ehp ENVIRONMENTAL HEALTH PERSPECTIVES

OPEN ACCESS

WHAT'S ALL THE BUZZ ABOUT? VECTOR-BORNE DISEASES AND CLIMATE CHANGE

What is a vector-borne disease? What does climate change have to do with spread of vector-borne disease? Students read the *EHP* article **Climate Change and Infectious Disease: Is the Future Here?** to learn about vectors and spread of infectious diseases. They perform an experiment to model transmission of vector-borne diseases and discuss how climate change may impact the spread of such diseases.

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Overview

Grade Level: **6–12**
(See addendum for additional challenge for high school students)

Subjects Addressed: General Science, Biology, Environmental Science, Health, Statistics

Class Time: **60 minutes**

EHP Reading:
Climate Change and Infectious Disease: Is the Future Here?
http://ehponline.org/article/info:doi/10.1289/ehp.119-a394

Dengue Reborn: Widespread Resurgence of a Resilient Vector
http://ehponline.org/article/info:doi/10.1289/ehp.116-a382

This lesson has been adapted from **Attack of the Killer Mosquitoes!** TAMU PEER lesson plan. Submitted by Nick Anthis, 2004
www.peer.tamu.edu/index.asp

OBJECTIVE

By the end of this lesson, students will **learn** how diseases are transmitted by vectors and model this process. Students will also **develop** hypotheses about how climate change may affect vectors, the pathogens they carry, and the diseases they spread.

MATERIALS (PER GROUP)

- PowerPoint presentation
- Excel file if you want to explain the model in more detail
- Vinegar
- Flour
- Baking soda
- 5-mL syringes (minus the needles)
- Optional: 10-mL syringes (minus the needles) for extension activity to demonstrate climate change scenario
- Paper cups
- Worksheet for each student

VOCABULARY WORDS

Vector-borne disease, zoonotic disease, disease host, disease reservoir, pathogen

Aligning with Standards

NATIONAL SCIENCE EDUCATION STANDARDS

Specific Content Standards

Unifying Concepts and Processes Standard
- Systems, order, and organization
- Evidence, models, and explanation
- Change, constancy, and measurement

Science As Inquiry Standards
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Life Science Standards
- Interdependence of organisms
- Behavior of organisms

Science in Personal and Social Perspectives Standard
- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

SKILLS USED OR DEVELOPED

- Critical thinking and response
- Manipulation
- Experimentation (conducting and data analysis)
- Observation
- Computation
- Communication (note taking, oral, written)

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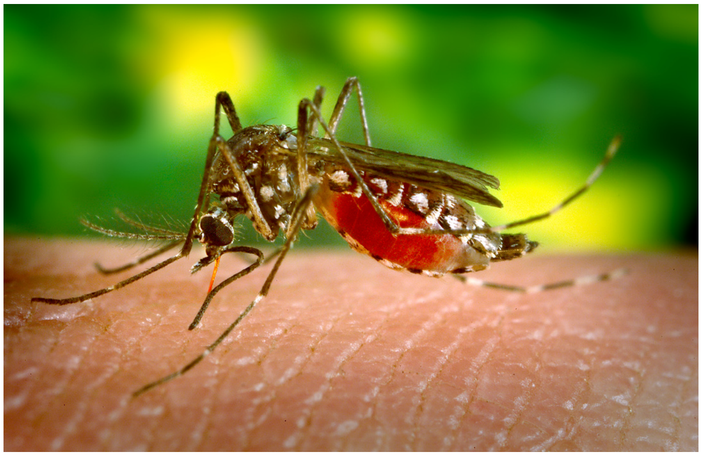
Background Information

Some of the world's most destructive diseases like malaria, dengue fever, West Nile virus, Rocky Mountain spotted fever and , Lyme disease are vector-borne. In a vector-borne disease, the disease-causing microbe is transmitted to humans by an animal intermediate as opposed to normal person-to-person transmission. Mosquitoes as well as rodents like mice, rats and rabbits and large mammals such as deer and the fleas and ticks found on the bodies of these animals are examples of common vectors that transmit these diseases. A zoonotic disease on the other hand is a disease that spreads from animals to humans, or vice versa. SARS, Ebola, swine flu, avian flu and *Salmonella* are some examples of zoonotic diseases. Sometimes the terms "vector-borne" and "zoonotic" are used interchangeably, given that both types of disease involve an animal host and an infectious agent (fungus, bacteria, virus).

Climate is one of many variables that affect the rates of vector-borne and zoonotic disease (VBZD) transmission. This is because climate influences the distribution of insect vectors and animal hosts and the life cycle of the disease-causing agents they carry. For example, as temperature increases, the malaria parasite reproduces at a higher rate, and infected mosquitoes take blood meals more frequently. Change in precipitation patterns can increase the occurrence of mosquito breeding grounds. Evidence suggests that the range of these diseases could change with a changing climate. Other variables not related to climate, such as land use change, trade and travel, and change in population dynamics will also play key roles in the emergence and distribution of these diseases. According to the World Health Organization (WHO) Scientific Working Group, dengue is the most rapidly spreading vector borne disease in the world. Effective prevention and control strategies will be needed to control the spread of such diseases.

Climate change is occurring as a result of an imbalance between the incoming and outgoing radiation in the atmosphere. When solar radiation enters the atmosphere, some of it is absorbed by the earth, and some of it is reflected back. Increases in greenhouse gases like carbon dioxide in the atmosphere prevent the solar radiation from escaping back into the atmosphere, and the retained heat is causing an increase in the earth's temperature. Additionally, deforestation is causing removal of plants that normally remove carbon dioxide from the atmosphere and act as carbon sinks. The InterGovernmental Panel on



NOTES AND HELPFUL HINTS

This activity explains vector-borne diseases, how they are transmitted and how climate change affects transmission. An interactive activity models mosquitoes infecting people with West Nile virus. Typically, a quarter of the students are "mosquitoes" with syringe barrels, and three-quarters of the students are "hosts" with cups filled with solution. See guidelines in Table 1 for different class sizes. Hosts are represented with cups containing a flour solution (uninfected) and a baking soda/flour solution (infected). Mosquitoes are represented using syringe barrels filled with "uninfected" or "infected" solution.

» Uninfected people and mosquitoes: solution with flour dissolved in water.
» Infected people and mosquitoes: solution of baking soda/ flour in water

A mosquito bite is simulated by expelling the contents of the syringe into a cup, mixing the solution in the cup, and re-filling the syringe with the solution from the same cup (this represents a mosquito biting a person, injecting the infectious agent into the bloodstream of the person, and then taking a blood meal from the same person before going and biting another person). To determine who has been infected with West Nile virus, a small amount of vinegar is added to the solution; bubbling of the solution upon addition of vinegar depicts an infection. The presentation includes graphs to demonstrate how this model works and how to quantify infected people. Students also learn how climate change will affect both the vector and the host populations, and then they complete the experiment incorporating these aspects into the model.

Climate Change (IPCC) forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century.

Increasing temperatures will alter humidity and the water cycle because warmer air can retain more water than cooler air. This means more extreme temperatures and weather, including both colder and warmer temperatures, than normal. Some geographic areas will see increase in rainfall, and some areas will experience more drought, which is why scientists have redefined the phenomenon as "climate change" rather than "global warming."

The general consensus among public health officials is that climate change and increased extreme weather events will move infectious diseases northward. Warmer winters and high-latitude warming are contributing to shifts and expansion of vector ranges. These events will likely lead to outbreaks of water-, mosquito- and rodent-borne diseases. Other factors are likely responsible for the spread of these diseases, and researchers need to better understand the science to determine the many factors that play a role in disease outbreak.

Prepping the Lesson

1. Download and review the PowerPoint presentation. The background is intended to be about 10-15 minutes long. Lecture notes integrated with these instructions, details of the experiment, and the worksheet are included in the PowerPoint presentation.
2. Make copies of student worksheet.
3. Assemble the materials needed for the activity.
4. Make solutions of water and flour (uninfected solution) and water, flour and baking soda (infected solution). See Table 1 to customize this lesson for different classroom sizes.
5. Add 1 cup of flour to 1 liter of water to make up a stock uninfected solution. Add 1/2 cup of flour and 1/2 cup of baking soda to 1 liter of water to make up a stock infected solution. Ensure that the flour and baking soda dissolve in the water and do not form clumps.
6. Each "host" receives a plastic cup with a number. Give each student approximately 2-3 ounces of either solution. Keep a cheat sheet that notes which cups contain the "infected" solution.
7. Each "mosquito" receives a 5-mL syringe barrel (without needle) that is numbered. Keep a cheat sheet that notes which barrels contain the "infected" solution.
8. For the purposes of this lesson, we assumed a class size of 20. Note: the written description is for the first demonstration. If you have sufficient time, you can do a second experiment demonstrating the effects of climate change on transmission of disease.
9. For a class size of 20 students:
   i. First demonstration for normal transmission of disease:
      1. 15 hosts, 0 infected
      2. 5 mosquitoes, 2 infected

   ii. Optional second demonstration to model effects of climate change:
      1. 15 hosts, 2 infected
      2. 5 mosquitoes, 4 infected

Implementing the Lesson

(Lesson plan is designed for 20 students; modify per your specific needs)

Step 1

Discuss the background slides explaining vectors, hosts and transmission of disease. West Nile virus is used as the example.

1. A zoonose is a disease that normally resides in an animal host but can cross over to humans. Well-known examples include SARS, *Salmonella*, and H1N1 (avian) flu.
2. Vector-borne diseases involve any disease-causing microorganism that is transmitted to people by an animal intermediate rather than by normal person-person transmission.
3. Mosquitoes, ticks, fleas, mice, and deer are all examples of vectors that can harbor vector-borne diseases.
4. Examples of vector-borne diseases include West Nile virus, malaria, dengue, Lyme disease, Hanta virus, yellow fever, Rocky Mountain spotted fever, and bubonic plague.
5. Vector-borne diseases have a transmission cycle that involves vectors and hosts (or reservoirs). In West Nile virus, the vector is a mosquito and the host is a bird. When the mosquito bites an infected host (in this case, birds that carry the virus) the mosquito gets infected with the virus. The host is usually not infected by the virus. West Nile virus is transmitted when the infected mosquito bites a secondary host (e.g., a human, pig, horse). The virus enters the bloodstream of the secondary host and spreads throughout the body, causing infection and disease.
6. How does transmission of West Nile virus differ from that of other vector-borne diseases? In malaria, the mosquito is the host carrying the parasite. When the infected mosquito bites a human, the parasite is injected into the human blood stream and causes infection.

Step 2

Explain to students how they are going to model mosquitoes. For the abbreviated version of the lesson plan, this will involve going through the experiment once. (Time permitting, you can repeat the experiment to model a climate change scenario.)

1. Ask for 5 volunteers to come up to the front of the class. These students represent mosquitoes.

2. Have 5 syringes, two filled with infected solution and 3 filled with uninfected solution. Give 1syringe barrel each to the 5 students.

3. Distribute 15 cups to the rest of the students, all filled with uninfected solution. Each cup of water represents a host (human).

4. Mosquitoes will simulate "biting" hosts by squirting out all the liquid into the cup.

5. Mosquitoes will simulate feeding by mixing the contents in the cup and filling the syringe with solution from the same cup (host).

6. The mosquitoes will bite a total of 3 people each. Note that a "host" can be bitten more than once. The goal is to mimic random bites as occurs in the real world.

7. After all the mosquitoes have bitten 3 people each, have the 5 mosquitoes stand at the front of the class. At this time, they should still have solutions in their syringes.

8. Why did the mosquitoes squirt out the contents of the syringe barrel, then suck it back up?

   This process mimics how a mosquito takes a blood meal. First it injects the contents of its salivary glands and then it sucks up blood from the host.

9. How many people do you think are infected?

   The answer should be around 1/3, although it may vary quite a bit.

10. To test the number of students who are infected, pour a small amount of vinegar in each cup and swirl the solution.

    Bubbling of the solution represents an infected individual. This reaction is the same as in homemade volcanoes where the acetic acid in vinegar reacts with baking soda to release carbon dioxide, the gas in the bubbles. (You can either have students pour the vinegar into their own cups or you can pour it into their cups. Adding too much vinegar will make the solutions bubble over and make a mess. A few milliliters of vinegar should be sufficient to observe the bubbling reaction.)

    If you are interested in reviewing the chemistry, baking soda reacts with vinegar to produce carbonic acid. Carbonic acid is unstable in water and breaks down to water and CO_2, the gas responsible for the bubbling along the surface of the water. The chemistry equation is as follows:

    $NaHCO_3 + CH_3COOH \text{->} CO_2 + H_2O + CH_3COONa$

11. Why didn't we test the mosquitoes before they bit people?

    Because in nature we cannot tell which mosquitoes carry a disease-causing microbe unless we kill it. Mosquitoes do not have any visible markers of infection.

11. Ask the students how many mosquitoes they think are infected.

    Because of dilution, usually 1/4 of the mosquitoes will be infected, although this may vary.

    At this point, you can test the syringes to determine how many mosquitoes are infected. To do this, have each mosquito squirt the contents of their syringe into a cup. Add a small amount of vinegar and determine how many mosquitoes are infected.

Optional Step 3

Modeling a climate change scenario where more people in the population are infected, mosquitoes have a higher parasite burden and bite more frequently.

1. If you are repeating the experiment to model the effects of climate change, pour out the contents of all of the cups and syringes. It is not important to rinse the cups or syringes.

2. Repeat the experiment with 4 cups filled with infected solution and 11 cups filled with uninfected solution. This time, 4 of 5 syringe barrels will be filled with infected solution, and 1 syringe barrel will be filled with uninfected solution.

3. The mosquitoes will bite 4 people each.

4. For additional challenge for your students, see the addendum, which is targeted for students in grades 9-12.

Optional Step 4

Discussion with worksheet and presentation.

1. As before, test how many people and how many mosquitoes are infected after 4 rounds of bites. Discuss how the results do or do not match anticipated results.

2. Why were so many more people and mosquitoes infected? Specifically, how did the modified experiment incorporate possible effects of climate change?

   a. Warmer temperatures and increased precipitation may lead to an increase in number of mosquitoes. We did not account for this in the experiment.

   b. The mosquitoes biting more frequently is modeled by an increase in number of bites.

   c. Because more people are infected, more mosquitoes become infected too. This scenario is modeled by having 4 infected people at the start of the experiment.

   d. Warmer temperatures and increased precipitation will also cause parasites to develop faster leading to a higher parasite load within the mosquito. We did not account for this in the experiment. (This can be modeled in the experiment by using a larger syringe volume.)

3. What factors does this model not incorporate? What assumptions were made?

   a. The model assumes that mosquito bites always transmit disease to both the vector and the host. In reality, there may be a delay before a mosquito transmits a particular microbe.

   b. The model also assumes that all mosquitoes are equally capable of transmitting disease. In reality, there is variation between mosquito strains in the parasite/microbe load and the degree to which mosquitoes can transmit a microbe.

   c. It assumes that people continue to transmit the disease. People may die, or they can be cured of the disease. Regardless, those individuals in the population do not continue to transmit the disease.

   d. It assumes there are more people than mosquitoes. In reality, that is not the case.

   e. This model also assumes that all people attract mosquitoes to an equal extent. Mosquitoes are attracted to 3 things: taste (they have odorant receptors on their feet; DEET makes our skin taste bad), heat (some people are warmer than others) and carbon dioxide (people who breathe faster release more carbon dioxide). Any one of these components can vary from person to person.

4. It is also important to note that we are limited by class size, which can result in sampling error. If this experiment is repeated on a much larger scale, the data are more robust.

Table to determine proportion of hosts and vectors. This is a starting point for modeling vector-borne diseases. Increase the proportion of infected people and mosquitoes when modeling the effects of climate change

Total # of students	People	Mosquitoes	Infected Mosquitoes
10	8	2	1
11	8	3	1
12	9	3	1
13	10	3	1
14	11	3	1
15	11	4	1
16	12	4	1
17	13	4	2
18	14	4	2
19	14	5	2
20	15	5	2
21	16	5	2
22	17	5	2
23	17	6	2
24	18	6	2
25	19	6	2
26	20	6	2
27	20	7	2
28	21	7	2
29	22	7	2
30	23	7	2
31	23	8	3
32	24	8	3
33	25	8	3
34	26	8	3
35	26	9	3
36	27	9	3
37	28	9	3
38	29	9	3
39	29	10	3
40	30	10	3
41	31	10	3
42	32	10	3
43	32	11	4
44	33	11	4
45	34	11	4
46	35	11	4
47	35	12	4
48	36	12	4
49	37	12	4
50	38	12	4

Assessing the Lesson

1. How does weather affect vector-borne diseases?

a. Temperature

b. Humidity

c. Surface water

d. Vectors are more common in tropical and subtropical regions

e. Predator patterns

2. How could climate change affect vector-borne disease distribution and outbreaks?

a. Climate constrains the prevalence of many vector-borne diseases. Many of the diseases are restricted to tropical and subtropical regions. For example, mosquitoes breed and survive within a certain temperature range. Winter freezing not only kills many invertebrates like mosquitoes and ticks but also limits food availability for many vectors.

b. Warmer temperatures may result in a larger geographic distribution where the disease is common.

c. Warmer temperatures and increased rainfall could increase the intensity and duration of outbreaks.

d. Erratic weather patterns could alter the seasonal distributions of vectors and hosts.

e. Effects of climate change on vector-borne diseases will disproportionately affect the developing world because the effects will likely to be more pronounced in the equatorial and tropical regions.

3. How could climate change alter the distribution of mosquitoes in particular?

a. The implications of climate change are complicated. For example, the increase in humidity and temperature will likely increase the incidence of West Nile virus. This is because at higher temperatures, mosquitoes develop more rapidly and bite more frequently, the viral load in mosquitoes is higher and some parasites develop faster. And finally, because more people are likely to be infected, more mosquitoes will become carriers that can transmit disease.

b. Increased drought may also increase vector-borne diseases by bringing mosquitoes and hosts (like birds and mice) into closer proximity because of limited water.

c. Additionally, fewer natural predators can also lead to increased mosquito populations. The spread of dengue to eastern Africa is thought to be a result of drought conditions that were not previously present in the area.

RESOURCES

Environmental Health Perspectives. News by Topic page, **http://ehponline.org/article/browsenews.action.** Choose Climate Change.

A human health perspective on climate change, **http://www.niehs.nih.gov/health/docs/climatereport2010.pdf**

CIA, The World Factbook, Gross Domestic Product information, By country, **https://www.cia.gov/library/publications/the-world-factbook/rankorder/2004rank.html**

Energy Information Administration, U.S. Department of Energy, Summary of the report on the impact of the Kyoto Protocol on the U.S. energy markets & economic analysis, **http://www.eia.doe.gov/oiaf/kyoto/kyotobrf.html**

Energy Information Administration, U.S. Department of Energy, International Energy Annual 2006 World Carbon Dioxide Emissions from Use of Fossil Fuels, **http://www.eia.doe.gov/emeu/iea/carbon.html**.

Global Warming: Early Warning Signs, clickable map of weather records and extremes across the world, **http://www.climatehotmap.org/**

International Energy Agency, CO_2 emissions from fuel consumption, **http://www.iea.org/co2highlights/co2highlights.pdf**

Kyoto Protocol: What Should We Do? **http://dx.doi.org/10.1289/ehp.scied007**

U.S. Environmental Protection Agency, Climate Change, **http://www.epa.gov/climatechange/**

Union of Concerned Scientists, Global Warming, **http://www.ucsusa.org/global_warming/**.

UN Framework Convention on Climate Change, **http://unfccc.int/2860.php**.