

TRACKING GENETICALLY MODIFIED MOSQUITOES

OVERVIEW

This activity accompanies the video [Genetically Modified Mosquitoes](http://www.hhmi.org/biointeractive/genetically-modified-mosquitoes), which can be downloaded or viewed at <http://www.hhmi.org/biointeractive/genetically-modified-mosquitoes>. In this activity, students are challenged to provide their own questions and ideas for experiments they could conduct to examine the impact of releasing genetically modified (GM) mosquitoes on the local population of wild mosquitoes. Students then learn the approaches scientists use to conduct such experiments, and then students use math, descriptive statistics, and line and bar graphs to analyze data from treated and untreated (control) areas. As an option, students may use spreadsheets to analyze and graph the data.

Pre-activity: Apply previous knowledge

Class discussion about
mosquitoes and
disease spread

5–10 minutes

Watch Scientists
at Work video

10 minutes

Class discussion to
answer questions
about film

5–10 minutes

Part 1: Research questions

Research Questions
(group work)

10 minutes

Class discussion about
research questions
(optional)

5–10 minutes

Reading

10 minutes

Part 2: Data analysis

Analyze Oxitec data

20 minutes

Write letter

10 minutes

Part 3: Extension

Additional questions

5–10 minutes

Figure 1. Activity Overview. The Video, Reading, and Extension may all be assigned as homework.



Activity **Tracking Genetically Modified Mosquitoes**

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KEY CONCEPTS AND LEARNING OBJECTIVES

- To explore the impact of GM mosquitoes on wild mosquito populations, scientists use experimental designs that include comparing the estimated density of mosquitoes in treated and untreated areas before and after the release of GM mosquitoes.
- To estimate the population dynamics of an organism that is hard to see and has a large population size, scientists must take numerous samples from the population.

Students will be able to

- compare and contrast their ideas for an experimental design to measure the impact of releasing GM mosquitoes on the relative density of wild mosquitoes to a design used by scientists,
- use data to calculate several population statistics,
- create and analyze graphs to identify patterns, and
- use evidence to form and support claims and conclusions.

CURRICULUM CONNECTIONS

| Curriculum | Standards |
|------------------------|--|
| NGSS (April 2013) | HS-LS2-2 |
| AP Biology (2012–2013) | 4.A.5 (L.O. 4.11, 4.12), 4.B.3 (L.O. 4.19) |
| IB Biology (2016) | 5.3.1 |

KEY TERMS

Aedes aegypti, average density, genetically modified (GM), mating fraction, ovitrap index, ovitraps

TIME REQUIREMENTS

This activity was designed to be completed within two 50-minute class periods, including viewing the video, although the time requirements depend on how comfortable your students are analyzing data and creating graphs. The lesson could be completed in one class period if students watch the video at home and complete their graphs for homework.

SUGGESTED AUDIENCE

This activity is appropriate for any life science student audience, including as an advanced or extension option in a middle school life science course. It is also appropriate for a high school college prep/general biology course. In an advanced high school biology (honors, AP, and IB) or introductory college biology course, the activity can be used to review of the nature of science or to enhance a discussion on transgenic technology.

PRIOR KNOWLEDGE

- Before watching the video, students should be familiar with the idea that genes code for proteins and that genetic information can be passed to offspring.
- It will be helpful for students to know what it means for an organism to be genetically modified.
- Students should know how to compute averages and construct line and bar graphs.



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MATERIALS

- Access to the video *Genetically Modified Mosquitoes*, available at <http://www.hhmi.org/biointeractive/genetically-modified-mosquitoes>, and a way to show it to the class
- 1 copy of the *Tracking Genetically Modified Mosquitoes* handout for each student or group of students
- 1 copy of the *Does Using GM Mosquitoes Work?* handout for each student or group of students
- 1 copy of the *Data Tables* for each student or group of students
- Access to the *Data Spreadsheet* (optional) and spreadsheet software for analysis and graphing (Microsoft Excel recommended)

TEACHING TIPS

- This activity lends itself to students working in groups. Look through the data analysis required for this lesson and make copies accordingly.
- Decide whether you would like students to use spreadsheet software to analyze the data and to create the graphs described in the activity. Arrange for student access to computers, if necessary. If students use spreadsheets, it will be helpful if they understand basic spreadsheet functions such as adding, writing functions, and computing averages across multiple cells.
- Before showing students the film, ask them how they feel about mosquitoes and why they feel that way. Many students in the United States are likely to think of mosquitoes as pests that occasionally bite them and cause irritating, itchy welts. However, they may not be aware of the severe health impacts of diseases carried by mosquitoes. Ask students to work in groups to list as many diseases they can think of, in humans, dogs, or horses, for which mosquitoes act as vectors of disease. Be sure to also help students think about the role mosquitoes play in food webs—for example, as food for birds and bats, and as population control of some nonhuman species by being disease vectors.
- After showing students the film, hold a brief discussion about any questions that the film raises.
- The scenario described at the start of the *Tracking Genetically Modified Mosquitoes* handout is based on an actual proposal from the biotechnology company Oxitec to release GM mosquitoes in Florida. To prepare for the potential release, the company submitted an environmental assessment to which thousands of people submitted public comments. On August 5, 2016, the Federal Drug Administration (FDA) agreed that the proposed experiment would not have significant impacts on the environment. The full statement from the FDA and the environmental assessment are available on the [FDA's website](http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/GeneticEngineering/GeneticallyEngineeredAnimals/ucm446529.htm) (<http://www.fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/GeneticEngineering/GeneticallyEngineeredAnimals/ucm446529.htm>). If you discuss this proposal, you may wish to emphasize to students an important aspect of the nature of science: the information gleaned from scientific research may inform discussions of public policy, but making decisions that reflect the values of a community falls outside the purview of science.
- The tasks described in Steps 1 and 2 of the *Tracking Genetically Modified Mosquitoes* handout give students an opportunity to design an investigation to match a specific scientific question, which is a critical science practice. Having students compare and contrast their research designs with the design from an actual experiment should provide students useful feedback on their designs. If class time is running low, consider assigning these tasks for homework. If you teach a more advanced class, you may want to alert students to a published scientific paper that describes the actual experiments carried out in Brazil (Carvalho et al., 2015, <http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0003864>).



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- After students read the handout *Does Using GM Mosquitoes Work?*, you may want to review the calculations required for computing the ovitrap index (OI), the average density (AD) of *Aedes aegypti*, the relative change in density in an untreated versus treated area, and the fraction of females that are mating with GM males (mating index, M).
- When calculating the relative change in mosquito density, you may need to emphasize that the values for average densities in untreated (U) and treated (T) areas before and after treatment (U_b , T_b , U_a , T_a) are averages across several months.
- The calculations in Steps 3–7 of the *Tracking Genetically Modified Mosquitoes* handout can be completed using a spreadsheet. HHMI's BioInteractive.org website has [tutorials](#) designed to introduce students to the basics of using spreadsheets, available at <http://www.hhmi.org/biointeractive/spreadsheet-data-analysis-tutorials>.
- In the *Does Using GM Mosquitoes Work?* handout, students calculate OI data. Explain that ovitrap data cannot be used to estimate population size. There are, however, methods for doing that, as explained in the *PLOS* paper (Carvalho et al., 2015).
- Consider having students visit the website for the [Invasive Mosquito Project](#) (<http://www.citizenscience.us/imp/index.php>). It is a citizen science project that provides students, teachers, and anyone interested with the opportunity to collect real data and contribute to a national mosquito species distribution study. The project not only gives individuals an opportunity to explore and collect data, but it also raises awareness of diseases that can be transmitted by mosquitoes and how people can make an effort to protect themselves, communities, and pets from illness.

ANSWER KEY

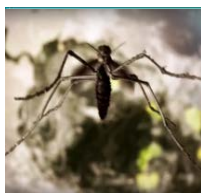
PART 1: Research Questions

1. Watch the video. Then work with a group of other students to develop one to three research questions you would like to see addressed to determine whether the release of GM mosquitoes into the environment is an effective method for reducing mosquito populations in your area. For each research question, work as a group to identify the data you need to answer your research question and brainstorm how to design the research project to help you get the data you need.

Here students are asked to think ahead and imagine what ideal data would look like. Many, if not most, students will find this thought process to be challenging; it is certainly a challenging process for experienced scientists. Be open to a range of student ideas, but work with them to ensure that the research plan they propose is linked directly to the research question. Many students struggle to design appropriate research experiments, so practice is helpful. If you have previously had students learn about designing controlled experiments, you may want to review those resources at this point.

2. Read and complete the handout *Does Using GM Mosquitoes Work?* Compare and contrast the question, research design, and data described in the reading to your ideas.

Student answers will vary depending on their research questions and experimental plans. You may want to review the value of including treated and untreated (control) areas.



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PART 2: Data Analysis

Table 1. Answer Key for *Brazilian Data: Untreated Area*

| | Before GM Mosquito Release | | | | After GM Mosquito Release | | | | | | | | |
|-----------|----------------------------|-------|------|------|---------------------------|------|-------|-------|------|------|------|------|------|
| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. |
| <i>L</i> | 3 | 5 | 6 | 9 | 8 | 9 | 10 | 8 | 5 | 4 | 2 | 1 | 2 |
| <i>T</i> | 10 | 10 | 9 | 10 | 9 | 10 | 10 | 10 | 9 | 9 | 10 | 9 | 9 |
| <i>E</i> | 5 | 13 | 34 | 65 | 85 | 98 | 116 | 112 | 45 | 24 | 7 | 2 | 3 |
| | | | | | | | | | | | | | |
| <i>OI</i> | 30% | 50% | 67% | 90% | 89% | 90% | 100% | 80% | 56% | 44% | 20% | 11% | 22% |
| <i>AD</i> | 0.50 | 1.30 | 3.78 | 6.50 | 9.44 | 9.80 | 11.60 | 11.20 | 5.00 | 2.67 | 0.70 | 0.22 | 0.33 |

Table 2. Answer Key for *Brazilian Data: Treated Area*

| | Before GM Mosquito Release | | | | After GM Mosquito Release | | | | | | | | |
|-----------|----------------------------|-------|------|------|---------------------------|------|------|------|------|------|------|------|------|
| | Aug. | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. |
| <i>L</i> | 4 | 7 | 7 | 6 | 6 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| <i>T</i> | 10 | 9 | 10 | 8 | 9 | 9 | 10 | 9 | 10 | 9 | 10 | 9 | 10 |
| <i>E</i> | 6 | 30 | 42 | 59 | 31 | 8 | 2 | 1 | 1 | 1 | 1 | 2 | 1 |
| | | | | | | | | | | | | | |
| <i>OI</i> | 40% | 78% | 70% | 75% | 67% | 33% | 20% | 11% | 10% | 11% | 10% | 11% | 10% |
| <i>AD</i> | 0.60 | 3.33 | 4.20 | 6.25 | 3.44 | 0.89 | 0.20 | 0.11 | 0.10 | 0.11 | 0.10 | 0.22 | 0.10 |

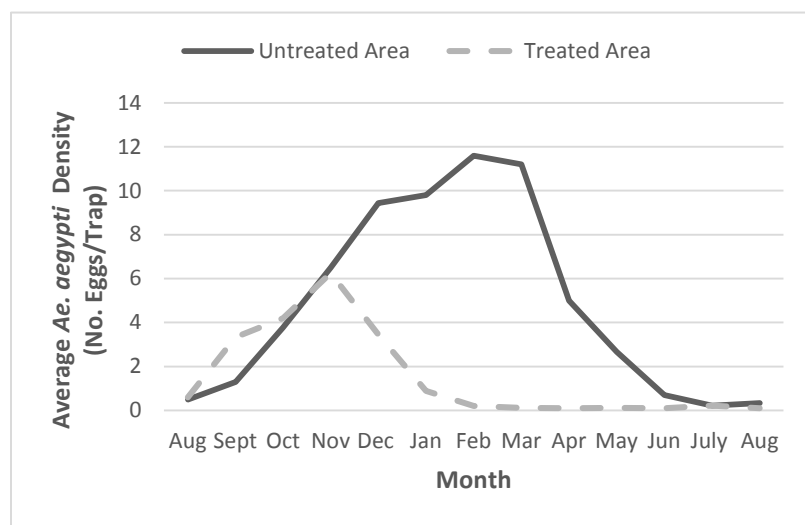


Figure 2. Sample Graph. The average *Aedes aegypti* density by month for the untreated and treated areas.



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5. Compute the relative change in mosquito density in the untreated versus treated areas by finding the average AD for the untreated and treated areas both before and after the mosquitoes were released (U_b , T_b , U_a , and T_a). For example, the average AD for $T_b = (6 + 30 + 42 + 59) \text{ eggs} / (10 + 9 + 10 + 8) \text{ traps} = 3.70$.

$$T_b = 3.70 \quad U_b = 3.00 \quad T_a = 0.56 \quad U_a = 5.79$$

$$\text{relative change} = \frac{\left(\frac{T_a}{U_a}\right)}{\left(\frac{T_b}{U_b}\right)} - 1 = -0.92 = -92\%$$

6. Use the data and evidence you gathered to make a claim about whether the GM mosquito program is effective in Brazil. Make sure to cite specific evidence to support your claim.

The data support the claim that the GM mosquito program seems to be reducing the size of the mosquito population in the treated area. Students may cite multiple sources of evidence, including the higher ovitrap index values in the untreated area versus the treated area from December until June, the higher average density of mosquitoes in the untreated area from December until June, and the higher overall average density of mosquitoes in the untreated area.

7a.. Compute the mating fraction (M) for the missing months on the Mating Fraction Data handout.

See Table 3 for the correct calculations.

Table 3. Answer Key for Computing the Mating Fraction Data

| | Impact of Releases | | | | | | | | | | | | | | | | | |
|---|--------------------|----|------|---|------|---|------|---|------|---|------|---|------|---|------|---|------|---|
| | Dec. | | Jan. | | Feb. | | Mar. | | Apr. | | May | | June | | July | | Aug. | |
| F | | 24 | | 8 | | 1 | | 1 | | 1 | | 1 | | 1 | | 2 | | 1 |
| N | 7 | | 1 | | 1 | | 0 | | 0 | | 0 | | 0 | | 0 | | 0 | |
| M | 77% | | 89% | | 50% | | 100% | | 100% | | 100% | | 100% | | 100% | | 100% | |

7b. On a separate piece of paper, create a bar graph by plotting the month on the x-axis and the mating fraction on the y-axis for the treated area.

See Figure 3 for a sample graph.



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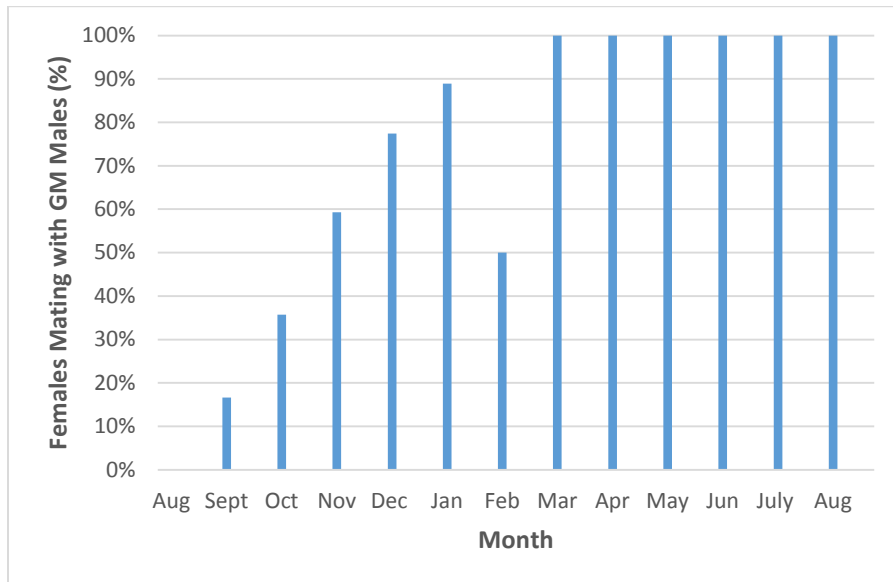


Figure 3. Sample Graph. The percentage of females mating with GM males in the treated area.

7c. Explain how the mating fraction evidence affects the claim you made in Step 6.

The data on mating fraction provide further evidence to support the claim that the GM mosquito program is causing a major decline in the size of the mosquito population in the treated area. If the decline in the population was due to another variable, the fraction of females mating with GM males would not necessarily increase.

8. Write a short letter to city officials summarizing evidence (based on the Oxitec data) about whether releasing GM mosquitoes may work. Be sure to emphasize the ultimate goal of the research and the GM mosquito technique. Also describe any further questions or concerns you have about the release.

This question provides students with the opportunity to summarize what they have learned in the lesson and provides you with an opportunity to learn what questions students still have about the video that you may want to address in future class sessions. Remind students here that the overall goal of the GM mosquito approach is to reduce and possibly eliminate the Zika virus from places where humans live to improve human health. A good letter to city officials will emphasize this point and how this might be accomplished with the GM mosquito technique.

9. Both the ovitrap index and the average density are measures of the population dynamics of *Ae. aegypti*. What ideas do you have for why the researchers use two different measures?

Researchers are often limited by time or funding, so they must make trade-offs. The ovitrap index provides less information than the average density, but researchers can collect OI data from more sites because they do not need to take the time to count all the eggs in each trap. Researchers can thus get a rough idea of trends in population size from OI data. Average density provides a more accurate description of the population size but is more time consuming to collect. Researchers use AD when they have the time or money to count all the eggs.



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10. *Why was it valuable for researchers to include an untreated area?*

Including a control like the untreated area helps researchers eliminate alternative explanations for patterns they find between the independent and dependent variables. For example, differences in standing water can influence mosquito density.

11. *What additional data do you think the scientists might have or could have collected at each study site that could influence the population dynamics of the mosquitoes?*

Student answers will vary, but look for answers that identify environmental factors that reduce population sizes. For example, bats and birds like swallows and nighthawks are important predators of mosquitoes, especially when mosquitoes are most active in the late evening. Bat studies have shown that, while moths may be the most abundant insect in the diets of many bat species, in some cases an individual bat can consume up to 600 mosquitoes in a single night. Knowing about the nightly activities of bats and birds at each study site would help the scientists better understand the effect of the GM mosquitoes on mosquito density.

REFERENCE

Carvalho, Danilo O., Andrew R. McKemey, Luiza Garziera, Renaud Lacroix, Christl A. Donnelly, Luke Alphey, Aldo Malavasi, and Margareth L. Capurro. "Suppression of a Field Population of *Aedes aegypti* in Brazil by Sustained Release of Transgenic Male Mosquitoes." *PLOS Neglected Tropical Diseases* 9, no. 7 (2015): e0003864.

AUTHORS

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