



Educational Materials

A Student Exploration of the Impacts of Climate Change on Human Health and Vector-borne Disease

A Student Exploration of the Global Impacts of Climate Change on Human Health-Vector-Borne Diseases

Summary

This module follows the **5E instructional model** to promote student discovery and learning about the interactions between climate change, the environment, vector-borne disease and human health. Using content from international reports, students are prompted to explore the impacts of changing climate and ecologic conditions on vector borne diseases relevant to human health with an emphasis on vulnerable populations. Students will then apply systems thinking to create a visual model that depicts the relationship between climate change, vectors and human health. To provide a solution focus to the module, a culminating activity is offered that enables students to engage with local, regional, or national data to evaluate climate adaptation and mitigation strategies. Additionally, and, if desired, students may contribute to the GLOBE Observer Mosquito Habitat Mapper (GO MHM) program. GO MHM is a mobile app developed for citizen and student scientists that enables users to locate, identify and count mosquito larvae and eliminate breeding sites in their communities.

Grade Level

Students completing their upper-secondary education, or US grades 9-12 equivalent.

Learning Objectives

By the end of this module, students should be able to:

- Describe the meteorological and ecological variables that are changing affected by climate change.
- Describe the impacts of climate change on vector-borne diseases relevant to human health with an emphasis on vulnerable populations.
- List climate-sensitive vector-borne diseases and the corresponding vectors.
- Demonstrate understanding of the complexities of the ecosystem through construction of a visual model.
- Describe and evaluate climate adaptation strategies that are protective of human health.

Instructional Time Needed

Engagement 15-20 minutes

Exploration 20-30 minutes, can be completed either in class or as homework, can also be extended to include time for independent research

Explanation 20-30 minutes

Elaboration 10-15 minutes

Evaluation Amount of time will vary depending on evaluation option selected



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Key Words and Phrases (note- specific diseases of interest may be modified to be regionally specific and relevant)

- adaptation, evidence-based, precipitation, Aedes aegypti, exposure pathway, prevalence, Anopheles sp., habitat, Rabies, climate change, health outcome, Rift Valley Fever, climate driver, incidence, susceptibility, co-benefit(s), Ixodes sp., systems thinking vector, drought, Lyme disease, vulnerable populations, Culex sp., Malaria, West Nile virus, Dengue virus, mitigation, Zoonotic disease, ecosystem, morbidity, 5E instructional mode, environmental hazard, mortality

Alignment to Frameworks for K-12 Science Education

This module promotes three-dimensional learning as described in the US National Research Council’s “A Framework for K-12 Science Education” (see Resources section). The Next Generation Science Standards (NGSS) also informed module development. This module, if successfully completed, integrates multiple science and engineering practices, disciplinary core ideas, and cross cutting concepts for both earth and life science.

Alignment to the Climate Literacy Framework

Climate Literacy: The Essential Principles of Climate Science was produced by the US Global Change Research Program to articulate the fundamental components of climate, climate change, and the human response to climate change. This module, if successfully completed, addresses the following essential principles of climate science as outlined in Climate Literacy:

Principle 3a: Individual organisms survive within specific ranges of temperature, precipitation, humidity, and sunlight. Organisms exposed to climate conditions outside their normal range must adapt or migrate, or they will perish.

Principle 3c: Changes in climate conditions can affect the health and function of ecosystems and the survival of entire species.

Principle 7e: Ecosystems on land and in the ocean have been and will continue to be disturbed by climate change. Animals, plants, bacteria, and viruses will migrate to new areas with favorable climate conditions. Infectious diseases and certain species will be able to invade areas that they did not previously inhabit.

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Principle 7f: Human health and mortality rates will be affected to different degrees in specific regions of the world as a result of climate change. The incidence and geographical range of climate-sensitive infectious diseases—such as malaria, dengue fever, and tick-borne diseases—will increase.

Authors

Series Information

This document is part of a series of educational models on climate and health. Additional versions in the series include:

- *A Student Exploration of the Impacts of Climate Change on Human Health in the United States*
- *A Clinical Health Care Student Exploration of the Impacts of Climate Change on Human Health in the United States*
- *A Public Health Student Exploration of the Impacts of Climate Change on Human Health in the United States*
- *A Student Exploration of the Global Impacts of Climate Change on Human Health*
- *A Clinical Health Care Student Exploration of the Global Impacts of Climate Change on Human Health*



The original version of the educational materials for United States high school students was prepared by Dana Brown Haine, MS, University of North Carolina, under temporary assignment to NIEHS through the Intergovernmental Personnel Act (IPA) Mobility Program. Additional versions for international, clinical and public health students were developed by Juliana Betbeze, Leann Kuehn, Betsy Galluzzo, Kimberly Hill, Cecilia Sorensen, and Mariana Surillo. Dr. Sorensen also provided the case studies accompanying the educational materials for graduate and professional students. Materials were generously reviewed by educators and professionals around the country.

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A-a-glance Summary

This module follows the 5E instructional model to promote student discovery and learning about the complex interactions between climate change, the environment, vector-borne disease and human health. The 5E model is based on the following steps: engage, explore, explain, elaborate, and evaluate. Students will build on existing knowledge and develop new ideas as they progress through the module.

Teaching Strategies

Engage

Students are prompted to consider the human health impacts of climate driven changes in temperature and precipitation. Data visualizations are used to facilitate student engagement and to help the teacher informally assess students' pre-existing knowledge. Students are prompted to consider the impact of changes in temperature and precipitation on vector populations

Explore

Students are assigned a reading from international reports to develop knowledge of the known impacts of climate change on vector borne diseases. Students are prompted to consider relevant vulnerable populations. Students can also be tasked with exploring epidemiologic data at a local, regional, or national level.

Explain

Using knowledge gained in section 2 (explore), students work in small groups or as a class to create and present a visual model to convey the complex ways that climate change affects vector-borne disease. The teacher's actions center on ensuring student explanations are accurate, addressing misinformation, and clarifying points of confusion. Teacher introduces systems thinking and emphasizes interactions of Earth's spheres and ecosystems.

Elaborate

A teacher introduces the concept that climate change mitigation strategies confer co-benefits to human health and the concept that adaptation strategies reduce negative health impacts. Students are tasked with identifying personal (individual) and societal (collective) solutions that could be advanced to address the negative health outcome(s) that were the focus of their assigned topic.

Evaluation (Assessment Strategies)

- **Option 1:** Students **evaluate the health impacts at least one vector borne disease** from an economic, social and environmental perspective and present their analysis either in writing or as an in-class presentation that could include development of a poster, brochure, infographic, video, etc.
- **Option 2:** Students **write a concluding paragraph** for their assigned reading that describes relevant health co-benefits of climate mitigation efforts and describes adaptation strategies that could be implemented to protect human health.
- **Option 3:** Students **design a solution** to combat a specific climate-sensitive vector-borne disease that is relevant to their local community, state or region of the country. Students are prompted to use relevant epidemiologic and geoscience data to investigate their assigned vector-borne disease, find epidemiologic data to support their findings, identify vulnerable populations, investigate and evaluate options for adaptation or mitigation and make a recommendation.

Extend

Students could extend their learning by either working to implement a resilience project in their school or community (if applicable) or by advocating for their adaptation strategy or resilience building project through civic engagement with relevant policymakers (students could partner with a local Government/Civics class).

Students could also extend their learning by participating, as small groups or individuals in citizen science activities using the [GLOBE Observer Mosquito Habitat Mapper](#) mobile app.

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Background

Much of the discussion around climate change has focused on the physical and chemical processes associated with climate change and the resulting environmental effects, such as extreme temperatures and melting glaciers. More recently the discussion has expanded to include impacts on human health and specifically the impact of climate change on vector-borne diseases.

Vector-borne diseases are those that are transmitted to humans by mosquitos, ticks, fleas and animals. Vectors transmit pathogens such as viruses, bacteria and protozoa. Important examples of vector borne diseases include malaria, dengue fever, Zika, West Nile Virus, Lyme disease, rabies and more. Examples of important vectors include the *Anopheles*, *Aedes* and *Culex* mosquitos and several species of ticks, including the *Ixodes* tick. The seasonality, distribution and prevalence of vector-borne diseases are significantly influenced by climatic factors, including high and low temperatures and precipitation patterns. Social factors also mediate the spread and exposure to disease, including domestic water storage patterns, housing conditions, access to piped water, occupation, age and gender. Climate change may result in alterations in the prevalence, incidence and geographic distribution of vector borne diseases, creating new public health challenges.

Examples of climate-sensitive vector-borne diseases include:

Dengue fever: A mosquito-borne disease, endemic to many tropical and subtropical regions caused by four related dengue viruses and transmitted by the *Aedes aegypti* mosquito.

Lyme disease: A tick-borne disease caused by the bacteria *Borrelia burgdoferi* in the United States and Europe and by *Borrelia afzelii* and *Borrelia garinii* in Europe and Asia. It is transmitted to humans by *Ixodes ticks* (“deer ticks”).

Malaria: A febrile illness caused by protozoan parasites of the genus *Plasmodium* and transmitted to humans by the *Anopheles* mosquito. Five species of *Plasmodium* cause human illness, the most deadly of which is *Plasmodium falciparum*.

West Nile Virus: A virus that is found in birds but transmitted to humans by the *Culex* mosquito.

Rabies: A disease caused by infection with *Lyssavirus*. Transmission occurs when victims are bitten by an animal carrying the virus. The most common animal vectors include bats, skunks, dogs, raccoons and more.

Importantly, there are a number of **vulnerable populations** that will experience disproportionate risks to their health and well-being in response to climate change. *The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report*, Chapter 11 Section 3 “Human Health: Impacts, Adaptations, and Co-Benefits” defines vulnerability as “the propensity or predisposition to be adversely affected.” The chapter notes causes of vulnerability, including individual and population characteristics and factors in the physical environment. Depending on the specific vector-borne disease, vulnerable populations may include children, pregnant women, the elderly, outdoor workers, low income

Additional Resources

Facilitators interested in U.S. focused readings on vulnerable populations can use Chapter 9 of [The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment](#).

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groups, some communities of color, indigenous peoples, immigrants, persons with disabilities and persons with pre-existing or chronic medical conditions. As the public health system attempts to mitigate the negative health consequences of climate change, it will be important to take vulnerable populations into account locally, regionally and globally.

As students consider the numerous vector-borne diseases impacted by climate change, it is important that they also be tasked with identifying adaptation and mitigation strategies that can be implemented to protect human health. **Mitigation strategies** reduce the amount of CO₂ being added to the atmosphere and include deployment of alternative energy sources such as solar and wind power. Current mitigation strategies will not be able to reverse the change in climate that has already occurred but can reduce future impacts. **Adaptation strategies** help minimize the negative impacts of climate change. An example of an adaptation strategy would be to strengthen disease surveillance systems.

Through changes in societal and public health practices, we may be able to limit the magnitude of changes to the planet's climate and thus reduce the negative impacts to human health. Many mitigation strategies will provide **co-benefits**, simultaneously reducing the negative effects of climate change while also reducing illness and death. However, it is also possible that some mitigation strategies may introduce unanticipated potential for human harm.

Teacher Preparation

1. Students should be introduced to the general concept of climate change and to the human activities influencing greenhouse gas emissions prior to conducting this module. This module is appropriate for both earth and life science courses and can be used to either introduce or reinforce the specific climatic changes (e.g., increased precipitation) that are occurring in response to warming.
2. Read Chapter 11 of Working Group II of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report and the World Health Organization's Climate and Health Global Overview for background on the health impacts of climate change. Each of these reports contain specific sections on vector-borne disease. You may also choose to read chapter 5 of the United States Climate Health Assessment on vector-borne disease for issues specific to the United States.
3. Decide which sections of the background sources the students read based on their reading level and/or the extent to which you want students to conduct background reading for this exercise. This is an opportunity for students to cultivate their literacy skills.
4. You will assign one group of students for each section of the readings you have chosen; determine how many students will be in each group and print one copy of the reading for each student. The readings will need to be downloaded as pdfs or by clicking on the relevant hyperlinks.

Climate and Health Global Overview, WHO.....[Report](#)

IPCC Fifth Assessment Report, Working Group II, Chapter 11.

Human Health: Impacts, Adaptations, and Co-Benefits..... [Report](#)

Climate Health Assessment – Chapter 5: Vector-borne diseases.....[Report](#)

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Options for low-level readers

If you have the time to work with students as they develop their literacy skills, prepare to assign each student individual sections of the WHO's Climate and Health Global Overview and provide them with one or more close reading strategies to use as they work through the text. Provide ample time for them to conduct this reading assignment and for you to review the text as a class – emphasizing vocabulary terms and key concepts. Students could also be placed in mixed-ability groups and tasked with reading the text, highlighting unfamiliar words and concepts before summarizing as a group.

5. Prepare for the *Engagement Activity* by visiting the [map visualizations](#) in the IPCC Data Distribution Centre (see *Resources* section) and observing predictions for your region. Here you will have access to temperature and precipitation data spanning from 1910 to present day (actual data) and predictions through 2100, for which you can invite students to consider human health impacts under the different greenhouse emission scenarios of the IPCC reports, past and current. If you choose to use a different visualization replace the content on *slide 4* with your selected visualization and modify the cause-effect model on *slide 7* if needed (see Supplemental materials). Additional information on how to use the IPCC visualization tool is available at http://www.ipcc-data.org/ddc/ddc_visualisation.html

The background information provided above is generalized to an international level. Climate impacts will vary based on geographic location. It is up to the instructor to select the appropriate resources provided and to investigate additional resources that may be available at the local level. To identify other relevant climate-sensitive health outcomes for your country or region, the following resources may be useful:

- *Health and Climate Assessment Country Profiles*: facts sheets from the WHO that include a section on human health by country [Factsheets](#)
- *The Regional Chapters* from Working Group II of the IPCC's *Fifth Assessment Report*

Chapter 22: Africa	Chapter
Chapter 23: Europe	Chapter
Chapter 24: Asia	Chapter
Chapter 25: Australasia	Chapter
Chapter 26: North America	Chapter
Chapter 27: Central and South America	Chapter
Chapter 28: Polar Regions	Chapter
Chapter 29: Small Islands	Chapter
Chapter 30: The Ocean	Chapter

6. Familiarize yourself with this entire lesson plan; review the accompanying PowerPoint slide set and update if needed to tailor it to your instructional goals and/or your region.
7. Assemble required materials (see *Materials section* below).

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8. Prepare a section of the room (whiteboard (recommended), chalkboard or blank wall) for students to display and organize their visual model of how climate change impacts vector-borne disease and human health.
 - a. Write the following headings on signs that could be a piece of colored paper, or, if using a white board or chalk board, colored markers or colored chalk, respectively, can be used instead of colored paper. Place the signs on the wall/space in this order from left to right: Climate Driver (green); Exposure Pathway (blue); Health Outcome (red). These signs will guide students as they place their work on the wall in these categories (also see photo on page 15).

Materials (Note: these materials may be substituted as needed depending on resources)

Computer with MS Office Software (including PowerPoint).

PowerPoint slide set that accompanies this module (see *Supplemental materials*) Projector.

Engagement

- PowerPoint slide set
- [Optional] Blank index cards

Exploration

- Print copies of the graphic organizer “worksheet” (provided on page 13), one per student.
- [Optional] Colored highlighters or colored pencils (green, orange, blue, red) for reading.
- Print one copy of the selected reading for each student.

Climate and Health Global Overview, WHO
Climate and Health Country Profiles

[Report](#)
[Reports](#)

IPCC Fifth Assessment Report, Working Group II, Chapter 11. *Human Health: Impacts, Adaptations, and Co-Benefits* (Section: 11.5.1)

[Report](#)

Climate Health Assessment – Chapter 5: Vector-borne

[Report](#)

Top Level Findings, Working Group II, Fifth Assessment Report, IPCC
[Arabic](#), [Chinese](#), [French](#), [Russian](#), [Spanish](#)

[Report](#)

Explanation

- Colored dry erase markers if using whiteboard for display of visual model
- Colored chalk if using chalkboard for display of visual model
- If using blank wall for display of visual model:
 - Colored (green, blue, red/orange) ¼ sheets of paper, index cards or Post-it notes
 - Masking tape to attach the colored paper to the wall (if not using Post-it notes) and for showing connections between items on the visual model
- [Optional] 1 copy (per student in the group) of blank systems diagram (see *PPT slide 11*)

Elaboration

- No special materials aside from PowerPoint slide set are needed for this activity.

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Evaluation

- [Optional] Computers with internet access, one per student or student group.

Procedure

Engagement

This short exercise is intended to quickly and informally assess students' pre-existing knowledge of how climate impacts human health and pique their interest in expanding their knowledge. The use of national and/or regional data visualizations provides relevance to students' lives. This activity also introduces students to the terminology that will be used in the exploration and explanation phases of this module.

Part I | Exploring prior knowledge

1. Draw a "T" chart on the board or large easel; label the left-hand column of the chart "examples of climatic change" and label the right-hand column "human health effects."
2. Ask students to name specific examples of climatic change (e.g., increased air temperature) to assess their pre-existing content knowledge. This query invites students to list specific ways the climate is changing (temperature, precipitation, extreme weather, etc.). Record their responses in the left-hand column of the T chart; do not worry about right or wrong answers, just record students' answers.
3. Project figures from the IPCC Data Distribution Centre that depict *observed* changes in temperature and precipitation for your nation (*Teacher PPT slides 2-4*). Alternatively, you may choose to project visualizations from the entire globe through NOAA's monthly Global Climate Report and Global Temperature and Precipitation Maps online tool (see Resources section).

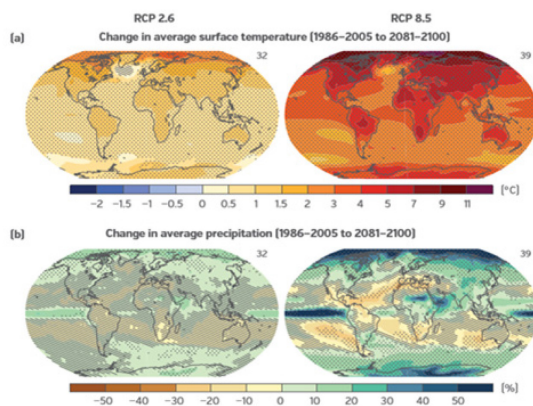


Figure 1.2. Maps of projected changes in average temperature and precipitation by the end of the current century, under the lower [RCP 2.6] and higher [RCP 8.5] of the pathways of greenhouse gas emissions assessed by IPCC [1].

Maps of projected changes in average temperature and precipitation by the end of the current century. Under the lower (RCP 2.6) and higher (RCP 8.5) of the pathways of greenhouse gas emissions assessed by the IPCC.

4. As a class, interpret each figure noting regions that are becoming cooler/warmer and drier/wetter and discuss the observed climate changes for your state and region of the country. Alternatively, students could be asked to interpret each figure in writing or aloud with a partner.
5. Next, ask students to list specific impact(s) of 1) a warming climate on human health; 2) a wetter climate on human health; and 3) a drier climate on human health. Record their responses in the

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right-hand column of the T chart aligned with any relevant climatic changes listed in the left-hand column; do not worry about right or wrong answers, just record students' answers.

- Next, define "vector" and ask students to list diseases that are transmitted by vectors and to list specific vectors. Make a "T" chart on the board or large easel and label the left-hand column "examples of vectors" and the right-hand column "vector-borne diseases."
- Introduce the concept of "ecosystem" and ask students to suggest ways in which the ecosystem impacts the life and survival of vectors. For example, how changes in temperature and precipitation may result in alterations in the prevalence, incidence and geographic distribution of vector borne diseases.

Alternative

Ask students to construct their own T charts on 4x6 notecards; cards could be collected as a pre-assessment. If done anonymously, students could swap cards and share recorded answers aloud as teacher constructs a T chart for the class at the front of the room.

Part II | Creating a visual model of cause and effect

- Tell the students that the class is going to construct a **visual model** to show the connection between a specific meteorological variable affected by climate change (*default example: heavy precipitation*) and several vector-borne diseases. This modeling activity will introduce students to the terminology that will be used in the exploration and explanation phases of this module.
- In order to create this visual model, use the template provided on *slide 7* as a prompt as you ask students to respond to the following questions:

Flooding, Vector-borne disease and Human Health	
What is the climate driver , also called specific climate change, which is referenced by this data visualization?	Heavy precipitation
What is/are the environmental condition(s) that arise in response to this specific climate change? <i>These conditions can either create(s) or exacerbate(s) an environmental hazard.</i>	Flooding
What is the environmental hazard being examined? <i>An environmental hazard is what will directly lead to a negative health outcome. Together, the environmental condition(s) and the hazard(s) comprise the exposure pathway.</i>	Stagnant, standing pools of water which create habitat for mosquito larvae
What is/are the health effect(s) that might arise from exposure to the environmental hazard? <i>Health outcomes refer to the specific impacts of the hazard on human health.</i>	Increased incidence of mosquito transmitted diseases

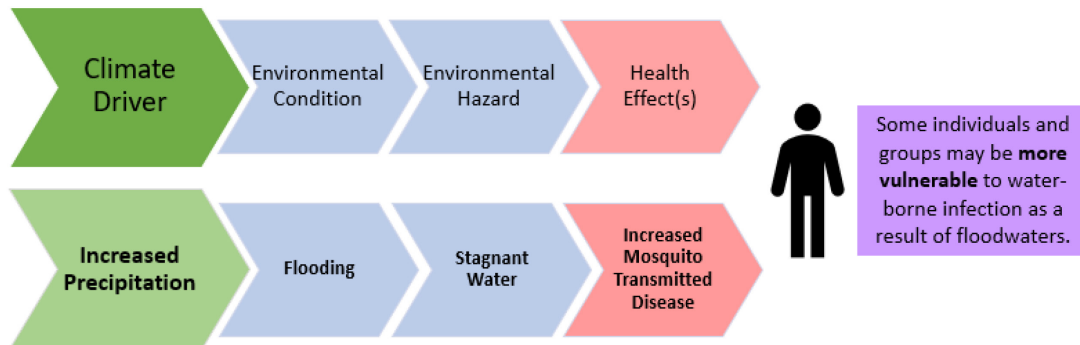
- Together, this information can be used by the class to construct a **visual model of this cause-effect mechanism using the template provided** (see slides 7-9).

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Visual Model | Cause and Effect | Flooding & Human Health



11. Point out to students that flooding can be both an environmental condition and a hazard if high water leads to destruction of homes and force people to live outside where they are exposed to vectors. Ask students if they can think of other human health hazards that might arise from flooding (e.g., growth of mold and mildew after water subsides). Slide 14 shows other hazards that can arise from flooding.

Teaching tip

To help students distinguish between an environmental condition(s) and hazard, provide some familiar examples that might arise as a result of thunderstorm:

Environmental condition: Heavy rain → **Hazard:** Slippery roads, contaminated water

Environmental condition: High winds → **Hazard:** Downed trees and power lines, power outages

12. To conclude this engagement activity, tell the students that they are going to work as a class to create a visual model of the various impacts of climate change on vector-borne disease as described in the provided readings using the same strategy.

Exploration

This activity invites students to develop their literacy skills by reading selected sections from Chapter 11 from Working Group II of the IPCC's Fifth Assessment Report or chapter 5 of the United States Climate and Health Assessment. For advanced students you may choose to ask them to read the entire chapter, or additional readings, such as the WHO's Climate and Health Global Overview. A graphic organizer is provided that can be used to guide students as they construct a visual model that will ultimately be shared with the class in order to construct a larger model that will convey the complex climate and health system during the explanation activity.

1. For each reading section, assign 3-4 students per section and distribute copies of the assigned reading to each group member.
2. Either in class or as a homework assignment, ask students to complete their reading assignment and either individually or in their group complete one or more rows of the graphic organizer provided on page 13 to summarize the climate and health impacts and vulnerable population

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identified in their reading. Time permitting, you may also choose to ask students to read IPCC Chapter 11 or Chapter 9 of the CHA to learn more about vulnerable populations and identify how they may be impacted. This is an opportunity for your students to cultivate their literacy skills – ask students to practice close reading and highlight and look up any words or concepts that are unfamiliar.

3. Next, task students with completing one or more rows of their graphic organizer. In general, students seem to find it easier to identify a hazard first and then work backwards to identify the underlying environmental condition(s) that creates the hazard and then the ultimate climate driver (s) that is responsible for producing the environmental condition(s). To complete a row, students list the specific health effects for each hazard identified and then list any vulnerable populations that are more susceptible to experiencing negative health outcomes in reaction to the hazard cited. **In some cases, it may be difficult to differentiate the environmental condition(s) from the environmental hazard. For example, increased temperature can be a change in climate, an environmental impact and an environmental hazard. Students may need guidance in this area; the Answer Key may assist you with that guidance.*
4. Depending on your instructional goals, students could be tasked with conducting additional research on their assigned reading(s) to investigate this topic from a local or regional perspective.
5. Tell each group that during the next phase of the activity (explanation phase), they will present their visual models to the class (some groups may have more than one model to present). Each group should identify one student who will present the model(s) aloud to the class while the other students in the group contribute to the model by writing and/or placing their model components on the board/wall.

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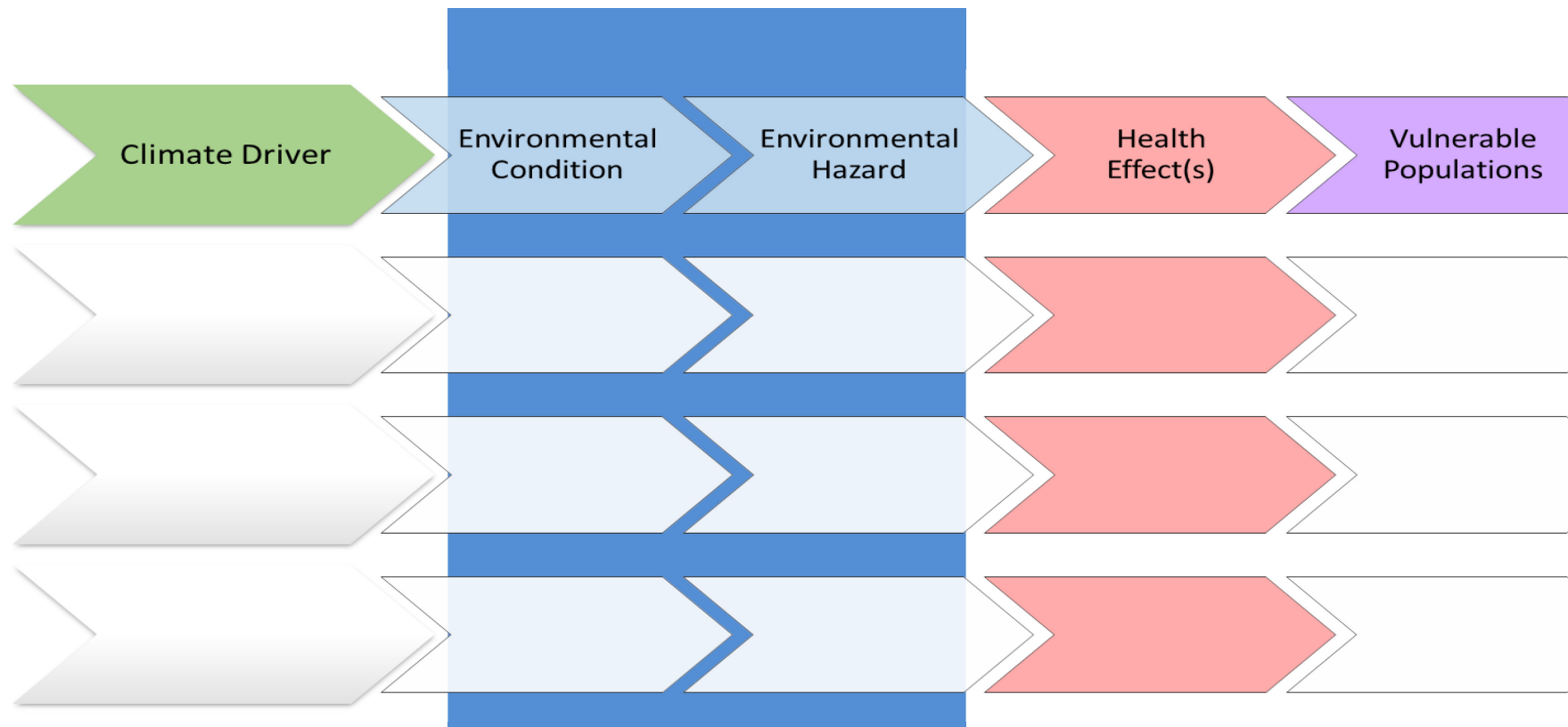


Graphic Organizer

Assigned Reading:

Name:

As you read, identify the environmental condition(s) that produce the environmental hazard(s) cited and then identify the underlying climate driver(s) (e.g., increased precipitation). For each hazard, list the health effect(s) and the most vulnerable people/groups. **Not all rows may need to be completed.**



It may be difficult to distinguish the environmental condition from the environmental hazard. For example, increased temperatures can be a change in climate, an environmental condition and an environmental hazard! An environmental hazard is what will directly lead to a negative health outcome.

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Explanation

During this activity, students have the opportunity to explain their visual model(s) to the class as a larger model is being constructed that will convey the complex climate-vector- health system. The teacher's actions center on ensuring student explanations are accurate, addressing misinformation, and clarifying points of confusion. During the debrief, the teacher introduces systems thinking and emphasizes interactions of Earth's spheres (atmosphere, biosphere, hydrosphere, lithosphere).

1. Tell the class they are going to combine their models to create a larger visual model to illustrate the complexity of the climate-vector- health system. One at a time, invite each group to come to the board/wall space you have identified and describe their visual model(s) aloud for each health outcome identified in their reading(s) as they place their model on the board/wall. For each health outcome identified, students should also mention any vulnerable populations to the class.
 - a. Students will either write their words on the board or place their post-it notes/cards in the appropriate location and connect the words using a marker, chalk or tape.
 - b. Students should note where one environmental condition (e.g. flooding) influences other health outcomes by adding arrows to the model.
 - c. If a change in climate or environmental condition is already represented on the board/wall, students should use the term that is already there and connect that term to the new information they are adding to the board.
 - d. **As a facilitator, prompt students to consider the terms that have already been placed on the board and make new connections using markers or even new terms when possible.**

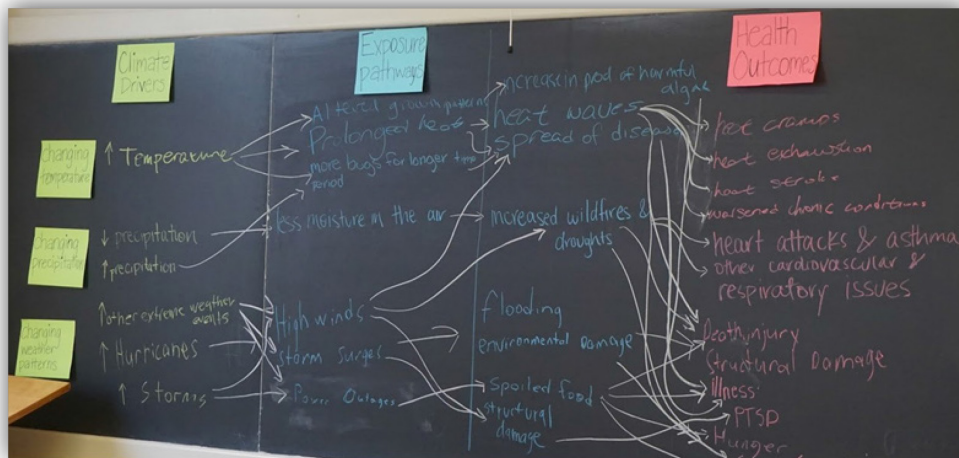
Teaching tip

Ask students to fill in a blank copy of the systems diagram provided on *PPT slide 13* (1 copy per student) to stay on task while others are presenting.

2. As the facilitator, it is important to check if the climate driver → environmental condition → environmental hazard → health outcome sequence identified is correct/logical and clearly depicted on the wall before inviting the next group to the board/wall.
3. Students will begin to see overlapping themes from the placement of the cards and connecting arrows. For example, flooding results in more than one environmental hazard (see slide 14) which, in turn, results in several potential health effects.

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4. The visual model created by the entire class might look chaotic, but it gives students an opportunity to see, both visually and intellectually, the complexity of the interactions between the environment and human health. They can see that one event leading to a change in climate (an increase in temperature) can result in many different environmental conditions (increase in heat index, drought) which in turn can generate many different environmental hazards. It is a complex system. NOTE: A systems diagram is provided for the teacher’s reference showing these connections (see PPT slide 15).

Systems-thinking Debrief

The goal of this activity is to create a visual representation of a complex system from the simple “cause-effect” models each group constructed. By building the larger model and answering the guiding questions provided below, students will begin to see the complex interconnected nature of our environment and its impact on human health, as well as the need to simplify in order to study and better understand the individual aspects of the system as well as their connections to each other.

5. Introduce systems thinking by asking the following questions:
- Is the climate change-human health system depicted here a simple or complex system?
Complex system –one environmental condition can lead to multiple hazards and multiple health outcomes; multiple climate drivers can interact to produce an environmental condition.
 - Is the climate change and human health system a physical system? A chemical system? A biological system?
Earth’s processes and its living inhabitants are systems within systems. The climate change and human health system is composed of physical, chemical, and biological systems that interact with each other and all interact to influence human health.
 - Are there any smaller (sub) systems within the climate-health system?
Yes, each sphere represents a system, together the systems make up the larger climate and health system. The human body is also a relevant system, and this is a good opportunity to emphasize that for each health outcome some individuals are going to be more vulnerable to climate impacts than others. Susceptibility can be influenced by factors such as age, genetic make-up, and socio-

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economic status. Chapter 9 of The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment provides more information on vulnerable populations with key findings that 1) vulnerability varies over time and is place-specific; 2) health impacts vary with age and life stage; 3) social determinants of health interact with climate factors to affect health risks.

- What is the value of a systems thinking approach to understanding the impact of climate on human health? (e.g., how does knowing about the bigger system help with the study of a smaller system, in this case the human body?)

Student answers may vary. Look for logical answers. Answers may include statements such as it helps identify potential variables/influences on the system; if you are not aware of the larger system you may reach erroneous conclusions or encounter unintended consequences. Taking a systems thinking approach can also be used to identify how communities (including schools) and the public health system will need to adapt to protect public health in response to a changing climate. You may want to use this as an opportunity to discuss how the diagram on the board relates to career interests of students; for example, there will be a need for informed public health professionals and adequate public health infrastructure along with informed city and regional planners and school administrators who can prepare schools and communities for these challenges and protect public health.

6. Refer to the visual model depicted on the classroom wall and ask students to consider the environmental condition for a single climate impact such as flooding (also see slide 11) and all of the potential health effects associated with it. **As the facilitator, you may choose to use a different colored marker or tape to denote the numerous health effects that can arise as a result of a single health threat such as flooding.**
7. Next, you will prompt the class to consider how scientists study the climate and health system; suggested questions are provided below but you may come up with your own questions depending on what you want to emphasize:
 - Why do you think scientists' study one part of a bigger system (e.g. why do scientists just study mosquito larval maturation in areas that have malaria or just study soil moisture and vegetation cover in areas that have malaria?)

Student answers may vary. Look for logical answers. Answers may include simple statements like "to make it easier." For example, there are many things that could be studied with respect to drought – weather patterns, occurrence, length of time, quality of water supplies, amount of water supplies, increase or decrease in specific pests, use of chemicals as a result of certain pests, etc. There is too much to look at if you tried to do it all. Thus, in order to study or understand a complex system it needs to be simplified. Simplifying a system can include looking at one part of the system, at a simple "cause and effect" level, or manipulating a variable within the system (experimentation).

- What do you think are the challenges for a scientist trying to study a smaller part of a bigger system? Consider the parts of a system and its boundaries.

Student answers may vary. Look for logical answers. Answers may include statements like: defining the boundaries (i.e. where do you stop? How much do you include in the study?) of the

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system; identifying and controlling for variables; keeping track of what enters and leaves the system; accurately identifying actions and reactions.

8. Conclude this activity by reiterating that the climate and health system is inherently complex. To better understand the system and assess how climate change is impacting human health it is essential to study its component parts while keeping interconnections in mind. The way scientists think about these interconnections is through the concept of a “system.” **But scientists and policy-makers also need to consider other systems connected to their system of interest as they advocate for strategies that are protective of human health.** For example, there is a push for use of biofuels to reduce our reliance on non-renewable petroleum-based sources. Doing that would solve one set of problems like oil spills and increasing independence from foreign oil, but it may introduce another set of problems in an interconnected system, such as using a food source as a fuel when the world’s population is increasing or the emissions from that alternative fuel may still contribute to air pollution or climate change. These interconnections will be explored further in the next activity.

Elaboration

During this solutions-focused activity, students elaborate on the concepts they have learned and make connections to other related concepts; this activity also promotes critical thinking by asking the students to evaluate solutions.

1. Reinforce to students that greenhouse gas emissions resulting from human activities are driving the climatic changes described in this module. Introduce students to the concept of **climate mitigation** (taking action to reduce or prevent the emissions of greenhouse gases) and prompt students to consider the **health co-benefits** that are conferred by such actions. For example, implementing renewable energy technologies means fewer greenhouse gas emissions and also reduced emissions of particulate matter, thus improving air quality which will translate into overall improved cardiopulmonary health. This improved health outcome is an example of a health co-benefit. It should also be emphasized that these health co-benefits may have maximum impact on already vulnerable populations (e.g. those with asthma).
2. Task students with considering how climate mitigation will impact the health outcomes described in their assigned reading(s). What are the relevant health co-benefits?
3. To further bring a solution focus to this module, tell students they will identify both personal (individual) and societal (collective) solutions that could be advanced to either prevent or manage the negative health outcome(s) that were the focus of their assigned reading(s). These solutions can be thought of as **adaptation strategies**. A list of possible adaptation strategies is included for each health topic in the *Answer Key*.
4. For their assigned reading(s), task students with identifying personal and societal adaptation strategies to:
 - a. **Prevent** the negative health outcome(s) from occurring in a changing climate; and/or
 - b. **Promote** preparedness/adaptation so that the negative health outcomes are less severe or occur to a lesser extent than without the intervention.

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Alternative

The class could vote on what they consider to be the most relevant human health impact for their community or state and in small groups come up with relevant adaptation strategies.

5. Students could also be asked to investigate local adaptation strategies that are either being planned or /implemented to address any health outcomes mentioned in their assigned reading(s).

Teaching Tip

Students may find that some strategies could be both a mitigation strategy and an adaptation strategy. For example, an urban forest can reduce greenhouse emissions (mitigation) and it can improve air quality (adaptation).

6. For each adaptation strategy identified have students evaluate the pros and cons of implementation. Some adaptation strategies may counter mitigation efforts! For example, building an urban cooling center for people to go to on extreme heat days will be associated with increased greenhouse gas emissions unless the center is powered by renewable energy.
7. Next, invite each group to share one or more of the adaptation strategies they identified to the class.

Evaluation

During this phase, students demonstrate what they have learned by extending their knowledge and practicing their science communication skills.

Depending on the amount of time devoted to assessment of student learning as result of this module, a range of evaluation options is provided and organized from least to most time intensive.

Option 1: Students **evaluate the health impacts at least one vector borne disease** from an economic, social and environmental perspective and present their analysis either in writing or as an in- class presentation that could include development of a poster, brochure, infographic, video, etc. Students may choose to write a letter to the editor of the local newspaper or to a policymaker outlining how their community should prepare for human health outcomes related to their reading(s).

Sample evaluation rubric

State specific health effect(s) cited in the reading(s)	10 points
Clearly describe the adaptation strategy being recommended	20 points
Evaluate strategy from an economic perspective (pros/cons)	20 points
Evaluate strategy from a social perspective (pros/cons)	20 points
Evaluate strategy from an environmental perspective (pros/cons)	20 points
End product clearly communicates information	10 points

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Option 2: Students **write a concluding paragraph** for their assigned reading that describes relevant health co-benefits of climate mitigation efforts and describes adaptation strategies that could be implemented to protect human health in light of climate change and resulting changing distributions of vector-borne diseases. In their writing students should demonstrate a clear understanding of the distinction between mitigation and adaptation; accurately describe the health co-benefits of mitigation efforts and the vulnerable populations that would especially benefit from these efforts; and describe at least one plausible adaptation strategy while mentioning the pros and cons of implementation.

Sample evaluation rubric

State specific health effect(s) cited in the reading(s)	10 points
Distinguish between mitigation and adaptation	20 points
Accurately describe health co-benefits of climate mitigation efforts	30 points
Clearly describe at least one adaptation strategy	20 points
Describe pros and cons of implementation of adaptation strategy	20 points

Option 3: Students **design a solution** to combat a specific climate-sensitive vector-borne disease that is relevant to their local community, state or region of the country. Students are prompted to use relevant epidemiologic and geoscience data to investigate their assigned vector-borne disease, find epidemiologic data to support their findings, identify vulnerable populations, investigate and evaluate options for adaptation or mitigation and make a recommendation. *Grading rubric is not provided but students should state the specific problem they are trying to solve and clearly describe their solution.*

Extend

Students could further extend their learning by either working to implement their resilience project in their school or community (if applicable) or by advocating for their adaptation strategy or resilience building project through civic engagement with relevant policymakers (students could partner with a local Government/Civics class).

Students could also extend their learning by participating, as small groups or individuals, in the [GLOBE Mosquito Habitat Mapper](#) citizen science program.

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Resources

Crimmins A, Balbus J, Gamble JL, Beard CB, Bell JE, Dodgen D, Eisen RJ, Fann N, Hawkins MD, Herrin SC, Jantarasami L, Mills DM, Saha S, Sarfim, MC, Trtanj J, Ziska L. 2016. The impacts of climate change on human health in the United States: a scientific assessment. US Global Change Research Program. Available at: <https://health2016.globalchange.gov/>

National Research Council. 2012. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, DC: The National Academies Press. <https://doi.org/10.17226/13165>.

Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R, Church JA, Clarke L, Dahe Q, Dasgupta P, Dubash NK, Edenhofer O, Elgizouli I, Field CB, Forster P, Friedlingstein P, Fuglestvedt J, Gomez-Echeverri L, Hallegatte S, Hegerl G, Howden M, Jiang K, Cisneros BJ, Kattsov V, Lee H, Mach KJ, Marotzke J, Mastrandrea MD, Meyer L, Minx J, Muluetta Y, O'Brien K, Oppenheimer M, Pereira JJ, Pichs-Madruga R, Plattner G-K, Portner H, Power SB, Preston B, Ravindranath NH, Reisinger A, Riahi K, Rusticucci M, Scholes R, Seyboth K, Sokona Y, Stavins R, Stocker TF, Tschakert P, van Vuuren D, van Ypersele J-P. 2014. Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. 151 pp. Available at: <https://www.ipcc.ch/report/ar5/syr/>

Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, Stewart BC, eds. 2018. Impacts, risks, and adaptation in the United States: Fourth National Climate Assessment. Volume II. US Global Change Research Program. doi:10.7930/NCA4.201. Available at: <http://nca2018.globalchange.gov/>

Online Resources

Intergovernmental Panel on Climate Change Fifth Assessment Report, Working Group II Chapter 11. Human Health: Impacts, Adaptation, and Co-Benefits https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf

Intergovernmental Panel on Climate Change Fifth Assessment Report, Working Group II Top Level Findings. https://www.ipcc.ch/site/assets/uploads/2018/03/WGIIAR5_SPM_Top_Level_Findings-1.pdf

NASA Global Climate Change: Vital Signs of the Planet <https://climate.nasa.gov/>

Next Generation Science Standards: For States, By States. 2013. NGSS Lead States. Washington, DC: The National Academies Press. www.nextgenscience.org/

NOAA's Global Climate Report: <https://www.ncdc.noaa.gov/sotc/global/202002>

NOAA's Global Temperature and Precipitation Maps

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<https://www.ncdc.noaa.gov/temp-and-precip/global-maps/>
Social Vulnerability Index
<http://svi.cdc.gov/>

US Global Change Research Program. 2009. Climate literacy: the essential principles of climate science. Available at:

https://pmm.nasa.gov/education/sites/default/files/article_images/Climate%20Literacy%20Booklet%20Hi-Res.pdf

Using Media to Enhance Teaching and Learning: What is a model?

<https://serc.carleton.edu/introgeo/models/WhatIsAModel.html>

WHO Climate and Health Global Overview

http://apps.who.int/iris/bitstream/10665/208855/1/WHO_FWC_PHE_EPE_15.01_eng.pdf?ua=1

WHO Health and Climate Assessment Country Profiles

<http://www.who.int/globalchange/resources/country-profiles/en/>

Multimedia

Feeling the Effects of Climate Change, PBS video (13-minute video)

<http://video.pbs.org/video/1939995285>

National Climate Assessment: Health chapter (appx 2-minute video)

<https://vimeo.com/92569617>

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Climate Change and Vector-borne disease | Graphic Organizer for Reading Comprehension

Answer KEY

Topic | Vector-Borne Diseases

Climate Driver(s)	Exposure pathway		Health Outcome(s)	Vulnerable Populations
	Environmental Condition	Environmental Hazard		
<i>Changes in extreme high and low temperatures</i>	<i>geographic range of disease vectors increases</i>	<i>increased vector-borne disease</i>	<i>increased incidence and prevalence of vector-borne and zoonotic diseases (e.g. malaria occurring at higher elevations)</i>	<i>persons in close proximity to vector habitat; persons with outdoor occupations; children ages 5-9 and adults ages 55- 59; males</i>
<i>↑ heavy precipitation events</i>	<i>Flooding</i>	<i>↑ standing water and vector habitat</i>	<i>Increased incidence and prevalence of vector-borne and zoonotic diseases</i>	<i>persons in close proximity to vector habitat; persons with outdoor occupations; low socioeconomic groups</i>
<i>altered weather patterns</i>	<i>drought</i>	<i>↓ some vector populations (e.g. mosquitoes require water)</i>	<i>↓ in some vector-borne diseases in some areas</i>	
<i>↑ temperature</i>	<i>Longer growing season; ↑ pests/vectors;</i>	<i>↑ use of pesticides</i>	<i>neurological diseases, cancer, developmental effects</i>	<i>outdoor occupations; low socioeconomic groups; children, pregnant women, and elderly</i>

Possible adaptation strategies

Personal: wear bug repellent, cover skin when outside during peak times of year, check for pests potentially carrying vector-borne diseases after prolonged time outdoors, make use of screens on windows and doors (barriers) and air conditioning to limit exposure to vector-borne pathogens; bednets; remove standing water.

Societal: educate vulnerable populations on how to limit exposure to vector-borne diseases, provide air-conditioned work conditions, vector control and public health practices, change landscape.

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Note: A discussion of the specific strategies being implemented to reduce exposure to the Zika virus would be timely as students may have heard many of these strategies communicated to people living in and traveling to areas with active Zika virus transmission.