White-Nose Syndrome (WNS) in Bats

White-Nose Syndrome (WNS) is a fatal condition that has been devastating hibernating bat populations across northeastern North America. The first case of WNS was discovered on February 16, 2006 in Howes Cave, a bat hibernaculum located west of Albany, NY.[1] Since its discovery, WNS has spread across the northeastern United States and has even extended into parts of Canada.[2] One of the most recent news releases from the U.S. Fish and Wildlife Service estimates that White-Nose Syndrome has killed between 5.7 million and 6.7 million bats and they expect these mortality numbers to rise.[3] The U.S. Geological Survey illustrates the rapid spread of WNS with two maps: one showing WNS in the Winter of 2005/2006 and the other showing WNS in the Winter of 2010/2011 (**Appendix A and B**). Locations of hibernacula afflicted with WNS, shown in yellow on the maps, appear to have increased in number and have expanded from the disease's initial epicenter in Howes Cave. To further stress the gravity of the situation, a series of graphs clearly demonstrate how WNS has affected the *Myotis lucifugus* populations (**Appendix C**). There is a sharp decline in population numbers during the short time span in which WNS became active. The loss of these hibernating bats could result in dire consequences for the ecosystems that depend on them.

The most common symptoms associated with White-Nose Syndrome include a "cutaneous infection caused by a … fungus" that is characterized by white growths on a bat's muzzle, ears and/or wings.[4] Others symptoms include dehydration and emaciation. Mortality from WNS strikes during the winter when bats are hibernating, thus making a bat's stored fat crucial to their hibernation process and survival. When a bat is infected with WNS, it "may arouse from hibernation more frequently or for longer periods than average and thereby prematurely expend fat reserves."[5] Bats also display erratic behaviors when infected with WNS, such as emerging during daylight hours when they're supposed to adhere to their nocturnal tendencies.[6]

Bats play an instrumental role in ecosystems, providing services that most humans are not conscious of. As White-Nose Syndrome spreads and bats continue to die, the ecosystem services that bats provide become threatened. Pollination and seed dispersal are two important services that bats contribute to the environment. Most bats and plants have a mutualistic relationship, in which plants provide a source of nutrients for the bat and the bat, in turn, pollinates and disperses the plants' seeds. Bats are vital to the biodiversity of plant species and through these aforementioned processes, humans benefit from the food, timber and medicinal plants that thrive due to the bat's pollination and seed scattering services. Genetic diversity of forests is maintained, as bats tend to introduce "novel plant species into previously disturbed landscapes and to islands."[7]

Bats are also responsible for the regulating ecosystem service of "insect suppression" through predation.[8] Bats consume agricultural pests, comprising of but not limited to "cucumber beetles, June bugs, corn earworm moths, cotton bollworm moths, tobacco budworm moths and Jerusalem crickets, which are important agricultural pests on such crops as corn, cotton and potatoes."[9] An astonishing 99% of agricultural pests are regulated by natural ecosystem services, such as bats' predator-prey relationship with insects.[10] Bats also consume bugs that threaten to harm wild plant species. Through the consumption of potentially harmful insects, bats suppress pests that could "transmit specific pathogens to humans and other mammals."[11] For instance, bats typically feed on

mosquitoes and their larvae, which could help prevent the spread of West Nile in humans and other animals due to reduced mosquito populations. Bats play a crucial role in keeping bug populations in check. Ultimately, WNS poses a threat to the biodiversity of plants achieved through pollination and seed dispersal and also threatens the insect regulation that bats provide. As bats are driven to endangerment and possibly even to extinction due to this disease, the effects will surely be felt across many ecosystems.

Today, one of the biggest obstacles scientists face with this epidemic is finding out the exact cause of White-Nose Syndrome. Scientists have conducted several studies to try to pinpoint the root cause of WNS but still have not found concrete evidence. In 2009, histopathologic examinations, or examinations of body tissues, were initially used to confirm that 105 out of 117 bats, collected from areas with known WNS cases, contracted a fungus.[12] The fungus was identified as *Geomyces destructans*.[13] While *G. destructans* was isolated as one of the pathogens leading to WNS, it is believed that there are other as-yet-unidentified pathogens involved.[14] Scientists have done experiments with *G. destructans* to see its effects on healthy bats. For instance, one experiment placed "healthy *Myotis lucifugus* in the laboratory under hibernation conditions and treated them with conidia of *G. destructans* harvested from pure culture."[15] Scientists discovered that 100% of the treated bats had contracted WNS after 102 days of administering treatment (**Appendix D**).[16] Another important study housed healthy bats with WNS-infected bats; 89% of the healthy bats contracted WNS, "demonstrating for the first time that WNS is transmissible."[17] Recognizing that White-Nose Syndrome could be transmitted through bat-to-bat contact was a breakthrough in WNS research.

While one means of transmission has been uncovered, *G. destructans* remains somewhat of a mystery to scientists, as they do not know exactly how the pathogen causes death in bats. Scientists are unsure if bats die directly from their skin infections or if perhaps, their premature arousal from hibernation, which leads to fat loss, could be the leading cause of death.[18] Also, it is still unclear if bats can contract WNS from coming in contact with surfaces in hibernacula that house infected bats. Thus, in order to better identify the root cause of White-Nose Syndrome, scientists need to continue studying *G. destructans* and come up with a more efficient way of diagnosing bats. It is of vital importance that scientists carefully study bat behavior, such as bat's "feeding and roosting behaviors [and] nightly, seasonal, and annual flight distances."[19] Researching the behaviors of bats and recording them may lead to useful information that can help uncover how WNS originated and how it is spreading to different hibernacula.

Because the root cause of White-Nose Syndrome remains unknown, it will be difficult to develop a solution to the problem. As of now, it seems the only way to develop a solution is to closely monitor bat populations in an effort to understand bat behavior and how WNS is spreading across the United States. Studying European bat populations will also be of great significance, especially if the fungus that causes WNS is an invasive species. Lorch *et al.* note that European bats have a similar fungus that "colonizes the skin [and] no unusual bat mortality events have been reported."[20] If scientists can figure out why European bats seem to be immune to the *G. destructans* fungus, then perhaps they can develop a vaccination for the affected bats of North America. Developing a vaccination and distributing it to bats in WNS-infected hibernacula is perhaps the best, but certainly costly, solution. Creating a vaccine ultimately means additionally funding for bat research, which could lead to expenses, such as histopathologic examinations of

individual bats and also multiple trials to see if the vaccine is successful. It is also a costly gamble as it is unknown if exposed bats can develop immunity against WNS on their own. The vaccination would be most effective if it could be administered in masse instead of given to individual bats. Therefore, it would be beneficial if the vaccine was a gas or in a form that could be inhaled, thus making it possible to spray the vaccine in bat caves. Treating bats and increasing the effectiveness of their immune systems would stabilize the falling bat populations. If bat numbers can be restored, then the ecosystem services that they provide will be preserved.

Other proposed solutions include creating a fungicide to combat *G. destructans* but there is the question of how the fungicide would be administered. Spraying fungicide in caves "would affect microbial flora in the cave."[21] Similar to the vaccination proposal, a positive aspect is that multiple bats can be treated at one time. A negative aspect of these kinds of plans is that it is unknown how spraying these solutions in hibernacula will affect the other organisms within the caves. In addition, hibernacula have vast interiors and spraying a solution to combat the fungus may not cover all surfaces.[22] Scientists may also not have access to caves on private land, making it difficult to administer a fungicide or vaccination to all infected hibernacula.[23] Another solution is preventing emaciation and dehydration through "supplemental feeding or watering [but] bats will likely not learn to feed from novel food sources during winter."[24] Quarantining infected bats is another possible solution.[25] By isolating infected bats, it may stop the spread of WNS caused by bat-to-bat contact. However, isolating each infected bat is a difficult and grueling task. Because it hard to cull WNS-infected bats, it would be easier to find a solution, such as the aforementioned vaccination, that could be given to large bat populations at once. Vaccines would be a better solution than fungicide, because if a vaccinated bat comes in contact with White-Nose Syndrome pathogens, they will be immune. Like in Lorch's experiment, transmission occurs from bat-to-bat, which means that developing a vaccine would be successful in preventing transmission from bat-to-bat contact.[26] Fungicide would only prevent the fungus from growing in hibernacula and it is still uncertain if *G. destructans* is the sole pathogen that causes WNS.

White-Nose Syndrome poses a serious threat to the bats of North America. Scientists need to continue to research the disease until a root cause is discovered, making it possible for a viable solution to be determined. Ecosystems depend on the pollination, seed dispersal and insect regulation services provided by bats. Most people need to be better educated in order to realize the instrumental role that bats play in the environment, and better educating them may cause them to have a personal investment in preserving bat populations. As scientists diligently work on researching WNS, one can only hope that a solution is not far away.

ENDNOTES

[1] David S. Blehert *et al*., "Bat White-Nose Syndrome: An Emerging Fungal Pathogen?" *Science* 323, no. 5911 (2009): 227, accessed February 27, 2012, http://www.sciencemag.org/content/323/5911/227.full.

[2] Winifred F. Frick *et al.,* "An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species," *Science* 329, no. 5992 (2010): 679, accessed February 25, 2012, http://www.sciencemag.org/content/329/5992/679.full.

[3] U.S. Fish and Wildlife Service, (2012, January 17), *North American Bat Death Toll Exceeds 5.5 Million from White-Nose Syndrome,* [News Release], accessed February 29, 2012, retrieved from http://www.fws.gov.
[4] Gudrun Wibbelt *et al.,* "Emerging Diseases in Chiroptera: Why Bats?" *Biology Letters* 6, no. 4 (2010): 439, accessed February 28, 2012, http://171.66.127.192/content/6/4/438.full.
[5] Janet Foley *et al.,* "Investigating and Managing the Rapid Emergence of White-Nose Syndrome, a Novel, Fatal, Infectious Disease of Hibernating Bats," *Conservation Biology* 25, no. 2 (2011): 224, accessed February 27, 2012, http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2010.01638.x/full.
[6] Ibid.
[7] Thomas H. Kunz *et al.,* "Ecosystem Services Provided by Bats," *Annals of the New York Academy of Sciences* 1223 (2011): 3, accessed February 27, 2012, doi: 10.1111/j.1749-6632.2011.06004.x.
[8] Ibid.
[9] Gareth Jones *et al.,* "Carpe Noctem: The Importance of Bats as Bioindicators," *Endangered Species Research* 8 (2009): 96, accessed March 1, 2012, doi: 10.3354/esr00182.
[10] Kunz, "Ecosystem Services," 3.
[11] Ibid.
[12] Blehert, "Bat White-Nose Syndrome," 227.
[13] Jeffrey M. Lorch *et al.,* "Experimental Infection of Bats with Geomyces Destructans Causes White-Nose Syndrome," *Nature* 480 (2011): 376, accessed February 29, 2012, http://www.nature.com/nature/journal/v480/n7377/full/nature10590.html.
[14] Ibid.
[15] Ibid.
[16] Ibid.
[17] Ibid.
[18] Foley, "Investigating and Managing the Rapid Emergence of White-Nose Syndrome," 225.
[19] Ibid.
[20] Lorch, "Experimental Infection," 376.
[21] Foley, "Investigating and Managing the Rapid Emergence of White-Nose Syndrome," 229.
[22] Ibid.
[23] Ibid.
[24] Ibid.
[25] Ibid.
[26] Lorch, "Experimental Infection," 376.

Bibliography

Blehert, David S. *et al*. "Bat White-Nose Syndrome: An Emerging Fungal Pathogen?" *Science* 323, no. 5911 (2009): 227. Accessed February 27, 2012. http://www.sciencemag.org/content/323/5911/227.full.

Foley, Janet *et al.* "Investigating and Managing the Rapid Emergence of White-Nose Syndrome, a Novel, Fatal, Infectious Disease of Hibernating Bats." *Conservation Biology* 25, no. 2 (2011): 223-231. Accessed February 27, 2012. http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2010.01638.x/full.

Frick, Winifred F. *et al.* "An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species." *Science* 329, no. 5992 (2010): 679-682. Accessed February 25, 2012. http://www.sciencemag.org/content/329/5992/679.full.

Jones, Gareth *et al.* "Carpe Noctem: The Importance of Bats as Bioindicators." *Endangered Species Research* 8 (2009): 93-115. Accessed March 1, 2012. doi: 10.3354/esr00182.

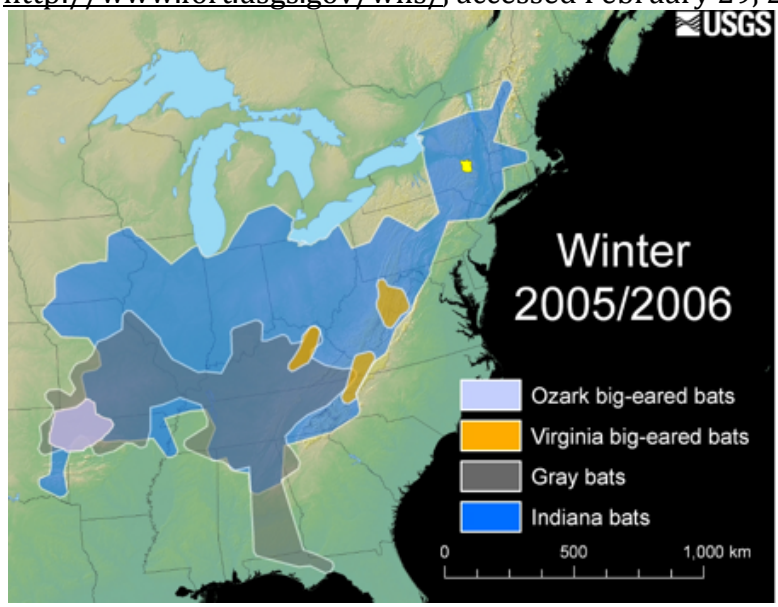
Kunz, Thomas H. *et al.* "Ecosystem Services Provided by Bats." *Annals of the New York Academy of Sciences* 1223 (2011): 1-38. Accessed February 27, 2012. doi: 10.1111/j.1749-6632.2011.06004.x.

Lorch, Jeffrey M. *et al.* "Experimental Infection of Bats with Geomyces Destructans Causes White-Nose Syndrome." *Nature* 480 (2011): 376-378. Accessed February 29, 2012. http://www.nature.com/nature/journal/v480/n7377/full/nature10590.html.

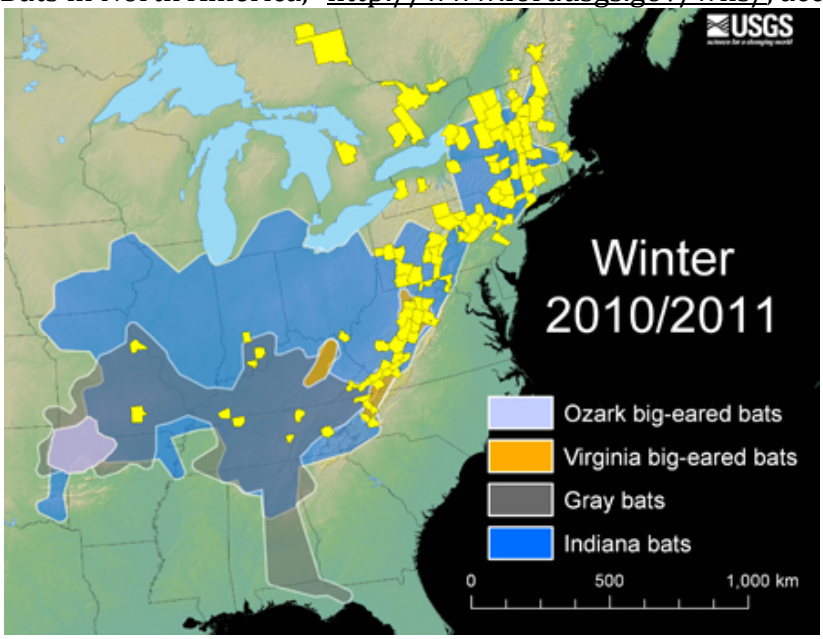
U.S. Fish and Wildlife Service. (2012, January 17). *North American Bat Death Toll Exceeds 5.5 Million from White-Nose Syndrome.* [News Release] Accessed February 29, 2012. Retrieved from http://www.fws.gov.

Wibbelt, Gudrun *et al.* "Emerging Diseases in Chiroptera: Why Bats?" *Biology Letters* 6, no. 4 (2010): 438-440. Accessed February 28, 2012 http://171.66.127.192/content/6/4/438.full.

APPENDIX A:
Winter 2005/2006 – Map showing the ranges of endangered bat species and the spread of WNS (shown here in yellow). Data compiled by Cal Butchkoski. **Source**: "White-Nose Syndrome Threatens Hibernating Bats in North America," http://www.fort.usgs.gov/wns/, accessed February 29, 2012.

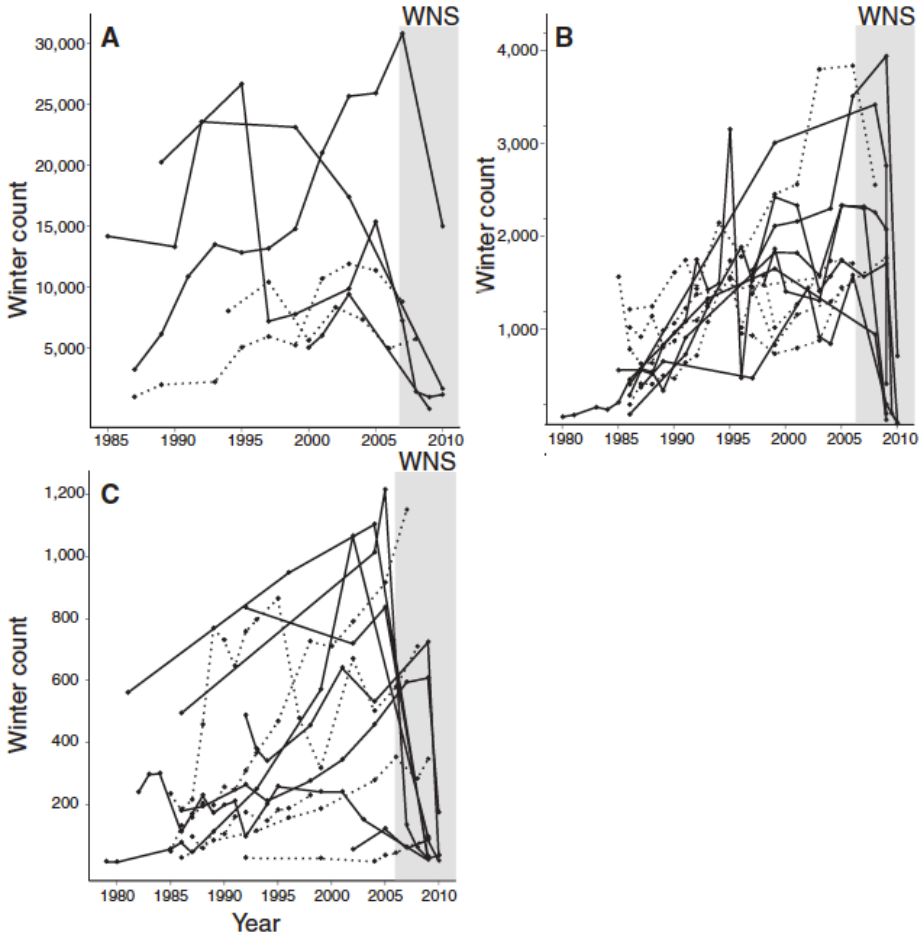


APPENDIX B:
Winter 2010/2011 – Map showing the ranges of endangered bat species and the spread of WNS (shown in yellow). Note how WNS has spread over the span of 5 years.
Data compiled by Cal Butchkoski. **Source**: "White-Nose Syndrome Threatens Hibernating Bats in North America," http://www.fort.usgs.gov/wns/, accessed February 29, 2012.



APPENDIX C: Graphs show decline of *Myotis lucifugus* over the past 30 years. Note the drastic drop in bat population due to WNS.
Source: Winifred F. Frick *et al.,* "An Emerging Disease Causes Regional Population Collapse of a Common North American Bat Species." *Science* 329, no. 5992 (2010): 681. http://www.sciencemag.org/content/329/5992/679.full

(**A** to **C**) Population trends of little brown myotis over the past 30 years at (A) small (<1500 bats), (B) medium (<5000 bats), and (C) large (>5000 bats) hibernating colonies in the northeastern United States. Solid lines represent sites with bats infected with WNS; dotted lines represent uninfected sites. Hibernacula infected with WNS experienced a significant reduction in numbers as compared to the lowest available count from the past 30 years (Wilcoxon test = 190; $P < 0.002$). Large decreases in winter counts at a few hibernacula in the mid-1990s were related to winter flood events.



APPENDIX D: Source: Jeffrey M. Lorch *et al.,* "Experimental Infection of Bats with Geomyces Destructans Causes White-Nose Syndrome," *Nature* 480 (2011): 378, accessed February 29, 2012, http://www.nature.com/nature/journal/v480/n7377/full/nature10590.html.

Development of WNS in experimentally infected bats

Treatment group	Number with WNS lesions present	Number with no WNS lesions	Total	Per cent infected
Negative control	0	34	34	0
Treated	29	0	29	100
Contact exposure	16	2	18	89
Airborne exposure	0	36	36	0
Positive control	25	0	25	100

The data show prevalence of WNS-associated fungal infections established in groups of healthy little brown bats inoculated with conidia of *G. destructans* from pure culture or exposed to bats known to have WNS (positive control group). Infection status was determined by histological examination of the wing.