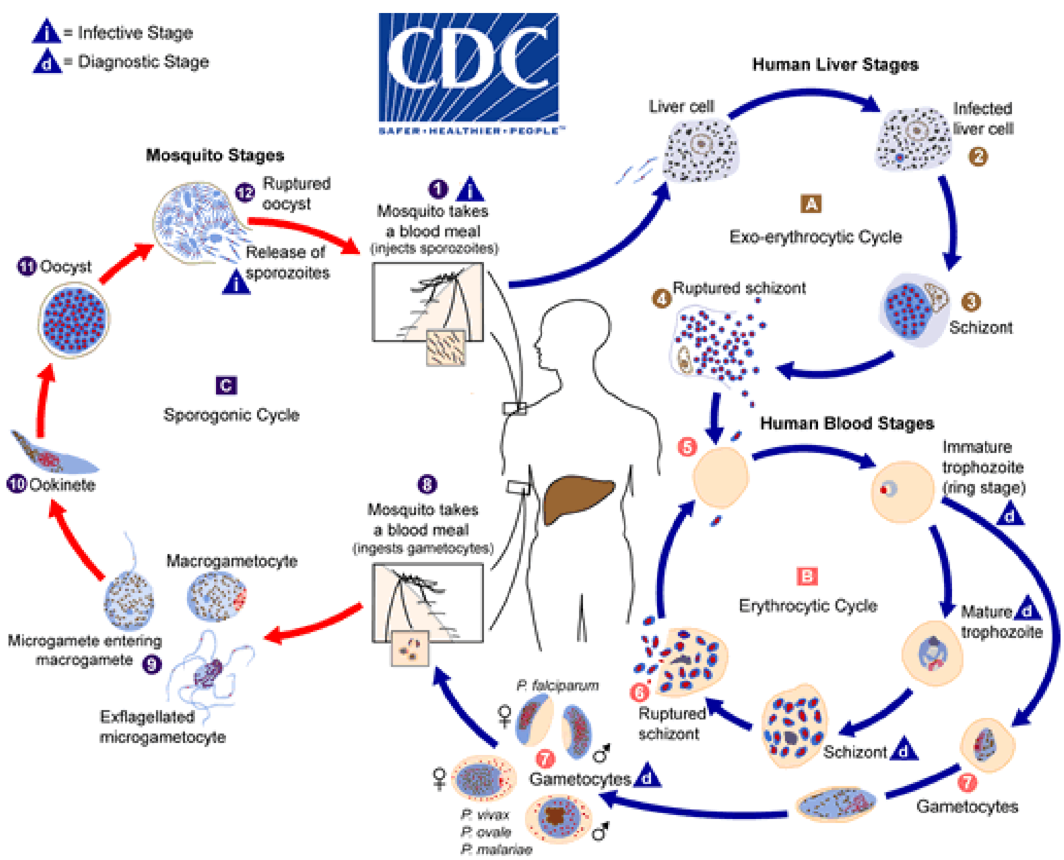
Using Linear Regression to Explore Environmental Factors Affecting Vector-borne Diseases

STUDENT ACTIVITY

Malaria and Temperature

Malaria is a mosquito-borne disease caused by a *Plasmodium* parasite. People with malaria often experience fever, chills, and flu-like illness. Left untreated, they may develop severe complications and die. Most cases of malaria occur in children in the African Region. The signs and symptoms of malaria typically begin 8–25 days following infection, but may occur later in those who have taken antimalarial medications as prevention. Initial manifestations of the disease, common to all malaria species, are similar to flu-like symptoms. Climate is a key determinant of both the geographic distribution and the seasonality of malaria. Without sufficient rainfall, mosquitoes cannot survive, and if not sufficiently warm, parasites cannot survive in the mosquito. The natural history of malaria involves cyclical infection of humans and female *Anopheles* mosquitoes. In humans, the parasites grow and multiply first in the liver cells and then in the red cells of the blood. In the blood, successive broods of parasites grow inside the red cells and destroy them, releasing daughter parasites ("merozoites") that continue the cycle by invading other red cells (CDC 2020).



For as big of a problem that malaria is in some parts of the world, there are a few environmental factors that could perhaps make these effects more severe and increase the prevalence of malaria and other mosquito-borne diseases worldwide. While mostly being associated with temperature fluctuations, large-scale events like climate change can also impact precipitation patterns. As surface temperatures increase in certain areas across the globe, so do evaporation rates and the water-holding capacity of the atmosphere, leading to increases in atmospheric moisture (Trenberth 1998). This could heavily impact the water cycle by influencing both the amount and frequency of precipitation, and perhaps contribute to the creation of powerful storms in the process (Trenberth 1998). As the number of rain events becomes more intense and the amount and duration of moisture and standing water increases, mosquitoes have more of an opportunity to breed and increase their already rapidly growing numbers. In turn, there is more of a chance that diseases like malaria, Zika, and others could become more prevalent, especially in the tropics where storms and sea-level rise are the most severe.

Introduction Questions

1. Describe the mode of transmission for Malaria to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries Malaria.
3. Describe environmental conditions that could contribute to the transmission of Malaria to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the occurrence of Malaria and temperature. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. How many Malaria cases should there be if the temperature is 87.6? Is this an example of extrapolation or interpolation?
9. What should the temperature be if there are 150 cases of Malaria?
10. What is the residual of the cases of Malaria in August?

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.

2. Are there any other environmental factors that could influence the occurrence of Malaria? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of Malaria)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

References:

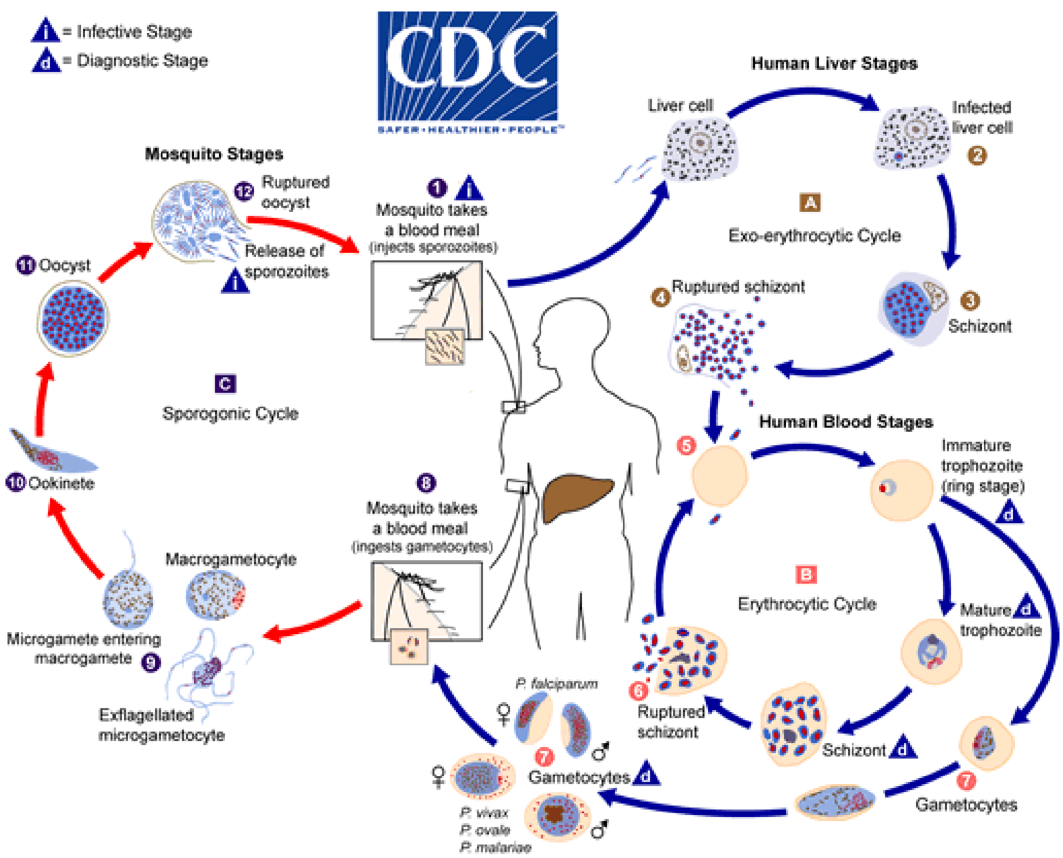
Center for Disease Control. Parasites - Malaria. (24 April 2020). Retrieved June 1, 2020, from https://www.cdc.gov/parasites/malaria/index.html

Trenberth, K.E. 1998. Atmospheric Moisture Residence Times and Cycling: Implications for Rainfall Rates and Climate Change. *Climatic Change* 39: 667–694. https://doi.org/10.1023/A:1005319109110

World Health Organization. Malaria. (14 January 2020). Retrieved June 1, 2020, from https://www.who.int/news-room/fact-sheets/detail/malaria

Malaria and Rainfall

Malaria is a mosquito-borne disease caused by a *Plasmodium* parasite. People with malaria often experience fever, chills, and flu-like illness. Left untreated, they may develop severe complications and die. Most cases of malaria occur in children in the African Region. The signs and symptoms of malaria typically begin 8–25 days following infection, but may occur later in those who have taken antimalarial medications as prevention. Initial manifestations of the disease, common to all malaria species, are similar to flu-like symptoms. Climate is a key determinant of both the geographic distribution and the seasonality of malaria. Without sufficient rainfall, mosquitoes cannot survive, and if not sufficiently warm, parasites cannot survive in the mosquito. The natural history of malaria involves cyclical infection of humans and female *Anopheles* mosquitoes. In humans, the parasites grow and multiply first in the liver cells and then in the red cells of the blood. In the blood, successive broods of parasites grow inside the red cells and destroy them, releasing daughter parasites (“merozoites”) that continue the cycle by invading other red cells.



For as big of a problem that malaria is in some parts of the world, there are a few environmental factors that could perhaps make these effects more severe and increase the prevalence of malaria and other mosquito-borne diseases worldwide. While mostly being associated with temperature fluctuations, large-scale events like climate change can also impact precipitation patterns. As surface temperatures increase in certain areas across the globe, so do evaporation rates and the water-holding capacity of the atmosphere, leading to increases in atmospheric moisture (Trenberth 1998). This could heavily impact the water cycle by influencing both the amount and frequency of precipitation, and perhaps contribute to the creation of powerful storms in the process (Trenberth 1998). As the number of rain events becomes more intense and the amount and duration of moisture and standing water increases, mosquitoes have more of an opportunity to breed and increase their already rapidly growing numbers. In turn, there is more of a chance that diseases like malaria, Zika, and others could become more prevalent, especially in the tropics where storms and sea-level rise are the most severe.

Introduction Questions

1. Describe the mode of transmission for Malaria to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries Malaria.
3. Describe environmental conditions that could contribute to the transmission of Malaria to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the occurrence of Malaria and rainfall. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. How many Malaria cases should there be if the monthly rainfall is 20 cm? Is this an example of extrapolation or interpolation?
9. What should the amount of rainfall be if there are 175 cases of Malaria?
10. What is the residual of the cases of Malaria in August?
11. Describe a potential limitation to your data set or the linear regression model.

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.

2. Are there any other environmental factors that could influence the occurrence of Malaria? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of Malaria)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

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Center for Disease Control. Parasites - Malaria. (24 April 2020). Retrieved June 1, 2020, from https://www.cdc.gov/parasites/malaria/index.html

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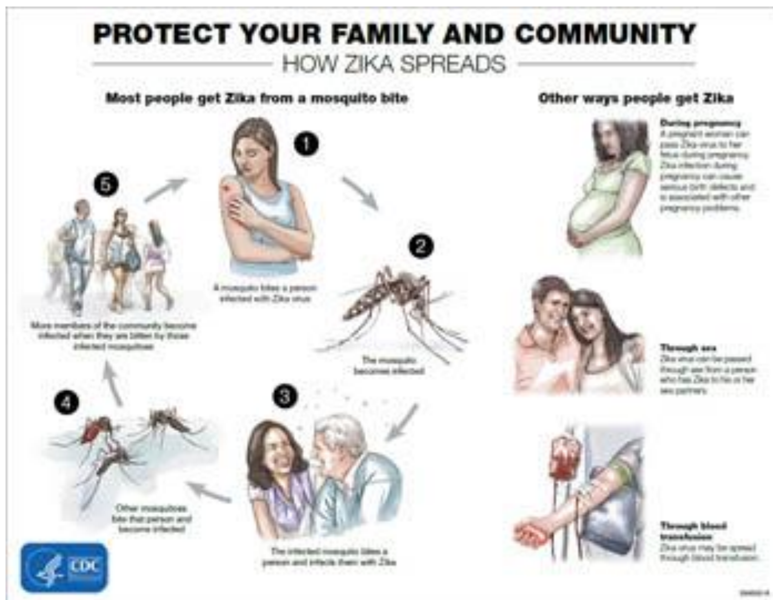
World Health Organization. Malaria. (14 January 2020). Retrieved June 1, 2020, from https://www.who.int/news-room/fact-sheets/detail/malaria

Zika

Zika virus disease is a mosquito-borne illness that has been seen in Africa, Asia, North America, and South America. Zika virus infections are often asymptomatic, but they can be accompanied by mild symptoms such as fever, rash, headache, conjunctivitis, malaise, and joint and muscle pain. More serious effects of the disease are seen in developing babies, where Zika has been associated with birth defects of the brain and skull, namely microcephaly.

The Zika virus is most often transmitted by the bite of an *Aedes* mosquito, but it can also be transmitted from mother to fetus, through a blood transfusion, or unprotected sex. The virus can replicate inside of the mosquito and be injected into a human when the mosquito feeds. Since *Aedes* mosquitoes serve as vectors for the Zika virus, Zika disease transmission (to humans) is closely linked to the range and density of the *Aedes* mosquitoes that can carry it. The *Aedes* mosquitoes thrive in climates that range from temperate to tropical and have displayed an increasingly broad range as a result of global changes in climate. Temperature and precipitation can affect the feeding habits, reproductive habits, and offspring survival of the *Aedes* mosquitoes. To reproduce, female mosquitoes deposit eggs in standing water, and the eggs hatch when fully submerged. While the eggs may resist desiccation, the larvae rely on warm and wet environments to develop.



There are a few environmental factors that could perhaps make these effects more severe and increase the prevalence of malaria and other mosquito-borne diseases worldwide. While mostly being associated with temperature fluctuations, large-scale events like climate change can also impact precipitation patterns. As surface temperatures increase in certain areas across the globe, so do evaporation rates and the water-holding capacity of the atmosphere, leading to increases in atmospheric moisture (Trenberth 1998). This could heavily impact the water cycle by influencing both the amount and frequency of precipitation, and perhaps contribute to the creation of powerful storms in the process (Trenberth 1998). As the number of rain events becomes more intense and the amount and duration of moisture and standing water increases, mosquitoes have more of an opportunity to breed and increase their already rapidly growing numbers. In turn, there is more of a chance that diseases like malaria, Zika, and others could become more prevalent, especially in the tropics where storms and sea-level rise are the most severe.

Introduction Questions

1. Describe the mode of transmission for Zika virus to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries Zika virus.
3. Describe environmental conditions that could contribute to the transmission of Zika virus to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the occurrence of Zika virus and temperature. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. What should the rate of Zika cases be if the temperature is 95℃? Is this an example of extrapolation or interpolation?
9. What should the temperature be if there are 10,000 cases of Zika virus in a country with a population of 6 million people?
10. What is the residual of the cases of Zika in Guatemala?

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.
2. Are there any other environmental factors that could influence the occurrence of Zika? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of Zika)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

References:

Reinhold, J.M., Lazzari, C.R., Lahondère, C. 2018. Effects of the Environmental Temperature on Aedes aegypti and Aedes albopictus Mosquitoes: A Review. *Insects* 9(4):158.

Sikka, V., Chattu, V.K., Popli, R.K., Galwanker, S.C., Kelkar, D., Sawicki, S.G., Stawicki, S.P., Papadimos, T.J. 2016. The Emergence of Zika Virus as a Global Health Security Threat: A Review and a Consensus Statement of the INDUSEM Joint working Group (JWG). *Journal of Global Infectious Diseases* 8(1):3-15. https://dx.doi.org/10.4103%2F0974-777X.176140.

Trenberth, K.E. 1998. Atmospheric Moisture Residence Times and Cycling: Implications for Rainfall Rates and Climate Change. *Climatic Change* 39, 667–694. https://doi.org/10.1023/A:1005319109110.

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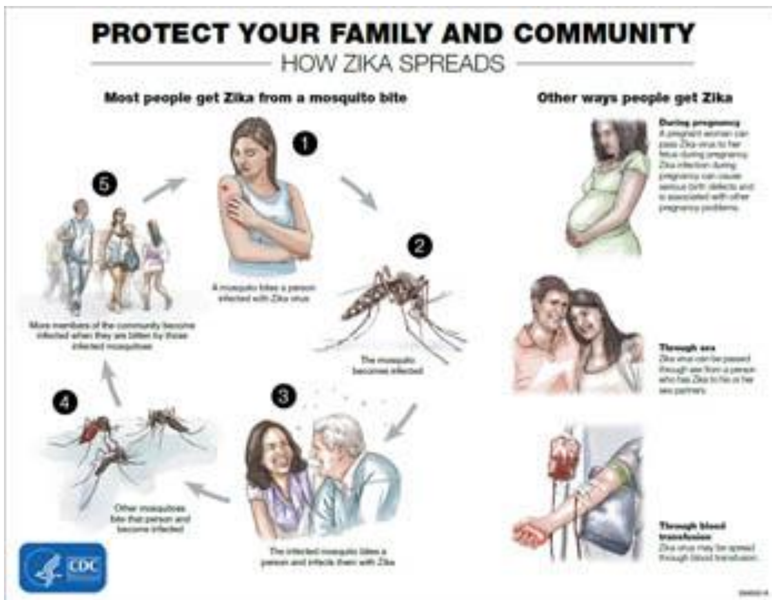
The Zika virus is most often transmitted by the bite of an *Aedes* mosquito, but it can also be transmitted from mother to fetus, through a blood transfusion, or unprotected sex. The virus can replicate inside of the mosquito and be injected into a human when the mosquito feeds. Since *Aedes* mosquitoes serve as vectors for the Zika virus, Zika disease transmission (to humans) is closely linked to the range and density of the *Aedes* mosquitoes that can carry it. The *Aedes* mosquitoes thrive in climates that range from temperate to tropical and have displayed an increasingly broad range as a result of global changes in climate. Temperature and precipitation can affect the feeding habits, reproductive habits, and offspring survival of the *Aedes* mosquitoes. To reproduce, female mosquitoes deposit eggs in standing water, and the eggs hatch when fully submerged. While the eggs may resist desiccation, the larvae rely on warm and wet environments to develop.



There are a few environmental factors that could perhaps make these effects more severe and increase the prevalence of malaria and other mosquito-borne diseases worldwide. While mostly being associated with temperature fluctuations, large-scale events like climate change can also impact precipitation patterns. As surface temperatures increase in certain areas across the globe, so do evaporation rates and the water-holding capacity of the atmosphere, leading to increases in atmospheric moisture (Trenberth 1998). This could heavily impact the water cycle by influencing both the amount and frequency of precipitation, and perhaps contribute to the creation of powerful storms in the process (Trenberth 1998). As the number of rain events becomes more intense and the amount and duration of moisture and standing water increases, mosquitoes have more of an opportunity to breed and increase their already rapidly growing numbers. In turn, there is more of a chance that diseases like malaria, Zika, and others could become more prevalent, especially in the tropics where storms and sea-level rise are the most severe.

Introduction Questions

1. Describe the mode of transmission for Zika to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries Zika virus.
3. Describe environmental conditions that could contribute to the transmission of Zika virus to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the occurrence of Zika virus and rainfall. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. What should the rate of Zika cases be if there was an average of 81 in. of rainfall? Is this an example of extrapolation or interpolation?
9. What would the average rainfall be if there are 10,000 cases of Zika virus in a country with a population of 6 million people?
10. What is the residual of the cases of Zika in Guatemala?

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.
2. Are there any other environmental factors that could influence the occurrence of Zika? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of Zika)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

References:

Reinhold, J.M., Lazzari, C.R., Lahondère, C. 2018. Effects of the Environmental Temperature on Aedes aegypti and Aedes albopictus Mosquitoes: A Review. *Insects* 9(4):158.

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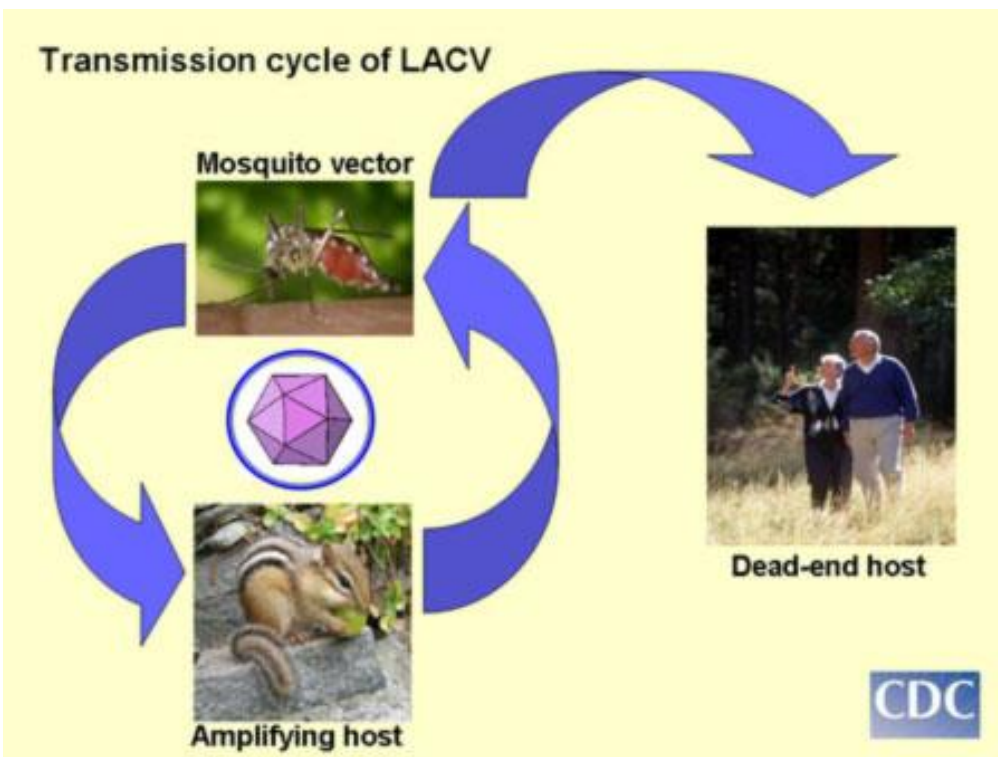
Trenberth, K.E. 1998. Atmospheric Moisture Residence Times and Cycling: Implications for Rainfall Rates and Climate Change. *Climatic Change* 39, 667–694. https://doi.org/10.1023/A:1005319109110.

La Crosse Virus

Although originally found in La Crosse, Wisconsin, La Crosse encephalitis is primarily diagnosed in southern Appalachia. This encephalitis, coming from infection with La Crosse virus, typically affects younger children with the strongest prevalence in male children between the ages of 5-9. This infection generates symptoms such as headache, fever, behavioral changes, and seizures. La Crosse virus frequently goes undiagnosed and can cause neurological deficits.

This virus is transmitted via the bite of an infected *Aedes* mosquito and is maintained in nature through a zoonotic cycle between the vectors and small mammals, like chipmunks or squirrels. Humans are dead-end hosts for this virus and cannot transmit the virus to other susceptible hosts.

Precipitation (accumulated over the previous 7 days in inches) and temperature in Celsius usually have effects on mosquito populations in life stage transitions and in oviposit rates (of eggs), which can affect the spread of this virus. The mosquito data (number of mosquitoes, population level averaged over traps from 8 sites where the virus had been present) presented here were collected in Knox County, TN, in 2013.



Transmission cycle of La Crosse Virus https://www.cdc.gov/lac/tech/transmission.html

Introduction Questions

1. Describe the mode of transmission for La Crosse Virus to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries La Crosse Virus.
3. Describe environmental conditions that could contribute to the transmission of La Crosse Virus to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the mosquito population level and temperature. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. What is the expected mosquito population level when the temperature is 20 Celsius? Is this an example of extrapolation or interpolation?
9. What should the approximate temperature be if the mosquito population level is 30?
10. What is the residual of the mosquito population level when the temperature is 23.06?

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.
2. Are there any other environmental factors that could influence the occurrence of La Crosse virus? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of LaCrosse virus)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

References:

Erwin, P.C., Jones, T.F., Gerhardt, R.R., Halford, S.K., Smith, A.B., Patterson, L.E., Gottfried, K.L., Burkhalter, K.L., Nasci, R.S., and Schaffner, W. 2002. La Crosse encephalitis in eastern Tennessee: clinical, environmental, and entomological characteristics from a blinded cohort study. *American Journal of Epidemiology* 155:11, 1060-1065. https://doi.org/10.1093/aje/155.11.1060

Ghatak, M., Urcuyo, J., Wise, P., Fryxell, R. and Lenhart, S. 2019. Modeling the Average Population of La Crosse Vectors in Knox County, Tennessee, *Letters in Biomathematics*, 6:1, 20-31.

Urquhart, A.C., Paulsen, D., Moncayo, A., and Fryxell, R.T.. 2016. Evaluating surveillance methods for arboviral vectors of La Crosse virus and West Nile virus of southern Appalachia. *Journal of American Mosquito Control Association* 32: 24-33. https://doi.org/10.2987/8756-971x-32.1.24

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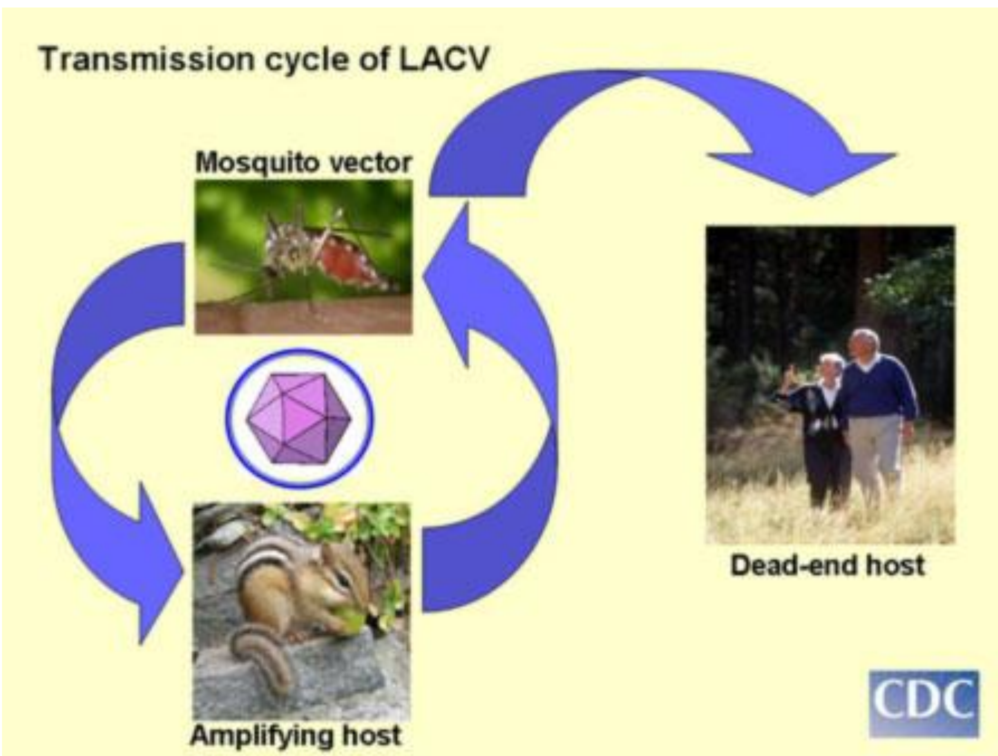
Although originally found in La Crosse, Wisconsin, La Crosse encephalitis is primarily diagnosed in southern Appalachia. This encephalitis, coming from infection with La Crosse virus, typically affects younger children with the strongest prevalence in male children between the ages of 5-9. This infection generates symptoms such as headache, fever, behavioral changes, and seizures. La Crosse virus frequently goes undiagnosed and can cause neurological deficits.

This virus is transmitted via the bite of an infected *Aedes* mosquito and is maintained in nature through a zoonotic cycle between the vectors and small mammals, like chipmunks or squirrels. Humans are dead-end hosts for this virus and cannot transmit the virus to other susceptible hosts.

Precipitation (accumulated over the previous 7 days in inches) and temperature usually have effects on mosquito populations in life stage transitions and in oviposit rates (of eggs), which can affect the spread of this virus. The mosquito data (population level averaged over traps from 8 sites where the virus had been present) presented here were collected in Knox County, TN, in 2013.



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Introduction Questions

1. Describe the mode of transmission for La Crosse Virus to humans.
2. Describe the habitat and optimal environmental conditions for the vector that carries La Crosse Virus.
3. Describe environmental conditions that could contribute to the transmission of La Crosse Virus to humans. Explain your reasoning.
4. Before viewing the data below, come up with a hypothesis regarding the relationship between the mosquito population level and temperature. Explain your reasoning.

Graphing and Data Analysis

1. You will create a scatter plot for the data above. Before doing so, answer the following questions.
    a. What is the dependent variable in this data set?
    b. What is the independent variable?
    c. What variable will you use on the X-axis?
    d. What variable will you use on the Y-axis?
2. After discussing your responses for the question above, make a scatterplot of the data. Describe the relationship between the data.
3. Calculate the correlation coefficient.
4. What does the value of the correlation coefficient suggest about the relationship between these two variables? Discuss the strength and direction of the correlation.
5. Calculate the line of best fit.
6. Interpret the slope from the model.
7. Is it possible to interpret the y intercept from the model? Why or why not?
8. What is the expected mosquito population level when the precipitation level is 2.0? Is this an example of extrapolation or interpolation?
9. What should the approximate precipitation level be if the mosquito population level is 30?
10. What is the residual of the mosquito population level when the precipitation level is 1.3?

Conclusion Questions

1. Does the data appear to support your hypothesis? Explain your reasoning.
2. Are there any other environmental factors that could influence the occurrence of La Crosse virus? List them and describe how.
3. How could climate change influence the life stages (development) and habitat of the mosquitos (and, thus, the occurrence of La Crosse virus)?
4. There are many other human health issues that could be exacerbated by climate change. Provide an example.

References:

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Co-Authors (Alphabetical): Andy Adams, Jessica Adams, John Bray, Tami Imbierowicz, Suzanne Lenhart, Breonna Martin. All co-authors contributed equally. This material is based upon work supported by the National Science Foundation under Grant No. 1919613. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.