Why are Bats going Batty?
_A Review of how White Nose Syndrome is impacting Bat Populations in New York State_

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EXECUTIVE SUMMARY

In 2006, in a cave near Albany, New York, a deadly disease to bats was discovered. This fungal disease, originating in Europe, is known as *Geomyces destructans*, or White Nose Syndrome. To date, more than six million bats in the United States have been killed as the fungus continues to spread. The disease is able to thrive in cold, dark, humid environments, making bat caves the perfect location. Thus, the disease tends to only affect hibernating bats that use these caves during the winter months. There are six species of bats in New York: big brown bat, eastern small-footed bat, Indiana bat, little brown bat, northern long-eared bat, and the tricolored bat (Yu, 2011). To date, the disease has caused a decline anywhere between 30-99% in each of the populations. This elicits a great concern not only for the preservation of the species, but also for the ecological impacts that the reduced number of bats could have, especially concerning insects. In this paper, we outline the concerns associated with White Nose Syndrome, the impacts it could potentially cause and multiple potential solutions. Although there are solution possibilities, only a few of them are feasible for the long run. Part of our final solution is to close caves in order to restrict public access and adhere to the Department of Environmental Conservation decontamination protocol. These solutions rely heavily upon the cooperation of the public and commercial cave owners. Our final conclusions imply that there is much more research that needs to be done on the biology of the disease before we can find a cure and that the stakeholders must continue to do their part in maintaining the diversity of New York bat species.
PROBLEM DEFINITION

Biology

Bats, which are part of the order Chiroptera meaning ‘hand-wing’, are the only mammals that can truly fly (Williams et al., 2014). There are currently more than 1000 bat species worldwide (Harris, 2001) which can be found in various habitats, including wetlands, fields, forests and cities (Williams et al., 2014). There are two suborders of Chiroptera, megachiroptera and microchiroptera. Megachiroptera (Fig. 1) are also known as fruit bats, or flying foxes. These vegetarian species can only be found in Africa, Asia and Australia, and can be recognized by their long muzzles. Microchiroptera (Fig. 2) are much smaller and can be found all over the world. Contrary to megachiroptera, these species are carnivorous and tend to have pushed-in snouts (Harris, 2001).

Figure 1. Megachiroptera bat  
Figure 2. Microchiroptera bat

Bats are a nocturnal species, thus they may be difficult to locate during the day. During the spring and summer days, they will likely be in a roosting position, which is in a sheltered area such as a garage, trees or other large structures. In these spots, the bats hang upside down and let their bodies relax as their talons grab hold of the surface. Most bat species will roost in the same location every night, forming a colony. This allows them to cluster together for warmth and security as well as form a complex social community. The roost puts the bats in an ideal
position for takeoff once the sun has set. Bats are unable to launch themselves into the air from the ground, as their wings do not provide them with enough life. If they do happen to be on the ground for hunting purposes, they must use their front claws to climb to a higher spot and fall into flight. Bats are also lucky that there is little competition for these roosting spots. There is no other flying animal with the ability to hang upside down, thus they have almost unlimited choices (Harris, 2001).

In the late Spring and early Fall, many bats will begin to mate. The male’s sperm will remain dormant in the female’s reproductive system until Spring. The female will then begin to ovulate and fertilization will occur, allowing the pups to be born in late May. Bats have one of the lowest reproduction rates for animals their size, having only one or two pups per year. This can make it difficult to maintain a stable population. However, this is partially offset by their long lifespan, which generally ranges between four and six years (Williams et al., 2014).

During the Autumn and Winter months, bats will then begin to either hibernate in a cave or migrate to warmer areas (Harris, 2001). This is not only due to the cold, but also due to the lack of food supply. In North America, there are 45 species of bats, 26 of which are hibernating (Yu, 2011). During this hibernation period, many physiological changes start to happen to the bats. The metabolic activity of the bats is reduced, their heart rate slows down to approximately 20 beats per minute, compared to the 1000 beats per minute that it experiences during flight, and their body temperature falls from 100 F to the temperature of the surrounding cave. All these changes allow the bats to survive on very small amounts of stored fat (Williams et al., 2014). The bats do have occasional natural arousals during these winter months, where they might drink, urinate or relocate, however these awakenings can take up to 90% of their winter fat reserves.
Thus, they must be very careful about keeping these arousals to a minimum as their energy balance could quickly tip towards starvation (Cryan, 2012).

A common misconception about bats is that they are blind. While this is not a true statement, they do heavily rely on another way of locating objects besides sight. Bats engage in what is known as echolocation. When in flight, the bat will emit ultrasonic sound pulses from its mouth that bounce back off of objects. The bat will use the echo of these pulses in order to locate an object, such as food (Williams et al., 2014). Bats are able to be in flight by using their wings, which are a fairly rigid bone structure. This bone structure is covered by the patagium, a thin membrane of skin which extends between the hand and the body of the bat (Harris, 2001). The wing membranes take up approximately 85% of the bat’s total surface area and has many important functions. This membrane helps to regulate body temperature, blood pressure, water balance, gas exchange, flying, and feeding (Cryan, 2012). The ability to fly and use of echolocation aids bats in locating their primary food source, insects. Bats tend to feed in areas where insects are swarming to conserve energy, such as over water or agricultural fields (Williams et al., 2014). Many can consume as many as 1200 mosquito sized insects in an hour (Yu, 2011). This insect control stresses the importance of bats to many of our ecosystems.

**Caves**

Caves are found all over the world and in a number of diverse formations. While some are formed in glaciers by meltwater, others are formed at sea from crashing waves. Some caves have even been formed by the cooling and hardening process of lava. However the majority of caves we find today are defined as solution caves (Caves: Underground Chambers, National Geographic).
Solution Caves are typically found in karst environments. Today around 20% of the United States is classified as this type of landscape (Caves Karst and Groundwater, National Caves Association). Karst is made up of limestone, dolomite, and gypsum rocks and over time these rocks are slowly dissolved by acidic water. As this acidic water seeps further into Earth’s surface it begins to form a number of cracks and fractures. As these cracks grow in size and number eventually they form a system of passages and chambers that in time form these solution caves (Caves: Underground Chambers, National Geographic).

Another important component of caves are four common speleothems, rock formations, found within them. Stalactites are formations that hang down from the ceiling of caves; they are formed by water the drips down. Stalagmites are formations that grow up from the floor of caves and are formed from the water that drops off of stalactites. Flowstones are typically found on the sides and the floor of caves; these formations are formed from a growth of calcite. Finally we have helictites; these twisting rock formations tend to form on the ceiling, floor, and even the walls of caves (Caves: Underground Chambers, National Geographic).

Caves are typically broken into three zones: entrance, twilight, and dark. Each of these zones differs in its makeup as well as life that live within it. The entrance zone is made up of the environment that is closest to land above the ground. This zone is able to receive sunlight therefore it possesses some forms of vegetation as well as has a variable temperature. All life that lives within this zone is defined as a trogloxene, or “cave visitor.” Examples include bears, raccoons, and some bats. These visitors come and go as they please however they never spend a complete life cycle within the cave. They utilize the entrance zone for a number of reasons including hibernation, nesting, or to give birth (Ronca, 2009).
The twilight zone serves as the next section within a cave. This zone receives much less light and vegetation than the entrance zone and has a much more constant temperature. But the temperature is still able to fluctuate from time to time. Trogloxenes live within this zone. Frogs, salamanders, crayfish, and even bats are all considered trogloxenes. Although each of these creatures are able to survive outside the cave they prefer not to. These organisms prefer a cool, moist environment (Ronca, 2009).

The dark zone serves as the final zone within caves. This zone possesses no light whatsoever and has an extremely constant temperature. Life that lives within this zone is called troglobites. Troglobites are fully adapted to cave life because they spend their entire life cycle within caves. They tend to have poorly developed eyes, little pigmentation, and a metabolism that enables them to go a long period of time without food. Cave fish, some shrimp, and some millipedes are all examples of troglobites (Ronca, 2009).

**White Nose Syndrome**

In the winter of 2006, a disease originating in Europe was discovered in Howe’s Cave in Schoharie county, New York (Dobony et al., 2011). It has since spread rapidly across the Eastern United States and Canada. This disease is known as *Geomyces destructans*, or White Nose Syndrome, stemming from the order helotiales (*Geomyces destructans*, Institute of the Study of Invasive Species). Bats in Europe seem to experience much lower mortality rates than what is currently happening in North America due to either smaller hibernation groups, greater resistance, or immunologically or behaviorally resistant (Wibbelt et al., 2010).

This fungus thrives in darkness, low temperatures of about 40-50 degrees fahrenheit, and humidity greater than 90 percent (Cryan, 2012), which makes the caves of hibernating bats an ideal environment for it to thrive. The fungus has the ability to live on any complex carbon
source, such as insects, wood, or dead fungi, however it needs to be in combination with the previously mentioned climate factors (Mclendon, 2013). Thus, not only can the fungus live on hibernating bats, but it can also remain in the cave soil which stays cool year round (Schweber, 2013).

The disease has many effects on the species of hibernating bats, and most commonly will lead to death. It is important to note that the disease is only able to infect the normally warm blooded animals because, as previously mentioned, hibernation decreases their body temperature to the surrounding temperature of the cave (Williams et al., 2014). Thus, non-hibernating bats are not likely to become infected. The disease can easily be spotted due to the white growth that occurs on the muzzles, wings, and ears of the bats. The fungal spores will begin to invade and destroy the once healthy skin (Yu, 2011). This disruption causes the bats to wake up early from hibernation, which can be very dangerous due to their limited fat reserves. The bats natural reaction to being woken up is to begin searching for food. Unfortunately, there are a very low number of insects that can be found during the winter (Mclendon, 2013). Infected bats will thus demonstrate very unhealthy side effects, such as tremors of the forearms as they crawl, flying during the daylight, collisions with large stationary objects, excessive thirst (Turner et al., 2011), frequent arousals from hibernation, premature depletion of fat reserves, severe dehydration (Local bat proposed for endangered species protection, 2013), and clustering near the entrances of the hibernacula zones of caves. Eventually, the bats will die due to the exhausting of their food supply (Geomyces destructans, Institute of the Study of Invasive Species).

One of the reasons this disease is particularly dangerous is how quickly it is able to spread. Hibernating bats cluster together, creating a very moist environment in close quarters (Yu, 2011). Thus, the primary method of spread is attributed to ‘bat-to-bat’ contact of either bats
within the same cave, or between bats from different hibernacula that may come in contact with one another. Humans also play a large role in the spread of this disease (Brooks, 2011) since the very beginning. The transfer of the disease from Europe to the United States is thought to have been due to humans transferring equipment from one area to another. It is also easy for humans to spread the disease as there are many recreational activities, such as spelunking, that can occur in caves. If equipment and clothing is not properly washed before going into another cave, the fungus could become introduced to the new cave, eventually infecting the hibernating bats.

**How is WNS affecting bats**

Since its initial introduction White Nose Syndrome has been extremely detrimental to bat populations throughout the United States and Canada, killing more than 6 million bats (McLendon, 2013). Almost 90% of bat populations throughout eastern United States and Canada have been destroyed due to this disease (Yu, 2011).

White Nose Syndrome has currently infiltrated 22 states as well as much of eastern Canada. Unfortunately this disease has the potential to infect over half of the bat species that occur throughout the United States as well as the potential to infect all species that occur within higher latitudes of North America, with the exception of 4 migratory tree bat species (Cryan, 2012).
Figure 3. Map that displays the range of endangered hibernating bats throughout the United States compared to the spread of the Geomyces destructans fungus that causes White Nose Syndrome. Purple, Orange, Grey, and Blue layers represents range of endangered bat species while Yellow indicates the range of the fungus and WNS. Available from: https://www.fort.usgs.gov/science-feature/123
New York State currently has 9 species of bats, 6 of which hibernate: big brown bat, eastern small-footed bat, Indiana bat, little brown bat, northern long-eared bat, and the tricolored bat (Yu, 2011). White Nose Syndrome has severely impacted all 6 species of these hibernation bats, causing a 30-99% decrease in their population every year. Specifically the little brown bat population has decreased by 90% in the Adirondacks, Indiana bats have decreased by 60%, and the northern bat species has decreased by an astounding 98% (Yu, 2011). In order to prevent the chance of extinction of the little brown bat White Nose Syndrome would need to have an annual decline of 5% per year.
METHODS

For this study, we conducted six interviews with individuals in the spring of 2014 that have an association to White Nose Syndrome. The persons who were interviewed, as well as their occupations, is provided in Appendix A. The interview questions varied based on whom we were interviewing and what their involvement is with the fungus.

The remaining facts and figures were collected via journal, newspaper, and magazine articles and various internet sources.
IDENTIFICATION OF STAKEHOLDERS

New York State Department of Environmental Conservation (NYSDEC)

The Department of Environmental Conservation is designed to protect the natural resources and environment and prevent pollution from affecting the health, safety and economic well being of the people of New York. They strive to achieve these goals through their own pursuits as well as rallying individuals for participation in any environmental decisions being made that may impact them.

Some members of the NYSDEC have been working with the U.S. Fish and Wildlife Service, the Northeast Cave Conservancy, the National Speleological society, and many other organizations, to monitor the effects of White Nose Syndrome in the state. Because of their ability to collaborate with many larger organizations throughout the country, the NYSDEC plays a vital role in ensuring cooperation in the solutions that may be put in place and pursuing accurate data from valid sources. Governmental organizations such as these will be very important if and when it becomes necessary to instill a solution, such as closing off caves to the public.

The DEC has currently been meeting with other stakeholders to provide recommendations for what they can do. They have been spreading information about what the best practices are, met with the Cave Conservancy organization to encourage them to close caves in the wintertime to protect the bats that are left and provided general information to the public. They have also instilled a contamination protocol for killing any fungus that may be on clothing or gear when people leave the caves\(^1\). It is important that anyone with questions regarding WNS contact the DEC, as they have the necessary contacts and information readily available.

\(^1\) Carl Herzog, Personal communication, 9 April 2014
Recreational Cavers

Spelunking is a term used to describe the recreation exploration of caves (Ronca 2009). While many experienced spelunkers may know the proper etiquette when entering a cave, many also do not realize the immense harm they could be causing. There are two ways in which recreational cavers could threaten the survival of bat colonies depending on what season they choose to enter the caves. Because there are no governmental restrictions currently in place (aside from some caves being closed), spelunkers have the freedom to go wherever and whenever they choose.

Spelunkers will not be disturbing any animals directly if they enter a cave during the spring and summer months when bats are not hibernating. However, because the fungus is able to thrive in the caves year round (Schweber 2013), there is a high chance that it could be attached to any piece of equipment or clothing as they leave the cave. Recreational cavers must thus be very conscious of cleaning any equipment or clothing that they use when going into a cave before entering another. This helps to reduce the risk of transferring the fungus to an uninfected cave.

Recreational cavers that visit the caves during winter, their hibernation season, can severely disturb the bats with their lights, voices, and body heat. These disturbances often cause the bat to wake up and fly out of the cave (Williams and Brittingham 2014). Due to the low amount of stored fat that hibernating bats have, they are very limited to the number of times they are allowed to wake up and be able to survive the winter months. This, in combination with the possibility of White Nose Syndrome waking them up as well could drastically reduce the number of bats surviving the winter. Recreational cavers should consider avoiding trips to caves during
the hibernation seasons or if they do go, be sure to leave the cave quickly and quietly should they come into contact with any bats.

Fortunately, many recreational cavers are aware of these potential threats that they have on the environment and have found ways to minimize their impacts (Williams and Brittingham 2014). It is important that spelunkers continue to be considerate and help to keep a watchful eye out for any signs of the fungus.

**Cave Companies as tourist attractions**

Caves, along with being a home to hibernating bats, are also used as tourist attractions by enticing people to go deep into the cave, walking through the dark corridors and seeing the strange formations of rock. While many caving associations try to avoid caves that are home to a large number of bats, it is inevitable that a few may show up.

Howe Caverns, located in Howe’s Cave, New York, offers many tours for tourists to explore the inside of these amazing caverns. Though there are not bats in the commercial areas of these caves, they are present in the more undeveloped parts. The business tries to stay out of these areas where the majority of bats are as much as possible to avoid any contacts or disturbances. Howe Caverns is aware of the dangers of WNS and have been taking steps towards becoming more involved in the search for a cure. They are actively working on supplying educational materials to those that come to their cave as well as other caves that offer similar tourist activities (Cite Howe Caverns website) as well as raising money for organizations that conduct research on the subject.

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2 Kevin Berner, Personal communication, 18 April 2014
3 Ibid.
These caves play a particularly important role in managing WNS because of the increased likelihood that they themselves or the tourists may transfer the disease from one cave to another. It would be difficult to force them to close their caves until WNS is cured for two reasons, 1. Many of their caves may not be an active hibernation home to bats, and 2. These are businesses, many of which have been around for a long time, and are thus their source of income.

It is important that we continually educate these caves on how to best prevent the spread of the disease (i.e. cleaning all clothes and equipment after entering a cave) as well as how to best identify a bat that may be carrying the fungus. Along with this, it is also important that good relationships are maintained such that researchers may be able to study any caves that may be at high risk and have the necessary cooperation to do what is best for the bats.

**Farmers**

Farmers are likely to become very important stakeholders for this spreading disease in the near future. Bats consume insects as a large portion of their diet, eating up to 8000 tons each year (Schweber 2013). Many of these insects are pests to these agricultural farms, thus the bats provide the ecological service of natural pest management. Bob Borchard, an agricultural farmer, suggested that the bats may take care of up to “about 80%” of the overall insect populations (Mercer 2011). With bat numbers on the decline, farmers could face crop loss and the search for other pest management strategies.

Researchers have found that bats save American farmers at least $3.7 billion a year in pest management (Mercer 2011). Another paper suggested that it might even be as high as between 4 to 50 billion dollars per year (http://www.nwhc.usgs.gov/disease_information/ white-
Regardless of which numbers are correct, it is still clearly a large amount that the farmers would be faced with.

Unfortunately for farmers, until a cure is found, there is not much that can be done to reduce the pest management costs that they will have to take on. On a good note, it is important to recognize that in the state of New York, agricultural farmers are likely to be much less impacted than farmers in the Midwest (Mercer 2011). Carl Herzog, a member of the DEC Wildlife Diversity Unit, does not get the impression that bats in New York concentrate on eating a lot of agricultural pests. Rather, they are much more likely to have an impact on forest pests, such as tree oriented insects whose populations may be limited due to the feeding behavior of the bats⁴.

Though it may not have as large of an impact in New York compared to other states, the population reductions will likely still have some sort of ecological consequence however small. Farmers will need to be aware of this potential impact and have potential solutions for how they will be able to handle the future situation.

**Researchers and Conservationists**

Researchers and conservationists play a very important role in what may happen to the New York bat populations, as they are the ones that have the ability to determine what species need protection and find potential solutions to the problem. There are many studies that have been done pertaining to how it all began, the status of populations, and testing for possible solutions.

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⁴ Carl Herzog, Personal communication, 9 April 2014
To date, the researchers and conservationists have been unable to receive the full protection for the bats that they believe is necessary; only a limited number of species has made it onto the endangered species list. In 2013, after finding that WNS caused 100 percent mortality in many colonies, the northern-long-eared bat was finally granted protection for the U.S. Fish and Wildlife Service Endangered Species Act. Prior to this, the only other bat in the Adirondacks that was on the endangered species list was Indiana bats. The northern long-eared bat was already fairly rare, thus the disease caused the species to become every more scarce (http://www.adirondackexplorer.org/local-bat-proposed-for-endangered-species-protection/2013/10). While the protection does not cure WNS in any way, it does increase the availability of resources to find a cure for this particular species. Currently, these two species, the Indiana bat and the northern-long eared bat, are the only New York bat species listed as endangered.

Other researchers have completed useful studies to monitor populations such that we can ensure that all species receive the necessary protection. One study suggests that there could be a 99 percent chance of regional extinction of the little brown myotis species over the next sixteen years should WNS continue to spread (Frick et al. 2010). This same study also made the prediction that even if mortality from the disease declines, there will likely be a regional population collapse from 6.5 million little brown myotis bats to less than 65,000.

It is extremely important that researchers and conservationists continue to monitor population numbers in New York (Turner et al. 2011) (Appendix B) to increase assistance from larger organizations and the local government. The data will be necessary to convince others of what is happening and how extreme the effects truly are.
Residents

Many caves are located on private property, thus the local residents will play a large role in how WNS is able to managed. One of the most important aspects currently in controlling the spread of the fungus is reducing the spread from cave to cave. Unless we have cooperation from these residents, it will be difficult to determine just how much the fungus has spread and whether the caves are being properly watched over.

There are no guidelines in place, nor any authoritative figures that have the right to enforce how a cave must be taken care of. Residents will be relied on to take personal responsibility for the status of the cave and reporting anything strange that they may notice.
GOVERNMENTAL ISSUES

What governments are responsible for the issue? Whose laws apply? Are there conflicts between local and regional policies? You must understand the legal parameters that frame the problem in order to think of feasible solutions. This section is different from simply identifying the Government as a stakeholder. Obviously, if e.g. the DEC is responsible to uphold environmental policy in the state, then the DEC is a stakeholder in an issue. But in this section, you need to identify which branches of government are responsible (if any), what specific pieces of legislation apply, etc.

It would not be just to deem any particular U.S state’s government overtly responsible for allowing White Nose Syndrome to spread, as the origins of the disease are from Europe. Despite originally appearing in New York State, there have been recent efforts to develop a national plan rather than to have state-by-state laws and regulations to control the spread of this deadly fungal disease.

According to the U.S Fish and Wildlife Service’s National Plan for Assisting States, Federal Agencies, and Tribes in Managing White-Nose Syndrome in Bats, there are advantages in management for establishing a national plan. This plan would assist state, federal agencies, and tribes in managing the control of WNS. Due to the mobility of bats, the rapid spread of WNS, the potential for human-assisted transmission, and the severity of the consequences make it imperative that a national effort on multiple scales s enacted (U.S Fish and Wildlife Service). A national plan will benefit the control of White Nose Syndrome in bats by centralizing all the management of the disease.

There have been historical relations between state and federal governments in addressing the control of WNS. In June 2008, the Department of the Interior the Department of Agriculture,
the Department of Defense, and State wildlife agencies agreed that a systematic approach is best in addressing the situation (U.S Fish and Wildlife Service). In doing so, the collaborative effort was met through the formation of a national plan steering committee that served to ensure that both federal and State agencies” coordinate and cooperate in the development and implementation of an effective national response to the disease” (U.S Fish and Wildlife Service).

Before the National plan, State, Federal, and Tribal wildlife, and management agencies had statutory and regulatory authorities for managing trust wildlife species and their habitats. Through being a part of these authorities, these agencies had to comply with all the applicable laws. This could be seen through how the Federal agencies were required to comply with laws such as the National Environmental Policy Act, the Endangered Species Act, and the Federal Cave Resources Protection Act (U.S Fish and Wildlife Service).

The laws and regulations being applied are administered through the steering committee of the National plan. According to The U.S Fish and Wild Service; this national plan has seven practical elements of implementation, these being:

A. **Communications**- Responsible for the successful development and implementation of a plan for communicating information about WNS to associates and partners involved in the disease’s investigation, as well as affected landowners, stakeholders, and the general public

B. **Data and Technical Information**- Responsible for the timely release and distribution of WNS information to all State, Tribal, Federal agencies, and any other constituents involved in the investigation and management of the disease.

C. **Diagnostics**- Responsible for instituting the laboratory standards used to conduct and interpret WNS testing. This includes identifying the capacity of laboratories to
process WNS syndrome disease samples, and project capacity to support further WNS management programs. This ensures that results from different laboratories are standardized and therefore accurate and comparable between laboratories.

D. **Disease Management** - Responsible for identifying any alternative, and best solution practices to eradicate and prevent or inhibit the spread of WNS into new areas. This will function by maintaining the genetic and regional diversity so that WNS syndrome affected areas may return back to conditions pre-WNS. This will allow the future bat populations to recover while avoiding risks to other cave dwelling species and natural systems. Collaboration with public health officials will be enacted to investigate the possibility of human health threats associated with WNS, and what course of action is most plausible should WNS poses a threat to human epidemiology.

E. **Epidemiological and Ecological Research** - Responsible for priority identification of ongoing research related to the origin, transmission, pathogenesis, and impact of WNS of bats and the environment. Specific research to inform management will function to understand the synergy between research and management in order to ensure to optimal results.

F. **Disease Surveillance** - Responsible for developing logistical standards for WNS surveillance in both affected and non-affected areas in an effort to describe best practices and techniques for surveillance strategies. These standards include early detection surveillance of WNS to determine its expansion, newly established epicenters, and the progression of the disease within an affected hibernating colony.

G. **Conservation and Recovery** - Responsible for developing the standards for determining the need, and subsequent monitoring of WNS affected bat species.
populations. Also this element of the plan will create the criteria that prioritize conservation and management of bat populations that of greatest conservation concern. Collecting baseline data for areas unaffected by WNS, and statewide accounting of caves and mines will also be a focus.

It is also believed that in order to control WNS control should be controlled internationally as humans are partly responsible for its spread. Humans acting as disease vectors, across international borders in the spread of WNS.

Map showing up to date spread of White Nose Syndrome in the contiguous U.S States and Canada.
DEVELOPMENT OF SOLUTIONS TO THE PROBLEM

Parameterizing Solutions

White nose syndrome continues to threaten bat populations at an alarming rate. In order to protect the future of hibernating bat species, some solution must be put in place. Each solution must meet certain requirements in order to be considered; in particular they must protect hibernating bat species from further decline as well as prevent the further spread of the fungus, *G. destructans*.

Identification and evaluation of potential solutions.

A number of potential solutions have been suggested as ways to both protect the status of bats as well as prevent the spread of WNS. Listed below are those potential solutions.

**Culling infected bat colonies and/or individuals**

Culling, the process of removing or killing animals that possess undesirable characteristics, serves as one potential solution. Under this solution all bat colonies or individual bats that exhibit unusual behavior attributed with WNS or that are present in areas that have detected WNS will be culled in order to contain the spread of this deadly fungus (Hallam *et al.* 2010). However this solution is not very practical as it will be next to impossible to catch each individual bat that is infected or carries traces of WNS. Also, even if all infected bats were culled, there will still be a viable reservoir of the fungus present in the environment; the fungus *G. destructans* grows in temperatures above 20 degrees Celsius and its spores are able to survive in temperature up to 49 degrees Celsius (Hallam *et al.* 2010). Furthermore according to Andrew Miller, mycologist at the Illinois Natural History Survey, the fungus “can live perfectly happily
off the remains of most organisms that co-inhabit the caves with the bats...this means that whether the bats are there or not, it’s going to be in the caves for a very long time” (McLendon 2013). This means that the culling of infected bats and bat colonies would only be a temporary fix, not a permanent solution (Hallam et al. 2010).

**Building Artificial Caves**

Building artificial caves serves as another potential solution. One major advantage that comes with the construction of artificial caves is that unlike natural caves they can be decontaminated and sterilized once bats finish hibernating. The Nature Conservancy has recently constructed an artificial cave that contains the ideal temperature, airflow, and wall texture necessary for bat hibernation. Once bats finish their hibernation season the cave will be sterilized from top to bottom. However this ideal cave comes at a price as the construction of this one cave has cost around $300,000 of privately donated funds (Gorman 2012).

**Converting Bunkers into Artificial Caves**

Another possible solution is to convert old war bunkers into artificial caves. For example a bunker in the Aroostook National Wildlife Refuge in Maine has recently been converted into an “artificial bat cave.” With the potential to house thousands of bats, an average humidity of 95%, and an average temperature of 37 degrees Fahrenheit this bunker serves as a prime location for bat hibernation (Platt 2013). Scientists stocked the bunker with 30 Little Brown Bats, all of which contained traces of WNS. Of these 30 bats, only 9 survived the hibernation. Once the surviving bats left the bunker scientists dedicated the entire summer and fall completely sterilizing and cleaning it. And when it comes time for the next hibernation season audio
recordings of swarming bats will be played in order to attract more bats and other cave dwelling animals to this fungus free environment (Platt 2013).

**Bat Boxes/Houses**

Another solution is to establish more bat boxes throughout the state of New York. These boxes serve as safe, secure, and alternative environments for bats to roost, breed, and hibernate in. And because bat boxes are easy to clean and sterilize the risk of any fungus growing within them is significantly reduced. Although these boxes serve as safe environments for a number of bat species, it is important to acknowledge that not all hibernating species utilize these boxes.

![Example of a bat box.](image)

**Disinfection of caves and/or bats**

The disinfection of both natural caves and bats serves as another possible solution to the eradication of WNS. However this solution is unpractical. Disinfecting an entire cave is expensive, time consuming, and risky. A number of chemicals are needed in order to sterilize caves however this could significantly disrupt the cave environment. Other species would be put
at risk not only from these potentially harmful chemicals, but also due to the increased and prolonged amount of human contact. Disinfecting entire bat colonies as well as attempting to disinfect each bat individually is very impractical as well (Kerwin et al. 2012).

**DEC National White-Nose Syndrome Decontamination Protocol**

Another potential solution is to prevent the further spread of WNS throughout North America through the enforcement of the Decontamination Protocol. Humans on a daily basis utilize caves all over the country for recreational purposes. As a result over the years humans have unintentionally helped spread the range of WNS by bringing infected and contaminated clothing, footwear, and equipment whenever they visit a cave. Therefore this decontamination protocol serves as a guideline of how items should be sterilized, cleaned, or even disposed before and after visiting caves. Procedures include submersing items in hot water for an extended period of time, bagging clothes, gear, etc after immediately exiting caves, as well as when to dispose of their clothing or gear (Revised Decontamination Protocol 2012).

**Closing caves (and mines) in order to restrict public access**

Humans are constantly utilizing a number of caves and mines for recreational purposes. However, since the invasion of WNS it has been speculated that humans may partly be to blame for the rapid geographical expansion of this fungus. Within the National Park System one in four caves and one in three mines now carry the deadly fungus (National Park System). Therefore another potential solution is to close public access to caves and mines in order to prevent the further spread of this fungus (Yu 2011).
**Buying caves**

Another potential solution is to buy caves and the land above them or to lease them from owners if they are located on private land. With this solution the regulation of caves will become much easier, especially those that contain traces of the fungus *G. destructans*. Infected caves can be closed to the public in order to prevent the spread of the fungus. Also all bought caves can be closed during hibernating season, which is when WNS is most lethal to bats. The future health of caves as well as their inhabitants will be much easier to preserve through this potential solution.

A number of organizations have begun to buy up caves in order to conserve them. For example, the Northeastern Cave Conservancy Inc (NCC) has been buying up caves for a number of years. Their mission is “committed to the conservation, study, management, and acquisition of caves” (NCC Our Mission). However this solution comes at a price.

**More bats listed as endangered species**

As of now only two bat species present in the Adirondacks are listed on the endangered species list: the Indiana bat and the Northern Long-Eared bat. As a result both these bat species will receive more protection and supervision. Also since WNS has been a significant cause behind their extreme population decreases more resources and funds will be dedicated to address WNS and other threats harming bat populations. However, as bat specialist Mollie Matteson pointed out “endangered species status…is not an automatic cure” (Adirondack Explore 2013). Gaining endangered species status does not happen casually therefore it may be awhile before additional bat species, if any, are given this status. Not only that but listing bats as endangered could potentially have significant implications for both business and private-property owners.
More severe restrictions would be set. For example homeowners would no longer be allowed to kill bats that invaded their home, even if the bat was suspected to have rabies (Yu 2011).

**More in depth research of fungus G. destructans**

Another potential solution is to better understand the fungus *G. destructans*. The US Forest Service is currently looking into the genetic makeup of this fungus and has even discovered its closest relative. According to Daniel Lindner, a researcher at USFS they “hope to use this information to interrupt the ability of this fungus to cause [WNS]” (McLendon 2013). Through the identification of its relatives combined with previous knowledge of the fungus researchers have determined this fungus to be invasive. In fact in its native region of Europe the fungus does not affect bats; “bat species in Europe may be immunologically or behaviorally resistant to *G. destructans* because of having coevolved with the fungus” (Wibbelt *et al.* 2010). This suggests that another potential solution is that North American bats have the potential to adapt and become resistant to the fungus as well (Forest Service 2013).

**Identification of feasible solutions**

Although a number of potential solutions have been proposed several of these are not practical nor will sufficiently address the current situation that is taking place. In order to prevent the spread of WNS as well as protect the population status of bats solutions that are not economically, socially, environmentally, or technically feasible must be eliminated. The following potential solutions are not feasible solutions:

- Culling infected bat colonies and/or individuals
- Building Artificial Caves
- Bat Boxes
- Disinfection of caves and/or bats
• Buying caves
• More bats listed as endangered species
• More in depth research of fungus G. destructans

The culling of infected bat colonies and/or individuals is infeasible because it does not directly target *G. destructans*. Even if all infected bats and colonies were killed the fungus would still remain within the interior of the cave. If traces of the fungus still remained within a cave that had been previously culled of bats as soon as a new group of bats began to hibernate, the fungus would once again target, spread, and eventually kill the bats.

The building of artificial caves is not feasible due to the significant amount of time, money, and maintenance needed to sustain them. As stated in the previous section one artificial cave will cost about $300,000 making this option way too expensive to carry out on a national scale.

Although bat boxes do provide a safe, alternative environment for bats this solution is not feasible. Not all hibernating bats utilize these boxes. Also bat boxes can only hold so many bats at one time whereas caves can house thousands of bats. As a result this solution will not make a big enough impact on improving bat population numbers. It cannot compete with the rapid

The disinfection of entire cave sites is infeasible as well. The disinfection process may be very detrimental to other species living within or around the cave environment and may inadvertently disrupt the natural balance of the cave. Not only that but it is nearly impossible to completely sterilize a natural cave therefore there is no guarantee that the fungus would be completely irradiated. Also many caves are found on private property. Therefore we do not have the authority to tell people that they must disinfect their caves after bats finish their hibernation period. The disinfection of bats, especially on an individual level, is also an infeasible solution due to its impracticality; this process is too costly as well as time and labor
extensive. Also since bats are small, quick, and have the ability to fly there is no guarantee that every single infected bat will be successfully disinfected.

The solution of buying up caves infeasible as well. This process does allow more regulations to be set as well as enables more research to be conducted on caves with or without WNS, however, it is too impractical as well as too costly to make it a feasible solution.

Although many bat species are declining at an alarming rate it the solution to have them all listed as endangered species is not feasible. First, the process to get any organism on this list does not happen over night. This process is very timely as there are a lot of estimations and views that must be taken in consideration. Furthermore not all people, especially homeowners, may not support having more bats listed as endangered species. More restrictions will be set into place therefore it will be much harder to remove invading bats from households, even if they may put the health of a family at risk. Also corporations, especially those who utilize wind turbines, may not support this decision, as they will have to make some expensive changes in order to meet new, stricter requirements.

It is extremely important to conduct more research on the fungus behind WNS. More research will enable us to have a better understanding of the fungus as well as potentially develop ways to combat this destructive disease. Having said that, this solution is not feasible as it is extremely difficult, time and labor extensive, as well as expensive to conduct research on this fungus.

The following are solutions that should be considered as feasible solutions.

- Converting Bunkers into Artificial Caves
- DEC National White-Nose Syndrome Decontamination Protocol
- Closing caves in order to restrict public access
One feasible solution is converting bunkers into artificial caves. There are a number of bunkers throughout the state of New York that can inexpensively be converted into artificial caves. The environment within these converted bunkers is very similar to a cave environment making it a desirable place for bats and other cave dwelling organisms to call home. And because these bunkers can be completely sterilized once bats end their hibernation period we are able to provide clean, fungus free environments for thousands of bats to utilize.

The DEC’s National White-Nose Syndrome Decontamination Protocol serves as another feasible solution. This protocol serves as a way to reduce the transmission of the fungus through the sterilization, and in some cases disposal, of any clothing, shoes, recreational gear, etc that may potentially contain traces of the fungus. Although the guidelines under this protocol are strict they are clear, concise, and easy to follow.

**Identification of best solutions**

Of the previously suggested options two have been identified as the best solutions: the enforcement of the DEC’s National White-Nose Syndrome Decontamination Protocol as well as closing caves in order to restrict public access.
EASE OF IMPLEMENTATION

Before implementing either of these solutions it is necessary to educate all stakeholders about White Nose Syndrome and how it is affecting hibernating bats throughout the state of New York. Also, why it is important to conserve our bats. Through educating the stakeholders we will have an easier time implementing solutions that will reduce the future spread of the fungus, which in turn protects future hibernating bat populations.

Closing off bat caves
DEC’s National White-Nose Syndrome Decontamination Protocol

The DEC’s National White-Nose Syndrome Decontamination Protocol, introduced in 2012, serves as a solution that will hopefully reduce the risk of the further spread and transmission of *G. destructans* throughout the United States.

The majority of the state of New York is already infected with WNS therefore it is our responsibility to take action and reduce the risk of transmission. Several options are laid out in the Decontamination Protocol, the first being submersing contaminated clothing, gear, etc in water that is at least 122 degrees Fahrenheit for 20 minutes. However not all items can be submersed in hot water. Therefore this protocol also lists other treatment options that may be used. Below is the table from the protocol that provides treatments for secondary and non-submersible items.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Clorox® (6% HOCl) Bleach</th>
<th>Lysol® IC Quaternary Disinfectant Cleaner</th>
<th>Professional Lysol® Antibacterial All-purpose Cleaner</th>
<th>Formula 409® Antibacterial All-purpose Cleaner</th>
<th>Lysol® Disinfecting Wipes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard, non-porous surfaces</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Non-porous personal protective safety equipment</td>
<td>No</td>
<td>Yes (headgear, goggles, rubber boots, etc.)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>All surfaces, including: porous clothing, fabric, cloth footwear, rubber boots</td>
<td>Yes (Do not use on ropes, harnesses or fabric safety gear.)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>DILUTION/TREATMENT (as per label)</td>
<td>Effective at 1:10 dilution (bleach : water)</td>
<td>Effective at 1:128 dilution (1 ounce : 1 gallon of water)</td>
<td>Effective at 1:128 dilution (1 ounce : 1 gallon of water)</td>
<td>Effective at concentrations specified by label</td>
<td>Effective at 0.28 % dimethyl benzyl ammonium chloride</td>
</tr>
</tbody>
</table>

Table 1. Secondary or non-submersible treatment options for a minimum of 10 minutes
The Decontamination Protocol also outlines rules to follow when visiting caves. It is always a good idea for one to know the status of the state, region, and cave prior to entering the site. By status we mean whether or not the state, region, and/or cave site has traces of the fungus or WNS. Another requirement is for all gear and clothing should be bagged up after so that it can remain quarantined until properly sterilized or disposed of; it is also recommended that one

Figure. Flowchart to determine whether or not gear should be used as well as how gear should be decontaminated.
use gear that can easily be decontaminated. Also make sure any vehicle used for transportation be sterilized as well.

As state before the primary mission behind this protocol is to prevent the spread of the fungus, particularly to places in the country that has yet to experience WNS, i.e. the Midwest. Therefore “under no circumstances should clothing, footwear, or equipment that was used in a confirmed or suspect WNS-affected state or region be used in a WNS-unaffected state or region.”

Closing caves to restrict public access
CONCLUSIONS

We can conclude three things regarding the current and future status of White Nose Syndrome in New York State.

**Information needs to continue to be gathered:**

To find a cure for the disease and hopefully replenish the bat populations.

**There are feasible solutions:**

That have the potential to stop spread the disease, however, these solutions need to be put into place as quickly as possible before WNS infects all of the remaining healthy bats.

**The stakeholders must:**

Continue to do their best to follow guidelines that are being put into place as well as instill and regulate any new guidelines that should be followed.
ACKNOWLEDGEMENTS

Thank Erika, all people we interviewed
LITERATURE CITED


Geomyces destructans. Institute of the Study of Invasive Species. 


Our Mission. Northeastern Cave Conservancy Online. 


White-Nose Syndrome (WNS) http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/


http://www.biologicaldiversity.org/campaigns/bat_crisis_white-nose_syndrome/Q_and_A.html
APPENDICES

Appendix A. Copy of survey instruments

1. Interview questions asked of stakeholders during phone interviews
   a. Asdfdsj
   b. Laksjdf
### Appendix B. Mortality from WNS from 26 sites of six hibernating bat species in New York

<table>
<thead>
<tr>
<th>Site Name (Year WNS confirmed)</th>
<th>Pre-/Post-WNS Count Year</th>
<th>Pre-WNS Count</th>
<th>Post-WNS Count</th>
<th>% Change</th>
<th>Pre-WNS Count (Year)</th>
<th>Post-WNS Count</th>
<th>% Change</th>
<th>Pre-WNS Count</th>
<th>Post-WNS Count</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New York</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baryte 'Garden of Dima' Mine (2007)</td>
<td>2006/2010</td>
<td>1</td>
<td>3</td>
<td>200%</td>
<td>6</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bartyes Cave (2009)</td>
<td>1986/2011</td>
<td>24</td>
<td>1</td>
<td>-96%</td>
<td>12</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bennett Hill Mine (2009)</td>
<td>2003/2011</td>
<td>17,399</td>
<td>1,669</td>
<td>-90%</td>
<td>26</td>
<td>11</td>
<td>-58%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarksville Cave (2008)</td>
<td>2006/2010</td>
<td>21</td>
<td>0</td>
<td>-100%</td>
<td>2</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eagle Cave (2009)</td>
<td>1985/2011</td>
<td>2,587</td>
<td>4,324</td>
<td>67%</td>
<td>7</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gage's Cave (2007)</td>
<td>1985/2011</td>
<td>940</td>
<td>40</td>
<td>-96%</td>
<td>1</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hailes Cave (2007)</td>
<td>2005/2011</td>
<td>15,574</td>
<td>1,496</td>
<td>-90%</td>
<td>685</td>
<td>0</td>
<td>-100%</td>
<td>14</td>
<td>4</td>
<td>-71%</td>
</tr>
<tr>
<td>Hasbrouck Mine (2009)</td>
<td>2006/2011</td>
<td>2,922</td>
<td>1,218</td>
<td>-58%</td>
<td>5</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Howe Cave (2006)</td>
<td>2005/2011</td>
<td>1,213</td>
<td>29</td>
<td>-98%</td>
<td>5</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Howes Quarry Mine (2008)</td>
<td>1995/2010</td>
<td>42</td>
<td>1</td>
<td>-98%</td>
<td>6</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knox Cave (2007)</td>
<td>2001/2011</td>
<td>1,820</td>
<td>354</td>
<td>-81%</td>
<td>5</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lawrenceville Mine (2009)</td>
<td>2004/2011</td>
<td>293</td>
<td>6</td>
<td>-98%</td>
<td>57</td>
<td>71</td>
<td>25%</td>
<td>25</td>
<td>0</td>
<td>-100%</td>
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<tr>
<td>Main Graphite Mine (2008)</td>
<td>2006/2010</td>
<td>83,500</td>
<td>2,499</td>
<td>-99%</td>
<td>109</td>
<td>0</td>
<td>-100%</td>
<td>440</td>
<td>0</td>
<td>-100%</td>
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<tr>
<td>Martin Mine (2008)</td>
<td>2004/2010</td>
<td>720</td>
<td>6</td>
<td>-99%</td>
<td>44</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Schoharie Cavern (2007)</td>
<td>1999/2010</td>
<td>953</td>
<td>22</td>
<td>-98%</td>
<td>18</td>
<td>0</td>
<td>-100%</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>South Bethlehem Cave (2008)</td>
<td>2005/2011</td>
<td>100</td>
<td>0</td>
<td>-100%</td>
<td>13,014 (2007)</td>
<td>122</td>
<td>-99%</td>
<td>1</td>
<td>1</td>
<td>0%</td>
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<tr>
<td>Walter Williams Preserve (2008)</td>
<td>1999/2010</td>
<td>87,400</td>
<td>16,673</td>
<td>-81%</td>
<td>30,000</td>
<td>7,200</td>
<td>-99%</td>
<td>3,000</td>
<td>718</td>
<td>71%</td>
</tr>
<tr>
<td>Williams Fire Pit Mine (2008)</td>
<td>2002/2011</td>
<td>0</td>
<td>323</td>
<td>32,300%</td>
<td>0</td>
<td>718</td>
<td>71,800%</td>
<td>3</td>
<td>0</td>
<td>-100%</td>
</tr>
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<td>Williams Lake Mine (2008)</td>
<td>2003/2011</td>
<td>531</td>
<td>33</td>
<td>-94%</td>
<td>0</td>
<td>18</td>
<td>1,800%</td>
<td>2</td>
<td>0</td>
<td>-100%</td>
</tr>
<tr>
<td>Williams Mine #7-8 (2008)</td>
<td>2002/2011</td>
<td>1</td>
<td>35</td>
<td>3,400%</td>
<td>0</td>
<td>18</td>
<td>1,800%</td>
<td>2</td>
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<td>-100%</td>
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<tr>
<td>Williams Mine #9-10 (2008)</td>
<td>2002/2011</td>
<td>1</td>
<td>35</td>
<td>3,400%</td>
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<td>18</td>
<td>1,800%</td>
<td>2</td>
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<td>-100%</td>
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<td>Williams Mine #11 (2008)</td>
<td>2007/2011</td>
<td>54</td>
<td>1</td>
<td>-98%</td>
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<td>0</td>
<td>-100%</td>
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<td></td>
<td></td>
</tr>
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<td><strong>New York Totals and % Difference</strong></td>
<td></td>
<td><strong>326,867</strong></td>
<td><strong>28,890</strong></td>
<td><strong>-91%</strong></td>
<td><strong>54,657</strong></td>
<td><strong>15,411</strong></td>
<td><strong>-72%</strong></td>
<td><strong>619</strong></td>
<td><strong>17</strong></td>
<td><strong>-97%</strong></td>
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<tr>
<td>Species</td>
<td>Pre-WNS Count</td>
<td>Post-WNS Count</td>
<td>% Change</td>
<td>Pre-WNS Count</td>
<td>Post-WNS Count</td>
<td>% Change</td>
<td>Pre-WNS Count</td>
<td>Post-WNS Count</td>
<td>% Change</td>
<td>Pre-WNS Grand Total</td>
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<td>---------------</td>
<td>----------------</td>
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<td>---------------</td>
<td>----------------</td>
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<tr>
<td>Mysis lehni</td>
<td>173</td>
<td>398</td>
<td>117%</td>
<td>97</td>
<td>60</td>
<td>-33%</td>
<td>115</td>
<td>154</td>
<td>-14%</td>
<td>17,668</td>
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<tr>
<td>Peringorgia subflavus</td>
<td>53</td>
<td>43</td>
<td>-19%</td>
<td>17</td>
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<td>100%</td>
<td>7</td>
<td>10</td>
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<td>Eptesicus fuscus</td>
<td>15</td>
<td>1</td>
<td>-95%</td>
<td>15</td>
<td>5</td>
<td>-100%</td>
<td>1</td>
<td>0</td>
<td>-100%</td>
<td>1,659</td>
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<td>88</td>
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<td>10</td>
<td>7</td>
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