Management Strategies for Responding to White-Nose Syndrome In Bats

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Introduction

Since the discovery of White Nose Syndrome (WNS) in 2006 over a million bats that use caves and underground mines for hibernation have died from this syndrome. WNS is named for a recently identified fungus, *Geomyces destructans*, (Gargas et al. 2009) which grows on infected bats and prominently on the noses of the bats. As of March 2009 WNS has been confirmed on bats from caves and underground mines in Massachusetts, New Jersey, Vermont, West Virginia, New Hampshire, Connecticut, Virginia, and Pennsylvania (Gargas et al. 2009). The extent to which WNS has spread since March 2009 is unknown for a combination of reasons. These include the fact that this is a slow-growing fungus that grows best on bats that are at low temperatures (such as during hibernation). When bats are not in hibernation they probably preen themselves and remove the more visually obvious fungus.

WNS does not infect humans and is not known to infect any animals other than bats. The decline in bat populations in the last three years has been described in testimony before the U.S. Congress as the most precipitous decline in North American wildlife since the loss of the passenger pigeon over 100 years ago.

Bat mortality in infected hibernacula exceeds 75% in surveyed sites (Blehert et al. 2008). Survivors routinely show injury and may die during the following summer or not survive a second hibernating season. There appears to be little natural or acquired immunity. Six bat species in three genera have been infected to date:

- *Myotis lucifugus*. Little Brown Bat
- *Myotis septentrionalis.* Northern Long-Eared Bat
- *Myotis sodalis*. Indiana Bat
- *Myotis leibii*. Eastern Small-Footed Bat
- *Eptesicus fuscus.* Big Brown Bat
- *Perimyotis subflavus.* Tricolored Bat (formerly known as Eastern Pipistrelle).

Optimum growth on artificial growth media in a laboratory experiment was at temperatures between 7 and 14 degrees C (45 to 57 degrees F) (Volk et al. 2009). Gargas et al. (2009) state: "The outstanding characteristics of *Geomyces destructans* are conidium shape, very slow growth on artificial media, and cold-adaptation with no growth at 24 degrees C [75 degrees F] or above. This fungus has currently only been identified from tissues of bats, where it invades living tissue (Meteyer et al 2009) with associated high mortality." It seems likely that spores from *G. destructans* also exist on cave and underground mine surfaces in infected hibernacula. It also seems likely that fungal spores are produced mainly and perhaps exclusively on hibernating bats because of temperature conditions and bat preening. If so, spore abundance in caves not used by hibernating bats would be much less than in caves used as hibernacula.

Laboratory studies have shown that the fungus can be spread from bat to bat and apparently from an infected hibernation site to uninfected bats. It is likely that fungal spores can persist at hibernation sites for multiple years. There is no present scientific proof that people can unintentionally transport the fungus or its spores from one underground mine or cave to another although such transport under at least some conditions seems likely. The risk of human transport is likely to be greatest when people visit infected hibernacula and then an uninfected site, or when infected bats are handled and the person subsequently handles uninfected bats. Risks can be decreased, but not eliminated, by disinfection of clothing and equipment.

WNS is currently viewed as a syndrome (Blehert et al. 2008). This is a reflection that the fungus may or may not be the sole cause (or even the cause) of the disease. Other species in the genus *Geomyces* are known from caves, but *G. destructans* was unknown prior to the onset of WNS (Gargas et al. 2009). It is not known if this is a native fungus that is attacking bats weakened by some other factor(s), a native fungus that has recently become particularly active for some reason(s), or a recently introduced exotic species that is spreading rapidly.

Management Strategies

Credible management strategies for public resource management agencies need to be based on reasonable assumptions and have a reasonable chance of success. Some of the WNS strategies that have been implemented or are under consideration by agencies fail to meet these basic requirements. At least part of these failures can be attributed to inadequate appreciation of the factors that limit management options. This article discusses some of these limiting factors and identifies management actions that appear to be reasonable. It is my hope that these discussions will aid people who care about caves and bats and concurrently help resource management agencies better assess which management options may work, which options are unlikely to work, and the difference between the two.

Alan Cressler

***Perimyotis subflavus*, one of the six bat species that has been affected by WNS. This one is covered in water droplets, not the fungus, which just appears on the nose.**

Caves are more than simply habitats for bats. Cave faunas include thousands of species, some of which are found in only one or two caves. A number of cave dwelling species are federally listed as threatened or endangered. Management efforts focused on WNS must not significantly increase the risk of harm to these other species. Additionally, caves have valuable recreational, educational, scientific, and economic uses that must also be protected. Current NSS membership is about 11,000; the interests of cavers and cave scientists must be given adequate consideration in developing management strategies, especially those where the chance of long-term success is low. Show caves, which provide annual employment for about 4,000 people in the United States, are an example of another significant cave use.

Gaps in essential knowledge are great, and as these gaps are filled by research findings management strategies may need to be changed. We must recognize that it may not be possible to prevent the loss of most or all of the bats sensitive to WNS in infected regions of North America. Furthermore, there may be no human actions that can effectively restrict WNS to areas and bat species already infected. The worst possible result would be management strategies that do not reduce the ultimate number of bat deaths or limit the area impacted by WNS, but result in significant damage to caves and cave ecosystems, and/or adversely impact human uses of caves and mines.

Factors Limiting Management Options

At least five major factors limit potential management actions. Other limiting factors, such as available agency budgets, exist.

Private Site Ownership

Individual states have regulatory authority over wildlife, but this gives very limited authority to regulate the use and management of caves, mines, or other bat habitats on private land. Federal authority over bats on private lands is even more limited except in cases where federally listed species may be involved.

In the United States east of the Rocky Mountains most caves and underground mines are located on private lands. Using Missouri as an example about 78% of the 6,200 known caves in the state are privately owned and about 92% of the total cave visits in the state are to privately owned caves. The conditions in Missouri are similar to those in many other midwestern and eastern states with numerous caves; these cave-rich states include Pennsylvania, West Virginia, Virginia, Tennessee, Alabama, Georgia, Indiana, Kentucky, and Arkansas. Let's assume that there are 60,000 known caves in the United States east of the Rocky Mountains and another 10,000 west of the Rockies and in Alaska. Some caves have multiple entrances with different landowners. As a result, any management strategy that would require consent and cooperation from most cave owners, even if limited to a single region or state, would probably not be effective.

Some abandoned underground mines provide habitat for bats, and some are important hibernacula. Almost all mine sites are on private lands and gaining access to the sites is often difficult due to concerns over safety and liability. Additionally, some mines are unstable and bats may use portions that are in danger of collapse or cannot readily be accessed by people to determine the extent of their use by bats. While bats usually avoid operating mines, this may not always be the case. In many regions the number of mines or the amount of underground space available for bat usage exceeds similar values for caves. As with caves, management strategies that require consent and cooperation from most landowners will not be effective.

Only a Tiny Fraction of Bat Habitat Sites Could Be Managed

While much attention has focused on bat hibernacula with relatively large numbers of bats, there are many caves and mines where lesser numbers of bats hibernate. Finding and then managing most bat hibernacula in and near areas already infected with WNS would involve hundreds of sites. Even simple management activities such as gaining access permission from landowners would represent an enormous task.

Summer bat roosts are much more numerous than the winter sites. In addition to caves and mines the summer sites include bridges, homes and outbuildings, and beneath the loose bark on dead trees. The following estimates for the United States are intended to indicate the unmanageably large number of summer bat roost sites.

If there are 60,000 caves in the United States, and if 95% of them provide at least some bat habitat, this represents 57,000 bat habitat sites.

There are probably between 10,000 and 100,000 underground mines in the United States. A recent study of mines in the Clark County area of Nevada (Agee et al. 2008) surveyed 250 mines and found 108 of them warranted bat-compatible closures. If we view this as 40% bat usage and estimate the number of underground mines in the U.S. at 30,000, then this represents 12,000 bat habitat sites.

Cleveland and Jackson (2007) randomly sampled 540 bridges in Georgia for bat usage and found that 55 were currently or previously occupied by roosting bats. That represents a 10% usage rate. The Missouri Department of Transportation reports 7,128 bridges and 3,121 box culverts on the Missouri state highway system. Missouri cities and counties have an additional 12,117 bridges and 1,730 box culverts that are over 20 feet long. Since bats use some culverts let's assume that we are dealing with 20,000 structures in Missouri (not counting private and railroad bridges). Missouri has 2.31% of the land area in the lower 48 states, so an estimated U.S. total for bridges and box culverts is about 868,000 with about 87,000 of them being used by bats.

Homes, barns, garages, church attics and other buildings are frequently used by bats. There are many tens of thousands of such sites in the United States.

The percent of bats using caves and underground mines during the summer varies by species. For the species that have already experienced mortality from WNS there is probably more warm-season use of buildings and other surface sites than of underground sites. While the estimate of the number of summer bat roost sites is clearly crude, the inference is clear. There are simply too many sites to manage most or all of them, or for that matter anything more than a trivial percent of the sites. Furthermore, any management strategy that focuses on summer roost sites in caves and mines while ignoring the overwhelmingly more numerous sites in and around buildings and other structures is missing most of the summer populations of the six species that have already been killed by WNS.

WNS Spreads Rapidly

In the three-year period from 2006 to 2009, WNS has spread from an initial point or cluster of points west of Albany, New York to sites as far north as Vermont and as far south as Virginia. The distance from the northeastern-most to southwestern-most sites is about 700 miles with the southwest movement from the initial site about 525 miles and the northeast movement about 175 miles. Thus WNS has been spreading at a mean rate of about 175 miles a year to the southwest and about a third of that rate to the northeast. The critical point is that WNS has been spreading both rapidly and unevenly.

Some researchers have concluded that the rapid spread of WNS is evidence that it has been spread by biologists, cavers, or other visitors who have visited infected caves or mines and then transported the disease to previously uninfected sites (Turner and Reeder 2009). Such anthropogenic transmission is possible, especially if bats have been handled or come in direct contact with equipment at both infected and uninfected sites.

Some bats migrate substantial distances and visit a number of caves, mines, and other roost sites during the course of a year. Schwartz and Schwartz (1959) provided some information on maximum travel distances observed for various species of bats. The data set is limited, and greater distances may occur. These authors report that banded *Perimyotis subflavus* have been found at sites as far as 85 miles from caves where they had been banded in the winter. Schwartz and Schwartz (1959) report that *Myotis lucifugus* display a marked homing tendency and that banded bats have been released as far as 190 miles from the cave where they were collected and later retaken in the original cave. They also report that marked *M. lucifugus* have moved as much as 156 miles from one cave to another under winter conditions, but that most tend to stay in the same location all winter. In summer, *M. lucifugus* have been as recaptured as far as 158 miles from the cave where they were banded, and bats removed from a summer colony and transported as far as 270 miles away returned to the initial site. *Myotis sodalis* routinely migrates long distances between the Great Lakes Region and cave areas of southern Indiana and Kentucky.

WNS is now relatively close to the edge of the range of grey bats (*Myotis grisescens*). Schwartz and Schwartz (1959) report that *M. grisescens* in Missouri commonly moves from hibernacula in the southern part of the state to caves as much as 200 miles north for summer sites. Tuttle (pers. comm.) reports that banded grey bats from a cave in northern Alabama moved to Florida, Georgia, Kentucky, Tennessee, and across Missouri almost to Kansas.

Some bats undoubtedly roost in trucks, railroad boxcars, and large shipping containers that are subsequently moved and release their bats at locations far from familiar roost sites. At least some of these transported bats would undoubtedly find roost sites used by other bats. Transported bats infected with WNS are a likely agent for spreading WNS beyond the boundaries of currently infected areas.

Given the migration patterns of the bat species that have been infected to date and the likelihood of bats being inadvertently transported substantial distances, transmission by people from an infected to an uninfected site is not necessary to explain the spread and distribution of WNS. Even more rapid spread should be expected if WNS infects *M. grisescens* populations since this species migrates more widely than any of the currently infected species. The rapid spread of WNS and the extensive movement of bats places severe limitations on the viability of any management strategy that seeks to limit the spread of WNS. This is especially true for strategies focused on human transmission of WNS.

Feasibility of Treatment Options and Sensitivity of Cave Ecosystems

Application of fungicides and biocides to infected bats and/or to infected or potentially infected bat habitats is a possible management strategy. This is probably the only strategy available for killing the fungus associated with WNS. However, such approaches are likely to be ineffective while concurrently damaging cave environments and other species living in caves. Common bleach solutions containing 0.525% sodium hypochlorite and 0.3% quaternary ammonium compounds have been shown to kill fungal spores with a 10-minute contact time (Barton 2009, pers. comm.). Footbaths using low concentration bleach solutions have been recommended by some state agencies for visits to show caves, but I am not aware of any study showing that the few second contact time achieved in a footbath would be adequate to kill fungal spores of *G. destructans*.

Application of fungicides or biocides directly onto bats would pose both challenges and problems. Infected bats would need to be captured and then treated and this would result in some level of injuries and mortality. Disturbing hibernating bats to treat them would cause them to arouse and consume energy needed for continued hibernation. Previous declines in bat populations have been attributed to bat banding during the winter. It seems likely that any treatment of bats would cause more disturbance to the bats than that resulting from banding, and the banding impacts were significant.

There are many limitations for the treatment of cave surfaces with fungicides and biocides. Clays and organic matter may inhibit adequate performance of the treating agents and the agents may break down rapidly and leave surfaces subject to re-infection. More persistent fungicides may contain heavy metals such as mercury or cadmium that are clearly toxic for cave environments. Even if *G. destructans* is pathogenic, it is highly unlikely that any liquid treating agent would reach essentially all cave surfaces where fungus or fungal spores could be present, thus permitting re-establishment of the fungus or continued new infection of some bats. Additionally, some bats will fly hundreds to thousands of feet through cave or mine passages before exiting the underground system and fungal spores at some density should be expected throughout this region. Finally, the spores can almost certainly be transported underground through the air for substantial distances, especially in the presence of mild air currents such as encountered in many caves and mines.

Caves contain many microbial species, some of which are probably integral to the functioning of cave ecosystems. Chemical efforts to kill *G. destructans* spores could adversely impact the rest of the microbial ecosystem and invertebrates that are dependent upon these microbial ecosystems. Many caves have unique cave faunas that include rare and endemic species including a number that are state or federally listed as threatened or endangered species. The introduction of toxic compounds into cave ecosystems would enhance the risk that these species would become more endangered or even extinct.

Mines used by bats would be less likely than caves to have important invertebrate faunas although there are exceptions. In the unlikely event that a chemical treatment of underground habitats for bats appeared potentially feasible it would be desirable to field test it at a mine hibernaculum rather than at a cave site.

Evaluation of Potential Management Strategies

Increased research and education funding

Considering the desirability of preventing extinctions, the value of bats to the environment, and the great gaps in our basic knowledge about WNS, enhanced funding for relevant research on the issue is clearly prudent. The research needs to occur in the very near future and the results need to be rapidly disseminated. Painfully slow public funding cycles and impediments to the sharing of results prior to journal publication are inconsistent with the time requirements for dealing with a rapidly expanding disease. Unless funding and sharing of results can be done quickly the potential for research to contribute in controlling WNS will be diminished.

A number of NSS grottos and members, and show caves belonging to the National Caves Association (NCA) have contributed money to WNS research and education. A number of other groups, and especially Bat Conservation International (BCI), have made significant contributions. These actions have been very helpful and findings from some of the studies are incorporated in this article. Unfortunately, WNS has enhanced the perception of some members of the public that caves and bats are both dangerous and undesirable. This has been an unintended (but not unpredictable) result of cave closures and negative publicity produced by some state and federal agencies.

Readers of this magazine do not need to be convinced of the values of caves and bats, but that is not necessarily true for the rest of our society. Educational efforts dealing with WNS and aimed at the general public are very much needed, whether one-on-one between a caver and a landowner or on a larger scale between guides at show caves and visitors on their tours. Approximately 5 million people a year visit show caves in the United States. That is a giant audience, and the NCA is currently working on enhancing the quality and quantity of information given to visitors about bats and WNS. Such programs also enhance public support for WNS research.

The annual WNS Science Strategy

Meetings (two to date) have been attended by leading WNS researchers, agency personnel, and representatives of the NSS, NCA, and BCI. These meetings help integrate scientific investigations and supply up-to-date information that can be disseminated to the public. They have been very valuable and should be continued with financial support from as many concerned entities as possible.

Public understanding of the WNS issue is critical to gaining support for needed research funding. The show-cave industry provides a critically important forum for disseminating this information.

Destroying Bats at Infected Sites

Bats at infected hibernation sites could be killed and their bodies collected and destroyed. This approach would be based on the premise that the bats would die anyway and this might protect other bats and bat roosts from becoming infected. There are obviously ethical and, in the case of endangered species, legal problems with this approach. Additionally, while there appears to be little natural or acquired immunity to WNS, there probably is at least some and this approach would kill the very bats that might serve to repopulate the species in the area. Furthermore, if there were ever a time when this was an appropriate strategy that time has long passed and WNS has now spread much too far for this strategy to be viable.

Preventing Bats from Entering Infected Sites

Closing caves and underground mines that are infected with WNS so that bats cannot enter is a highly undesirable strategy. It would deprive bats of essential habitat that is already in short supply and could enhance the spread of WNS by forcing excluded bats to seek new roost sites.

Closing All Public Caves and Mines to Visitation

The U.S. Forest Service and some other state and federal agencies have already implemented this approach. The closures are a reflection of agency concerns about WNS and a perceived need to "do something." The approach is premised on the unverified presumption that people spread WNS. In reality the major (and perhaps exclusive) mode of transmission is bat to bat. This closure approach is the opposite of "science-based" agency management.

As noted earlier, there are far too many bat habitats for this approach to work, and most of the bat habitat sites are on private lands where agencies have little or no control. Cave closures on public lands where the caves are not gated and agency employees seldom visit are likely to result in only minor decreases in cave visitation to the publicly owned cave. Even if potential visitors observe the cave closures they are likely to divert their visit to another cave on private land. Finally, people not associated with organized caving and who are unlikely to be aware of the cave closures make many visits to wild caves.

Selectively restricting human entry to caves and mines used for hibernation by large numbers of bats is a more feasible and reasonable approach. However, there is no reason to expect this approach to ultimately reduce the spread of WNS or the ultimate areal extent of the disease. At best this approach might slightly reduce the rate of spread of the disease and thus allow more time for the potential discovery of a control strategy.

Closing Show Caves to Visitation

Show caves in the United States are operated by both public and private entities. While there are notable exceptions, the majority of the show caves do not provide appreciable amounts of bat habitat. Blanchard Springs Caverns in Arkansas, operated by the U.S. Forest Service, is an important exception and a tour route open in the summer passes through an important hibernation area used in the winter by the federally endangered gray bat. WNS is not known to presently exist in Arkansas, but as the syndrome spreads it might reach this state in the future. While the U.S. Forest Service has closed all other caves on their lands east of the Great Plains, that closure has not extended to this show cave. While this approach may initially appear inconsistent, a better explanation is that this agency recognizes that show caves have great value in public education and provide important employment in rural areas. Additionally, the U.S. Forest Service apparently recognizes that visits to show caves do not create appreciable risks for spreading WNS.

The majority of American show caves are privately owned and closing them to visitation due to concern over WNS would have severe economic results. Additionally, show caves that cease operations, be they public or private, lose much of their protection against vandalism and are frequently severely damaged. Our existing collection of American show caves has tremendous natural resource and economic values. These values must be protected.

Reducing Disturbance of Bats

Disturbance of bats during hibernation is very harmful. One result of WNS concern has been an increase in visits to hibernacula in the eastern United States and a resulting increase in disturbance of bats in those sites. The increased disturbance, especially if it involves capture and handling of bats, may be a significant contributing factor to the high mortalities reported in some hibernacula. Most, if not all, state fish and game departments have the authority to regulate activities that involve the capture and disturbance of bats. This authority should be used more rigorously by state agencies to minimize or prevent disturbance of bats during hibernation. Learning whether or not WNS is found in a particular cave or mine during the hibernation season may not be worth the disturbance and potential additional mortalities that such a visit will cause. If the disease exists in the cave, dead bats will probably be found at and around the entrance later in the hibernation period.

Responsible cavers will avoid hibernating bats wherever they are encountered. It is also important to encourage efforts that reduce disturbance of bats during the non-hibernation periods of the year. In many cases this must be coordinated with, and have the cooperation of, landowners. Gates and educational programs have been very useful in this regard.

Studies associated with environmental impact statements often include netting and species identification of bats. Such handling may spread WNS from infected to uninfected bats. Approaches other than capture and handling of bats should be used to the greatest extent possible. Where capture and handling is necessary, the protocols used must be capable of preventing any increased risk of spreading WNS.

Decontamination of People and Equipment

Utilization of decontamination protocols can reduce (but not eliminate) the risk of spreading WNS. Laundering clothing worn in a cave prior to taking it into another cave is an important part of decontamination. Several years ago signs at trailheads in Tasmania asked hikers to clean their boots before hiking in other areas. In reality, not cross contaminating caves with our clothing and equipment is an approach that cavers should have adopted long ago to help protect caves and their ecosystems.

Some decontamination protocols require a substantial amount of time and involve chemicals that can damage equipment. It is difficult to effectively clean other equipment or clothing. The simple solution is a separate set of equipment for caves in WNS infected areas and another set for caves outside the current range of WNS. Visiting caves in areas where WNS may or may not exist poses a distinct challenge and may necessitate additional equipment.

The use of footbaths that people walk through before or after visiting a show cave has been recommended by a couple of state agencies. As proposed, the footbaths would commonly contain a 10% solution of common household bleach containing 5.25% sodium hypochlorite. While this solution has been shown in laboratory tests to kill fungal spores with a 10-minute contact time, footbaths provide contact for only a few seconds. In the absence of a study showing that a few seconds of contact time is adequate to kill *G. destructans,* the value of footbaths is unproven and questionable. Even if the footbaths were to effectively kill *G. destructans* fungi or spores, the approach is unlikely to be of any benefit in halting the spread of WNS for at least three reasons. First, the footbaths treat only the soles of shoes. If the person is transporting fungal spores on the soles of his shoes he is probably also transporting them on other untreated parts of his clothing. Second, most visitors to show caves are not wearing shoes that they would have worn caving. The muddy booted caver could simply be asked to clean his boots or wear other shoes before going on a tour. Third, most show caves do not provide habitat for appreciable numbers of bats and it is unlikely that the footbaths would have any appreciable effect in combating WNS.

The use of footbaths could also be harmful to the cave ecosystem. Based on studies by the Ozark Underground Laboratory, 36% of NCA-member show caves have their entrances inside buildings (typically gift shops). Especially at these caves, residual bleach solution from the footbaths would be tracked into the caves where it could injure or kill native cave fauna.

Can WNS Be Controlled?

Based upon what we know today, there is a low to very low probability that human intervention can prevent the spread, or control the severity, of WNS. The rapid rate of spread of WNS and the high rate of mortality in bat hibernacula are among the very discouraging factors related to the potential for WNS control. The disease is apparently readily spread from bat to bat in nature (hence the high mortality rates in infected sites), and many bat species range widely after leaving hibernacula and can potentially spread the disease to previously uninfected bats and bat roosts. It is likely that the fungus, and/or fungal spores, are spread from infected to uninfected bats during both hibernation and non-hibernation periods. If so, there are tens of thousands of warm-season bat roosting sites where infected bats could potentially transmit WNS to uninfected bats, and many of the sites are not in any database. To the best of my knowledge there is no promising and credible "silver bullet" cure or control on the horizon and it is likely that none exists or will be discovered in time to halt or substantially slow the spread of WNS.

If the extent and/or severity of WNS is limited it will most likely result from natural processes, but people can help. Reducing human disturbance of bat colonies will enhance the chance that some bats will survive WNS. This can involve actions such as gates and eliminating underground visits that may disturb the bats, especially during the hibernation season. Visits to hibernacula where the main purpose is simply to check on mortality due to WNS are seldom warranted. Projects that involve the trapping or handling of bats also present an enhanced risk of spreading WNS. If some bats survive WNS because of natural or acquired immunity then human actions to protect these survivors and their habitats will be critically important.

References

Agee, John; R. Sherwin; S. Skalak; and C. Ross. 2008. A landscape level approach to abandoned mine reclamation in Nevada. Abstract. Bat Research News 49:4, Winter 2008. p. 95.

Anon. 2009. White Nose Syndrome science strategy meeting II, May 27-28, 2009, Austin, TX. 12p. + appendixes.

Barton, Hazel. 2009. Personal communication. Dr. Hazel Barton, Dept. of Biological Sciences Northern Kentucky University, Highland Heights, KY 41099.

Blehert, David S.; Alan C. Hicks; Melissa Behr; Carol U. Meteyer; Brenda M. Berlowski-Zier; Elizabeth L. Buckles; Jeremy T.H. Coleman; Scott R. Darling; Andrea Gargas; Robyn Niver; Joseph C. Okoniewski; Robert J. Rudd; and Ward B. Stone. 2008. Bat white-nose syndrome: an emerging fungal pathogen? Sciencexpress/www.sciencexpress.org. October 30, 2009, 10.1126/science.1163874. 8 p.

Cleveland, Arthur G. and Jennifer G. Jackson. 2007. Environmental factors influencing the status and management of bats under Georgia (USA) bridges. Abstract. Bat Research News 44:4 (Winter 2007). Abstract. p. 195.

Gargas, A.; M.T. Trest; M. Christensen; T.J. Volk; and D.S. Blehert. 2009. *Geomyces destructans* sp. nov. associated with bat white-nose syndrome.

Krupka, Robert A. 1965. An evaluation of the shelter potential in mines, caves and tunnels. Hudson Institute contract report for U.S. Army, Office of Civil Defense. 59p. + appendixes.

Meteyer, C.U.; E.L. Buckles; D.S. Blehert; A.C. Hicks; D.E. Green: V. Shearn-Bochsler; N.J. Thomas; A. Gargas; and M.J. Behr. 2009. Pathology criteria for confirming white-nose syndrome in bats. Jour. of Veterinary Diagnostic Investigation Vol. 21:4 (in press)

Schwartz, Charles W. and Elizabeth R. Schwartz. 1959. The wild mammals of Missouri. Univ. of Mo. Press and Mo. Dept. of Conservation. 341p.

Turner, Gregory G. and DeeAnn M. Reeder. 2009. Update of white nose syndrome in bats, September 2009. Bat Research News, Vol. 50:3, pp. 47-53.

Tuttle, Merlin. 2009. Personal communication. Dr. Merlin Tuttle, Bat Conservation International, PO Box 162603, Austin, TX 78716

U.S. Fish and Wildlife Service. 2009. Recommended procedures to prevent the spread of white-nose syndrome (WNS). June 2009. On-line at http://www.fws.gov. 6p.