Mexican free-tailed bat

The emergence of white-nose syndrome in North America and potential implications for bat populations at the Jornada Caves at the Armendaris Ranch New Mexico

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Goals

- To provide a primer on the emerging epizootic disease, white-nose syndrome, that is causing precipitous declines in hibernatory bat species in North America.
- To summarize our current understanding of how bats use the Jornada bat caves on the Armendaris Ranch, NM.
- To assess the threat posed by white-nose syndrome to bat populations inhabiting the Jornada bat caves.
- To make recommendations for bat management at the Jornada bat caves.

Background

White-nose syndrome (WNS) is an emerging epizootic disease that is causing precipitous declines in North American hibernatory bat populations. WNS was first observed at Howes Cave, west of Albany, New York, in February 2006[1], when a caver photographed a powdery white substance on the muzzle of a hibernating bat[2]. WNS has since spread to thirteen states and two Canadian provinces[3] (Figure 1). It has now been detected in nine hibernatory bat species (Table 1), two of which are federally listed as Endangered.

Mortality rates at hibernacula affected by WNS exceed 75%[1], and it is estimated that over one million bats have died from this disease to-date[4]. Such massive and unprecedented mortality rates have dire implications for species persistence. For example, the little brown myotis (*Myotis lucifugus*), a species considered to be a widespread and common bat species in 2001, has suffered population collapses in the northeastern United States. A recent population viability analysis predicted regional extinction of this species within 20 years[3].

The production of fungal hyphae and conidia (spores) on the muzzles, ears, and/or wing membranes of bats[5] is the most conspicuous field manifestation of WNS[4] (Figure 1). Recent work has identified this pathogen as *Geomyces destructans*[5], a species of phychrophilic (cold-loving) fungus that is new to science. Whilst the precise role that *G. destructans* plays in WNS

is as yet unconfirmed, recent evidence suggests that this fungus induces mortality either through indirect impacts on hibernation physiology[6] or more direct pathogenic mechanisms[4;7]. The following list summarizes our current understanding of the pathogen, *G. destructans*, and its pathology in hibernatory bats:

- **Bat physiology during hibernation linked to success of *G. destructans*:** During hibernation, immune function and metabolism of bats are substantially downregulated, with a concomitant reduction in body temperature to between 1 and 10ºC[4]. This lowered core body temperature is within the range at which *G. destructans* exhibits optimal rates of growth (5 – 10ºC[1]).
- **Bat behaviors may facilitate *G. destructans* colonization:** Life history characteristics of some bat species have evolved to maximize survival during hibernation, but may predispose these species to colonization by *G. destructans*. For example, selection of humid areas of hibernacula or dense clustering to conserve energy and decrease evaporative water loss creates an ideal growth and transmission environment for the fungus. This, coupled with the natural downregulation of immune function in hibernating species, is likely to allow the invasion of *G. destructans* into body tissues without encountering an immune response[8]
- **Fungal growth causes physical damage to bat tissues:** The outward manifestation of WNS is the presence of white, psychrophilic, keratinophilic fungus (*Geomyces destructans*) on the face, ears, and wing membranes of infected bats. The hyphae of *G. destructans* penetrate the dermis and erode wing and ear tissues.
    - **Disruption of water balance through destruction of wing tissues:** Invasion by *G. destructans* leads to the destruction of the delicate wing membranes, which results in functional impairment. Healthy wing membranes are essential for maintaining water balance in bats. Exposed wing membranes and large lungs predispose bats to evaporative water loss, and such losses can account for around 99% of total water loss in healthy hibernating bats. Infection with *G. destructans* can result in extensive loss of dermal integrity, and it is hypothesized that fluid regulatory mechanisms that require intact skin will also be lost in bats infected with WNS[4].

- **Loss of thermoregulatory mechanisms due to wing damage:** Damage to the wings by fungal growth, coupled with increased frequency of arousal during winter, act in concert to inflict high rates of mortality on infected bats. This is not only a result of mechanical impairment of flight and feeding efficiency due to physical damage of wing tissues, but is also a consequence of an inability of the damaged wing epidermis and circulatory system to regulate core body temperature. Destruction of wing tissues by *G. destructans* is likely to increase the rate of heat loss out of the body, making survival during mid-winter arousals extremely tenuous[4].

- **Bats infected with WNS display aberrant behavior:** Healthy bats typically arouse from torpor for brief periods to maintain immune function[2], restore neural and muscular function, excrete waste, and replenish water and energy stores[4] at 13 to 15 day intervals[2]. However, bats infected with WNS have been found to awaken and become active as frequently as every 2 to 4 days[2]. Each of these arousals requires the expenditure of substantial energy resources, both for thermogenesis and movement[2]. Several hypotheses have been postulated to explain higher frequency arousals in WNS infected bats, but none have been conclusively established. Hypotheses include the following:
  - Skin irritation by the fungus prompts bats to awaken prematurely.
  - Fungal infection stimulates bats to arouse to enhance immune function.
  - Higher frequency arousals and symptomatic mid-winter daylight flights of infected bats occur because starving bats are emerging in a last-ditch effort to feed[9].
  - Arousals are driven by thirst, with anecdotal accounts of bats at hibernacula affected by WNS flying over and drinking from water surfaces or eating snow[4].

Ecological/economic roles of bats

The potential impacts of WNS are considered to be significant and far-reaching due to the highly beneficial ecological roles played by bats. Bats are important seed dispersers, pollinators, and are major consumers of crepuscular and nocturnal invertebrates, including species that cause extensive forest and agricultural damage. Additionally, bat guano provides allochthonous

nutrient inputs to many otherwise nutrient-limited cave environments, and is essential for supporting cavernicolous species communities[10;11].

Jornada bat caves on the Armendaris Ranch, NM

The Jornada Caves in New Mexico are the second largest known lava tubes on the North American continent, and provide habitat for eight species of bat (Table 2). The migratory population of Mexican free-tailed bats (*Tadarida brasiliensis*) at Jornada is the largest in New Mexico, and the fifth largest in North America. There are unsubstantiated reports of seven hibernatory bat species at Jornada (Table 2), with the caves reportedly providing habitat for the largest known winter hibernaculum population of Townsend's big-eared bat (*Corynorhinus townsendii*), and several federal Species of Concern.

Whilst it is unknown how the spread of WNS amongst the bat populations of North America will proceed, the observed pattern of infection shows a rapid an inexorable transmission westward (Figure 1). In spring 2010, *G. destructans* was detected in a cave myotis (*M. velifer*) individual from northwestern Oklahoma (Paul Cryan, USGS, pers. Comm.). Genetic tests indicated that the bat was harboring the *G. destructans* fungus, although was not symptomatic of WNS. Despite there being no reports of WNS related mortality in Oklahoma, both the Oklahoma Department of Wildlife Conservation and the U.S. Fish and Wildlife Service are concerned about the future development of WNS in Oklahoma.

The detection of *G. destructans* in northwest Oklahoma places the putative pathogen of WNS approximately 800 km from the Jornada bat caves. It is suspected that the spectacular Mexican free-tailed bat (*T. brasiliensis*) population at Jornada may not at risk from *G. destructans* (since they do not lower their body temperatures to levels at which *G. destructans* grows). However, there is concern that this long-distance migratory species could be a vector for transmission of the fungus to more vulnerable species with which they share habitat (Mylea Bayless, Bat Conservation International, pers. Comm.). The Jornada caves therefore may have seven species at risk from WNS, five of which are listed as Species of Concern by the U.S. Fish and Wildlife Service (Table 2).

Recommendations for Jornada bat caves

From the available information, it appears that hibernatory bat species at the Jornada caves will be at risk from WNS mortality with any further westward expansion of *G. destructans*. However, there is a clear need for comprehensive ecological surveys at the caves to fully evaluate the threat posed by this epizootic disease. Understandably, most of our current information on bat ecology at Jornada focuses on *T. brasiliensis*, with poor and incomplete records for other species that may be resident. Therefore, the following actions are recommended to correct our knowledge deficit regarding bat ecology at this site, attempt to circumvent spread of *G. destructans* to Jornada, and to contribute to national bat conservation efforts:

- Any activity that involves entry to the Jornada caves should meticulously follow decontamination protocols (e.g. Appendix A) to reduce the risk of human transmission of *G. destructans* to the Jornada bat colonies.
- Baseline data on bat community ecology at the Jornada caves needs to be acquired. Initial surveys should aim to provide the following information:
    - Bat species present and abundance estimates
    - Habitat conditions (relative humidity, temperature, invertebrate prey densities)
    - Testing for the presence of *G. destructans*
- Periodic monitoring of bat populations should be initiated to contribute to the USGS's Bat Population Database (BPD), and hence our understanding of bat ecology in North America. There is currently no bat population data available in the BPD (http://www.fort.usgs.gov/BPD/) for the county encompassing the Jornada caves (Sierra County, NM).

Table 1: North American bat species presently impacted by WNS.

Common name	Species	Current listing status[Ψ]
Big brown bat	*Eptesicus fuscus*	Species of concern
Eastern small-footed myotis	*Myotis leibii*	Under review
Little brown myotis	*Myotis lucifugus*	Least concern*****
Northern myotis	*Myotis septentrionalis*	Least concern
Indiana myotis	*Myotis sodalist*	Federally endangered
Tri-colored bat	*Perimyotis subflavus*	Least concern
Gray myotis	*Myotis grisescens*	Federally endangered
Cave myotis	*Myotis velifer*	Species of concern
Southeastern myotis	*Myotis austroriparius*	Species of concern

[Ψ] Source: U.S. Fish & Wildlife Service, Endangered Species Program (http://www.fws.gov/endangered).
***** Request for status review[2] submitted to US Fish and Wildlife Service on December 16th, 2010.

Table 2: Bat species reportedly using the Jornada bat caves on the Armendaris Ranch, NM.

Common name	Species	Current status[Ψ]	Jornada cave population
Mexican free-tailed bat	*Tadarida brasiliensis*	No species status	Present[12]. Fifth largest population in North America
Pallid bat	*Antrozous pallidus*	Species of concern	Present[12]
Allen's big-eared bat	*Idionycteris phyllotis*	Species of concern	Unknown/unconfirmed[#]
Yuma myotis	*Myotis yumanensis*	Species of concern	Unknown/unconfirmed[#]
Townsend's big-eared bat	*Corynorhinus townsendii*	Least concern	Present[12]. Largest known winter hibernaculum population (unconfirmed).
Spotted bat	*Euderma maculatum*	Species of concern	Unknown/unconfirmed[#]
California myotis	*Myotis californicus*	Species of concern	Present[12]
Fringed myotis	*Myotis thysanodes*	No species status	Unknown/unconfirmed[#]

[Ψ] Source: U.S. Fish & Wildlife Service, Endangered Species Program (http://www.fws.gov/endangered).
[#] Source: Jornado bat caves – summary. Personal communication from Tom Waddell, Armendaris Ranch Manager.

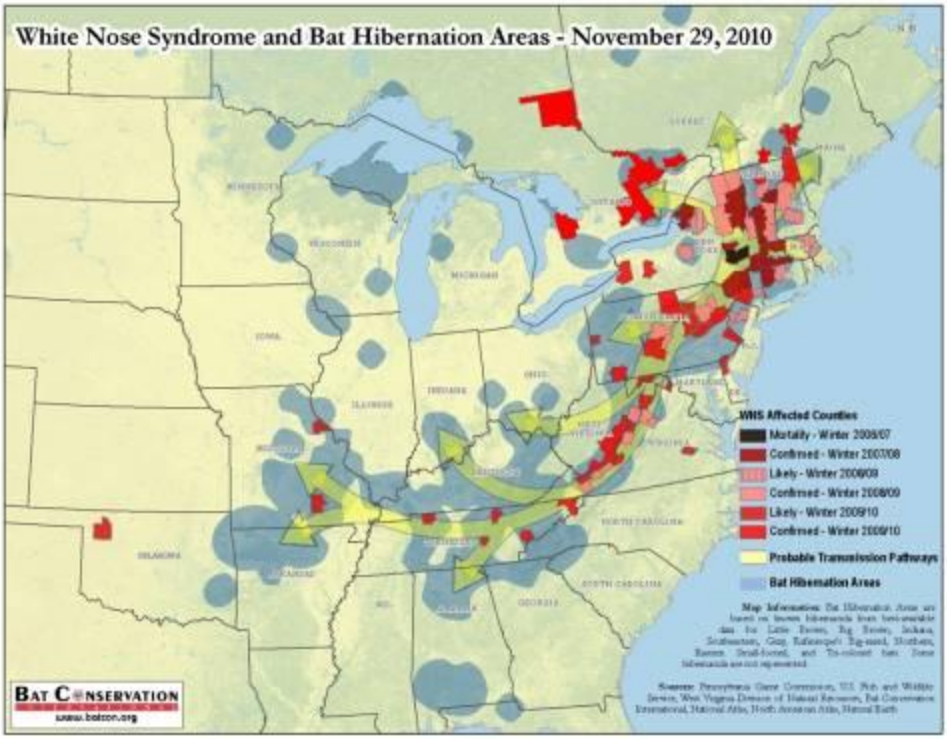

Figure 1: The geographic spread of WNS from initial detection in winter 2006. Source: (Bat Conservation International **http://www.batcon.org/**).

Figure 2: A little brown bat exhibiting white fungal growth on its muzzle, ears, and wings. (Source[1]).

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Appendix A (Source: http://www.fws.gov/WhiteNoseSyndrome/)

White-Nose Syndrome Decontamination Protocol (v.3)
U.S. Fish and Wildlife Service – Draft 7.31.2010

The USFWS strongly recommends compliance with all cave closures, advisories, and regulations in all Federal, State, tribal, and private lands. By disregarding this recommendation, you could potentially promote the transmission of the fungus *Geomyces destructans (G.d.)*, likely the causative agent for white-nose syndrome (WNS), which is responsible for significant bat mortality in eastern North America. Should you choose to disregard this recommendation, the following protocol outlines the best known procedures to help reduce the spread of the fungus. You should not handle bats. If you observe live or dead bats (5 or more individuals in a single location) that may exhibit signs of WNS, contact a wildlife professional in your state wildlife agency (http://www.fws.gov/offices/statelinks.html) or contact your nearest USFWS Ecological Services Field Office (http://www.fws.gov/offices/). Researchers, contact your state or federal agency for permitting requirements.

RECOMMENDED DECONTAMINATION PRODUCTS: The following chemical products were tested in a laboratory setting and were found to be particularly effective against killing the more resistant, spore-form of *G.d.*, as well as the hyphae.

1. Lysol® IC Quaternary Disinfectant Cleaner (0.3% quaternary ammonium compound minimum) - 1 part concentrate to 128 parts water
or 1 ounce of concentrate per gallon of water;

2. Lysol® All-purpose Professional Cleaner (0.3% quaternary ammonium compound minimum);

3. Formula 409® Antibacterial All-Purpose Cleaner (0.3% quaternary ammonium compound minimum);

4. A 10% solution of household bleach - 1 part bleach to 9 parts water (an estimate of 1:9 is insufficient);

5. Lysol® Disinfecting Wipes; or

6. Boil submersible gear in water for 15 minutes

***BEFORE CAVING*:** In order to effectively reduce the risk of human transfer of *G.d.*, it is imperative that you follow these decontamination procedures any time you plan cave visits, and **under no circumstances should clothing, footwear or gear that was used in a WNS-affected state or region be used in a non-affected state.** If gear **cannot** be thoroughly decontaminated or disposed of, we advise that you not enter caves or parts of caves requiring use of this gear. If gear **can** be thoroughly decontaminated and you must enter a cave, isolate and decontaminate these items after last exiting a cave. Gear should not be used in multiple caves in the same day unless the decontamination procedures below can be performed **between each cave visit.**

AFTER EACH CAVE VISIT: Thoroughly scrape or brush off any dirt and mud from clothing, boots, and gear and then place them in a sealed plastic bag or plastic container with lid to be cleaned and disinfected off site. Outer clothing should be removed prior to entering a vehicle

after/between a site visit. A clean change of clothing is recommended. To decontaminate clothing, footwear and gear, please follow the procedures listed below.

For Submersible Gear (i.e. clothing and equipment that can be submerged without damage)**:** Wash all clothing and any appropriate equipment in washing machine or by hand using conventional detergents. Use cold, warm, or hot water. Woolite® fabric wash has been found to be highly effective for this procedure. Rinse thoroughly, and then follow by soaking for a minimum of 10 minutes in one of the decontaminating products above, then rinse and air dry. As an alternative to chemical products, boiling submersible gear at a fast boil for 15 minutes is also recommended, followed by air drying.

For Non-submersible Gear (i.e. equipment that will be damaged by submersion)**:** Clean thoroughly with soap and water, and then decontaminate by applying one of the recommended products above to the outside surface for a minimum of 10 minutes, then rinse and air dry.

For Footwear:
Where possible, rubber (wellington-type) caving boots (which withstand harsh decontaminating products and are easily cleaned) are recommended. Boots need to be fully scrubbed and rinsed to remove all soil and organic material. Decontaminate rubber and leather boots, (including soles and leather uppers) with a product listed above for a minimum of 10 minutes, then rinse and air dry.

For Ropes and Harnesses:
To date, only Sterling rope and webbing have proved to sustain no damage when using products above. Wash rope/webbing in a front loading washing machine on the gentle cycle using Woolite® Extra Delicates detergent. Immerse in a dilution of Lysol IC Quaternary Disinfectant Cleaner for 15 minutes. Rinse twice in clean water and air dry. Brands of rope/webbing other than Sterling have not yet been tested for integrity after decontamination. Brands not tested should be dedicated to a single cave or not used at all.

For Cameras and Electronic Equipment:
If possible, do not bring electronic equipment into a cave. If practical, cameras and other similar equipment that must be brought to a cave may be placed in plastic casing (i.e. underwater camera housing) or wrapped in plastic wrap where only the lens is left unwrapped to allow for photos to be taken. The plastic wrap can then be decontaminated by using Lysol® Disinfecting Wipes and discarded after use or wipes can be applied directly on camera surfaces or plastic casing.

For Vehicles:
In addition to gear, vehicles used to transport equipment can also harbor spores. Keep vehicles as clean as possible by storing gear in clean containers, and decontaminate those containers with your other equipment using the decontamination products above.

Note: Protocol updated as of 7-31-2010. Please visit http://www.fws.gov/WhiteNoseSyndrome/ for updated materials and for **comprehensive supplemental documents that detail decontamination procedures for 1. cavers, and 2. researchers**.