There's a Fungus Among Us – WNS Transmission

EXPLORATION QUESTION

"What is White-Nose Syndrome, how is it spread, and why is it important?"

MATERIALS

- Copies of Student Investigation Worksheet, Instruction Sheet, and Graph
- Black light/ultraviolet light source
- Powder laundry detergent with whitening agent (e.g. Ultra Tide with Acti-Lift crystals)
- Confectioner's Sugar
- Blue food coloring
- Paper towels
- Water

OVERVIEW

Students will investigate how infectious diseases are spread, focusing on the disease White-Nose Syndrome (WNS), and the scientific methods used to investigate diseases. Students will simulate the interactions of bats in a cave when bats are in close proximity and may spread WNS fungal spores. By coming into physical contact with other "bats," students will have the chance to test to see if they have been infected with WNS and observe how quickly the disease can spread. Students will also interpret graphs to learn about doubling effects, exponential equations, and population growth curves.

VOCABULARY

Endangered, extinct, hibernation, infectious disease, maternity colony, microbes, threatened, torpor

GROUP SIZE

15 or more

AGE

13 and above

Background

Infectious diseases are caused by microbes - organisms too small to be visible to the naked eye. The most common infectious disease-causing microbes are bacteria, viruses, fungi, and protozoa. Fungi are important causes of disease in wild birds and other species. Infections may occur when birds, bats, or other species have suppressed immune systems, when their mechanisms for inflammatory response are inhibited, or when they experience physical, nutritional, or other stress for prolonged periods of time. Add in high rates of contact between animals and you have the perfect conditions for the spread of infectious disease.

White-Nose Syndrome (WNS) is an emerging wildlife disease that is causing unprecedented declines in hibernating North American bats. More than half of the bats that live in the United States hibernate in caves and mines to survive the winter. Four of these bats are federally endangered (Indiana, gray, Virginia and Ozark big-eared bats) and live within WNS-affected areas.

First detected in New York in the winter of 2006-2007, WNS has spread south through the Appalachian Mountains and into the Southeast, north through New England and into eastern Canada, and west into the Great Lakes region and the Midwest. There is great concern that WNS will continue to spread across North America. In the northeastern United States and Canada, WNS has killed more than six million bats and has caused population declines greater than 90% in some populations.

The effects of WNS on North American bat populations has led the U.S. Fish & Wildlife Service to consider listing several of the most affected species for either threatened or endangered species status under the Endangered Species Act. Endangered species are those animals and plants that are in danger of becoming extinct throughout all or a significant portion of their range. Threatened species are those that are likely to become an endangered species within the foreseeable future throughout all or a significant portion of their range.

Infectious Disease Transmission – The Epidemiologic Triangle

The Epidemiologic Triangle is a model that scientists have developed for studying health problems. It can help your students understand infectious diseases and how they spread. In general, for infectious disease to occur, three basic components are required: an agent or microbe that causes the disease (the "what" of the Triangle), a susceptible host (the "who" of the Triangle), and a suitable environment that enables both the agent and the host to come into contact and allow for disease transmission (the "where" of the Triangle). These three components make up the corners of The Triangle (called vertices). In the case of WNS, the causative agent is the cold-adapted fungus, *Pseudogymnoascus destructans*; the host are hibernating bat species; and the environment consists of caves and mines in North America.

Hosts

Forty-four insectivorous species of bats exist in the United States, 25 of which hibernate in caves or mines during the winter. As of 2014, seven cave species have been confirmed to have WNS including the big brown, eastern small-footed, gray, Indiana, little brown, northern long-eared, and tri-colored (previously known as the eastern pipistrelle) bats. The gray bat and the Indiana bat were already federally endangered species prior to the emergence of WNS, and the northern long-eared bat is now proposed for listing due to severe population declines caused by WNS.

Bats are all relatively long-lived in the wild, typically around 10 years, with some cases of individuals living longer. Records exist for six bat species living longer than 30 years and for 22 species living more than 20 years in the wild. The oldest record is a male *Myotis brandii* living 41 years. Mating occurs in the fall and females typically give birth to one pup per year in the spring at maternity colonies. Maternity colonies are where female bats congregate to give birth and raise young during the summer. These areas normally are found in dead (and sometimes live) trees with exfoliating bark, tree cavities, caves, or in mines, but they may also be found in buildings. Because of the low reproductive capability of bats (most have one or two pups once a year) it is difficult for the population to recover from the mass die-offs caused by WNS.

The seven bat species affected by WNS survive winter--when their insect prey is unavailable-- by hibernating in the cold environments of caves or mines. During hibernation, there is very little food for bats to eat, so survival depends upon the regulated use of the fat deposits that were built up during the fall. Hibernating bats save energy by spending most of the time in a state of torpor. In torpor, bats allow their body temperature to decrease to the surrounding environment and they reduce their metabolic rate to about 2% of their normal resting rates. Other physiologic processes including respiration, cardiovascular output, and immune function are also greatly decreased to conserve energy. These are great conditions for invading microbes.

Throughout hibernation, bats will arouse or awake from torpor by raising their body temperature approximately every 10 – 14 days. These arousals are energetically expensive but are likely necessary to maintain hydration and essential body functions. Bats affected by WNS arouse more frequently during hibernation than unaffected bats. Bats quickly deplete their fat reserves and are unable to replenish them because insects are not available for food during the winter. Bats with WNS often exhibit unusual behavior, such as flying during the day in near-freezing weather.

The Disease Agent

White-Nose Syndrome is caused by a newly discovered, cold-loving fungus named *Pseudogymnoascus destructans* or *Pd*. The term “White-Nose Syndrome” comes from the visible white growth of this fungus on the muzzle and other parts of the bat during hibernation. The fungus grows most often on the hairless portions of the body, such as the wings, ears, muzzle, and tail of hibernating bats. However, the fungus can also persist in the environment in the absence of bats and can grow in the cave or mine environment even when bats are not present.

Bats may be infected with the fungus for a period of time before they show visible signs of WNS. The fungus invades the surface of the skin, causing damage to the underlying connective tissue, blood vessels, and muscles. In severe cases, holes and tears can occur in the wing membrane due to the extensive cellular damage. Bat wings comprise 85% of the body surface and are important for controlling body temperature, blood circulation, water balance, and gas exchange. Damage to the wing membrane not only inhibits flight, but more importantly disrupts crucial physiological functions during torpor. Disruption of these vital processes due to WNS leads to life-threatening dehydration, electrolyte imbalances, and acid-base disturbances.

The rapid spread and mass mortality associated with the disease suggests that WNS is a newly introduced disease to North America (i.e. a non-native invasive species). In addition, *Pd* has been found on hibernating bats and within hibernacula across Europe. These infections in bats have been associated with wing damage (characteristic for WNS), but there have been no reports of mass mortalities caused by WNS in Europe. These observations provide evidence that *Pd* may have been introduced into North America from Europe.

Environment

Many North American bats spend significant portions of their lives underground in caves or mines where microclimates remain relatively constant throughout the year. Bats use this stable environment to hibernate over the winter and for daily rest during the remainder of the year. Some bats even use this environment in the summer to raise their young. Unfortunately, the cold and stable microclimates in a cave also provide ideal conditions for the growth of *Pd*.

Bats are able to fight off infection during the summer when they are active, but their immune system is greatly reduced when they hibernate. This provides a long window for the growth of *Pd*. Additionally, *Pd* can persist in the underground environment without the presence of bats. This means that once a cave or mine is contaminated with *Pd*, it remains contaminated and can serve as a reservoir to uninfected bats that visit. As more sites become contaminated, more bats are infected.

Transmission

Transmission of *Pd* occurs both through direct contact between bats and contact between bats and contaminated environments. Hibernating bats can congregate at high densities in caves and mines to overwinter. During hibernation, bats often cluster together and touch one another. This allows for the direct transfer of fungal spores between bats. Fungal spores are also deposited on the walls and ceilings when infected bats touch these surfaces. Fungal spores persist on walls, ceiling, and in the ground substrate. Uninfected bats touch these surfaces and spores are transferred indirectly. So, direct bat to bat contact is not necessary for spores to spread.

Movement of Pseudogymnoascus destructans

A number of hypotheses exist to describe the movement of *Pd* across the landscape. Bats infected with *Pd* that emerge early from hibernacula may move to new sites and spread the fungus. Transmission between bats during the fall when bats are mating before they enter hibernacula is also likely. Infected bats that survive the winter may spread the fungus as they migrate to summer roosting sites that are occupied with bats from other locations. It is also possible that humans and other animals moving between caves may carry fungal spores from one place to the next. Future research will offer more concrete evidence on how WNS is moved across the landscape.

White-Nose Syndrome Detection

Clinical signs of WNS infection in bats include the white fuzzy fungal growth on hairless skin and varying degrees of wing membrane damage. However, not all infected bats display clinical signs and other means are required to effectively diagnose infection. Ultra-violet (UV) light causes WNS fungi that are invading skin cells to fluoresce (glow) and it can be used as a preliminary WNS screening tool. Unfortunately, fungal spores present on the bat which have not begun invasion of the skin and fungal spores in the environment (i.e. hibernacula walls, ceilings, and substrate), do not fluoresce. Microscopic examination of the skin and genetic testing for *Pd* DeoxyriboNucleic Acid (DNA) from bats or environmental samples are required for definitive detection of WNS. In this activity, the teacher will simulate looking for fungal spores on “infected” students.

Treatment

Currently, effective means of WNS treatment do not exist. Management efforts have focused on slowing transmission and improving bat survival. Research on effective anti-fungal agents is ongoing but it is important to remember that hibernacula are very sensitive ecosystems. Applying chemical treatment to bats or the environment may have unforeseen and unintended consequences. For example, microbes and fungi are the foundation of cave food webs and could be wiped out with chemical treatments. Furthermore, the logistics of medicinally treating wildlife populations is often unpractical.

<u>Get Ready – Background Activity</u>

1. Assess your students’ knowledge of infectious disease by asking questions such as:
How do people get sick?
What are some symptoms?
What are some ways to keep from getting sick?
Do wildlife species get sick?
What symptoms do they have?

2. Clarify the difference between infectious disease and non-infectious disease, such as those caused by nutritional deficiencies or other environmental factors or genetic abnormalities.

3. Ask students what kinds of things cause infectious disease. Discuss some of the ones that students have heard of or that have been in the news.

4. Hand out the Student Investigation Worksheet, “The Epidemiologic Triangle.” This background activity can be done in class or may also be given as a homework assignment. Tell your students they are now going to learn about how epidemiologists or “disease detectives” study an infectious disease. They use a method called *The Epidemiologic Triangle*.

5. Ask a student to read the definition of “agent” written on the Student Investigation Worksheet. This is the “What” of *The Epidemiologic Triangle*. Ask the class if they know the agent for any of the diseases that they discussed earlier. Most of them will not. Tell them that the information is available to doctors and scientists and they will be doing some research to determine the “agent” that causes White-Nose Syndrome, a disease that has killed over six million bats in just six years.

6. Ask another student to read the definition of “host.” This is the “Who” of *The Epidemiologic Triangle*. Under this section, students will also describe the symptoms of the disease that a “host” may experience. These may be clinical signs or other symptoms.

7. Ask a student to read the definition of “environment.” This is the “Where” of *The Epidemiologic Triangle*.

8. Tell the students they are going to become epidemiologists, looking at a devastating disease that is killing bats in the United States and Canada as they hibernate. Students will research and describe the agent, the host (including symptoms of the disease), and the environment by using the following resources: “Battle for Bats: Surviving White-Nose Syndrome” film (available at http://vimeo.com/76705033) and brochure (available at https://www.whitenosesyndrome.org/resource/battle-bats-brochure-july-2013-pdf).

9. When students have completed the activity, review their answers in class. Be sure to clearly point out to the students that any disease can be understood by looking at the agent, host, and the environment.

Get Set - Set Up Stations

1. If needed, consult your school’s safety standards for using black light sources in the classroom.

2. You will need a good quality black light/ultraviolet light source. Make sure that it is working before preparing the activity. This activity is structured so that the teacher keeps the light source and supervises its use with each student. Checking one student’s hand to see if it is “infected” (fluoresces) can be done with just one light source. You will also be able to give a quick “no” or “yes” to students who are not sure if they are “infected.”

3. Many laundry detergents have blue specks. You will need to prepare two mixtures including “WNS infected” and “uninfected” and make sure that the two mixtures look similar. This is done by creating a mixture that is laundry detergent and sugar combined at a one to one ratio (WNS infected) and a second mixture that is sugar and sugar dyed with blue food coloring also at a one to one ratio (uninfected).

4. To keep the “infected” student’s identity a secret, you will need to plan ahead. You can have students close their eyes when they place their hands in the powder. You can switch bowls (without students seeing the switch) to “infect” just one student. You could also designate a trustworthy student to be the “infected” student and work out a way for them to secretly place their hand in the laundry detergent powder. Or, you can have the mixtures in a box. Students will reach their hand into hole at the top of the box without seeing which mixture is being used. You can switch the bowls without the students knowing.

Go! – Transmission Activity

1. Before you begin the activity, ask one student to place one moistened hand in the sugar mixture and one moistened hand in the laundry detergent/sugar mixture. Show the entire class what an infected vs.

non-infected hand looks like under black light.

2. Give each student a copy of the Student Instruction Sheet. Have the students write down their name at the top of the sheet and then work through the directions.

3. After students complete their graphs, review the data as a whole class.

4. Discuss doubling effects, exponential functions, and population growth curves.

5. Discuss the ecosystem implications of 95% bat mortality after WNS infection.

Go Even Further – Additional Activities

Here is an additional activity that you can do with your students. This activity will build on how WNS is spread. Bats also transmit fungal spores by landing/roosting in their environment (e.g. on cave walls and ceilings) and leaving spores. Other bats then land/roost on the same place and pick up the spores.

To simulate this environment-to-bat (indirect) transmission, repeat the main activity, but have students touch designated roost areas (desk tops or other appropriate surfaces in the classroom). Students (bats) become infected when they touch a surface that has been infected by a student (bat) that was carrying spores.

Reflect – Evaluation

1. Accurately fill out "The Epidemiologic Triangle."

2. Student worksheet complete; Correct and thoughtful answers to all questions.

3. Graph complete; Data points match worksheet numbers.

Extension – Descriptive Writing
Invite students to use descriptive writing to describe the spread of WNS throughout their state. Encourage them to think about blogs, magazine articles, journals, stories, and even email. Prompt them to talk about why good descriptions make writing better and more interesting. Explain to students that they will be writing their own piece of descriptive text. Depending on the amount of time available, you may want to assign a specific kind of descriptive writing like a journal or letter, or you may allow students to pick their own format. Remind them that capturing this event will involve focusing on details and using all five senses. Here are some questions they might ask themselves: What does the disease look like? What might I hear or see in a cave that has been infected by WNS? What can I smell inside the cave? How does losing these bats make me feel? How does their loss affect me, my community, and my state? Encourage the students to use a thesaurus to find new and specific words. For example, instead of the word cave, a thesaurus may suggest different ideas such as cavern, grotto, fissure, cavity, etc.

Further Reading and Resources – Discover More

About White-Nose Syndrome:

Battle for Bats: Surviving White-Nose Syndrome - http://vimeo.com/76705033

National White-Nose Syndrome (WNS) Website – http://whitenosesyndrome.org/

National Wildlife Health Center - http://www.nwhc.usgs.gov/disease_information/white-nose_syndrome/

Overview of Current Knowledge for Land Managers - http://www.treesearch.fs.fed.us/pubs/45305

Screening for WNS using UV light - http://www.jwildlifedis.org/doi/abs/10.7589/2014-03-058

About Infectious Diseases

BAM! Teacher's Corner from the Center for Disease Control and Prevention - http://www.cdc.gov/bam/teachers/

Disease Detectives - http://www.diseasedetectives.org/

Teacher Answer Page

There's a Fungus among Us - WNS Disease Transmission

Background Activity

What is an infectious disease?
Infectious diseases are disorders that are caused by organisms — such as bacteria, viruses, fungi or parasites – that are transmitted from animal to animal by direct or indirect contact. Malaria, measles, and chickenpox are examples of infectious diseases in humans. White-Nose Syndrome, avian influenza, chronic-wasting disease, and rabies are examples of infectious diseases that affect wildlife.

Non-infectious diseases (often known as non-communicable diseases) are those that are caused by factors such as genetics, environment, and lifestyle. They are not caused by disease-causing organisms and do not pass from one animal to another.

The Epidemiological Triangle and WNS - The **Agent** of WNS is a cold adapted fungus, *Pseudogymnoascus destructans* also referred to as *Pd*.

The **Host** of WNS is hibernating bats found in North America. **Symptoms** include:

- fungal growth on the muzzle, wings, ears, and tail of hibernating bats;
- invasion of the surface of the skin by the fungus causing damage to the underlying connective tissue, blood vessels and muscles;
- wing damage including holes and tears; and
- abnormal behaviors such as flying outside during the day in near-freezing temperatures or clustering in a cave entrance during winter.

The **Environment** of WNS consists of caves and mines in North America.

Interaction questions

How many bats were infected?

1 interaction	2 infections
2 interactions	4 infections
3 interactions*	8 infections*
4 interactions*	16 infections*
5 interactions*	32 infections*

* Your class infection numbers might be slightly less than these idealized numbers, even as early as the <u>three</u> interactions round. If an infected bat (student) interacts with an already infected bat (student), no new "infections" will happen.

10. Think about your answer to "after 5 interactions." How many students are in your class? What happens to your graph when you run out of bats (students) to infect?
When there are no new bats (students) to infect, the graph line will fall back to zero. Some students might also note that the curve will begin to flatten out as the number of healthy individuals that are available to be infected decreases.

Whole group discussion

1. Our class data roughly illustrates the doubling effect. What function equation could you use to draw this effect? (Hint: It's a very simple exponential equation.)

$y = 2^n$ - an exponential equation where y equals 2 to the nth power

To broaden the discussion, educators could introduce the topic of "super-spreaders." In wild populations, not all infected individuals in a population have equal chances of transmitting infection to others. In what has become known as the 20/80 rule, a small percentage of individuals in a population have often been observed to control most transmission events. These "super-spreaders" exhibit a higher ability to infect others. The 20/80 rule is a concept documented by observational and modeling studies that has profound implications for infection control, 20% of the individuals within any given population are thought to contribute at least 80% to the transmission potential of a pathogen. Many host-pathogen interactions have been found to follow this empirical rule.

2**. What will happen in an ecosystem if 95% of the bats die from White-Nose Syndrome?** Bat biologists are currently working on the answer to this question. Like most areas of environmental science and biological research, there is no simple answer. Students should recognize that the near-elimination of bats from an ecosystem could have dramatic effects on population dynamics of bat prey (e.g., insects) and on bat predators (e.g. snakes and many mammals).

You could also introduce the idea that bats are considered a keystone species in many cave systems. The droppings of cave-roosting bats (called guano) provide vital nutrients for cave ecosystems and are often the basis of a cave's food chain. This guano is used by microorganisms and invertebrates, which become food for fish, salamanders, frogs, and other larger animals.

Because of the low reproductive capability of bats (most have one or two pups each year) it is difficult for the population to recover from the mass die-offs caused by WNS. Many bat species do not reproduce until they are two years or older.

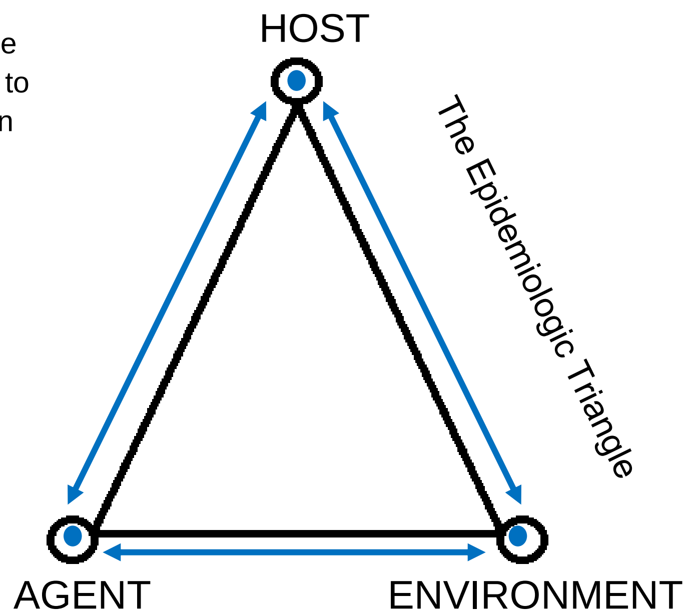
To take it further, bats also play a significant role in science and medicine. Research conducted on bats has led to advancements in sonar, vaccine development, blood anti-coagulation, and more. For example, scientists used enzymes taken from vampire bat saliva to develop a blood-clot dissolving drug called Draculin. Draculin is now used for the treatment of strokes and heart attacks! What other discoveries might we make as we continue to learn about bats?

Student Investigation Worksheet

The Epidemiologic Triangle **Student's Name:**___________________________

You will learn a scientific method of problem-solving used by epidemiologists or "disease detectives" to study an infectious disease. This method can be applied to diseases of humans and wildlife. Like investigators at the scene of a crime, disease detectives look for clues and gather information about what happened. They ask questions like: Who or what is sick? What are their symptoms? When did they get sick? Where could they have been exposed to the illness?

The Epidemiologic Triangle is a model that scientists have developed for studying health problems and wildlife diseases, specifically to understand infectious diseases and how they spread. The Triangle has three corners which are called vertices.



Vertex 1. The Agent is the cause of the disease and usually is a microbe, an organism too small to be seen with the naked eye. Most people call an agent a "germ." The agent is the "What" of *The Epidemiologic Triangle*.

My research on the "agent" for White-Nose Syndrome shows that it is:

Vertex 2. The Host is an organism, usually a human or other animal, which has been exposed to and harbors a disease. The host can be the organism that gets sick or any animal carrier that may carry the disease and not get sick. The same microbes affect different hosts in many different ways. The host is the "Who" of *The Triangle*.

My research on the "host" for White-Nose Syndrome (including symptoms of the disease) shows:

Vertex 3. The Environment is the favorable surroundings and conditions outside the host that cause or allow the disease to be transmitted. For example, some diseases live best in dirty water while others can survive only in blood or living tissue. The environment is the "Where" of *The Epidemiologic Triangle*.

My research on the "environment" for White-Nose Syndrome shows:

Student Instruction Sheet

There's a Fungus among Us **Student's Name** ________________________________

You will simulate one way, physical contact, that bat biologists believe White-Nose Syndrome spores are spread by bats.

Round One - One Interaction
1. Wash your hands and rinse them thoroughly. Wipe one hand (your non-writing hand) on a wet paper towel.

2. Gently pat your hand in the container of powder. Your hand represents a bat and the powder represents WNS fungal spores. One of your classmates (maybe you?) has placed their hand in powder that is "infected" with WNS fungal spores.

3. Walk around the room and choose another bat (student) to interact with. During your interaction, you will firmly shake hands. DO NOT TOUCH YOUR POWDERED HAND ON ANYTHING ELSE IN THE ROOM!

4. Return to your seat.

5. Estimate how many bats (students) you think will be infected. ____________

6. To find out who is infected, wait until your teacher calls you to place your hand under the black light source. If you interacted with the original infected bat (student), you will see brightly glowing specks under the black light.

7. How many bats (people) were infected? __________

8. Wash your hands thoroughly again, especially if you were "infected."

Round Two – Two Interactions
1. Wash your hands and rinse them thoroughly. Wipe one hand (your non-writing hand) on a wet paper towel.

2. Gently pat your hand in the container of powder. Your hand represents a bat and the powder represents WNS fungal spores.

3. You will do another round of interactions with other bats. Once again, only one bat (student) will be "infected" at the beginning of this activity. This time, you will interact with <u>two</u> different bats (students). Walk around the room and choose another bat (student) to interact with. During your interaction, you will firmly shake hands. DO NOT TOUCH YOUR POWDERED HAND ON ANYTHING ELSE IN THE ROOM!

4. Find another bat (student) and repeat the handshake as described in step 3.

5. Return to your seat.

6. Estimate how many bats (students) you think will be infected after <u>two</u> interactions. ________

7. Test your hands again to find out how many bats (people) were actually infected.__________

There's a Fungus among Us (continued)

Round Three - Three Interactions

You will do one more round of interactions with other bats. Once again, only one bat (student) will be "infected" at the beginning of this activity. This time, you will interact with <u>three</u> different bats (students). You will complete steps 1-2 listed above.

3. You will complete three rounds of interactions with other bats (students). Once again, only one bat (student) will be "infected" at the beginning of this activity. Walk around the room and choose another bat (student) to interact with. During your interaction, you will firmly shake hands. DO NOT TOUCH YOUR POWDERED HAND ON ANYTHING ELSE IN THE ROOM! Repeat this step two more times.

4. Return to your seat.

5. Estimate how many bats (students) will be infected after <u>three</u> interactions. _________

6. Test your hands again to find out how many bats (people) were actually infected._________

7. Graph how the number of infected bats (students) increased with the number of interactions. To help you make the graph, think about the following questions:

Graph Q1. How many bats (students) were infected before you started the first round of interactions? ______

Graph Q2. How many bats (student) were infected after just one round of interactions? ______

Graph Q3. How many bats (student) were infected after two rounds of interactions? ______

Graph Q4. How many bats (student) were infected after three rounds of interactions? ______

More interactions

8. Use the graph to predict how many (bats) students would become infected after four interactions. ______

9. How about after 5 interactions? ______

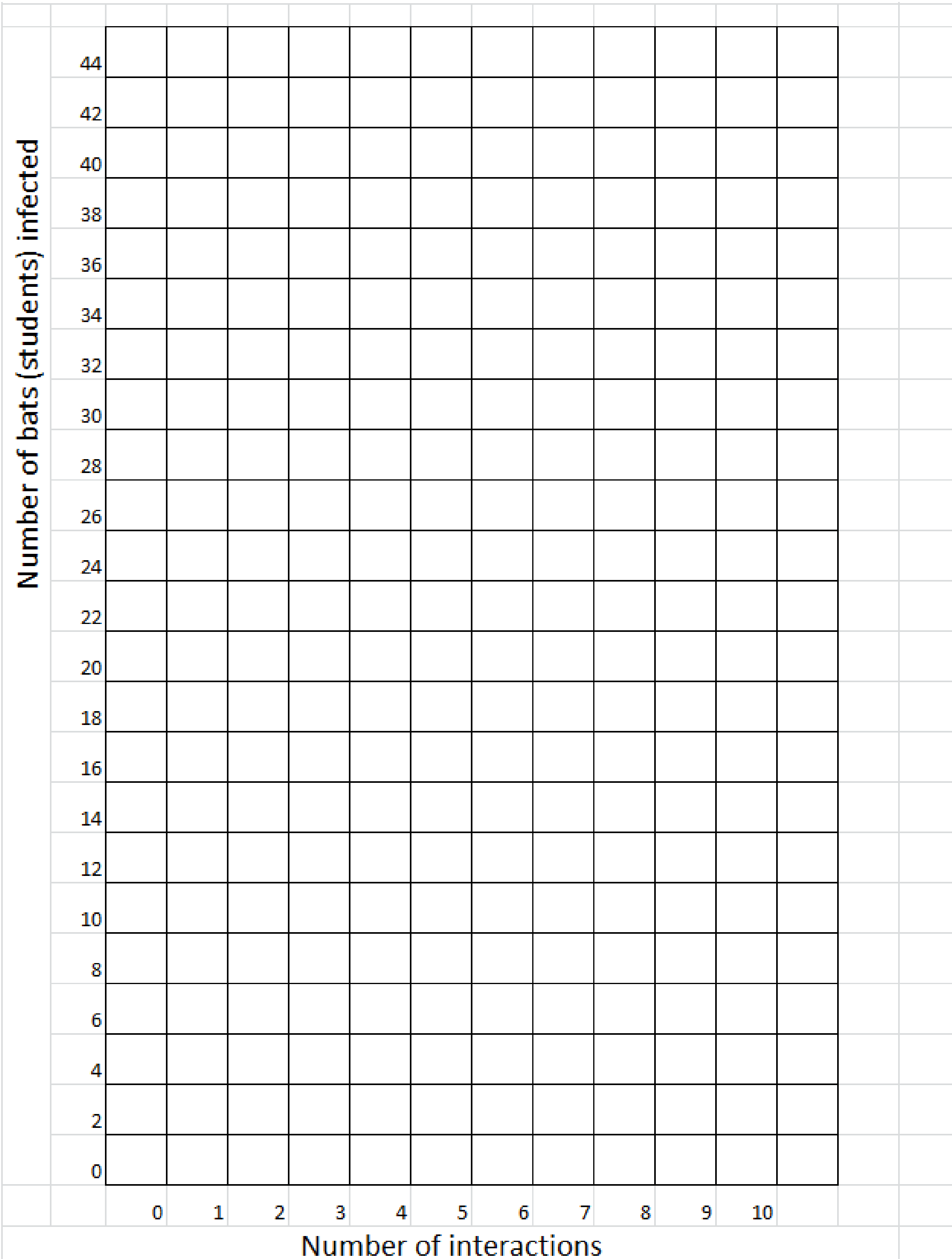
10. Think about your answer to "after 5 interactions." How many students are in your class? What happens to your graph when you run out of bats (students) to infect?

Whole group discussion

1. Our class data roughly illustrates the doubling effect. What function equation could you use to draw this effect? (Hint: It's a very simple exponential equation.)

2. What will happen in an ecosystem if 95% of the bats die from White-Nose Syndrome?

Student Graph - White-Nose Syndrome Transmission



Curriculum/Standards Connections

Common Core State Standards: Math: High School
CCSS.MATH.CONTENT.HSF.IF.C.7.E
Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

CCSS.MATH.CONTENT.HSF.IF.C.8.B
Use the properties of exponents to interpret expressions for exponential functions. For example, identify percent rate of change in functions such as $y = (1.02)^t$, $y = (0.97)^t$, $y = (1.01)12^t$, $y = (1.2)^t/10$, and classify them as representing exponential growth or decay.

Next Generation Science Standards

Middle School Life Science
MS-LS2-4. Ecosystems: Interactions, Energy, and Dynamics: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

High school Life Science
HS-LS2-6 Ecosystems: Interactions, Energy, and Dynamics: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.