description
Bedrock inclusions - mineral				
Bedrock inclusions - mineral			Chert	
Bedrock inclusions - mineral			Glauconite	
Bedrock inclusions - mineral			Geothetite	
Bedrock inclusion- fossil				
Bedrock inclusion- fossil			Crinoids	
Bedrock inclusion- fossil			Stromatolite	
Bedrock inclusion- fossil			Coral	
Cross bedding				
Vertical jointing				
Ripple marks				
	Differential solution			
	Dissolution enlarged bedding planes			
	Dissolution enlarged joints (domes)			
	Speleogen			
	Speleogen		Echinoliths	
	Speleogen		Karren	
	Unconsolidated sediment			
	Unconsolidated sediment		Breakdown blocks	
	Unconsolidated sediment		Bones/fossils	
	Unconsolidated sediment		Gravel- rounded	
	Unconsolidated sediment		Gravel- rounded	Glacial
	Unconsolidated sediment		Gravel- clastic	
	Unconsolidated sediment		Sand	
	Unconsolidated sediment		Clay	
	Unconsolidated sediment		Stratification	
	Unconsolidated sediment		Organic material	
	Unconsolidated sediment		Organic material	Vermiculations

Unconsolidated sediment		Organic material	Guano/scat
Unconsolidated sediment		Organic material	Seeds/nuts
Unconsolidated sediment		Organic material	Wood/stick/board
Unconsolidated sediment		Organic material	Mouse nest
Unconsolidated sediment		Cross bedding	
Speleothem			
Speleothem		Flowstone	
Speleothem		Coral/popcorn	
Speleothem		Soda straws	
Speleothem		Stalactite	
Speleothem		Stalagmite	
Speleothem		Helectite	
Speleothem		Oolite/calcite coating	
Speleothem		Rimstone dams	
Speleothem		Ribbon stalactite	
Speleothem		Drip cup (calcite)	
Speleothem		Spatter cone/marks	
	Meteoric water		
	Meteoric water	Dripping	
	Meteoric water	Flowing	
	Meteoric water	Pool- perched	24x12cm resting on flowstone coverd breakdown
	Meteoric water	Pool- ephemeral	
	Meteoric water	Perched sump	
	Groundwater	Sump	
	Drip holes in mud		
	Erosion of calcite	Toothed ribbon stalactite	

Table XX. List of features recorded in Horseshoe Bay Cave, Door County, Wisconsin. Last updated 2013.

Bedrock geological/Hydro	**Secondary geomorphological**	**Tertiary geomorphological**	**Classification/type**	**Detail/description**	**Location**

Bedrock inclusions - mineral				
Bedrock inclusions - mineral		Chert		
Bedrock inclusions - mineral		Glauconite		
Bedrock inclusions - mineral		Geothetite		
Bedrock inclusion- fossil				
Bedrock inclusion- fossil		Crinoids		
Bedrock inclusion- fossil		Stromatolite		
Bedrock inclusion- fossil		Coral		
Cross bedding				
Vertical jointing				
Ripple marks				exposed in multiple locations beyond Crevice
	Differential solution			
	Dissolution enlarged bedding planes			
	Dissolution enlarged joints (domes)			
	Speleogen			
	Speleogen	Echinoliths		Edges of upper passage in Zone 3
	Speleogen	Karren		
	Unconsolidated sediment			
	Unconsolidated sediment	Breakdown blocks		
	Unconsolidated sediment	Bones/fossils		
	Unconsolidated sediment	Gravel- rounded		
	Unconsolidated sediment	Gravel- rounded	Glacial	
	Unconsolidated sediment	Gravel- clastic		
	Unconsolidated	Sand		

sediment				
Unconsolidated sediment		Clay		
Unconsolidated sediment		Stratification		
Unconsolidated sediment		Organic material		
Unconsolidated sediment		Organic material	Vermiculations	
Unconsolidated sediment		Organic material	Guano/scat	
Unconsolidated sediment		Organic material	Seeds/nuts	Passage to Big Room
Unconsolidated sediment		Organic material	Wood/stick/board	
Unconsolidated sediment		Organic material	Mouse nest	
Unconsolidated sediment		Cross bedding		
Speleothem				
Speleothem		Flowstone		
Speleothem		Coral/popcorn		
Speleothem		Soda straws		
Speleothem		Stalactite		
Speleothem		Stalagmite		
Speleothem		Helectite		
Speleothem		Oolite/calcite coating		
Speleothem		Rimstone dams		
Speleothem		Ribbon stalactite		
Speleothem		Drip cup (calcite)		
Speleothem		Spatter cone/marks		
	Meteoric water			
	Meteoric water	Dripping		
	Meteoric water	Flowing		

Meteoric water	Pool- perched	24x12cm resting on flowstone coverd breakdown	Rocky Mountain Rm
Meteoric water	Pool- ephemeral		
Meteoric water	Perched sump		
Groundwater	Sump		
Drip holes in mud			Big Rm
Erosion of calcite	Toothed ribbon stalactite		

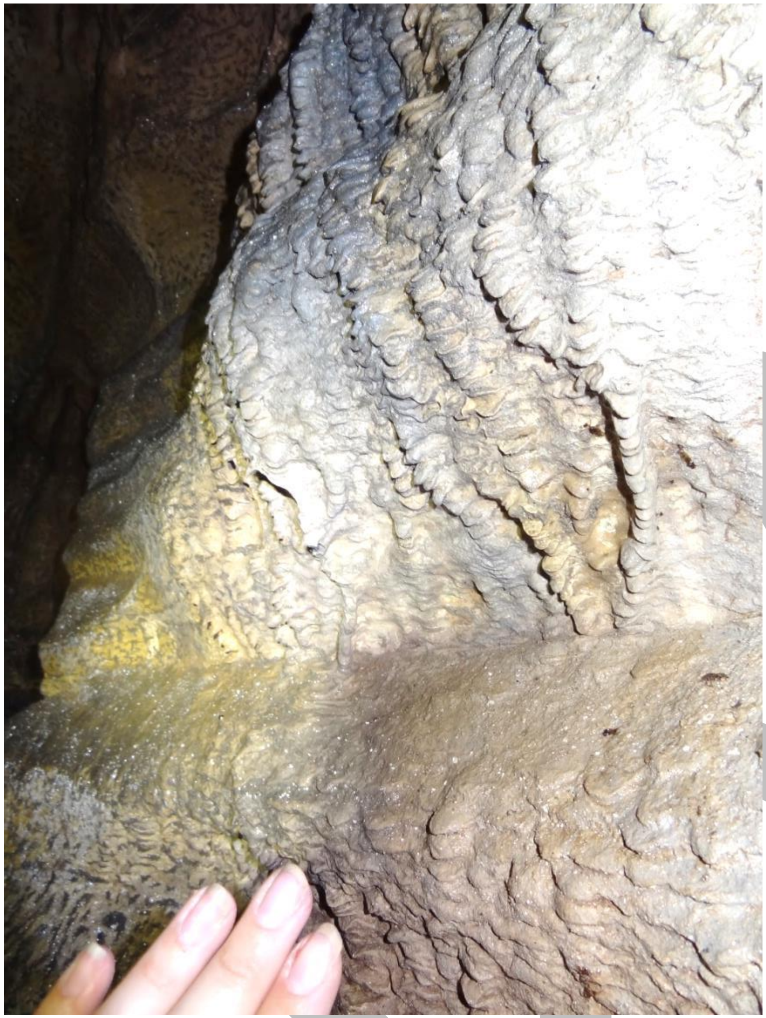


Figure 14 (Left) Unusual rippled flowstone/ ribbon stalactites are found in several areas of HSB Cave.
Figure 15 (Right) Unconsolidated sediment banked along the wall of the entrance passage near the Cloak Room. Calcite flowstone is beginning to form over the bank (upper left). Strata are present (center). In some places in the cave glacial gravels are present, indicating an opening to the surface

Figure 16 View of the Rocky Mountain Room, one of the only places in the cave tall enough to stand.

Figure 17 Calcite covers breakdown in the Rocky Mountain Room and flowing water depositing calcite has formed rimstone dams on the surfaces. The tiny pools created behind the dams provide habitat for cave invertebrates.

Figure 18 Tiny rimstone dams cover the breakdown on the floor of the Rocky Mountain Room. Headlamp for scale.

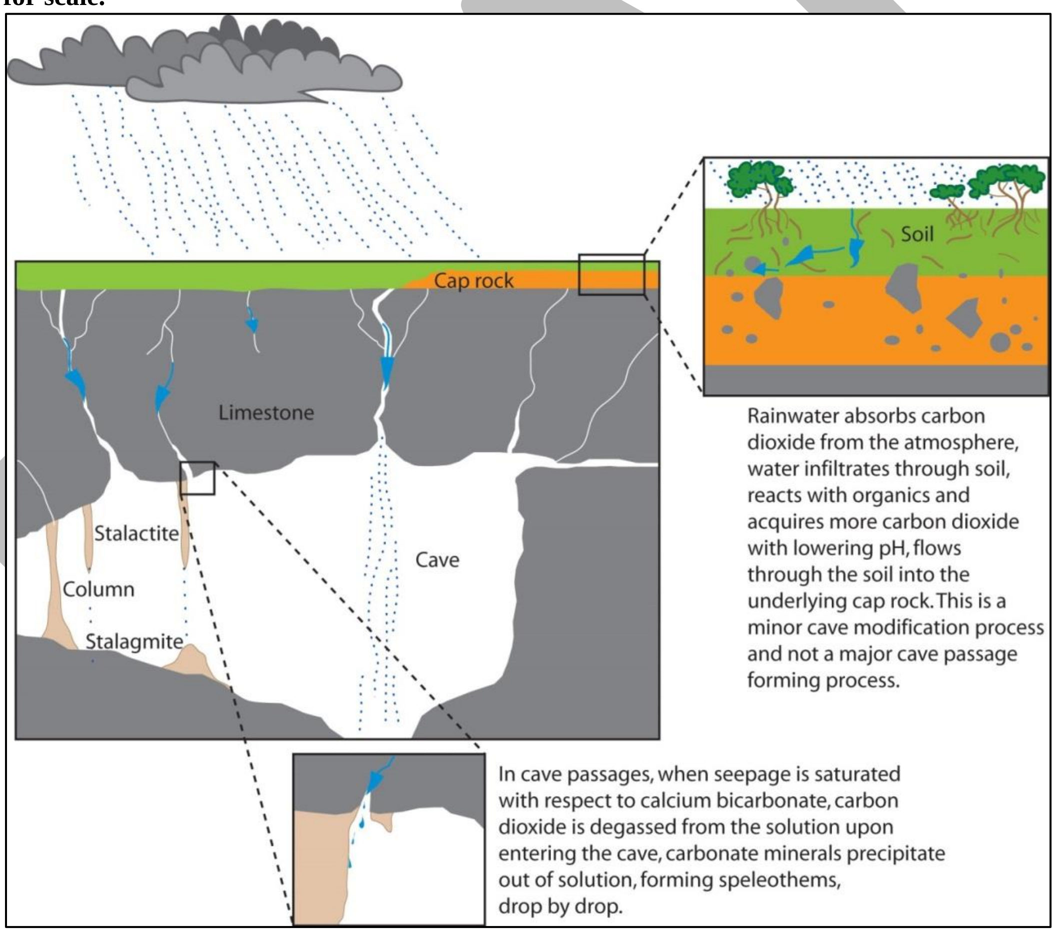


Figure 19 Speleothem formation in caves. (www.nature.nps.gov)

Speleothems

Speleothems are formed when calcium carbonate (calcite, $CaCO3$) precipitates from dripping, flowing, or seeping groundwater within underground caves (Bloom, 1998). While speleothems in HSB Cave are less abundant than in caves of the Driftless Area, they are present in many areas of the cave and should be protected from damage. Figures 9-13 illustrate several notable features, including speleothems, in HSB Cave, worthy of further doucmentation, monitoring, and protection. In some cases speleothems may be annually banded or contain compounds that can be radiometrically dated to reveal the timing of precipitation and have major implications for our understanding of past climate changes (e.g., Drysdale and others, 2007). Speleothems have intrinsic value for their beauty, are often very delicate, and can easily be broken due to a careless brush of the hand or helmet. This damage mars the beauty of the cave, eliminates clues to the cave's formation and processes, and takes hundreds or thousands of years to repair or replace, if ever.

Figure 20 One of few large ribbon stalactites in HSB Cave near the Elephant Room. Photo Ethan Brodsky

Clastic materials

Should be left in place—habitat, host isolated pools, provide clues to past cave events, etc.

Unconsolidated sediment

Unconsolidated sediment can contain and protect bones, teeth, wood, pollen, and other organic materials can reveal much about the history of a cave and should remain undisturbed except for valid scientific study.

Suggested Future Work

Mapping underground features and correlating the map of the cave to surface features may help determine which joints and surface features control the cave and will be useful in determining sources of pollution and nutrient enrichment (if found to be problematic).

Isotopic age dates obtained from speleothems or cave decorations and organic materials could yield age dates to help determine the timing of cave development.

Johnson and Stieglitz suspect that further analysis may indicate that vertical joints (paralleling the domed rooms in HSB Cave) are responsible for a large proportion of vertical recharge (Johnson & Stieglitz, 1990).

Speleothems, such as stalagmites, stalactites and flowstones, are a rich archive of terrestrial paleoclimate information. This has led to focused and high-quality research that has utilized many of the more recently available state-of-the-art sampling (e.g. laser ablation mass spectrometry) and dating (e.g. multi-collector ICPMS) techniques. The more commonly examined speleothem-based paleoclimate proxies are:

1. **Growth intervals**: determined by Uranium-series age determinations and used to identify wetter vs. drier or warmer vs. cooler climate intervals (e.g., Ayliffe et al., 1998; Spötl *et al.*, 2002).

2. **Oxygen (!18O) isotope ratio**: interpreted as variations in cave temperature and properties of rainfall (temperature, air mass trajectory, source and amount effects etc.) (McDermott et al., 2004).

3. **Carbon (13C) isotope ratio**: interpreted as changes in overlying vegetation (C3 versus C4 plants) and vegetation density (Dorale et al., 1998; Baldini et al., 2008). The potential corruption of this signal downstream of the source caused by equilibration of aqueous CO2 with cave air is also recognised, and in some cases, exploited as a proxy.

4. **Annual band thickness**: used as a proxy for the amount of rainfall (Polyak et al., 2001; Fleitmann *et al.*, 2004) or mean annual temperature (Frisia *et al.*, 2003; Tan et al., 2003).

5. **Trace elements**: interpreted as proxies for rainfall, vegetation, and growth rate and increasingly measured at high resolution to resolve seasonal information and annual features (e.g., Treble *et al.*, 2003; Johnson et al., 2006).

Figure 21 Sampling clay vermiculations near the Cloak Room.

Figure 22 On its way from the surface groundwater carries dissolved calcite into the cave, leaving delicate soda-straw stalactites on the ceiling as it drips. It may take 100 years for a cubic inch of calcite to be deposited in this manner.

Figure 23 Rimstone dams form tiny pools covering flowstone in the corner of the Cathedral Room. Photo: Ethan?

Hydrological component

Hydrogeologic Setting

Groundwater movement in the Niagaran is through discontinuous bedding plane joints and nearly vertical joints in the upper part and continuous bedding plane joints in the lower part (Sherrill, 1978). Recharge to the aquifer is from precipitation that enters the dolomite through abundant, near-vertical joints. Groundwater surface mapping indicates that groundwater movement in this area is east toward the Niagaran escarpment and Green Bay (Sherrill, 1978). A dye tracer test under forced gradient conditions at a Niagaran aquifer well pumping 225 GPM demonstrated that groundwater can move rapidly through the joints in the dolomite (Sherrill, 1978). The tracer dye moved 173 ft. horizontally from the injection well to the pumping well in less than two minutes.

Karst features such as sinkholes, dolomite pavements, springs, and caves are ubiquitous in Door County. The karst landscape here is charachterized by very rapid, direct drainage of surface and soil waters into the karst aquifer Figure 24. HSB Cave has internal drainage that discharges to the regional groundwater system. Soil boring information indicates… 0-5’ of fine sandy loam till over bedrock containing karst features…?

The entire HSB Cave area is in the Holokarst B Karst Drainage Zone (Johnson & Stieglitz, 1990).

In this drainage zone “surface runoff is contained within closed drainage basins and is channeled primarily by intermittent streams into alluvial sinkholes”. This accurately describes the hydrology and physiography of the surface area above HSB Cave. They also describe the vulnerability of the holokarst areas: “The holokarst regions have a high potential for infiltration and movements of contaminant throughout the aquifer”. Aquifer vulnerability was also assessed by Sherrill in 1978.

Plum Bottom is in one the areas of the county with the highest aquifer vulnerability.

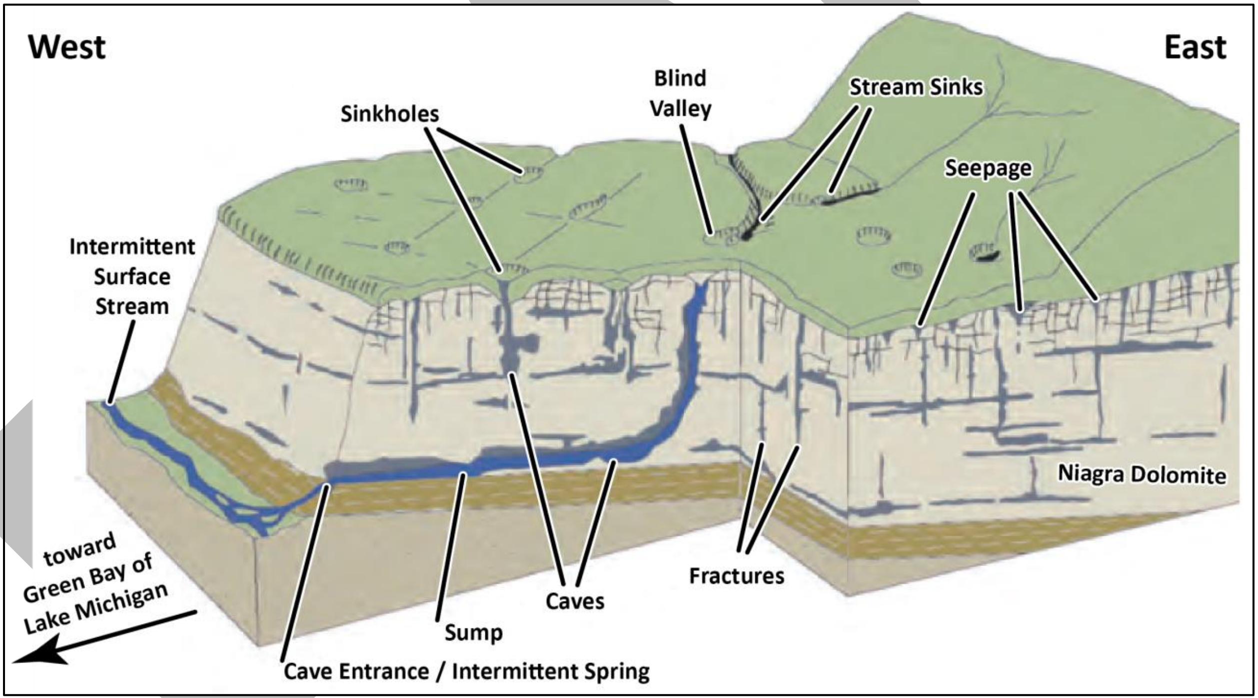


Figure 24 Diagramatic representation of karst structure in the vicinity of a cave similar to Horseshoe Bay Cave in western Door County, Wisconsin. Modified after Bradbury (2009) and Runkel et al. (2003). Note the bedding dipping to the East, while the high-flow resurgence is to the West. ((Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014)

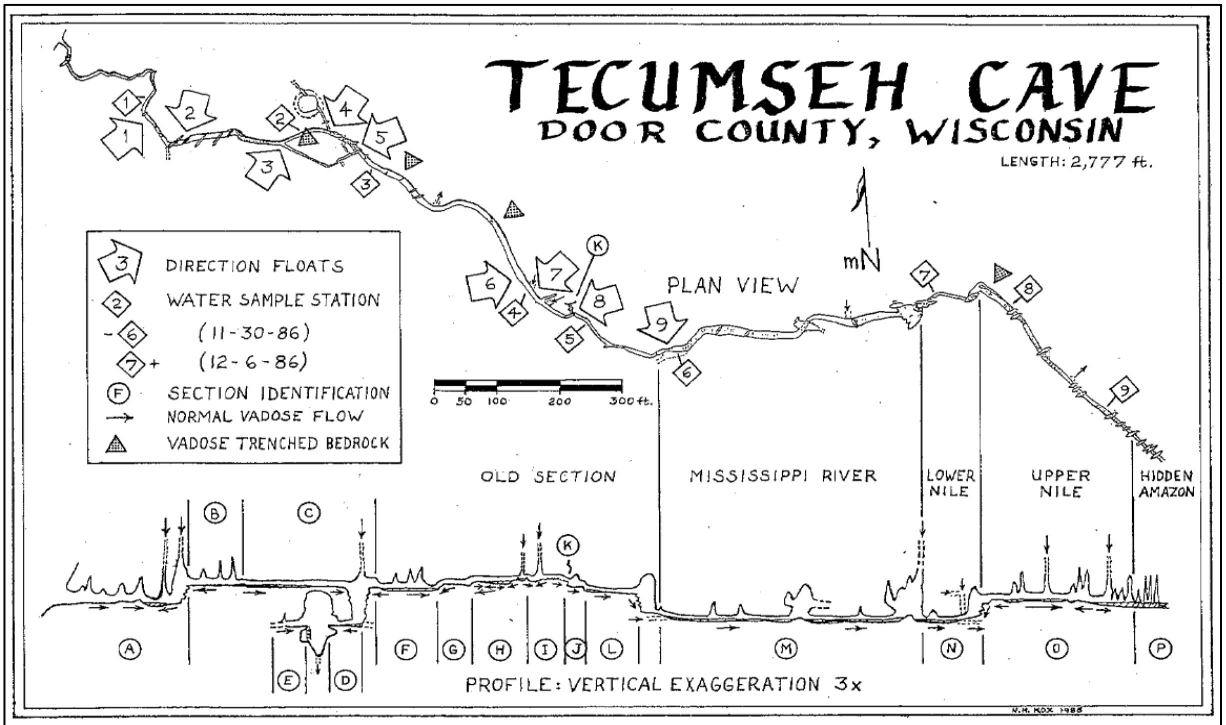


Figure 25 Map illustrating the dirction of flow in HSB Cave as observed by Kox (Kox, Tecumseh Cave, Horseshoe Bay, WI, 1986).

Paleontological component

Figure 26 Clastic material in layered clay sediments fill a pocket in the wall in the lower level of the cave.

Figure 27 Thousands of bat finger bones and skulls present in sediement on the floor in the Big Room.

Figure 28 Sediment profiles, like this one being coverd by flowstone along the cave wall, should be flagged so they are not destroyed. (Photo: M. Muldoon)

Figure 29 Drip cups and pools forming in sediment in the Big Room.

The sediments in HSB cave contain an important record of the events responsible for filling the cave, and may shed light on the geological processes operating on the surface. Although caves have long been recognized by paleontologists as valuable sources for fossils, there has been little research related to taphonomy and caves. Caves provide opportunities for, or conditions conducive to, the exposure and/or preservation of fossils. Paleontological resources associated with caves are significant to our understanding of pre-European fauna.

Little paleontological work has been conducted in Wisconsin caves. Mammal, reptile, and bird bones have been studied at a crevice in southwest Wisconsin, providing 14C dates ranging from 17,050 +/- 1500 ybp (West and Dallman, 1980). In Door County Brussels Hill Pit Cave preserves numerous remains of wood, leaves, shrews, bats, deer, bear, beaver, muskrat, and otter. Two 14C dates on organic sediments at the 28 meter depth were dated at 671 and 1,820 14C ybp (Luczaj, pers. Communication). Karst records such as these provide important information about Wisconsin's pre-European settlement faunal assemblages (Brozowski and Day, 1994).

Bones have been observed in HSB Cave both buried in sediment (Soule G. K., 1975) and exposed from sediment by dripping or flowing water. Most observations consist of bat bones (easily identified because of the long, thin phalanges). Larger bones have been observed in the cave however; between the bottom of the Crevice and entrance to the Big Room. Determining the locations and ages of cave bones may help determine if the cave is an ecological trap for hibernating bats and warrents further investigation and study through systematic, carefully recorded scientific collection by an expert.

Figure 30 Dripping water exposed bat finger bones in a sediment pile in the Big Room at HSB Cave. The sediment was dug out of an upper filled passageway in the 1980's and placed on the floor of the Big Room. The bones likely originated in the upper passage rather than on the Big Room floor.

Cave microclimate (environmental conditions) componant

A cave is typically defined as a natural cavity, recess, chamber, or series of chambers and galleries beneath the surface of the earth, large enough for a person to enter. True caves typically have a zone of total darkness, buffered or stable temperature and humidity conditions and differ from rock shelters, which are overhangs or cave-like openings in a bluff, cliff or ledge that are shallow and do not provide an area of substantial daytime darkness.

Bats and other biota use certain caves because of the combination of characteristics that lead to their success. Some of these are temperature, humidity, and airflow (wind). The suitability and availability of these characteristics determines whether or not the cave is usable by any given species. Some hibernating bats, for instance, prefer cold, stable temperatures. Slightly warmer temperatures will not allow them to lower their metabolisms to the optimum range for conserving energy through the winter, making them burn fat at a higher rate and leaving them very few reserves for coping with long winters, wet springs, or other environmental pressures. Likewise, cave temperatures that fluctuate with outside temperatures also cause hibernating bats to arouse themselves more frequently to move to warmer or cooler zones in the cave as needed. And caves that are ideally cold only during a short period of the entire winter are also energetically expensive for roosting bats. (Kennedy, http://www.nckms.org/pdf/2006nckcf.pdf, monitoring & restoring cave microclimates)

Exisiting literature about cave climate cites a number of strong influences to cave temperature and humidity, including number, size, and position of entrances, passage size, contour and slope, overall cave volume, distance of greatest volume from entrances, amount and seasonal timing of entry of surface water, air flow, and the annual range of surface temperature (Tuttle & Stevenson, 1977). Overal temporal and spatial variation of temperature and humidity among and within caves, however, is far greater than is generally suspected, and even a small amount of such variation can have great impact on cave faunas ((Jegla & Poulson, 1970) (Juberthie & Delay, 1973) (Tuttle, Population ecology of the gray bat (Myotis grisescens): factors influencing early growth and development, 1975) (Tuttle, 1976) (Peck, 1976) (Wilson, 1975)

Factors that influence cave temperature

Cave temperature is dependent on several factors including the Mean Annual Surface Temperature (MAST) of the area (itself a function of latitude, elevation, and climatic conditions). Geographic location and altitude are important factors affecting cave temperature (Vandel, Biospeleology: The Biology of Cavernicolous Animals, 1965). Conduction from cave walls means that any area in a cave more isolated from outside influeces than areas nearer the surface or entrance (depth and distance) the more similar its temperature will be to MAST (Cropley, 1965). Water is most likely to cause deviations from mean annual surface temperatures when it enters directly from the surface in seasons when surface temperatures deviate farthest from the mean annual temperature (Cropley, 1965).

The greatest effect on cave temperature is air circulation, may be created by one or more factors including, barometric pressure, resonance, surface wind, and thermal convection (Plummer, 1964). Thermal convection is generally believed to be the most important factor in determing the direction and amount of air exchange with the surface (Plummer, 1964) (Geiger, 1965). Air escapes (rises) through upper entrances, or through the top portion of a single entrance, when it is warmer than the outside air (winter) Figure 32. Conversely air escapes through lower entrance areas when it is cooler than outside air (summer). Caves may exhibit such airflow seasonally, daily, or in response to passing weather fronts. (HSB Thermocline)

Figure 31 On warm summer days a thermocline is clearly present near the cave entrance.

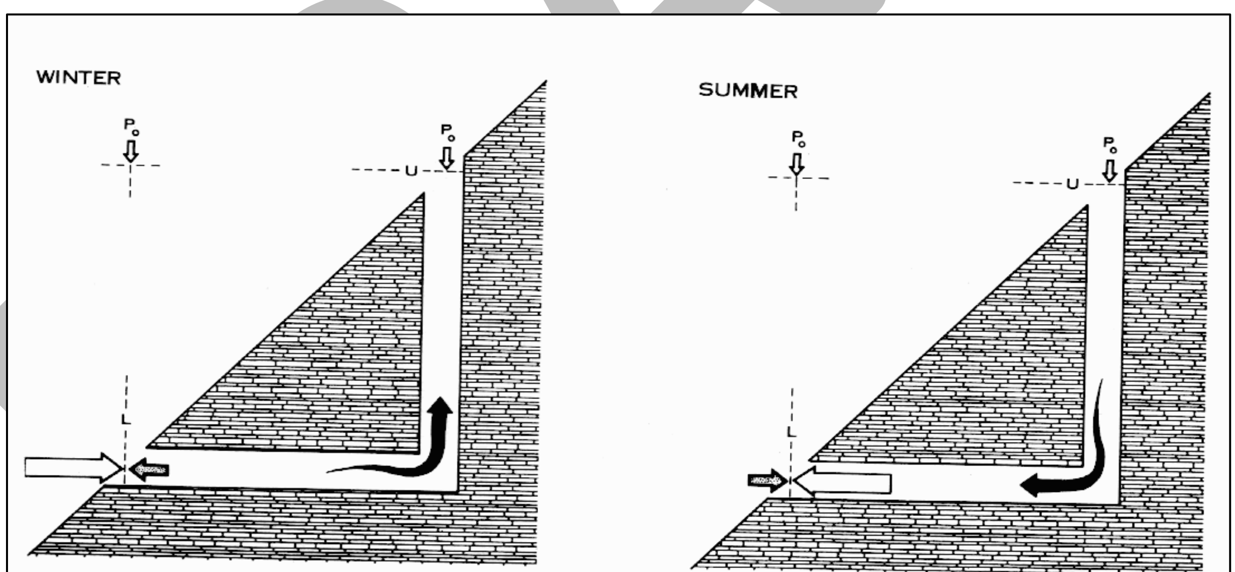


Figure 32 Air flow in caves can be caused by the "chimney effect" many caves experience in winter when the cold outside air column creates pressure greater than the air column inside. The pressure imbalance causes air to move within the cave from L to U. In summer the opposite effect takes place. (T. M.L Wigley and M.C. Brown).

Cave configuration and airflow

Direction and timing of air flow, and therefore temperature and humidity, are heavily influenced by the structure of a particular cave. Tuttle and Stevenson discuss how airflow is heavily influenced by the configuration of the cave passages; and the number, size, and location of the entrances (1978). They even note that sub-human openings (which may be present at HSB Cave) may be critical to cave airflow and temperature and that vertical undulations (present at HSB Cave) are especially effective natural dams against the free flow of convection currents. Small passages, in addition to acting as baffles, also dampen temperature fluctuations through their increased cave wall-surface-to-volume ratio (meaning the tendancy of walls to return air to MAST will have maximum effect). Caves with the greatest volume above the entrance (HSB Cave) can act as warm air traps; cooled air sinks out as warm air rises in.

Oftentimes, cave management does not take into account the management of surface activities. When small blowing holes are blocked through trash dumping, construction, road-building, logging, or even natural processes, it can have major impacts on the cave environment and the biota of the site. Regarless of season or temperature of inflowing air relative humidity is lowest near entrances where outside air enters. A gradient of increasing relative humidity exists between the places of entry and exit of flow. Furthermore, caves have seasonally reversing airflow and passages with high humidity in one season may have low humidity in another.

Biological implications

Data on effects of modifications of cave entrances, such as internal cave gates to internal cave microclimates, are extremely limited (Richter, Humphrey, Cope, & Brack, 1993)

In hibernacula, ambient and substrate temperatures influence body temperature and ultimately metabolic rates of hibernating bats (McNab, 1974) (Humphrey, 1978). Humidity is a very important environmental parameter for many terrestrial cavernicolous animals (Barr, Caves of Tennessee, 1961) (Barr, Observations on the ecology of caves., 1967) (Vandel, Biospeleology: The Biology of Cavernicolous Animals, 1965). Although bats have lowered their body temperatures to conserve energy respiratory water loss for an animal with a body temperature warmer than air is more severe due to the greater temperature difference. Additionally, the size of the boundary layer associated a particular organism's coupling with its environment is proportional to the size of the organism and the roughness of the substrate on which the animal rests, as well as the wind speed (Juberthie, Relations entre le climat, le microclimat et les Aphaenops cerberus dans la Grotte de SainteCatherine (Ariege), 1969). For small arthropods the substrate moisture may be of more importance than air moisture, however larger bats roosting in more exposed areas may be more greatly affected by low air humidity.

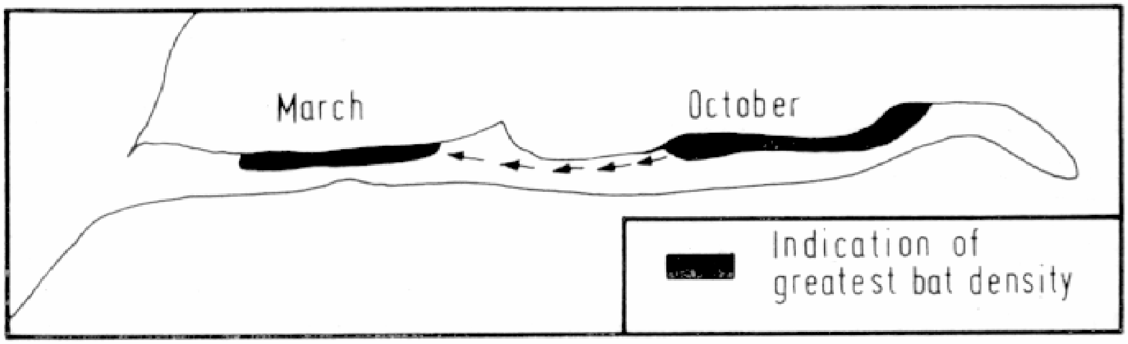


Figure 33 Diagram illustrating the seasonal movement (spring staging) activity of bats withing a hibernaculum (Kuipers & Daan, 1970).

Spring staging and emergence

Bats follow an “internal migration” from hibernation areas deep within cave in early winter to move to areas close to entrances preceeding spring emergence (Kuipers & Daan, 1970). Temperature, humidity and wind speed are correlated with bat activity, however, airflow direction through a hibernaculum appears to be the best way to predict a peak emergence (Redell, 2005).

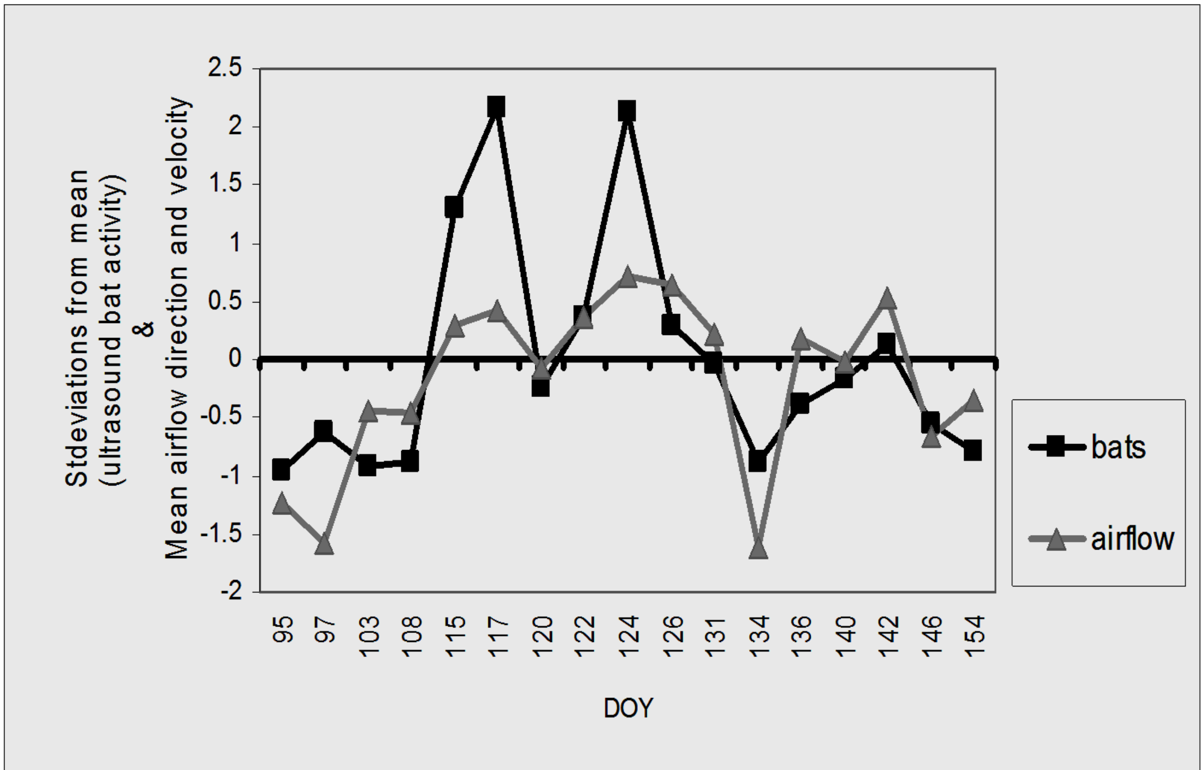


Figure 34 Graph illustrating the correlation between airflow reversal and peak bat activity (spring emergence) at Neda Mine (Redell, 2005)

Impacts to cave microclimates

Natural impacts (water influx, collapse)

Flooding/Meltwater

Flooding can play a vital role in triggering reproduction of aquatic troglobites (Jegla & Poulson, 1970).

Cave microclimates can easily be altered (usually negatively) by physical changes at entrances or in the passages themselves. Opening new entrances, enlarging entrances, closing or restricting entrances, or enlarging or restricting passages can all alter airflow and therefore temperatures within caves, whether these changes are natural or human-induced. Cave entrances naturally open and close periodically through geologic time. When humans interact with cave they often accelerate these processes, leading to dramatic impacts on the fauna using the cave. Most notable impact comes from commercialization efforts, either developing the cave for tourism or extracting saltpeter or other resources (like bat guano). Changes can also be caused by exploration, recreational caving, conservation efforts, and even scientific research. In fact, poorly designed or located gates can sometimes be more harmful to the cave ecosystem than unlimited human access (Roebuck, et al. 2002).

Figure 35 Water droplets condense on surface midrobial colonies in HSB Cave.

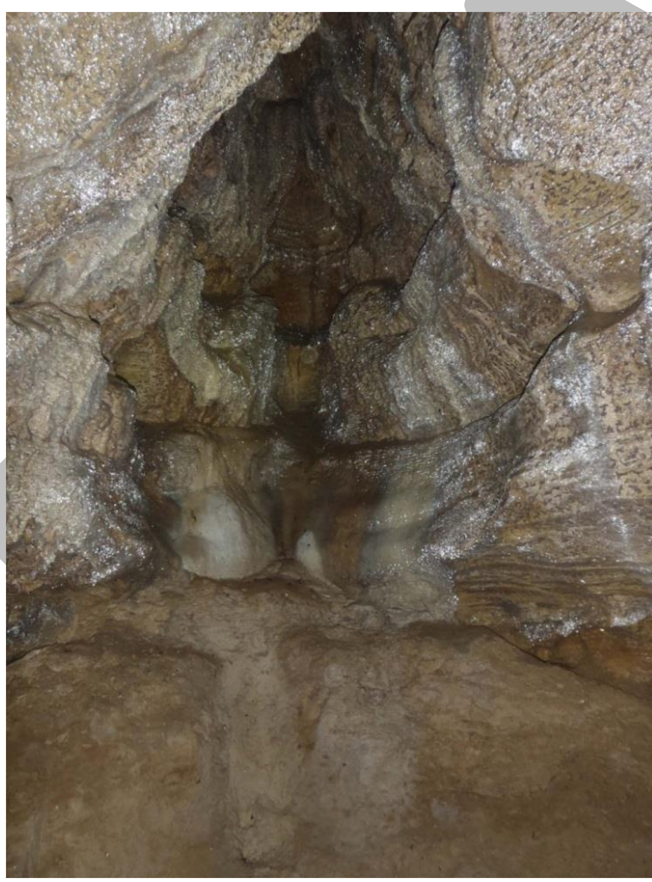


Figure 36 Photo showing one of the many enlarged bedrock joints ("dome rooms") of HSB Cave. Clay vermiculations and bacterial colonies cover the walls while ivory colored calcite flowstone coats the lower wall and cascades onto unconsolidated sediment on the floor. (Photo: M. Muldoon)

Monitoring microclimate

In an ideal world, temperatures, humidity, invertebrate presence and diversity, impact, and a myriad other factors would be monitored immediately upon discovering a new cave. Realistically, that almost never happens. Some of the most important bat caves have been known, visited, and impacted for generations, some even for more than two centuries. However, baseline information is an extremely important tool for cave management. Without it, managers can only make a best guess as to what needs to be done, or base decsions on indirect evidence. Even in a heavily altered and impacted cave, year-round microclimate monitoring throughout the cave gives us a picture of the current processes and conditions in the cave, and a yardstick by which to measure future restoration and management efforts.

Cave microclimate monitoring can take many forms, from simple spot measurements made at several stations in the cave to electronic sensors and monitors recording numerous parameters continuously (and even providing live data via computers and the internet). Anecdotal evidence at HSB Cave shows that near freezing meltwater in late winter and early spring may alter temperatures in flood-prone areas of HSB Cave (as observed when biologists crawled through freezing water in both the lower level “Duck Under” and the “Mississippi River” sections in 2013 & 2014).

Environmental conditions in HSB Cave

Methods

HOBO temperature & humidity data loggers were deployed in three areas of HSB Cave (Cloak, HH, and Big Rooms) to monitor hibernation season conditions. Loggers were left in place for the winter hibernatinon period and some preliminary results are shown below.

Table 5 Temperatures in the Cloak Room (nearest the entrance) fall steadily over the course of the winter.

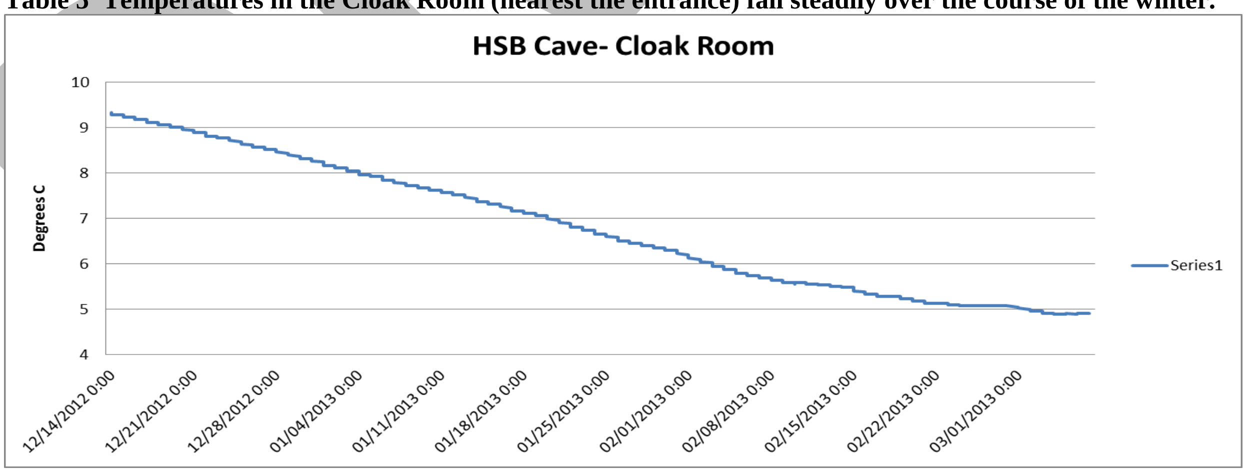


Table 6 Approximately 400 feet from the entrance temperatures in the HH/Wall Room show sligh variation.

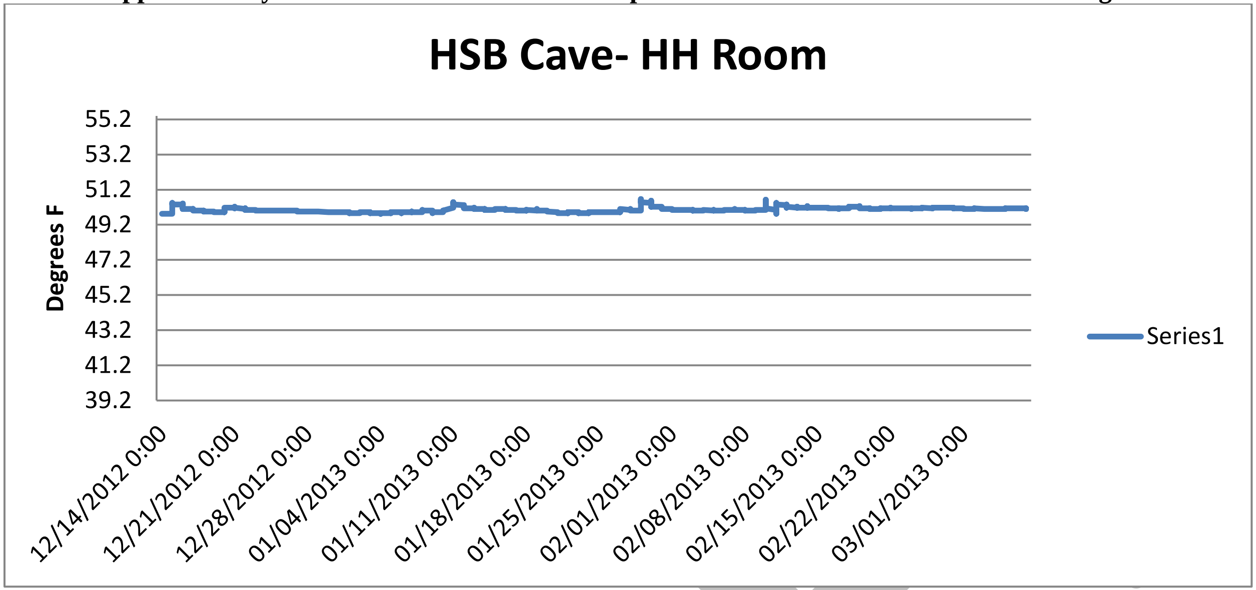
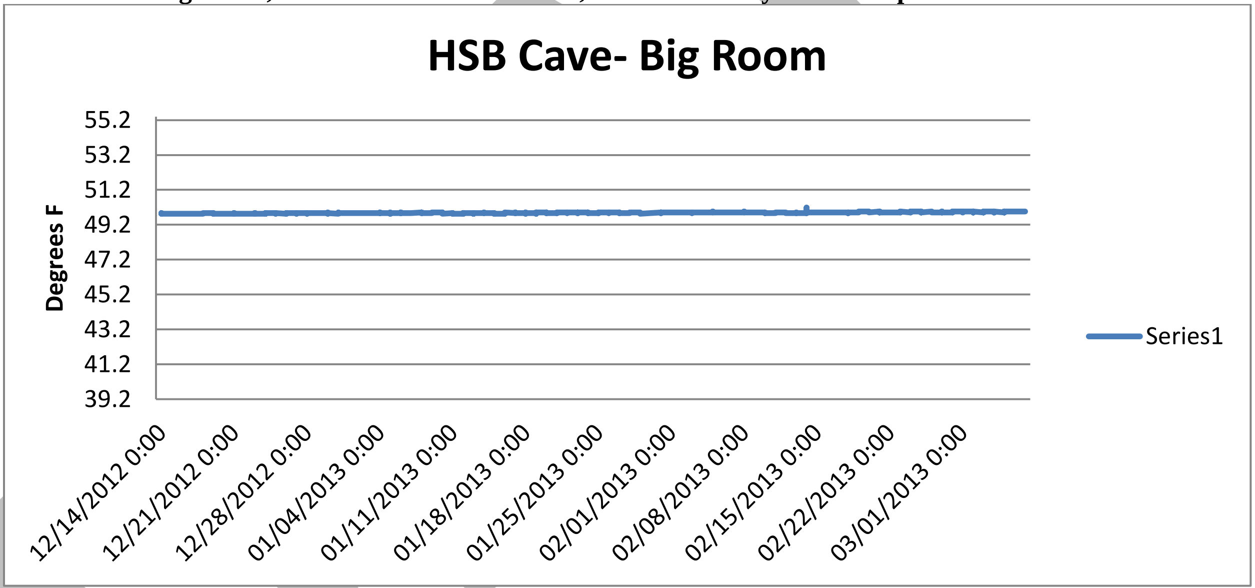


Table 7 The Big Room, farthest from the entrance, shows relatively stable temperatures.



Cultural componant

See Appendix XX Archaeological assessment of HSB Cave

Biological

Introduction to Cave Ecosystems **(Taylor & Webb, IL Dept. of Natural Resources, 2011)**

The unique and fragile cave environment is home to a diverse array of creatures, including organisms that are completely limited to the cave environment, species that may be found in similar habitats above ground, and the many animals that accidentally wander, fall, or are washed into caves. Many cave animals are highly adapted for the unique and harsh living conditions they encounter underground.

Caves can be divided into three ecological zones. The entrance zone is similar in light, temperature, and relative humidity to the surrounding surface habitat, and the creatures that live there resemble the animals that live in the moist shaded areas near the cave. Hear we find the eastern phoebe (*Sayornis phoebe*), a small gray bird whose nest is constructed on bare bedrock Walls out of mosses and other debris. In the leaf litter, we find many animals of the forest floor: redbacked salamanders, harvestmen (or daddy-longlegs), snails, earthworms, millipedes, centipedes, beetles, ants, and springtails. Cave entrances are often funnel shaped or have sheer vertical Walls, and organisms and organic debris tend to concentrate at the bottom. The entrance zone also provides a highly protected environment for overwintering organisms.

Deeper inside the cave, in the twilight zone, there is much less light, and photosynthesizing plants are no longer able to grow. The temperature and relative humidity fluctuate here, but the environment is usually damp and cool. Many animals from the entrance zone wander into the twilight zone, but most of these creatures must eventually return to the land above. Several species of cave crickets are common in this part of the cave, sometimes appearing in large numbers on Walls or ceilings.

Table: *Cave Organism Classification from least cave adapted to most cave adapted.*

Accidentals	Accidentals are animals that find themselves in caves by accident. These include everything from a turtle being washed in during a spring flood to an unfortunate cow falling into a pit. They have no adaptations to the cave and usually die, contributing nutrients to the food base.
Trogloxenes	Trogloxenes (cave-foreigners or cave-guests) are species that use caves, but are also found in other locations. Common trogloxenes include bats and some cave crickets like Ceuthophilus that only use caves as a roost or to overwinter, and a frog or snake seeking the cool of an entrance on a hot summer day.
Troglophiles	Troglophiles are animals that use the cave for most parts of their life cycle, but have to return to the surface for some purpose, like feeding or reproduction. Some cave crickets, like Hadenoecus, are troglophiles. They reproduce entirely within the cave, but leave at night to feed on the surface.
Troglobites	Troglobites are limited to caves and similar environments. The most extreme forms show adaptations to the cave environment such as reduced eyes and pigmentation. They complete their entire life cycle within the cave. We sometimes separate terrestrial troglobites and aquatic stygobites.

In larger caves, there is a dark zone characterized by constant temperature (about 54-58*F in Illinois) and the absence of light. Here, the relative humidity approaches the saturation point. Many animals in the dark zone are capable of completing their entire life cycles without leaving the cave although food is scarce in the absence of photosynthesis. In this zone, there are fewer species of organisms. Creatures who live here eat primarily organic debris-wood, leaves, and accidental animals. Dark-zone dwellers get some of their nutrients from the feces of bats and cave crickets, animals that leave the cave at night to feed on the surface. Raccoons, common cave explorers in Illinois, also leave their waste behind. A wide array of bacteria and fungi feast upon these nutrient-rich items. Other animals then feed upon the fungi and bacteria. Springtails, minute insects typically overlooked by the casual observes, are important fungus feeders, and a variety of beetles, flies, and millipedes get their nourishment this way as well. These organisms may then become the prey of cave-inhabiting spiders, harvestmen, predacious fly larvae known as webworms, and an occasional cave salamander. In the winter, pickerel frogs, mosquitoes, and some moths move into cave to wait for warmer weather.

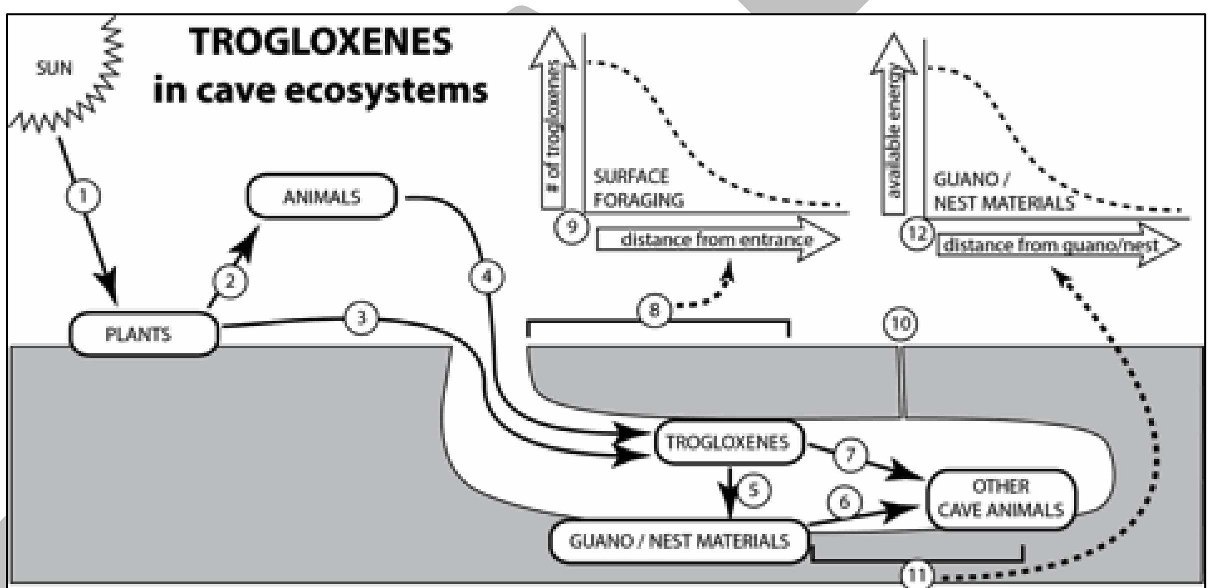


Figure 37 *Energy entering cave by action of trogloxenes.* (Baker)

1. Energy from sunlight converts to plant biomass;
2. Energy transfer to above-ground animals as they eat plants;
3. Surface foraging trogloxenes feed on plants, organic debris;
4. Surface foraging animals feed on animals (such as bats feeding on flying insects);
5. Nesting material, feces (guano), &/or food stores or caches transfer nutrients to the cave;
6. Other animals in the caves feed on the organic material brought into the cave by trogloxenes, or on the fungi & bacteria growing on organic materials;
7. Bodies, eggs, & young of trogloxenes serve as energy for other cave animals;
8. Foraging range is how far trogloxenes travel from cave to feed;
9. We expect higher numbers of trogloxenes closer to cave entrances;
10. Sometimes cave entrances are too small for humans to notice, but these can be used by some trogloxenes (mice, crickets, etc.);

11. Abundance and diversity of cave animals drops with increasing distance from guano &/or nest materials;
12. High concentrations of guano, such as at bat roosts, provide lots of energy, but the available energy decreases with increasing distance from the source.

Most cave animals are trogloxenes and troglophiles; only 20 to 30% of the animals in North American caves are troglobites. Troglobites are animals that live exclusively in caves; they are especially interesting because of their unique morphological, physiological, behavioral, and life-history adaptations. Many troglobites, for example, lack body pigment. Because they live where there is no light, there is no evolutionary advantage for them in maintaining the colors that might be characteristic of their relatives and ancestors that live above ground. In cave-adapted species, the evolutionary pressure to maintain functional eyes is also greatly reduced, and these species have been under strong selective pressure to evolve other means of sensing their surroundings. Their legs and antennae usually have more sensory nerve endings than related above-ground species. These appendages serve important tactile functions and are often greatly elongated in cave-dwelling creatures.

Adaptations that allow species to exist in an environment with very low nutrient input are not as obvious. Many cave-adapted species produce fewer offspring than their surface-inhabiting relatives, but individual eggs may contain more nutrients. In some species, timing of reproduction may be synchronized with spring flooding and its new supply of nutrients. Other species, lacking the above-ground seasonal cues of temperature and photoperiod, may reproduce year-round. Cave adaptations may include a reduced metabolic rate, allowing animals to live on limited food resources for long periods of time. Illinois has many troglobitic invertebrates but no troglobitic vertebrates.

As cave-adapted species become specialized, they also tend to become geographically isolated. The geological and hydrological history of some areas may divide species into isolated populations, and these populations, over time, may evolve into distinct species. During glacial periods, caves, as serve as refugia for some aquatic, soil-, and litter-inhabiting animals. These species may become "stranded" in caves when glaciers retreat surface conditions are not suitable for recolonization.

Human disturbance affects cave ecosystems just as it affects other ecosystems. As a result of changes we make on the surface, we unknowingly alter cave environments, destroying unique and valuable organisms before we even know of their existence. The public knows very little about caves and the organisms that inhabit them. Small wonder then that the importance of protecting groundwater, caves, and cave life is not fully appreciated. It is not uncommon to find sinkholes filled with trash, serving as natural garbage cans for rural waste disposal. Visitors sometimes permanently damage caves with graffiti, break stalactites and stalagmites, and carelessly set fires.

The very adaptations that allow troglobites to survive in the harsh cave environment make these animals more vulnerable to changes made by humans. The reduced metabolic rates that allow these animals to survive in a nutrient-poor environment also make them less competitive when organic enrichment is introduced in the form of fertilizers, livestock and agricultural waste, and human sewage. In Illinois, this effect is commonly seen in stream-inhibiting amphipods (small shrimplike animals) and isopods (small crustaceans related to terrestrial pillbugs or sowbugs). These groups contain troglobites that are highly adapted to cave environments; they also contain more opportunistic troglophilic species, which have a competitive advantage in the presence of high levels or organic waste.

Amphipods and isopods feed on small particles of organic debris and on decomposers such as bacteria and fungi. Because they ingest large quantities of this material, they are exposed to contamination from a variety of pollutants. In Illinois, samples of these animals collected in 1992 were found to contain dieldrin and breakdown products of DDT. They were also found to contain moderate levels of mercury, although mercury was not detected in any water samples from the same sites.

Sedimentation also threatens aquatic species. Topsoil run-off from rural development and agricultural fields enters caves readily when vegetative buffers around sinkholes are too small or nonexistent. This sediment fills the spaces in gravel streambeds, eliminating the microhabitats that allow many cavedwelling species to exist. As a result, cave streams with high sediment loads ten to contain few species.

Scientists can estimate the level and types of threats that this growth brings to the biological integrity of the region, but it's much more difficult to develop protected areas, educational programs, and new regulatory mechanisms within the existing political, social, and geographic framework. Caves are a high priority for conservation because cave organisms face serious threats from agriculture and increasing urbanization. Also, the unique and fragile cave and environment provides a home for organisms found nowhere else in the world.

It is not usually possible to include the entire drainage basin of significant caves within nature preserves or other conservation easements. To manage a cave effectively, scientists must understand the hydrology of a cave's subterranean conduits. This knowledge is gained by doing extensive dye tracing studies and cave mapping. Both of these activities are time- and labor-intensive. Already, the drainage basins of some of our largest cave systems are being compromised by agriculture and rural housing projects. Educating the public-particularly politicians, farmers, and children-about land use and the impact of human activities is key to the long-term health of cave communities. We must also enact appropriate regulations for rural residential development-especially wastewater treatment-and for agricultural activities in a karst landscape. (Taylor & Webb, IL Dept. of Natural Resources, 2011)

Invertebrate species of HSB Cave

Sampling methods

Sampling sites were randomly selected between the cave entrance and the Big Room. The dominant habitat types in which invertebrates might occur were sampled,with sampling technique varying by habitat. Techniques used are as follows:

Pitfall trapping

Pitfall containers were 1.5 ml microtubes (more commonly used for molecular biology lab work) standardized for size and repeatability. Traps were filled with 1-1.2 ml of ethanol, and baited with a small amount of limburger cheese, and then placed wherever there was suitable substrate – that is, substrate where a small hole could be made to place the trap and level the substrate up to or above the lip of the trap so that the lip of the container did not constitute a barrier to springtail movement . Traps were placed in arrays of 5 traps, in an area roughly equal in area and proportions to the quadrat , when the nature of the substrate dictated otherwise, we distributed the traps over a similar sized area, but with differing proportions. Traps were left in place 2 days, then recovered, closed, and returned to the laboratory for sample sorting.

Quadrat searching

A pvc pipe quadrat was placed on the substrate (e.g., clay, gravel, bedrock floors or walls) and a trained expert (one of the PIs) searched the entire area, recording the amount of time needed to search the quadrat. We attempted to collect any springtails observed using an aspirator, preserving them in 95% ethanol.

Drip pools

Individual drip pools were visually searched, recording the amount of time needed to search the pool. We attempted to collect any springtails observed using an aspirator or by hand, preserving them in 95% ethanol.

Litter samples

Where accumulations of leaf litter were available, samples were collected into 3-4-liter ziplock bags and removed from the cave for extraction using a Berlese funnels or similar litter extraction device. Samples were extracted for three days.

Figure 38 Water droplets form on colonies of actinomycetes on walls near the cave entrance. (Photo: M. Muldoon)

Figure 39 Clay vermiculations are found on nearly all cave walls and may provide nutrient material and habitat for cave invertebrates. (Photo: M. Muldoon)

Figure 40 Isolated drip pools like this elevated pool in the Rocky Mountain Room provide habitat for rare, and sometimes cave endemic species. Pools in this room contained freshwater cyclopoid copepods, springtails in the genus Ceratophysella and Falsomia, and two sinella species (Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014)

Biotic inventory of HSB Cave

Numerous rare species and high-quality examples of sensitive features have been documented in and around Horseshoe Bay Cave. Table 8

Table 8 *Documented species More than one element occurrence of a particular species or natural community may be at each location. For an explanation of state and global ranks, as well as state status, see Appendix XX.*

Family: Subfamily	Taxon	Common Name	Location/Remarks	Global Rank	State Rank	Federal Status	State Status	SGCN
Dermatophyte??	*Trichophyton redellii*	Ringworm	Cloak Rm, Big Rm					
Vespertilionidae	*Eptesicus fuscus*	Big brown bat	Zone 1	G5	S2S4		THR	Y
	Myotis lucifugus	Little brown bat	Zones 1-4	G3	S2S4		THR	
	Myotis septentrionalis	Northern long-eared bat	Zones 1-4	G1G3	S2S3	Proposed endangered	THR	Y
	Perimyotis subflavous	Eastern pipestrelle (Tri-colored) bat	Zones 1-4	G3	S1S3		THR	
	Peromyscus maniculatus??	White-footed mouse??						
	Peromyscus maniculatus??	Deer mouse??						
	Procyon lotor	Raccoon	Zone 1-2					
	Erethizon dorsatum	Porcupine	Wellever Cave					
	Didelphis virginiana	Virginia opposum	Zone 1-2					
Arionidae	cf *Arion subfuscus*	Slug	Zone 1					
Zonitidae	cf *Paravitrea multidentata*	Terrestrial Snail	Zone 1					
	Undetermined	Terrestrial Snail	Zone 1					
Enchytraeidae	*Fridericia* sp.	Worm	Big Room					
Lumbricidae	*Allolobophora chlorotica*	Earthworm						
	Eiseniella tetraedra	Earthworm						
	Undetermined	Earthworm						
Crangonyctidae	*Crangonyx* sp.	Amphipod	Passage to Big Rm					
Asellidae	*Caecidotea* sp.	Aquatic Isopod						

Cylisticidae	*Cylisticus convexus*	Terrestrial Sowbug
Undetermined		Cyclopoid copepod
		Mite
Agelenidae	cf *Cicurina* sp.	Funnel-web Spider
Amaurobiidae		Hacklemesh Weaver
Linyphiidae	*Lepthyphantes* sp.	Sheet-web Weaver
	Undetermined	Sheet-web Weaver
Pisauridae	*Dolomedes* sp.	Fishing Spider
	Pisaurina sp.	Fishing Spider
Tetragnathidae	*Meta ovalis*	Spider
Theridiidae		Comb-clawed Spider
Sclerosomatidae	*Leiobunum* sp.	Harvestman
Sabaconidae	*Sabacon cavicolens*	Harvestman
Scutigerellidae	*Scutigerella* sp.	Symphylan
Hypogastruridae	*Ceratophysella* sp.	Springtail
Entomobryidae	*Entomobrya nivalis*	Springtail
	Lepidocyrtus languinosus	Springtail
	Lepidocyrtus paradoxus	Springtail
	Lepidocyrtus violaceus	Springtail
	Lepidocyrtus sp. 1	Springtail
	Pseudosinella sp.	Springtail
	Sinella sp. 1	Springtail
	Sinella sp. 2	Springtail
Isotomidae	*Folsomia* sp.	Springtail
Tomoceridae	*Pogonognathellus* sp. 1	Springtail

	Pogonognathellus sp. 2	Springtail
Katiannidae	*Sminthurinus* sp.	Globular Springtail
Arrhopalitidae	*Pygmarrhopalites* sp.	Globular Springtail
Machilidae		Silverfish
Rhaphidophoridae	*Ceuthophilus* sp.	Cave Cricket
Nabidae		Damsel Bug
Curculionidae: Cryptorhynchinae	Weevil	
Curculionidae: Entiminae		Broad-nosed Weevil
Scarabaeidae: Aphodiinae	Scarab Beetle	
Scarabaeidae: Melolonthinae	Scarab Beetle	
Staphylinidae		Rove Beetle Larva
Cecidomyiidae		Gall Gnat
Chironomidae		Midge
Culicidae	*Culex* sp.	Mosquito
Heleomyzidae	*Oecothea* sp.	Sun Fly
	Amoebaleria sp.	Sun Fly
	Heleomyza sp.	Sun Fly
Mycetophilidae	*Rymosia* sp.	Fungus Gnat
	Undetermined	Fungus Gnat
Phoridae	*Megaselia* sp.	Scuttle Fly
Psychodidae: Psychodinae	Moth Fly	
Sciaridae	cf *Corynoptera* sp.	Dark Fungus Gnat
Sphaeroceridae	*Leptocera* sp. 1	Lesser Dung Fly
	Leptocera sp. 2	Lesser Dung Fly
Tipulidae		Crane Fly

Ichneumonidae		Ichneumon Wasp
Alucitidae	*Alucita* sp.	Many-plumed Moth
cf Noctuidae		Moth
Geometridae		Inchworm

Rare invertebrate species of HSB Cave

Isopods

Cave amphipods inhabit the bottoms of pools and riffles in large cave streams, where they creep among cobbles and under stones, feeding on decaying leaf litter and organic debris. Food is scarce in this environment, and the amphipods have developed chemosensory structures that detect the odor of food sources, such as dead or injured animals.

Injured or dying amphipods are vulnerable to such predators as flatworms, cave salamanders, and even other amphipods. But the greatest threat these vulnerable creatures face is the deterioration of the environment. Continued urbanization without appropriate sewage treatment and disposal is especially threatening to the amphipods existence. Other serious threats are siltation and the presence of agricultural chemicals in subterranean aquifers.

Fortunately for the amphipod, the quality of life for people on the land above depends on water quality in streams below. Because agricultural chemicals and bacteria associated with sewage have been found in well water, springs, and cave streams in this area, a concerted effort is being made to improve the water quality in this karst region. Efforts to provide communities with safe drinking water could also provide a healthy cave environment and help ensure the further existence of our underground neighbors.

Collembola (springtails)

Springtails are small hexapods characterized by the presence of four-segmented antennae, six-segmented abdomen, a large vesicle (the collophore) on the ventral part of the first abdominal segment, and, in many species, a jumping organ complex formed by the tail-like furcula and the furcula catch or retinaculum (Figure 2). Springtails are most commonly found in soil and leaf litter, but they have invaded other specialized habitats, including caves. Many soil or leaf litter species are commonly found in caves as xenobionts, but some species are cave-adapted or cave limited and do not sustain surface populations (Christiansen & Culver 1987).

Terrestrial/Land Snails

Wisconsin's snail species all represent remnant populations from the pre-European settlement period. Land snails, in general, have a slow rate of dispersal and without suitable habitat or habitat corridors they cannot disperse or expand as a viable population(s). With the historic fragmentation and loss of native communities as a result of Euro- American disruption, few intact habitats remain that will support the rarer native snail populations. Terrestrial snail habitat includes depressions in rocky exposures with pockets of leaf litter, under or adjacent to decaying downed logs of deciduous trees, under loose tree bark on downed logs, or at protected locations on seasonally moist cliff faces. In Algific Talus Slope settings, habitat includes detritus adjacent to rock exposures, and downed wood.

The Cherrystone drop (State Threatened) as living colonies were found just south of HSB Cave. Check NHI data   Cherrystone drop is a Pleistocene relict, finding suitable habitat niches in the protected, steep slopes of the Driftless Area.

Three locations also produced broad-banded forest snail (Special Concern); both living snails and fresh shells were found. These locations were in historic fire shadow zones and protected by the rugged terrain.

These larger-sized snail species are vulnerable to predation by rodents and insectivores that can negatively impact population density. Other rare terrestrial snails that were observed include Domed disk

(*Discus patulus*; Special Concern), dull gloss (*Zonitoides limatulus*; Special Concern), and ribbed striate (*Striatura exigua*; Special Concern).

Conclusions from a terrestrial snail survey in the Driftless Area Study Streams include:

1) The Driftless Area stream corridors that were least disturbed by historic Euro-American practices held the highest potential for rare terrestrial snail populations in remnant habitats. In general, these were the areas with the greatest topographic relief.

2) The poorest habitats for terrestrial snails included areas that have been cultivated, subjected to intense livestock grazing, and/or heavily logged.

3) Some species of rare terrestrial snails can survive limited selective logging, especially if invasive plants such as garlic mustard are not introduced by logging equipment.

4) Terrestrial snails associated with prairie and oak savanna can diminish or disappear if woody invasion reaches advanced stages in the absence of fire.

5) Access to areas below moist sand stone cliffs should be limited, as they are fragile and can be easily damaged by foot traffic.

6) The best opportunities for terrestrial

Conclusions from the invertebrate inventory (Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014) See Appendix XX *for full report*

The fauna of Horseshoe Bay Cave (Door County, Wisconsin) is fairly typical of north-temperate, Midwestern cave faunas found in caves prone to occasional flooding. The relatively recent glaciation of the Door Peninsula may contribute to the limited cave-adapted fauna. Particularly notable among the organisms found in the cave are a presumptively groundwater-inhabiting amphipod species in the genus *Crangonyx*, which could conceivably depend upon the maintenance of good groundwater quality for its' long-term survival, and an apparently cave-adapted globular springtail, *Pygmarrhopalites* sp., found on the surface of drip pools and could represent an undescribed cave species. The entrance fauna includes several widespread native invertebrates, but also some taxa which are introduced species – a pattern common to many Midwestern caves and perhaps resulting from movement of materials (water, soil, etc.) by humans over the last 150 years.

Management recommendations focus on areas relating to the entire cave ecosystem. Understanding the hydrological groundwater basin of the cave and maintaining land use practices which do not result in degradation of the cave ecosystem through contamination, sedimentation, changes in in-cave meteorological conditions (air flow, humidity), and maintaining natural levels of nutrient inputs into the system are all important to maintaining ecosystem health. The decline of overwintering bat populations, as well as potential impacts from climate change, are factors that may not be easily addressed in site-specific management, but should be considered areas of major concern.

Vertebrate species information (for caves in Door County)

LUCZJA INFO ON BRUSSELS HILL

Eastern phoebe

Mouse

Vole/Shrew

Raccoon

Opossum

Porcupine

Red-backed salamander

Blue-spotted salamander

Rare vertebrate species informationOverview of bats in Wisconsin

Wisconsin has seven species of bats, all of which are insectivorous and use echolocation to navigate and capture prey. Four species are known as the cave bats and hibernate in caves and mines throughout the winter. The cave bats are all susceptible to the devastating bat disease white-nose syndrome. The other three are known as tree bats, and these bats migrate south to warmer climates during winter. Bats are important consumers for agricultural, forestry and human pest insects. It is estimated that bats in Wisconsin save farmers up to $658 million every year in the form of pest control services.

Annual cycle for Wisconsin bats:

State	Hibernation season	Spring staging season	Summer maternity season	Fall swarm/mating season
Wisconsin	Oct 1-May 15	Apr 1-May 15	Apr 1-Sep 30	Aug 15-Oct 15

The Wisconsin Wildlife Action Plan (WAP) recognizes 14 mammal Species of Greatest Conservation Need including four bat species (Hoary bat, Eastern red bat, Silver-haired bat, and Northern long-eared bat). The WAP also identifies four other bats as species with additional information needs (Eastern pipistrelle, Little brown bat, Big brown bat, and Indiana bat). As of June 1, 2011, all four cave bats (excluding the federally endangered Indiana bat) have been listed as State Threatened species, and are therefore protected under the Wisconsin endangered species act. All surveillance, monitoring, handling and sampling of live bats must meet WDNR ACUC approval and require an endangered species permit.

The WAP lists management of bat hibernacula as a high priority due to their limited number within the state and the importance they serve for a large landscape area during the winter. Hibernacula can be scarce in some areas and concentrated in others, and therefore a single suitable site can harbor large numbers of bats of multiple species, dispersing in summer over foraging grounds that cover more than a thousand square miles. Seasonal aggregation makes bats extremely susceptible to catastrophic events, but these congregations also provide opportunities to inventory, monitor, manage and protect a large proportion of these populations by focusing conservation and management efforts at these known sites. Knowing the locations of all hibernacula and having current data aids land managers in making decisions when questions arise, as well as improving plans for bat population monitoring and surveillance for White-nose syndrome.

The devastating threat of WNS to the Wisconsin cave bat population is a major concern of WDNR. There is a lack of general information about Wisconsin bats now faced with the imminent threat of WNS. Planning for cave bat population recovery following the arrival of WNS, will require up to date information at each hibernaculum. The significant bat population in HSB Cave, combined with the anticipated arrival of WNS to the site creates a unique opportunity to gather both pre & post bat and WNS data.

Cave bat species information

All cave bats currently listed in Wisconsin (NR 27.07, Wis. Admin. Code):

Little brown bat (*Myotis lucifugus*) – State Threatened

The little brown bat is a medium-sized member of the genus *myotis*. This insectivorous bat weighs 5.0-12.5 grams, and has tan, reddish-brown or dark brown fur. This species commonly uses artificial structures such as attics and barns as summer roosting sites, but will also roost in crevices and cavities of trees. In fall, little brown bats make local long-distance migrations of up to 279 miles to caves and mines where they will hibernate for the winter.

Big brown bat (*Eptesicus fuscus*) – State Threatened

The big brown bat is a large insectivorous bat, weighing 15.0-26.0 grams. Fur color is russet to dark brown, and the muzzle is black and hairless. In summer, big brown bats commonly roost in artificial structures such as barns, but these bats will also use crevices in trees and rock faces. Big brown bats migrate short distances to caves and mines where they will hibernate for the winter.

Eastern pipistrelle (*Perimyotis subflavus*) – State Threatened

The eastern pipistrelle is Wisconsin's smallest bat weighing 4.0-8.0 grams. Fur color ranges from golden brown to reddish brown, and the wing membrane is black with red forearms. The eastern pipistrelle is an insectivorous bat. In summer, these bats commonly roost in the branches of deciduous trees disguised as a leaf. This species migrates short distances to caves and mines in the fall where they hibernate over the winter.

Northern long-eared bat (*Myotis septentrionalis*) – State Threatened, *Proposed Federal Endangered*

The northern long-eared bat is dark brown with a gray belly, weighing 5.0-8.0 grams and is insectivorous. In summer this bat roosts in trees close to the trunk. It rarely roosts in artificial structures. Unlike most of the state's bats, this species commonly forages in forest interior. In fall the northern long-eared bat migrates to caves and mines where they will hibernate for the winter.

Overview of bats in Door County

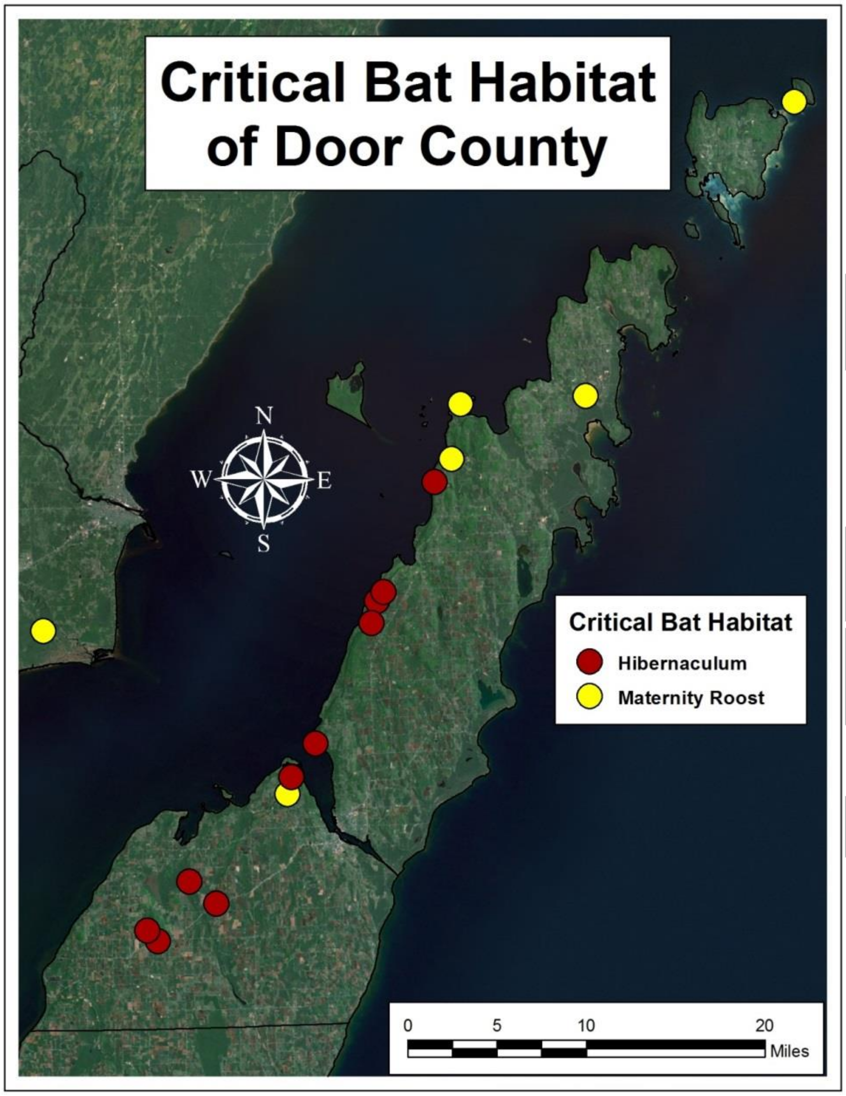


Figure 41 Known Door County bat habitat. Other cave and roost locations can be reported to the Wisconsin Bat Program.

Acoustic monitoring of bats

An acoustic survey is a non-invasive method for detecting relative density and species richness. Acoustic recording systems detect echolocation calls can survey bats as they fly through an area. These surveys are performed for all Wisconsin bat species in spring, summer and fall, and are used to determine presence/absence, phenology, and distribution around the state. Surveys can be used by land managers to create inventories of species distribution and relative abundance. The WDNR's eventual goal is to use acoustic survey data to determine bat population trends in Wisconsin. WDNR will continue acoustic surveys both pre and post-WNS introduction to the state.

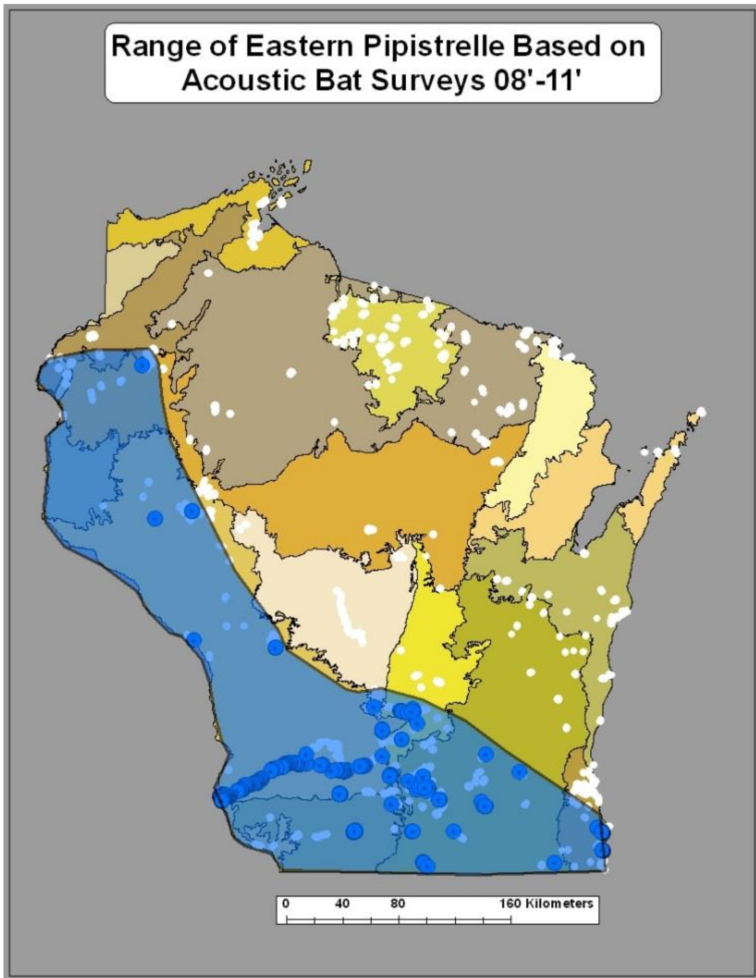


Figure 42 Species range map for the Eastern pipestrelle during the summer residency period (June & July). White dots indicate all areas surveyed in summer. Note that PESU are not present in Door County during summer months but are present at HSB Cave and other Door County caves during the fall migration/swarm period (August- October) and during the hibernation period (October- May).

Methods of acoustic monitoring

Current methods for surveys require the use of broadband frequency division ultrasound detection equipment with a PDA (Personal Data Assistant) and a GPS (Global Positioning System). The bat detection system detects and records these acoustic signals as bats fly by, and records the date and time of each encounter. The acoustic surveys begin April 1st through September 30th during the right environmental condition (daytime temperature >50°F, starting at civil twilight, no precipitation, and wind speed <30 mph). The surveys are divided into three time periods to monitor species presence and movement patterns during spring migration, summer residency, and fall migration. Acoustic surveys record bat passes, which can then be identified to species by trained individuals.

Results of acoustic monitoring in Door County

Since 2007, there have been 34 acoustic bat surveys conducted in Door County. Most surveys have been conducted by walking transects (n=27), although other methods have been implemented such as driving transects (n=3) and water-based transects (n=4). The most encountered species was the little brown bat, which was observed on all 34 acoustic surveys, followed by the eastern red bat and big brown bat. All species known to reside in WI were detected to some degree, with the exception of the eastern pipistrelle. More acoustic surveys are needed to assess Door County land-use and presence by bats during their active months.

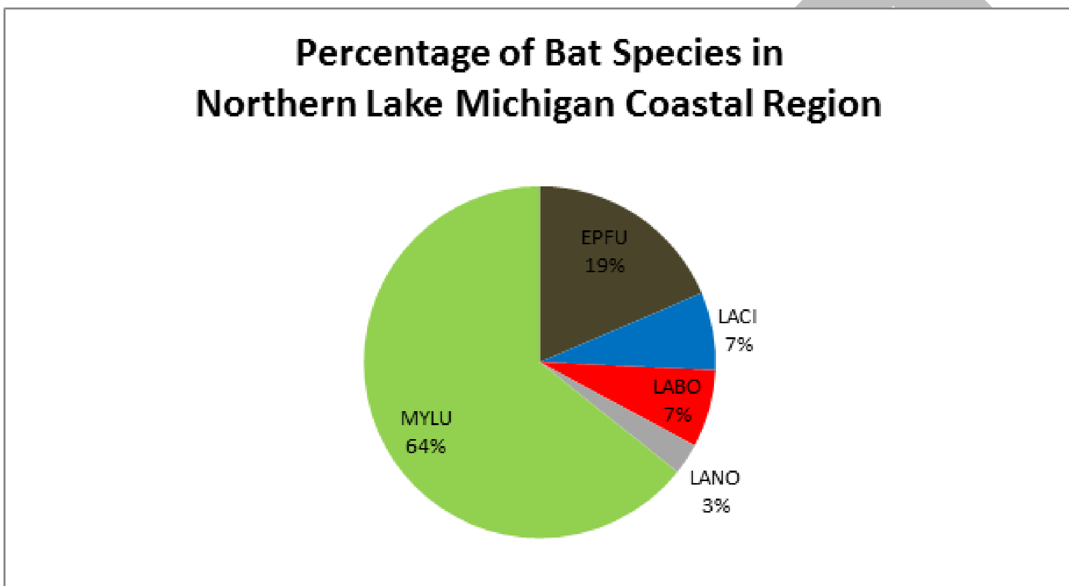


Figure 43

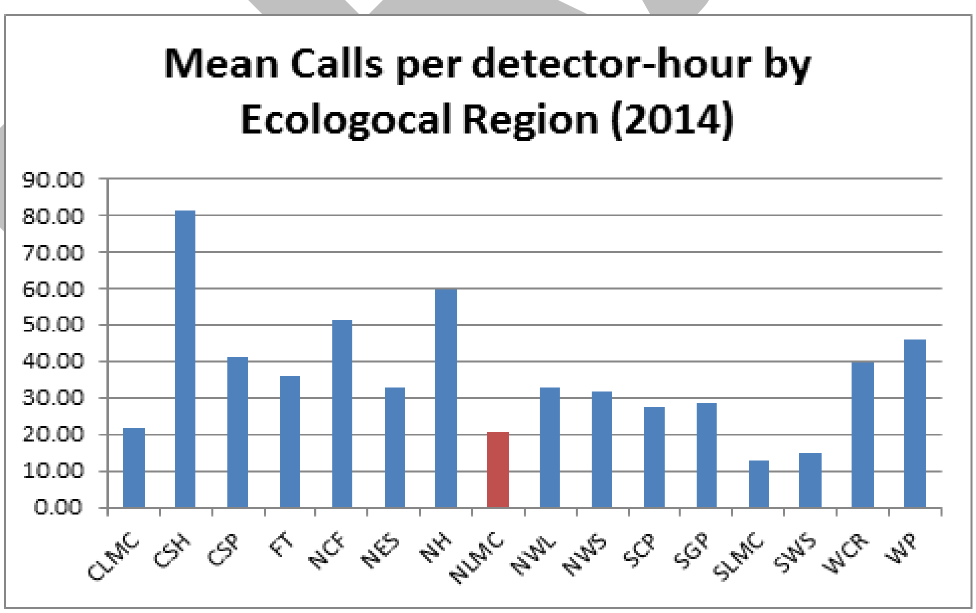


Figure 44

The following maps depict several Door County surveys conducted in 2012. Legends use species name initials.

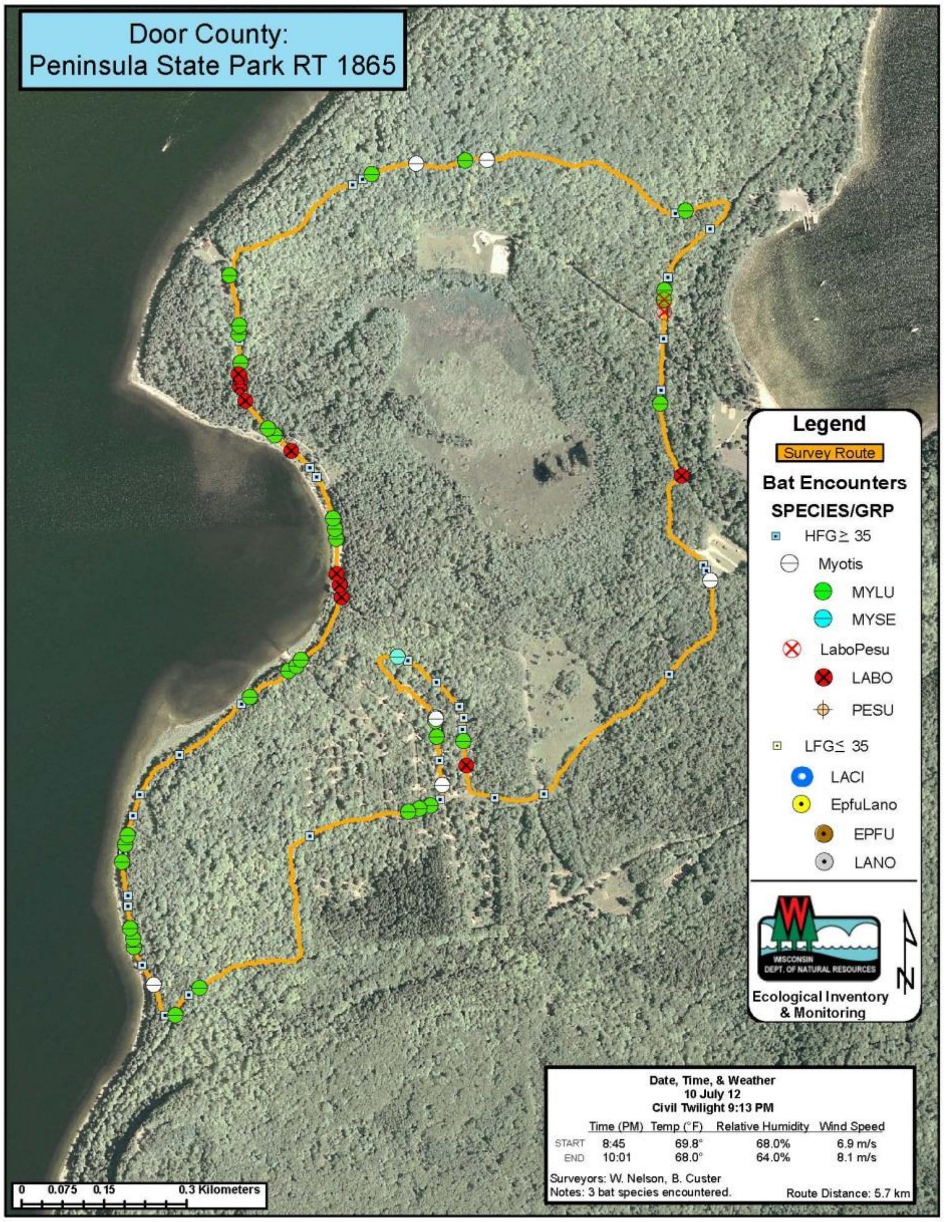


Figure 45 An example of an acoustic bat survey conducted near HSB Cave. Note the higher levels of bat activity near water/shorelines.

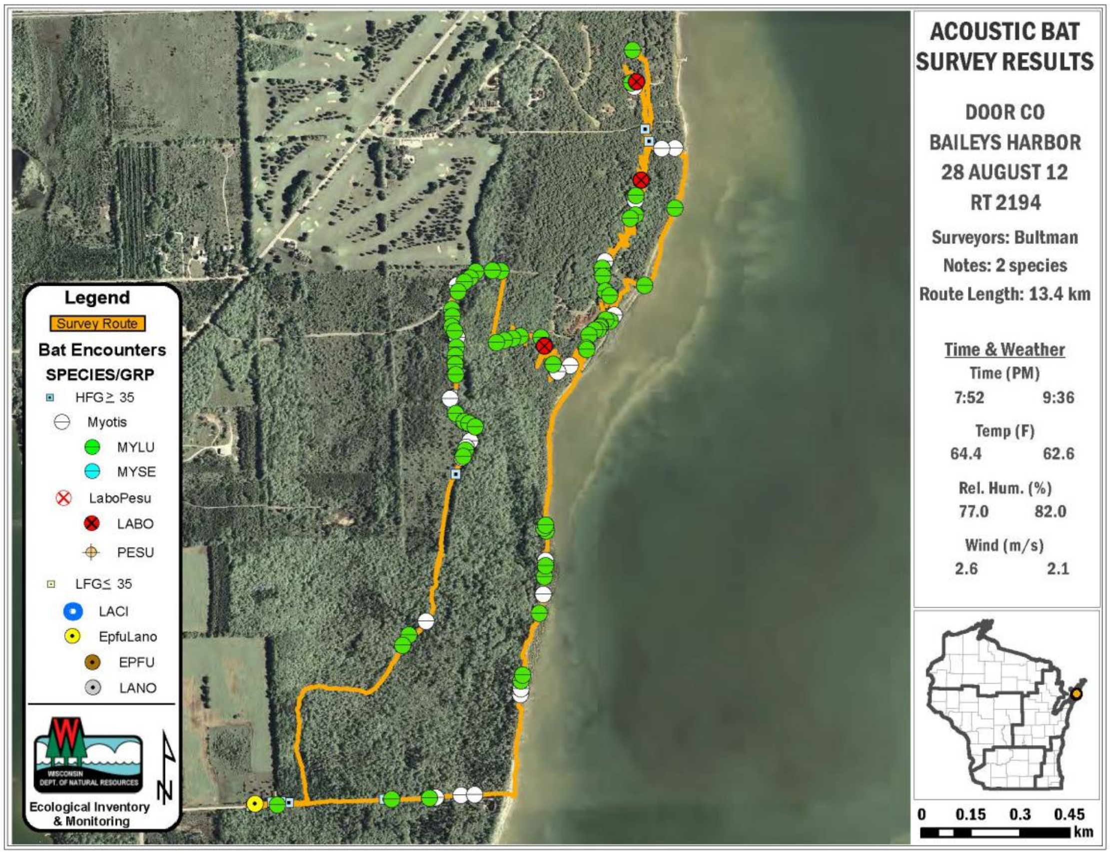


Figure 46 An example of an acoustic survey conducted near HSB Cave, this route includes a shoreline, and illustrates the higher levels of bat activity near water.

Bat summer roosts

Summer bat congregations are called colonies. In Wisconsin, little brown bats and big brown bats form colonies across the state ranging from just a few bats to over 1000 animals. In these summer colonies, females who had mated the previous fall give birth and raise their young, called pups (**Error! Reference source not found.**). Because of this behavior, bats choose ummer roosts that are protected and stay warm throughout the night. Warm conditions help speed gestation and maturation of the young who are unable to fly for three to six weeks after birth in June. Bat houses, attics and other buildings provide ideal habitat for mother bats to raise young. Roosts with these ideal conditions are often a limited resource and it is thought that prior to white-nose syndrome, availability of summer roost habitat was a limiting factor in growth of bat populations. Human residents of the buildings where bats may choose to roost tend to exclude or destroy this critical habitat without providing alternate habitat options (bat houses).

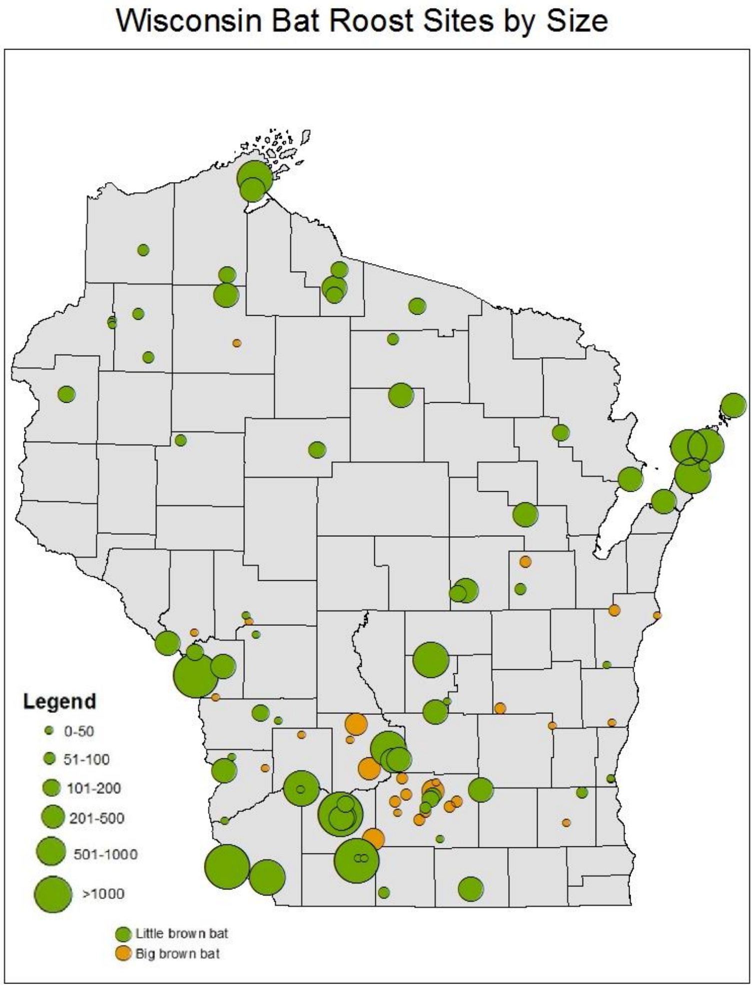


Figure 47

Methods of roost monitoring

Summer roosts are monitored by conducting emergence counts shortly after sunset when starting time temperatures are above 60ºF and wind and weather is moderately calm. At some locations both pre and post-volant counts are conducted (early in summer prior to pups learning to fly and later in summer after pups are flying) in order to evaluate emergence variances and to compare the number of reproductive verses non-reproductive females.

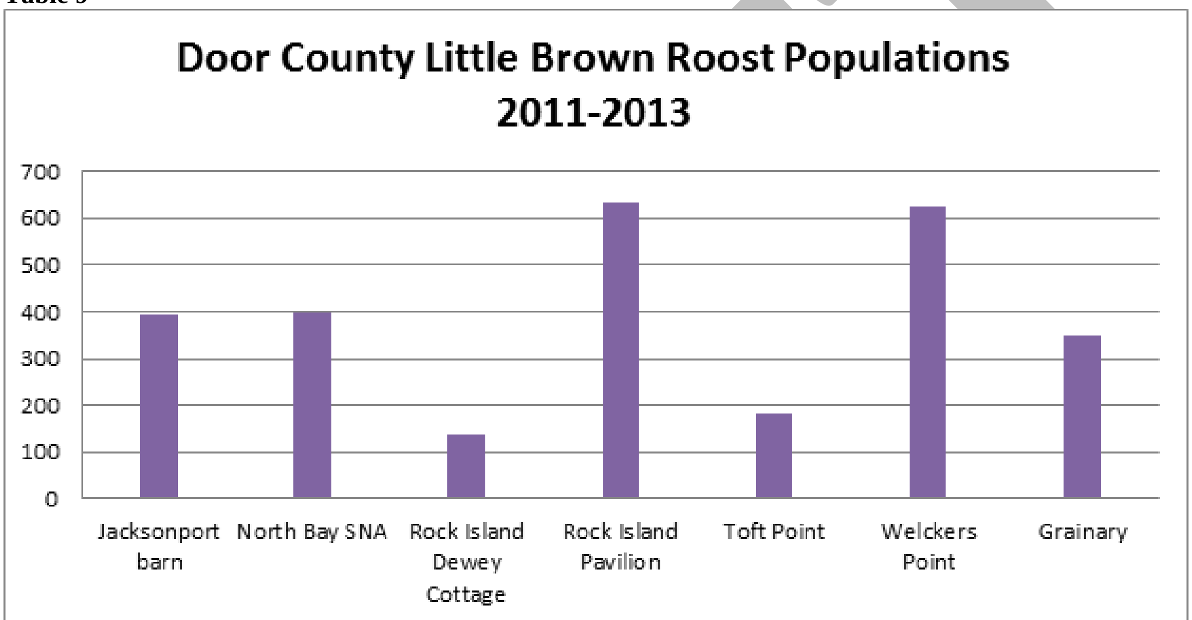
Results for roost monitoring in Door County

The Door County peninsula is rich in summer bat roost habitat. It has one of the highest ratios of roosts to land area in Wisconsin and hosts the most large summer congregations of little brown bats in the state. Abundant water resources on and along the peninsula combined with an abundance of deteriorating buildings provide a haven for little brown bats in particular.

Monitoring efforts by Door County residents have provided extensive information about these roosts.

At least seven roost sites are known in Door County, all with populations greater than 200 little brown bats and some cases, the populations swell to over 500 in the late summer (Table 9). Four of the seven monitored sites are on public property and volunteers count the bats at these sites. The other three sites are privately owned but are still monitored by volunteers. All sites are within 50 miles of Horseshoe Bay Cave and bats using these summer roosts are likely to use the cave in the fall or winter.

Table 9



Bat hibernacula

Habitat requirements & limiting factors

Caves are much more likely to be bat caves (current or historic) have multiple entrances, vertical complexity (even multiple levels), large passages and rooms, cold air traps and/or warm air traps, relatively stable temperatures, are not flood-prone, and are free from predators and human disturbance (Brown, 1996; Tuttle and Kennedy, 2002). HSB Cave is no exception. For cave dwelling bats the selection of appropriate roosting temperatures is of critical importance. Most bats hibernate in caves or mines where the ambient temperature remains below 10°C (50.0°F) but infrequently drops below freezing, and the temperature is relatively stable. McManus (1974) found hibernating Little brown bats demonstrated a clear preference for temperatures near 2°C, the temperature at which Hock (1951) found the species' oxygen consumption to be the lowest. A number of authors have since noted the high metabolic cost of the wrong ambient temperature for bats (Hock, 1951; Herreid, 1963, Stones, 1965, Davis, 1970; McManus, 1974). More recently studies prompted by WNS have found

HSB Cave's volume and complexity help buffer the cave environment against rapid and extreme changes in outside temperature, and vertical relief helps provide a range of temperatures and roost sites.

The known migratory distance of Myotis lucifigus (little brown bats) is 282 miles (Kurta and Murray 2002; Humphrey and Cope 1976), making the potential summer distribution range for little brown bats at a given hibernaculum approximately 250,000 square miles Figure 48. However, during winter hibernating bats are restricted to suitable underground hibernation sites (hibernacula).

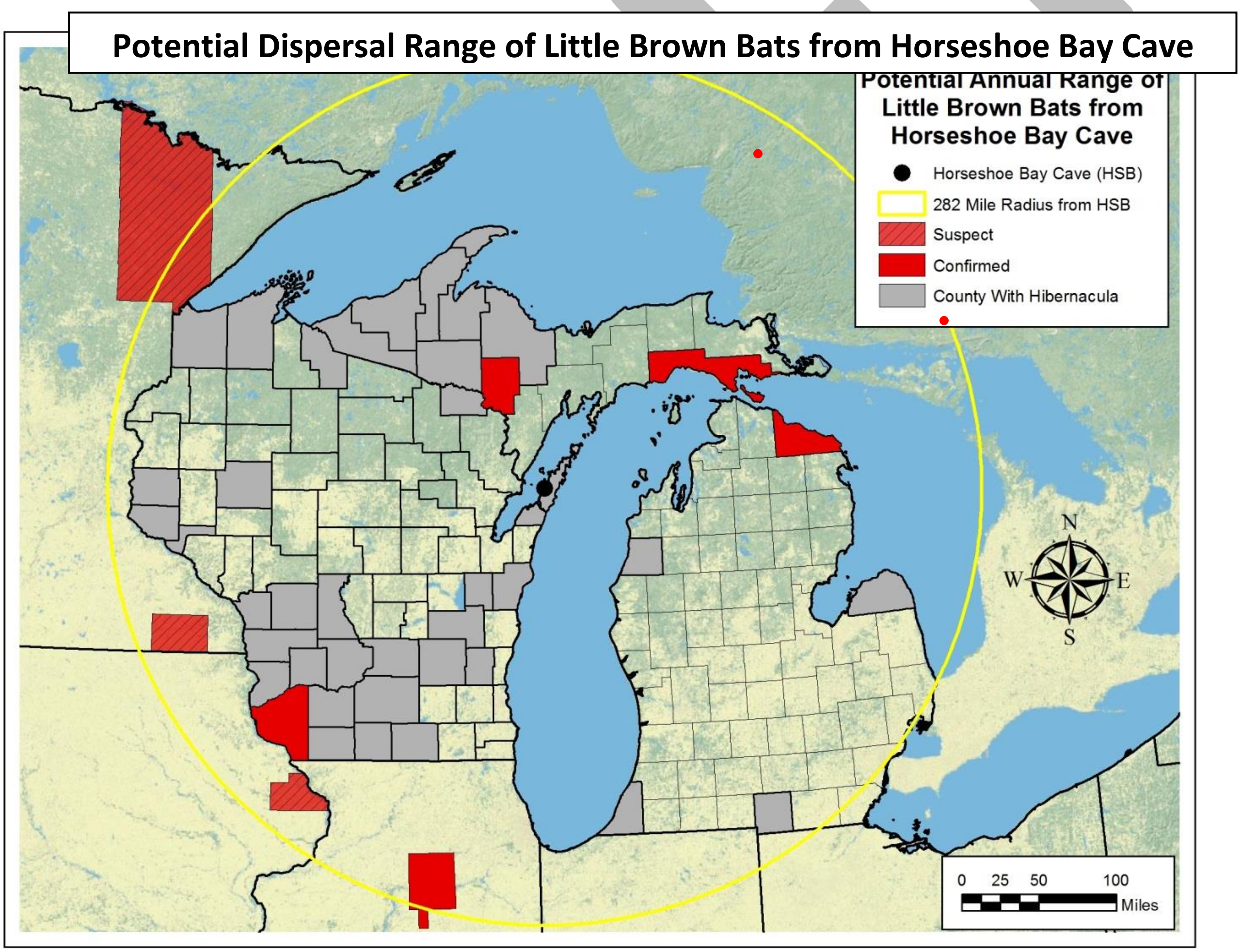


Figure 48 This map illustrates how critical one hibernaculum can be, allowing bats to congregate in winter for mating and survival, while the population may disperse to cover up to 250,000 square miles of summer foraging area. Known WNS affected hibernacula (in red) are already within the range of HSB Cave bats.

Natural caves in southwest Wisconsin account for approximately 60% of the 150 suitable and known bat hibernacula in the state; however, bats also hibernate in other cave-like locations, including mines, tunnels and cellars. All known hibernacula in Door County are caves, often sites which have been enlarged by human removal of sediment or rock for purposes of exploration. Door County ranks within the top few counties in Wisconsin for number of hibernacula, though Horseshoe Bay Cave is the most suitable and has the highest bat species diversity of these known sites.

Horseshoe Bay Cave contains more hibernating bats than any other cave in Wisconsin, however, the largest known concentrations of hibernating bats in Wisconsin are located in mines (Neda Mine, Maiden Rock Mine, Bay City Mine). Still, Horseshoe Bay Cave falls within the top 10 largest hibernation sites in the state and is one of few suitable choices for bats hibernating in the northern and eastern halves of Wisconsin. Critically, it is positioned on the migration corridor of the Niagara Escarpment and shoreline of Lake Michigan. It is located between the many large mines (5-10,000) of Michigan's Upper Peninsula and the caves and mines of the driftless region of Wisconsin, Michigan, and Iowa. It is one of the nearest significant sites to the largest known hibernaculum in the Midwest, Neda Mine, which is also located to the south on the Escarpment migration corridor.

Historic bat use of HSB Cave

Historically, bats may have had a winter range restricted to areas of cavernous limestone in the karst regions of the Wisconsin driftless area. Prior to and during much of the European settlement of the eastern United States, winter populations of bats likely occurred in karst regions of what would eventually become Wisconsin, Minnesota, and Iowa.

Bats are referenced in a number of caver trip reports from HSB Cave:

- In 1961 cavers noted a quantity of bat guano in the Top Shelf area of the Big Room (Kox, A General History of Horseshoe Bay Cave (Tecumseh Cave), 1990).
- In 1985 cavers found a "pile of dead bats and thousands of bat bones spilling down a pile of sloping sediments" in the upper "Top Shelf" passageway off the Big Room (Kox, A General History of Horseshoe Bay Cave (Tecumseh Cave), 1990)
- In 1986 cavers found and named the "Bat Room" next to the Waterfall Room at the end of the Mississippi River section of HSB Cave. (Due to low water levels the WDNR was able to survey for bats in these rooms in February of 2014 and found 100 bats in the two rooms, with a smaller number of bats found using smaller rooms in the Mississippi River section.)
- Molars identified as those from a little brown bat (*Myotis lucifugus*) were unearthed during an exploratory test pit project by then student Gary K. Soule. The bones were

found in sediment at a depth of 12-27inches from the floor of the Cloak Room (currently one of two areas where most bats are known to hibernate). (Soule G. K., 1975)

Methods of bat monitoring at the HSB Cave hibernaculum

These methods are dependent on seasonal activities of the bats and are thus represented here by season.

Harp traps/mist netting

Fall and spring trapping of bats allows biologists to gather important data on bats Figure 49. This includes obtaining baseline weight and wing scoring before and after hibernation as well as collecting tissue for genetic work. When a bat is in the hand of an observer it can be examined for signs of WNS and samples for diagnostics are then easy to acquire. Other examples of reasons for capturing and handling individuals include banding or PIT tagging individual bats, collecting tissue for genetic material and fecal samples for diet analysis, or for verifying species for acoustics.

Figure 49 A harp trap placed near the entrance of HSB Cave in 2012 was used to capture bats in flight during fall swarm activity in the entrance zone.

Emergence counts

An emergence count is a non-invasive method for measuring relative abundance at hibernacula or roost sites. Data from these emergence counts are useful for detecting change at a site with an extant long-term data set (to understand pre-WNS annual variation.)

An Infrared Directional Beam-Break Detection system installed at Horseshoe Bay Cave in the summer of 2013 uses infrared light and directional sensing electronics to automatically tally and data-log bats entering and exiting a hibernaculum (Redell et al. 2006) **Error! Reference source ot found.**. At sites with large populations, staff calibrate the system (Redell 2005) to derive a census of the bat population to allow WDNR to monitor trends and population dynamics. The electronic system, capable of detecting the direction of bat flight entering or leaving a cave or mine, can monitor bat movement 24 hours per day, 365 days per year Figure 51. Bat numbers may then be quantified based on statistically defensible information.

Figure 50 A photo-voltaic system provides power to the GateKeeper system and PIT tag antenna installed at the cave entrance.

Figure 51 An infrared beam-break detection system was installed near the entrance of HSB Cave in the summer of 2013.

Use of wing bands, and PIT tags to mark individuals at HSB Cave

Banding and passive integrated transponder (PIT) tags are the two marking techniques that allow for the identification of individual bats at summer and winter colonies which helps track their movements, provides data about overall health and longevity, survival after WNS arrives, and reproductive success. Both are likely to grow in importance in future years, as fewer and fewer bats remain, and the need to understand the apparent successes (or failures) of these individuals becomes critical. Among specific needs are confirming the presence and persistence of potential survivors, and determining immigration, emigration, and recruitment rates, at white-nose syndrome (WNS) infected colonies (both summer and winter).

Roughly 1.5 million bands have been applied to 36 species of bats using a variety of band designs issued by the USFWS between 1932 and 1972, (Ellison 2008) and an unknown number provided by other sources since then. A recent studfy found it is unlikely that the presence of a single band will noticeably affect survival and that Little brown bats exhibit high band retention rates. The low rate of visible injuries and little evidence of bands being chewed suggest very little mortality, at least from banding. (Hicks, et al., 2013)

PIT tags have been used to permanently mark bats of several species, including E. fuscus (O'Shea et al. 2010, Journal of Mammalogy, 91:418), M. bechsteinii (Kerth et al. 2001, Oecologia, 126:1), and P. subflavus (Damm and Geluso 2008, Western North American Naturalist, 68:382), with a unique identification number. Ellison et al. (2007, Acta Chiropterologica, 9:149) demonstrated that PIT-tagged bats can provide more precise data on short- and long-term survival of marked individuals when coupled with automatic PIT-tag readers at roost sites than through recapturing bats through conventional means (e.g., mist-nests or harp-traps). One opportunity for the use PIT tags and PIT reader arrays is at entrances to caves and mines to gain insight into bat behavior during swarming, winter activity, and emergence Figure 53. This application has the potential to address questions about bat use of hibernacula, including aspects of bat response to White-nose Syndrome. Positioning reader arrays at cave entrances to passively re-sight PIT tags does not limit bat movements (Britzke, Gumbert, & Hohmann, 2014)

Currently, there are banded and PIT tagged bats in Wisconsin from a Minnesota directed study of dispersal. Additionally, since 2013 bats have been banded and PIT tagged in several areas of Wisconsin Figure 52. Recapture information on these and other tagged bats will continue to be recorded opportunistically.

Figure 52 Little brown bat marked with a wing band resighted in a Wisconsin mine during hibernation.

Figure 53 A looped PIT tag reading antenna was placed near the entrance to HSB Cave in 2014.

Methods of marking individuals near HSB Cave

At Horseshoe bay cave, bats were trapped with harp-traps and mist-nets preceding the hibernation period and were either PIT-tagged or banded depending on availability of tags/bands and capture weight. Trapping followed established protocols to net, tag and recapture bats. Harp traps are specifically designed for capturing bats and are an efficient method when placed near the entrances to hibernacula and summer roosts. Mist-nets were setup along flight corridors for capturing flying bats of all species. Between trap checks, previously captured bats were processed for standard measurements including right forearm length, species, sex, and age class--if distinguishable. When bands were applied, individuals were marked with split-ring forearm band suitable for bats with a pair of banding pliers to reduce band application error and the band number recorded on the data sheet. Bands were made of a durable incoloy (a nickel-chromium alloy) manufactured by Porzana LTD (Icklesham East, Sussex, UK). 9mm PIT tags were used (manufactured by Biomark, Boise, ID).

A IS1001 Portable Enclosure with Cord Antenna manufactured by Biomark was installed at the cave entrance in February 2014. The flexible cord antenna is a new antenna design which allows it to be used in many different configurations making it a versatile option for applications such as cave entrances. The reader operates at a frequency of 134.2 kHz and is a 24V DC device and the system has continuous current draw up to 1 amp. The antenna can be coiled for smaller openings (as done at HSB Cave). The read range for this antenna opening is up to 21" pass-through and 16" pass-by with a 12mm tag. A reduced read range (maybe 30% or so) with 9mm PIT-tags is expected. The system has a local interface for set-up, maintenance, status monitoring, and data logging with remote capabilities. A data logging memory for up to 5,350 tags with reader ID, antenna number, and date and time stamp for each tag will provide the WDNR and County with information about each tagged individual. Simple data acquisition applications are used for interpretation of data, BioTerm and BioStat which incorporate graphical representation of the reader diagnostics which is helpful for troubleshooting.

Methods of winter WNS surveillance

External survey

External hibernacula surveys are a non-invasive technique for WNS surveillance. Caves can be visited on days normally too cold for bat activity to check for bats roosting or flying near the cave entrance. They may also be visited in late winter as well to search for carcasses and to conduct exit counts. Acoustic monitoring and beam-break technology (see descriptions above under emergence counts and acoustic surveys) are external non-invasive techniques currently implemented in multiple states including Wisconsin. These tools can be used to conduct remote monitoring and could document the abnormal winter bat emergence activity associated with WNS.

Internal survey

Entering hibernacula is an active surveillance tool. Whether conducting a rapid assessment or a complete count, the number of visits to the site and the time spent during each visit should be kept to a minimum in order to reduce disturbance to the bats. Visual and photographic survey methods were used while also looking for general bat roosting in abnormal places. If white fungal growth is observed on hibernating bats during these surveys, individuals are collected for laboratory submission when possible. Bat species, bat counts, and distribution information are recorded for each site. Internal hibernacula surveys should be limited to once a year unless there are concerns warranting additional entry. All surveillance, monitoring, handling and sampling of live bats must meet WDNR ACUC approval and require an endangered species permit.

In order to expand early detection capabilities the WDNR partnered with the University of California- Santa Cruz in 2013-2014 in a continental WNS transmission and surveillance study. Thousands of samples taken from 9 species spanning 25 states as part of this study comprise the largest and most current database for Pd/WNS. HSB Cave was one of 15 Wisconsin locations selected for participation in the study which will look at co-infection dynamics, viral diversity and persistence, and modeling population declines in North American bat species affected by WNS. Results of the three year study will identify the diversity and prevalence of viruses in Little brown an d Big brown bats in North America, as well as how viral infection patterns correlate with WNS. This study will identify broad patterns of viral diversity and prevalence not currently known for North American bat species, and will allow researchers to identify populations susceptible to future viral or fungal introductions. This study will greatly improve knowledge of how co-infection dynamics may impact vulnerable wildlife species. The study is ongoing but preliminary results show that the amount of fungus on bats (Pd loads) varies by species and is a strong predictor of population declines from WNS. (Frick, 2012) (Frick, Pers. Communication)

Results of bat monitoring in HSB Cave

Emergence counts (beam-break monitoring)

Spring emergence timing has not been monitored due to placement of the beam-break system in the fall of 2013 (bats will not emerge until late April/early May of 2014 after this document is prepared). Preliminary results are provided in the table below **Error! Reference source not ound.**. The system will be able to provide the WDNR and Door County with information about bat population size and seasonal use of the cave which will help inform decisions regarding human activities conducted at the cave **Error! Reference source not found.**.

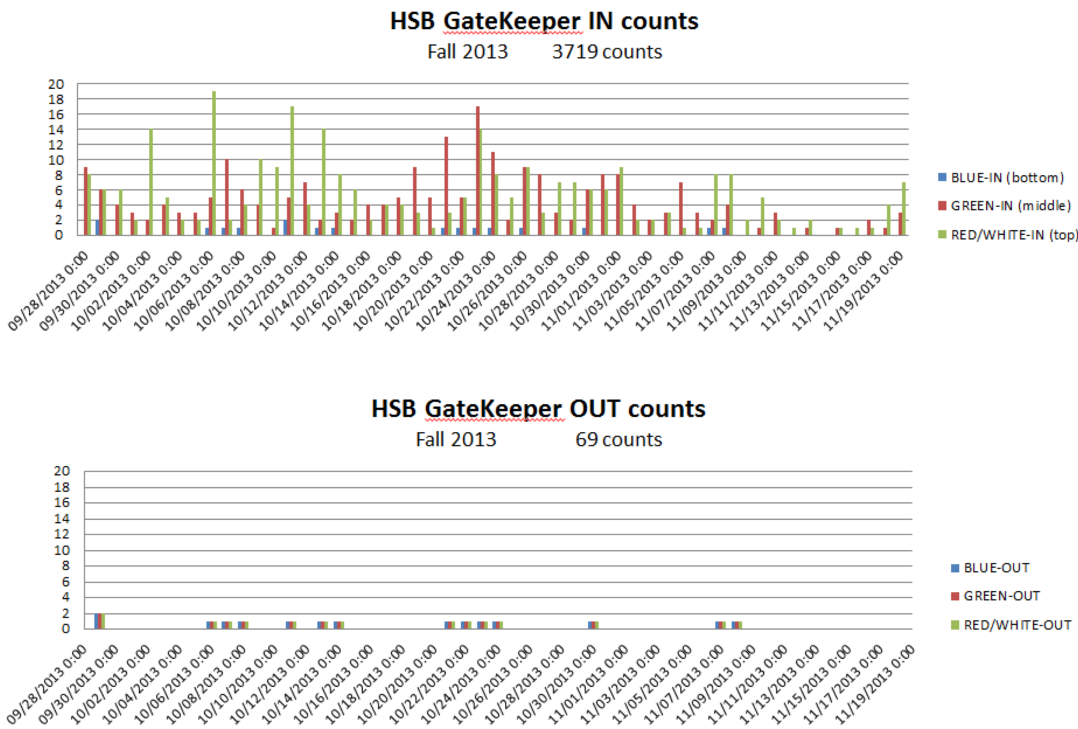


Figure 54 Preliminary results from the beam-break system installed in the fall of 2014 showing bat activity at the cave entrance during the fall swarm (mating) period.

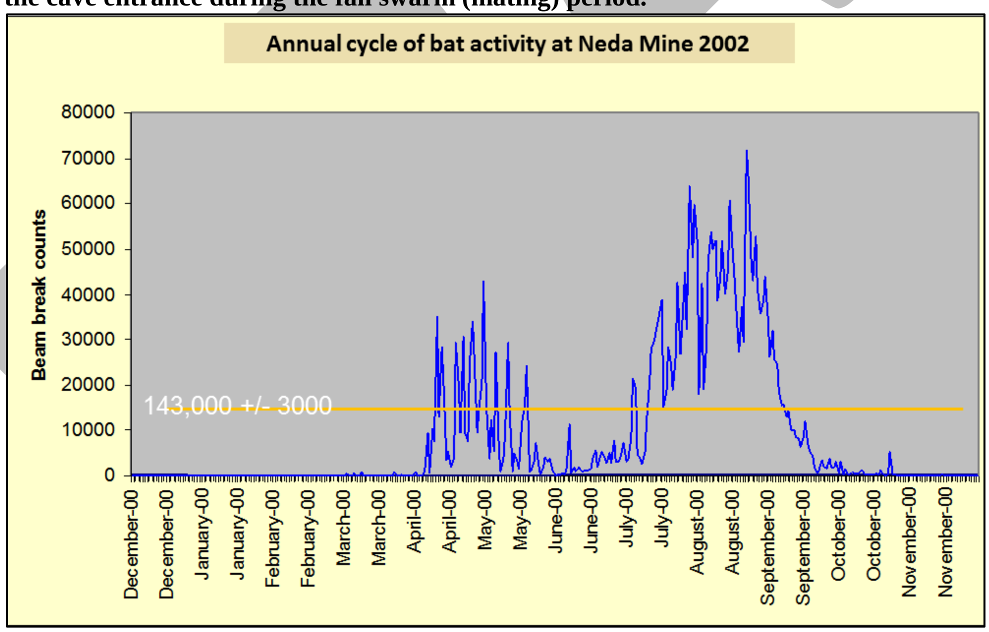


Figure 55 An example of data gathered by a beam-break system installed at the state's largest hibernaculum, Neda Mine to give a sense of how the use of a similar system at HSB Cave will provide information about population size and seasonal bat use of the cave. The yellow line indicates Neda Mine's bat population and error rate as determined by the beam-break system.

<u>WNS disease surveillance & winter survey</u>

WDNR staff conducted WNS surveillance at over 90% of known hibernacula from the end of January through the middle of April each year from 2011- 2014. HSB Cave was visited in February each year from 2011-2014, prior to the spring staging movement of bats to areas closer to the cave entrance. The wet, muddy, low ceilinged passageways of HSB Cave make the cave very challenging to survey Figure 56. For the same reasons cave photography is highly challenging and use of camera equipment is generally restricted to summer visits when travel through the cave can be leisurly due to the absence of hibernating bats and concerns about disturbance. High water conditions restrict times when the Mississippi River section of the cave can be entered and thus the cave was only surveyed from the entrance through the Crevice/Big Room area. The Mississippi River section was not surveyed until 2014 when low water levels allowed WDNR staff to enter this area. A significant number of bats (100+) were found to be using this area, with most using the Bat/Waterfall Rooms.

Figure 56 Entering HSB Cave for any purpose (in this case winter WNS surveillance) requires special gear. DNR and County staff wear wetsuits, neoprene gloves, hoods, and socks and helmets with lights in order to crawl through passages containing frigid meltwater. Regular coveralls and/or tyvek suits can be worn for work near the entrance where conditions are fairly dry.

An average 1247 bats were present at HSB Cave each winter from 2011-2014 **Error! Reference ource not found.**. Similar to other large Wisconsin hibernacula, 99% of the hibernating population is comprised of Little brown bats though all four cave species are present **Error! eference source not found.**. Though not present in Door County during the summer resident period, Eastern pipestrelles were found hibernating in the cave (and also found during harp trapping at the cave entrance during the fall swarm period).

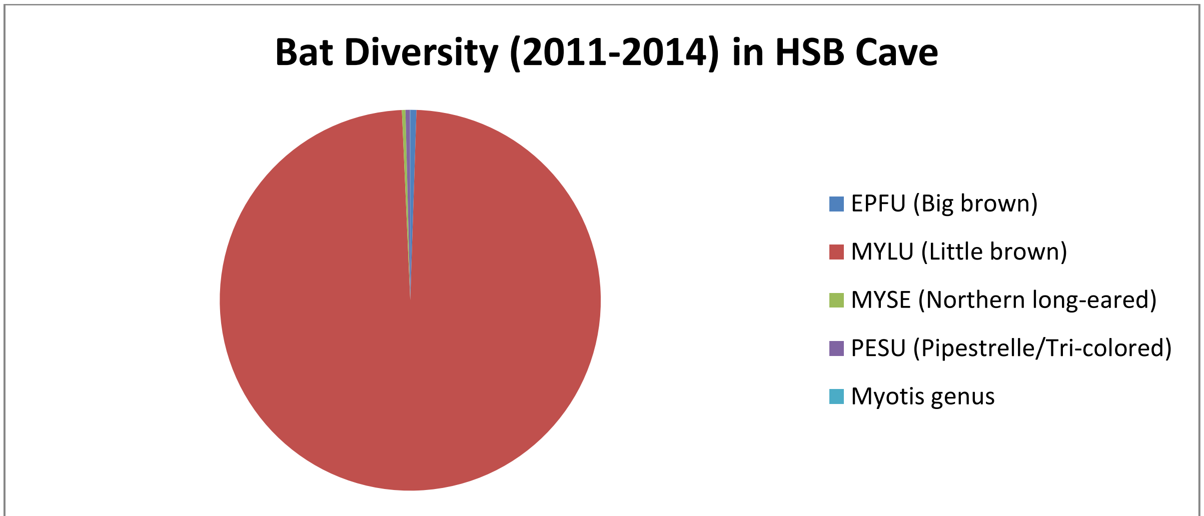


Figure 57 Most bats using HSB Cave are Little brown bats.

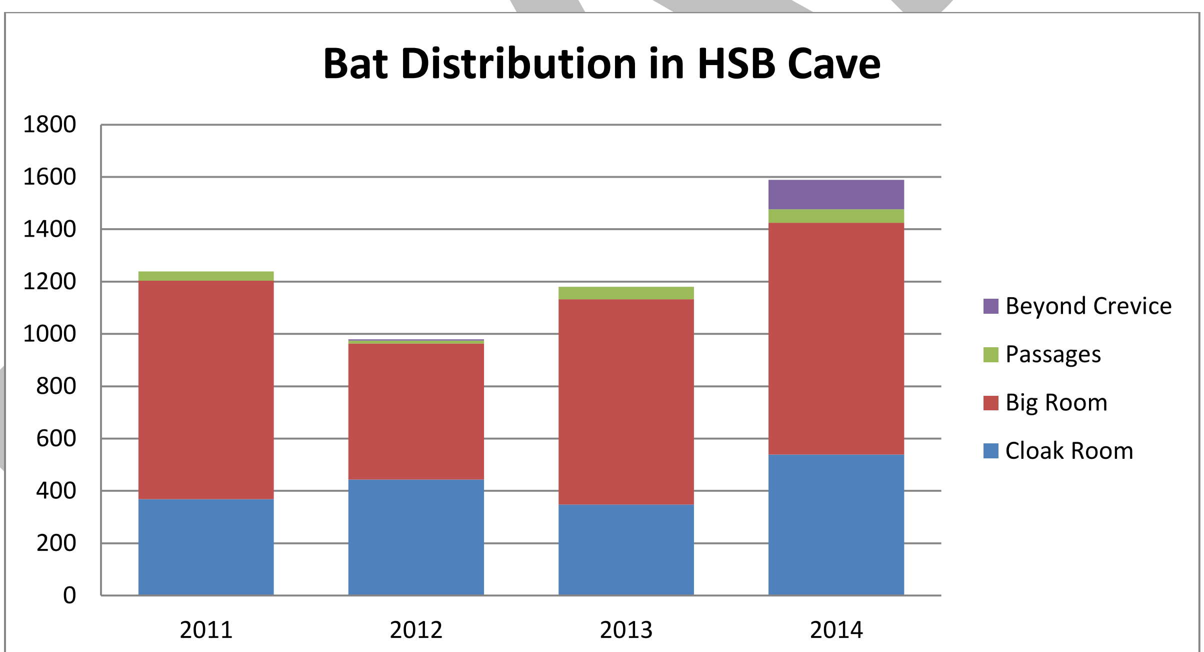


Figure 58 Hibernating population & distribution information for HSB Cave. The cave gate was replaced between 2012 & 2013. Due to extreme conditions (cold & high water) the Elephant, Mud Bank, Bat and Waterfall Rooms were not surveyed until 2014.

Large numbers of bats were located in and near the Cloak Room within 50 feet of the cave entrance (avg. 34%) Figure 59 while over half of the cave's winter population (avg. 60%) were found using the Big Room Figure 61-38 approximately 700 feet from the cave entrance. Species distribution was normal throughout the site; Big brown bats located near the entrance in cold, dry, variable conditions Figure 60 and Little brown bats were located in warmer, humid, more stable conditions. Larger, dense clusters of bats were observed in the Cloak Room where temperatures are generally colder and drop steadily over the course of the winter while bats using the Big Room and Waterfall/Bat Rooms were scattered as individuals or present in small clusters. Eastern pipistrelles and Northern long-eared bats were dispersed throughout the cave. Eastern pipistrelles are a non-clustering species and were found hibernating individualy.

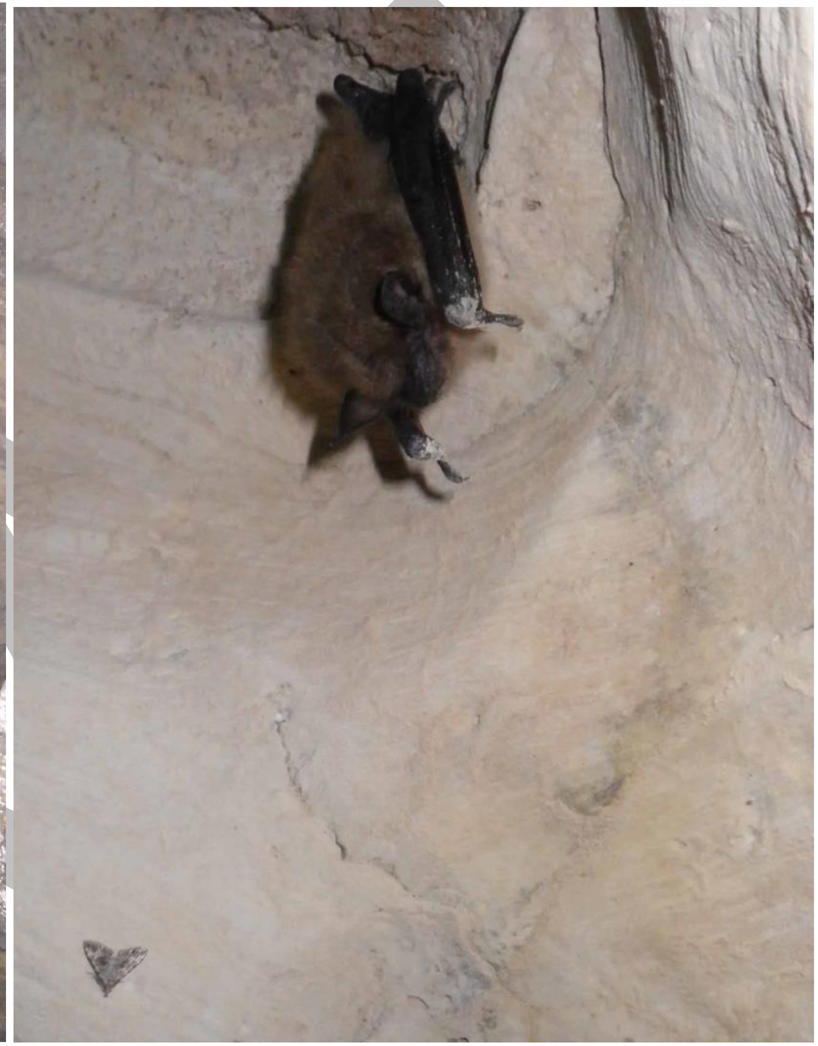


Figure 59 (Left) Cloak Room in winter. Note the (relatively) large, dense clusters of hibernating bats present due to the colder, more variable conditions present in this area of the cave.
Figure 60 (Right) Big brown bat (*Eptesicus fuscus*) hibernating near a hop vine moth between the Cloak Room and the entrance. EPFU are often found in colder, drier areas of caves and near entrances where environmental condtions are highly variable.

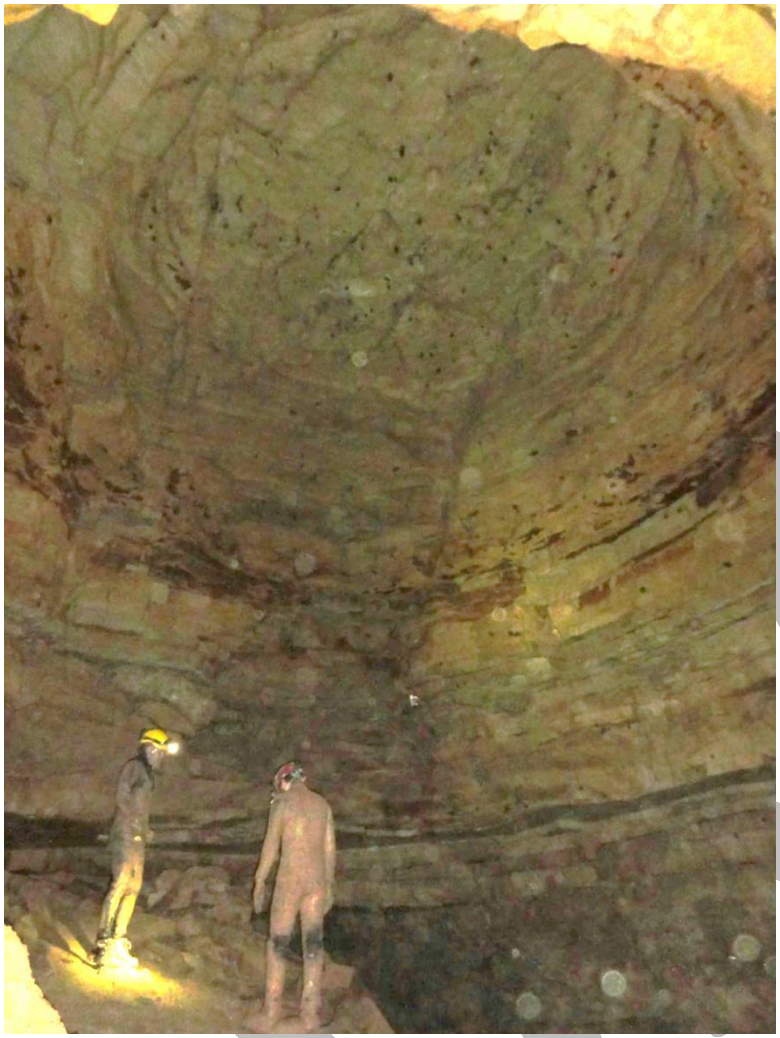


Figure 61 (Left) The Big Room at HSB Cave hosts just over half of the hibernating bat population. Bats are barely visible in this photo due to the extreme humidity and dripping water in this room. Note the bands of iron-stained dolostone present halfway up the walls. WDNR staff in this photo are wearing mud-covered wetsuits. The presence of so much mud and water makes photography a challenge.
Figure 62 (Right) A pair of mating Little brown bats (*Myotis lucifugus*) in the Big Room. Infrequent arousals from hibernation are common and are opportunities for drinking, movement to maximize energy consumption during torpor, and mating.

Figure 63 Bats using the Big Room form fewer, smaller clusters or hibernate alone due to the warmer, more stable conditions present here. Note the flying bat in the lower right corner of the photo.

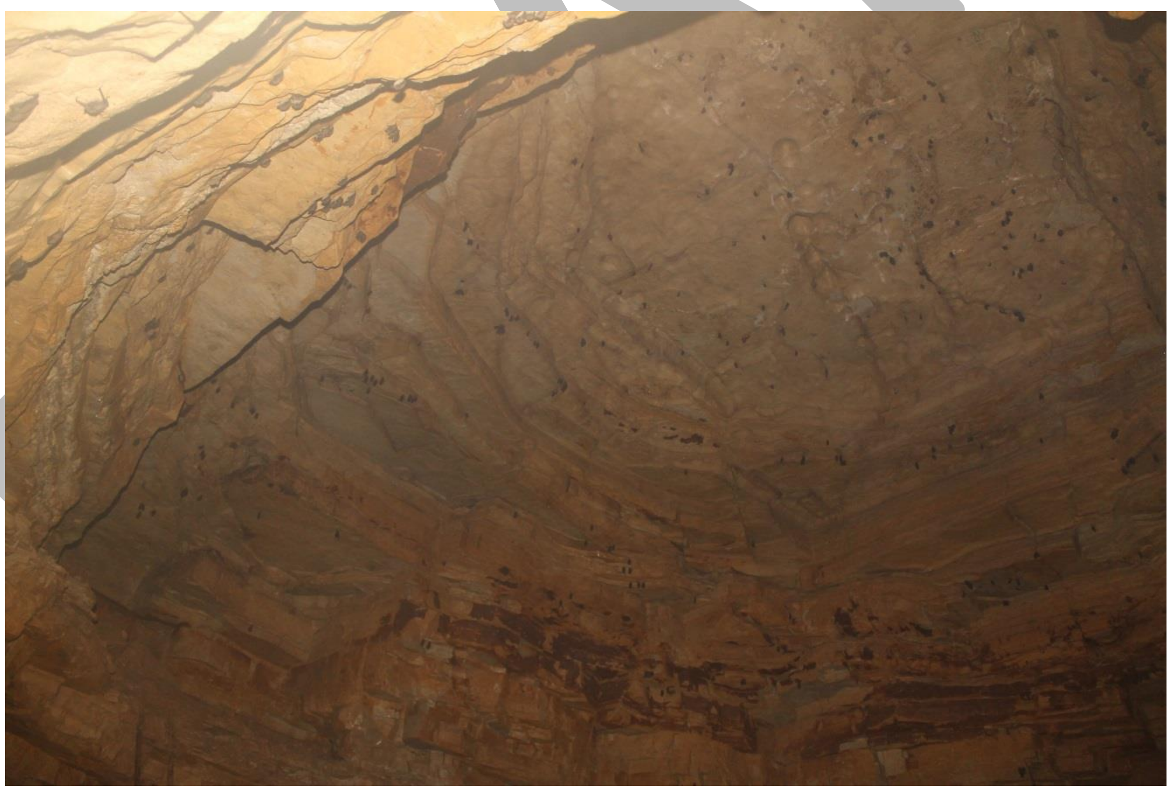


Figure 64 View of the wall and ceiling of the Big Room depicting the scattered nature of bats throughout this space. Bats on the ceiling 40 feet above are barely visible.

Figure 65 Solution-enlarged fractures like this one in Brown County could serve as access points for bats to enter caves or enlarged crevices suitable for hibernating.

Visual signs and symptoms of WNS were not detected in HSB Cave (or Wisconsin) during surveillance visits from 2011-2013 A subset of individual bats in HSB Cave were swabbed for Pd/WNS as part of the Frick transmission study during November, 2012 and March, 2013 and November, 2013. Results of qPCR testing of the samples were negative for Pd/WNS.

Marked individuals

During 2012-2013, 75 bats of four cave obligate species Figure 66 were marked using PIT tags (n=44) or wing bands (n=31) near the entrance to Horseshoe bay cave Figure 66. In an effort to maximize the likelihood of recapture at the cave and to link summer roosting habitat to winter hibernacula, an additional 22 bats were PIT-tagged at a nearby maternity roost. The 97 marked bats represent 8% of the entire Horseshoe Bay Cave bat population (avg. 1247). All bats were marked during the fall migration period (Aug. 1-Sept. 15).

A total of 15 marked bats (13 PIT tags and 2 bands) were resighted on subsequent hibernaculum surveys, which represents a 20% recovery rate for the Horseshoe bay cave marked bat population. Results reveal hibernation-site fidelity for these individuals. None of the 22 individuals from the nearby maternity roost were resighted at Horseshoe bay cave, which may indicate the use of hibernacula other than HSB Cave.

Figure 66 A Northern long-eared bat (*Myotis septentrionalis*) captured in a harp trap at the HSB Cave entrance during the fall swarm period in 2013. This individual was PIT tagged.

Summary of resources by Management Zone

Resource table by zone

CHAPTER 3: THREATS TO RARE SPECIES & SENSITIVE FEATURES

List of threats to cave and karst ecosystems, modified after categories of Elliott (2000) and supplemented in part with recommendations from the HSB Cave Invertebrate Inventory (Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014).

Land development

Caves are an extension of the surface environment and are affected by the activities of humans. Land development can result in filling of sinkholes, destruction of host rock through building of roads, road spills, utility impacts (such as septic lines, or trenching to install fiber optic cables), and increased impervious cover (parking lots, buildings). Activities which could have a detrimental effect on a cave's environment include road, parking lot and trail construction; the development of water sources, leach fields, septic systems, and wells; the construction of buildings and the installation of utilities; the diversion or pollution of water and all types of non-structural fires. Future developments involving these types of alterations to the surface environment, must also consider the subsurface environment.

Cave development (cave tours)

The presence of visitors on public tours in HSB Cave impact caves. Impacts from visitation include shedding of foreign debris, disturbed sediment, introduction of heat, oil staining and polishing from touching, and vandalism. Visitors unintentionally shed lint, hair, skin cells, shoe rubber, microbes, and spores (Horrocks and Ohms, 2004c). Spores shed by visitors cause algal growths in artificially lit areas. The natural lint fibers degrade more quickly, while the synthetic fibers remain longer in the cave (Jablonsky, Kramer, and Yett, 1994). Water condenses on these fibers and dissolves cave surfaces and minerals. These fibers affect cave biota by providing unnatural carbon and nitrogen sources for their consumption (Moore, 1997). This condition supports unnaturally high cave biota population levels and introduces non-native species. Intentional vandalism includes boxwork breakage, graffiti, leaving trails, the removal of cave formations, and litter. The cave is additionally impacted from visitors occasionally urinating and defecating along tour routes.

Non-native species have been introduced to caves by being inadvertently carried in by park visitors or provided artificial travel corridors by lights and paved trails. Studies have shown greater species diversity along the developed tour routes, including several species common to the surface or humans (Moore, 1996). Some species, such as wood rats or bats, can leave waste on the trails that are undesirable for visitor contact. Due to the decomposition of flood debris and degassing of infiltrating water, it is common for CO_2 levels in caves to be slightly higher than on the surface. Individuals exhale CO_2 into the cave environment. No studies have been undertaken to determine if people elevate natural CO_2 levels to unsafe or resource impacting levels.

Development of the cave for anything beyond occasional “wild” caving tours would have serious impacts to the cave ecosystem, due to the small size of the passages combined with the fragile nature of cave ecosystems. Though this is one of the largest, most significant cave in Door County, it is completely unsuited for tourist visits, in part because most of the passage is wet and crawling height and the cave is so small that even activity in the front (standing/stooping height) passage would result in excessive trampling of habitats resulting in injury and death of cave invertebrates and other cave resources. That is, most of the floor would be stepped on because the passage is not very wide. Removal of sediment fill would mean removal of invertebrate habitat and would likely result in dramatic changes to cave microclimate, which in turn may affect bat hibernation or create an ecological trap for individual fauna accustomed to the natural cave climate (i.e. bats) when they are unable to move to suitable caves (in winter). Installation of platforms, lights, walkways and other infrastructure often result in permanent alteration of exposed bedrock and significant geological features. Secondary effects of development and high levels of human visitation include nutrient enrichment and resulting fungal growth from organic material carried in on footwear and clothing, litter and food sources, lint and algae growth in areas with permanent lights.

Isolation

Concerns with faunal isolation through land development and down-cutting through bedrock are unlikely to be major impacts, but quarrying and major excavations within the hydrological basin of the cave should be strictly regulated.

Nutrient stress (loss & enrichment)

Dependable food sources in a cave environment are of vital consequence to its fauna; whether they be guano from bats and crickets, entrance leaf litter, or detritus from flooding, supplies vary seasonally (Barr, Observations on the ecology of caves., 1967). Nutrient stress from nutrient loss can accompany land development, which may limit the quantity and change the nature of organic inputs through sinkholes. If restoration work is conducted and wood and other organic materials are removed from the cave care should be taken to remove these items in stages over a long period of time. Losses associated with the potential extirpation of bats from the cave as a consequence of the spread of WNS could also be detrimental to the rest of the cave ecosystem due to the loss of energy sources contributed by bats.

Nutrient enrichment is likely already occurring within the caves' recharge area. Private residential applications of fertilizers commonly exceed manufacturer specifications, and fertilizer use on the golf course likely contributes significantly to nutrient enrichment in the cave, particularly in aquatic habitats. Enrichment originating from poorly maintained septic tanks or leaking sewer lines may also be a serious concern in the Horseshoe Bay Cave drainage basin, as has been documented elsewhere (Panno et al. 1996, 1997, 1998).

Nutrient enrichment may also occur on a smaller scale in localized areas of the cave due to human activities (littering, crumbs from food, spilled beverages) and care should be taken to leave areas clean after rest stops on caving trips.

Hydrological threats (runoff, chemical pollution)

Groundwater is an important source of potable water, and groundwater contamination has been a significant issue along the Escarpment for some years (Valvassori 1990). In areas of karst pathways develop for water movement through the rock leading directly to the groundwater with little or no filtration. Surface activities such as agriculture (both crops and grazing), road salting, and non-point source pollution can contaminate water moving directly into the groundwater. The thin soils in the area can create other difficulties including the adverse effects of leaking underground storage tanks or deteriorating septic tanks. (WDNR, 2002)

Chemical pollution of Horseshoe Bay Cave is most likely to come from sources above the cave among the sinkholes in the recharge area. The potential for improper disposal of chemicals by private residences and the golf course are high. Use of herbicides and, especially, insecticides by private residences and the golf course should be regulated, with a special focus on keeping these and other chemicals away from sinkholes. Sinkhole vegetative buffers can help in this effort.

Hydrologic disruption

Caves, sinkholes, springs, and other karst features provide unique habitats for a vast array of rare species and natural communities, many of which are susceptible to hydrologic disruptions. For example, new construction can directly or indirectly affect groundwater infiltration rates and consequently change the amount of water that discharges from a spring. The other threats listed above can, directly or indirectly, alter the hydrologic cycle and thereby change the conditions necessary for the continued health of rare species populations and some natural communities.

Communities, especially wetlands, in the study area that are not on karst may also be subject to hydrologic disruptions. Wetlands ecosystems are important for many reasons, functionally (groundwater recharge areas, buffers, and water retention areas) and biologically (habitat for rare species, spawning areas for fish, prime nesting sites for birds). Hydrologic disruptions such as draining or isolation alter the functioning of wetlands and reduce or eliminate important habitat for many species. (WDNR, 2002)

Changes to substrate & water locations/flow

Sediment compaction

Sediment removal

Water changes (flooding/drought as a result of human activity)

Microclimate effects

Altering microclimate by changing cave morphology

At the local level, climatological threats from entrance modification/creation seem to bee a real threat due to interests in discovering other entrances to the cave. We strongly discourage opening additional cave entrances (via sinkholes) unless these have been artificially closed by human activities. Such entrances can alter airflow patterns resulting in reduced thermal stability and lower relative humidity within the cave

Climate change

Climate change will have an impact on the natural resources of HSB Cave, though understanding of these changes is a growing science. Some regional changes that may result from climate change include increases in both summer and winter minimum temperatures, shifts in seasonal precipitation (more in the winter, less in the summer), and more frequent extreme weather events such as very heavy rainstorms or heat waves (WICCI, 2011). Results of these changes may include the shifting of species ranges: Species at the southern edge of their range in Door County may diminish in the region, while species at the northern edge of their range may expand further northward. Natural communities of caves, cliffs, and north-facing slopes (and the plants and animals associated with them) will also be vulnerable, as their very existence is founded in their exceptionally cool, moist microclimate; this particularly applies to Pine Relicts, Hemlock Relicts, and Algific Talus Slopes. Lastly, the magnitude and frequency of intense rain events are anticipated to increase with climate change. Heavy downpours increase the occurrence of flooding in HSB Cave, which can damage or destroy micro-habitats within the cave and create a ecological (population) sink for bats using the cave during flood events.

Impacts of global climate change on the cave ecosystem are difficult to mitigate, but we can expect these to result in changes to the cave ecosystem as the quantity and timing of hydrological recharge is altered and the thermal regime shifts (Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014). The unique topography around HSB Cave presents opportunities to mitigate the impacts of Climate Change on vulnerable plants, animals, and natural communities. This could involve maintaining high canopy cover on north facing slopes, helping to maintain a cool microclimate for northern species. Maintaining canopy cover and diverse ground flora in spring recharge areas may also help increase rainwater infiltration, which in turn supplies springs and streams.

Adaptation strategies that are recommended for riparian settings include promoting stream bank and channel stability, reducing erosion and siltation, and protecting streams from damaging flood events (WICCI 2011).

Killing, over-collection, disturbance of fauna

Killing, over-collecting, and disturbance of the cave fauna of Horseshoe Bay Cave will remain limited to manageable levels as long as visitation is limited to visits associated with managing cave resources (bat inventories, cave mapping, hydrological research, bioinventories, etc.). All surveillance, monitoring, handling and sampling of live bats must meet WDNR ACUC approval and require an endangered species permit.

Bat use/hibernation disturbance

Human activity during bat use (Fall swarm Aug. 15- November; Hibernation Oct. 1- May 15; Spring staging & emergence March 15- May 31).

Summer solitary bat use/day roost/generally males

All surveillance, monitoring, handling and sampling of live bats must meet WDNR ACUC approval and requires an endangered species permit.

The consequences of various forms of disturbance have long been a topic of concern among bat researchers and managers (Ellison 2008) but are not well documented or understood for either WNS-free or WNS-infected bats. Thomas (1995) demonstrated that hibernating bats can respond to the non-tactile disturbance associated with hibernacula surveys, although the response may not necessarily be dramatic (Speakman et al. 1991). Arousals are energy-expensive events (Thomas et al. 1990) and increased disturbance could deplete fat reserves before insects are available on the spring landscape. The depletion of fat reserves is associated with most WNS deaths (Blehert et al. 2009) and it is assumed, but not yet demonstrated, that WNS-affected bats would suffer more from additional winter disturbance than non-infected animals.

People automatically think on a human size scale, and therefore protect the openings that are human size but cave airflow may be dependent on sub-human connections to the surface through “dead bottom” pits, small caves, cracks, crevices, bedrock ledges, “choked” sinkholes, and other karst features. In HSB Cave the presence of significant numbers of bats in the far reaches of HSB Cave (Bat/Waterfall Rooms) combined with observed patterns of low/no air-space in the Mississippi River section and “Duck under” area near the HH Room may indicate that these bats are entering the cave through areas other than the main entrance. Glacial gravels, bones, sprouted seeds, and seed hulls have been observed on a number of trips to this area which also indicate a relatively open pathway to the surface in this region of the cave.

Threats to hibernation include modifications to the cave and surrounding areas that change airflow and alter microclimate. Human disturbance and vandalism pose significant threats during hibernation through direct mortality and by inducing arousal and consequent depletion of fat reserves. Natural catastrophes can also have a significant effect during winter because of the concentration of individuals in a relatively few sites. During summer months, possible threats relate to the loss and degradation of forested habitat. Migration pathways and swarming sites may also be affected by habitat loss and degradation. In addition to these threats, significant information gaps remain regarding the species' ecology that hinder sound decision-making on how best to manage and protect the species. A list of detailed conservation guidelines can be found in Appendix XX- MYSE guidance currently in Plan document

Ecological trap

A hibernaculum having a history of repeated flooding or severe freezing events that have resulted in the mortality of large numbers of hibernating bats is an ecological trap. Hibernacula with other environmental conditions that pose a severe and/or imminent threat to the majority of hibernating bats may also be designated as "ecological traps" (e.g., threat of catastrophic collapse). As of October 2006, three caves hosting federally endangered bats had been preliminarily designated as ETs by the USFWS: Bat Cave (Shannon Co.) in Missouri (freezing), Haile's Cave in New York (flooding), and Clyfty Cave in Indiana (flooding). These preliminary designations were made based on the recommendations of Indiana bat experts familiar with these caves, and on the history of Indiana bat mortality in these caves. The designations will be reevaluated when procedures for evaluation and designation of hibernacula as ETs are developed (see Indiana Bat Recovery Action 1.1.2). HSB Cave may be a candidate for this designation if further flood mortanilty events are documented there.

White nose syndrome (& exotic/invasive species)

The invasive, pathogenic fungus *Pseudogymnoascus destructans*, causative agent of WNS, is an example of an invasive species with anticipated serious impacts on the cave ecosystem at Horseshoe Bay Cave in the near future. Based on the rapid expansion of WNS on the landscape (USFWS 2013) Figure 67, the last substantial winter colonies of little brown bats (*Myotis lucifugus)* in the United States, located in Michigan and Wisconsin, are expected to become infected within the next few years. Nearly all large winter colonies of little brown bats in the Northeast have suffered 85 percent to 99 percent losses (Turner et al. 2011). WNS could result in the extinction or large-scale extirpation of this and other bat species (Frick et al. 2010; Thogmartin et al. 2013). P.d. is thought to have been introduced from Europe to N. America sometime before 2006. Ongoing research hs shown that Pd survives and is maintained in the environment for extended periods, and it has become well established in N. America.

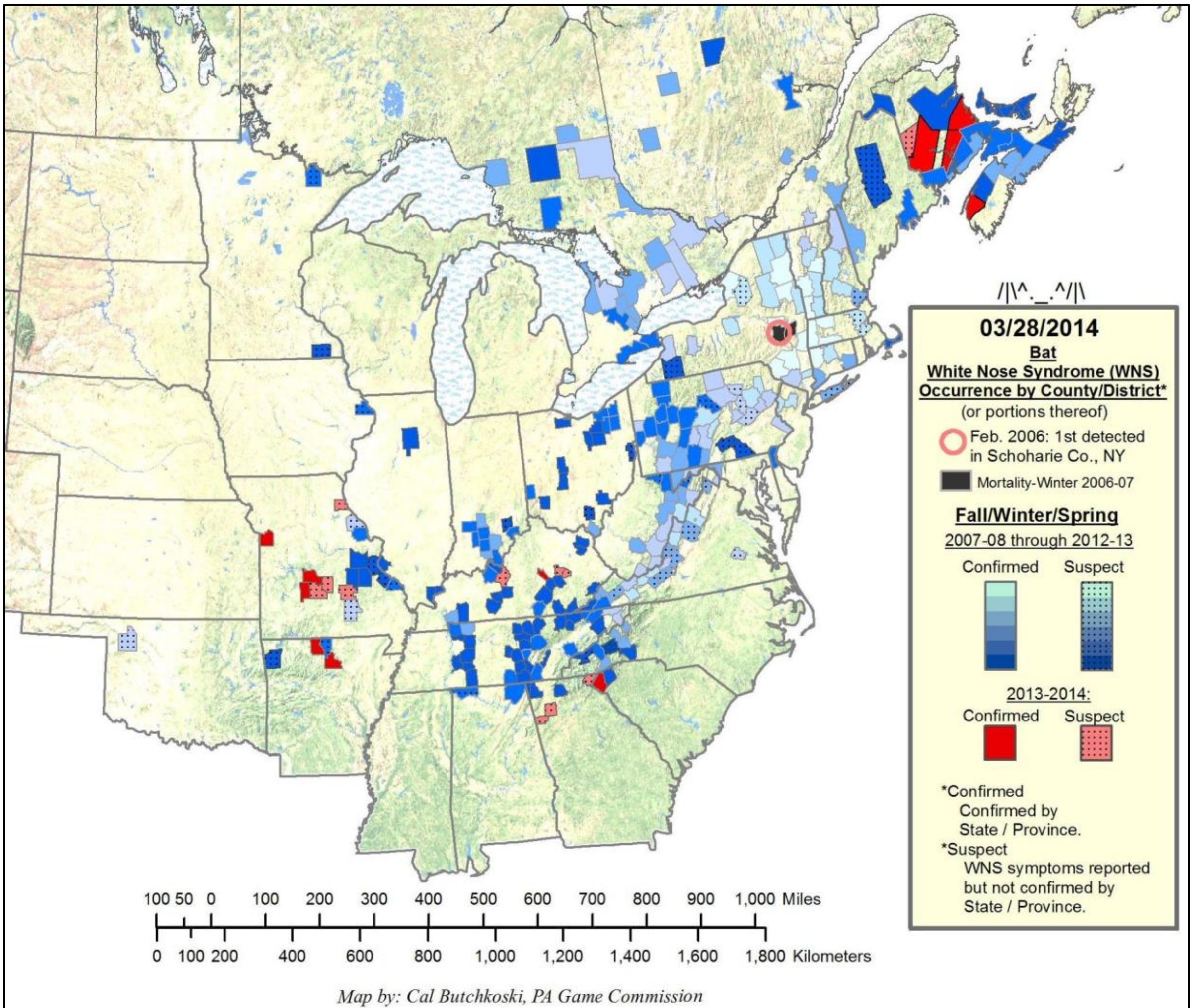


Figure 67

The overall goal of WNS management is to slow the spread of the disease into and through Wisconsin and minimize its impact where it does occur. Because the natural movement of bats cannot be controlled, the current focus of the WDNR strategy is to limit the anthropogenic spread of WNS. The main tools used to limit WNS impact are decontamination, physical exclusions at caves and mines, and disease management. Three permanant rules that came into effect in June 2011 list cave bats as threatened, name *Pseudogymnoascus destructans* a prohibited invasive species, and adds White-nose syndrome management options under NR 40, including mandatory decontamination procedures when entering and exiting caves or handling cave bats. Under this authority, WDNR adopted decontamination measures that allow Wisconsin caves and mines to remain open for human use and prevent the rehabilitation of infected or presumed-infected bats until disinfection protocols can be developed. Restricting unauthorized human access is highly recommended for all caves and mines, both public and private. WDNR will work with property and business owners on a site-by-site basis to find practical and effective management strategies that meet the commercial, recreational, or other needs of the owner while at the same time slowing the spread of WNS.

Monitoring Wisconsin's bat populations is crucial for WNS management for two reasons: establishment of pre-WNS baseline data and early disease detection. Baseline data on population densities, hibernacula locations, movement patterns, and health is necessary for ongoing research on WNS. This information is also essential for accurately understanding the effects of the disease when it arrives and for planning the recovery of the bat population. WDNR field crews have already surveyed more than 90% of the Wisconsin's 120 potential hibernacula, recording information on species, estimated number of bats present, temperature, and general site conditions. This information will help determine where *Pseudogymnoascus destructans* could survive or spread, prioritize future monitoring, and identify potential future hibernacula for a recovering bat population. Early WNS detection will give managers and researchers the earliest opportunity to develop and experiment with control methods focused on stopping or slowing the spread of the disease.

Early detection of WNS will contribute to the number of disease management options available if Horseshoe Bay Cave becomes infected. All baseline data on bats currently and after the anticipated arrival of WNS could help future bat management practices in WI and nationally, as well as establish recovery goals to pre-WNS population levels.

The WDNR has developed a Surveillance and Response Implementation Strategy as an internal document to guide the state's response to this imminent wildlife health crisis. The main goals of Wisconsin's WNS response are to prevent the anthropogenic introduction of WNS into the state, slow its spread once it arrives, control the disease to the point where bat populations may recover, and to do so in a cost-effective manner that minimizes impacts to stakeholders.

Non-native invasive species thrive in new areas because they establish quickly, tolerate a wide range of conditions, are easily dispersed, and are no longer limited by the diseases, predators, and competitors that kept their populations in check in their native range. As a result, the invasive pests kill native plants and the invasive plants out-compete native plants by monopolizing light, water, and nutrients. In situations where invasive plants become dominant, they may even alter ecological processes by limiting the use of prescribed fire, modifying hydrology, and stabilizing naturally shifting dunes and beaches. In addition to the threats on native communities, invasive species negatively impact forestry (by reducing tree regeneration, growth and longevity), recreation (by degrading fish and wildlife habitat and limiting access), agriculture, and human health.

Non-native invasive species are numerous and widespread on the Door Peninsula (Table 2). Table 2 lists non-native invasive species that are found on the DPPG and those that are not known on DPPG sites, but are potential threats to the habitats of the DPPG. Table 2 does not include non-native plants that are not currently known to be invasive.

Invasive plant species that invade relatively high-quality areas are the most serious threat to biodiversity.Within the DPPG these species are: garlic mustard (*Alliaria petiolata)*, common reed grass, common hound's-tongue (*Cynoglossum officinale),* garden forget-me-not *(Myosotis sylvatica),* spotted knapweed, yellow sedum, and glossy buckthorn.

Found in the HSB Cave Invertebrage Inventory were some exotic species, such as earthworms, which may have long since had an impact on the cave ecosystem by out-competing native fauna. Similarly, some of the entrance fauna is non-native, with undocumented impacts.

CHAPTER 4: MANAGEMENT OPPORTUNITIES

This section describes actions that will contribute to conservation of HSB Cave's resources. They are grouped into 3 broad categories: monitoring & protection, education & interpretation, and future inventory needs.

Monitoring & protection

Once high quality natural communities, rare species, and special features have been identified, it becomes important to attempt to perpetuate those features. The following are basic approaches that land managers can use to maintain important occurrences.

Monitoring: Monitoring changes is an important tool in determining the long-term health of and changes to natural communities and sensitive species populations. A long-term cave monitoring program is needed for populations of rare/listed species, hydrological activity and water quality, and sensitive features in HSB Cave. Baseline data can be collected on these resources to monitor changes over time. The comparison of results of monitoring over time with baseline can suggest appropriate management strategies.

Decision making: With the overall goal of multi-use of the cave decisions will need to be carefully reviewed and made regarding human activity in and near the cave. Human activities can have significant and irreversible effects on sensitive cave features and resources, and secondary (often unintentional) effects on fauna that require the cave habitat. One of the core values of the WDNR is to anticipate and prevent damage to the environment and develop processes and policies to protect our resources and the well-being of the public. When making decisions related to the management of HSB Cave and its resources the WDNR and Door County should follow the precautionary principle:

Precautionary principle means taking action to protect the environment if a reasonable threat of serious or irreversible harm exists based upon the best available science, even if abundant scientific evidence is not available to assess the exact nature and extent of risk.

Trail delineation: Marking (sometimes minute) sensitive features can help ensure their protection. The long, narrow passage of HSB Cave means that even a knowledgable trip leader has difficulty communicating with those people not following immediately behind them in line. Flagging and trail designation will help communicate the presence of sensitive features to visitors. Cave managers should be aware of the potential ecological impacts of trail widening and construction (for example a raised walk/crawlway can be placed over cave floors/sediments to avoid compaction and crushing invertebrate fauna, particularly in Mangement Zone 1 where visitation is expected to be highest).

Protection efforts: HSB Cave is protected from unauthorized human entry by the physical presence of a bat-friendly gate, however vandalism or disturbance are not the only threats to the cave. The cave's drainage basin and land area around the cave are all important to the cave system. Development of the Cave Mangement Plan will address some of the issues associated with protecting the cave. Some mechanisms that should be considered are MOU's, outright purchase, conservation easements, or dedication as State Natural Areas.

Planning: As identified in the Bay-Lake Regional Planning Commission (2001) report, many of the existing land use plans and zoning ordinances along the Niagara Escarpment do not consider the unique ecological functions and attributes of the study area and are not therefore not compatible or consistent with the existing ecological features. An attempt to integrate planning between local, state, and federal agencies should be a priority. Detailed planning recommendations can be found in the Bay-Lake Regional Planning Commission report.

Niagara Escarpment

The Niagara Escarpment is a globally important feature that provides habitat to rare species that have specialized habitat requirements. Research has shown that although natural communities associated with the Niagara Escarpment are impacted by numerous natural disturbance events, many aspects of them have essentially remained unchanged for thousands of years. The talus slope, an area of large boulders at the base of the cliff face of the Niagara Escarpment, is believed to have been formed in the immediate postglacial environment (Larson et al. 2000). This area of talus often supports lush herbaceous growth and, due in part to the lack of deer browse relative to other areas, contains the most abundant cover of shrubs and saplings. It is in these areas that birds such as Winter Wren (*Troglodytes troglodytes)* and Canada Warbler (special concern) are found. Surveys along the Niagara Escarpment in Southern Ontario discovered the oldest known forest ecosystem in eastern North America, with northern white-cedar trees up to 1032 years old growing in dolostone crevices (Larson and Kelly 1991). A northern white-cedar was aged in Peninsula State Park to be 507 years old. Kelly and Larson (1997) showed that widespread disturbance events are rare in these forests and that the current uneven-aged forest structure is in a steady-state condition. Thus, these forests offer many opportunities to study climate change on a forest that changes very little along the entire Niagara Escarpment.

Because the Niagara Escarpment provides an environment buffered from natural disturbances, unique geology and cool microclimates, it supports numerous rare species. With much of the Niagara Escarpment located on private lands, protection of this unique resource and the important habitat it supports is critical.

Rare snails

Rare terrestrial snails (terrestrial gastropods), some of which occur in few or no other locations in the world and date back to the last Ice Age, are found along the Niagara Escarpment (WDNR 2002). These snails were widespread in the Pleistocene and are now restricted in the Midwest to cool moist microhabitats found primarily along in the Niagara Escarpment and in the Driftless Area. Of the approximately 100 species of land snail in Wisconsin, almost one-third are tracked by NHI and seven are globally rare to globally imperiled (WDNR 2002). About 20% of Wisconsin's land snail fauna are imperiled to critically imperiled in the state and three species are currently protected as state endangered or threatened. Most are species of cliffs with a few instead using woodlands or wetlands. All of these rare snails are very small, with shell diameters of only a few millimeters. Rare terrestrial snails found within the DPPG are listed in Table 4.

Cave gates & gating guidance

Future gating decisions will occur on an "as-needed" basis as recommended by the Parks Dept and approved by the WDNR Bureau of Natural Heritage Conservation. Internal gates limiting access to selected sections or passages of a cave may also be considered. Potential negative effects upon wildlife or other resources that gating might entail will be reviewed by the WDNR. Gating design must constitute a synthesis of management strategy for the cave in question, biological concern and potential uses in the cave including research, and search and rescue operations.

General Considerations for Cave Inventory and Monitoring

Designing inventory and monitoring programs for cave ecosystems poses particular challenges: many cave species are rare and/or cryptic, and their distributions can be highly patchy and variable over time. Logistics of accessing sites can be complex, and observers must take unusual care to avoid damaging the ecosystems they are

tasked with monitoring. Programs aimed at monitoring microbial species are particularly problematic, as the majority of microbial species found in caves (99.99%) cannot be studied using traditional culture techniques and instead require expensive and time-consuming molecular techniques.

In addition to cave-specific considerations, a good longterm monitoring program for any habitat:

• provides useful information to conservation managers;

• can track either communities or single species;

• doesn't neglect rare species that are not protected under endangered species legislation, but also considers prioritizing common species for monitoring;

• can focus on either charismatic species or inconspicuous-but-ecologically-critical biota;

• doesn't limit itself to tracking species that may become extirpated early or do not follow general trends;

• addresses questions that have management solutions;

• tracks metrics that are of interest to the general public; and,

• creates ground-breaking, publishable ecological data.

A primary objective of this *Cave Ecology Inventory and Monitoring Framework* (Framework) is to determine variability and long-term trends in cave biota using summaries of descriptive statistics for selected parameters. Additional objectives of the Framework include helping cave managers prioritize monitoring activities and providing guidance on conducting in-cave monitoring work by promoting safe and sustainable methods. Ultimately, the primary goal of the Framework is to encourage cave managers to understand as much as possible about local cave ecology and threats to the biota supported by caves in order to make informed decisions geared towards cave conservation and protection of cave ecological systems.

Terrestrial Cave Ecosystems

A terrestrial cave ecosystem can vary widely from one cave to another, and even within a single cave. Included in this section are taxa that are likely to be encountered, including bats, woodrats, cave crickets, birds, and cave obligate invertebrates. We also consider other wildlife use of caves, detritivores and predators linked to keystone species, and listed or other special interest species.

Aquatic Cave Ecosystems

Aquatic cave ecosystems can vary considerably from one cave to the next. Some include one river that sinksinto a cave and later reemerges. Others could include multiple inputs from numerous streams and sinkholes.

Aquatic cave ecosystems are not limited to surface water. Groundwater can play a large part, with springs emerging in caves or water tables dropping to allow more access to deeper parts of the cave and then rising and restricting access.

Aquatic cave ecosystems are vulnerable to threats from sinkhole inputs up-gradient and from surface streams that can back-flood into cave streams through springs. They may also include threatened, endangered, or endemic species.

Plants

Plants are often not considered at first when thinking about monitoring cave ecology, but they can be an important part of the cave ecosystem. Vegetation near the cave entrance can influence what lives in the entrance and twilight zones. Ferns, mosses, and lichens are common within cave entrances, and the microclimate of some entrances may support rare and/or specialized plant species. In addition, the vegetation above the cave can have an impact on the cave environment via its roots, evapotranspiration, amendments to the soil, and more.

Lamp flora, or flora growing near artificial lights in the cave, often supports its own ecological communities. Since lamp flora is unnatural to the cave, eradication is usually the goal of cave managers, though short-term inventory and monitoring may be useful for quantifying impacts and determining mitigations.

Microbes

Microorganisms (microbes) are ubiquitous in caves, although their small size means they are often overlooked despite their important role in nutrient recycling, decomposition, and primary productivity.

Microorganisms include bacteria, archaea, fungi, singlecelled protozoa, and algae (although such photosynthetic species are limited to the entrance zone). Despite their small size, visible growth of bacteria can often be seen in the form of colonies, or in the case of fungi, reproductive structures (mushrooms and molds) may be seen. In some caves, the presence of microbes is displayed through geomicrobial processes that cause bedrock alteration (e.g., corrosion residue) or contribute to formation of secondary deposits (e.g., webulites, pool fingers). Routine monitoring of water quality by monitoring coliforms can indicate potential problems.

Data Management

We encourage cave managers to consider data management as an integral component of monitoring.

Development of databases and data sheets should be tightly integrated with monitoring protocols to improve the efficiency and success of the monitoring program.

This Framework is not mandating that any park or region must follow one specific data management plan.

Although it would be advantageous in many ways to have a nationwide cave ecology database, at this time neither funding nor time is available for such an endeavor. However, if all parks conducting cave ecology projects consider the recommendations herein, the potential for assembling a large nationwide database in the future, if desired, will be improved. We refer readers to the Klamath I&M Network protocols (Krejca et al. 2013) for specifics in data management with regards to a cave ecology program.

Data Analysis

Analysis of cave ecology data can be varied. Before any data are collected it is recommended that a statistician or someone with a great deal of experience with statistics be contacted. This person can help ensure that the data gathering will result in meaningful data.

Pilot data, or data gathered during a short-term or smallarea pilot testing period, can help inform whether the data being gathered are useful. It can also be used to help conduct a power analysis to determine the sample size needed to determine an effect of a given size with a specified level of confidence.

Many cave ecology projects target very rare species that are not conducive to data analysis used for surface ecology projects. This section touches on some of these considerations.

Management guidance by cave zone (ecological zone)

In attempting to understand the distribution and microhabitat use of caves, another spatial factors is even more important than spatial positioning mentioned above. The cave zones entrance, twilight, and dark are particularly important determinants of species distributions. These zones are of course aspects of a continuum in multiple dimensions, but nonetheless we define the **entrance zone** as that area which is under the dripline (the point at which vertical rain does not fall directly on the ground) of the cave, yet has sufficient light for plant growth such as mosses, ferns, and some flowering plants and in which fluctuations of light, temperature, and humidity take place on a daily basis with little moderation. As we move deeper into the cave, light levels drop off dramatically, and only a few plants, such as algae and a few mosses can survive in the dim light. This is the **twilight zone**, where temperature and humidity are often moderated somewhat by the deeper cave conditions, and energy sources begin to be more scarce. Beyond the twilight zone, there is a complete absence of light, and no flowering plants can survive beyond germinating and using up the energy already stored within the seed. Energy is very scarce here in the **dark zone**, and, typically, temperatures begin to approach the average yearly temperature of the area near the cave entrance, while relative humidity usually (especially when there is only a single entrance to the cave) become elevated and stable. Temperature, humidity, light, soil moisture, and available energy sources all vary from one zone to another, and these factors may also vary from cave to cave, depending on its configuration (for example a cold trap, or a cave with many entrances) and setting (a shallow cave beneath a parking lot may differ dramatically from a deep cave in a primary growth forest). (Taylor & Soto-Adames, Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations, 2014)

The health of any cave is always dependant on the health of the land above the cave and areas contributing to the cave drainage basin. There is a high probability of cave nutrient enrichment when fertilizers are applied to land areas within closed depressions and within drainage areas that contribute runoff to sinkholes or bedrock opentings. Land areas near channels and concentrated flow paths that deliver runoff to closed depressions, sinkholes and bedrock openings are the most critical to the quality of runoff water.

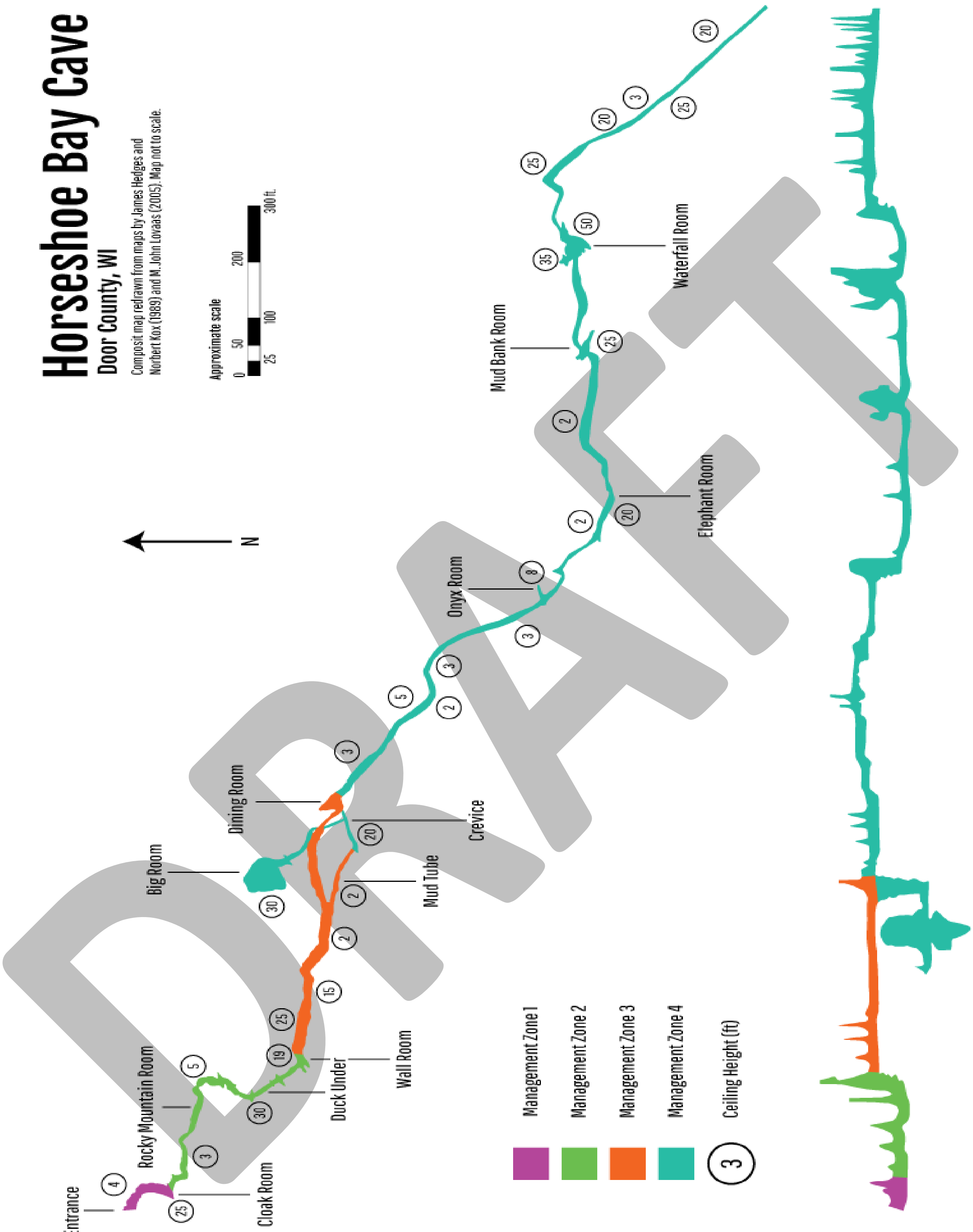


Figure 68 Management zones of HSB Cave as outlined in Management Plan for HSB Cave & WNS Prevention Plan (2014).

Ecological zones differ from access management zones (as described in the *Management Plan for HSB Cave*). Ecological zones within caves are defined by both the presence/absence of light and the fluxtuation/stability of environmental conditions. A description of HSB cave ecological zones follows:

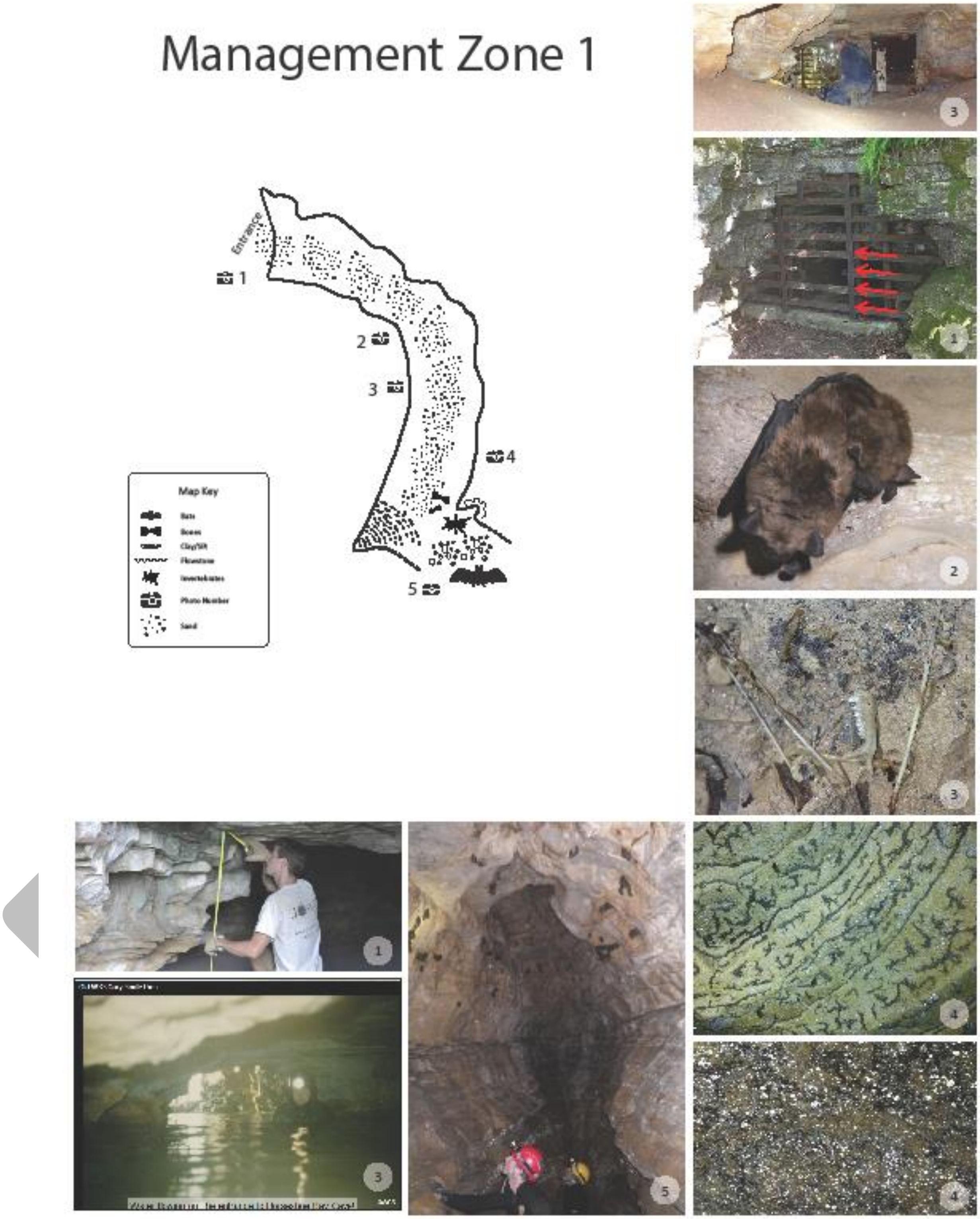
Cave entrance zone (Zone 1): The ecological entrance zone at HSB Cave includes the area of the talus slope in front of the cave as well as the dripline bedrock opening, cave gate, and narrowed passage approximately 15 feet inside where the GateKeeper & PIT tag antenna are located.

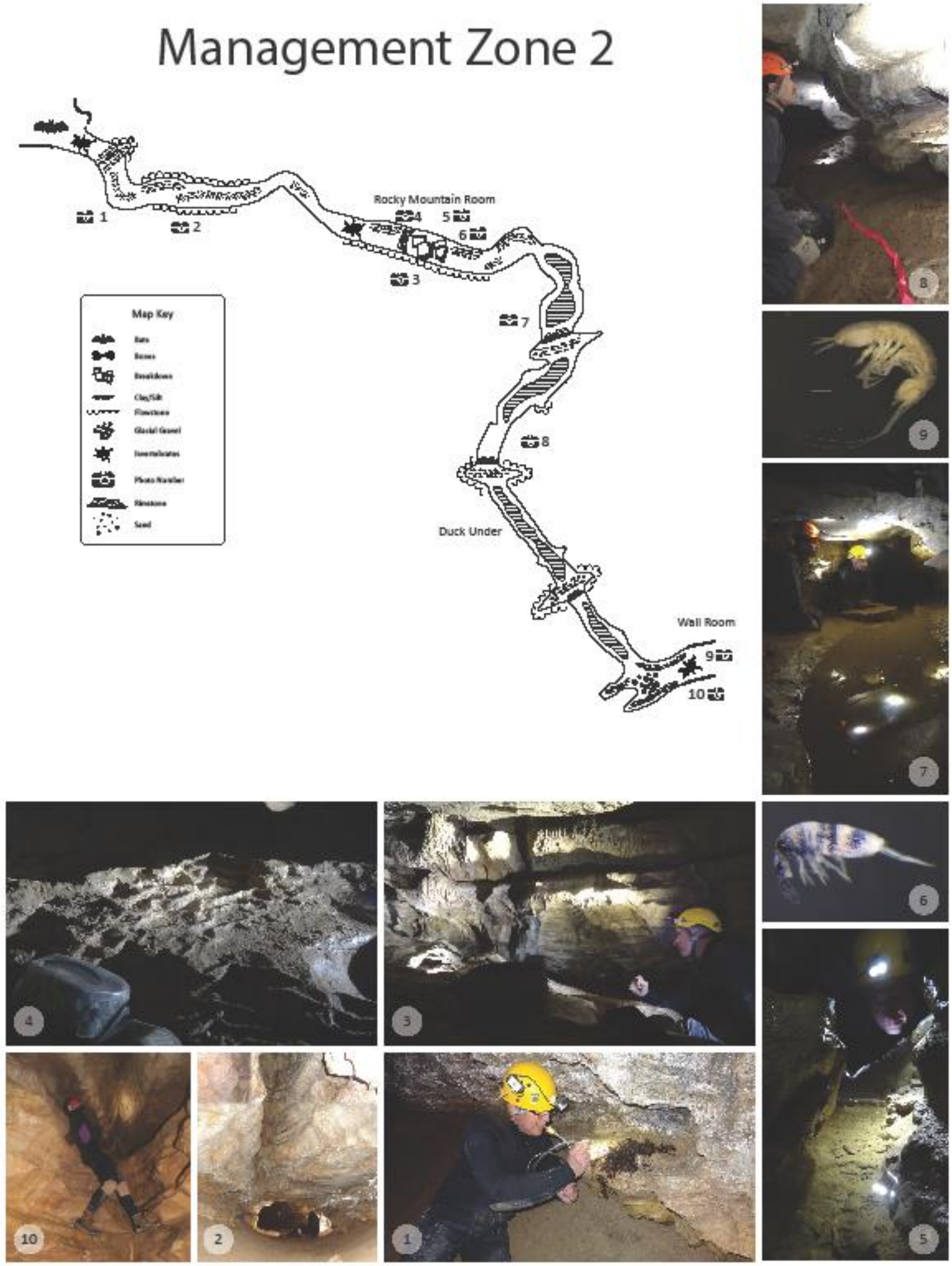
Twilight zone (Zone 1): The ecological twilight zone at HSB Cave includes the area of the GateKeeper system and PIT tag antenna, Cloak Room, and curving passage for several feet beyond the Cloak Room.

Dark zone (Zones 2-4): The ecological dark zone of HSB Cave begins several feet beyond the Cloak Room and makes up the remainder of the cave.

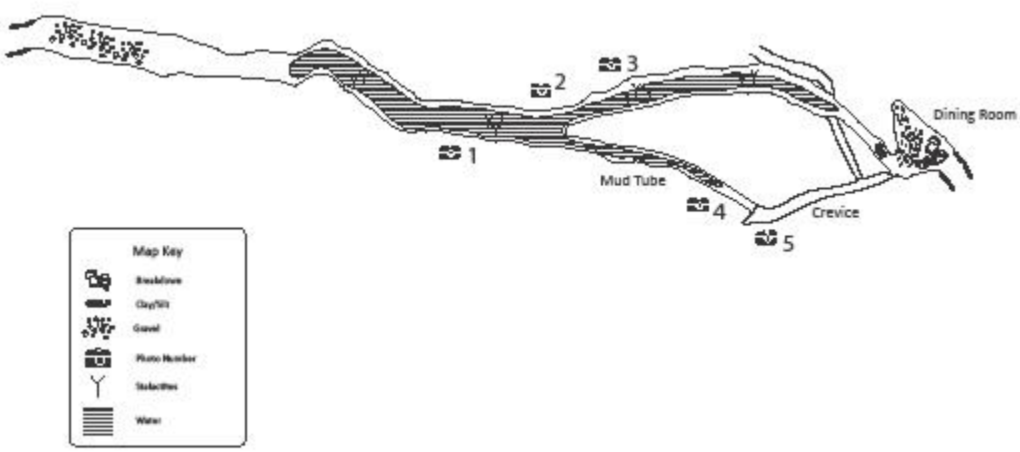
Cave drainage basin: While the drainage basin for HSB Cave is not clearly defined, due to the complex nature of karst hydrology the obvious feautres associated with HSB Cave (the cave itself, sinkholes directly above the cave, the entrance, etc.) should not be the only features considered for conservation measures. Instead, these features indicate that carbonate bedrock is near the surface, and while they may be potential direct conduits to HSB Cave, they may or may not be the primary conduit. Dozens of smaller sinkholes, conduits or features may be covered by soil and not visible. Conservation measures should be implemented on a larger scale, as part of a "Karst Landscape Unit." (adapted from (Erb & Steiglitz, 2007)

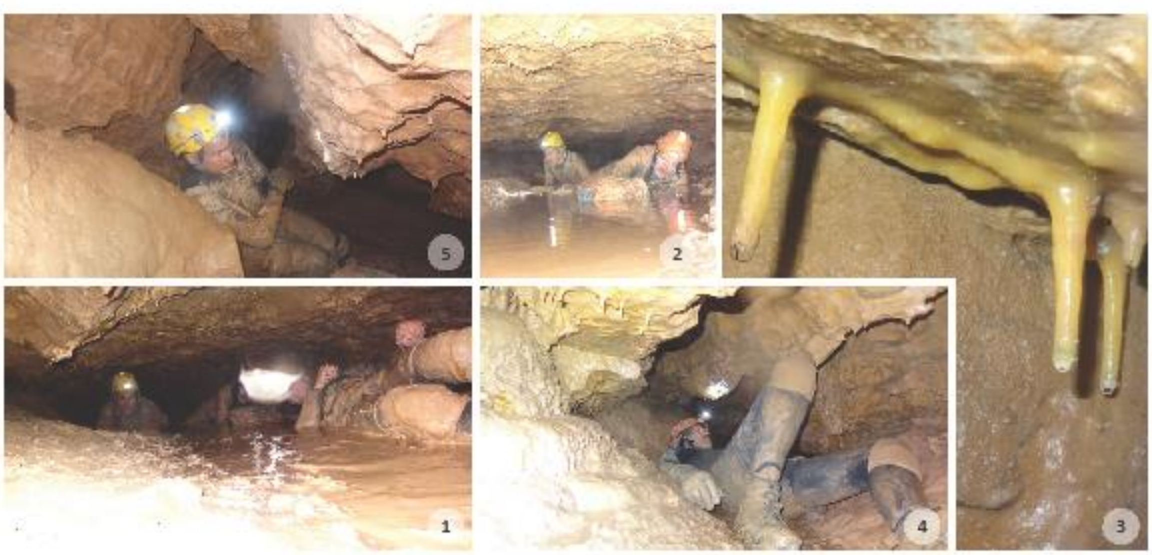
Detailed Zone Maps of HSB Cave



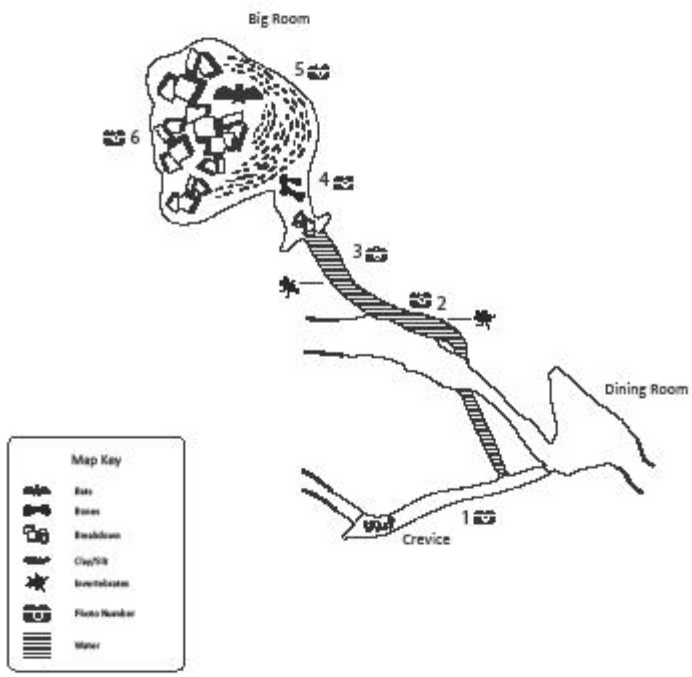

Management Zone 2
Rocky Mountain Room
Duck Under
Wall Room
1
2
3
4
5
6
7
8
9
10
Map Key
Bats
Bones
Breakdown
Clay/Silt
Flowstone
Glacial Gravel
Invertebrates
Photo Number
Rimstone
Sand

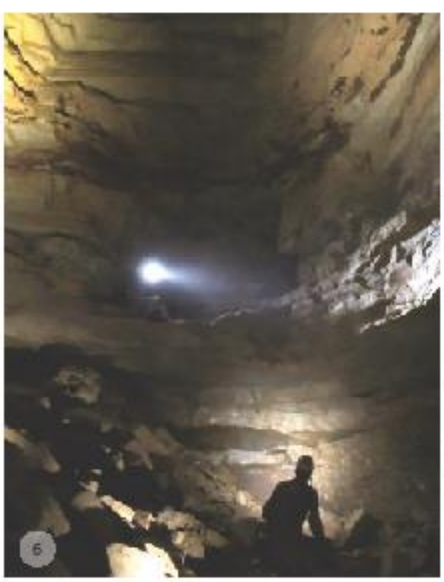
Management Zone 3





Management Zone 4a





Specific management guidance of ecological zones at HSB Cave:

Cave entrance zone: Opportunities exist here for restoration of a more natural entrance (and approach to the entrance).

1. Placement of an elevated walkway will help limit sediment compaction and helps allow invertebrates to travel without being stepped on in the event of high levels of human visitation.
2. Rocks that were apparently removed from the natural entrance (prior to cave "discovery") have been stacked along a down sloping karst channel in the bedrock on the approach to the cave entrance and could be moved into a more natural configuration similar to the tumbled rock of the original talus slope, while still allowing for a designated trail leading to the entrance.
3. Forest management including removal of invasive vegetation and restoration of a native floral community. Maintaining a natural woody edge habitat extending as far as possible from the cave entrance parallel to the escarpment could be critical in helping bats locate the cave entrance during the fall swarm period (migration & mating).
4. Leave large diameter snags standing to allow for summer roosting opportunities for both cave and tree bat species.
5. Maintain forest edges for use by bats in foraging and migration. Maintain the connectivity of edge habitat on a landscape level Figure 69-51

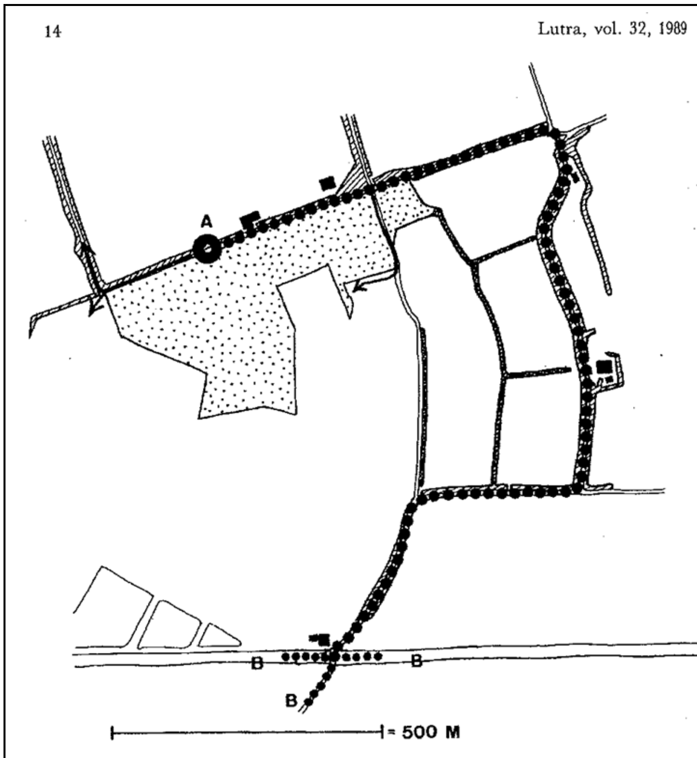


Figure 69 Black dots illustrate the travel route of a bat commute across the landscape utilizing hedgerows and treelines. (Lutra, 1989)

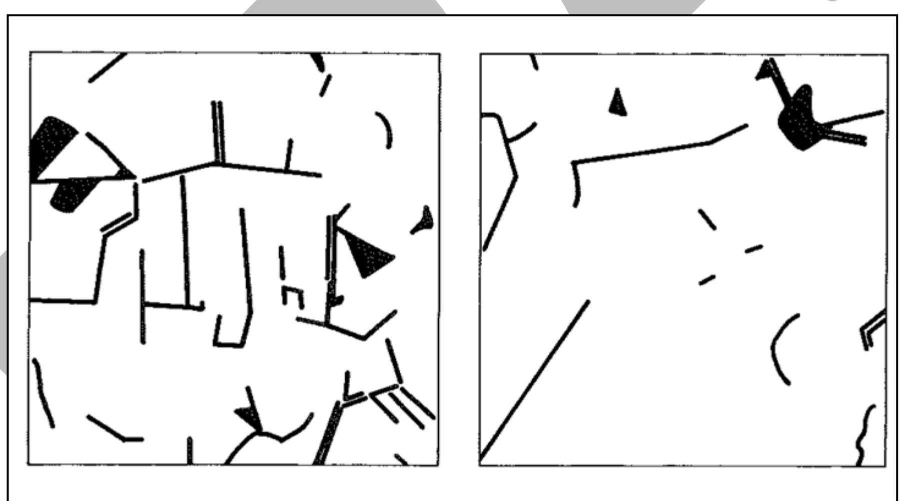
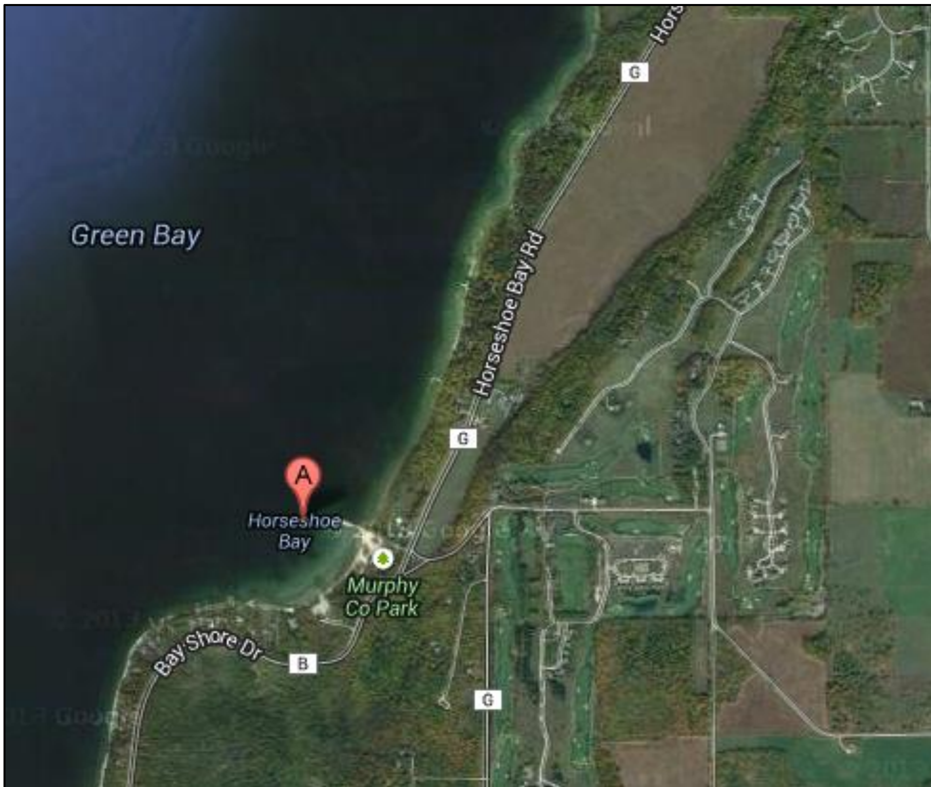


Figure 70 Diagrams of tree lanes, hedgerows and woodlots in two of the 1x1 km squares studied, illustrating the variation in density and degree of fragmentation of linear landscape elements in the study area. (Use of edge habitats by commuting and foraging bats)

Figure 71 An example of the Niagara Escarpment exposure at Neda Mine. Note how the rocky ledge has not been cultivated, creating a treeline across the landscape.


Green Bay
Horseshoe Bay Rd
Horseshoe Bay
Murphy Co Park
Bay Shore Dr
G
B

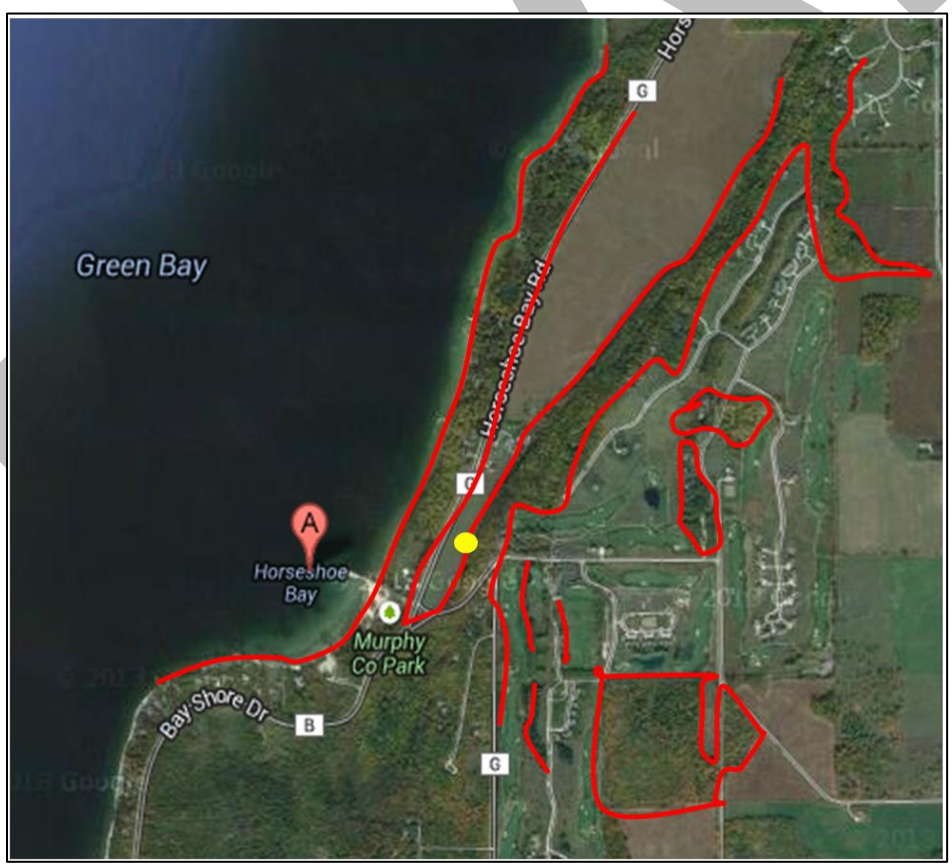

Green Bay
Horseshoe Bay Rd
Horseshoe Bay
Murphy Co Park
Bay Shore Dr
G
B

Figure series 72 Bats may use the shoreline of the Great Lakes to migrate long distances (fall and spring migration), however local treelines (like the one present along the field at Murphy County Park) may help bats find the cave entrance (yellow dot) and provide wind-buffered habitat for insect activity during nightly foraging.

Cave twilight zone: Opportunities exist here to protect what is left of the natural integrity of cave fill (sediment) and microclimte. Opportunities also exist to ensure the natural high diversity of this cave area is maintained or even restored to a more natural balance.

1. Placement of an elevated walkway will help limit sediment compaction and helps allow invertebrates to travel without being stepped on in the event of high levels of human visitation.
2. Leaves, sticks, animal waste, and other natural nutrient sources should be left in situ when washed, blown, or deposited by animals in this area of the cave. These microhabitats provide nutrient sources for both microbes and invertebrates and protective habitat for invertebrates.
3. Temperature and humidity data loggers may be used to help determine the effects of cave human use on the microclimate of the twilight zone. Light loggers can be used in

the cloak room to help ensure that accurate records of human visitation are kept to compare to temperature & humidity records.

4. It is anticipated that this area of the cave will receive the highest number of human visitors. Rules should be established and appropriate clean-up acitivties should occur relating to these group visits. Visitors should not touch cave ceilings or walls as the residual oils from skin can inhibit the deposition of calcite and encourage the growth of non-native biofilms. Additionally, touching cave walls may discolor them, muddy them, may remove clay vermiculations and native biofilms and/or other microbial colonies, and may eventually lead to erosional marks. Visitors should not be allowed to chew gum, spit, or eat food or beverages (other than water) inside the cave. Gum, candy, spilled drinks, and food wrappers are all considerable nutrient input and will quickly grow mold in the cave environment.
5. Electric lights should not be placed in the cave in any area as these create algal blooms on rocks and sediment, leading to discoloration, nutrient input, and decomposition of rock or formations. Additional heat contributed by light bulbs may alter the microclimate of the cave. If there is a future need for permanent cave lighting careful planning should take into consideration findings by the National Parks regarding cave-friendly lighting.

Cave dark zone: Opportunities exist here to protect what is left of the natural integrity of cave fill (sediment) and microclimte. Opportunities also exist to ensure the natural diversity of this cave area is maintained or even restored to a more natural balance.

1. Temperature and humidity data loggers may be used to help determine the effects of cave human use on the microclimate of the twilight zone. Light loggers can be used in the cloak room to help ensure that accurate records of human visitation are kept to compare to temperature & humidity records.
2. It is anticipated that this area of the cave will receive the lowest number of human visitors. Rules should be established and appropriate clean-up acitivties should occur relating to occasional group visits. While some touch of walls and ceiling is unavoildable while travelling in this area, visitors should exercise caution when doing so as fragile soda-straw stalactites and other secondary calcite formations exisit in these areas. Additionally, visitors are covered in mud that ends up coating everything they touch, obscuring the naturally clean appearance of the bedrock. Once in place the mud is nearly impossible to remove given the remote location of these areas and difficulty in transporting cleaning equipment to these areas. Additionally, touching cave walls may discolor them, muddy them, may remove clay vermiculations and native biofilms and/or other microbial colonies, and may eventually lead to erosional marks. Visitors should exercise caution when eating in this part of the cave and attempt to contain crumbs and

spills for removal from the cave. Gum, candy, spilled drinks, and food wrappers are all considerable nutrient input and will quickly grow mold in the cave environment while contributing nutrients to an otherwise starved cave ecosystem.

3. Electric lights should not be placed in the cave in any area as these create algal blooms on rocks and sediment, leading to discoloration, nutrient input, and decomposition of rock or formations. Additional heat contributed by light bulbs may alter the microclimate of the cave.

Cave drainage basin: Opportunities exist here to protect both cave climate, natural hydrological activity, and water quality. Opportunities also exist to ensure the natural diversity of this cave area is maintained or even restored to a more natural balance.

1. Map sensitive features above/near cave.
2. Establish and maintain a permanent vegetative buffer around these features that is at least 100 feet wide.
3. No diverting or directing surface runoff or concentrated flow of liquid fertilizers into these features and no dumping of waste materials or fertilizers into these features.
4. No applications of wastes or fertilizers within 100 feet of sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions. No applications within 100 feet of delivery systems to sinkholes, etc. (Delivery systems include channels and flow paths.)
5. Adjust fertilizer application rates to vegetation requirements, soil tests, exisiting soil conditions, and when possible, to weather forecasts. Avoid applications when conditions pose the greatest risk.
6. Avoid fertilizer application on areas with shallow bedrock and identified features.
7. Facility should have a spill response plan for fertilizer and waste storage, transport, and applications.
8. Staff could be trained on karst topography, spill response, and field identification of sensitive featrues.

Management guidance by cave feature

Bedrock walls & features: do not touch, mud transfer

Speleothems: caution and slow movement, flagging, do not touch

Sediment/clastic fill: present almost everywhere in the cave; glacial gravels should be flagged and avoided

Isolated standing pools: avoid touching, creating runoff or contamination (locations include Rocky Mountain Room, Big Room, etc.)

Large water-filled passages/running water: Mississippi River Section

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CHAPTER 5: RECOMMENDATIONS FOR FUTHER STUDY

While the inventory of the study area examined many sites and many elements, there is need to conduct additional work.

1. **Cave hydrologic activity monitoring.** Document and better understand the changing flow rates in Horseshoe Bay Cave. Observations of past flooding, resurgence, and resulting bat mortality are crucial to protecting these threatened species at HSB Cave. Use loggers to record water depth/flood events/water temperature throughout the cave throughout the year.
2. **Environmental monitoring.** Use loggers to record temp/humidity/velocity/direction of air throughout the cave. Results can be correlated with water temperature data.
3. **Geological & paleontological studies.** Radiometric dating of bat and other bones in the cave and sediment analysis may help create a timeline for bat and other faunal use of HSB Cave.
4. **Archaeological sampling.** Excavations should by a qualified archaeologist in consultation with other specialists who might also benefit from recovered data. Profiles should be photographed and mapped for permanent record.
5. **Historical documentation.** Systematic recoding of the extant historic names and dates in the cave. This effort should consist of accurate mapping of the location of the glyphs and digital photo documentation. The location of the graffiti can be added to extant maps of the cave with more precise maps developed as needed for specific rooms where complex graffiti is present.
6. **Additional aquatic surveys.** Additional aquatic sites and cave micro-habitats should be sampled in HSB cave and surrounding area to further understanding of the ecology and distribution of rare species and natural communities in the Door Peninsula.
7. **Bat roosts and hibernacula.** Continue to study the use of the cave by bats and movement of bats between HSB Cave, summer roosts, and other hibernacula.
8. **Map/remap/geologic inventory**. A modern, detailed, complete digital map of the cave, allowing addition of multiple data layers in support of management and, perhaps, interpretation, is necessary to most effectively manage Horseshoe Bay Cave. This should be fully documented with an archive including scanned field notes and full survey data.
9. **Surface alignment.** Align the cave map with surface karst features and landowners. Determining the location of cave passages relative to above ground features should take

place. This is best achieved using a cave radio approach. At present, any cave overlay on an area map is only a best guess, as multiple sources of error are possible. This management action has profound impacts on resource manager understanding of the location and extent of the cave.

10. **Drainage basin.** Determining the groundwater drainage basin of the cave is an important, but expensive, management action that should take place. One of the greatest impacts on the cave ecosystem is the quality, quantity, and periodicity of the water entering the cave. These parameters, especially (but not exclusively) the water quality, can best be managed by influencing land use practices within the hydrological drainage basin of the cave. It would be necessary to employ a specialist – experienced in conducting dye traces in karst settings – to appropriately complete this management action.
    a. Once the hydrological drainage basin of the cave is established, conduct sinkhole cleanups to remove any hazards (chemicals, metals, plastics, etc.) that might be having a negative influence on the cave ecosystem. Note that these should not conducted as digs, attempting to create unnatural cave entrances.
    b. Once the hydrological drainage basin of the cave is established, we recommend a complete inventory of features (including georeferencing of all sinkholes and other karst features) and potential threats to the cave ecosystem from above ground land use practices within the drainage basin. This inventory, likely including a GIS component, should carefully, objectively, thoroughly and honestly consider hazardous chemicals, application of fertilizers, herbicides and pesticides, septic waste, agricultural practices, etc. This work should involve input from an expert in karst landscape impacts. Findings from this action may result additional management actions.
11. **Vegetation sampling.** More detailed characterization of Escarpment-associated bedrock communities is needed to better understand the structure, composition, and function of the vegetation. In addition to vascular plants, lichens and mosses will be important groups to study.

Cave research

Valid scientific research is important in furthering our understanding of the cave and should be encouraged at HSB Cave but should be the result of the scientific process, which is implemented by means of a research plan. Research plans proposed at HSB Cave should be carefully reviewed by knowledgable resource experts prior to granting permission (see HSB

Cave Management Plan for details about the research proposal process). Current research proposal requirements are outlined in the Management Plan for HSB Cave.

A sound research plan promotes unbiased, repeatable results; it includes background information on the topic and describes whether any of the identified hypotheses have already been successfully tested, clearly noting whatever critical information is lacking. A research plan or final research report should include the following elements:

1. A clear statement of objectives
2. A conceptual model, which is a framework for characterizing systems, stating assumptions, making predictions, and testing hypotheses
3. A good observational or experimental study design and a standardized method for collecting data
4. Reliable, consistent and secure data and metadata storage
5. Statistical rigor and sound logic for analysis and interpretation
6. Clear documentation of methods, results, and conclusions6
7. Peer Review

CHAPTER 6: COMMUNICATION, EDUCATION & INTERPRETATION

While it is very important to obtain high quality information about cave resources, it is equally important to communicate the results to land managers and landowners, and visitors. Caves are sensitive, potentially variable features, which are challenging to understand and assess. They are important County and State resources and of significance in their own right. Caves could also present an extreme hazard to inexperienced or unskilled visitors who attempt to visit them. Cave conservation is a management challenge that requires a conservative, judicious approach to the dissemination of information, an active approach to research, information gathering and data collection, and sensitivity on the part of cave managers to the special features of caves which may be easily and irreparably damaged, and which may present potential dangers to uninformed members of the public.

All partners involved in the use of HSB Cave (including the cave system itself) benefit when a larger portion of the target audience understands the role of caves and karst. Presentations, tours, pamphlets, interpretive signs, websites, news stories (including photographs + diagrams of the subterranean "plumbing"), public meetings and, especially, face-to-face discussions are all avenues of effective communication about the cave.

Communication: It is hoped that the cave inventory results will be shared and discussed by landowners, land managers, agency personnel, local conservation groups, law enforcement/emergency personnel and tourists/visitors. Any mention of Horseshoe Bay Cave should include a message regarding cave preservation & protection. Interested parties seeking information on caves should be given assistance and information based upon the purpose of their inquiry and the management criteria pertinent to their area of interest.

Sensitive information: HSB Cave is part of Wisconsin's Natural Heritage Inventory (NHI) database. Data about endangered or threatened species are sensitive because many rare species are vulnerable to collection, disturbance and/or destruction. Sharing NHI data with the public may threaten the continued existence of these species. NHI data are exempt from the Wisconsin Open Records Law and WDNR staff may not share specific information with external individuals or organizations. Caution should be used when sharing information specific to the use and timing of HSB Cave as a bat hibernation site (for example, spring emergence and fall swarm dates should not be shared or advertised unless staff will be on hand at the event to provide guidance for the public about how to watch without disturbing bats).

Interpretation:
Effective EE:

- Place based
- Provide an authentic experience in the field
- Include analysis of a current environmental issue
- Build in 1me for reflection
- Have measurable outcomes

NPS defines interpreta1on as "a catalyst in creatng an opportunity for the audience to form their own intellectual and emotional connections with the meanings and significance inherent in the resource (National Park Service, 2001).

Accepted interpretive principles hold
• Skill of presenter has great impact on audience
• Audience behavior change is more likely when desired behavior was made explicit
• People do not necessarily seek out information for information's sake
• Information---laden, formal styles are not par1cularly successful

Visitors to the cave area (entrance only, interior, and surface landscape) should be made aware of the geology and ecology of the site and its critical importance as a Priority 1 Bat Hibernaculum. Staff managing areas of special ecological significance and sensitivity on state, county, or local public lands will have special use for this information. Resources for cave and karst interpretation/education/outreach are readily available from various sources (De Waele 2010). Most conveniently available among these is the excellent booklet "Living on Karst" (Zokaites 1997). WDNR has developed a number of educational and informational materials related to bats and WNS, and some specifically targeted at cave visitors. Bat Conservation

International has, and is continuing, to develop educational materials for teaching about bats conservation.

2) Interpretative Staff

The Interpretative staff works with the Physical Science staff to ensure a high level of visitor understanding and satisfaction for cave and karst resources in the park is achieved while minimizing impacts from tour operations. The Chief of Interpretation will ensure that interpretive activities on the surface and in the cave are compatible with polices and goals of this plan. Tools, materials, and supplies used in interpretative programs

Partnerships: A dialogue between County cave managers and Natural Heritage Inventory staff should continue to be an important outcome of this project. Cave science advisory group members and similar resource experts will continue to be important to cave management efforts.

Landowner stewardship: An attempt should be made to work with private landowners to inform them of the ecological significance of their properties and how to effectively manage them. Alternatives, such as conservation easements or tax law incentives, should be presented to landowners to enroll their land in some sort protection status.

Less active public participation/More active public participation:

GLOSSARY

cuesta - is a ridge formed by gently tilted sedimentary rock strata in which the strata are tilted in the same direction. Cuestas have a steep slope, where the rock layers are exposed on their edges, called an escarpment or, if more steep, a cliff.
dolostone – the rock equivalent of the mineral dolomite
Ecological Landscape - landscape units developed by the WDNR to provide an ecological framework to support natural resource management decisions. The boundaries of Wisconsin's sixteen Ecological Landscapes correspond to ecoregional boundaries from the National Hierarchical Framework of Ecological Units, but sometimes combine subsections to produce a more manageable number of units.
element occurrence - an Element Occurrence (EO) is an area of land and/or water in which a rare species or natural community is, or was, present. An EO should have practical conservation value for the Element as evidenced by potential continued (or historic) presence and/or regular recurrence at a given location. For species, the EO often corresponds with the local population, but when appropriate may be a portion of a population (e.g., a single nest territory or long distance dispersers) or a group of nearby

populations (e.g., metapopulation). For communities, the EO may represent a stand or patch of a natural community or a cluster of stands or patches of a natural community. Because they are defined on the basis of biological information, EOs may cross jurisdictional boundaries.

Ecological Trap (ET): A hibernaculum having a history of repeated flooding or severe freezing events that have resulted in the mortality of most hibernating *bats*. Hibernacula with other environmental conditions that pose a severe and/or imminent threat to the majority of hibernating bats may also be designated as "ecological traps"

escarpment - a transition zone between different physiogeographic provinces that involves a sharp, steep elevation differential, characterized by a cliff or steep slope. Most commonly, an escarpment is a transition from one series of sedimentary rocks to another series of a different age and composition. When sedimentary beds are tilted and exposed to the surface, erosion and weathering may occur differentially based on the composition. Less resistant rocks will erode faster, retreating until the point they are overlain by more resistant rock. When the dip of the bedding is gentle, a cuesta is formed. Steeper dips (greater than 30-40°) form hogbacks.

mapping precision – the locational accuracy to which an element occurrence is known.

natural community – an assemblage of plants and animals, in a particular place at a particular time, interacting with one another, the abiotic environment around them, and subject to primarily natural disturbance regimes. Those assemblages that are repeated across a landscape in an observable pattern constitute a community type. No two assemblages, however, are exactly alike.

Niagara Escarpment – commonly known as "the Ledge" in Wisconsin is a sickle-shaped ridge with a steep face on one side (an escarpment) and a gentle slope on the other (a cuesta) that begins in south-central Wisconsin, arches east through Michigan and southern Ontario and ends in western New York State.

representative - native plant species that would be expected to occur in native plant communities influenced primarily by natural disturbance regimes in a given landscape - e.g., see Curtis (1959).

SGCN (or "Species of Greatest Conservation Need") – native wildlife species with low or declining populations that are most at risk of no longer being a viable part of Wisconsin's fauna (from the "Wisconsin Wildlife Action Plan," WDNR 2006b).

talus - or scree, is loose rock created by physical weathering that typically lies on steep mountainsides or the base of cliffs.

element - the basic building blocks of the Natural Heritage Inventory. They include natural communities, rare plants, rare animals, and other selected features such as colonial bird rookeries, bat hibernacula, and mussel beds. In short, an element is any biological or ecological entity upon which we wish to gather information for conservation purposes.

element occurrence - an Element Occurrence (EO) is an area of land and/or water in which a rare species or natural community is, or was, present. An EO should have practical conservation value for the

Element as evidenced by potential continued (or historic) presence and/or regular recurrence at a given location. For species, the EO often corresponds with the local population, but when appropriate may be a portion of a population (e.g., a single nest territory or long distance dispersers) or a group of nearby populations (e.g., metapopulation). For communities, the EO may represent a stand or patch of a natural community or a cluster of stands or patches of a natural community. Because they are defined on the basis of biological information, EOs may cross jurisdictional boundaries.

endemic - native to or confined to a certain region.

graminoid – a grass or grass-like plant, including grasses (Poaceae), sedges (Cyperaceae), rushes

(Juncaceae), arrow-grasses (Juncaginaceae), and quillworts (Isoetes).

Karst topography - a landscape that is characterized by numerous caves, sinkholes, fissures, and underground streams. Karst topography usually forms in regions of plentiful rainfall where bedrock consists of carbonate-rich rock, such as limestone, gypsum, or dolomite, that is easily dissolved.

Landtype Association (LTA) - a level in the National Hierarchical Framework of Ecological Units (see next entry) representing an area of 10,000 – 300,000 acres. Similarities of landform, soil, and vegetation are the key factors in delineating LTAs. **loess** - windblown deposit of fine-grained, calcareous silt or clay.

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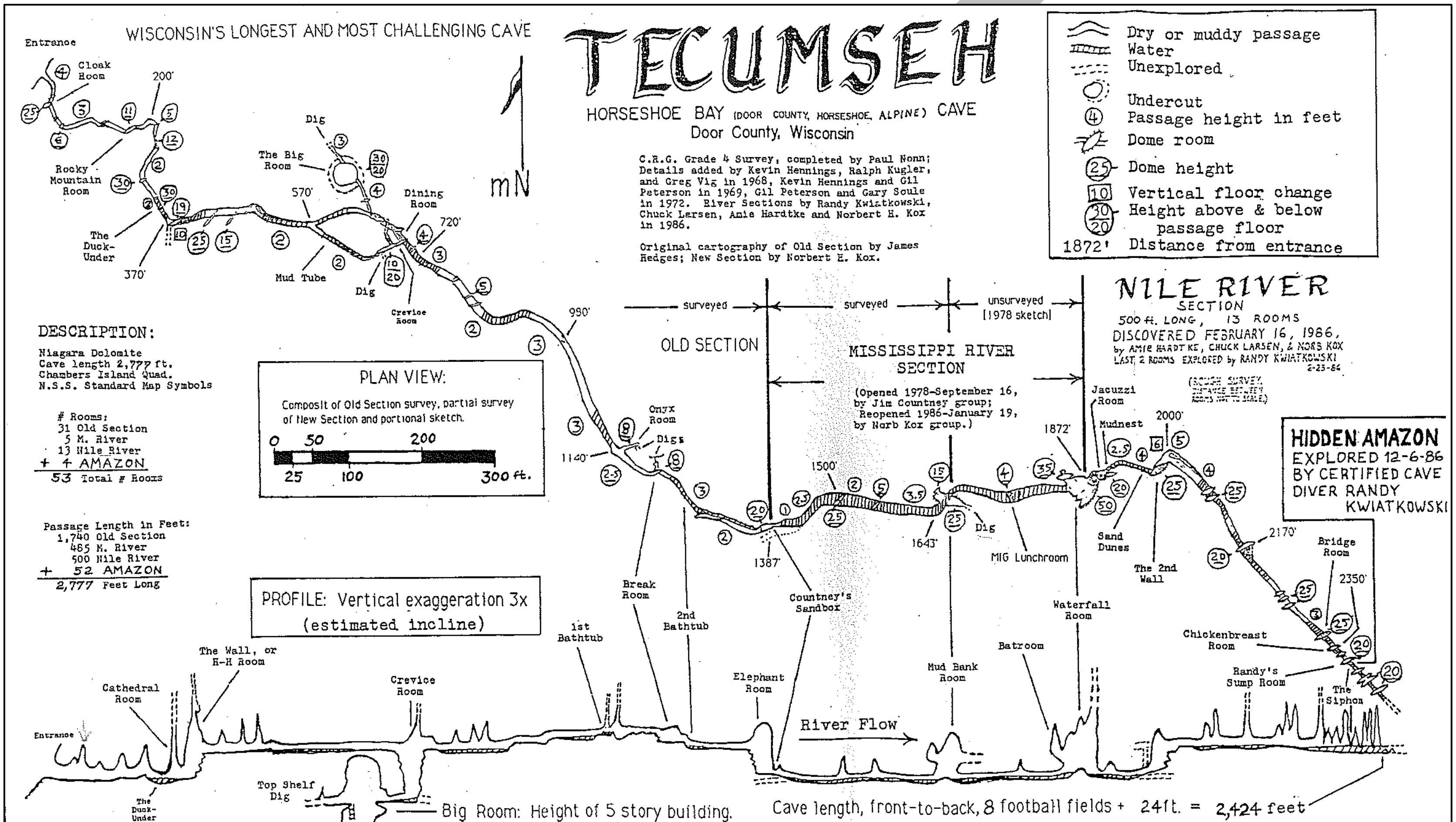
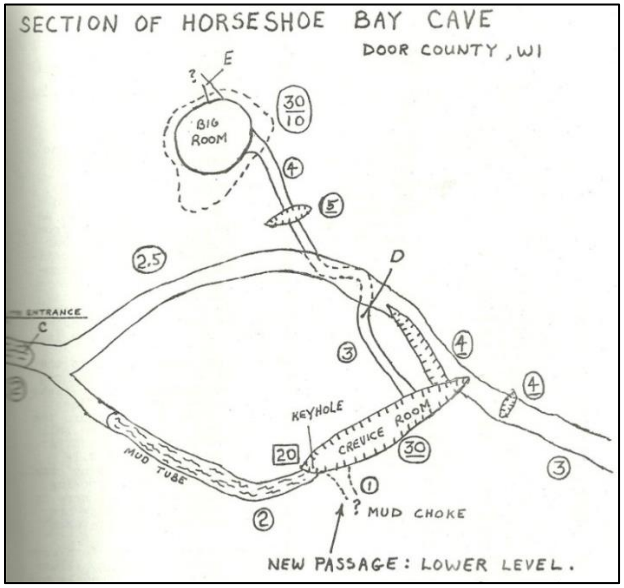
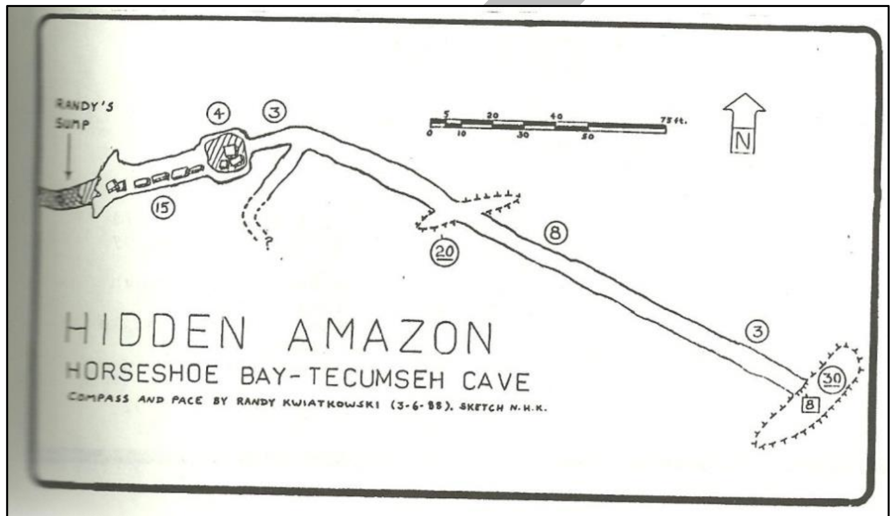
. Lyons et. All (see WI climate change)

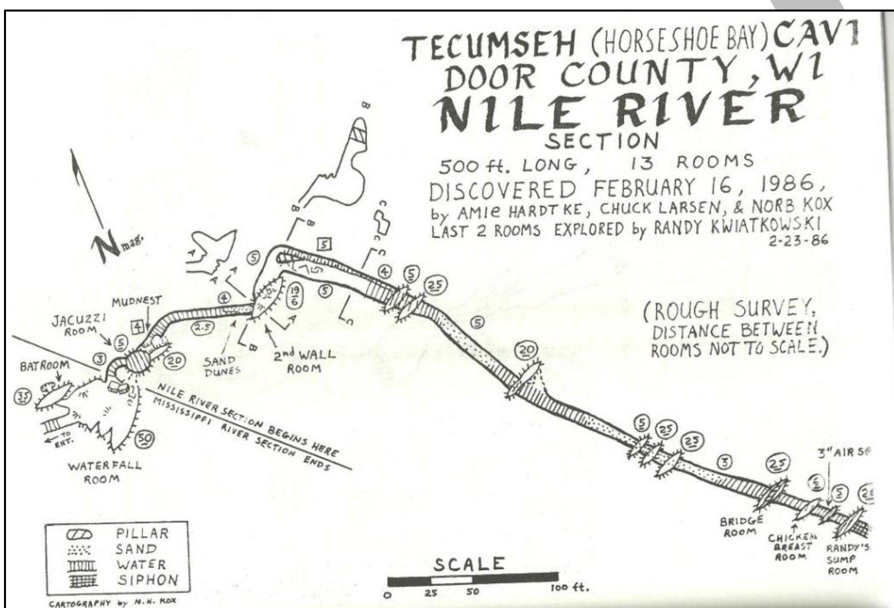
APPENDICES

Appendix A. Maps (Kox, A General History of Horseshoe Bay Cave (Tecumseh Cave), 1990)



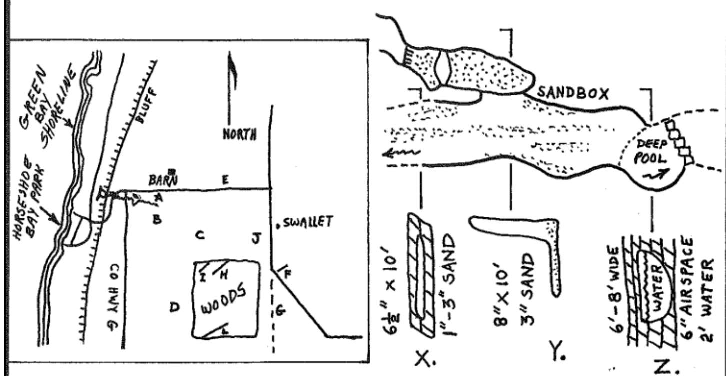

SECTION OF HORSESHOE BAY CAVE
DOOR COUNTY, WI
BIG ROOM
ENTRANCE
KEYHOLE
CREVICE ROOM
MUD TUBE
MUD CHOKE
NEW PASSAGE: LOWER LEVEL.


RANDY'S SUMP
HIDDEN AMAZON
HORSESHOE BAY-TECUMSEH CAVE
COMPASS AND PACE BY RANDY KWIATKOWSKI (3-6-88). SKETCH N.H.K.


TECUMSEH (HORSESHOE BAY) CAVE
DOOR COUNTY, WI
NILE RIVER
SECTION
500 ft. LONG, 13 ROOMS
DISCOVERED FEBRUARY 16, 1986,
by AMIE HARDTKE, CHUCK LARSEN, & NORB KOX
LAST 2 ROOMS EXPLORED by RANDY KWIATKOWSKI
2-23-86
(ROUGH SURVEY, DISTANCE BETWEEN ROOMS NOT TO SCALE.)
JACUZZI ROOM
MUDNEST
BATROOM
SAND DUNES
2nd WALL ROOM
WATERFALL ROOM
NILE RIVER SECTION BEGINS HERE
MISSISSIPPI RIVER SECTION ENDS
BRIDGE ROOM
CHICKEN BREAST ROOM
RANDY'S SUMP ROOM
PILLAR
SAND
WATER
SIPHON
SCALE
CARTOGRAPHY by N.N. KOX

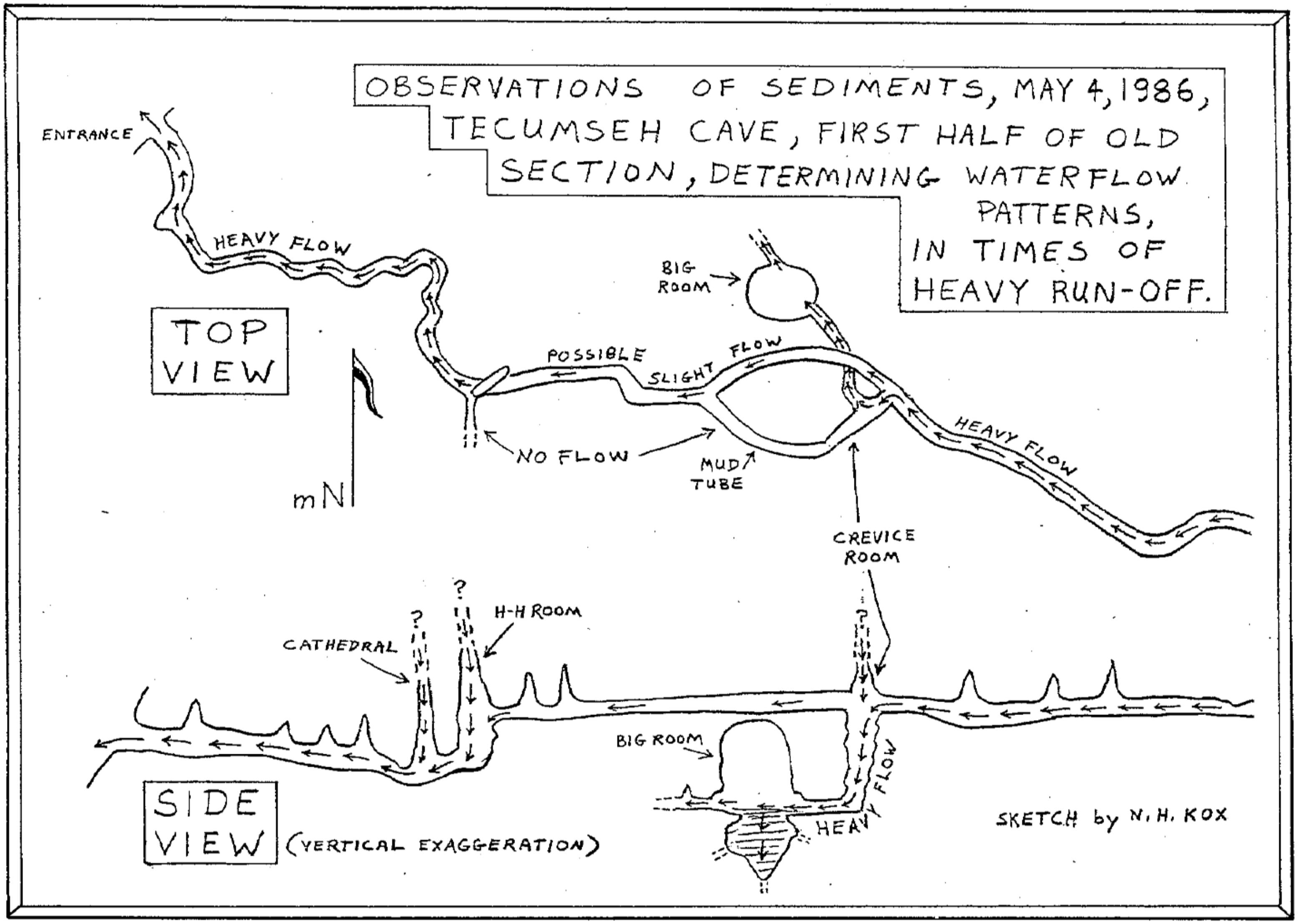
SURFACE FEATURES
NEAR HORSESHOE BAY CAVE
DOOR COUNTY, WISCONSIN
&
COUNTNEY'S SANDBOX

Memory Sketch By Jim Countney



LEGEND

H,I,F,L: Crevices in bedrock. L & F are closed. H & I open intermittently to a depth of 6 feet.
A,B,C,D,E: Closed sinks.
G: Open sink, 4 feet deep.
J: Brush pile. Possible filled sink.
~: Horseshoe Bay Cave, Roughly aligned.
Z: My point of furthest penetration, when I went into cold shock trying to cross the pool. Weak flow, as shown by arrow at Z. (1978 & 1979).
Y: Point where Bob Drysdale, Jim Johnson and I dug through from the terminal room on many occasions. Ponded or barely flowing water--1 inch deep, with sand arranged in sandbars, which sometimes filled the passage to the ceiling in places. On two trips, sand was sorted into layers of 2 distinct grain sizes.
X: Open, but too tight in 1977. Blocked by sand in 1979. Weak water flow in 1977, as shown by flow arrow at X.


OBSERVATIONS OF SEDIMENTS, MAY 4, 1986, TECUMSEH CAVE, FIRST HALF OF OLD SECTION, DETERMINING WATERFLOW PATTERNS, IN TIMES OF HEAVY RUN-OFF.
ENTRANCE
HEAVY FLOW
TOP VIEW
BIG ROOM
POSSIBLE SLIGHT FLOW
NO FLOW
MUD TUBE
HEAVY FLOW
mN
CREVICE ROOM
CATHEDRAL
H-H ROOM
BIG ROOM
HEAVY FLOW
SIDE VIEW
(VERTICAL EXAGGERATION)
SKETCH by N. H. KOX

Appendix B. Natural Heritage Inventory Overview

General Methodology

This biotic inventory and analysis was conducted by the Wisconsin Natural Heritage Inventory (NHI) program. The Wisconsin NHI program is part of the Wisconsin DNR's Bureau of Endangered Resources and a member of an international network of Natural Heritage programs representing all 50 states, as well as portions of Canada, Latin America, and the Caribbean. These programs share standardized methods for collecting, processing, and managing data for rare species, natural communities, and certain other natural features (e.g., bird rookeries). NatureServe, an international non-profit organization, coordinates the network. This appendix provides a general overview of the methodology we use for these projects.

Please see the NatureServe Web site for more detailed information about standard methods used by the Heritage Network (*www.NatureServe.org*) for locating, documenting, and ranking rare species and natural community occurrences.

General Process Used when Conducting Biotic Inventories for Master Planning

The Wisconsin NHI Program typically uses a "coarse filter-fine filter" approach to conducting biotic inventory projects for master planning. This approach begins with a broad assessment of the natural communities and aquatic features present, along with their relative quality and condition. The area's landforms, soils, topography, hydrology, current land uses, and the surrounding matrix are also evaluated using Geographic Information Systems (GIS) and other electronic and hardcopy data sources. Data that describe conditions for the area prior to Euro-American settlement are often used during this step and at other times to further understand the ecological capabilities of the area. Often, we consult with local managers, biologists, or others familiar with the ecology of the area when preparing for an inventory project. The goals for this step are to identify the important ecological attributes and biological processes present, as well as to focus our inventory efforts.

The level of survey intensity varies based on the size and ecological complexity of the property or group of properties, as well as the resources available. For larger properties such as state forests, biotic inventory efforts typically take more than one year. Ideally, taxa surveys are conducted following a coarse-filter analysis that sometimes include extensive natural community surveys. There is often time for "mop-up work" during the year following the completion of the main survey effort, whereby additional surveys are conducted for areas that could not be reached the first year or for which new information has become available. For smaller properties, a "Rapid Ecological Assessment" often takes the place of a full-scale biotic inventory. The level of effort for these projects varies based on the needs of the study area, although surveys are almost always completed during one field season. Coarse filter work for rapid assessments is often done based on GIS data, aerial photos, data acquired from previous efforts, and information from property managers and others knowledgeable about the area.

Taxa-specific surveys can be costly and intensive and sometimes must be completed during a very narrow period of time. For example, bird surveys must be completed within an approximately one-month time window. For this and several other reasons, ***our surveys cannot locate every rare species***

occurrence within a given area. Therefore, it is important to use resources as efficiently as possible, making every effort to identify the major habitats present in the study area from the start. This approach concentrates inventory efforts on those sites most likely to contain target species to maximize efficient use of resources. Communication among biologists during the field season can help identify new areas of interest or additional priorities for surveys. The goal is to locate species populations with the highest conservation value whenever possible.

After all of the data are collected, occurrences of rare species, high-quality natural communities, and certain other features are documented, synthesized, and incorporated into the NHI Database. The NHI program refers to this process as “mapping” the data and uses a tabular and spatial database application designed specifically for the Heritage Network. Other secondary databases are also used by the

Wisconsin NHI Program for storing additional species and community information such as species lists, GPS waypoints, photos, and other site documentation.

Once the data mapping and syntheses are completed, the NHI Program evaluates data from the various department biologists, contractors, and other surveyors. This information is examined along with many other sources of spatial and tabular information including topographic maps, various types of aerial photography, digital soil and wetland maps, hydrological data, forest reconnaissance data, and land cover data. Typically, GPS waypoints and other spatial information from the various surveys are superimposed onto these maps for evaluation by NHI biologists.

In addition to locating important rare species populations and high-quality natural community occurrences, the major products culminating from all of this work are the “Primary Sites.” These areas contain relatively undisturbed, high-quality, natural communities; provide important habitat for rare species; offer opportunities for restoration; could provide important ecological connections; or some combination of the above factors. The sites are meant to highlight, based on our evaluation, the best areas for conserving biological diversity for the study area. They often include important rare species populations, High Conservation Value Forests, or other ecologically important areas.

The final report describes the Primary Sites, as well as rare or otherwise notable species, and other ecological opportunities for conserving or enhancing the biological diversity of the study area. The report is intended for use by department master planning teams and others and strives to describe these opportunities at different scales, including a broad, landscape context that can be used to facilitate ecosystem management.

Select Tools Used for Conducting Inventory

The following are descriptions of standard tools used by the NHI Program for conducting biotic inventories. Some of these may be modified, dropped, or repeated as appropriate to the project.

File Compilation

Involves obtaining existing records of natural communities, rare plants and animals, and aquatic features for the study area and surrounding lands and waters from. Biotics. Other databases with potentially useful information may also be queried, such as: forest stand/compartment reconnaissance, which is available for many public agency owned lands; the DNR Surface Water Resources series for summaries of the physical, chemical, and biological characteristics of lakes and streams (statewide, by county); the Milwaukee Public Museum's statewide Herp Atlas; museum/herbarium collections for various target taxa; soil surveys; and the fish distribution database (by watershed, WDNR-Research). Additional data sources are sought out as warranted by the location and character of the site, and the purpose of the project. Manual files maintained within the Bureau of Endangered Resources contain information on a variety of subjects relevant to the inventory of natural features and are frequently useful.

Literature Review

Field biologists involved with a given project consult basic references on the natural history and ecology of the region within which the study area is situated. This can both broaden and sharpen the focus of the investigator.

Target Elements

Lists of target elements including natural communities, rare plants and animals, and aquatic features are developed for the study area. Field inventory is then scheduled for the times when these elements are most identifiable or active. Inventory methods follow accepted scientific standards for each taxon.

Map Compilation

USGS 7.5 minute topographic quadrangles serve as the base maps for field survey and often yield useful clues regarding access, extent of area to be surveyed, developments, and the presence and location of special features. WDNR wetland maps consist of aerial photographs upon which all wetlands down to a scale of 2 or 5 acres have been delineated. Each wetland polygon is classified based on characteristics of vegetation, soils, and water depth. Ecoregion maps are useful for comprehensive projects covering large geographic areas such as counties, national and state forests, and major watersheds. These maps integrate basic ecological information on climate, landforms, geology, soils, and vegetation. As these maps evolve, they should become increasingly useful, even for relatively small, localized projects. Geographic Information Systems (GIS) are increasing our ability to integrate spatial information on lands and waters of the state and are becoming a basic resource tool for the efficient and comprehensive planning of surveys and the analysis of their results.

Aerial photographs

These provide information on a study area not available from maps, paper files, or computer printouts. Examination of both current and historical photos, taken over a period of decades, can be especially useful in revealing changes in the environment over time.

Original Land Survey Records

The surveyors who laid out the rectilinear Town-Range-Section grid across the state in the mid-nineteenth century recorded trees by species and size at all section corners and along section lines. These notes also record general impressions of vegetation, soil fertility, and topography, and note aquatic features, wetlands, and recent disturbances such as windthrow and fire. As these surveys typically occurred prior to extensive settlement of the state by Europeans, they constitute a valuable record of conditions prior to extensive modification of the landscape by European technologies and settlement patterns.

Interviews

Interviews with scientists, naturalists, land managers or others knowledgeable about the area to be surveyed often yield information not available in other formats.

Analysis of Compiled Information

The compiled information is analyzed to identify inventory priorities, determine needed expertise, and develop budgets.

Meetings

Planning and coordination meetings are held with all participants to provide an overview of the project, share information, identify special equipment needs, coordinate schedules, and assign landowner contact responsibilities.

Appendix C. WDNR WNS Implementation & Response Summary

Wisconsin's response to WNS, as outlined in the WI WNS Implementation & Response Strategy, will by necessity (1) involve multiple state and federal agencies and stakeholders, (2) continually incorporate findings from ongoing WNS research, surveillance, and management, and (3) be highly and regularly adaptive to the changing status of bats and WNS in Wisconsin, and to the needs of Wisconsin's citizens, and (4) be tiered off of, and informed by, the national response plan: A National Plan for Assisting States, Federal Agencies, and Tribes in Managing White-Nose Syndrome in Bats, released May 2011.

Wisconsin will choose WNS management actions with the goals to:
1) prevent anthropogenic introduction of *Pseudogymnoascus destructans* into the state,
2) prevent or slow the spread of WNS to additional sites once WNS is identified in WI,
3) attain sufficient control of the disease in affected areas to conserve bat populations and their potential for recovery to pre-WNS abundance,

4) secure the future of bats without affecting other natural systems beyond acceptable levels,
5) minimize the impacts of WNS and WNS management actions on stakeholders interests, and
6) maintain resource and cost effectiveness so that management efforts can be sustained as long as necessary.
The roles and responsibilities for the WNS Science Advisory Group, the Stakeholder Advisory Group and each agency, cooperator, or stakeholder are described below.

Appendix D. Legal basis for bat & WNS response at HSB Cave

Among the state laws that apply to the management of wildlife, the following are particularly relevant to the management of HSB Cave as a bat hibernaculum:

The WDNR holds the public trust responsibility for managing wildlife as embodied in State Statute 29.011 Title to wild animals (1) *The legal title to, and the custody and protection of, all wild animals within this state is vested in the state for the purposes of regulating the enjoyment, use, disposition and conservation of those wild animals.*

Chapter NR 1.015(2), Wis. Adm. Code, establishes WDNR responsibility for ensuring healthy wildlife populations: *The primary goal of wildlife management is to provide healthy life systems necessary to sustain Wisconsin's wildlife populations for their biological, recreational, cultural and economic values.*
Chapter NR 27, Wis. Adm. Code, establishes an endangered and threatened species list. Threatened species listing of four cave bats species grants WDNR authority in state statutes 29.604, 227.11, and 227.24 Wis. Stats

HSB Cave is part of Wisconsin's Natural Heritage Inventory (NHI) database. Data about endangered or threatened species are sensitive because many rare species are vulnerable to collection, disturbance and/or destruction. Sharing NHI data with the public may threaten the continued existence of these species. NHI data are exempt from the Wisconsin Open Records Law and WDNR staff may not share specific information with external individuals or organizations.
Requirement for project review & ET permitting…

Chapter NR 40, Wis. Adm. Code, establishes a classification system for invasive species and regulates those in the prohibited and restricted categories. Prohibited Invasive Species listing of *Pseudogymnoascus destructans* grants WDNR authority in Sections 23.09 (2) (intro.), 23.091, 23.11 (1), 23.22 (2) (a) and (b) and (2t) (a), 23.28 (3), 27.01 (2) (j), 29.039 (1), 227.11(2)(a), and 227.24 (1) (a), Stats Chapter NR 40, Wis. Adm. Code also establishes preventive measures that when followed will help minimize the spread of invasive species into or within Wisconsin. The *Pseudogymnoascus destructans* and WNS management ruling grants WDNR authority in Sections 23.09 (2) (intro.), 23.091, 23.11 (1), 23.22 (2) (a) and (b), 23.28 (3), 27.01 (2) (j), 29.039 (1) and 227.11(2) (a), Wis. Stats.

Appendix E. Provisions for WNS In & Around WI Caves & Mines: WI ADC s NR 40.07

(7) INTRODUCTION PROHIBITED. Unless authorized by a permit issued by the department under this chapter, no person may introduce a nonnative algae or cyanobacteria species in any water of the state. This subsection does not apply to the incidental introduction of a nonnative algae or cyanobacteria species by a person operating an aircraft, vehicle, equipment or gear while engaged in fire suppression.

Note: Section 23.24 (3) (a) 1., Stats., prohibits any person from introducing nonnative aquatic plants into waters of this state unless the person has a valid aquatic plant management permit issued by the department.

(8) WHITE-NOSE SYNDROME PREVENTION. (a) *Definition.* In this subsection "near a cave or mine" means within 100 feet of a cave or mine.

(b) *Entry with imported items prohibited*. Except as provided in par. (e), no person may bring or place any equipment, gear, clothing or other object of any kind in or near a cave or mine if the equipment, gear, clothing or other object has been in or near a cave or mine located outside of Wisconsin.

(c) *Requirements.* 1. Except as provided in subd. 5. and par. (e), no person may bring or place any equipment, gear, clothing or other object of any kind in or near a cave or mine if the equipment, gear, clothing or other object has been in or near a cave or mine located in this state unless the equipment, gear, clothing or other object has first been cleaned in accordance with par. (d).

2. Except as provided in subd. 5. and par. (e), any person removing any equipment, gear, clothing or other object of any kind from any cave or mine or from within 100 feet of any cave or mine or exiting any cave or mine or the area within 100 feet of any cave or mine with any equipment, gear, clothing or other object of any kind shall clean the equipment, gear, clothing and other objects in accordance with par. (d).

3. Except as provided in subd. 5. and par. (e), any person who caused or will cause contact to occur between a bat and an individual or object of any kind, including but not limited to a net, trap, weighting tube, bat bag, wing punch, ruler, clothing, glove, electronic equipment or exclusion material shall, prior to and immediately following the contact, clean the individual or object in accordance with par. (d).

4. Except as provided in subd. 5. and par. (e), any person who owns or operates an active mine or a commercial cave or mine shall ensure that each individual entering or exiting the person's active mine or commercial cave or mine complies with par. (b) and subds. 1. to 3.

5. The requirements of subds. 1. to 4. do not apply to dedicated equipment, gear, clothing and other objects of any kind that are used exclusively in or near and stored exclusively in or near a single cave or mine.

(d) *Protocols.* Individuals, equipment, gear, clothing and other objects of any kind to which the requirement of par. (c) 1., 2., or 3. applies shall be cleaned in accordance with protocols approved by the department. Unless it determines that emergency conditions require otherwise, the department shall provide notice and opportunity for public comment at least 14 days before it materially changes an approved protocol.

Note: Detailed information about department-approved cleaning protocols may be obtained at http://WDNR.wi.gov/org/land/er/bats/ or by writing to Wisconsin Department of Natural Resources,

Wisconsin Bat Monitoring Program, Bureau of Natural Heritage Conservation, P.O. Box 7921, Madison, WI 53707-7921.

(e) *Written exemption.* The department may exempt any person in writing from par. (b) or (c) if it determines that the exemption will not significantly increase the risk that *Pseudogymnoascus destructans* (white-nose syndrome fungal pathogen) would be introduced or transported to other locations. The department may set conditions in any written exemption granted under this paragraph. Any person who receives a conditional exemption from the department under this paragraph shall comply with the conditions of the exemption.

(f) *Site-specific prevention plan.* Except as provided in subd. 5., any person who owns or operates a cave or mine shall develop a written plan for each of the person's caves and mines to prevent the introduction and transmission of *Pseudogymnoascus destructans* (white-nose syndrome fungal pathogen).

1. The prevention plan shall include a description of practices that will be installed or implemented by the owner or operator to prevent the introduction or transmission of *Pseudogymnoascus destructans* via human transmission. The plan may include practices such as screening visitors, cleaning equipment, gear, clothing and other objects before they are brought into the cave or mine or upon their removal, the use of dedicated equipment, gear, clothing and other objects, and modification of the cave or mine environment to make it unsuitable for establishment and transmission of *Pseudogymnoascus destructans*.

2. The prevention plan shall be submitted by the owner or operator to the department by June 1, 2011, for its review and approval. The department may set conditions for the approval of any plan required under this paragraph and shall include any exemption granted under par. (e) to the owner or operator of a cave or mine in a plan approval issued under this paragraph. In setting conditions for the approval of any plan, the department shall consider the site-specific risk of *Pseudogymnoascus destructans* introduction and transmission along with the feasibility and reasonableness of alternative practices for the prevention of *Pseudogymnoascus destructans* transmission or introduction.

3. The owner or operator shall implement the plan as approved by the department and shall maintain as appropriate all practices specified in the plan.

4. The owner or operator shall maintain a copy of the approved prevention plan at the cave or mine covered by the plan or an alternate location approved by the department and shall make the copy available for inspection upon request by the department at any reasonable time.

5. This paragraph does not apply to any of the following:

a. A cave or mine that the department has determined in writing lacks the environmental conditions, including temperature and humidity, suitable for the introduction or transmission of *Pseudogymnoascus destructans*.

b. A cave or mine where the owner or operator restricts human access through the use of department-supplied and maintained signage or bat-friendly barriers or gates.

c. A cave or mine where the primary reason for human presence in the cave or mine relates to the storage or processing of a food or beverage intended for human consumption.

Appendix F. Summary Descriptions for Species and Natural Communities Documented in and around HSB Cave

The Wisconsin Natural Heritage Inventory's recognized Natural Communities – Working Document. Prepared by Eric Epstein, Emmet Judziewicz and Elizabeth Spencer. This document will be periodically updated and expanded. Future editions will include or be linked to additional descriptive information, range maps, and crosswalks to other vegetation classification systems.

Algific Talus Slope. This rare community of southwestern Wisconsin's Driftless Area consists of steep slopes of fractured limestone (dolomite) rock that retains ice and emits cold air throughout the growing season. The cold microhabitats enable the persistence of northern species and "periglacial relicts" such as northern monkshood (*Aconitum noveboracense*) and rare terrestrial snails. The woody overstory is often sparse, with scattered small black ash (*Fraxinus nigra*) and white birch (*Betula papyrifera*). Mountain maple (*Acer spicatum*), a northern shrub, may be frequent and extensive beds of bulblet fern (*Cystopteris bulbifera*) and mosses are characteristic.

Alvar. This rare community consists of areas of thin discontinuous soil overlying horizontal beds of limestone or dolomite in the vicinity of Great Lakes shorelines. They are characterized by

72 relatively low tree cover and a distinctive biota which includes elements of rock pavement, prairie, savanna and boreal forest communities. Among these are regional endemics, some very rare. Small coniferous and deciduous trees (cedar, fir, pine, oak, aspen, birch) are scattered among an assemblage of species that can include big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indian-grass (*Sorghastrum nutans*), and wood lily (*Lilium philadelphicum*), as well as shoreline plants such as silverweed (*Potentilla anserina*) and dwarf lake iris (*Iris lacustris*).

Boreal Forest. In Wisconsin, mature stands of this forest community are dominated by white spruce (*Picea glauca*) and balsam-fir (*Abies balsamea*), often mixed with white birch (*Betula papyrifera*), white cedar (*Thuja occidentalis*), white pine (*Pinus strobus*), balsam-poplar (*Populus balsamifera*) and quaking aspen (*Populus tremuloides*). Mountain-ash (*Sorbus* spp.) may also be present. Common understory herbs are large-leaved aster (*Aster macrophyllus*), bluebead lily (*Clintonia borealis*), Canada mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), and bunchberry (*Cornus canadensis*). Most Wisconsin stands are associated with the Great Lakes, especially the clay plain of Lake Superior, and the eastern side of the northern Door Peninsula on Lake Michigan. Of potential interest from the perspectives of vegetation classification and restoration, white pine had the highest importance value of any tree in the Lake Superior region, as recorded during the original land survey of the mid-1800's.

Cedar Glade. Dry sandstone, quartzite or dolomite exposures vegetated with dense thickets of red cedar (*Juniperus virginiana*). Red maple (*Acer rubrum*), paper birch (*Betula papyrifera*) and black and bur oaks (*Quercus velutina* and *Q. macrocarpa*) may also be present. This community is usually if not always the result of fire suppression on dry prairies, and in pre-settlement times it may have occurred only where extensive cliffs served as firebreaks. Common herbs include bluestem and grama grasses (*Andropogon* spp. and *Bouteloua* spp.), prickly-pear cactus (*Opuntia compressa*), flowering spurge (*Euphorbia corollata*), stiff sandwort (*Arenaria stricta*), and gray goldenrod (*Solidago nemoralis*).

Dry Cliff. These dry vertical bedrock exposures occur on many different rock types, which may influence species composition. Scattered pines, oaks, or shrubs often occur. However, the most characteristic plants are often the ferns, common polypody (*Polypodium vulgare*) and rusty woodsia (*Woodsia ilvensis*), along with herbs such as columbine (*Aquilegia canadensis*), harebell (*Campanula rotundifolia*), pale corydalis (*Corydalis sempervirens*), juneberry (*Amelanchier* spp.), bush-honeysuckle (*Diervilla lonicera*), and rock spikemoss (*Selaginella rupestris*).

Forested Seep. These are shaded seepage areas with active spring discharges in (usually) hardwood forests that may host a number of uncommon to rare species. The overstory dominant is frequently black ash (*Fraxinus nigra*), but yellow birch (*Betula allegheniensis*), American elm (*Ulmus americana*) and many other tree species may be present including conifers such as hemlock (*Tsuga canadensis*) or white pine (*Pinus strobus*). Understory species include skunk cabbage (*Symplocarpus foetidus*), water-pennywort (*Hydrocotyle americana*), marsh blue violet (*Viola cucullata*), swamp saxifrage (*Saxifraga pennsylvanica*), golden saxifrage (*Chysosplenium americanum*), golden ragwort (*Senecio aureus*), silvery spleenwort (*Athyrium thelypterioides*) 75 and the rare sedges (*Carex scabrata* and *C. prasina*). Most documented occurrences are in the Driftless Area, or locally along major rivers flanked by steep bluffs.

Mesic Cedar Forest. This is a rare upland forest community of mesic sites in northern Wisconsin, characterized by white cedar (*Thuja occidentalis*) and various associates including hemlock (*Tsuga canadensis*), white spruce (*Abies balsamea*), yellow birch (*Betula alleghanensis*), and white pine (*Pinus strobus*). The herb layer may contain Canada mayflower (*Maianthemum canadense*), twinflower (*Linnaea borealis*), clubmosses (*Lycopodium* spp.), and others. More information is needed on this community type.

Moist Cliff. This "micro-community" occurs on shaded (by trees or the cliff itself because of aspect), moist to seeping mossy, vertical exposures of various rock types, most commonly sandstone and dolomite. Common species are columbine (*Aquilegia canadensis*), the fragile ferns (*Cystopteris bulbifera* and *C. fragilis*), wood ferns (*Dryopteris* spp.), rattlesnake-root (*Prenanthes alba*), and wild sarsaparilla (*Aralia nudicaulis*). The rare flora of these cliffs vary markedly in different parts of the state; Driftless Area cliffs might have northern monkshood (*Aconitum noveboracense*), those on Lake Superior, butterwort (*Pinguicula vulgaris*), or those in Door County, green spleenwort (*Asplenium viride*).

Talus Forest (Description in preparation)

Appendix G. A Preliminary Archaeological Assessment of Horseshoe Bay Cave, Murphy County Park, Door County, Wisconsin

A Preliminary Archaeological Assessment of Horseshoe Bay Cave

Murphy County Park

Door County, Wisconsin

By: Robert "Ernie" Boszhardt

9/10/2012

Introduction

On July 9, 2012 I was guided to and into Horseshoe Bay Cave by John "Paul" White and Heather Kaarakka of the Wisconsin DNR Bat protection program, Bill Schuster of the Door County Parks Department, and Bob Bultman a local caver who has explored and worked at this cave on approximately 75 previous trips. The purpose of this visit was to assess the potential for archaeological resources as a contribution to a developing management plan for the countyowned cave.

In Wisconsin there are two primary types of prehistoric Native American use of caves and, much more commonly, rockshelters. The first is use of these natural shelters as habitation sites. Based on the professional excavation of approximately 20 rockshelters, most in the unglaciated Driftless Area, we know that Native American people occupied these sites for much of the Holocene. Occupations seem to have been relatively rarely during the terminal glacial Paleoindian (ca.12,000 - 9,000 BP) and warm-dry Early Archaic (ca. 9,000 - 6,000 BP) periods. Beginning about 5,000 BP in the Middle Archaic, rockshelters appear to have been occupied on a regular basis during the cold fall-winter seasons, where inhabitants subsisted primarily by hunting deer. That seasonal round pattern persisted until the end of the Effigy Mound culture about 1,000 BP (Theler and Boszhardt 2003). Typical archaeological rockshelter habitation assemblages consist of ash and charcoal from fires, numerous broken and partially burned deer bone, bone awls for sewing hides, stone tools (especially broken and discarded projectile points), and broken ceramics during the Woodland/Mississippian/Oneota Traditions (2,500 – 350 BP). Most of the known occupied rockshelters are situated in sandstone formations with dry floors. Few limestone shelters are known, although the relatively small Gibson rockshelter was excavated in the Niagara Escarpment near Green Bay in the 1940s (Hall et. al. 1944). Indeed the few deep-cave archaeological sites known in Wisconsin are collapsed sandstone caves such as Tainter and Larsen in the Driftless Area (Boszhardt 2003). No known habitation sites are as yet reported for deep limestone caves, which tend to be wet, with floors of slick clay and sharp, cherty dolomite.

The second Native American use of caves and rockshelters is for ritual purposes such as vision quests or other religious activities. Material remains for such activities are expected to be less than that of habitation areas and perhaps distinct. For example, vision quests typically involve fasting, resulting in no food refuse or cooking vessels. Special religious objects such as sacred bundles might contain a variety of unusual materials such as raptor talons. Many rockshelters contain human remains, including four burials found in the aforementioned Gibson rockshelter.

One archaeological expression of potential ritual cave use is rock art, either as pictographic drawings/paintings or carved petroglyphs. There are only a handful of Native American pictographs sites reported from the northern tip of Door County, including several on Washington Island. These tend to be made of red pigment and are situated on somewhat protected limestone ledges rather than actual shelters or caves. Rock art can be threatened by natural weathering and impacted by historic graffiti.

The August 9 reconnaissance to Horseshoe Bay Cave involved approximately 20 minutes of introductory conversation (going over the background, goals, and plan of action) as caving gear and clothing were prepared; 1 hour inside the "old section" nearest the entrance; and another 20 minutes reviewing preliminary impressions and potential recommendations after exiting the cave and while removing cave clothing for sanitation in consideration of the threat of White Nose Syndrom. I did not carry a camera into the cave due to anticipated wet conditions, but Heather did and took some photos up to the "Duck-Under". Afterward, the group walked to a limestone rockshelter about a quarter mile to the north along the same escarpment finding evidence of extensive burning and probable Native American rock art (see Appendix A).

Background

Horseshoe Bay Cave is not recorded as an archaeological site in the Wisconsin Archaeological Sites Inventory, a statewide database maintained by the Wisconsin Historical Society. No other land based sites are currently reported within a mile of the cave. An unverified shipwreck is reported in Horseshoe Bay itself.

Before visiting Horseshoe Bay Cave, I read a series of background articles (Kox 1990a-c, Soule 1976, Wendricks-Schleis 1990, and Zachariasen 1990) that had been provided in pdf format by Jennifer Schehr-Redell, also with the DNR's bat protection program. Those articles detailed the history of the cave including a local legend that the Indian leader Tecumseh had visited in the early 1800's (Kox 1990c), and of its initial discovery around 1879 (Kox 1990b) or 1897 (Soule 1976) through subsequent explorations (many under the auspices of the Wisconsin Speleological Society) until the end of the 1980s. These revealed that the entrance to this limestone solution cave was naturally closed at the time of its discovery when a spring as noticed emanating from the talus. In addition, after a few hundred feet in from the entrance, further passage involves crawling through a normally wet "Duck-Under" that leads to the "HH" room with graffiti, beyond which a step up leads to a long but low crawl space beyond which is a river section ultimately requiring scuba diving in a submerged tunnel (Kox 1990a, Wendricks-Schleis 1990).

The known extent of this, the longest documented cave in Wisconsin, has been increased through combinations of caver digging for new passages and specialized diving through submerged tunnels. The water level has fluctuated substantially with reports of a wooden ladder floating up to 25 feet above the floor upon which it had been placed, and that water flows out of the entrance at times (ibid). Finally, there is a record of a 3 x 3 foot controlled excavation placed about 36 feet in from the entrance which collected samples for particle-size analysis and bones for animal identification (Soule 1976). That excavation found sediments extending to a depth of about 33 inches and containing bat bones and wood fragments, one of which from near the base appeared to have been cut, suggesting the sediments are relatively recent. The entrance was gated by the Wisconsin Speleological Society in 1986 (Zachariasen 1990) while privately owned, and regated in 2012 after ownership transferred to the County (Jennifer Schehr-Redell and Bill Schuster personal communication).

Reconnaissance

The August 9 visit coincided with an unusually dry summer. The cave is situated at the top of a 20 foot talus slope where a small Silurian limestone outcrop occurs approximately ¼ mile east of the east shore of Green Bay. Loose talus also occurs above the shelter on a steeply wooded slope and appears to release rocks and sediment on a periodic basis, which if left alone would ultimately reseal the entrance. A field below the cave reveals a slight alluvial fan, and Mr. Schuster reported having seen water flushing from the cave into the field on at least one occasion in the past, a phenomenon also documented in the cave literature, usually coinciding with spring snow melt (Kox 1990a). The cave entrance has been cleared away of fragmented limestone and soil creating a substantial pile on the outside. A rough profile of remaining talus exists to the south of the gate. Brief examination of this profile revealed jumbled limestone slabs and soil with no indications of cultural material. The new gate consists of welded steel beams mounted on the same concrete footing from the original 1986 gate. Zachariaen's (1990) detailed report on the 1986 gate construction describes hand excavating and enlarging a trench down to bedrock in order to pour the concrete foundation. That report makes no mention of observing or looking for archaeological resources during those excavations.

Upon entering the cave with Paul, Heather, and Bob; the floor appeared to be compacted sediment that was relatively dry. Welding scraps from the gate construction were visible on the surface along with a few fragments of broken (clear bottle) glass just inside the gate. No prehistoric artifacts or charcoal were observed on the surface, but the floor for the first 50 feet or so seems to hold potential for buried cultural resources. That first section is about 4 feet wide by 4 feet tall, requiring hands and knees crawling. Occasional glass fragments were observed on the floor in small splash areas where sediment had been cleared away by drips from the ceiling. The walls were coated with condensation droplets. After about 50 feet, the natural light fades and the cave opens in a tall room called the "Cloak Room" because, according to Bob, this is where cavers traditionally changed clothing during winter explorations as the temperature is a constant 46 degrees or so. No graffiti or smoke smudging was observed at the entrance, in the first segment, or the "Cloak Room".

Beyond the "Cloak Room" the ceiling lowers again requiring renewed crawling, and the floor dips becoming moister as one proceeds. After a turn to the right, a puddle of standing water was reached, which was traversed by crawling through a now slick mud floor. At the other end, a small room contained several examples of graffiti written in pencil/graphite. This room was the entrance to the "Duck Under" a normally wet passage with a low roof. At the time of our visit, there was a good two feet of air above the water, which was about 6 inches deep. Written accounts, confirmed by Bob, indicate that there are times when the water level leaves only a few inches of air below the ceiling, although at times this can also be free of water. Bob, Paul, and I passed through the Duck-Under", getting mud soaked along the way.

The "HH" room is an opening with a tall ceiling, but wet floor. This room has substantial amounts of graffiti, including a bold swastika and "HEIL HITLER" that were brush painted in red on the rock face above the "Duck-Under". This indicates post-1933 graffiti, and according to Bob has been there a relatively long time. There is also some green paint lower on the same wall that had been smeared over with mud by more recent cavers and a large "79" in orange spray paint on the opposite wall, which was flaking off the rock surface. Around 30 other names/dates were observed on both walls as pencil writing or narrow-line carvings, the latter likely made with knives or other metal tools. One small (4 x 4 ") pecked "+" symbol was seen on a nearly horizontal ledge opposite the "Duck-Under"; the only pecked glyph observed and a rare form in Wisconsin. Several black smudge marks were seen in this room, the first charring I observed in the cave. Kox (1990a) describes a 1959 visit by himself and boyhood friends around 1959 during which they found Lestoil torches at the entrance and lit them to explore at least to the "HH" room, which "filled with smoke".

Some of the glyphs in the "HH" room were placed on surfaces where a rippled "travertine" had been removed exposing water-smoothed bedrock surfaces. Some were partially covered by flowstone. The pencil graffiti consisted of several styles including cursive and block, with the cursive seemingly earlier. For example, a name and associated date of "1898" are done in cursive. In other Wisconsin sites, a sequencing of historic graffiti styles is often mi-19th century gothic letters/numbers, changing to cursive in the late 19th century, and shifting to angular block characters by the 1930's later replaced by spray paint. No gothic style letters were observed during the August 9 reconnaissance.

In the "HH" room Bob described the continuation of the cave as a lower passage that begins atop a ledge and leads to a large room that also contains more graffiti, including some of the same red paint as the swastika/"HEIL HITLER" . I climbed to look into the upper passage, but we did not proceed further.

Summary and Recommendations

After we worked our way back to the entrance and exited, Bill, Bob, Paul, Heather, and I discussed the archaeological potential and management options for the known historic cultural features in the cave. Based on my visit, I saw no obvious signs of prehistoric or early historic Native American visitation. The pecked "+" in the "HH" room could be a Native American glyph, but is more likely historic Euro-American based on the correlation of the earliest glyph seen (1898) to the 1897(?) record of the initial discovery and subsequent opening of the cave entrance (Soule 1976). If the cave entrance was closed by talus for the entirety of the Holocene until the end of the 19th century, the possibility for Native American cultural resources is nil.

However, it is possible that the cave entrance was open at various times in the past, becoming closed by subsequent slope wash. The historic literature for Horseshoe Bay Cave implies that the cave entrance was sealed at the time of discovery, opened for initial exploration, and closed again by slope wash during the early 20th century before being "rediscovered" in the 1933 (Kox 1990b). Samuel's Cave in La Crosse County was likewise nearly completely closed upon its discovery in 1878, but contained numerous prehistoric petroglyphs and pictographs and deeply stratified floor deposits containing ash, pottery and bone (Stiles-Hanson 1987).

Thus the potential for prehistoric archaeology does exist at Horseshoe Bay Cave. If so, corroborating evidence is most likely to consist of winter occupation in the relatively dry and light/twilight zone in the first 50 feet from the entrance. Evidence for such use should consist of ash and charcoal, animal bone, stone artifacts, and perhaps ceramic sherds in the floor sediments.

Prior excavations in this section of the cave did not reference any such indicators, but the excavators were also not looking for them. In addition, spring snow melt outflows could have washed surface ash, charcoal and artifacts out of the cave. Logically, fires near the entrance would also have blackened the ceiling, and no evidence for smudging was observed here. The absence of smudging near the entrance might reflect an absence of fires or smudge marks may have been scoured way from the occasional reverse flooding spilling from the entrance.

Recommendation 1: The most effective way to determine if pre-1898 prehistoric or early historic cave use occurred would be to excavate one or two 1 x 1 meter controlled test units to bedrock. Excavations should by a qualified archaeologist in consultation with other specialists who might also benefit from recovered data. Sediment deposits should be removed in thin (5-10 cm) levels and all soils should be screened with selected samples processed through fine mesh water screening and others through flotation. Profiles should be photographed and mapped for permanent record. If no pre-1898 artifacts are recovered, or if historic artifacts are found all the way to the floor, the probability for Native American occupational use of the cave is diminished further.

However, even if this cave were not used for habitation, it is possible that it was visited for ritual purposes such as vision questing, which would result in few artifacts or ecofacts. But, such activities might be represented by rock art. With the possible exception of the pecked "+" in the "HH" room, no potential Native American pictographs or petroglyphs were observed. However, this preliminary assessment did not examine all potential rock art surfaces in detail. Still, the creation of any glyphs beyond the first 50 feet would have required artificial light, such as birch bark torches that were found in Tainter Cave in Vernon County (Boszhardt 2003). Such torches would have created smudging, none of which was seen until reaching the "HH" room past the "Duck-Under". It is difficult to conceive of carrying a lit torch through the "Duck-Under" when it was wet, but the 1959 exploration by local boys indicates carrying lit Lestoil torches through much wetter "Duck-Under" conditions (Kox 1990a).

Horseshoe Cave contains a number and variety of historic names and dates. These constitute cultural resources that reflect the history of the cave since at least 1898. As graffiti, these can be seen as offensive or fascinating and one could recommend removing some or all. Removal in an appropriate manner would require consultation with a cave conservator, a costly prospect. The argument can also be made to leave the graffiti as a record of historic use. One problem with graffiti is that is usually leads to more graffiti, which inevitably damages the cave and obscures earlier names and dates. Fortunately, the gating of the cave since 1986 appears to have stopped subsequent graffiti. Leaving the extant graffiti is cost effective, but the historic names are subject to erosion and some are being obscured by a continually forming flow stone.

Recommendation 2: Consequently, I strongly recommend a systematic recoding of the extant historic names and dates in the cave. This effort should consist of accurate mapping of the location of the glyphs and digital photo documentation. The location of the graffiti can be added to extant maps of the cave with more precise maps developed as needed for specific rooms where complex graffiti is present. The digital photography should be done in a manner that will enable an archival record and manipulation be graphic programs that may be able to enhance feint glyphs. Painted and pencil graffiti can usually be photographed straight on with a flash and no other supporting light. Carved names and dates are best photographed by raking light across their surfaces and not using a flash. An inventory of the person names, place names, and dates, and associated medium (e.g., pencil/crayon/brush paint/ spray paint/etc.) and style (e.g., gothic, cursive, block, other) can be used for subsequent historic research into the visitors to the cave.

The effort will also allow for more systematic examination of the walls for potential pre-1898 graffiti or Native American rock art that would change the story of the discovery of the cave.

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Appendix H. Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin with notes on habitats and management recommendations

Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin, with notes on habitats and management recommendations

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Invertebrate fauna of Horseshoe Bay Cave, Door County, Wisconsin, with notes on habitats and management recommendations

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Introduction

Horseshoe Bay Cave (HSB) (**Figures 1,2**), located in Door County along the western side of the Niagara Escarpment (**Figure 3**), is one of the longest known natural caves in Wisconsin. More than 4000 feet of passage are thought to exist in the cave, though only 3,083 feet have been surveyed. The cave is developed in Silurian Niagra Dolomite, and the hydrology of the site is somewhat complicated as the bedding planes of the bedrock dip downwards towards the East, but during especially high water levels, an intermittent spring flows out of the cave entrance toward the West, draining into Green Bay of Lake Michigan (**Figure 4**). Glacial ice covered the Door Peninsula as recently as 14,000 year BP, and as recently as 7000 years BP, the peninsula was not separated from the mainland of Wisconsin and Michigan to the West because Green Bay was not filled with water during that period.

Horseshoe Bay Cave is significant not only for its' length, but also because it is a Priority 1 Bat Hibernaculum, providing winter habitat for more than 1,000 individuals four important cave bat species – little brown myotis (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*), northern long-eared myotis (*Myotis septentrionalis*), and tri-colored bat (*Perimyotis subflavus*; formerly known as the eastern pipistrelle, *Pipistrellus subflavus*) (Jennifer Redell, Wisconsin DNR, pers. comm. 2013). These four species were recently afforded official status as state threatened species in Wisconsin (Wisconsin Legislature 2011: Wisconsin Administrative Code, NR 27.03, June 2011, pg. 357). These bats are susceptible to infection by the fungus *Pseudogymnoascus destructans* (Blehert & Gargas 2009) (formerly known as *Geomyces destructans* Blehert & Gargas 2009, see Minnis & Lindner 2013). The fungus *P. destructans* is the causative agent of White Nose Syndrome (WNS), a devastating disease of cave-hibernating bats that is presently spreading across much of eastern North America. Based on current distribution and the pattern of detection thus far (**Figure 5**), it is likely that WNS will be detected in Wisconsin hibernacula (caves, mines) during the winter of 2013-2014 – the time during which we are writing this report – or the following winter.

Wisconsin DNR and Door County are working together to enact effective management and protection for this site (Jennifer Redell, Wisconsin DNR, pers. comm. 2013). Because little is known about the cave's unique biological and other resources, both a cave inventory and a management plan are needed. The plan will identify the goals and objectives for managing and maintaining the sensitive cave habitat and other resources, and will serve as a guide for resource protection by agency and county managers. Agency personnel are also responsible for developing a WNS Prevention Plan required by the State of Wisconsin (NR 40.07), which will be prepared as part of the overall management plan for the site.

Bat monitoring and surveillance at the cave are described in the recently completed "White Nose Syndrome Surveillance and Response Implementation Strategy" (Wisconsin DNR 2011). These actions were deemed necessary because disease confirmation is within the migratory distance of bat species found in Horseshoe Bay Cave. A "bat-friendly" gate, preventing unauthorized human entry, has been installed at the cave entrance (**Figure 6**) and an automated bat counting system is being installed to count bats entering and leaving the cave (**Figure 7**). Wisconsin DNR also plans to capture movement and survival data about individually tagged bats using a Passive Integrated Transponder (PIT) tag-reading antenna (Jennifer Redell, Wisconsin DNR, pers. comm. 2013).

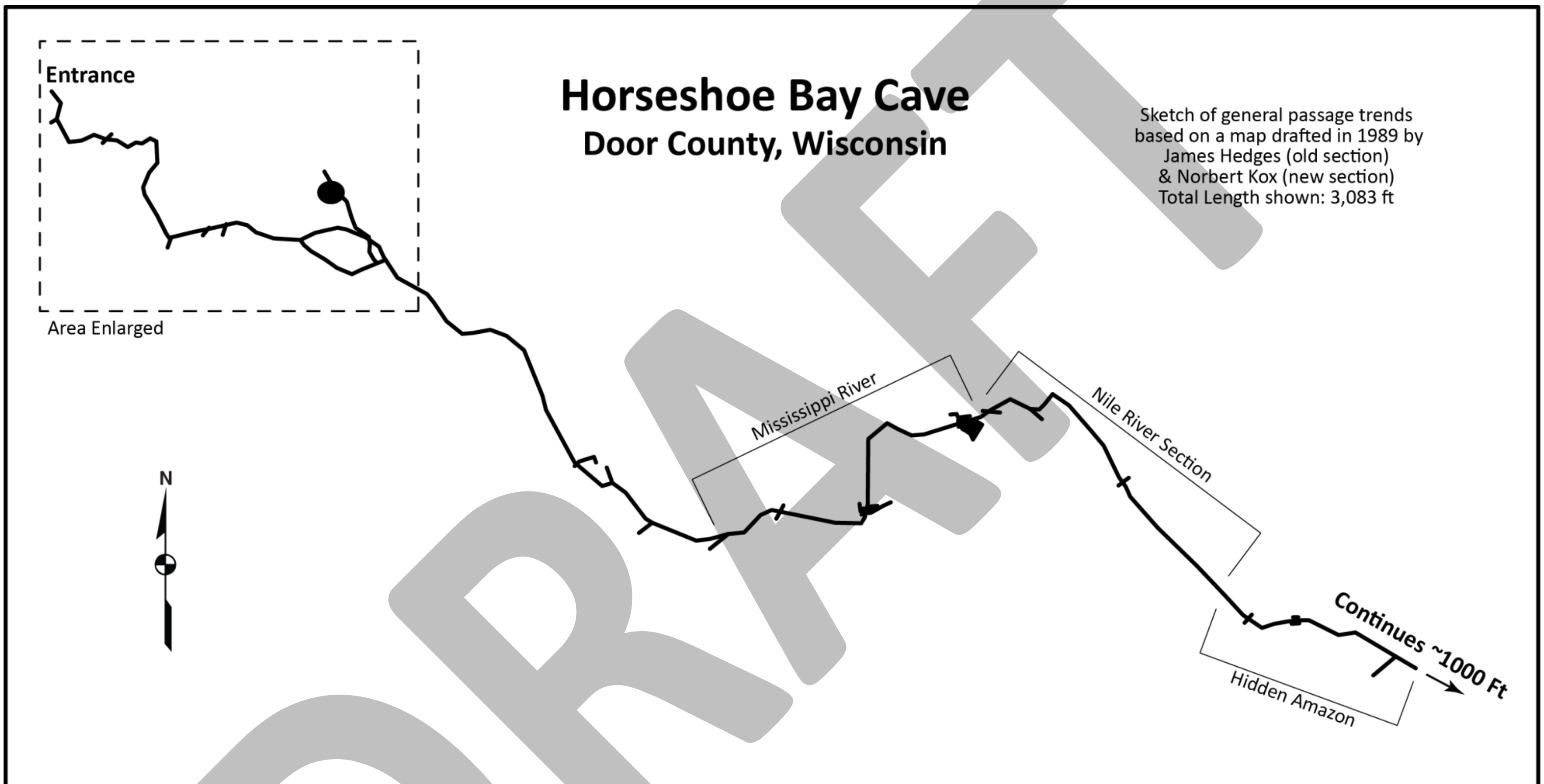


Figure 1. Horseshoe Bay Cave, Door County, Wisconsin. This map is a simplified sketch of general passage trends based on an earlier map drafted by James Hedges and Norbert Kox. Over 3,000 feet of passage are shown, but unsurveyed passage extending beyond the map has been explored, adding approximately 1000 feet of passage. Names with brackets indicate cave passage section names given by survey teams. Dashed box indicates area of detail shown in **Figure 2**.

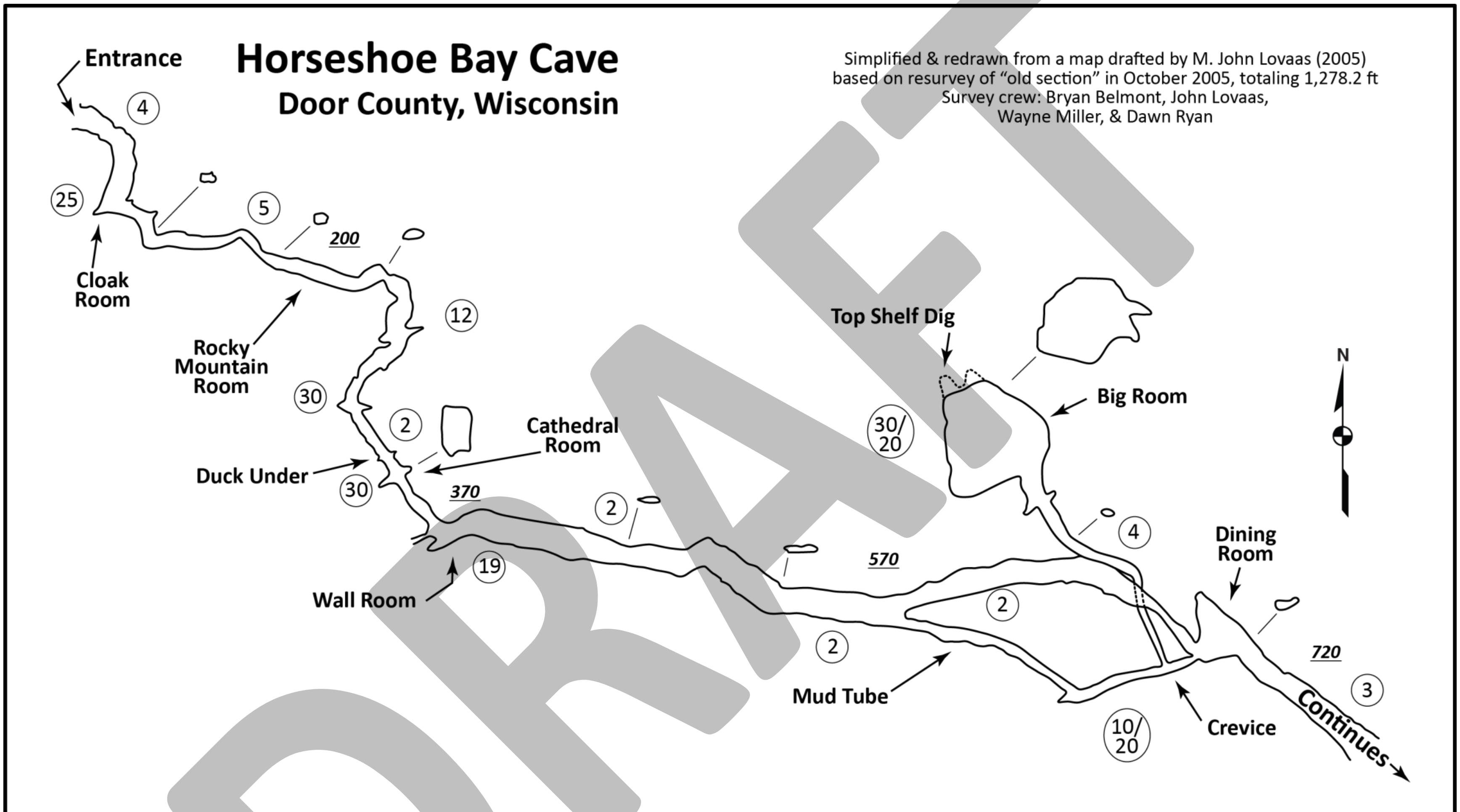


Figure 2. Horseshoe Bay Cave, Door County, Wisconsin. This map is a detail of Figure 1, showing the portion cave closest to the entrance, simplified from a map drafted by John Lovaas in 2005. Circled numbers are passage heights (feet). Bold, italicized underlined numbers are distance from entrance (feet). Thin lines indicate approximate locations of cross sections. Names for various areas in the cave are noted with arrows.

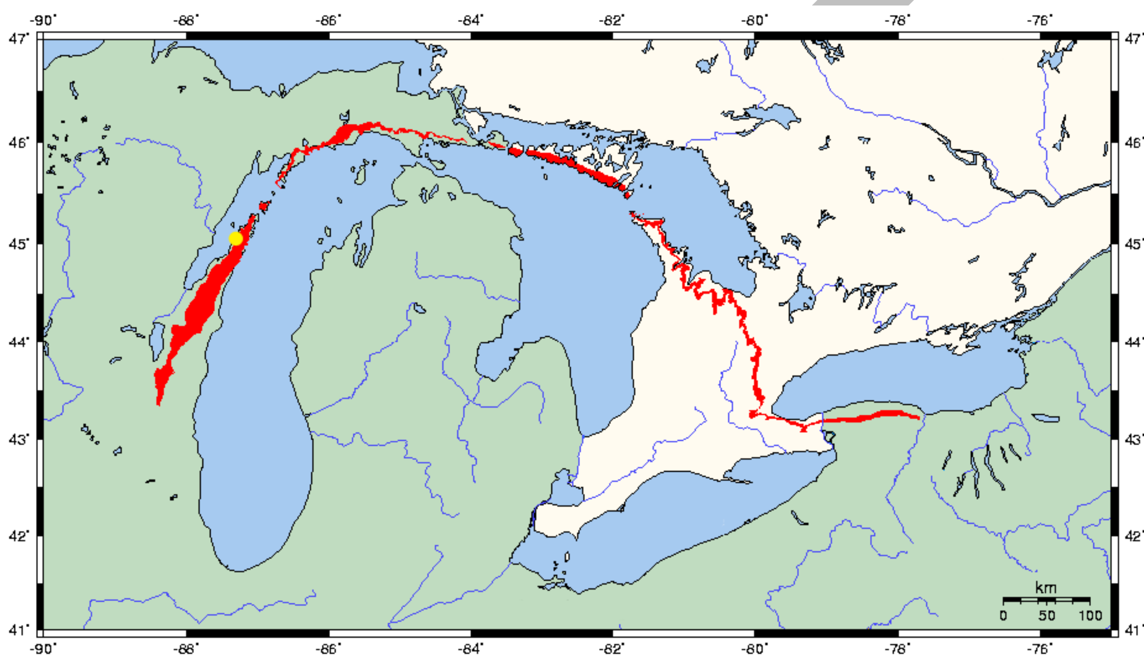


Figure 3. Map of Great Lakes region showing approximate location of Horseshoe Bay Cave (yellow dot to the West) in Door County, Wisconsin. Red indicates the near-surface and surface exposure of dolomitic bedrock of the Niagara Escarpment, extending from west-central Wisconsin in an arc up through the Door Peninsula and across and down through Ontario (where several caves are found in this rock formation; see Peck 1988, Figs. 1,2), Canada just south of Toronto, to the better known exposures at Niagara Falls to the east, extending then further eastward toward Rochester, New York. Map modified after <http://wisco2012.blogspot.com/p/geology-of-door-county.html>.

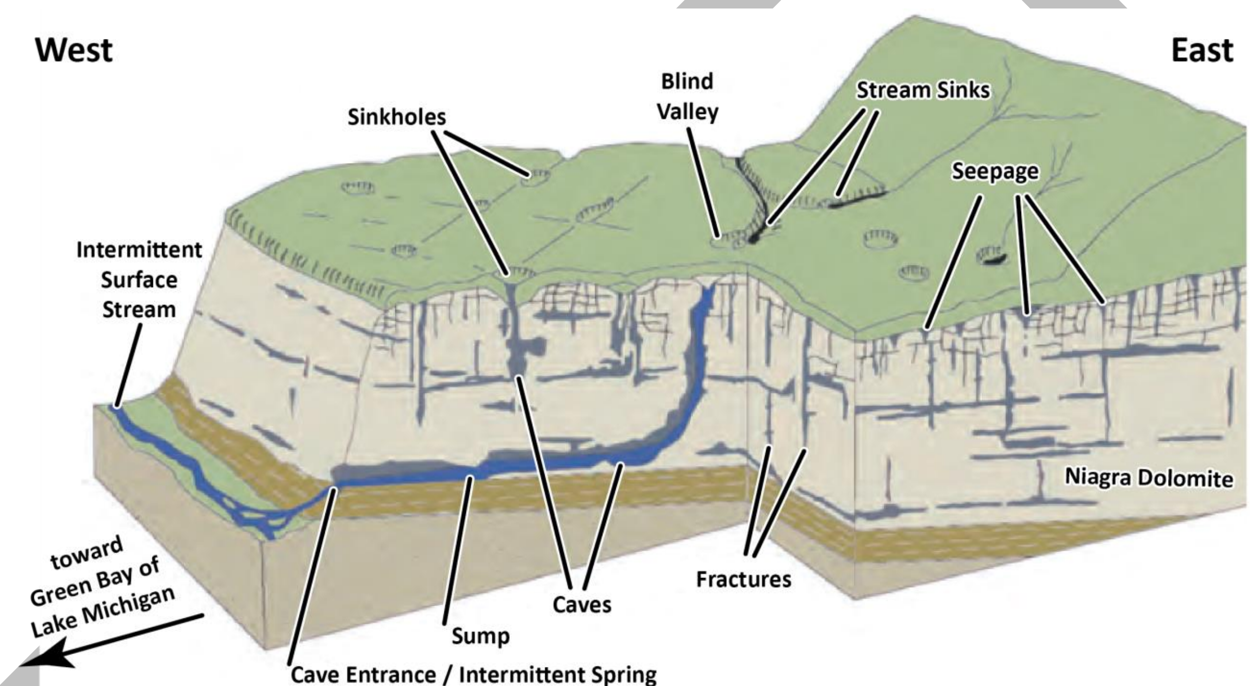


Figure 4. Diagramatic representation of karst structure in the vicinity of a cave similar to Horseshoe Bay Cave in western Door County, Wisconsin. Modified after Bradbury (2009) and Runkel et al. (2003). Note the bedding dipping to the East, while the high-flow resurgence is to the West.

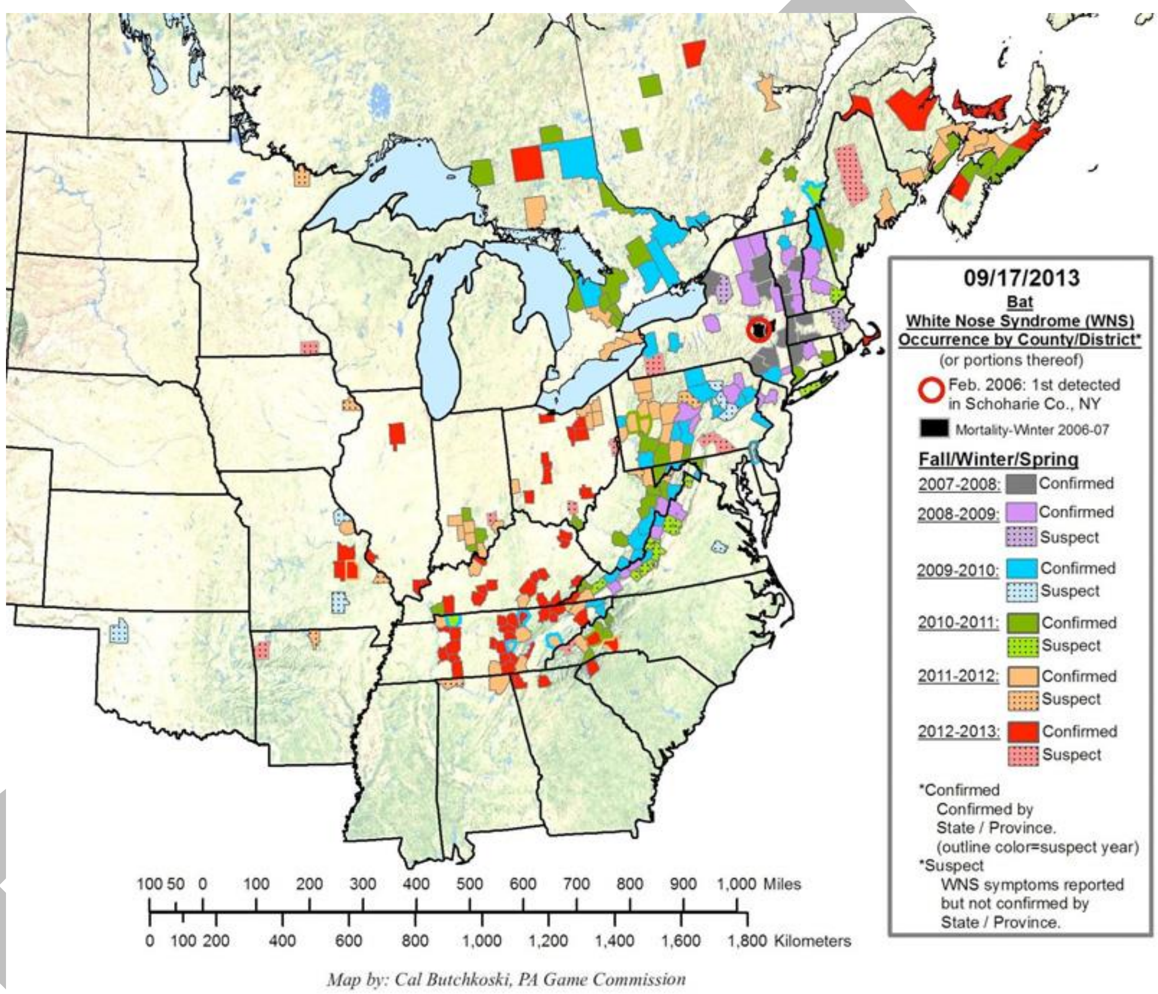


Figure 5. The known distribution of White Nose Syndrome in North America as of 17 September 2013. Map from <http://whitenosesyndrome.org/>, accessed 24 November 2013.

Figure 6. Bat friendly gate installed at the entrance to Horseshoe Bay Cave. The gate is open in the photo, as Wisconsin DNR bat biologists are working inside. Photo by Steven J. Taylor.

Figure 7. Panoramic photo of automated bat county apparatus under construction by Wisconsin DNR bat biologists, near the entrance of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Objectives

Our goal was to conduct an initial biological inventory (through sampling) of cave invertebrates, identify to family or genus (and if possible species) level animals present and develop a description of the invertebrate cave fauna, which may include various arachnids, crustaceans, and insects.

The findings of this study can help determine future cave management decisions and actions. The data from the inventory, and future monitoring & research at this site also can provide land managers and agency personnel with a model for developing better knowledge of important cave resources in Wisconsin.

Materials & Methods

We conducted field work to gather baseline data about invertebrate cave resources with the collaboration of our Wisconsin DNR Liaison (Jennifer Redell). On-site collections were made in HSB from the entrance zone to the Big Room (**Figure 1**), in order to obtain a representative sample of invertebrates found in the cave.

Collections were patch-based, where individual sample locations correspond to patches, and spatially explicit in that patches will be geo-referenced according to the locations on the cave map. Patches will be identifiable for future studies and contain information such as sample site description (water depth, water temperature, photograph, wall or ceiling collection, core sample, and other pertinent information to describe where the invertebrates were found).

All samples were taken back to the Illinois Natural History Survey (INHS) laboratories for identification. Each sample was recorded using standard data forms that correspond with notes taken in the field. This report describes the findings of our surveys, and provides data relevant to the Wisconsin DNR HSB Cave Management Plan document.

Below, we provide a list of macroinvertebrates identified based on inventory of the cave, and provide additional information on these animals as available. In addition, we provide Wisconsin DNR with general cave management recommendations as they relate to cave invertebrates. Because of the complexity of karst systems which tie all sorts of factors to the well being of cave invertebrates (such as impacts of water flow & quality, nutrient sources, and impacts of visitation), our recommendations may seem to reach much more broadly.

Sampling Methods

Litter samples were field-collected into two gallon Ziplock® bags (**Figure 8**) and kept cool until they could be transported to a building where extraction could be carried out, beginning later the same day. Extraction of invertebrate fauna was carried out utilizing a portable Berlese funnel device (**Figure 9**), and resulting samples preserved in ethanol were returned to the laboratory for sorting and identification.

For aquatic crustaceans, we used a funnel trap design developed by Todd Oakley (Duke University, 25 January 2009) wherein a 50 mL conical centrifuge tube – commonly found in laboratories using molecular biology techniques – has the cone shaped end cut off, with a hole drilled in the middle of it (~1/4 inch in diameter). This cone was glued inside of the threaded end of the tube (**Figure 10**), with a piece of discarded T-shirt rubber-banded onto the open end. A string tied around the trap and duct-taped in place was used for easy retrieval. Bait consisted of small pieces of raw shrimp, aged without refrigeration. These traps were placed in pooled water deep within the cave near the Big Room, weighted with a stone to keep them from floating. Two days later, the traps were recovered and removed from the cave, where the contents were removed. Some specimens were photographed live before final preservation in ethanol for return to the laboratory for sorting and identification.

Pitfall traps were used to collect ground-dwelling arthropods. These were small, wide mouth Nalgene jars buried in the soil/clay/sand/gravel up to their rims, partially filled with 80% ethanol, and with Limburger Cheese smeared just inside the upper lip of the jars (**Figure 11**). Special care was taken to ensure the substrate was back-filled all the way to the top of the jar, so that the rim of the jar did not limit block entry by the smallest arthropods (mites, springtails, etc.). Locations of traps were marked with flagging tape to aid in trap recovery, and traps were retrieved after two days, before being brought back to the laboratory for sorting and identification.

The surface film of isolated, small drip pools commonly harbors springtails and mites. This habitat is difficult to collect from, and we used both an aspirator and also removed springtails by dipping them out of the pools with a small plastic spoon (**Figure 12**).

The remaining invertebrate records are from either hand collections, often with forceps or an aspirator (**Figure 13**) or via photographs. Various microhabitats were carefully inspected, especially where ever there was suitable cover (small stones, debris) where animals could hide and/or deposits of organic material (wood, leaves, acorns, animal feces, etc.).

Figure 8. Jennifer Redell (Cave & Mine Specialist, Wisconsin DNR) and Steve Taylor with two-gallon Ziplock® bags full of leaf litter at the end of the first day of field sampling. Note the wetsuits - essential for work in this cave. Photo by Steven J. Taylor.

Figure 9. Collapsable Berlese funnels used to extract leaf litter fauna. The upper, cylindrical compartment is filled with leaf litter collected from the cave. Above it is suspended a 25 watt light bulb. The litter sits upon a coarse mesh (1/2 inch) hardware cloth, above a slippery cloth funnel, leading down to a container partially filled with ethanol preservative (and a sample label). Invertebrates in the litter move downwards in response to heat and drying, and are captured in the preservative. Photo by Steven J. Taylor.

Figure 10. Nearly completed funnel trap constructed from a 50 ml centrifuge tube. Photo by Steven J. Taylor.

Figure 11. A pitfall trap placed in a soil and clay bank in Horseshoe Bay cave. Striped flagging tape facilitated recovery of the traps. Photo by Steven J. Taylor.

Figure 12. A drip pool with plastic spoon used to dip out springtails and mites found on the surface film. Photo by Steven J. Taylor.

Figure 13. Steve Taylor using an aspirator to collect invertebrates from an old mouse nest. The yellowish device near his mouth is a filter used to block spores and other debris. Note the glistening water droplets on the cave ceiling, indicative of the presence of fungal and bacterial colonies. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Results & Discussion

Habitat Characteristics

Species vary in their use of microhabitats, and thus a brief summary of habitat characteristics in general is warranted. The physical position varies by taxon - some animals such as bats, cave crickets, the cave spider cave spider *Meta ovalis*, and the various genera of flies in the family Heleomyzidae are almost always only found on cave ceilings or walls. Others, such as earthworms, many springtails, aquatic isopods, and a variety of other taxa associated especially with decaying organic deposits, are most frequently encountered on the floor of caves, or on the lower parts of cave walls. This latter group, those found on the floor of the cave, is particularly vulnerable to effects of trampling by humans.

In attempting to understand the distribution and microhabitat use of caves, another spatial factors is even more important than spatial positioning mentioned above. The cave zones entrance, twilight, and dark are particularly important determinants of species distributions. These zones are of course aspects of a continuum in multiple dimensions, but nonetheless we define the **entrance zone** as that area which is under the dripline (the point at which vertical rain does not fall directly on the ground) of the cave, yet has sufficient light for plant growth such as mosses, ferns, and some flowering plants and in which fluctuations of light, temperature, and humidity take place on a daily basis with little moderation. As we move deeper into the cave, light levels drop off dramatically, and only a few plants, such as algae and a few mosses can survive in the dim light. This is the **twilight zone**, where temperature and humidity are often moderated somewhat by the deeper cave conditions, and energy sources begin to be more scarce. Beyond the twilight zone, there is a complete absence of light, and no flowering plants can survive beyond germinating and using up the energy already stored within the seed. Energy is very scarce here in the **dark zone**, and, typically, temperatures begin to approach the average yearly temperature of the area near the cave entrance, while relative humidity usually (especially when there is only a single entrance to the cave) become elevated and stable. Temperature, humidity, light, soil moisture, and available energy sources all vary from one zone to another, and these factors may also vary from cave to cave, depending on its configuration (for example a cold trap, or a cave with many entrances) and setting (a shallow cave beneath a parking lot may differ dramatically from a deep cave in a primary growth forest).

The presence and nature of water in caves is also important. Much of the deeper portions of Horseshoe Bay Cave are strongly influenced by the perennial presence of water pooled in the cave passage. This limits available habitats for ground-dwelling taxa, while providing habitat for some aquatic species. Closer to the entrance of Horseshoe Bay Cave, there is only occasional pooled water much of the year, but occasional heavy flooding probably limits what species can maintain continuous populations within the cave. Water dripping from the ceiling of the cave from the bedrock and soils above can provide a window into a little-studied ecosystem, the **epikarst**, where a variety of small animals, many aquatic but some terrestrial, have yet to be studied. These drips can accumulate in small drip pools, which not only have the potential to harbor animals from the epikarst, but also can serve as a habitat for tiny invertebrates living on the surface film of the water - such as certain springtails and mites.

The nature of the substrate - breakdown, loose rocks, bedrock, gravel, sand, and clay - can influence the composition of the cave ecosystem.

Organic materials

In the absence of sunlight or any other obvious chemoautotrophic energy sources in Horseshoe Bay Cave, it is reasonable to assume that most energy in the cave comes from organic materials that fall into the cave, or are washed into the cave (via sinkholes above). Other energy can be brought into the cave by vertebrate animals (**Figure 14**) and some invertebrates which utilize the cave habitat temporarily, such as bats and mice and cave crickets, with their feces (**Figure 15**), dead bodies, nesting materials (**Figure 16**), and remains prey items (**Figure 17**) forming rich sources of energy for cave adapted invertebrates. Where the cave passage is not too deep below the surface, and plant roots can penetrate deeply and emerge into the cave, where they, too, may serve as an energy source (**Figure 18**). This organic material, largely from sources mentioned above, is soon colonized by fungal and bacterial communities that often need little more than dissolved organics transported in groundwater and perhaps deposited on the cave walls to be able to grow and reproduce (**Figure 19**). Small invertebrates such as springtails (Collembola) and mites (Acari) may graze on these fungal and microbial communities, in addition to feeding directly on decomposing organic materials. These species, in turn, may fall prey to larger invertebrates such as spiders.

Figure 14. An acorn, perhaps brought into the cave by a mouse, serves as a rich source of energy for fungi, bacteria, springtails, and other animals. Photo by Steven J. Taylor.

Figure 15. Fresh bat guano is an important source of energy for cave invertebrates. The potential impact on invertebrates in cave ecosystems caused by the decimation of North American cave-dwelling bats by WNS has not been well studied. Photo by Steven J. Taylor.

Figure 16. An old mouse nest on a wall ledge in the dark zone of Horseshoe Bay Cave (pencil for scale). Nest materials brought into the cave by mammals serve as a rich source of energy for microbial and invertebrate communities. Photo by Steven J. Taylor.

Figure 17. Bats commonly return from foraging while still holding uneaten moths, finishing the snack while roosting in the cave. The wings of the moths are discarded by the bats and fall to the cave floor (as seen here, in Horseshoe Bay Cave), but serve as an energy source for cave invertebrates and microbes, in addition to serving as a sign of bat usage of the cave. Photo by Steven J. Taylor.

Figure 18. Tree roots penetrating into Horseshoe Bay Cave from the land above are not common, but do bring energy into the cave ecosystem. Photo by Steven J. Taylor.

Figure 19. Microbial (fungi and bacteria) colonies, some covered with glistening water droplets, are common on cave walls and ceilings of the dark zone in Horseshoe Bay Cave. Several hundred species of fungi and bacteria may occur in an area only a few inches across. Flies, springtails, and other invertebrates may be found, presumably feeding, in such habitats. Photo by Steven J. Taylor.

Other Cave Resources

The primary focus of this study is cave macroinvertebrates. However, we would like to point out that the cave does harbor a variety of other cave resources including speleothems (cave formations) (**Figure 20**) and interesting features such as vermiculations (**Figure 21**), ancient gravel fills possibly dating back to the Pleistocene (**Figure 22**), and even possible paleontological deposits (**Figure 23**). These resources are fragile in their own ways, and are subject to damage through ignorance of their presence and values.

Figure 20. Although Horseshoe Bay Cave is not well decorated with speleothems, a few formations, such as these, can be found in the cave. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Figure 21. Vermiculations formed of mud or clay on the cave ceiling are common in parts of Horseshoe Bay Cave. The formation of these features has been studied by various authors (e.g., Bini et al. 1978). Two flies (Heleomyzidae) can be seen perched among the vermiculations. Photo by Steven J. Taylor.

Figure 22. Some older gravel fill in portions of Horseshoe Bay Cave, such as this one, may date from the Pleistocene. Photo by Steven J. Taylor.

Figure 23. Old bat bones in Horseshoe Bay Cave being eroded out of the cave substrates due to the action of water. It is possible these bones are quite old, and, if so, they may be able to tell us a story about the use of this cave by bats in ancient times. Digging to enlarge or open passages can destroy such deposits. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Ecological Classification

Invertebrate Taxa

Mollusca
  Gastropoda
    Stylommatophora
      Arionidae
        Arion subfuscus

Slugs (**Figure 24**) were found in the entrance zone on the ground under leaf litter and on bedrock. This is likely *Arion subfuscus* (Draparnaud, 1805), an introduced Palearctic species that feeds on plant material and debris (Beyer and Saari 1978). These animals probably occur widely in cool, moist litter habitats in forests of Door County, Wisconsin.

Mollusca
  Gastropoda
    Stylommatophora
      Zonitidae
        ? Paravitrea multidentata ?

A single individual of a terrestrial snail was collected from the surface of the soil under a stone in the twilight zone (**Figure 25**). Since Hubricht's (1985) monograph on land snails of eastern North America, much work has been undertaken in Wisconsin under the direction of Kathryn E. Perez (Department of Biology, University of Wisconsin - La Crosse)[1]. Nekola (2004) found this species commonly in Door County, where it was restricted to upland forests and rock outcrops.

Mollusca
  Gastropoda
    Stylommatophora
      Zonitidae
        ? *Striatura ferrea* ?

A land snail (**Figure 26**) was taken in leaf litter at the entrance to Horseshoe Bay Cave, and is likely an accidental. Since Hubricht's (1985) monograph on land snails of eastern North America, much work has been undertaken in Wisconsin under the direction of Kathryn E. Perez (Department of Biology, University of Wisconsin - La Crosse)[1]. Nekola (2004) recorded multiple locations for this species in Door County, which was largely limited to forest habitats, with a preference for "rich, lowland forests."

[1] http://www.uwlax.edu/biology/faculty/perez/Perez/PerezLab/Research/WIsnails.html

Figure 24. A slug (Gastropoda: Stylommatophora), probably *Arion subfuscus* (Arionidae), from the entrance of Horseshoe Bay Cave. These animals are likely common in cool, most shaded areas with woodland leaf litter throughout Door County, Wisconsin. Photo by Steven J. Taylor.

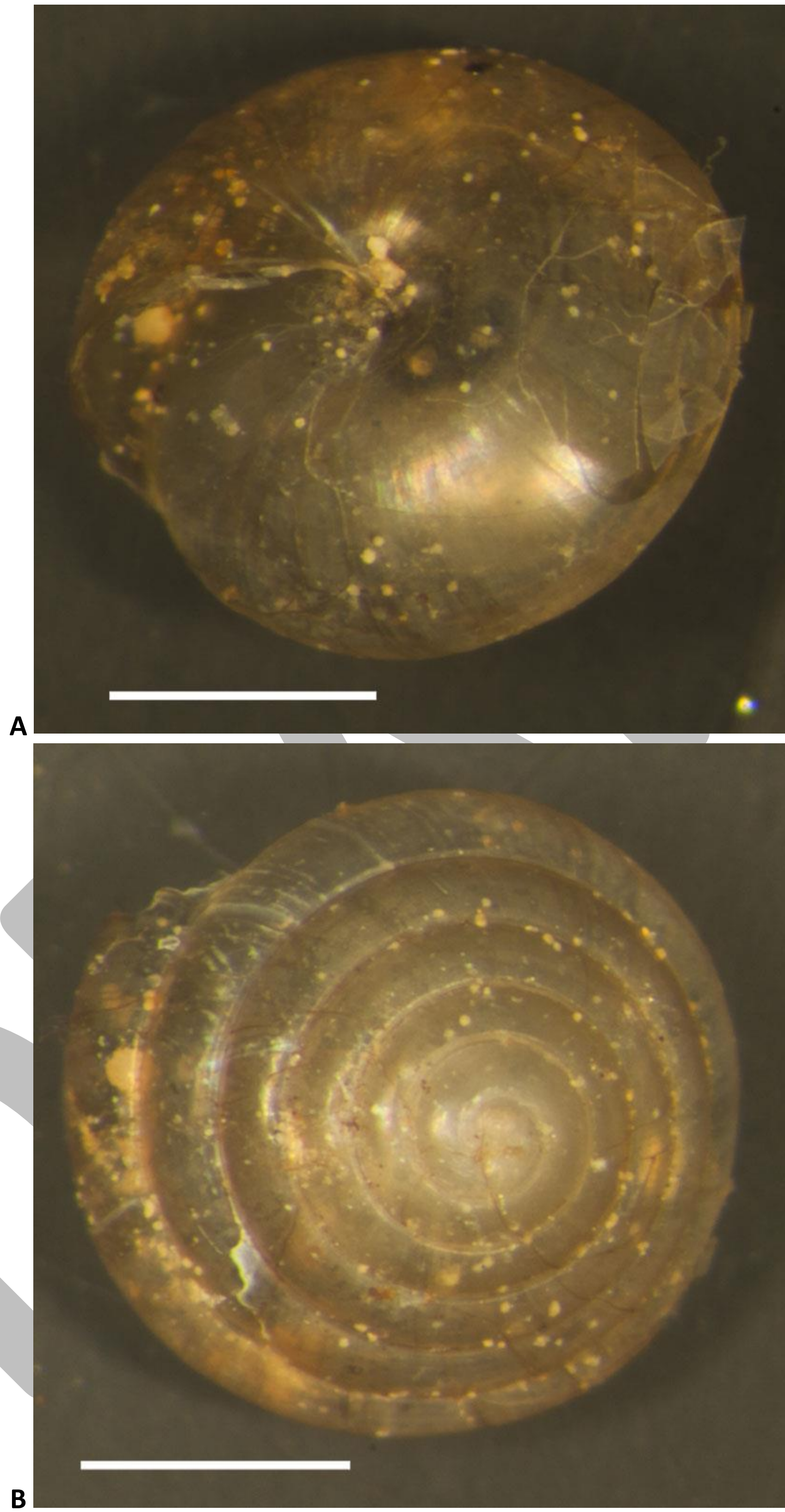
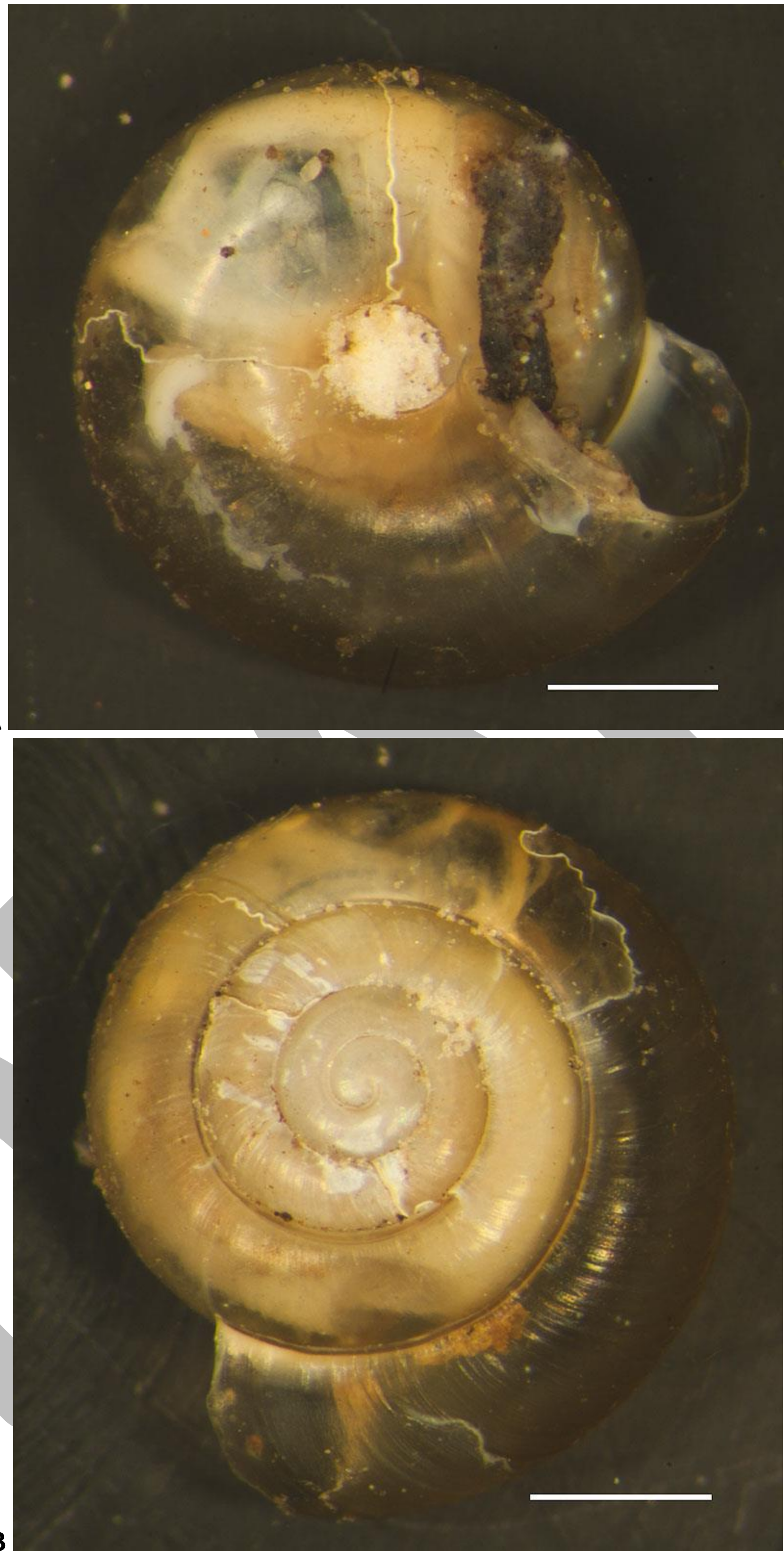


Figure 25. A terrestrial snail, probably *Paravitrea multidentata* (Zonitidae), from the twilight zone of Horseshoe Bay Cave. A. bottom, B. top. Scale bar is 1 mm. Photo by Steven J. Taylor.



A

B

Figure 26. A terrestrial snail, probably *Striatura ferrea* (Zonitida), from leaf litter in the entrance zone of Horseshoe Bay Cave. A. bottom, B. top. Scale bar is 1 mm. Photo by Steven J. Taylor.

Annelida
Clitellata
Opisthopora
Lumbricidae
Eiseniella tetraedra
Allolobophora chlorotica

Several collections of megadrile earthworms were made in Horseshoe Bay Cave, and these were examined by taxonomists J.W. Reynolds (Kitchener, Ontario, Canada) and M.J. Wetzel (Illinois Natural History Survey, University of Illinois). In addition to an undetermined juvenile specimen in this family, two species, *Eiseniella tetraedra* (Savigny, 1826) (**Figure 27**) and *Allolobophora chlorotica* (Savigny, 1826) (**Figure 28**), were recorded. Both species are considered introduced, are widespread and commonly collected, and have previously been recorded from Wisconsin (Reynolds and Wetzel 2004, 2008, 2012). The family Lumbricidae is the largest, most diverse family of earthworms in North America, with the largest number of introduced species. *Eiseniella tetraedra* was found on soil/clay floor in the dark zone, more than 200 feet into the cave, while *A. chlorotica* was found in the entrance on soil under leaf litter.

Annelida
Clitellata
Enchytraeida
Enchytraeidae
Fridericia sp.

A microdrile worm, *Freidericia* sp., was identified by taxonomist M.J. Wetzel from material taken in the Big Room and at the entrance dripline of Horseshoe Bay Cave. Worm tailings observed in the Big Room (**Figure 29**) could be produced by this species. Unfortunately these animals are immatures, and thus cannot be identified to species level (Kathman and Brinkhurst 1998, Wetzel et al. 2009). This genus is common to microhabitats both aquatic and terrestrial, and is likely a common native species (M.J. Wetzel, per. comm. 2013).

Figure 27. *Eiseniella tetraedra* (Annelida: Clitellata) from Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 28. *Allolobophora chlorotica* (Annelida: Clitellata) from Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 29. Fecal pellets on the floor of the Big Room. These may be worm tailings of *Freidericia* sp. (Annelida: Enchytraeidae). Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Arthropoda
- Malacostraca
  - Amphipoda
    - Crangonyctidae
      - *Crangonyx* sp.

An amphipod of the genus *Crangonyx* was recorded from pooled water deep in the lower level passage leading to the Big Room (**Figure 30**). This species appears intemediate in its degree of cave adaptation, as the ommatidia of the eye are somewhat reduced (**Figure 31**), suggesting it is possible this form may be restricted to groundwater habitats. Eye development in the genus *Crangonyx* varies from fully developed with essentially no space between ommatidia in some surface species, to completely lacking eye pigment in some troglobitic species. More research is needed, especially using baited funnel traps in shallow wells, to document the distribution of this animal in Door County, Wisconsin karst groundwaters.

Species of *Crangonyx* likely to occur in the Great Lakes region include *Crangonyx richmondensis* Ellis, 1940, C*rangonyx gracilis* Smith 1871, and *Crangonyx pseudogracilis* Bousfield 1958, all widespread species mostly from surface habitats and only rarely recorded from caves (Zhang and Holsinger 2003). There are records for *C. richmondensis* and *C. gracilis* from surface habitats in Manitowoc County, Wisconsin and for *C. pseudogracilis* from surface habitats in Calumet County, Wisconsin (Zhang and Holsinger 2003). Peck (1988) reports *C. gracilis*, *C. pseudogracilis*, and *C. rivularis* from caves in Canada, and Barton and Hynes (1976) record *C. gracilis* and *C. pseudogracilis* in shallow waters of the Great Lakes on the Canadian side.

Arthropoda
Malacostraca
Isopoda: Oniscoidea
Cylisticidae
Cylisticus convexus

Terrestrial isopods, *Cylisticus convexus* (De Geer 1778), were common under leaf litter and stones and low on bedrock walls in cool, moist microhabitats at the entrance to Horseshoe Bay Cave (**Figure 32**). These are likely widespread in woodland habitats and other habitats in Door County. Jass and Klausmeier (1987, 1996, 2000) record eleven species of terrestrial isopods from Wisconsin. While our collections represent a new county record for *Cylisticus convexus*, and in fact for the entire suborder Oniscoidea, in Wisconsin (see: Jass and Klausmeier 1996), but this is no doubt merely and artifact of limited collecting.

Arthropoda
Malacostraca
Isopoda
Asellidae
Caecidotea sp.

A single aquatic isopod, *Caecidotea* sp. (**Figure 33**), was collected well into the dark zone in a pool at the base of the Wall Room (Figure 2). The specimen has a weakly developed eye, light grey body pigmentation, and the appendages are not markedly elongate. Jass and Klausmeier (1997) record four species of freshwater isopods (*Ceacidotea communis*, *Ceacidotea forbesi*, *Ceacidotea intermedia*, and *Ceacidotea racovitzai*) from Wiscosin, all in the genus *Ceacidotea*, but *Lirceus lineatus* (Say, 1818*)*, is also known only from the state (<http://winvertebrates.uwsp.edu/4140.html>, accessed 16 December 2013), and Hubricht and Mackin (1949) record *L. lineatus* as widespread, extending north into waters of Ontario, and Barton and Hynes (1976) record *L. lineatus*, *C. forbesi*, *C. intermedia*, and *C. racovitzai* from the Great Lakes on the Canadian side. Our specimen is not a mature male, and thus species-level identification is not feasible, however, it does not appear to be markedly cave adapted.

Figure 30. Aquatic habitat where *Crangonyx* sp. was collected. This is the lower level passage leading from the "Crevice" to the "Big Room," more than 600 feet from the cave entrance (see **Figure 2**). Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Figure 31. Live photograph of a groundwater amphipod, *Crangonyx* sp., collected near the Big Room in Horseshoe Bay Cave (Door County, Wisconsin). Photo by Steven J. Taylor.

Figure 32. A terrestrial isopod, *Cylisticus convexus*, at the base of a bedrock wall in entrance zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 33. An aquatic isopod, *Caecidotea* sp. (Asellidae) taken from a pool in the dark zone. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
Maxillopoda
Clyclopoida

Two tiny freshwater cyclopoid copepods (**Figure 34**) were taken in pooled water at the bottom of the big crevice, and an additional ~50 specimens were observed in a drip pool in the Rocky Mountain Room (**Figure 2**), some 200 feet into the cave in the dark zone of Horseshoe Bay Cave. These may be a groundwater species, but even family-level identification is difficult. Copepods are common in caves, and some cave-limited taxa have been described. When epikarst is sampled via ceiling drips entering a cave copepods are among the most frequently collected groups of invertebrates (e.g., Pipan and Culver 2013).

Arthropoda
Arachnida
Acari

A variety of mite species were taken at Horseshoe Bay Cave from soil normal soil floor under litter in the entrance zone and from Berlese-extracted leaf litter habitats near the entrance to the dark zone where mites were observed on the surface of a drip pool deeper in the cave. Mite identifications are difficult, and few taxonomic experts work in this area. A few of the species recorded are shown in **Figures 35-40**.

Arthropoda
Arachnida
Araneae
Agelenidae
cf *Cicurina* sp.

A funnel-web spider, probably *Cicurina* sp. (**Figure 41**), was taken from normal-moisture soil floor under litter in the entrance zone.

Arthropoda
Arachnida
Araneae
Amaurobiidae

A hacklemesh weaver (Amaurobiidae) was extracted from a leaf litter sample taken at the entrance of the cave.

Arthropoda
Arachnida
Araneae
Linyphiidae
Lepthyphantes sp.

Undetermined

Two sheet-web weavers (Linyphiidae) were collected at Horseshoe Bay Cave, including one that is perhaps *Lepthyphantes* sp. (**Figure 42**). Linyphiids are commonly associated with North American cave habitats.

Arthropoda
Arachnida
Araneae
Pisauridae
Dolomedes sp. Fishing Spider
Pisaurina sp. Fishing Spider

Two genera of fishing spiders were recorded from the *Dolomedes* sp. (**Figure 43**) was taken from a dry bedrock wall at the entrance, while *Pisaurina* sp. (**Figure 44**) was taken well within the dark zone, on normal-moisture sandy floor between pitfalls 2 and 3.

Arthropoda
Arachnida
Araneae
Tetragnathidae
Meta ovalis (Gertsch, 1933)

The cave spider *Meta ovalis* (Gertsch, 1933) is common in caves of the eastern United States and southeastern Canada, and is without a doubt the most frequently encountered spider found in the entrance and twilight zones of caves in eastern North America (Dondale et al. 2003). Yoder et al. (2009) suggest that entomopathogenic fungi found on *M. ovalis* may be pathogenic to some cave crickets (Rhaphidophoridae). Prey of *M. ovalis* may include millipeds (Reeves et al. 2000, Slay et al. 2009), ground beetles (Lavoie et al. 2007, Reeves et al. 2000), spiders and cave crickets (Lavoie et al. 2007), and these spiders have been found co-occurring with aggregations of cave crickets (Yoder et al. 2010). *Meta ovalis* was found in Horseshoe Bay Cave, primarily in the entrance and twilight zones (**Figures 45, 46**).

Arthropoda
Arachnida
Araneae
Theridiidae

A adult male comb-clawed spider (**Figure 47**) was taken from a dry bedrock ceiling in the twilight zone.

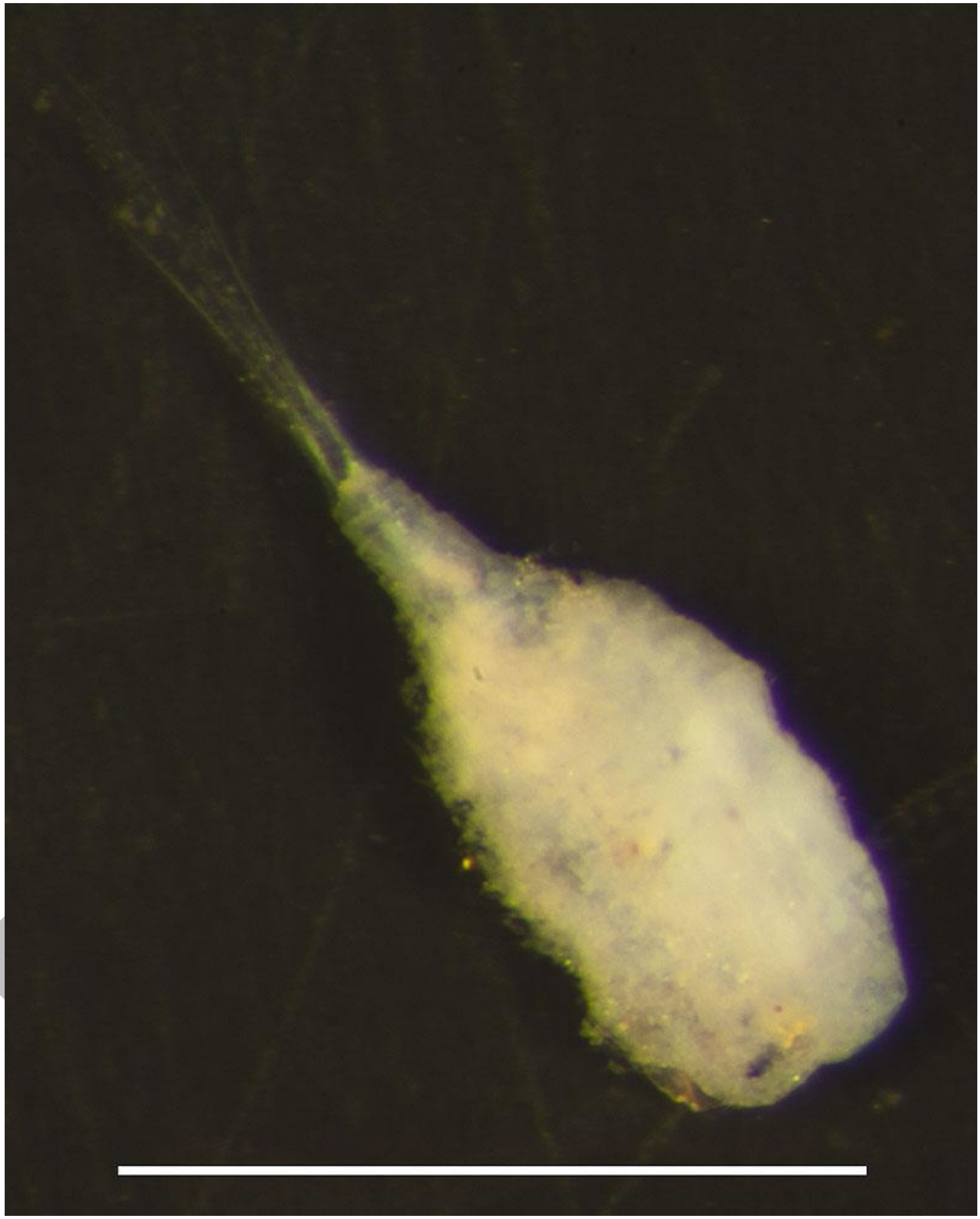


Figure 34. A clyclpoid copepod from groundwater in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 35. A mite taken from normal soil floor under litter in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

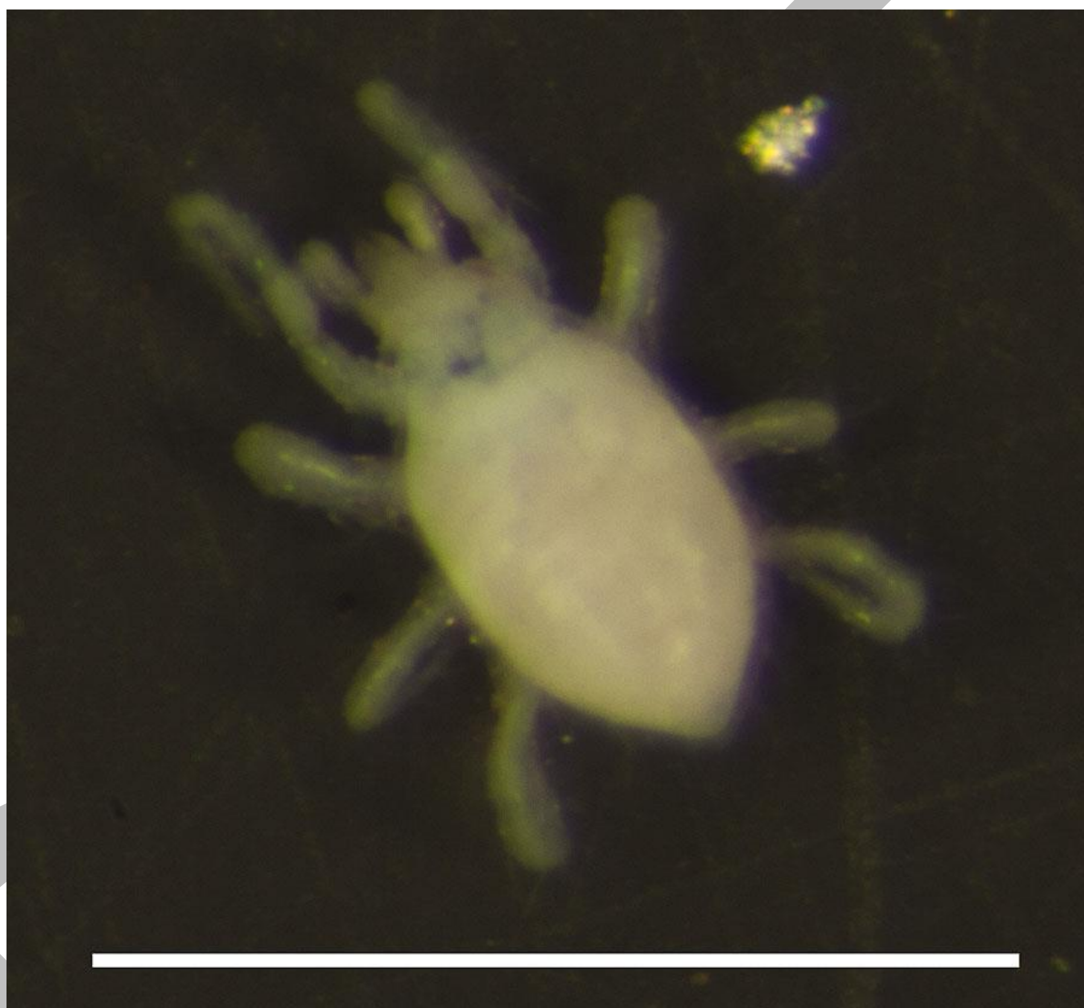


Figure 36. A mite taken from Berlese leaf litter extraction from entrance zone in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 37. A mite taken from Berlese leaf litter extraction from entrance zone in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

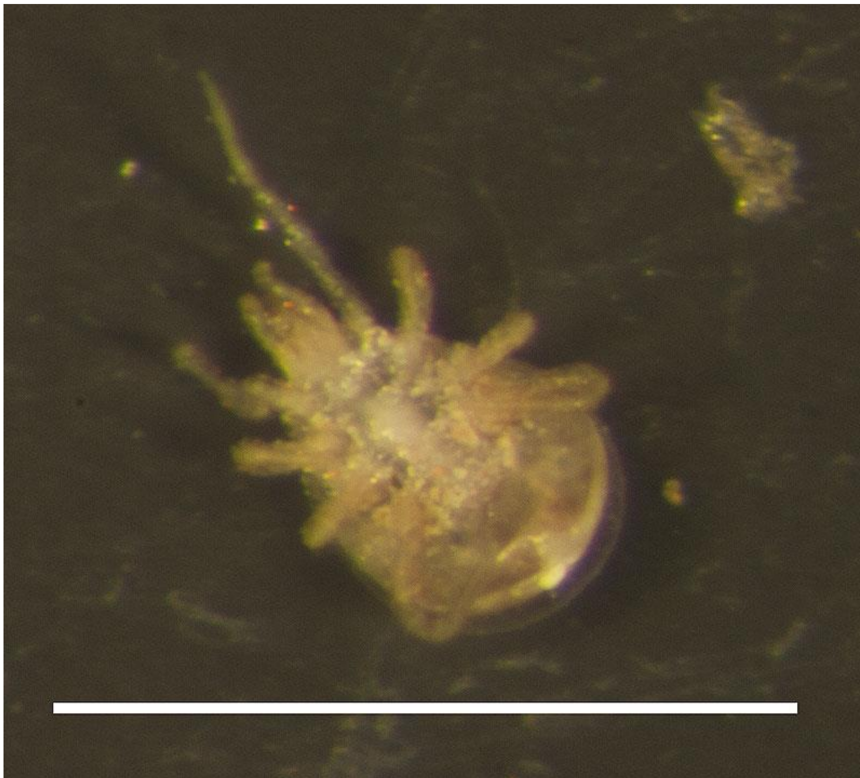


Figure 38. A mite taken from Berlese leaf litter extraction from entrance zone in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 39. A mite taken from normal soil floor under litter in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 40. A mite taken from soil floor under litter in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 41. *Cicurina* sp., a funnel-web spider (Agelenidae) from the entrance zone of Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 42. *Lepthyphantes* sp. (Linyphiidae), a sheet-web weaver, was taken a from soil floor under litter in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 43. *Dolomedes* sp. (Araneae: Pisauridae) from the entrance of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 44. *Pisaurina* sp. (Araneae: Pisauridae) from the dark zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 45. An adult female *Meta ovalis* (Tetragnathidae) with her egg case, at the junction of the cave wall and ceiling in the entrance zone of Horseshoe Bay Cave, 25 July 2013. Photo by Steven J. Taylor.

Figure 46. An adult male *Meta ovalis* (Tetragnathidae) from Horseshoe Bay Cave,. Photo by Steven J. Taylor.

Figure 47. A comb-clawed spider (Araneae: Theridiidae) from the dark zone of Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
Arachnida
Opiliones
Sclerosomatidae
Leiobunum sp.

The common harvestman *Leiobunum* sp. was collected from the entrance zone of Horseshoe Bay Cave (**Figure 48**) both from dry bedrock walls and ceilings and from beneath leaf litter on the ground. These arachnids commonly roost in caves and crevices during the daytime, foraging in the forest during the night.

Arthropoda
Arachnida
Opiliones
Sabaconidae

A smaller havestman, *Sabacon cavicolens* (Packard 1884), (**Figure 49**) was taken under a stone on soil of normal moisture in the twilight zone. It has well developed eyes, and is not cave-limited. Shear (1975) recorded this species from northwestern Kewaunee County, essentially on the Door peninsula.

Arthropoda
Symphyla
Scutigerellidae
Scutigerella sp.

Specimens (**Figure 50**) collected from normal moisture sandy soild with gravel, under stones in the Cloak Room (**Figure 2**) key readily to *Scutigerella* in Edwards (1959). *Scutigerella immaculata* is sometimes considered a pest species in crops, feeding on small roots and decaying vegetation. Some 27 species have been described in this genus. It is somewhat odd that no other myriopods were recorded from the cave.

Figure 48. The common harvestman *Leiobunum* sp. (Opiliones Sclerosomatidae) from Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 49. A harvestman, *Sabacon cavicolens* (Opiliones: Sabaconidae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 50. Two symphylans, *Scutigerella* sp. (Scutigerellidae) from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
Collembola
Poduromorpha
Hypogastruridae
Ceratophysella sp.

Two specimens of a springtail in the genus *Ceratophysella* were recorded from the surface film of a drip pool (**Figure 51**) in the Rocky Mountain Room (**Figure 2**), some 200 feet into the cave in the dark zone of Horseshoe Bay Cave.

Arthropoda
Collembola
Entomobryomorpha
Entomobryidae
Entomobrya nivalis

Entomobrya nivalis was collected from a Berlese leaf litter sample taken from dry, sandy soil, just inside the cave entrance. This species is likely incidental in Horseshoe Bay Cave.

Arthropoda
Collembola
Entomobryomorpha
Entomobryidae
Lepidocyrtus paradoxus
Lepidocyrtus violaceus
Lepidocyrtus languinosus
Lepidocyrtus sp. 1

Four species of *Lepidocyrtus* (**Figure 52**) were recorded from leaflitter in the entrance zone, by a mixture of hand collecting and Berlese extraction. These species are likely incidental in Horseshoe Bay Cave, but are among the most dominant taxa in the entrance zone, where they accounted for 92 of the recorded specimens.

Arthropoda
Collembola
Entomobryomorpha
Entomobryidae
Pseudosinella sp.

One species, and only one specimen, of *Pseudosinella* (**Figure 53**) was recorded, taken by hand from old mammal scat in the twilight zone.

Arthropoda
Collembola

Entomobryomorpha
Entomobryidae
Sinella sp. 1
Sinella sp. 2

Two *Sinella* species were recorded, taken by hand under a rock in the Rocky Mountain Room (**Figure 2**), and from wet wood in the Big Room (**Figure 2**), and from the surface film of a drip pool (**Figure 51**) in the Rocky Mountain Room (**Figure 2**), some 200 feet into the cave in the dark zone of Horseshoe Bay Cave. These species clearly have some sort of cave association, and were not recorded from the entrance or twilight zones. In total, three specimens of one species and four other the other were collected.

Arthropoda
Collembola
Entomobryomorpha
Isotomidae
Folsomia sp.

A springtail belonging to the genus *Folsomia* was collected from the surface film of a drip pool (**Figure 51**) in the Rocky Mountain Room (**Figure 2**), some 200 feet into the cave in the dark zone of Horseshoe Bay Cave.

Arthropoda
Collembola
Entomobryomorpha
Tomoceridae
Pogonognathellus sp. 1
Pogonognathellus sp. 2

Two species of *Pogonognathellus* were recorded from Horseshoe Bay Cave, where they were taken in litter and under stones in the entrance and twilight zones (*Pogonognathellus* sp. 1) and from Berlese leaf litter extractions (*Pogonognathellus* sp. 2). Though the genus is widespread and frequently recorded from surface habitats, Soto-Adames and Taylor (2013) recorded one species in the P*ogonognathellus flavescens* species complex (**Figure 54**) as common in Illinois caves, where it was common in the dark zone. This was not the case at Horseshoe Bay Cave.

Arthropoda
Collembola
Symphypleona
Katiannidae
Sminthurinus sp.

Two specimens of a species of *Sminthurinus* were taken at the entrance in leaf litter, and these are likely incidental in the cave.

Arthropoda
Collembola
Symphypleona
Arrhopalitidae
Pygmarrhopalites sp.

Numerous species of the genus *Pymarrhopalites* (**Figure 55**), or globular springtails, are thought to be narrowly endemic troglobites, though some cave-inhabiting taxa are widespread (Soto-Adames and Taylor 2013, Zeppelini et al. 2009). Globular springtails are most frequently collected in caves by careful examination of the surface film of drip pools, but they are also sometimes hand collected, especially in riparian cave habitats, or taken in pitfall traps. The Horseshoe Bay Cave specimens were taken from the surface film of a drip pool (**Figure 51**) in the Rocky Mountain Room (**Figure 2**), some 200 feet into the cave in the dark zone.

Figure 51. Drip pool where a mite was oabserved and sprintails (Collembola) of four species were collected: *Pygmarrhopalites* sp. 1, *Ceratophysella* sp., *Sinella* sp. 1, and *Sinella* sp. 2. Photo by Steven J. Taylor.

Figure 52. *Lepidocyrtus helenae*, a representative member of the genus. This photograph is shown only to give a sense of the genus - this species was not recorded from Horseshoe Bay Cave. Photo by Felipe N. Soto-Adames.

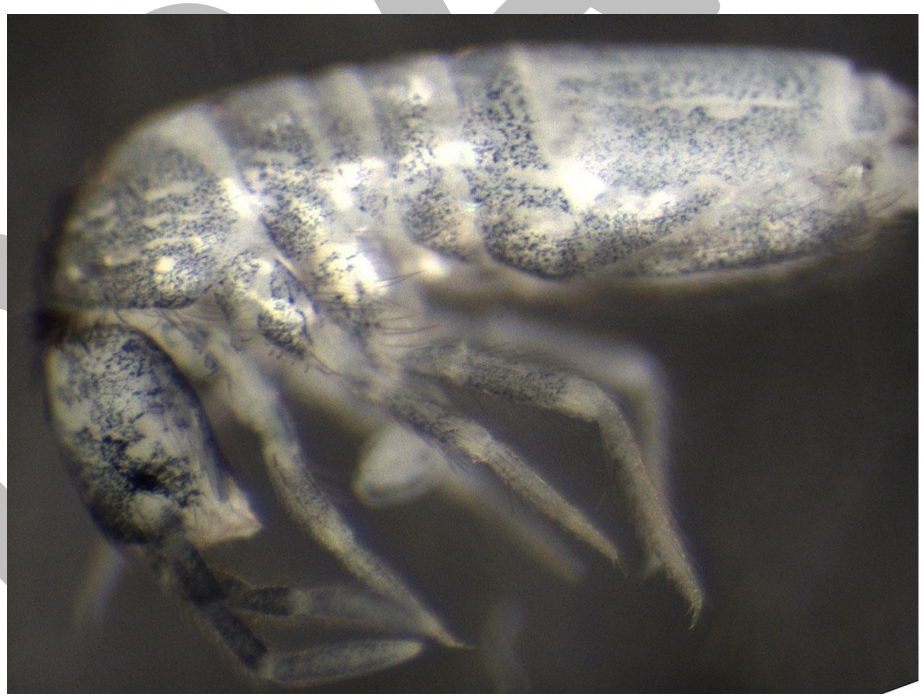


Figure 53. *Pseudosinella aera* from an Illinois cave, a representative member of the genus. This photograph is shown only to give a sense of the genus - this species was not recorded from Horseshoe Bay Cave. Photo by Felipe N. Soto-Adames.

Figure 54. A species in the *Pogonognathellus flavescens* species complex, from an Illinois cave, as a representative member of the genus. This photograph is shown only to give a sense of the genus - this species was not recorded from Horseshoe Bay Cave. Photo by Felipe N. Soto-Adames.

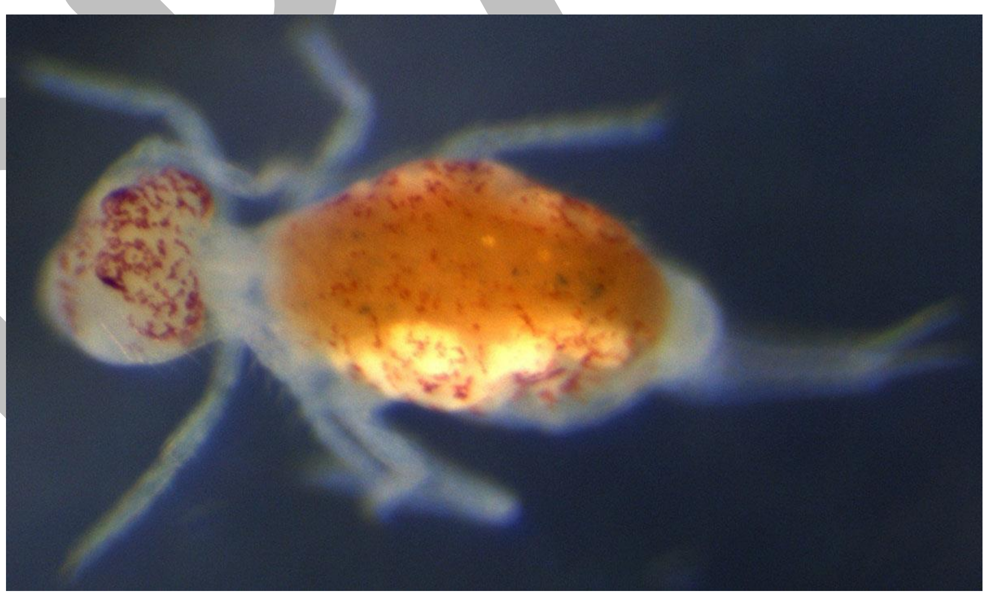


Figure 55. *Pygmarrhopalites sapo* from an Illinois cave as a representative member of the genus. This photograph is shown only to give a sense of the genus - this species was not recorded from Horseshoe Bay Cave. Photo by Felipe N. Soto-Adames.

Arthropoda
Insecta
Zygentoma
Machilidae

A silverfish (**Figure 56**) was taken on a dry bedrock wall in the entrance zone, and is clearly an accidental species.

Arthropoda
Insecta
Orthoptera
Rhaphidophoridae
Ceuthophilus sp.

A single specimen belonging to the genus *Ceuthophilus* (**Figure 57**) was collected from a dry bedrock wall in the twilight zone of the cave. The genus *Ceuthophilus* includes some species with strong ties to the cave environment, but also some woodland species and species found in association with animal burrows. Cavernicolous species in Texas, southern New Mexico, and Kentucky roost in caves during the daytime, leaving the caves at night to forage (primarily upon plant material). Taylor et al. (2005) defined the minimum foraging range for one species in Texas as being up to 344 feet from the cave entrance, suggesting a zone around caves needs to be protected to protect the full functioning of cave ecosystems.

Arthropoda
Insecta
Hemiptera
Nabidae

A nymph of the family Nabidae (**Figure 58**) taken at the cave entrance is an accidental.

Arthropoda
Insecta
Coleoptera
Curculionidae
Cryptorhynchinae

A weevil belonging to the large subfamily Cryptorhynchinae (**Figure 59**) was taken at the entrance, and is an accidental.

Figure 56. A silverfish (Machilidae) from the entrance zone of Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 57. A cave cricket (*Ceuthophilus* sp., Rhaphidophoridae) from the twilight zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 58. A nabid nymph from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 59. A weevil (subfamily Cryptorhynchinae) from the entrance of Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
    Insecta
        Coleoptera
            Curculionidae
                Entiminae

Two Entiminae (broad-nosed weevils, **Figure 60**) were taken in leaf litter samples from inside the cave entrance and are accidentals.

Arthropoda
    Insecta
        Coleoptera
            Scarabaeidae
                Aphodiinae

An Aphodinae scarab beetle (**Figure 61**) was taken from under a stone about 5 feet in-cave from the entrance gate, but is probably an accidental.

Arthropoda
    Insecta
        Coleoptera
            Scarabaeidae
                Melolonthinae

A Melolonthinae scarab beetle (**Figure 62**) taken at the entrance to the cave is an accidental.

Arthropoda
    Insecta
        Coleoptera
            Staphylinidae

Some rove beetles are clearly cave-associated (Peck and Thayer 2003), though none are troglobites. It is unclear if the larval rove beetles (**Figure 63**) we collected off of mammal scat in the deep twilight zone is particularly cave associated.

Figure 60. A weevil (subfamily Entiminae) from the entrance of Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 61. A scarab beetle (subfamily Aphodinae) from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 62. A scarab beetle (subfamily Melolonthinae) from the entrance of Horseshoe Bay Cave. Photo by Steven J. Taylor.

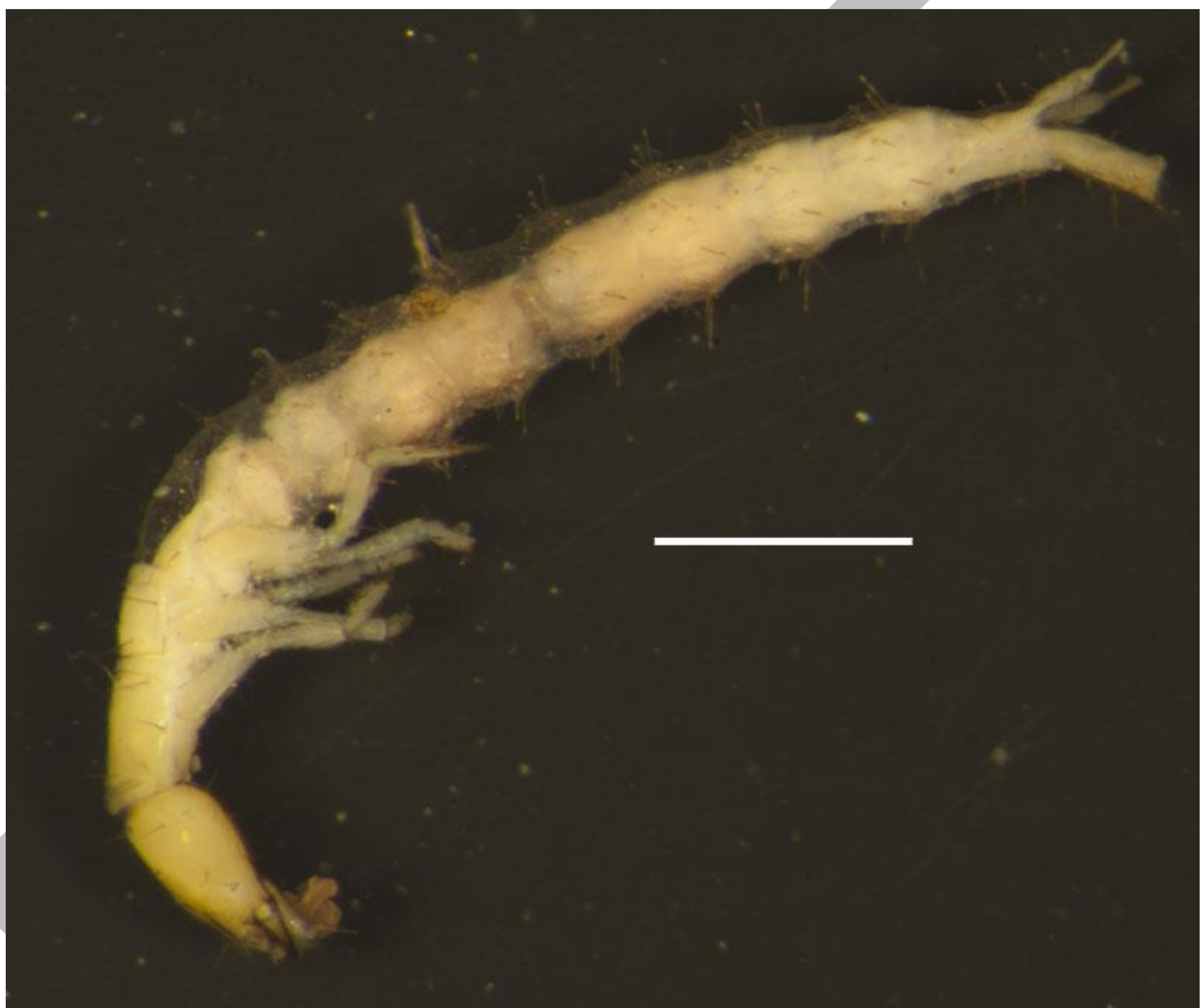


Figure 63. Larval rove beetle (Staphylinidae) from scat in Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
Insecta
Diptera
Cecidomyiidae

Gall gnats of several genera have been reported from caves in the Arkansas and Missouri Ozarks (Barnes et al. 2009), Ontario (Peck 1988) and Georgia (Reeves et al. 2000). Ozark specimens belonged to four genera taken in the entrance and twilight. Our specimens (**Figure 64**), adults, were collected in habitats in the entrance zone, including dry bedrock wall and ceiling and on the floor under litter.

Figure 64. Gall gnat (Cecidomyiidae) from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
    Insecta
        Diptera
            Chironomidae

Various midges have been recorded from caves in the midwest (Peck and Lewis 1978) and Canada (Peck 1988). Ours (**Figure 65**), taken on bedrock in the entrance zone, are likely accidentals.

Arthropoda
    Insecta
        Diptera
            Culicidae
                Culex sp.

A mosquito of the genus *Culex* was taken from a dry bedrock wall (**Figure 66**), and another was taken under leaf litter, both from the entrance zone. Though these animals are not particularly cave adapted, mosquitoes commonly utilize caves as overwintering sites (Barnes 2004), and *Culex pipians* is among the most frequently recorded from midwestern caves (Barnes et al. 2009, Peck and Lewis 1978). Peck (1988) lists a variety of mosquito taxa from caves in Canada, including *Culex restuans*.

Figure 65. A midge (Chironomidae) from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 66. A mosquito, *Culex* sp., resting on a dry bedrock wall in the entrance zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Arthropoda
  Insecta
    Diptera
      Heleomyzidae
        Oecothea sp.
        Amoebaleria sp.
        Heleomyza sp.

These three Sun Fly genera are frequently associated with cave environments (Barnes et al. 2009, Peck and Lewis 1978, Peck 1988). *Oecothea* sp. (**Figure 67**), perhaps *Oecothea specus*, was taken in the twilight zone from bedrock ceiling habitat. *Amoebaleria* sp. (**Figure 68**), likely either *Amoebaleria defessa* or *Amoebaleria sackeni*, was taken from sandy walls well into the dark zone in the Rocky Mountain Room (Figure 2), and *Heleomyza* sp. was taken from normal bedrock wall habitat just beyond the Cloak Room (Figure 2).

Arthropoda
  Insecta
    Diptera
      Mycetophilidae
        Rymosia sp.
        Undetermined

The fungus gnat *Rymosia* sp. (**Figure 69**) was taken from soil floor under litter near bedrock wall in the entrance zone. Species in this genus have been recorded from caves in Illinois (Peck and Lewis 1978), Georgia (Reeves et al. 2000), Canada (Moseley 2007, Peck 1988) and Arkansas, Missouri, and Oklahoma (Barnes et al. 2009), and some species may be troglophiles (Barnes et al. 2009). An undetermined genus of fungus gnat (**Figure 70**) was taken on dry bedrock wall habitat, also in the entrance zone and also probably an accidental.

Arthropoda
  Insecta
    Diptera
      Phoridae
        Megaselia sp.

Several scuttle flies were collected (**Figure 71**). The scuttle fly genus *Megaselia* is a large genus with many described species (Disney et al. 2010, 2011). Four species in the genus are known to be characteristic of Nearctic caves: *Megaselia breviterga, M. cavernicola, M. spelophila* and *M. taylori*, though more than a dozen other species have been recorded from Nearctic caves (Disney et al. 2010), with at least one species recorded from Canadian caves (Peck 1988, Moseley 2007). The saparophilic larvae of these phorids likely develop in caves, and adults of some species show peaks in abundance associated with cave conditions such as elevated humidity and low light levels (Disney et al. 2010).

Figure 67. A heleomyzid fly, *Oecothea* sp., from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 68. A heleomyzid fly, *Amoebaleria* sp., from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 69. A fungus gnat, *Rymosia* sp. (Mycetophilidae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 70. An unidentified fungus gnat (Mycetophilidae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 71. A scuttle fly, *Megaselia* sp. (Phoridae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Arthropoda
Insecta
Diptera
Psychodidae
Psychodinae

Moth flies (Psychodidae) are occasionally encountered in caves (Barnes et al. 2009, Peck and Lewis 1978, Moseley 2007, Peck 1988). *Psychoda satchelli* was found to be the most common in caves of Arkansas and Missouri (Barnes et al. 2009). Adult moth flies are primarily nocturnal, and the saprophagous larvae feed on decaying organic debris (Barnes et al. 2009). Our specimens (**Figure 72**) were taken from dry bedrock walls in the cave entrance, soil floor under leaf litter in the entrance, on the underside of stones deeper in the entrance zone, and on bedrock wall in the twilight zone.

Arthropoda
Insecta
Diptera
Sciaridae
cf *Corynoptera* sp.

The family Sciaridae includes a number of species that may be associated with caves, and likely there are undescribed species remaining to be discovered in Nearctic caves (Vilkamaa et al. 2011). Graening et al. (2003) record an unidentified *Corynoptera* from an Arkansas cave, and Barnes et al. (2009) record more than 200 specimens from Ozark caves, mostly represented by females (males are necessary for species level identification) and some of the males matching *Corynoptera* in morphology, but Barnes et al. (2009) did not take into account Hippa and Vilkammaa's (1994) new genus *Camptochaeta.* Peck and Lewis (1978) recorded several genera from caves in Illinois and Missouri, indicating that some are trogloxenes or troglophiles. Moseley (2007) and Peck (1988) record several genera from Canadian caves. Our specimens (**Figure 73**) were taken from a soil floor under litter near a bedrock wall in the entrance zone.

Arthropoda
Insecta
Diptera
Sphaeroceridae
Leptocera sp. 1
Leptocera sp. 2

Sphaerocerid flies, or Lesser Dung Flies, are common in midwestern caves (Barnes et al. 2009, Peck and Lewis 1978) and in Canada (Peck 1988), where larvae may feed on dead plant and animal material. Some species may be facultative cavernicoles and some may be associated with bat roosts. We collected two species of *Leptocera* (**Figure 74**), one of which was quite abundant.

Arthropoda
Insecta
Diptera
Tipulidae

Adult crane flies were found on dry bedrock walls in the entrance zone (**Figures 75, 76**). This family is large and contains a variety of genera recorded from caves. Several species of crane flies were commonly found resting in the entrance zones of caves in Arkansas and Missouri by Barnes et al. (2009), in entrances of caves and mines in Canada (Peck 1988), and are reported from caves in Illinois and Missouri by Peck and Lewis (1978). Many adults are nocturnal and may facultatively use caves as daytime shelter. Larval habits vary, and may include aquatic and detritus habitats.

Figure 72. A moth fly (Psychodidae: Psychodinae) from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 73. A dark-winged fungus gnat, cf *Corynoptera* sp. (Sciaridae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 74. A lesser dung fly, *Leptocera* sp. (Sphaeroceridae), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Figure 75. A crane fly (Tipulidae), from Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 76. Adult crane flies on bedrock in the entrance zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Arthropoda
Insecta
Hymenoptera
Ichneumonidae

An unidentified ichneumonid wasp was noted at a variety of locations in the dark zone of Horseshoe Bay Cave, where it was observed wandering on the floor of the cave in a manner that suggested it was hunting for prey (**Figure 77**). Normally we would consider ichneumonids to be accidental in a cave setting, but there were so many animals of this species that it seems likely they were actively seeking out the cave habitat to search for prey (?spiders?).

Arthropoda
Insecta
Lepidoptera
Alucitidae
Alucita sp.

A Many-plumed Moth, *Alucita* sp., was found roosting in the entrance zone on the bedrock and another about 5 feet further inside of the cave (**Figure 78**). This species is likely an accidental, facultative using the cave for temporary shelter. Three species are known from North America (Landry and Landry 2004), and larvae of this dusk-flying moth probably feed on snowberry (*Symphoricarpos* sp.) or possibly honeysuckle (*Lonicera* sp.).

Arthropoda
Insecta
Lepidoptera
cf Noctuidae

The large, diverse family Noctuidae was recorded on the basis of several specimens from the entrance and twilight zones, where they were likely seeking daytime shelter. These are night-flying insects, and important food for bats (**Figure 17**).

Arthropoda
Insecta
Lepidoptera
Geometridae
Undetermined.

An inchworm caterpillar (Geometridae) extracted from leaflitter taken just inside the entrance gate is an accidental. Another, unidentified small caterpillar was also collected and is accidental (**Figure 79**).

Figure 77. An ichneumonid wasp wandering on the floor of Horseshoe Bay Cave, deep within the dark zone. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Figure 78. A Many-plumed Moth, *Alucita* sp. (Alucitidae) resting on bedrock in the entrance zone of Horseshoe Bay Cave. Photo by Steven J. Taylor.

Figure 79. An unidentified caterpillar (Lepidoptera), from Horseshoe Bay Cave. Scale bar is 1 mm. Photo by Steven J. Taylor.

Table 1. List of taxa recorded from Horseshoe Bay Cave, Door County, Wisconsin, based on collections and visual observations on 23 through 25 July 2013.

Phylum: Class / **Order**	**Family: Subfamily**	**Taxon**	**Common Name**
Mollusca:Gastropoda			
Stylommatophora	Arionidae	cf *Arion subfuscus*	Slug
	Zonitidae	cf *Paravitrea multidentata*	Terrestrial Snail
		Undetermined	Terrestrial Snail
Annelida:Clitellata			
Enchytraeida	Enchytraeidae	*Fridericia* sp.	Worm
Opisthopora	Lumbricidae	*Allolobophora chlorotica*	Earthworm
		Eiseniella tetraedra	Earthworm
		Undetermined	Earthworm
Arthropoda:Malacostraca			
Amphipoda	Crangonyctidae	*Crangonyx* sp.	Amphipod
Isopoda	Asellidae	*Caecidotea* sp.	Aquatic Isopod
	Cylisticidae	*Cylisticus convexus*	Terrestrial Sowbug
Arthropoda:Maxillopoda			
Cyclopoida	Undetermined		Cyclopoid copepod

Arthropoda:Arachnida

Acari			Mite
Araneae	Agelenidae	cf *Cicurina* sp.	Funnel-web Spider
	Amaurobiidae		Hacklemesh Weaver
	Linyphiidae	*Lepthyphantes* sp.	Sheet-web Weaver
		Undetermined	Sheet-web Weaver
	Pisauridae	*Dolomedes* sp.	Fishing Spider
		Pisaurina sp.	Fishing Spider
	Tetragnathidae	*Meta ovalis*	Spider
	Theridiidae		Comb-clawed Spider
Opiliones	Sclerosomatidae	*Leiobunum* sp.	Harvestman
	Sabaconidae	*Sabacon cavicolens*	Harvestman

Arthropoda:Symphyla

	Scutigerellidae	*Scutigerella* sp.	Symphylan

Arthropoda:Collembola

Poduromorpha	Hypogastruridae	*Ceratophysella* sp.	Springtail
Entomobryomorpha	Entomobryidae	*Entomobrya nivalis*	Springtail
		Lepidocyrtus languinosus	Springtail
		Lepidocyrtus paradoxus	Springtail
		Lepidocyrtus violaceus	Springtail
		Lepidocyrtus sp. 1	Springtail
		Pseudosinella sp.	Springtail

		Sinella sp. 1	Springtail
		Sinella sp. 2	Springtail
	Isotomidae	*Folsomia* sp.	Springtail
	Tomoceridae	*Pogonognathellus* sp. 1	Springtail
		Pogonognathellus sp. 2	Springtail
Symphypleona	Katiannidae	*Sminthurinus* sp.	Globular Springtail
	Arrhopalitidae	*Pygmarrhopalites* sp.	Globular Springtail

<u>Arthropoda:Insecta</u>

Zygentoma	Machilidae		Silverfish
Orthoptera	Rhaphidophoridae	*Ceuthophilus* sp.	Cave Cricket
Hemiptera	Nabidae		Damsel Bug
Coleoptera	Curculionidae: Cryptorhynchinae		Weevil
	Curculionidae: Entiminae		Broad-nosed Weevil
	Scarabaeidae: Aphodiinae		Scarab Beetle
	Scarabaeidae: Melolonthinae		Scarab Beetle
	Staphylinidae		Rove Beetle Larva
Diptera	Cecidomyiidae		Gall Gnat
	Chironomidae		Midge
	Culicidae	*Culex* sp.	Mosquito
	Heleomyzidae	*Oecothea* sp.	Sun Fly
		Amoebaleria sp.	Sun Fly
		Heleomyza sp.	Sun Fly
	Mycetophilidae	*Rymosia* sp.	Fungus Gnat
		Undetermined	Fungus Gnat

	Phoridae	*Megaselia* sp.	Scuttle Fly
	Psychodidae: Psychodinae		Moth Fly
	Sciaridae	cf *Corynoptera* sp.	Dark Fungus Gnat
	Sphaeroceridae	*Leptocera* sp. 1	Lesser Dung Fly
		Leptocera sp. 2	Lesser Dung Fly
	Tipulidae		Crane Fly
Hymenoptera	Ichneumonidae		Ichneumon Wasp
Lepidoptera	Alucitidae	*Alucita* sp.	Many-plumed Moth
	cf Noctuidae		Moth
	Geometridae		Inchworm

Geocache

During the 23-25 July 2013 fieldwork, SJT noticed a geocache inserted under some rocks near the entrance to the cave. The cache, "Road to Sheol" by Dcexplorer < http://www.geocaching.com/geocache/GC2EH2A_road-to-sheol >, was placed on 3 September 2010. **Figure 80** summarizes cache visits from 3 September 2010 through 25 July 2013, as recorded in the geocache logbook (not the website). There have been at least 87 days during which the cache was visited, and minimum of 138 individuals have visited this geocache.

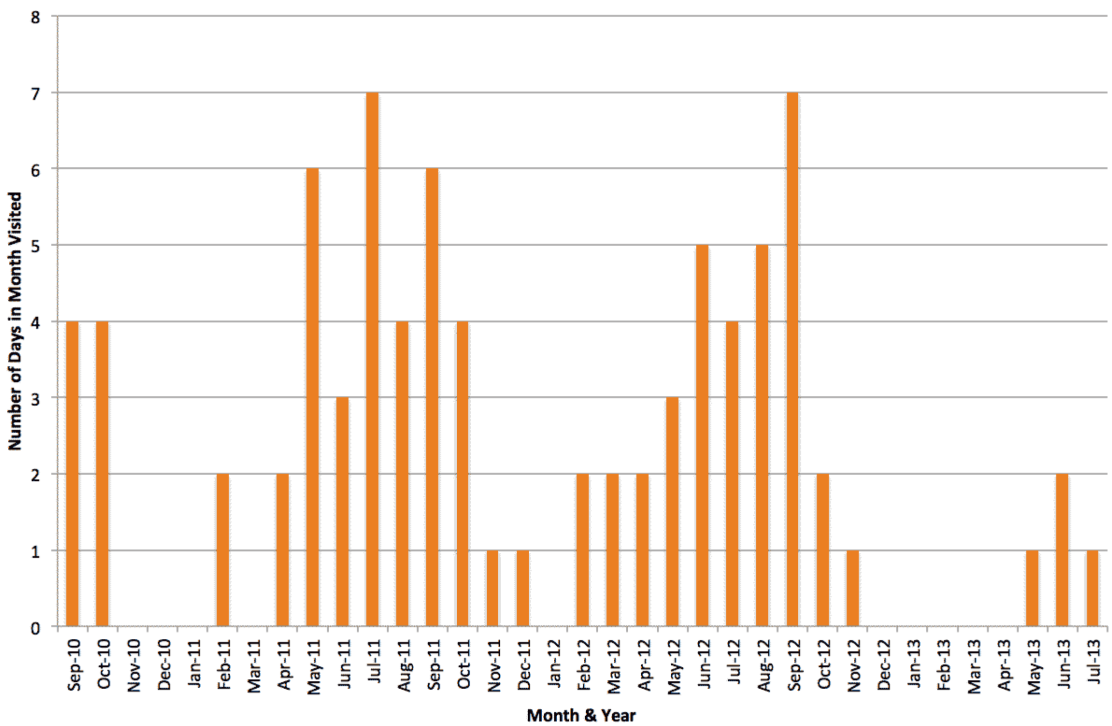


Figure 80. Monthly summaries of cache visits for the geocache "Road to Sheol" by Dcexplorer < http://www.geocaching.com/geocache/GC2EH2A_road-to-sheol > from date of placement through 25 July 2013 as recorded in the geocache logbook.

Unsurprisingly, visits to the Geocache exhibit a distinct seasonal pattern (**Figure 80**), with more visits in the warmer months (May-September). The majority of visits are unlikely to interfere with use of the cave by bats. Many geocaches see their heaviest visitation during the first few years, as local geocachers add the find, with numbers dropping somewhat after that. However, with Door County being a tourist destination, it is likely that the cache will continue to see activity. This may provide an opportunity for outreach and education, either via the geocach webpage (by working the cache owner) and/or through the installation of interpretive signage.

Management Recommendations

Horseshoe Bay Cave already receives considerable protection due to the installation of a cave gate and active management for bats. However, management of cave resources is complex, often involving multiple landowners and a variety of scientific, cultural, financial and political considerations. Land use, geology, hydrology, climate, biology and sociology interact to influence management, and thus it is best to be informed by collecting as much objective data as feasible. With these factors in mind, we make the following recommendations, recognizing that not all of these are feasible given time, resources and other factors:

A. Regular seasonal visits to the cave entrance (not the interior of the cave!) are recommended to ensure gate integrity and to check for any evidence of change in the surrounding landscape.

B. Though this is the largest, most significant cave in Door County, it is completely unsuited for tourist visits, in part because:

1) most of the passage is wet and crawling height (**Figure 81**)
2) the cave is so small that even activity in the front (standing/stooping height) passage would result in excessive trampling of habitats (**Figure 82**), resulting in injury and death of cave invertebrates and other cave resources (**Figure 83**). That is, most of the floor would be stepped on because the passage is not very wide.

We strongly recommend that no wild cave tours or tourist visits to the cave be allowed, and that no plans be undertaken towards developing Horseshoe Ba Cave as a commercial cave - such undertakings would be disastrous for the cave ecosystem, due to the small size of the passages combined with the fragile nature of cave ecosystems.

Figure 81. Resource managers (L-R: Grant Thomas, Door County Corporation Counsel; William Schuster, Door County Conservationist; and Jennifer Redell, Cave & Mine Specialist for the Wisconsin Department of Natural Resources) in typical passage height and conditions for much of Horseshoe Bay Cave. Wetsuits are essential gear, and conditions are unsuited for visits by casual tourists. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

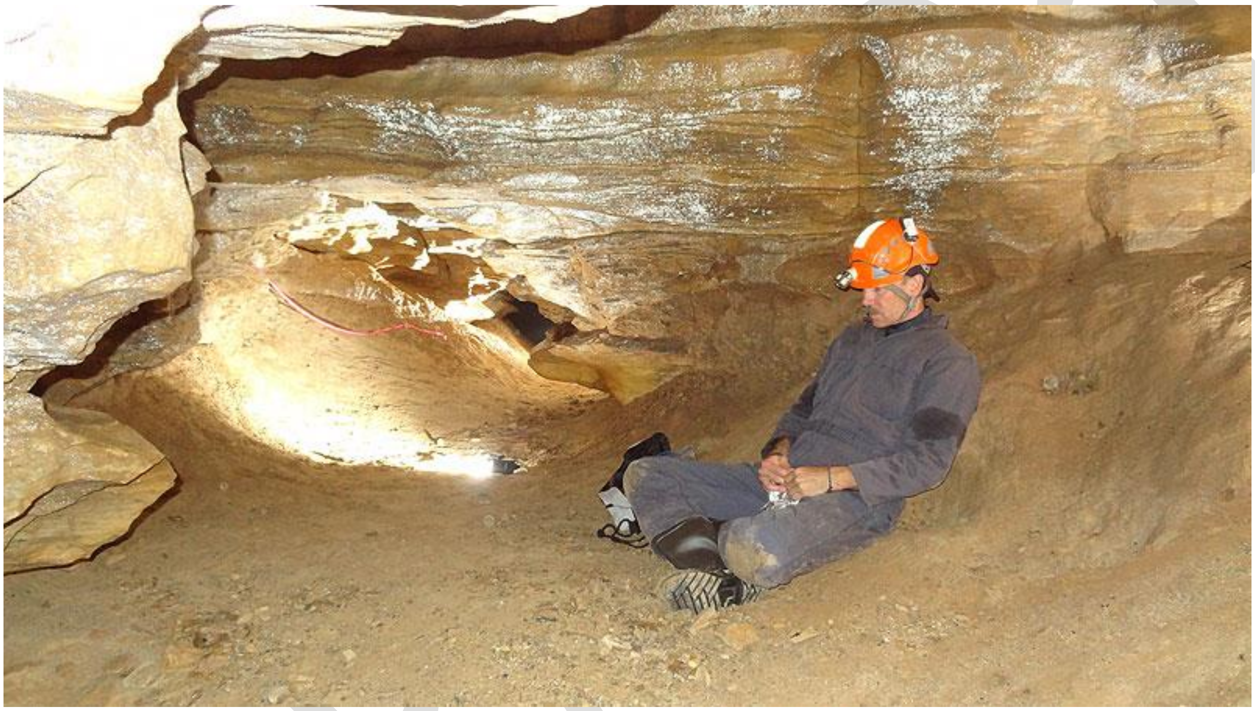


Figure 82. William Schuster, Door County Conservationist, in larger passage near the entrance to Horseshoe Bay Cave. Note how most of the substrate is subject to potential trampling by visitors, to the detriment of tiny cave invertebrates. Pink flagging tape marks off sensitive area in effort to protect cave resources. White areas high on walls above the seated individual are likely comprised of a variety of fungal and microbial species. Photo by and courtesy of Jennifer Redell, Wisconsin DNR.

Figure 83. Bat bones on the floor of Horseshoe Bay Cave are among the fragile resources that could be damaged by careless cave visitors. These bones potentially could be used by future researchers to document species use of the cave and, perhaps, even to obtain DNA samples if these species are completely extirpated by White Nose Syndrome. Photo by Steven J. Taylor.

C. A modern, detailed, complete digital map of the cave, allowing addition of multiple data layers in support of management and, perhaps, interpretation, is necessary to most effectively manage Horseshoe Bay Cave. This should be fully documented with an archive including scanned field notes and full survey data. There are a number of highly experienced, competent cave surveyors and cartographers with strong resumes and track records of working well with agencies, but given a sufficiently strong and motivated crew it may be possible to do this internally. We recommend:

1) Clinometer data be required for all survey shots because of the unusual hydrology of the area
2) Back-sights for both compass and clinometer should be required because there are few opportunities for survey correction via loop closure
3) Use of a disto (waterproof laser rangefinder) for distance measurements to reduce errors relative to use of a fiberglass tap.
4) Key stations should be tied to radio location data (see D, below)
5) Compasses and clinometers should be calibrated and tested on a survey course, with individual instruments needing to be logged and approved by an accepted modern standard prior to use in the cave
6) There should be established compass and clinometer error limits
7) At a few key locations, permanent survey station marks should be established in a manner which is robust to extreme flooding, mud, etc.
8) All of the above must be done in collaboration with an appropriate Wisconsin DNR and/or Door County point of contact

This list should not be considered exhaustive.

D. Determining the location of cave passages relative to above ground features is something that we feel is an important management action that should take place. This is best achieved using a cave radio approach. Specialized cave radios can transmit signals from within the cave passages to crews with receivers located above ground in the vicinity of where the passage is thought to be located. Fixing multiple locations using this approach is best achieved by consulting with a cave radio expert, and would require a strong in-cave crew with the capacity to sit in water for prolonged periods while keeping delicate electronics dry. No doubt, multiple trips would be needed to achieve this management recommendation. Outcomes would include:

1) fixed points to associate with cave survey data to allow more accurate line plots
2) a cave map overlay compatible with other GIS layers, with confidence that the cave location is sufficiently accurate

At present, any cave overlay on an area map is only a best guess, as multiple sources of error are possible. This management action has profound impacts on resource manager understanding of the location and extent of the cave.

E. Determining the groundwater drainage basin of the cave is an important, but expensive, management action that should take place. One of the greatest impacts on the cave ecosystem is the quality, quantity, and periodicity of the water entering the cave. These parameters, especially (but not exclusively) the water quality, can best be managed by influencing land use practices within the hydrological drainage basin of the cave. It would be necessary to employ a specialist – experienced in conducting dye traces in karst settings – to appropriately complete this management action.

F. We recommend documenting and better understanding the changing flow rates in Horseshoe Bay Cave as a needed management action. At present, there is anecdotal information about the cave stream resurging from the entrance. Better would be to have a series of data loggers deployed which log depth and temperature throughout the year. These data may become increasingly important as we face climatic changes in the future.

G. It is difficult to imagine management actions that would support a need for digging/excavation/blasting within this cave. It may be possible to open an upstream entrance to the cave via one or more sinkholes. However, such actions would significantly alter airflow, increase access control issues, and potentially alter hydrology. The only condition under which this might be warranted is if it is determined that a former entrance existed but was closed through the activity of humans (as apposed to by natural processes). Sinkholes open and close naturally over geological time (and sometimes human-relevant time), and we don't feel that interfering with this process is in the best interests of natural systems.

H. Once the hydrological drainage basin of the cave is established, we recommend conducting sinkhole cleanups to remove any hazards (chemicals, metals, plastics, etc.) that might be having a negative influence on the cave ecosystem. Such cleanups can involve the general public, and also provide a chance for cavers to demonstrate good will efforts to work with Wisconsin DNR and/or Door County. Note that these should not conducted as digs, attempting to create unnatural cave entrances.

I. Once the hydrological drainage basin of the cave is established, we recommend a complete inventory of features (including georeferencing of all sinkholes and other karst features) and potential threats to the cave ecosystem from above ground land use practices within the drainage basin. This inventory, likely including a GIS component, should carefully, objectively, thoroughly and honestly consider hazardous chemicals, application of fertilizers, herbicides and pesticides, septic waste, agricultural practices, etc. This work should involve input from an expert in karst landscape impacts. Findings from this action may result additional management actions.

J. Occasional visits by experienced, physically competent, intelligent, cooperative cavers with proper caving gear, following appropriate safety and decontamination protocols, and affiliated with the National Speleological Society should be considered in cases where these cavers can contribute value to management priorities within the cave that are not safely or practically achievable by Wisconsin DNR & Door County staff. This is particularly true of portions of the cave beyond the Big Room, where small, wet passages make travel difficult.

Caver visits should include clear reporting and data ownership guidelines. For example, if cavers are utilized for cave mapping (this could also be done internally if a strong crew is available), then survey notes, survey data, compiled survey data and completed cave maps in their original digital form should be made available to, "owned" and by carefully archived by Wisconsin DNR and/or Door County as soon as each step is completed (for example, upon exiting the cave, survey notes would go to Wisconsin DNR and/or Door County, with quality copies returned to survey team leader). Examples are available to serve as models and also providing potential contacts (e.g., Lechuguilla Cave and Snowy River Cave, both in New Mexico). Some such relationships have started with painful, tumultuous beginnings leading ultimately to the establishment of strong, positive working relationships.

Potential uses of cavers in management of Horseshoe Bay Cave might include:

1) extra personnel on Wisconsin DNR and/or Door County management trips may be useful at times for safety reasons
2) cave mapping
3) support of/participation in resource inventory, monitoring and photo-documentation
4) support of cave science (examples: collection of water samples for laboratory analysis; servicing data loggers and downloading of data from data loggers)
5) cave radio location trips
6) cave photography/videography in support of resource interpretation

We saw no evidence of need for cave cleanup trips or graffiti removal (which are other activities which might be appropriate for trained, experienced cavers).

K. Some attention should be given to interpretation/education/outreach relating to karst resources. The target audience includes:

1) local landowners
2) city, county, and state officials
3) politicians & planners
4) business owners
5) landowners
6) law enforcement / rescue personnel (typically fire department)
7) cavers (associated with the National Speleological Society)
8) developers
9) environmental groups
10) visitors/tourists
11) groups which commonly utilize the open field just outside of/below the cave

Wisconsin DNR and Door County – and the natural ecosystem of Horseshoe Bay Cave and other cave systems in Door County – benefit when a larger portion of the target audience understands the role of caves and karst in the county. Consider presentations, pamphlets, interpretive signs, news stories (including photographs + diagrams of the subterranean "plumbing"), public meetings and, especially, face-to-face discussions. Resources for cave and karst interpretation/education/outreach are readily available from various sources (De Waele 2010). Most conveniently available among these is the excellent booklet "Living on Karst" (Zokaites 1997).

L. All visits to the interior of the cave should comply fully with U.S. Fish & Wildlife Service decontamination procedures (available at: <http://whitenosesyndrome.org/>) associated with the devastating wildlife disease, White Nose Syndrome, as supplement by policies and procedures of Wisconsin DNR and Door County.

M. Cave management plans and operational procedures should be considered living documents, subject to revisions in light of new information. We recommend that regular reviews of management plans and operations be scheduled. External assessment by appropriate karst experts may also be warranted, and

Wisconsin DNR & Door County have already (January 2013) created a *Horseshoe Bay Cave Science Advisory Group* which partially addresses this recommendation.

Threats & Climate Change Impacts

We have already touched on a variety of threats to cave biota in the treatment above. Caves and groundwater systems are complex, closely tied to the land above and strongly influenced by geomorphology and hydrology. A review by Elliott (2000) lists a variety of major classes of threats (Table 2), to which we add climate threats. Given its proximity to the great lakes and position on a narrow peninsula, Horseshoe Bay Cave is relatively immune to hydrological threats such as dam building and groundwater pumping. Land development is a potentially serious threat, which may already be having impacts on the cave ecosystem - both rural residential development and the presence of a golf course over the cave fall in this category. Land development can result in filling of sinkholes, destruction of host rock through building of roads, road spills, utility impacts (such as septic lines, or trenching to install fiber optic cables), and increased impervious cover (parking lots, buildings). All of these threats are very real for Horseshoe Bay Cave. Nutrient stress from nutrient loss can accompany land development, which may limit the quantity and change the nature of organic inputs through sinkholes. Losses associated with the potential extirpation of bats from the cave as a consequence of the spread of WNS could also be detrimental to the rest of the cave ecosystem due to the loss of energy sources contributed by bats. Nutrient enrichment is likely already occurring within the caves' recharge area. Private residential applications of fertilizers commonly exceed manufacturer specifications, and fertilizer use on the golf course likely contributes significantly to nutrient enrichment in the cave, particularly in aquatic habitats. Enrichment originating from poorly maintained septic tanks or leaking sewer lines may also be a serious concern in the Horseshoe Bay Cave drainage basin, as has been documented elsewhere (Panno et al. 1996, 1997, 1998). Our list of taxa includes some exotic species, such as earthworms, which may have long since had an impact on the cave ecosystem by out-competing native fauna. Similarly, some of the entrance fauna is non-native, with undocumented impacts. The invasive, pathogenic fungus *Pseudogymnoascus destructans*, causative agent of WNS, is an example of a pest species with anticipated serious impacts on the cave ecosystem at Horseshoe Bay Cave in the near future. Chemical pollution of Horseshoe Bay Cave is most likely to come from sources above the cave among the sinkholes in the recharge area. The potential for improper disposal of chemicals by private residences and the golf course are high. It seems likely that Door County and Wisconsin DNR can work with the golf course to implement practices that protect against contamination, but this becomes more difficult with private residences. Use of herbicides and, especially, insecticides by private residences and the golf course should be regulated, with a special focus on keeping these and other chemicals away from sinkholes. Sinkhole vegetative buffers can help in this effort. Killing, over-collecting, and disturbance of the cave fauna of Horseshoe Bay Cave will remain limited to manageable levels as long as visitation is limited to visits associated with managing cave resources (bat inventories, cave mapping, hydrological research, bioinventories, etc.). Concerns with faunal isolation through land development and down-cutting through bedrock are unlikely to be major impacts, but quarrying and major excavations within the hydrological basin of the cave should be strictly regulated. At the local level, climatological threats from entrance modification/creation seem to bee a real threat due to interests in discovering other entrances to the cave. We strongly discourage opening additional cave entrances (via sinkholes) unless these have been artificially closed by human activities. Such entrances can alter airflow patterns resulting in reduced thermal stability and lower relative humidity within the cave. Impacts of global climate change on the cave ecosystem are difficult to mitigate, but we can expect these to result in changes to the cave ecosystem as the quantity and timing of hydrological recharge is altered and the thermal regime shifts. The relative isolation of the peninsula is likely to influence these changes. It *almost* goes without saying that maintaining natural vegetation (tree cover) in as broad an area around the cave, and especially around the entrance and important sinkholes within the drainage basin, will go a long way towards providing suitable habitat, nutrient inputs and buffering of climate variability.

Table 2. List of threats to cave and karst ecosystems, modified after categories of Elliott (2000).

Threats to cave and karst communities
Hydrological threats
Land development
Nutrient stress
Nutrient loss
Nutrient enrichment
Exotic and pest species
Chemical pollution
Killing, over-collecting, and disturbance of fauna
Isolation
Climatological threats
Altering microclimate by changing cave morphology
Global climate change impacts

Conclusions

The fauna of Horseshoe Bay Cave (Door County, Wisconsin) is fairly typical of north-temperate, Midwestern cave faunas found in caves prone to occasional flooding. The relatively recent glaciation of the Door Peninsula may contribute to the limited cave-adapted fauna. Particularly notable among the organisms found in the cave are a presumptively groundwater-inhabiting amphipod species in the genus *Crangonyx*, which could conceivably depend upon the maintenance of good groundwater quality for its' long-term survival, and an apparently cave-adapted globular springtail, *Pygmarrhopalites* sp., found on the surface of drip pools and could represent an undescribed cave species. The entrance fauna includes several widespread native invertebrates, but also some taxa which are introduced species – a pattern common to many Midwestern caves and perhaps resulting from movement of materials (water, soil, etc.) by humans over the last 150 years.

Management recommendations focus on areas relating to the entire cave ecosystem. Understanding the hydrological groundwater basin of the cave and maintaining land use practices which do not result in degradation of the cave ecosystem through contamination, sedimentation, changes in in-cave meteorological conditions (air flow, humidity), and maintaining natural levels of nutrient inputs into the system are all important to maintaining ecosystem health. The decline of overwintering bat populations, as well as potential impacts from climate change, are factors that may not be easily addressed in site-specific management, but should be considered areas of major concern.

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<http://www.dcr.virginia.gov/natural_heritage/livingonkarst.shtml>
As a pdf file from the original source at:
<http://caveconservancyofvirginia.org/>
Paper copies may be requested from the Cave Conservancy of the Virginias (contact via above link) or from:
http://www.livingonkarst.org/

Appendix I. Wisconsin Bat Species Guidance

Little Brown Bat (*Myotis lucifugus*) Species Guidance

Family: Vespertilionidae – the evening bats

State Status: Threatened

State Rank: S3S4

Federal Status: None

Global Rank: G3

Wildlife Action Plan Area of Importance Score: None

Range of little brown bat in Wisconsin.
Source: Wisconsin Bat Program 2012

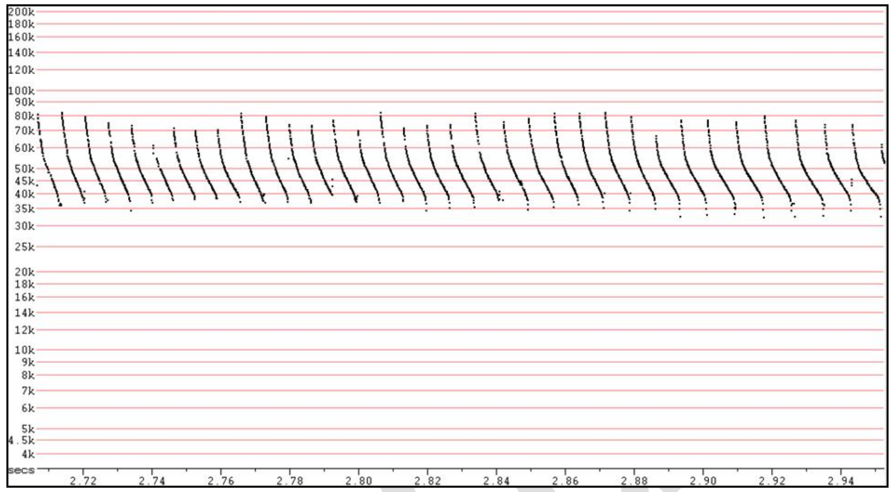
Paul White, Wisconsin DNR

Heather Kaarakka, Wisconsin DNR

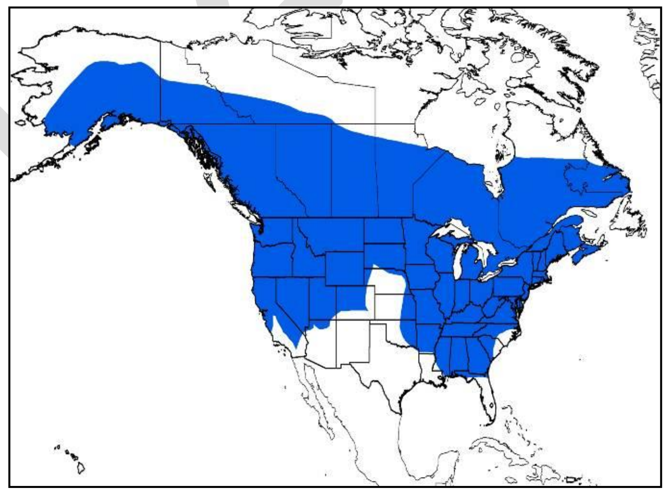
Species Information

General Description: The little brown bat is a member of the genus *Myotis*, which is represented by three species in Wisconsin. This bat weighs between 5.5 and 12.5 g (0.19-0.44 oz), and individual bats' weights vary seasonally and are least in the spring as bats emerge from hibernation (WI Bat Program unpublished data). Adult forearm lengths range from 36 to 40 mm (1.4-1.6 in), and total body length is 8.0-9.5 cm (3.1-3.7 in) (Kurta 1995). Adult little brown bat wingspan is 222-269 mm (8.75-10.5 in; Barbour and Davis 1969). Body color ranges from pale tan to reddish to dark brown, and is lighter on the ventral side. Feet have long toe hairs that extend to the tips of the toes.

Similar Species: Three bat species in Wisconsin – the little brown bat, the northern long-eared bat (*Myotis septentrionalis*) and the Indiana (*Myotis sodalis*) bat – are best distinguished by close (in-hand) inspection. The northern long-eared bat has longer ears than the little brown bat, and a pointed, spear-like tragus. Tips of little brown bat ears, when ears are folded alongside the head, should extend no more than 3 mm beyond the tip of the nose; in contrast, the northern long-eared bats' ears extend 3 mm or more. Little brown bat ear length in Wisconsin, however, can be highly variable, and tragus shape and length in relation to the rest of the ear are the two best features to use to distinguish these two species. The little brown bat also appears similar to the Indiana bat, but the little brown bat has long toe hairs that extend beyond the toe, and also lacks the Indiana bat's keeled calcar, a spur of cartilage extended from the ankle and supporting the interfemoral membrane (Barbour and Davis 1969, Fenton and Barclay 1980). Little brown bat fur is also generally glossier and lighter-colored than that of the grayer Indiana bat (see figure 1). The little brown bat can also be identified by its echolocation call (figure 2), but northern long-eared and Indiana bats share similar call characteristics and only trained individuals should positively identify bat species through echolocation calls.



Associated Species: Little brown bat predators include owls, hawks, occasionally snakes, and raccoons (*Procyon lotor*). As many as 13 feral cats have also been observed congregating at a mine entrance at dusk to prey upon the bats as they leave the hibernaculum (D. Redell pers. obs.). Little brown bats often share hibernacula with other bat species such as the tri-colored bat (*Permyotis subflavus*), the northern long-eared bat, the Indiana bat and the big brown bat (*Eptesicus fuscus*), but the little brown bat will rarely, if ever, form hibernating clusters with other species. Little brown bats forage with other bat species, but there is no evidence of direct competition between species.



Global distribution of the little brown bat. (BCI 2012)

State Distribution and Abundance: Little brown bats are presently common and widespread in Wisconsin (but see "Threats" section below), and are generally more common in the southern and western part of the state than in the north (Jackson 1961, WDNR 2013).

Global Distribution and Abundance: The little brown bat is currently one of the most abundant bats in North America. It ranges from southern Alaska to the northern part of Florida, and into southern California. It is absent from the middle plains region, Texas, New Mexico and southern Florida (BCI 2012), and is more common in the northern part of its range.

Diet: The Little brown bat is a generalist insectivorous bat. Its diet consists mainly of aquatic, soft-bodied insects such as moths (*Lepidoptera*), wasps (*Hymenoptera*), gnats, mosquitoes, and crane flies (all *Diptera*) (Barbour and Davis 1969).

Reproductive Cycle: The little brown bat's reproductive cycle begins in the spring after hibernation, when females become fertilized with sperm they have stored in the uterus over the winter. Reproductive females form a maternity roost with other female conspecifics (members of the same species), and give birth to a single pup in June or early July after a 50- to 60-day gestation period (Wimsatt 1945). Little brown bats rarely give birth to more than one pup. The pup nurses for about a month and is left at the roost nightly while the mother goes out to feed. The pup begins to fly and explore on its own when it is six weeks old. Maternity colonies disperse in late July and August, and bats move closer to hibernacula in the fall and mate before they hibernate (Barbour and Davis 1969). Young-of-year do not usually mate, but some juvenile males appear reproductively active (WI Bat Program unpublished data).

Figure 2. Echolocation call: The little brown bat produces high-frequency calls (40-80 kHz). These bats emit about 20 pulses/second while they search for prey, and when they identify a target and enter the capture phase they increase the rate to 50 pulses/second, to produce a sequence of calls known as the feeding buzz (Fenton and Barclay 1980). The little brown bat sonogram is similar to those of the northern long-eared bat and the Indiana bat.

Ecology: Male and female little brown bats in Wisconsin begin to leave hibernacula in April, and often migrate great distances to reach their summer roosting sites and foraging grounds. A study in Kentucky showed that little brown bats migrate six to 280 miles (Humphrey and Cope 1976). Females begin forming maternity colonies in late April and early May. Little brown bats are born between early June and the end of July (but annual variation around this range is typically one to three weeks). Bat phenology (timing of life cycle stages) in northern Wisconsin tends to lag behind that of southern-Wisconsin colonies. Maternity colonies disperse in late July and August, after which bats visit several summer roosting sites before settling on a hibernaculum in which to hibernate from November through April. The little brown bat is long-lived for its size, and lives over 10 years in most cases (Barbour and Davis 1969). Recent identification-band recoveries in Wisconsin found two male little brown bats captured 18 years after banding, and one 25 years after banding (D. Redell unpublished data).

Little brown bats make both short- and long-distance migrations in the spring to their summer foraging ranges and maternity roosts, and they return in the fall to their hibernacula. Many return to the same site year after year. More research is needed on little brown bats' basic life history and behavior.

Natural Community Associations: (WDNR 2005 and WDNR 2009)

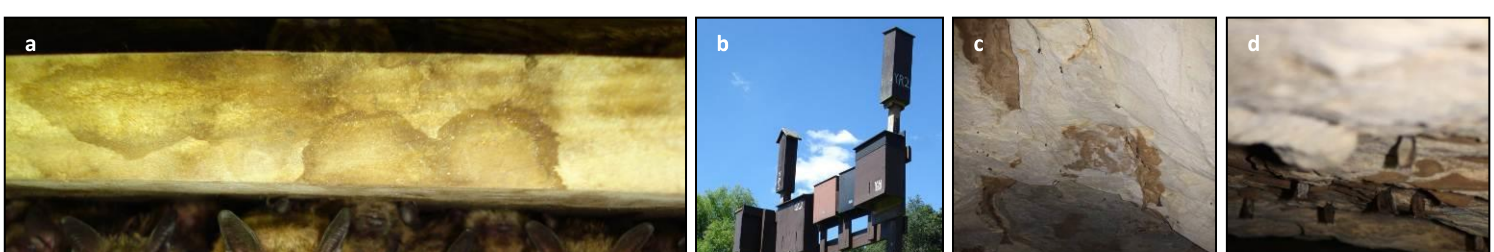
Many bat species are associated more with structural features within natural communities than with any particular natural community or group of natural communities (see "Habitat" section). However, additional research may reveal new information regarding bat species' natural community requirements.

Significant: none
Moderate: none
Minimal: none
Habitat: Little brown bat habitat use changes over the course of the year, and varies based on sex and reproductive status. Reproductive females often use different summer habitat from males and non-reproductive females.

Summer: Little brown bats commonly roost in human-made structures, but have also been found in the summer under tree bark, in rock crevices, and in tree hollows (Humphrey and Cope 1976; Fenton and Barclay 1980). Male and female little brown bats both prefer old-growth and mature trees because they provide more crevices and cavities (Fenton and Barclay 1980, Crampton and Barclay 1998). Reproductive females form maternity colonies in buildings, bat houses, and tree hollows and select sites based on ambient temperature and shelter. These colonies usually number 300-1200 bats (adults and offspring), but can reach up to 3000 (Humphrey and Cope 1976). Maternity colonies are usually located near water where little brown bats prefer to forage. These colonies do not occur in caves or mines (reproductive females and their young need warmer temperatures), but larger maternity colonies tend to be close to hibernacula, presumably because the bats do not need to travel very far to reach them after hibernation (Humphrey and Cope 1976). Reproductive female little brown bats prefer hot and humid roosting sites in summer, with roost temperatures ranging from 23.3° C to 34.4° C (Burnett and August 1981) or as much as 8° C to 10° C above ambient temperature (Brittingham and Williams 2000). In Illinois, maternity colonies of little brown bats may be found in natural roost sites such as oak (*Quercus spp.)* and maple (*Acer spp)* trees in both upland and bottomland hardwoods (Bergeson et al. 2012). These colonies are found in dead or dying trees about 8 m off the ground in crevices or hollows or rarely under loose bark (Bergeson et al. 2012). Males often roost alone, and do not share maternity colonies' high-temperature needs (Fenton and Barclay 1998). Males may use tree crevices, buildings and occasionally caves and mines as day roosts (Fenton and Barclay 1980). Both sexes choose roosts based on proximity to water, because the bats prefer to forage over open water or near shorelines and along edge habitat (Fenton & Barclay, 1980). Males often roost alone or with a few other males in summer and choose a variety of roost sites. This species chooses day roosts based on temperature and degree of shelter. Roosts are often in confined spaces that may help bats prevent heat loss, and also may be chosen by proximity to foraging habitat (Fenton and Barclay 1980). They tend to choose old growth forest over younger stands because the reduced understory clutter of the old growth forests makes prey easier to find and capture (Crampton and Barclay 1998). More information is needed to accurately describe little brown bat foraging habitats and summer roosting in Wisconsin.

Home range: Female little brown bats have small summer home ranges of 32-64 acres, and lactating female bats have smaller ranges than non-reproductive females (Jackson 1961, Henry et al. 2002).

Winter: Little brown bats hibernate during winter in humid caves and mines with constant temperatures (Barbour and Davis 1969, Humphrey and Cope 1976). This species often forms clusters of both sexes during hibernation. More research is needed to determine what characteristics make suitable caves and mines for little brown bat hibernation.



Edge habitat (transition zone between two types of vegetation) is important for little brown bats as they migrate and forage. When bats migrate from wintering caves to summer habitat, or commute from roosts to feeding grounds, they move through the landscape in a manner that protects them from wind and predators. Instead of flying the shortest distance across a field, for instance, bats will take longer routes that follow edge habitat. In addition to offering protection, this behavior may also allow bats more feeding opportunities because food is more abundant around edge habitat (Limpens and Kapteyn 1991). Commuting along edge habitat may assist the bats with navigation and orientation through use of linear edges as landmarks (Verboom and Huitema 1997).

Threats: Lack of information on bat species' basic ecology is one of the greatest threats to bat conservation in Wisconsin. The little brown bat faces two emerging threats, and several ongoing threats. White-nose syndrome (WNS) was discovered in 2006 in a hibernaculum in New York State, and appears as a white, powdery substance on the bat's face and body. White-nose syndrome has spread rapidly since 2007 to other hibernacula in neighboring states (USFWS 2012). Infected little brown bat hibernacula in New York and surrounding states have experienced mortality rates of over 90%. White-nose syndrome has been called the "most precipitous wildlife decline in the past century in North America" (BCI 2009), and is caused by a fungus called *Geomyces destructans* (Lorch et al. 2011). This fungus grows best in the cool, wet conditions of hibernacula (Verant et al. 2012). Mortality from the fungus appears to come from increased arousals during torpor, which deplete bats' fat reserves and cause starvation (Reeder et al. 2012) and dehydration (Cryan et al. 2010). For up-to-date WNS information, see the USFWS WNS website and the USGS National Wildlife Health Center website (see *Additional Information*). Wisconsin's little brown bat population is particularly vulnerable to WNS because almost all of the state's little brown bats concentrate each winter in a few large hibernacula. Neither the fungus nor the disease has been found in Wisconsin as of this writing. Cave-hibernating bats, including the little brown bat, should be monitored closely for any indication of WNS; the Wisconsin Bat Program conducts WNS surveillance and monitoring in the state.

Wind power is another emerging threat to bats – wind turbines have been shown to fatally impact all bat species in Wisconsin (Johnson 2003, Arnett et al. 2008). Wind-turbine blades cause mortality through direct impact or through the pressure differential caused by the motion of the spinning blades. This pressure differential causes a bat's lungs to fill with fluid as it flies near the spinning blades, and this phenomenon (known as barotrauma) kills the bat instantly (Baerwald et al. 2008). More research is under way to better understand bat wind-turbine vulnerabilities, but current studies suggest that bats face the greatest risk during migration from summer foraging sites to wintering grounds (tree bats) or hibernacula (cave bats) (Johnson 2003, Kunz et al. 2007). Research is needed on all Wisconsin bat species to better understand wind-turbine mortality in the state and the long term population impacts of turbine-related deaths.

Little brown bats also face the ongoing threat of habitat degradation. Habitat degradation is caused by increased agricultural, industrial, and household pesticide use, and it has negative effects on bats through direct exposure and through dietary accumulation (O'Shea et al. 2001). Pesticides are a threat to many taxa, but bats may be more vulnerable than other small mammals due to certain life characteristics (Shore et al. 1996, O'Shea et al. 2001). Bats' longevity and high trophic level means pesticides can concentrate in their body fat (Clark and Prouty 1977, Clark 1988). Even after pesticide exposure ceases, residues can be passed on to nursing young (Clark 1988). Bat species that migrate long distances may be more affected because pesticide residues become increasingly concentrated in the brain tissue as fat reserves are depleted during long-distance flights. This concentration can lead to convulsions and even death (Geluso et al. 1976, Clark 1978).

Little brown bats also face the ongoing threat of hibernaculum disturbance from humans entering hibernacula in winter and waking bats from torpor. Bats in torpor reduce their metabolism and body temperature to low levels that require less energy than being fully awake. Interrupting torpor costs energy; a little brown bat uses up to 100 mg of fat reserves waking and the returning to torpor (and more if the bat starts flying), or the energetic equivalent of up to 67 days of torpor (Thomas et al. 1990, Thomas 1992). This loss clearly represents a large percentage of total body weight of the bat, and repeated arousals may cause bats to run out of energy reserves before spring arrives and therefore starve in the hibernaculum or die from the elements if they seek food outside (Thomas 1995).

Climate Change Impacts: The effects of climate change on the little brown bat are unclear. Predictions suggest a northward expansion in the ranges of all cave-bat species, in pursuit of optimal hibernation (Humphries et al. 2002, USFWS 2007). This prediction assumes an abundance of suitable caves and other hibernaculum structures further north, but this assumption may not hold for karst-free regions at higher latitudes. Bat species may adapt by reducing torpor depth and duration during winter if prey insect species are available for more of the year (Weller et al. 2009), but bats' adaptive capacities in this regard may be limited and are not well known. Shifts in prey insect emergence may also cause mismatches with bat emergence and cause food shortages in the spring or fall.

Survey Guidelines: Persons handling little brown bats must possess a valid Endangered and Threatened Species Permit. If surveys are being conducted for regulatory purposes, survey protocols and surveyor qualifications must first be approved by the Endangered Resources Review Program (see Contact Information).

Acoustic surveys, which should be done by trained individuals, are performed for all Wisconsin bat species in spring, summer and fall, and are used to determine presence/absence, phenology, and distribution around the state. The Wisconsin Bat Program's eventual goal is to use acoustic survey data to determine bat population trends in Wisconsin. Little brown bats are ubiquitous around the state, and therefore surveys can be done wherever standing water or edge habitat exists. Acoustic recording systems that detect echolocation calls can survey bats as they fly through an area. The bat detection system detects and records these acoustic signals as bats fly by, and records the date and time of each encounter. The Wisconsin Bat Program currently uses broadband frequency division ultrasound detection equipment with a PDA (Personal Data Assistant) and a Global Positioning System. Start acoustic surveys half an hour after sunset, but only if the daytime temperature exceeds 50° F, and conduct the survey for at least one hour. There are three seasons for acoustic surveys: spring (April and May), summer (June and July), and fall (August and September). Acoustic surveys record bat passes, which can then be identified to species by trained individuals. These surveys could be used by land managers to create inventories of species distribution and relative abundance. Visit the Wisconsin Bat Program website for additional information.

Wisconsin DNR also conducts a roost monitoring program to determine abundance of bats roosting in buildings and bat houses. People with bat houses or other roost sites identify species and count bats over the summer at night as bats leave the roost. People who find a bat roost while doing surveys should contact the Wisconsin Bat Program to report the information.

Little brown bats will roost in tree cavities, but such roosts are hard to locate in practice and more information is needed to determine little brown bats' roost preference and conditions of roost trees. Suspected roost trees (see "Habitat" section) may be identified by sitting at the tree site at dusk and watching for emergence or looking for evidence of bats such as buildup of guano. Known roost trees are of particular importance for both conservation and research purposes and should be avoided. People who find roost trees should contact the Wisconsin Bat Program to report the information.

Summarize results, including survey dates, times, weather conditions, number of detections, detection locations, and behavioral data and submit via the WDNR online report: <http://dnr.wi.gov, keyword "rare animal field report form">.

Management Guidelines

The following guidelines typically describe actions that will help maintain or enhance habitat for the species.

Summer Management

Summer roost (see "Habitat" section) availability may limit little brown bat population levels (Fenton & Barclay, 1980), and therefore current summer roost sites should be protected and managed. Little brown bats choose sites based on specific conditions that can be found in both artificial and natural roost settings (bat houses and snag trees). This bat species congregates in large colonies at roost sites to reproduce, and therefore providing safe habitat is one of the best ways to protect this species. Bat houses are an important artificial habitat for little brown bats where females may successfully rear their young in protected conditions. Place bat houses on the south and east-facing sides of buildings or tall poles. Steps to ensure that a bat house succeeds can be found on the Wisconsin Bat Program website (see *Additional Information*).

Bats appear to choose natural roosting sites based on the maturity of the forest. In particular, little brown bats are found roosting in old stands significantly more often than in younger stands presumably because old stands offer more opportunities for roosting in cavities (Crampton and Barclay 1998). Protection and management of old stands of forest may be the best way to encourage little brown bats to use an area. Forestry management practices that reduce clutter, such as thinning and burning, within the forest and increase edge habitat can encourage little brown bats to forage and roost (Duchamp et al. 2007, Hayes & Loeb 2007). Linear corridors are important for bat commuting, and forests may be managed such that suitable foraging habitat is connected by corridors; this may include managing edge habitat along roads, logging trails and riparian corridors. Land managers should also make an effort to reduce or eliminate burdock (*Arctium minus*), an exotic weed that produces seeds that trap bats and cause death from exposure.

Special consideration should be given to protecting snags or dying trees, especially those near known roost locations, particularly from June 1 through August 15 while bats may have pups at the roost.

Woodland seasonal pools may be important foraging and water sources for the little brown bat and other Wisconsin bat species because they provide areas for feeding and drinking in an otherwise closed-canopy forest (Francl 2008). Pool size and depth do not appear to determine usage by little brown bats; instead the presence of an opening in the forest is enough to encourage foraging and drinking (Francl 2008).

Fall Management
During fall swarm, large proportions of Wisconsin's cave bat population gather near entrances of the state's hibernacula (see "Habitat" section), and become concentrated and vulnerable to direct impacts. To avoid disturbance during crucial life history events, management activities such as logging and use of heavy machinery within 0.25 miles of hibernacula entrances should be avoided during fall swarm (August 15-October 15) or during spring emergence (April 1-May 15) because bats may use surrounding area for roosting during those time periods (USFWS 2007).

Winter Management
Little is known about how little brown bats choose hibernation sites, but suitable Wisconsin hibernacula typically have steady temperatures between 4° C and 12° C (39-53° F), high humidity, and no human disturbance. Artificial sites that can mimic this environment may provide suitable hibernacula. Artificial hibernacula include bunkers, food storage-caves and basements. Contact the Wisconsin Bat Program to inquire about developing artificial hibernacula.

Natural hibernacula can also be managed to encourage bat use. For example, closing but not sealing the entrance to an abandoned mine not only buffers temperature and humidity, but also reduces disturbance from humans and predators. Eliminating disturbance from humans, except for WNS surveillance, is the best management activity for natural cave hibernacula. Contact the Wisconsin Bat Program for more information about managing bat hibernacula.

Little brown bats – and their populations as a whole – are particularly vulnerable during winter hibernation because they are concentrated in just a few major hibernacula and because repeated disturbance during hibernation can lead to mortality (see "Threats" section above). Each time a bat is aroused from torpor, it uses up a substantial proportion of the fat reserves it relies on to hibernate through the winter and faces greater odds of starvation before spring (see "Threats" section above). Therefore, avoid entering hibernacula from October 1 through May 15 unless conducting approved and permitted management, surveillance, or research.

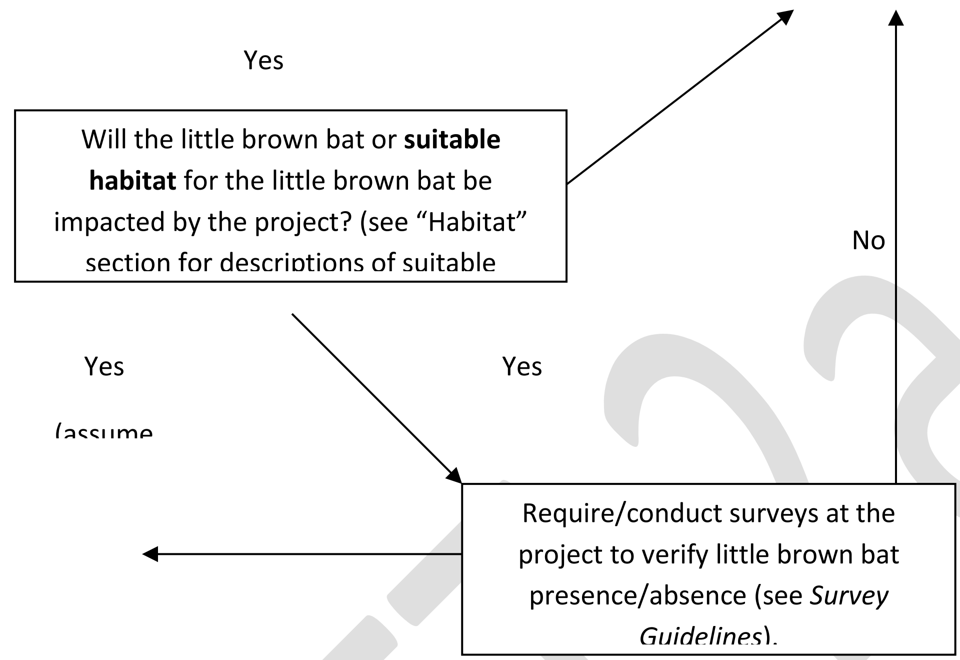
Screening Procedures

Follow the "Conducting Endangered Resources Reviews: A Step-by-Step Guide for Wisconsin DNR Staff" document (summarized below) to determine if little brown bats will be impacted by a project (WDNR 2012):

Is there a little brown bat **element occurrence** (within project area or a 1 mile buffer), regardless of "last obs" date or element occurrence precision OR is there reason to believe little brown bats may be present

No → No additional screening is required. Document conclusions in project file and continue

No



Avoidance Measures

The following measures are specific actions required by DNR to avoid take (mortality) of state threatened or endangered species per Wisconsin's Endangered Species law (s. 29.604, Wis. Stats.) These guidelines are typically

According to Wisconsin's Endangered Species Law (s. 29.604, Wis. Stats.), it is illegal to take, transport, possess, process, or sell any wild animal on the Wisconsin Endangered and Threatened Species List (ch. NR 27, Wis. Admin. Code). Take of an animal is defined as shooting, shooting at, pursuing, hunting, catching or killing.

If *Screening Procedures* above indicate that avoidance measures are required for a project, please follow the measures below. If you have not yet read through *Screening Procedures*, please review them first to determine if avoidance measures are necessary for the project.

1. The simplest and preferred method to avoid take of little brown bats is to avoid directly impacting individuals, known little brown bat locations, or areas of suitable habitat (described above in the "Habitat" section and in *Screening Procedures*). The U.S. Fish and Wildlife Services identifies humans and their equipment as possible vectors for spores of *Geomyces destructans* – the fungus that causes white-nose syndrome (WNS) – and therefore simply entering hibernacula at any time of year and moving between them poses threats to bats. Cavers and researchers must observe all cave and mine closures and decontamination protocols (s. NR 40.07, Wis. Admin. Code) (see *Additional Information*). In addition, it is illegal to use pesticides and poisons when attempting to evict bats from house roosts (s. 94.708, Wis. Stats.).

2. If suitable habitat cannot be avoided, follow these time-of-year restrictions to avoid take:

Summer Avoidance **(June 1-Aug 15)**

Reproductive females and their young are highly vulnerable to mass mortality during the species' maternity period (June 1 – August 15) because they aggregate in maternity colonies, and because pups cannot fly and therefore cannot leave the roost for several weeks after birth. Many maternity colonies occur in human structures, and those seeking to exclude bats from a building or other roost must follow the Cave Bat Broad Incidental Take Permit and Authorization (see *Additional Information*).

3. If impacts cannot be avoided during restoration or management activities, including wind projects and forestry management, but activities are covered under the Cave Bat Broad Incidental Take Permit and Authorization; the project is covered for any unintentional take that may occur. For information about natural roost avoidance, see *Management Guidelines* and "Habitat" section above.

4. Those seeking to complete wind farm projects should review and follow the Guidance for Minimizing Impacts to Natural Resources from Terrestrial Commercial Wind Energy Development created by the WDNR.

5. If little brown bat impacts cannot be avoided, please contact the Natural Heritage Conservation Incidental Take Coordinator (see *Contact Information*) to discuss possible project-specific avoidance measures. If take cannot be avoided, an Incidental Take Permit or Authorization (see *Additional Information*) is necessary.

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Linked Websites:

- Cave bat Broad Incidental Take Permit and Authorization:< http://dnr.wi.gov/topic/erreview/itbats.html>
- Natural Communities of Wisconsin: <http://dnr.wi.gov/org/land/er/communities/>
- Natural Heritage Conservation Permit Requirements: <http://dnr.wi.gov/topic/EndangeredResources/permits.html>
- Rare Animal Field Report Form: <http://dnr.wi.gov, key word "rare animal field report form">
- USFW WNS Website: <http://www.whitenosesyndrome.org>
- USGS National Wildlife Health Center: <http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/>
- Wind Guidance: <http://dnr.wi.gov/topic/Sectors/documents/energy/WindGuidelines.pdf>
- Wisconsin Bat Program Exclusion Instructions: <http://wiatri.net/inventory/bats/Monitoring/Roosts/docs/BatExclusion.pdf>
- Wisconsin Bat Program: <http://wiatri.net/inventory/bats>
- WDNR Decontamination Protocols for Preventing Spread of White-nose syndrome: http://dnr.wi.gov/topic/WildlifeHabitat/documents/WNS_DeconProtocols.pdf
- Wisconsin Endangered and Threatened Species: <http://dnr.wi.gov, key word "endangered resources">
- Wisconsin Endangered and Threatened Species Permit: <http://dnr.wi.gov, key word "endangered species permit">"
- Wisconsin Initiative on Climate Change Impacts: <http://www.wicci.wisc.edu/>
- Wisconsin Natural Heritage Inventory Working List Key: <http://dnr.wi.gov/topic/NHI/WList.html>
- Wisconsin's Wildlife Action Plan: <http://dnr.wi.gov/topic/wildlifehabitat/actionplan.html>

Funding

- Natural Resources Foundation of Wisconsin: <http://www.wisconservation.org/>
- USFWS State Wildlife Grants Program: <http://wsfrprograms.fws.gov/subpages/grantprograms/swg/swg.htm>
- Wisconsin Natural Heritage Conservation Fund
- Wisconsin DNR Division of Forestry

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Big Brown Bat (*Eptesicus fuscus*) Species Guidance

Family: Vespertilionidae – the evening bats

State Status: Threatened

State Rank: S2S4

Federal Status: None

Global Rank: G5

Wildlife Action Plan Area of Importance Score: None

Range of big brown bat in Wisconsin. Source: WI Bat Program 2012

Heather Kaarakka, Wisconsin DNR

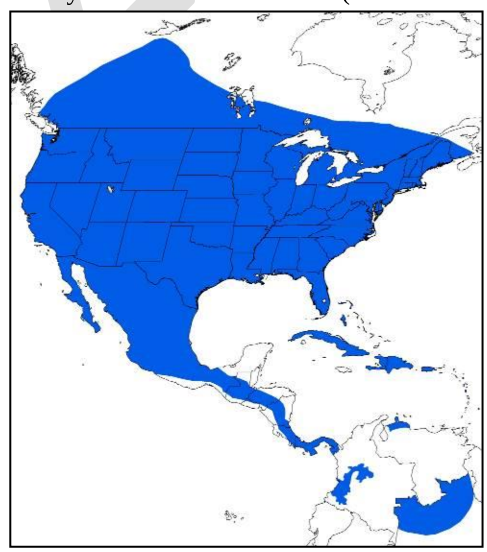
Dave Redell, Wisconsin DNR

Species Information

General Description: The big brown bat receives its name from its russet to dark brown color, as well as its size relative to other Wisconsin bats. Adults weigh 15-26 g (0.5-0.9 oz), and individual bats' weights vary seasonally and are least in the spring as bats emerge from hibernation (WI Bat Program unpublished data). Adult total length is 110-130 mm (4.3-5.1 in) and forearm length 41-50 mm (1.6-2.0 in; Kurta 1995, WDNR 2009). Wingspan ranges from 32.5-35 cm (12.8-13.8 in) and females are usually slightly larger than males (Barbour and Davis 1969). Dorsal fur is brown to reddish brown and glossy; ventral fur is lighter brown. The skull is larger than other Wisconsin species. The ears are rounded, black in color, naked, and have a rounded tip tragus. Wings, tail membrane, and muzzle are also black and naked.

Similar Species: The big brown bat shares physical characteristics with the hoary bat (*Lasiurus cinereus*) and the silver-haired bat (*Lasionycteris noctivagans*), but close inspection reveals a much duller and solid fur color on the big brown bat with no white-tipped fur. *Myotis* species may be similar in color and form, but big browns can be distinguished by their larger dimensions and broad muzzles. Big brown bats also have a larger tragus and forearms when compared to the evening bat's 34-38 mm (1.3-1.5 in) (Kurta 1995). The big brown bat can also be identified by its echolocation call (Fig. 1), but the silver-haired bat and the hoary bat share similar call characteristics with the big brown bat, and only trained individuals should positively identify bat species through echolocation calls.

Associated Species: Big brown bat predators include owls, hawks, occasionally snakes, and raccoons (*Procyon lotor*). As many as 13 feral cats have also been observed congregating at a mine entrance at dusk to prey upon bats as they leave the hibernaculum (D. Redell pers. obs.). Big brown bats often share hibernacula with other bat species such as the tri-colored bat (*Permyotis subflavus*), the northern long-eared bat (*Myotis septentrionalis*) and the little brown bat (*Myotis lucifugus*), but the big brown bat will rarely, if ever, form hibernating clusters with other species. Big brown bats forage with other bat species, but there is no evidence of direct competition between species.



Global distribution of the big brown bat. (BCI 2012)

State Distribution and Abundance: Big brown bats are presently common and widespread in Wisconsin and are generally more common in the southern part of the state than in the north (Jackson 1961, WDNR 2013).

Global Distribution and Abundance: The big brown bat is currently one of the most abundant and widely distributed bats in North America. It ranges from northern Canada, across the continental United States and into Central and South America (BCI 2012).

Diet: Big brown bats are insectivorous, and eat insects from many orders but specialize in beetles (*Coleoptera*) (Whitaker 2004). Other prey include wasps and ants (*Hymenoptera*), flies and mosquitoes (*Diperta*). All prey are caught in-flight using echolocation. Big brown bats may become more beetle-specialist as they mature (Hamilton and Barclay 1998). Regional variation in diet composition exists (Duchamp et al 2007).

Reproductive Cycle: The big brown bat's reproductive cycle begins in the spring after hibernation, when females become fertilized with sperm they have stored in the uterus over the winter. Reproductive females form a maternity roost with other female conspecifics (members of the same species), and give birth to usually a single pup in June after about a 60-day gestation period (Kurta 1990). Young are naked, blind, and small at just three grams (0.1 oz). The pup nurses for about a month and is left at the roost nightly while the mother leaves to feed (Kurta 1995, Davis et al. 1996). The pup begins to fly and explore on its own at three to five weeks old. Maternity colonies disperse in late July and August, and bats move closer to hibernacula in the fall to mate before they hibernate (Barbour and Davis 1969). Male big brown bats may become mature by their first autumn, whereas females may not reach maturity until after their first year.

Ecology: Male and female big brown bats in Wisconsin begin to leave hibernacula in March and April. During the summer, males are usually solitary while females may form large maternal colonies averaging in size from 20-100 adults in houses or barns. Some males have been observed roosting with females or in all-male colonies (Barbour and Davis 1969). Forest-dwelling reproductive females frequently switch roosts (about every two days, Willis and Brigham 2004). Big brown bats are intolerant of high heat, and mother bats will move their young if temperatures in a roost exceed 32° C (89°F; Davis et al. 1968, Ellison et al. 2007). Another purpose for roost switching may be to maintain a large network of social connections (Willis and Brigham 2004). Maternity roosts usually disband in August and September when bats migrate to their hibernacula. Interannual fidelity to maternity roost sites is common (Kurta 1995).

Big brown bats of both sexes start foraging 20 minutes after sundown unless conditions are rainy, very windy, or below 10° C (50° F). Bats may use night roosts such as barns, shutters, and awnings to rest and digest their meal but return to their day roost by dawn (Kurta 1995). In September and October, big brown bats put on substantial weight to prepare for hibernation. Mating occurs during autumn and early winter during the "fall swarm" when bats congregate at cave and mine entrances before or during the start of hibernation. Sperm is stored in the uterus during winter, and fertilization occurs in the spring when the bats emerge from hibernation. Big brown bat life expectancy is up to 19 years in the wild (Kurta 1995). More research is needed on big brown bats' basic life history and behavior.

Natural Community Associations: (WDNR 2005 and WDNR 2009)

Many bat species are associated more with structural features within natural communities than with any particular natural community or group of natural communities (see "Habitat" section). However, additional research may reveal new information regarding bat species' natural community requirements.

Significant: none
Moderate: none
Minimal: none

Habitat: Big brown bat habitat use changes over the course of the year and varies based on sex and reproductive status. Reproductive females often use different summer habitat from males and non-reproductive females.

Summer: Big brown bats are present in a wide variety of habitats, and are most abundant in farmland, urban areas, and edge habitat near water. Summer roosts occur in crevices and holes of trees or snags or dead-top live trees, caves, and the attics, eaves and walls of buildings (Rancourt et al. 2007). Reproductive females form maternity colonies of 20-100 bats primarily in buildings and bat houses, but they also use tree cavities of beech (*Fagus*), oak (*Quercus*) and aspen (*Populus*) and, rarely, rock crevices (Brigham 1991, Agosta 2002, Duchamp et al. 2007). Structures housing maternity colonies are typically warmer than ambient temperature (outside air temperature), and this elevated temperature helps growth and maturation of the young (Agosta 2002, Lausen & Barclay 2006). Year-to-year summer roost fidelity by females is common (Willis et al. 2003, Duchamp et al. 2007), but bats switch roosts over the summer, particularly when temperatures are high (Kurta 1990, Ellison et al 2007). Males and non-reproductive females roost alone or with a few other males in buildings, trees and rock crevices. Willis et al. (2006) suggests big brown bats choose tree roosts based on the volume of roost cavities in the tree, rather than tree height or stem diameter. Big brown bats may use bridges, buildings, caves, mines, rock crevices or trees as night roosts where they rest and digest for short periods of time. Foraging occurs in forest gaps and riparian areas (Duchamp et al. 2007). Big brown bats prefer to forage in urban landscapes along forest and field edges, over open water and along shorelines (WI Bat Program 2010, 2011, 2012). More information is needed to more fully describe big brown bat foraging habitats and summer roosting in Wisconsin.

Examples of common big brown bat summer roosts: A barn roost in Iowa County (left; Heather Kaarakka, Wisconsin DNR) and a roost in a bat house in Iowa County (right; © Boyd Geer).

Home range: Brigham (1991) found average distance traveled between roost sites and foraging area 1.8 km (1.1 miles), and Brigham and Fenton (1986) found an average distance of 0.9 km (0.5 miles) traveled between roost sites and foraging habitat. More research is needed to accurately describe big brown bat home range.

Winter: Big brown bats hibernate in caves and in man-made structures such as mines, basements, buildings or culverts. Big brown bats are the only Wisconsin bat species known to roost in buildings during winter (all other Wisconsin cave bat species hibernate exclusively underground in caves or mines). Buildings in which big brown bats hibernate remain above freezing through the winter and typically range from 9° to 14° C (48-57° F) (Whitaker 1992). Building use by big brown bats may lower predation risk and save on energy costs (Lausen and Barclay 2006, Duchamp et al. 2007). In cave and mine hibernacula, big brown bats hibernate in areas and sites that are colder, drier, and more exposed to air flow than other Wisconsin bat species. This species occasionally forms clusters during hibernation, but is also found hanging singly from the ceiling or wall. More research is needed to determine what characteristics make caves and mines suitable for big brown bat hibernation.

Big brown bat hibernacula in southwestern Wisconsin: Cluster on a wall in Monroe County (left), and single bat hanging from ceiling in Crawford County. Heather Kaarakka, Wisconsin DNR

Edge habitat (transition zone between two types of vegetation) is important for big brown bats as they migrate and forage. When bats migrate from wintering caves to summer habitat, or commute from roosts to feeding grounds, they move through the landscape in a manner that protects them from wind and predators. Instead of flying the shortest distance across a field, for instance, bats will take longer routes that follow edge habitat. In addition to offering protection, this behavior may also allow bats more feeding opportunities because food is more abundant around edge habitat (Limpens and Kapteyn 1991). Commuting along edge habitat may assist the bats with navigation and orientation through use of linear edges as landmarks (Verboom and Huitema 1997).

Threats: Lack of information on bat species' basic ecology is one of the greatest threats to bat conservation in Wisconsin. The big brown bat faces two emerging threats, and several ongoing threats. White-nose syndrome (WNS) was discovered in 2006 in a hibernaculum in New York State, and appears as a white, powdery substance on the bat's face and body. White-nose syndrome has spread rapidly since 2007 to other hibernacula in neighboring states (USFWS 2012). Infected big brown bat hibernacula in New York and surrounding states have experienced mortality rates of over 90%. White-nose syndrome has been called the "most precipitous wildlife decline in the past century in North America" (BCI 2009), and is caused by a fungus called *Geomyces destructans* (Lorch et al. 2011). This fungus grows best in the cool, wet conditions of hibernacula (Verant et al. 2012). Mortality from the fungus appears to come from increased arousals during torpor, which deplete bats' fat reserves and cause starvation (Reeder et al. 2012) and dehydration (Cryan et al. 2010). For up to date WNS information, see the USFWS WNS website and the USGS National Wildlife Health Center website (see *Linked Websites*). Neither the fungus nor the disease has been found in Wisconsin as of this writing. Cave-hibernating bats, including the big brown bat, should be monitored closely for any indication of WNS; the Wisconsin Bat Program conducts WNS surveillance and monitoring in the state.

Wind power is another emerging threat to bats – wind turbines have been shown to fatally impact all bat species in Wisconsin (Johnson 2003, Arnett et al. 2008). Wind-turbine blades cause mortality through direct impact or through the pressure differential caused by the motion of the spinning blades. This pressure differential causes a bat's lungs to fill with fluid as it flies near the spinning blades, and this phenomenon (known as barotrauma) kills the bat instantly (Baerwald et al. 2008). More research is under way to better understand bat wind-turbine vulnerabilities, but current studies suggest that bats face the greatest risk during migration from summer foraging sites to wintering grounds (tree bats) or hibernacula (cave bats) (Johnson 2003, Kunz et al. 2007). Research is needed on all Wisconsin bat species to better understand wind-turbine mortality in the state and the long term population impacts of turbine-related deaths.

Big brown bats also face the ongoing threat of habitat degradation. Habitat degradation is caused by increased agricultural, industrial, and household pesticide use, and it has negative effects on bats through direct exposure and through dietary accumulation (O'Shea et al. 2001). Pesticides are a threat to many taxa, but bats may be more vulnerable than other small mammals due to certain life characteristics (Shore et al. 1996, O'Shea et al. 2001). Bats' longevity and high trophic level means pesticides can concentrate in their body fat (Clark and Prouty 1977, Clark 1988). Even after pesticide exposure ceases, residues can be passed on to nursing young (Clark 1988). Bat species that migrate long distances may be more affected because pesticide residues become increasingly concentrated in the brain tissue as fat reserves are depleted during long-distance flights. This concentration can lead to convulsions and even death (Geluso et al. 1976, Clark 1978).

Big brown bats also face the ongoing threat of hibernaculum disturbance from humans entering hibernacula in winter and waking bats from torpor. Bats in torpor reduce their metabolism and body temperature to low levels that require less energy than being fully awake. Interrupting torpor costs energy; a little brown bat uses up to 100 mg of fat reserves waking and the returning to torpor (and more if the bat starts flying), or the energetic equivalent of up to 67 days of torpor (Thomas et al. 1990, Thomas 1992). This loss clearly represents a large percentage of total body weight of the bat, and repeated arousals may cause bats to run out of energy reserves before spring arrives and therefore starve in the hibernaculum or die from the elements if they seek food outside (Thomas 1995).

Climate Change Impacts: The effects of climate change on the big brown bat are unclear. Predictions suggest a northward expansion in the ranges of all cave-bat species, in pursuit of optimal hibernation (Humphries et al. 2002, USFWS 2007). This prediction assumes an abundance of suitable caves and other hibernaculum structures further north, but this assumption may not hold for karst-free regions at higher latitudes. Bat species may adapt by reducing torpor depth and duration during winter if prey insect species are available for more of the year (Weller et al. 2009), but bats' adaptive capacities in this regard may be limited and are not well known. Shifts in prey insect emergence may also cause mismatches with bat emergence and cause food shortages in the spring or fall.

Survey Guidelines: Persons handling big brown bats must possess a valid Endangered and Threatened Species Permit. If surveys are being conducted for regulatory purposes, survey protocols and surveyor qualifications must first be approved by the Endangered Resources Review Program (see *Contact Information*).

Acoustic surveys, which should be done by trained individuals, are performed for all Wisconsin bat species in spring, summer and fall, and are used to determine presence/absence, phenology, and distribution around the state. The Wisconsin Bat Program's eventual goal is to use acoustic survey data to determine bat population trends in Wisconsin. Big brown bats are ubiquitous around the state, and therefore surveys can be done wherever suitable habitat exists. Acoustic recording systems that detect echolocation calls can survey bats as they fly through an area. The bat detection system detects and records these acoustic signals as bats fly by, and records the date and time of each encounter. The Wisconsin Bat Program currently uses broadband frequency division ultrasound detection equipment with a PDA (Personal Data Assistant) and a Global Positioning System. Start acoustic surveys half an hour after sunset, but only if the daytime temperature exceeds 50° F, and conduct the survey for at least one hour. There are three seasons for acoustic surveys: spring (April and May), summer (June and July), and fall (August and September). Acoustic surveys record bat passes, which can then be identified to species by trained individuals. These surveys could be used by land managers to create inventories of species distribution and relative abundance. Visit the Wisconsin Bat Program website for additional information.

Wisconsin DNR also conducts a roost monitoring program to determine abundance of bats roosting in buildings and bat houses. People with bat houses or other roost sites identify species and count bats over the summer at night as bats leave the roost. People who find a bat roost while doing field surveys should contact the Wisconsin Bat Program to report the information.

Big brown bats will roost in tree cavities, but such roosts are hard to locate in practice and more information is needed to determine big brown bats' roost preference and conditions of roost trees. Suspected roost trees (see "Habitat" section above) may be identified by sitting at the tree site at dusk and watching for emergence or looking for evidence of bats such as buildup of guano. Known roost trees are of particular importance for both conservation and research purposes and should be avoided. People who find roost trees should contact the Wisconsin Bat Program to report the information.

Summarize results, including survey dates, times, weather conditions, number of detections, detection locations, and behavioral data and submit via the WDNR online report: <http://dnr.wi.gov, keyword "rare animal field report form">

Management Guidelines

The following guidelines typically describe actions that will help maintain or enhance habitat for the species.

Summer Management

Summer roost (see "Habitat" section) availability may limit big brown bat population levels (Fenton & Barclay, 1980), and therefore current summer roost sites should be protected and managed. Big brown bats choose sites based on specific conditions that can be found in both artificial and natural roost settings (bat houses and snag trees). This bat species congregates in large colonies at roost sites to reproduce, and therefore providing safe breeding habitat is one of the best ways to protect this species. Bat houses are an important artificial habitat for big brown bats where females may successfully rear their young in protected conditions. Place bat houses on the south- and east-facing sides of buildings or tall poles. Steps to ensure that a bat house succeeds can be found on the Wisconsin Bat Program website (see *Linked Websites*).

Bats appear to choose natural roosting sites based on the maturity of the forest. Big brown bats seem to choose mature forest because the large trees offer more roosting cavity availability (Williams and Brittingham 1997, Agosta 2002). Research shows that big brown bats use natural tree roosts when building roosts are not available, but it is unclear whether they prefer natural roosts and use building roosts as a result of loss of natural habitat or whether their use of man-made structures is simply exploitation of whatever roosting habitat may be in the area (Brigham 1991, Agosta 2002). Protection and management of mature stands of forest may be the best way to encourage big brown bats to use an area. Forestry management practices that reduce clutter within the forest, such as thinning and burning, and increase edge habitat can encourage big brown bats to forage and roost (Duchamp et al. 2007). Thinning in a southern pine stand led to increased use by big brown bats, which implies that reducing clutter, especially thinning, increases habitat suitability (Loeb and Waldrop 2008). Forested landscapes with a variety of stand types, ages, and management conditions varying in size and topographic location likely provide the landscape elements required to maintain multiple species of bats (Perry et al. 2008).

Linear corridors are important for bat commuting, and forests may be managed such that suitable foraging habitat is connected by corridors; this may include managing edge habitat along roads, logging trails and riparian corridors. Land managers should also make an effort to reduce or eliminate burdock (*Arctium minus*), an exotic weed that produces seeds that trap bats and cause death from exposure.

Special consideration should be given to protecting snags or dying trees, especially those near known roost locations, particularly from June 1 through August 15 while bats may have pups at the roost.

Woodland seasonal pools may be important foraging and water sources for the big brown bat and other Wisconsin bat species because they provide areas for feeding and drinking in an otherwise closed-canopy forest (Francl 2008). Pool size and depth do not appear to determine usage by big brown bats; instead the presence of an opening in the forest is enough to encourage foraging and drinking (Francl 2008).

Fall Management

During fall swarm, large proportions of Wisconsin's cave bat population gather near entrances of the state's hibernacula (see "Habitat" section above), and become concentrated and vulnerable to direct impacts. To avoid disturbance during crucial life history events, management activities such as logging and use of heavy machinery within 0.25 miles of hibernacula entrances should be avoided during fall swarm (August 15-October 15) or during spring emergence (April 1-May 15) because bats may use the surrounding area for roosting during those time periods (USFWS 2007).

Winter Management

Little is known about how big brown bats choose hibernation sites, but suitable Wisconsin hibernacula typically have steady temperatures between 4° C and 12° C (39-53° F), high humidity, and little to no human disturbance. Artificial sites that can mimic this environment may provide suitable hibernacula. Artificial hibernacula include bunkers, food storage-caves and basements. Contact the Wisconsin Bat Program to inquire about developing artificial hibernacula.

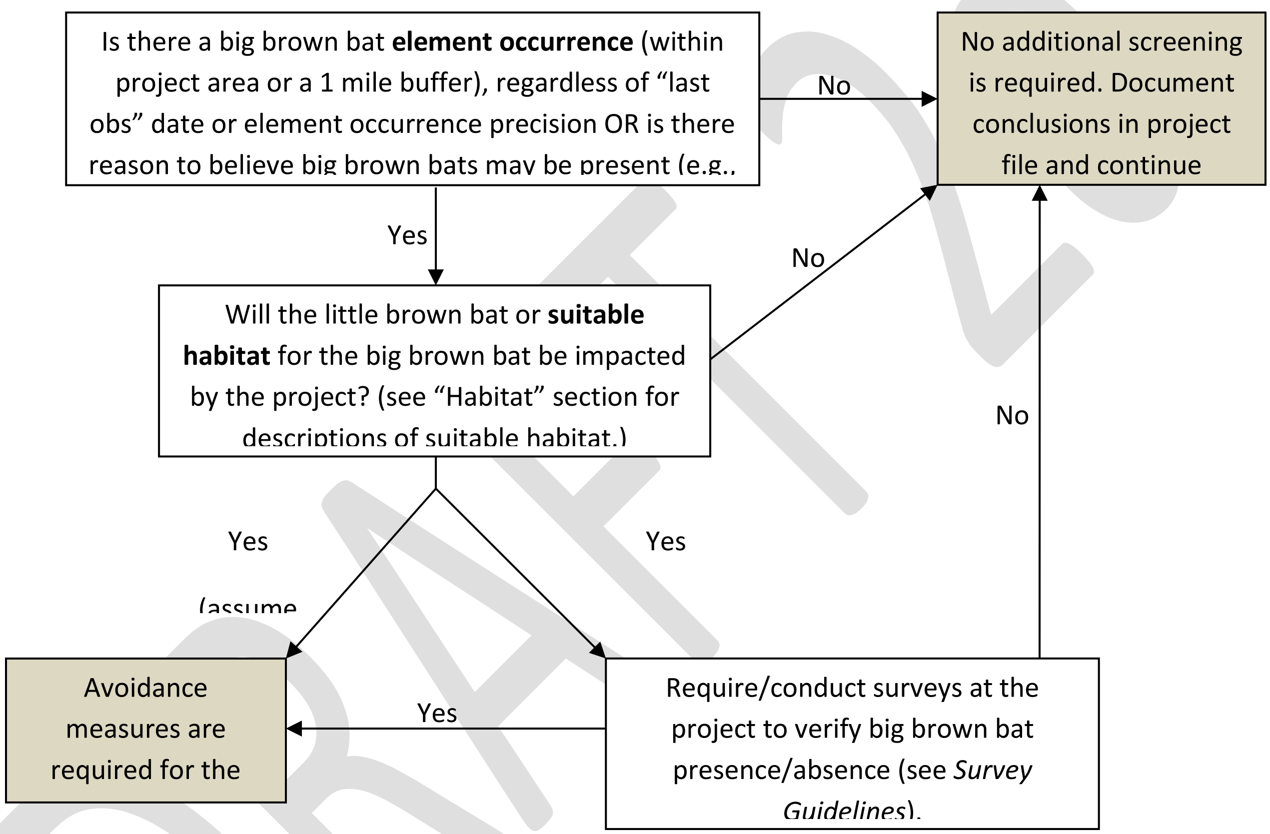
Big brown bats may use buildings as hibernation sites during the winter, especially summer homes that are unheated in winter. Such colonies are normally small (fewer than 30 bats) and inactive, and the best course of action is to leave the colony alone until spring. Big brown bats may become active in the middle of winter during warm bouts, and attempting to exclude the bats (i.e., putting up one-way doors) will trap the bats outside and expose them to the elements. Conduct exclusion in late March through April to evict the bats. If a large number of bats must be removed for health reasons, contact the Wisconsin Bat Program for information on removal and transfer of the colony.

Natural hibernacula can also be managed to encourage bat use. For example, closing but not sealing the entrance to an abandoned mine not only buffers temperature and humidity, but also reduces disturbance from humans and predators. Eliminating disturbance from humans, except for WNS surveillance, is the best management activity for natural cave hibernacula. Contact the Wisconsin Bat Program for more information about managing bat hibernacula. Big brown bats – and their populations as a whole – are particularly vulnerable during winter hibernation because they are concentrated in just a few major hibernacula and because repeated disturbance during hibernation can lead to mortality (see "Threats" section above). Each time a bat is aroused from torpor, it uses up a substantial proportion of the fat reserves it relies on to hibernate through the winter and faces greater odds of starvation before spring (see

"Threats" section above). Therefore, avoid entering hibernacula from October 1 through May 15 unless conducting approved and permitted management, surveillance, or research.

Screening Procedures

Follow the "Conducting Endangered Resources Reviews: A Step-by-Step Guide for Wisconsin DNR Staff" document (summarized below) to determine if big brown bats will be impacted by a project (WDNR 2012):



Avoidance Measures

The following measures are specific actions required by DNR to avoid take (mortality) of state threatened or endangered species per Wisconsin's Endangered Species law (s. 29.604, Wis. Stats.) These guidelines are typically

According to Wisconsin's Endangered Species Law (s. 29.604, Wis. Stats.), it is illegal to take, transport, possess, process, or sell any wild animal on the Wisconsin Endangered and Threatened Species List (ch. NR 27, Wis. Admin. Code). Take of an animal is defined as shooting, shooting at, pursuing, hunting, catching or killing.

If *Screening Procedures* above indicate that avoidance measures are required for a project, please follow the measures below. If you have not yet read through *Screening Procedures*, please review them first to determine if avoidance measures are necessary for the project.

1. The simplest and preferred method to avoid take of big brown bats is to avoid directly impacting individuals, known big brown bat locations, or areas of suitable habitat (described above in the "Habitat" section and in *Screening Procedures*). The U.S. Fish and Wildlife Services identifies humans and their equipment as possible vectors for spores of *Geomyces destructans* – the fungus

that causes white-nose syndrome (WNS) – and therefore simply entering hibernacula at any time of year and moving between them poses threats to bats. Cavers and researchers must observe all cave and mine closures and decontamination protocols (s. NR 40.07, Wis. Admin. Code) (see *Additional Information*). In addition, it is illegal to use pesticides and poisons when attempting to evict bats from house roosts (s. 94.708, Wis. Stats.).

2. If suitable habitat cannot be avoided, follow these time-of-year restrictions to avoid take:

Summer Avoidance **(June 1-Aug 15)**

Reproductive females and their young are highly vulnerable to mass mortality during the species' maternity period (June 1 – August 15) because they aggregate in maternity colonies, and because pups cannot fly and therefore cannot leave the roost for several weeks after birth. Many maternity colonies occur in human structures, and those seeking to exclude bats from a building or other roost must follow the Cave Bat Broad Incidental Take Permit and Authorization (see *Additional Information*).

3. If impacts cannot be avoided during restoration or management activities, including wind projects and forestry management, but activities are covered under the Cave Bat Broad Incidental Take Permit and Authorization; the project is covered for any unintentional take that may occur. For information about natural roost avoidance, see *Management Guidelines* and "Habitat" section above.

4. Those seeking to complete wind farm projects should review and follow the Guidance for Minimizing Impacts to Natural Resources from Terrestrial Commercial Wind Energy Development created by the WDNR.

5. If big brown bat impacts cannot be avoided, please contact the Natural Heritage Conservation Incidental Take Coordinator (see *Contact Information*) to discuss possible project-specific avoidance measures. If take cannot be avoided, an Incidental Take Permit or Authorization (see *Additional Information*) is necessary.

Additional Information

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Linked Websites:

- Cave bat Broad Incidental Take Permit and Authorization:< http://dnr.wi.gov/topic/erreview/itbats.html>
- Natural Communities of Wisconsin: <http://dnr.wi.gov/org/land/er/communities/>
- Natural Heritage Conservation Permit Requirements: <http://dnr.wi.gov/topic/EndangeredResources/permits.html>
- Rare Animal Field Report Form: <http://dnr.wi.gov, key word "rare animal field report form">
- USFW WNS Website: <http://www.whitenosesyndrome.org>
- USGS National Wildlife Health Center: <http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/>
- Wind Guidance: <http://dnr.wi.gov/topic/Sectors/documents/energy/WindGuidelines.pdf>
- Wisconsin Bat Program Exclusion Instructions: <http://wiatri.net/inventory/bats/Monitoring/Roosts/docs/BatExclusion.pdf>
- Wisconsin Bat Program: <http://wiatri.net/inventory/bats>
- WDNR Decontamination Protocols for Preventing Spread of White-nose syndrome: <http://dnr.wi.gov/topic/WildlifeHabitat/documents/WNS_DeconProtocols.pdf>
- Wisconsin Endangered and Threatened Species: <http://dnr.wi.gov, key word "endangered resources">
- Wisconsin Endangered and Threatened Species Permit: <http://dnr.wi.gov, key word "endangered species permit">"
- Wisconsin Initiative on Climate Change Impacts: <http://www.wicci.wisc.edu/>
- Wisconsin Natural Heritage Inventory Working List Key: <http://dnr.wi.gov/topic/NHI/WList.html>
- Wisconsin's Wildlife Action Plan: <http://dnr.wi.gov/topic/wildlifehabitat/actionplan.html>

Funding

- Natural Resources Foundation of Wisconsin: <http://www.wisconservation.org/>
- USFWS State Wildlife Grants Program: <http://wsfrprograms.fws.gov/subpages/grantprograms/swg/swg.htm>
- Wisconsin Natural Heritage Conservation Fund
- Wisconsin DNR Division of Forestry

Endangered Resources Review Program Contacts

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Suggested Citation

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Eastern Pipistrelle (*Perimyotis subflavus*) Species Guidance

Also known as: Tri-colored bat and formerly *Pipistrellus subflavus*

Family: Vespertilionidae – the evening bats

State Status: Threatened

State Rank: S1S3

Federal Status: None

Global Rank: G3

Wildlife Action Plan Area of Importance Score: None

Range of eastern pipistrelle in Wisconsin. Source: WI Bat Program 2012

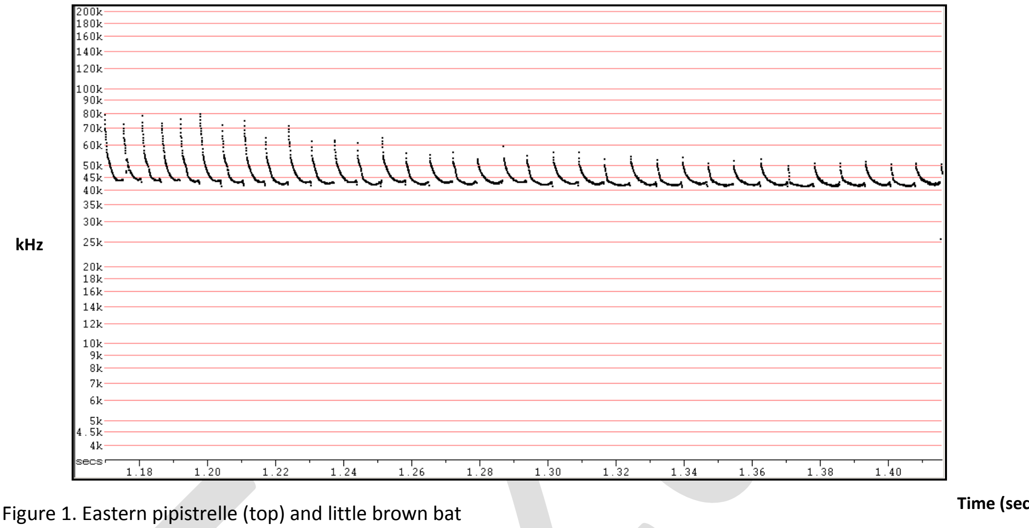
Dave Redell, Wisconsin DNR

Species Information

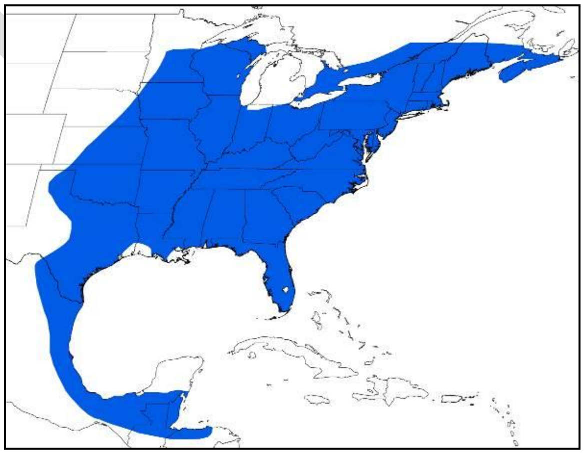
General Description: The eastern pipistrelle is Wisconsin's smallest bat, and weighs just four to eight grams (0.1 – 0.3 oz; Kurta 1995). This species has a forearm length of 32-36 mm (1.3-1.4 in) and a total length of seven to eight centimeters (2.8-3.1 in; Kurta 1995). Total wingspread is 21-26 cm (8.3-10.2 in; Barbour and Davis 1969). Fur color ranges from golden brown to reddish brown. The eastern pipistrelle has black forearms that contrast with the red membrane of the wing. The dorsal guard hairs have a distinct tricolored appearance – dark at base, yellowish in middle and dark at the tip – that give the bat a harlequin appearance.

Similar Species: The eastern pipistrelle may be confused from a distance with Wisconsin's *Myotis* species, the little brown bat (*Myotis lucifugus*) and northern long-eared bat (*Myotis septentrionalis*), because of its similar size and coloring. However, it is readily distinguished at close range by its distinct tri-colored fur and harlequin appearance (Barbour and Davis 1969). The eastern pipistrelle and the *Myotis* species can sometimes be confused during hibernaculum surveys because the two species appear similar from a distance. The eastern pipistrelle can be identified by its tan or sandy coloring, and also by its heart-shaped face and ears compared to the dark brown fur and linear face and ears of the little brown bat (see Fig. 1). The eastern pipistrelle can also be identified by its echolocation call (see Fig. 2), but the eastern red bat (*Lasiurus borealis*) shares similar call characteristics, and only trained individuals should positively identify bat species through echolocation calls.

Figure 1. Eastern pipistrelle (top) and little brown bat (bottom) hibernating together. The eastern pipistrelle has lighter fur and a heart-shaped face. Heather Kaarakka, Wisconsin DNR



Associated Species: Eastern pipistrelle predators include owls, hawks, occasionally snakes, and raccoons (*Procyon lotor*). As many as 13 feral cats have also been observed congregating at a mine entrance at dusk to prey upon bats as they leave the hibernaculum (D. Redell pers. obs.). Eastern pipistrelles often share hibernacula with other bat species such as the little brown bat, the northern long-eared bat, the Indiana bat (*Myotis sodali*) and the big brown bat (*Eptesicus fuscus*), but the eastern pipistrelle will rarely, if ever, form hibernating clusters with other species. Eastern pipistrelles forage with other bat species, but there is no evidence of direct competition between species.



Global distribution of the eastern pipistrelle. (BCI 2012)

State Distribution and Abundance: Eastern pipistrelles are primarily found in the western half of the state, possibly because the Great Lakes create a cold landscape (Jackson 1961, Kurta 1995, WDNR 2013), but hibernaculum surveys show hibernating tri-colored bats in Door County and northeastern Wisconsin (WI Bat Program 2011). Eastern pipistrelles are not a common species in Wisconsin (Kurta 1995).

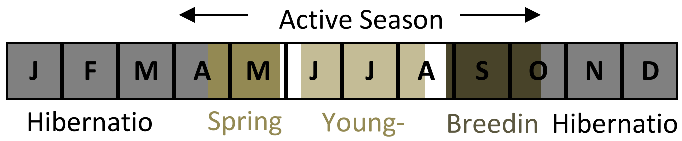
Global Distribution and Abundance: The eastern pipistrelle was a common species in North America before white-nose syndrome (see "Threats" section). It ranges from northern United States into Florida and Central America. It is absent from the western portion of the United States (BCI 2012), and is in severe decline in the northeastern US and adjacent areas in Canada.

Diet: The eastern pipistrelle is a generalist insectivorous bat. Diet consists mainly of small beetles (*Coleoptera*), wasps (*Hymenoptera*), flies (*Diptera*) and moths (*Lepidoptera*; Fujita and Kunz 1984). Eastern pipistrelles use echolocation to locate capture prey most commonly while in flight.

Reproductive Cycle: The eatern pipistrelle's reproductive cycle begins when fertilization occurs in spring with sperm stored by the female over winter (Fujita and Kunz 1984). Reproductive female bats exit hibernacula in late spring and usually roost alone, or rarely with other female eastern pipistrelles. Gestation period is around 45-50 days (Wimsatt 1945). Females give birth to usually two pups in late June and early July (Fujita and Kunz 1984). The pups are left at the roost nightly while the mother goes out to forage, and they mature after about three weeks. After pups become volant (able to fly), the bats work their way to hibernacula where mating occurs in late

Figure 2. The eastern pipistrelle produces a high-frequency call, the hook of which hovers almost exclusively at 42 kHz. Each call in the pass has a distinct hook at the base during the search phase of the pass. This pattern is similar to that of the eastern red bat.

summer through fall. Females and males do not reach sexual maturity until the following fall (Fujita and Kunz 1984).



Ecology: In Wisconsin, eastern pipistrelles leave hibernacula in late April and early May, and make short migrations to summer roosting sites. Reproductive females roost alone or may form small maternity colonies of up to 30 bats in trees, buildings, and rock crevices (Whitaker 1998). Birthing dates for eastern pipistrelles are from mid-June through July, although some regional variation exists within the state. Maternity colonies disperse in late July and August, and both males and females make their way to winter hibernacula. The eatern pipistrelle is long lived for its size, and lives up to seven and eight years in most cases, and males generally live longer than females (Barbour and Davis 1969). Eastern pipistrelles are among the earliest bats to feed in the evening and have a characteristic slow, erratic flight pattern (Fujita and Kunz 1984) that sometimes causes these small-sized bats to be mistaken for moths.

Eastern pipistrelles typically hibernate alone, rather than in clusters like other cave bat species, and the association shown in figure 1 is unusual. They prefer to hang from the walls of the cave rather than from the ceiling, and in deeper and warmer parts of the site than other cave hibernating bats (Fujita and Kunz 1984). More research is needed on eastern pipistrelles' basic life history and behavior.

Natural Community Associations: (WDNR 2005 and WDNR 2009)

Many bat species are associated more with structural features within natural communities than with any particular natural community or group of natural communities (see "Habitat" section). However, additional research may reveal new information regarding bat species' natural community requirements.

Significant: none
Moderate: none
Minimal: none
Habitat: Eastern pipistrelle habitat use changes over the course of the year, and varies based on sex and reproductive status. Reproductive females often use different summer habitat than males and non-reproductive females.

Summer: Male and non-reproductive female eastern pipistrelles are solitary and roost in the foliage of deciduous trees (Fujita and Kunz 1984), where they disguise themselves as leaves for protection from predators. Reproductive female eastern pipistrelles may occasionally use human-made structures such as barns for maternity colonies, but they also normally choose to roost in clusters of oak and maple leaves (Fujita and Kunz 1984, Perry and Thill 2007). Both sexes appear to prefer to roost in dead and live leaf clusters on oak trees (*Quercus*) of upland, mature forests (> 50 years) (Veilleux et al 2003, Perry and Thill 2007). Year-to-year site fidelity may be high for females of this species, but bats often switch roost trees over the course of the summer (Perry and Thill 2007). Eastern pipistrelles use caves, mines and rock crevices as summer night roosts (Barbour and Davis 1969). Foraging habitats of the eastern pipistrelle include waterways, along forest edges and in forest canopies (Fujita and Kunz 1984). More information is needed to more fully describe eastern pipistrelle foraging habitats and summer roosting in Wisconsin.

Eastern pipistrelle summer roosting habitat: Oak savanna with numerous foliage roosting opportunities (left; Ryan O'Connor, Wisconsin DNR) and southern dry mesic white oak forest (right; Andy Clark, Wisconsin DNR).

Edge habitat (transition zone between two types of vegetation) is important for eastern pipistrelles as they migrate and forage. When bats migrate from wintering caves to summer habitat, or commute from roosts to feeding grounds, they move through the landscape in a manner that protects them from wind and predators. Instead of flying the shortest distance across a field, for instance, bats will take longer routes that follow edge habitat. In addition to offering protection, this behavior may also allow bats more feeding opportunities because food is more abundant around edge habitat (Limpens and Kapteyn 1991). Commuting along edge habitat may assist the bats with navigation and orientation through use of linear edges as landmarks (Verboom and Huitema 1997).

Home range: Little is known about tri-colored bat home range and daily movement, and more research is needed.

Winter: Eastern pipistrelles overwinter deep in caves and abandoned mines by hanging on walls where temperatures remain relatively constant (Fujita and Kunz 1984). They tend to hibernate alone rather than in clusters like bats of other species (Fujita and Kunz 1984).

Hibernating eastern pipistrelles in sites in southwestern WI: Eastern pipistrelle hibernating on a wall with water condensation on its fur (left) and in a room of a cave (right). Heather Kaarakka, Wisconsin DNR

More research is needed to determine summer roosting and foraging habitats as well as home range.
Threats: Lack of information on bat species' basic ecology is one of the greatest threats to bat conservation in Wisconsin. The **e**astern pipistrelle faces two emerging threats, and several ongoing threats. White-nose syndrome (WNS) was discovered in 2006 in a hibernaculum in New York State, and appears as a white, powdery substance on the bat's face and body. White-nose syndrome has spread rapidly since 2007 to other hibernacula in neighboring states (USFWS 2012). Infected tri-colored bat hibernacula in New York and surrounding states have experienced mortality rates of over 90%. White-nose syndrome has been called the "most precipitous wildlife decline in the past century in North America" (BCI 2009), and is caused by a fungus called *Geomyces destructans* (Lorch et al. 2011). This fungus grows best in the cool, wet conditions of hibernacula (Verant et al. 2012). Mortality from the fungus appears to come from increased arousals during torpor, which depletes bats' fat reserves and causes starvation (Reeder et al 2012) and dehydration (Cryan et al. 2010). For up to date WNS information, see the USFWS WNS website and the USGS National Wildlife Health Center website (see *Additional Information*). Neither the fungus nor the disease has been found in Wisconsin as of this writing. Cave-hibernating bats, including the tri-colored bat, should be monitored closely for any indication of WNS; the Wisconsin Bat Program conducts WNS surveillance and monitoring in the state.

Wind power is another emerging threat to bats – wind turbines have been shown to fatally impact all bat species in Wisconsin (Johnson 2003, Arnett et al. 2008). Wind-turbine blades cause mortality through direct impact or through the pressure differential caused by the motion of the spinning blades. This pressure differential causes a bat's lungs to fill with fluid as it flies near the spinning blades, and this phenomenon (known as barotrauma) kills the bat instantly (Baerwald et. al. 2008). More research is under way to better understand bat wind-turbine vulnerabilities, but current studies suggest that bats face the greatest risk during migration from summer foraging sites to wintering grounds (tree bats) or hibernacula (cave bats) (Johnson 2003, Kunz et al. 2007). Research is needed on all Wisconsin bat species to better understand wind-turbine mortality in the state and the long term population impacts of turbine-related deaths.

Eastern pipistrelles also face the ongoing threat of habitat degradation. Habitat degradation is caused by increased agricultural, industrial, and household pesticide use, and it has negative effects on bats through direct exposure and through dietary accumulation (O'Shea et al. 2001). Pesticides are a threat to many taxa, but bats may be more vulnerable than other small mammals due to certain life characteristics (Shore et al. 1996, O'Shea et al. 2001). Bats' longevity and high trophic level means pesticides can concentrate in their body fat (Clark and Prouty 1977, Clark 1988). Even after pesticide exposure ceases, residues can be passed on to nursing young (Clark 1988). Bat species that migrate long distances may be more affected because pesticide residues become increasingly concentrated in the brain tissue as fat reserves are depleted during long-distance flights. This concentration can lead to convulsions and even death (Geluso et al. 1976, Clark 1978).

Eastern pipistrelles also face the ongoing threat of hibernaculum disturbance from humans entering hibernacula in winter and waking bats from torpor. Bats in torpor reduce their metabolism and body temperature to low levels that require less energy than being fully awake. Interrupting torpor costs energy; for example a little brown bat uses up to 100 mg of fat reserves waking and the returning to torpor (and more if the bat starts flying), or the energetic equivalent of up to 67 days of torpor (Thomas et al. 1990, Thomas 1992). This loss clearly represents a large percentage of total body weight of the bat, and repeated arousals may cause bats to run out of energy reserves before spring arrives and therefore starve in the hibernaculum or die from the elements if they seek food outside (Thomas 1995).

Climate Change Impacts: The effects of climate change on the tri-colored bat are unclear. Predictions suggest a northward expansion in the ranges of all cave-bat species, in pursuit of optimal hibernation (Humphries et al. 2002, USFWS 2007). This prediction assumes an abundance of suitable caves and other hibernaculum structures further north, but this assumption may not hold for karst-free regions at higher latitudes. Bat species may adapt by reducing torpor depth and duration during winter if prey insect species are available for more of the year (Weller et al. 2009), but bats' adaptive capacities in this regard may be limited and are not well known. Shifts in prey insect emergence may also cause mismatches with bat emergence and cause food shortages in the spring or fall.

Survey Guidelines: Persons handling eastern pipistrelles must possess a valid Endangered and Threatened Species Permit. If surveys are being conducted for regulatory purposes, survey protocols and surveyor qualifications must first be approved by the Endangered Resources Review Program (see *Contact Information*).

Acoustic surveys, which should be done by trained individuals, are performed for all Wisconsin bat species in spring, summer and fall, and are used to determine presence/absence, phenology, and distribution around the state. The Wisconsin Bat Program's eventual goal is to use acoustic survey data to determine bat population trends in Wisconsin. In summer, eastern pipistrelles are found in southern and western portions of the state and surveys can be conducted wherever suitable habitat exists. Acoustic recording systems that detect echolocation calls can survey bats as they fly through an area. The bat detection system detects and records these acoustic signals as bats fly by, and records the date and time of each encounter. The Wisconsin Bat Program currently uses broadband frequency division ultrasound detection equipment with a PDA (Personal Data Assistant) and a Global Positioning System. Start acoustic surveys half an hour after sunset, but only if the daytime temperature exceeds 50° F, and conduct the survey for at least one hour. There are three seasons for acoustic surveys: spring (April and May), summer (June and July), and fall (August and September). Acoustic surveys record bat passes, which can then be identified to species by trained individuals. These surveys could be used by land managers to create inventories of species distribution and relative abundance. Visit the Wisconsin Bat Program website for additional information.

Wisconsin DNR also conducts a roost monitoring program to determine abundance of bats roosting in buildings and bat houses. People with bat houses or other roost sites identify species and count bats over the summer at night as bats leave the roost. People who find a bat roost while doing surveys should contact the Wisconsin Bat Program to report the information.

Eastern pipistrelles roost in tree foliage, but such roosts are hard to locate in practice and more information is needed to determine tri-colored bats' roost preference and conditions of roost trees in Wisconsin. Suspected roost trees (see "Habitat" section above) may be identified by sitting at the tree site at dusk and watching for emergence or looking for evidence of bats such as buildup of guano. Known roost trees are of particular importance for both conservation and research purposes and should be avoided. People who find roost trees should contact the Wisconsin Bat Program to report the information.

Summarize results, including survey dates, times, weather conditions, number of detections, detection locations, and behavioral data and submit via the WDNR online report: <http://dnr.wi.gov, keyword "rare animal field report form">.

Management Guidelines

The following guidelines typically describe actions that will help maintain or enhance habitat for the species.

Summer Management

Summer roost (see "Habitat" section) availability may limit eastern pipistrelle population levels (Fenton & Barclay, 1980), and therefore current summer roost sites should be protected and managed. Eastern pipistrelles choose sites based on conditions that can be found in foliage of specific tree species. Bats also appear to choose natural roosting sites based on the maturity of the forest. In particular, eastern pipistrelles are found roosting in mature stands significantly more often than in younger stands, presumably because old growth oak provide more roosting opportunities as the branches break and fold down (Veilleux et al. 2003, Perry and Thill 2007). Protection and management of old stands of forest may be the best way to encourage eastern pipistrelles to use an area. Forestry management practices that reduce clutter within the forest, such as thinning and burning, and increase edge habitat can encourage eastern pipistrelles to forage and roost (Duchamp et al. 2007). Linear corridors are important for bat commuting, and forests may be managed such that suitable foraging habitat is connected by corridors; this may include managing edge habitat along roads, logging trails and riparian corridors. Land managers should also make an effort to reduce or eliminate burdock (*Arctium minus*), an exotic weed that produces seeds that trap bats and cause death from exposure.

Special consideration should be given to protecting dead and dying oak trees, especially those near known roost locations, particularly from June 1 through August 15 while bats may have pups at the roost.

Woodland seasonal pools may be important foraging and water sources for the eastern pipistrelle and other Wisconsin bat species because they provide areas for feeding and drinking in an otherwise closed-canopy forest (Francl 2008). Pool size and depth do not appear to determine usage by eastern pipistrelles; instead the presence of an opening in the forest is enough to encourage foraging and drinking (Francl 2008).

Fall Management

During fall swarm, large proportions of Wisconsin's cave bat population gather near entrances of the state's hibernacula (see "Habitat" section above), and become concentrated and vulnerable to direct impacts. To avoid disturbance during crucial life history events, management activities such as logging and use of heavy machinery within 0.25 miles of hibernacula entrances should be avoided during fall swarm (August 15-October 15) or during spring emergence (April 1-May 15) because bats may use surrounding area for roosting during those time periods (USFWS 2007).

Winter Management

Little is known about how eastern pipistrelles choose hibernation sites, but suitable Wisconsin hibernacula typically have steady temperatures between 4° C and 12° C (39-53° F), high humidity, and no human disturbance. Artificial sites that can mimic this environment may provide suitable hibernacula. Artificial hibernacula include bunkers, food storage-caves and basements. Contact the Wisconsin Bat Program to inquire about developing artificial hibernacula.

Natural hibernacula can also be managed to encourage bat use. For example, closing but not sealing the entrance to an abandoned mine not only buffers temperature and humidity, it also reduces disturbance from humans and predators. Eliminating disturbance from humans, except for WNS surveillance, is the best management activity for natural cave hibernacula. Contact the Wisconsin Bat Program for more information about managing bat hibernacula.

Eastern pipistrelles – and their populations as a whole – are particularly vulnerable during winter hibernation because they are concentrated in just a few major hibernacula and because repeated disturbance during hibernation can lead to mortality (see "Threats" section). Each time a bat is aroused from torpor, it uses up a substantial proportion of the fat reserves it relies on to hibernate through the winter and faces greater odds of starvation before spring (see "Threats" section above). Therefore, avoid entering hibernacula from October 1 through May 15 unless conducting approved and permitted management, surveillance, or research.

Screening Procedures

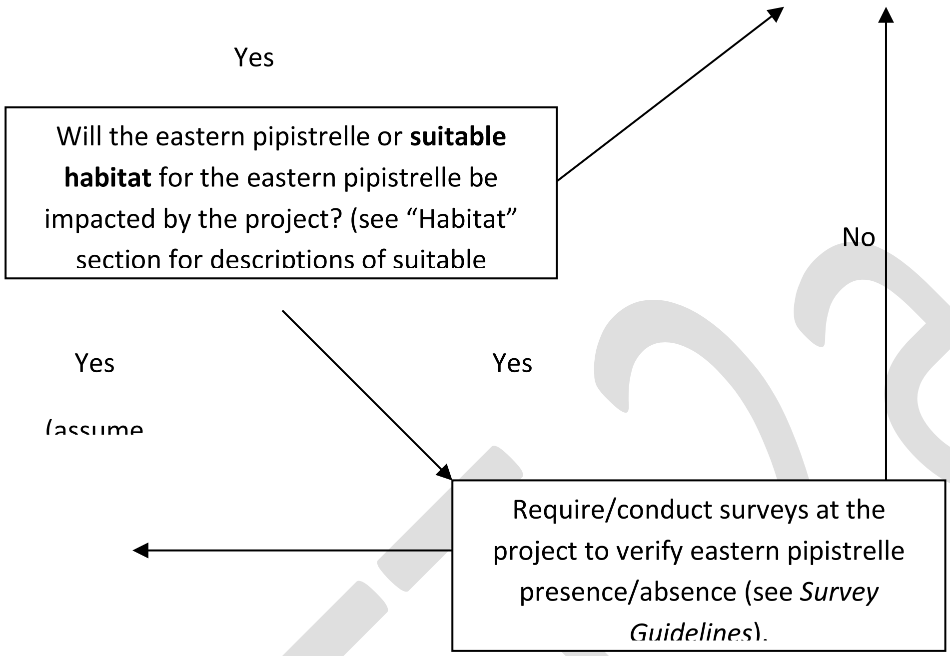
Follow the "Conducting Endangered Resources Reviews: A Step-by-Step Guide for Wisconsin DNR Staff" document (summarized below) to determine if eastern pipistrelles will be impacted by a project (WDNR 2012):

Is there an eastern pipistrelle **element occurrence** (within project area or a 1 mile buffer), regardless of "last obs" date or element occurrence precision OR is there reason to believe eastern pipistrelles may be

No

No additional screening is required. Document conclusions in project file and continue

No



Avoidance Measures

The following measures are specific actions required by DNR to avoid take (mortality) of state threatened or endangered species per Wisconsin's Endangered Species law (s. 29.604, Wis. Stats.) These guidelines are typically

According to Wisconsin's Endangered Species Law (s. 29.604, Wis. Stats.), it is illegal to take, transport, possess, process, or sell any wild animal on the Wisconsin Endangered and Threatened Species List (ch. NR 27, Wis. Admin. Code). Take of an animal is defined as shooting, shooting at, pursuing, hunting, catching or killing.

If *Screening Procedures* above indicate that avoidance measures are required for a project, please follow the measures below. If you have not yet read through *Screening Procedures*, please review them first to determine if avoidance measures are necessary for the project.

1. The simplest and preferred method to avoid take of eastern pipistrelles is to avoid directly impacting individuals, known eastern pipistrelle locations, or areas of suitable habitat (described above in the "Habitat" section and in *Screening Procedures*). The U.S. Fish and Wildlife Services identifies humans and their equipment as possible vectors for spores of *Geomyces destructans* – the fungus that causes white-nose syndrome (WNS) – and therefore simply entering hibernacula at any time of year and moving between them poses threats to bats. Cavers and researchers must observe all cave and mine closures and decontamination protocols (s. NR 40.07, Wis. Admin. Code) (see *Additional Information*). In addition, it is illegal to use pesticides and poisons when attempting to evict bats from house roosts (s. 94.708, Wis. Stats.).

2. If suitable habitat cannot be avoided, follow these time-of-year restrictions to avoid take:

Summer Avoidance **(June 1-Aug 15)**

Reproductive females and their young are highly vulnerable to mass mortality during the species' maternity period (June 1 – August 15) because they may aggregate in maternity colonies, and because pups cannot fly and therefore cannot leave the roost for several weeks after birth. Many maternity colonies occur in human structures, and those seeking to exclude bats from a building or other roost must follow the Cave Bat Broad Incidental Take Permit and Authorization (see *Additional Information*).

3. If impacts cannot be avoided during restoration or management activities, including wind projects and forestry management, but activities are covered under the Cave Bat Broad Incidental Take Permit and Authorization; the project is covered for any unintentional take that may occur. For information about natural roost avoidance, see *Management Guidelines* and "Habitat" section above.

4. Those seeking to complete wind farm projects should review and follow the Guidance for Minimizing Impacts to Natural Resources from Terrestrial Commercial Wind Energy Development created by the WDNR.

5. If eastern pipistrelle impacts cannot be avoided, please contact the Natural Heritage Conservation Incidental Take Coordinator (see *Contact Information*) to discuss possible project-specific avoidance measures. If take cannot be avoided, an Incidental Take Permit or Authorization (see *Additional Information*) is necessary.

Additional Information

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Linked Websites:

- Cave bat Broad Incidental Take Permit and Authorization:< http://dnr.wi.gov/topic/erreview/itbats.html>
- Natural Communities of Wisconsin: <http://dnr.wi.gov/org/land/er/communities/>

- Natural Heritage Conservation Permit Requirements: <http://dnr.wi.gov/topic/EndangeredResources/permits.html>
- Rare Animal Field Report Form: <http://dnr.wi.gov, key word "rare animal field report form">
- USFW WNS Website: <http://www.whitenosesyndrome.org>
- USGS National Wildlife Health Center: <http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/
- Wind Guidance: <http://dnr.wi.gov/topic/Sectors/documents/energy/WindGuidelines.pdf>
- Wisconsin Bat Program Exclusion Instructions: <http://wiatri.net/inventory/bats/Monitoring/Roosts/docs/BatExclusion.pdf>
- Wisconsin Bat Program: <http://wiatri.net/inventory/bats>
- WDNR Decontamination Protocols for Preventing Spread of White-nose syndrome: <http://dnr.wi.gov/topic/WildlifeHabitat/documents/WNS_DeconProtocols.pdf>
- Wisconsin Endangered and Threatened Species: <http://dnr.wi.gov, key word "endangered resources">
- Wisconsin Endangered and Threatened Species Permit: <http://dnr.wi.gov, key word "endangered species permit">"
- Wisconsin Initiative on Climate Change Impacts: <http://www.wicci.wisc.edu/>
- Wisconsin Natural Heritage Inventory Working List Key: <http://dnr.wi.gov/topic/NHI/WList.html>
- Wisconsin's Wildlife Action Plan: <http://dnr.wi.gov/topic/wildlifehabitat/actionplan.html>

Funding
- Natural Resources Foundation of Wisconsin: <http://www.wisconservation.org/>
- USFWS State Wildlife Grants Program: <http://wsfrprograms.fws.gov/subpages/grantprograms/swg/swg.htm>
- Wisconsin Natural Heritage Conservation Fund
- Wisconsin DNR Division of Forestry

Endangered Resources Review Program Contacts
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- Wisconsin Bat Program (608-266-5216, DNRbats@wisconsin.gov)

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http://dnr.wi.gov, keyword "ER"

Northern Long-Eared Bat (*Myotis septentrionalis*) Species Guidance

Family: Vespertilionidae- the evening bats

State Status: Threatened

State Rank: S1S3

Federal Status: None

Global Rank: G4

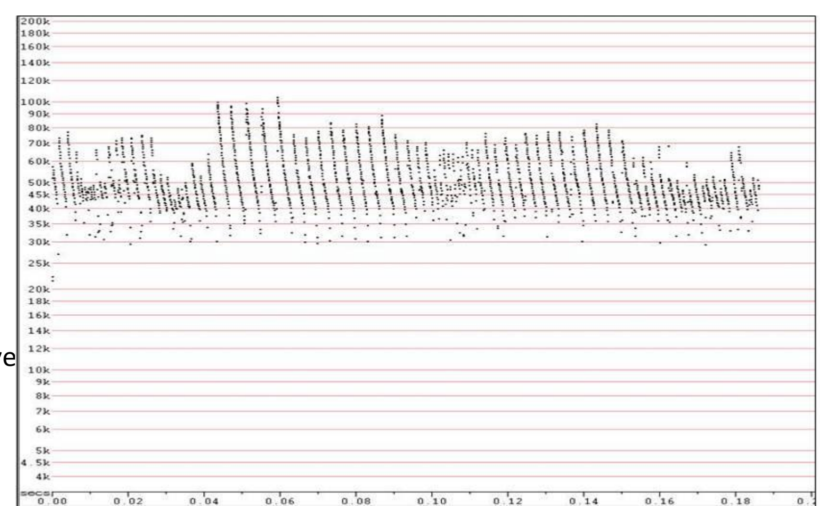
Wildlife Action Plan
Area of Importance Score: 3

Range of the northern long-eared bat in Wisconsin. Source: WI Bat Program 2012

Dave Redell, Wisconsin DNR

Species Information

General Description: The northern long-eared bat, also referred to as the northern bat, is a medium-sized member of the genus *Myotis*. Adults weigh five to nine grams (0.2-0.3 oz). Individual weights vary seasonally and are lowest in the spring as bats emerge from hibernation (WI Bat Program 2010). Total length is 77-92 mm (3.0-3.63 in), adult forearm length is 34-38 mm (1.3-1.5 in), and females are generally larger than males (Kurta 1995). Wingspan is 23-26 cm (9.1-10.2 in; Barbour and Davis 1969). Fur color is light to dark brown. The northern long-eared bat is classified as a cave bat because it uses caves and mines for hibernation.



Similar Species: Three bat species in Wisconsin- the northern long-eared bat, the little brown bat (*Myotis lucifugus*) and the Indiana (*Myotis sodalis*) bat – are best distinguished by close (in-hand) inspection. The northern long-eared bat is most often confused with the little brown bat. The northern long-eared bat has longer ears than the little brown bat, and when folded alongside the head, the tips of the ears should extend 3 mm or more past the tip of the nose. Little brown bat ear length in Wisconsin, however, can be highly variable, and tragus shape and length in relation to the rest of the ear are the two best features to use to distinguish these two species (Fig. 1). The tragus of the northern long-eared bat is more pointed and spear-like than that of the little brown bat. The little brown bat also has a glossier appearance than the northern long-eared. The northern long-eared bat may also be confused with the Indiana bat, but the two can be distinguished much the same way as the little brown bat from the northern long-eared bat. The Indiana bat's keeled calcar, a spur of cartilage extended from the ankle and supporting the interfemoral membrane, is a distinguishing feature that the northern long-eared bat lacks. The northern long-eared bat can be identified by the echolocation call (Fig. 2), however both other *Myotis* species share similar call characteristics, and only trained individuals should positively identify the species through echolocation calls.

Figure 1. The asymmetrical tragus of the little brown bat (left), and the symmetrical, spear-like tragus of the northern long-eared bat (right). Dave Redell, Wisconsin DNR

kHz

Time (seconds)

Figure 2. Echolocation call: Norther produce high-frequency calls of a shorter duration, broader bandwidth and lower intensity than other *Myotis* species. The call frequency ranges between 126 and 40 kHz (Caceres and Barclay 2000). The northern long-eared bat sonogram may appear similar to the little brown bat and the Indiana bat.

Associated Species: Northern long-eared bat predators include owls, hawks, occasionally snakes, and raccoons (*Procyon lotor*). As many as 13 feral cats have also been observed congregating at a mine entrance at dusk to prey upon bats as they leave the hibernaculum (D. Redell pers. obs.). Northern long-eared bats often share hibernacula with other bat species such as the tri-colored bat (*Perimyotis subflavus*), the little brown bat, the big brown bat (*Eptesicus fuscus*) and the Indiana bat, but the northern bat rarely, if ever, forms hibernating clusters with other species. Northern long-eared bats forage with other bat species, but there is no evidence of direct competition between species.

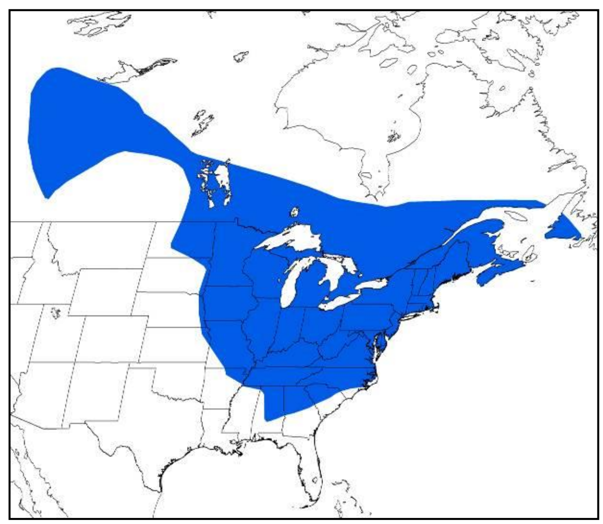


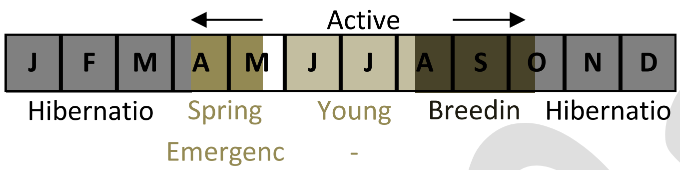
Figure 3. Global distribution of *Myotis septentrionalis*. (BCI 2012)

State Distribution and Abundance: Northern long-eared bats are found throughout the state of Wisconsin (but see “Threats” section below), but they are never abundant (Jackson 1961, WDNR 2013).

Global Distribution and Abundance: Northern long-eared bats are widely distributed in the eastern United States and Canada, with the exception of the very southeastern United States and Texas (see Fig. 3, BCI 2012).

Diet: The northern long-eared bat is insectivorous and uses echolocation to locate and capture prey. Northern long-eared bat prey includes moths (*Lepidoptera*), flies (*Diptera*) and beetles (*Coleoptera*). This species is commonly referred to as a gleaning bat because it often catches insects that are at rest on leaves or twigs, in addition to catching insects that are flying (Lee and McCracken 2004).

Reproductive Cycle: The reproductive cycle for the northern long-eared bat begins when breeding occurs in the fall and sometimes into winter hibernation. Sperm is stored in the uterus of the female until April or May when the females emerge from hibernation and fertilization occurs. Females form small maternity colonies of up to 30 bats in late spring and females give birth to a single pup in June or early July (Caceres and Barclay 2000, Owen et. al. 2002). Pups are born hairless and flightless. The pup nurses for about a month and is left at the roost nightly while the mother goes out to feed. The pup begins to fly and explore on its own at four to six weeks. Maternity colonies disperse shortly after young are volant (able to fly) and bats move closer to hibernacula in the fall and mate before they hibernate. Young of the year do not usually mate, but some juvenile males appear reproductively active (WI Bat Program 2009, 2010). More research is needed to determine breeding and reproductive behavior of the northern long-eared bat.



Ecology: Female and male northern long-eared bats emerge from hibernation in April and May. In summer, the northern long-eared bat roosts alone, or females may form a colony with some other females. The northern long-eared bat chooses day roosts in tall trees and snags. Night roosts for this species include caves and rock shelters where they will rest between feeding bouts (Caceres and Barclay 2000). Roost fidelity is low in this species, and individual bats switch roosts about every two days in the summer (Foster and Kurta 1999). This species is a relatively long lived mammal for its size, and usually lives up to 8-10 years. Banding records indicated a northern long-eared bat caught in the wild lived up to 18 years (Caceres and Barclay 2000). In the fall, northern long-eared bats will make short migrations from summer habitat to winter hibernacula (caves and abandoned mines), and will often return to the same hibernaculum but not always in sequential seasons (Caceres and Barclay 2000). This species hibernates with other species such as the little brown bat and tri-colored bat, but often in different parts of the hibernaculum. The northern long-eared bat hibernates deep in crevices, rather than clustering on exposed surfaces like other cave bats, which makes it difficult to survey and monitor for this species during the winter (Caceres and Barclay 2000). More research is needed on northern long-eared bats' basic life history and behavior.

Natural Community Associations: (WDNR 2005 and WDNR 2009)

Many bat species are associated more with structural features within natural communities than with any particular natural community or group of natural communities (see "Habitat" section).

Significant: coldwater streams, coolwater streams, ephemeral pond
Moderate: alder thicket, bog relict, boreal rich fen, calcareous fen (southern), central sands pine – oak forest, coastal plain marsh, emergent aquatic, floodplain forest, hemlock relict, inland lakes, northern dry forest, northern dry-mesic forest, northern hardwood swamp, northern mesic forest, northern sedge meadow, oak barrens, oak woodland, open bog, shrub carr, southern dry forest, southern dry-mesic forest, southern hardwood swamp, southern mesic forest, southern sedge meadow, submergent aquatic, submergent aquatic-oligotrophic marsh, warmwater rivers, warmwater streams, white pine – red maple swamp
Minimal: none

Habitat: Northern long-eared bat habitat use changes over the course of the year, and varies based on sex and reproductive status. Reproductive females often use different summer habitat from males and non-reproductive females.

Summer: Northern long-eared bats commonly roost in trees but have been known to roost in man-made structures. This species often roosts under bark or close to the tree trunk in crevices of tree species such as maples and ashes (Foster and Kurta 1999). Northern long-eared bats prefer to roost in tall trees with a dynamic forest structure including old growth and some young trees (Foster and Kurta 1999). Females form small maternity colonies which are located in trees, under shingles, and in buildings. Northern long-eared bats commonly forage within the forest and below the canopy mainly in upland forests on hillsides and ridges (Owen et al. 2003), but have also been noted to forage along paths, ponds and streams, and at forest edges. Foster and Kurta (1999) found all roost trees to be close to wetlands. More information is needed to more fully describe northern long-eared bat foraging habitats and summer roosting in Wisconsin.

Home range: Northern long-eared bats use approximately 150 acres for their home range in summer (Owen et al. 2003). More information is needed to accurately describe northern long-eared bat home range and habitat in Wisconsin.

Winter: The northern long-eared bat hibernates in caves and abandoned mines in winter and tends to be found in deep crevices (Kurta 1994, Caceres and Barclay 2000). More research is needed to determine what characteristics make suitable caves and mines for northern long-eared bat hibernation.

Northern long-eared bat hibernacula in southwestern Wisconsin: Passage of a mine in Grant County that houses northern bats (left), and solitary northern long-eared bat in a crevice in Pierce County (right). Heather Kaarakka, Wisconsin DNR

Edge habitat (transition zone between two types of vegetation) is important for northern long-eared bats as they migrate and forage. When bats migrate from wintering caves to summer habitat or commute from roosts to feeding grounds, they move through the landscape in a manner that protects them from wind and predators. Instead of flying the shortest distance across a field, for instance, bats will take longer routes that follow edge habitat. In addition to offering protection, this behavior may also allow bats more feeding opportunities because food is more abundant around edge habitat (Limpens and Kapteyn 1991). Commuting along edge habitat may assist the bats with navigation and orientation through use of linear edges as landmarks (Verboom and Huitema 1997).

Threats: Lack of information on bat species' basic ecology is one of the greatest threats to bat conservation in Wisconsin. The northern long-eared bat faces two emerging threats, and several ongoing threats. White-nose syndrome (WNS) was discovered in 2006 in a hibernaculum in New York State, and appears as a white, powdery substance on the bat's face, tail and wings. White-nose syndrome has spread rapidly since 2007 to other hibernacula in neighboring states (USFWS 2012). Infected little brown bat and northern bat hibernacula in New York and surrounding states have experienced mortality rates of over 90%. White-nose syndrome has been called the "most precipitous wildlife decline in the past century in North America" (BCI 2009), and is caused by a fungus called *Geomyces destructans* (Lorch et al. 2011). This fungus grows best in the cool, wet conditions of hibernacula (Verant et al. 2012). Mortality from the fungus appears to come from increased arousals during torpor, which deplete bats' fat reserves and cause starvation (Reeder et al. 2012) and dehydration (Cryan et al. 2010). For up-to-date WNS information, see the USFWS WNS website and the USGS National Wildlife Health Center website (see *Additional Information).* Neither the fungus nor the disease has been found in Wisconsin as of this writing. Cave-hibernating bats, including the northern long-eared bat, should be monitored closely for any indication of WNS; the Wisconsin Bat Program conducts WNS surveillance and monitoring in the state.

Wind power is another emerging threat to bats – wind turbines have been shown to fatally impact all bat species in Wisconsin (Johnson 2003, Arnett et al. 2008). Wind-turbine blades cause mortality through direct impact or through the pressure differential caused by the motion of the spinning blades. This pressure differential causes a bat's lungs to fill with fluid as it flies near the spinning blades, and this phenomenon (known as barotrauma) kills the bat instantly (Baerwald et. al. 2008). More research is under way to better understand bat wind-turbine vulnerabilities, but current studies suggest that bats face the greatest risk during migration from summer foraging sites to wintering grounds (tree bats) or hibernacula (cave bats) (Johnson 2003, Kunz et al. 2007). Research is needed on all Wisconsin bat species to better understand wind-turbine mortality in the state and the long term population impacts of turbine-related deaths.

Northern long-eared bats also face the ongoing threat of habitat degradation. Habitat degradation is caused by increased agricultural, industrial, and household pesticide use, and it has negative effects on bats through direct exposure and through dietary accumulation (O'Shea et al. 2001). Pesticides are a threat to many taxa, but bats may be more vulnerable than other small mammals due to certain life characteristics (Shore et al. 1996, O'Shea et al. 2001). Bats' longevity and high trophic level means pesticides can concentrate in their body fat (Clark and Prouty 1977, Clark 1988). Even after pesticide exposure ceases, residues can be passed on to nursing young (Clark 1988). Bat species that migrate long distances may be more affected because pesticide residues become increasingly concentrated in the brain tissue as fat reserves are depleted during long-distance flights. This concentration can lead to convulsions and even death (Geluso et al. 1976, Clark 1978).

Northern long-eared bats also face the ongoing threat of hibernaculum disturbance from humans entering hibernacula in winter and waking bats from torpor. Bats in torpor reduce their metabolism and body temperature to low levels that require less energy than being fully awake. Interrupting torpor costs energy; a little brown bat uses up to 100 mg of fat reserves waking and the returning to torpor (and more if the bat starts flying), or the energetic equivalent of up to 67 days of torpor (Thomas et al. 1990, Thomas 1992). This loss clearly represents a large percentage of total body weight of the bat, and repeated arousals may cause bats to run out of energy reserves before spring arrives and therefore starve in the hibernaculum or die from exposure if they seek food outside (Thomas 1995).

Climate Change Impacts: The effects of climate change on the northern long-eared bat are unclear. Predictions suggest a northward expansion in the ranges of all cave-bat species, in pursuit of optimal hibernation (Humphries et al. 2002, USFWS 2007). This prediction assumes an abundance of suitable caves and other hibernaculum structures further north, but this assumption may not hold for karst-free regions at higher latitudes. Bat species may adapt by reducing torpor depth and duration during winter if prey insect species are available for more of the year (Weller et al. 2009), but bats' adaptive capacities in this regard may be limited and are not well known. Shifts in prey insect emergence may also cause mismatches with bat emergence and cause food shortages in the spring or fall.

Survey Guidelines: Persons handling northern long-eared bats must possess a valid Endangered and Threatened Species Permit. If surveys are being conducted for regulatory purposes, survey protocols and surveyor qualifications must first be approved by the Endangered Resources Review Program (see *Contact Information*).

Acoustic surveys, which should be done by trained individuals, are performed for all Wisconsin bat species in spring, summer, and fall; and are used to determine presence/absence, phenology, and distribution around the state. The Wisconsin Bat Program's eventual goal is to use acoustic survey data to determine bat population trends in Wisconsin. Northern long-eared bats are ubiquitous around the state, and therefore surveys can be done wherever appropriate habitat exists. Acoustic recording systems that detect echolocation calls can survey bats as they fly through an area. The bat detection system detects and records these acoustic signals as bats fly by, and records the date and time of each encounter. The Wisconsin Bat Program currently uses broadband frequency division ultrasound detection equipment with a PDA (Personal Data Assistant) and a Global Positioning System. Start acoustic surveys half an hour after sunset, but only if the daytime temperature exceeds 50° F, and conduct the survey for at least one hour. There are three seasons for acoustic surveys: spring (April and May), summer (June and July), and fall (August and September). Acoustic surveys record bat passes, which can then be identified to species by trained individuals. These surveys could be used by land managers to create inventories of species distribution and relative abundance. Visit the Wisconsin bat monitoring website for additional information.

Wisconsin DNR also conducts a roost monitoring program to determine abundance of bats roosting in buildings and bat houses. People with bat houses or other roost sites identify species and count bats over the summer at night as bats leave the roost. People who find a bat roost while doing field surveys should contact the Wisconsin Bat Program to report the information.

Summarize results, including survey dates, times, weather conditions, number of detections, detection locations, and behavioral data and submit via the WDNR online report: <http://dnr.wi.gov, keyword “rare animal field report form”>

Management Guidelines

The following guidelines typically describe actions that will help maintain or enhance habitat for the species.

Summer Management

Roost availability is thought to limit northern long-eared bat populations, as it does for many bat species, and thus habitat management is important for the continued survival of this species (Duchamp et al. 2007). Northern long-eared bats are forest dwelling bats, and forest management to promote occupation by this species should increase roosting and foraging habitat (see Habitat section above). Northern long-eared bats have been shown to use both live and dead trees for roosting sites (Foster and Kurta 1999). These bats often roost under exfoliating bark, and therefore snags and dying trees may be important for encouraging northern long-eared bats. Forest managers are encouraged to promote mixed-species, mixed-aged plots as the northern long-eared bat chooses trees based on suitability of crevices and bark as roosts, rather than on tree species (Foster and Kurta 1999). The northern long-eared bat is known to switch roost trees frequently (about every 2 days) over the course of the summer, and therefore this species needs a large number of trees

(Foster and Kurta 1999). As with many bat species, suitable forested habitat for northern long-eared bats is a multi-species matrix that contains some open areas (Owen et al. 2003).

Linear corridors are important for migrating and commuting bats, and forests may be managed such that suitable foraging habitat is connected by corridors; this may include managing edge habitat along roads, logging trails and riparian habitat. Land managers should also make an effort to reduce or eliminate burdock (*Arctium minus*), an exotic weed that produces seeds that trap bats and cause death from exposure.

Special consideration should be given to protecting snags or dying trees, especially those near known roost locations, particularly from June 1 through August 15 while bats may have pups at the roost.

Seasonal pools in woodlands may be important foraging and water sources for the northern long-eared bat and other Wisconsin bat species because they provide areas for feeding and drinking in an otherwise closed-canopy forest (Francl 2008). Pool size and depth do not appear to determine usage by northern long-eared bats; instead the presence of an opening in the forest is enough to encourage foraging and drinking (Francl 2008).

Fall Management

During fall swarm, large proportions of Wisconsin's cave bat population gather near entrances of the state's hibernacula (see "Habitat" section), and become concentrated and vulnerable to direct impacts. To avoid disturbance during crucial life history events, management activities such as logging and use of heavy machinery within 0.25 miles of hibernacula entrances should be avoided during fall swarm (August 15-October 15) or during spring emergence (April 1-May 15) because bats may use the surrounding area for roosting during those time periods.

Winter Management

Little is known about how northern long-eared bats choose hibernation sites, but suitable Wisconsin hibernacula typically have steady temperatures between 4° C and 12° C (39-53° F), high humidity, and no human disturbance. Artificial sites that can mimic this environment may provide suitable hibernacula. Artificial hibernacula include bunkers, food storage-caves and basements. Contact the Wisconsin Bat Program to inquire about developing artificial hibernacula.

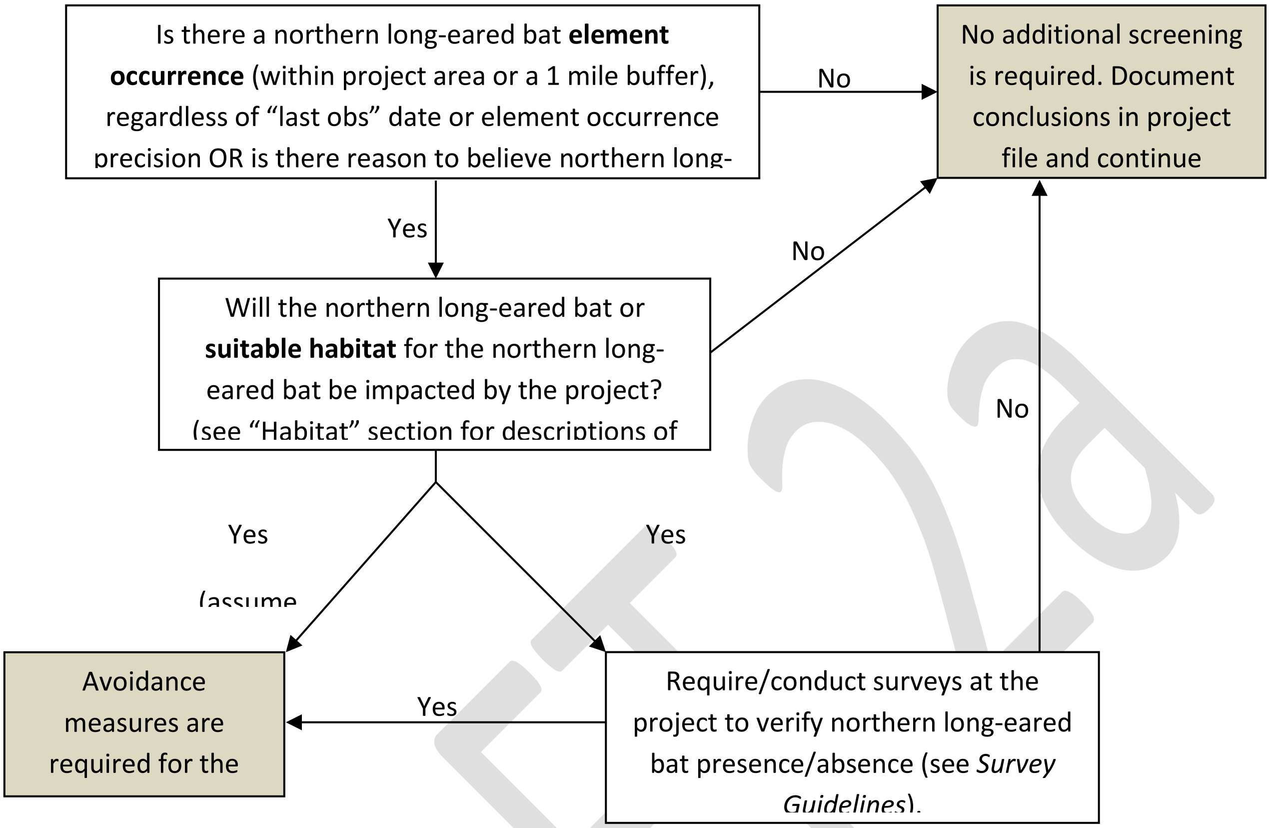
Natural hibernacula can also be managed to encourage bat use. For example, closing but not sealing the entrance to an abandoned mine not only buffers temperature and humidity, but also reduces disturbance from humans and predators. Eliminating disturbance from humans, except for WNS surveillance, is the best management activity for natural cave hibernacula. Contact the Wisconsin Bat Program for more information about managing bat hibernacula.

Northern long-eared bats – and their populations as a whole – are particularly vulnerable during winter hibernation because they are concentrated in just a few major hibernacula and because repeated disturbance during hibernation can lead to mortality (see "Threats" section above). Each time a bat is aroused from torpor, it uses up a substantial proportion of the fat reserves it relies on to hibernate through the winter and faces greater odds of starvation before spring (see "Threats" section above). Therefore, avoid entering hibernacula from October 1 through May 15 unless conducting approved and permitted management, surveillance, or research.

Screening Procedures

Follow the "Conducting Endangered Resources Reviews: A Step-by-Step Guide for Wisconsin DNR Staff" document (summarized below) to determine if northern long-eared bats will be impacted by a project (WDNR 2012):

Those seeking to complete wind farm projects should review and follow the Guidance for Minimizing Impacts to Natural Resources from Terrestrial Commercial Wind Energy Development created by the WDNR.



Avoidance Measures

The following measures are specific actions required by DNR to avoid take (mortality) of state threatened or endangered species per Wisconsin's Endangered Species law (s. 29.604, Wis. Stats.) These guidelines are typically

According to Wisconsin's Endangered Species Law (s. 29.604, Wis. Stats.), it is illegal to take, transport, possess, process, or sell any wild animal on the Wisconsin Endangered and Threatened Species List (ch. NR 27, Wis. Admin. Code). Take of an animal is defined as shooting, shooting at, pursuing, hunting, catching or killing.

If *Screening Procedures* above indicate that avoidance measures are required for a project, please follow the measures below. If you have not yet read through *Screening Procedures*, please review them first to determine if avoidance measures are necessary for the project.

1. The simplest and preferred method to avoid take of northern long-eared bats is to avoid directly impacting individuals, known northern long-eared bat locations, or areas of suitable habitat (described above in the "Habitat" section and in *Screening Procedures*). The U.S. Fish and Wildlife Services identifies humans and their equipment as a possible vectors for spores of *Geomyces destructans* – the fungus that causes white-nose syndrome (WNS) – and therefore simply entering hibernacula at any time of year and moving between them poses threats to bats. Cavers and researchers must observe all cave and mine closures and decontamination protocols (s. NR 40.07, Wis. Admin. Code; see *Additional Information*). In addition, it is illegal to use pesticides and poisons when attempting to evict bats from house roosts (s. 94.708, Wis. Stats.).

2. If suitable habitat cannot be avoided, follow these time-of-year restrictions to avoid take:

Summer Avoidance **(June 1-Aug 15)**

Reproductive females and their young are highly vulnerable to mass mortality during the species' maternity period (June 1 – August 15) because they may aggregate in maternity colonies, and because pups cannot fly and therefore cannot leave the roost for several weeks after birth. Maternity colonies may occur in human structures, and those seeking to exclude bats from a building or other roost must follow the Cave Bat Broad Incidental Take Permit and Authorization (see *Additional Information*).

3. If impacts cannot be avoided during restoration or management activities, including wind projects and forestry management, but activities are covered under the Cave Bat Broad Incidental Take Permit and Authorization; the project is covered for any unintentional take that may occur. For information about natural roost avoidance, see *Management Guidelines* and "Habitat" section above.

4. If northern long-eared bat impacts cannot be avoided, please contact the Natural Heritage Conservation Incidental Take Coordinator (see *Contact Information*) to discuss possible project-specific avoidance measures. If take cannot be avoided, an Incidental Take Permit or Authorization (see *Additional Information*) is necessary.

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Linked Websites:

- Cave bat Broad Incidental Take Permit and Authorization:< http://dnr.wi.gov/topic/erreview/itbats.html>
- Natural Communities of Wisconsin: <http://dnr.wi.gov/org/land/er/communities/>
- Natural Heritage Conservation Permit Requirements: <http://dnr.wi.gov/topic/EndangeredResources/permits.html>
- Rare Animal Field Report Form: <http://dnr.wi.gov, key word "rare animal field report form">
- USFW WNS Website: <http://www.whitenosesyndrome.org>
- USGS National Wildlife Health Center: <http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/>
- Wind Guidance: <http://dnr.wi.gov/topic/Sectors/documents/energy/WindGuidelines.pdf>
- Wisconsin Bat Program Exclusion Instructions: <http://wiatri.net/inventory/bats/Monitoring/Roosts/docs/BatExclusion.pdf>
- Wisconsin Bat Program: <http://wiatri.net/inventory/bats>
- WDNR Decontamination Protocols for Preventing Spread of White-nose syndrome: <http://dnr.wi.gov/topic/WildlifeHabitat/documents/WNS_DeconProtocols.pdf>
- Wisconsin Endangered and Threatened Species: <http://dnr.wi.gov, key word "endangered resources">
- Wisconsin Endangered and Threatened Species Permit: <http://dnr.wi.gov, key word "endangered species permit">"
- Wisconsin Initiative on Climate Change Impacts: <http://www.wicci.wisc.edu/>
- Wisconsin Natural Heritage Inventory Working List Key: <http://dnr.wi.gov/topic/NHI/WList.html>
- Wisconsin's Wildlife Action Plan: <http://dnr.wi.gov/topic/wildlifehabitat/actionplan.html>

Funding

- Natural Resources Foundation of Wisconsin: <http://www.wisconservation.org/>
- USFWS State Wildlife Grants Program: <http://wsfrprograms.fws.gov/subpages/grantprograms/swg/swg.htm>
- Wisconsin Natural Heritage Conservation Fund
- Wisconsin DNR Division of Forestry

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