Exploration

Research Question: *What effect does the type of vegetation (trees, shrubs, flowers, and none) have on mosquito abundance, as measured by the number of larvae found in oviposition traps, in a local park?*

Background Information:

Figure 1: Mosquito Larvae[1]

Mosquitoes are winged insects that originate from the family Culicidae. They have a life cycle that consists of four stages: egg, larva, pupa, and adult. First, gravid female mosquitoes lay their eggs in a source of stagnant water. The eggs are laid one at a time, or they form rafts by attaching to each other. After about 48 hours, the eggs hatch into larvae, as shown in Figure 1[1], which live in the water and consume organic matter and microbes. The larvae shed their skin four times, growing into a larger one; by the fourth shedding, which occurs after seven to ten days, the larvae turn into pupae. While the pupae are in a resting and non-feeding stage, they are mobile and responsive to environmental changes, such as light. Finally, after another two to three days, an adult mosquito emerges by breaking through the pupal skin.[2]

In this breeding process, there are many factors that attract mosquitoes towards a specific breeding site. However, one of the most important factors is the presence and type of vegetation. Vegetation is significant, as it provides a resting habitat for mosquitoes.[3] Also, vegetation is a source of nutrients for mosquitoes; mosquitoes need sugar in order to survive and is able to receive it by consuming plant juices, sap, and nectar. According to a study conducted by Weigdong Gu and Robert Novak from University of Alabama, Günter Müller and Yosef Schlein from Hebrew University, and John C. Beier from University of Miami, which investigated mosquitoes from the genus *Aedes* and *Culex*, the number of female mosquitoes was four times as much in a sugar-rich site than in a sugar-poor one. This is because sugar feeding was higher in the sugar-rich site, so a larger population of female mosquitoes were able to survive long enough to reproduce.[4] In addition, in order for female mosquitoes to lay eggs, they consume some proteins, which can be obtained by sucking on the blood of animals, such as small mammals or birds. Hence, areas surrounded with vegetation tend to attract a wide variety of animals that could serve as hosts for these mosquitoes. In fact, female mosquitoes use their proboscis, an elongated sucking mouthpiece, to consume the sugars and blood, and then they store both items in their fore-gut. However, their foregut has two parts: a frontal section for sugar storage and a rear section for the blood.[5]

The purpose of this investigation is to explore the correlation between the type of vegetation source and mosquito abundance. In this exploration, I will measure the number of mosquito larvae found in mosquito traps positioned in proximity to four different vegetation sites: trees, shrubs, ground flowers, and barren (no vegetation). For this investigation, to distinguish between trees and shrubs, I will use similar standards that were listed in a study conducted by researchers Allison Gardner, Tavis Anderson, Gabriel Hamer, Dana Johnson, Kate Varela, Edward Walker, and Marilyn Ruiz; this study focused on shrubs that were shorter than 1 meter and it established a positive correlation between the presence of

---

1 "Mosquito Larvae," MDC Discover Nature (Missouri Department of Conservation), accessed December 3, 2019, https://nature.mdc.mo.gov/discover-nature/field-guide/mosquito-larvae)

2 The American Mosquito Control Association. "Life Cycle." Life Cycle - American Mosquito Control Association, n.d. https://www.mosquito.org/page/lifecycle.

3 Chowell, G., K. Mizumoto, J. M. Banda, S. Poccia, and C. Perrings. "Assessing the Potential Impact of Vector-Borne Disease Transmission Following Heavy Rainfall Events: a Mathematical Framework." *Philosophical Transactions of the Royal Society B: Biological Sciences* 374, no. 1775 (June 2019): 20180272. https://doi.org/10.1098/rstb.2018.0272.

4 Gu, Weidong, Günter Müller, Yosef Schlein, Robert J. Novak, and John C. Beier. "Natural Plant Sugar Sources of Anopheles Mosquitoes Strongly Impact Malaria Transmission Potential." *PLoS ONE* 6, no. 1 (2011). https://doi.org/10.1371/journal.pone.0015996.

5 Capinera, John L., ed. *Encyclopedia of entomology*. Springer Science & Business Media, 2008.

mosquitoes and vegetation.[6] Similarly, for my experiment, I am identifying shrubs with a height of less than 1 meter and anything taller than that as a tree. Furthermore, I will build oviposition mosquito traps, which are particularly effective in attracting gravid female mosquitoes, and will check these traps every 4 days. With this, I could establish the type of vegetation conditions mosquitoes endemic to the Houston area, such as *Aedes aegypti, Aedes albopictus, Anopheles quadrimaculatus,* and *Culex pipiens,* all known transmitters of diseases like Malaria and West Nile Virus, prefer.[7]

As a resident of the 5th nationally ranked worst mosquito cities, Houston, Texas, and as a person who has seen family members suffer from mosquito-borne diseases, such as malaria, dengue fever, and yellow fever, I am no stranger to mosquitoes. In 2017, Hurricane Harvey hit my city, causing a boom in the mosquito population. In some flooded areas, there was even double the normal amount of mosquito larvae found.[8] This led to a higher risk of contracting mosquito-borne illnesses among the Houston population. Hence, with this research question, I want to gain insight into the conditions that spur mosquito breeding and thus increase the risk of contracting mosquito-borne infectious diseases. I decided to learn more about the relationship between vegetation and mosquitoes due to mosquitoes' dependence on the vegetation source and how the investigation's results could be used to reduce the mosquito population in urban areas, such as Houston.

<u>*Hypothesis:*</u> There will be a higher mosquito abundance in sites that contain trees, shrubs, or flowers in comparison to barren sites. According to an Ohio State University study conducted Dr. Woodbridge A. Foster, this is because sites with vegetation provide more resources and nutrients to nourish female mosquitoes, increasing their chances of survival and likelihood of reproducing. Also, surrounding the vegetation will be small mammals or birds that could be potential hosts for female mosquitoes, where they could receive a blood meal.[9] However, the traps positioned near ground flowers will likely have the largest number of mosquito larvae, due to the presence of sugar-rich nectar in flowers. Flowers provide a steady supply of sucrose, glucose, and fructose, and given their smaller height (relative to trees), nectar in flowers is more accessible to these mosquitoes, most of which prefer lower elevations.

<u>*Variables:*</u>

	Variable Measured	**Method to Adjust & Record**
Independent	Type of Vegetation: Trees (*Chamaerops humilis*), Shrubs (*Elaeagnus pungens*), Ground Flowers (*Rosa pendulina*), No Vegetation	Position mosquito traps within 5 to 10 centimeters of the vegetation type
Dependent	Number of Mosquito Larvae	The number of larvae is recorded from the water samples in the oviposition traps and are viewed with an LED clip-on microscope

---

6 Allison M Gardner et al., "Terrestrial Vegetation and Aquatic Chemistry Influence Larval Mosquito Abundance In Catch Basins, Chicago, USA," *Parasites & Vectors* 6, no. 1 (January 11, 2013), https://doi.org/10.1186/1756-3305-6-9)

7 Martin Reyna Nava and Mustapha Debboun, "A Taxonomic Checklist of the Mosquitoes of Harris County, Texas," *Journal of Vector Ecology* 41, no. 1 (June 27, 2016): pp. 190-194.

8 Olena, Abby. "After Harvey, Mosquito Control Ramps Up." The Scientist Magazine®, September 15, 2017. https://www.the-scientist.com/daily-news/after-harvey-mosquito-control-ramps-up-30917.

9 Woodbridge A Foster, "Mosquito Sugar Feeding and Reproductive Energetics," *Review of Entomology* (1995).

Controlled Variables	Variable Measured	Method to Control
	Location	While each mosquito trap will be positioned near different vegetation types, they will be located within a 0.5 kilometer radius of each other in the local park. Because the general location is the same, any weather changes, such as temperature, will be experienced by all traps.
	Amount of Sunlight	The amount of sunlight that a mosquito trap receives influences mosquito abundance. Therefore, because mosquitoes prefer a shady environment, I will be placing all of my traps in locations with little to no sunlight. The no vegetation traps, in particular, will be placed outside near the restrooms, as they have a covering that provides shade and and are located away from the surrounding vegetation.
	Mosquito Trap	The type of mosquito trap that was built was an oviposition trap. All of the traps will be built in the same exact way, including using the same brand and color for long black socks. The color black is important, as it absorbs more heat, creating favorable hot and humid conditions that attract mosquitoes.
	Trap Bait	Alfalfa pellets are used as trap bait to increase the mosquitoes' attraction to the trap. The same bait is used for all traps, as well as the same amount (4 pellets per trap). Each alfalfa pellet is 3 grams.
	Water Source	The source of water, a local swamp, placed in all traps is constant. This source will contain rank and stagnant water that mosquitoes favor, increasing its attraction to the trap. A visual check of the water is necessary to ensure that there is no contamination (no presence of mosquito eggs or larvae).
	Time	The time at which the data from all of the traps was recorded was constant. They were checked every four days at 5:30 PM. This time for data collection must be kept constant to ensure that no one trap had more time than others for mosquitoes to lay eggs.

Materials:

- 12 22 oz. Black Stadium Cups
- 6 Pairs of Black Socks (Size Large)
- 18 Gauge Wire
- Walt's Organic Alfalfa Pellets (2 lb)
- Metal Screen: 2 Pack TORIS Stainless Steel Woven Wire Mesh (11.8" x 8.2")
- Max Cordless Drill with a ¼ inch Drill Bit

- Silicone Glue
- Wire Cutters
- Universal Clip Type LED Cell Phone Microscope (80X-120X)
- Petri Dish

Safety Considerations:

- Tools, such as drills and wire cutters, were used when building oviposition traps. Hence, it is important to be mindful while utilizing these tools to avoid cutting oneself, and this can be done by putting gloves on.
- While recording data related to mosquitoes, it is necessary to dress appropriately. Long pants and shirt should be worn, as well as closed-toed shoes. This will provide protection from insect bites while walking through different types of vegetation.
- While conducting this experiment, ecological concerns must also be taken into account. This investigation does not disturb the surrounding ecosystem, as the mosquitoes are not harmed while performing the experiment. The mosquito eggs simply hatch and grow into larvae within a confined space for a period of a few days before they are released into the environment. The traps are simply placed next to vegetation or in an area with no vegetation, and hence, this doesn't damage the surrounding area.

Procedure:

There are two steps in this investigation: Building oviposition traps and positioning them and recording data.

First, the following is the procedure for building oviposition traps:

1. Drill two holes in the 22 oz. black stadium cup. One hole should be placed close to the top of the cup, and it must be wide enough to fit an 18 gauge wire. The second hole should be .25 inches wide, and it should be positioned at about 80% of the way up the cup. There should be two sets of these holes on opposing sides of the stadium cup.
2. Using silicone glue, paste the toe of the black crew sock to the bottom of the stadium cup. The color black is specifically vital for the socks used in these traps, since mosquitoes are attracted towards the heat that these darker colors absorb.
3. Use the top of the stadium cup as a template to trace it onto the metal screen sheet. Then, cut the circles of metal screening.
4. Next, cut the 18 gauge wire into a 1.5 feet long piece.
5. Stretch the sock to cover the mouth of the stadium cup. Stretch it around the bottom, too. The sock needs to be taut around the cup, so be sure to cut any excess sock at the bottom.
6. Place the circular metal screen into the top of the cup. This screen must be pressed into the cup, to the point where the screen is right above the .25 inch hole drilled. This can be done by pressing the screen at the center until half of the screen is at the appropriate height, and then, rotating the cup and pressing down the other half. This will allow the uneven edges of the screen to hold onto the stadium cup. The purpose of this screen is to allow the mosquito larvae to live in the water in the trap, but prevent them from escaping once they have become adults.
7. Then, insert a piece of 18 gauge wire through the two small holes near the top of the cup, and twist them to keep it in place. With this, the trap can be carried or hung anywhere.
8. Dip the trap into stagnant and rank water from a local swamp. The .25" hole should drain any excess water. By dipping the trap, the sock will become moist, which will attract mosquitoes.
9. Add 4 alfalfa pellets into the water to use as bait, as well as to keep the water rank.
10. Repeat the following steps until 12 oviposition traps are constructed.

Next, the following is the procedure for the positioning of the traps and the recording of data.

1. Place three mosquito traps for each vegetation type, as shown in Figure 2[10].
2. When placing a trap near a tree, flower, or shrub, ensure that it is placed under or behind the vegetation type and is no more than 5-10 centimeters of the vegetation, as shown in Figure 3, so that the trap is located in a shady environment that attracts mosquitoes.
3. Check mosquito traps every four days at 5:30 PM in the evening.
4. To check the mosquito trap for larvae, pour a sample of water from the trap onto the petri dish. All of the water in each trap was sampled and poured onto the petri dish. After draining the water, the trap was refilled for the next trial using the same water source.
5. Next, attach the microscope to a phone and open a camera app
6. Cover the petri dish with a clear cover and lay the microscope flat on the cover's surface.
7. After adjusting and focusing the microscope, move it around and search for mosquito larvae. Slowly move the microscope across the petri dish from left to right in order to avoid double counting larvae.
8. Before placing the next water sample on the petri dish, clean the petri dish after each observation.
9. Record data and repeat the following steps.

Figure 2: Map of Mosquito Traps in Park[10]

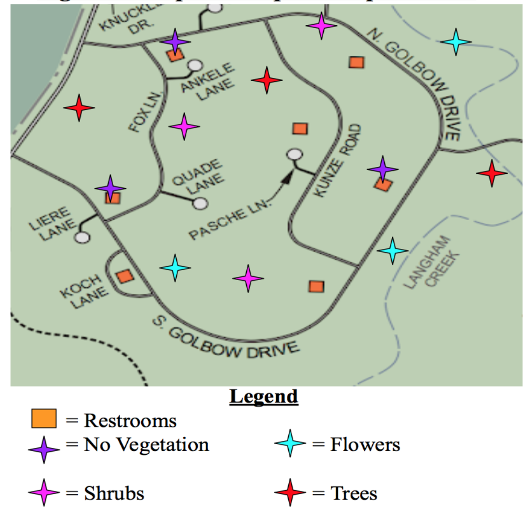


Figure 3: Picture of Traps in Each Vegetation Site

Data and Analysis:

Qualitative Observations:

The weather wasn't consistent during the period of 20 days. For the first four days, the weather was warm, with an average day temperature of 25 °C (range is 22 to 27 °C). Then, during the next four days, the weather was still warm, with the average temperature dropping only by 2°C to 23 °C (21 to 27 °C). However, there was a sudden change in the weather during the third set of four days, when the skies became cloudy and it rained over the next two to three days. In this period, the average temperature dropped to 9 °C (6 to 12 °C), and it rained a total of 0.25 inches. However, after the fourteenth day, while the skies still remained slightly cloudy, the heavy precipitation stopped, and the temperature increased to 19 °C (17 to 24 °C). Finally, for the final four days, the skies were fully cleared and temperature increased even further to 26 °C (24 to 27 °C). During the 20 days, there was no significant change in the humidity of the environment, which was an average of 76%.

Furthermore, this investigation focuses on mosquito larvae, and hence, it is important to note the distinguishing characteristics between mosquito larvae and pupae. Mosquito larvae have their heads pointed downwards and a breathing tube known as a siphon at the water's surface. However, the pupae simply float on the water's surface and have two breathing tubes known as trumpets.

[10] "Bear Creek Pioneers Park," Commissioner Steve Radack (Harris County, n.d.), http://www.pct3.com/Parks/Bear-Creek-Pioneers-Park).

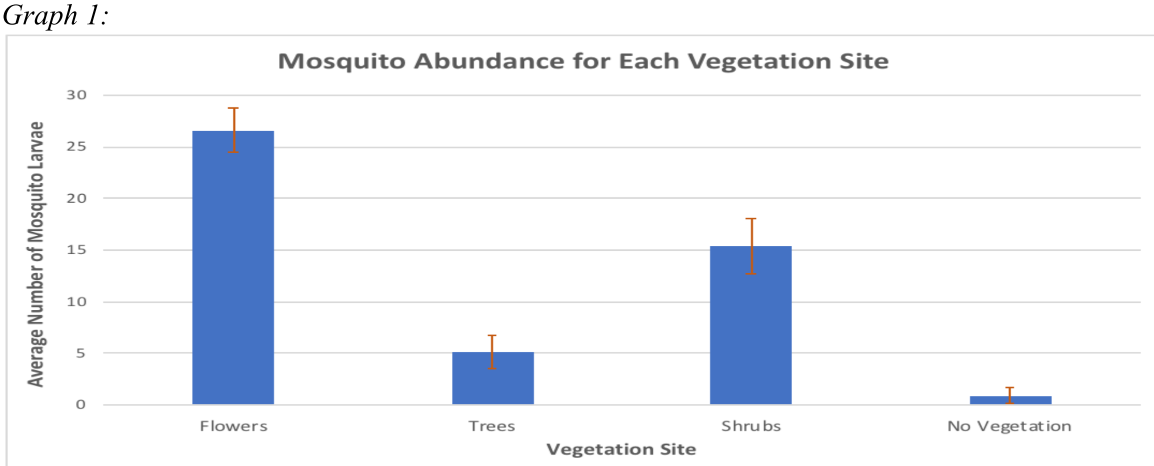
Mosquito Larvae for Each Vegetation Site

Vegetation Type	Traps	Mosquito Larvae (± 1)					Total Average (Number of Mosquito Larvae)	Standard Deviation (Number of Mosquito Larvae)
		Day 4	Day 8	Day 12	Day 16	Day 20		
Ground Flowers	Trap 1	28	26	22	27	29		
	Trap 2	26	28	24	28	27		
	Trap 3	29	28	23	26	28		
	Average	27.67	27.33	23	27	28	26.6	2.13
Trees	Trap 1	6	8	4	5	7		
	Trap 2	4	5	3	4	6		
	Trap 3	5	6	2	6	6		
	Average	5	6.33	3	5	6.33	5.13	1.55
Shrubs	Trap 1	15	16	11	14	17		
	Trap 2	17	18	12	15	19		
	Trap 3	18	17	10	15	17		
	Average	16.67	17	11	14.67	17.67	15.4	2.67
No Vegetation	Trap 1	0	1	0	0	1		
	Trap 2	1	2	1	1	2		
	Trap 3	2	0	0	1	1		
	Average	1	1	0.33	0.67	1.33	0.87	0.74

Source of Uncertainty: The uncertainty of ± 1mosquito larvae is due to the chance of double counting a mosquito larvae while collecting results.

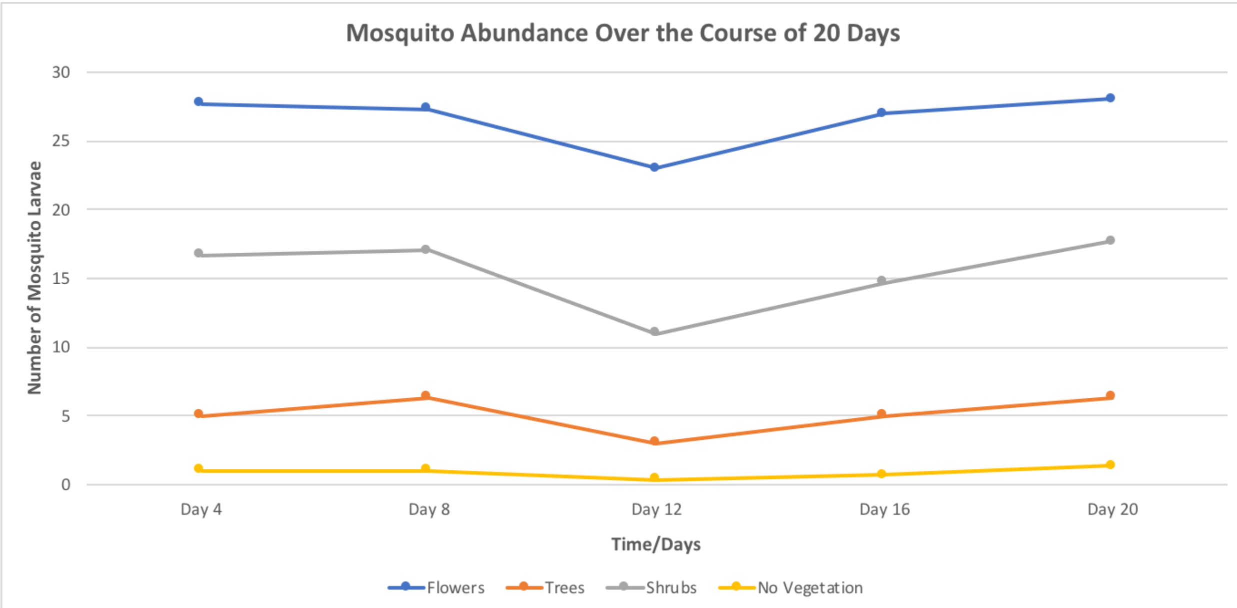
Graphs:

Graph 1:



Graph 1 depicts the mean number of mosquito larvae for each vegetation site; the error bars are representative of the standard deviation. As seen in Graph 1, the highest number of mosquito larvae was found near flowers, with the average number of mosquito larvae to be 26.6. Following flowers, shrubs had the second highest number of larvae. The lowest number was found in barren areas where no vegetation was present, as the mean number of larvae was only 0.87.

Graph 2:



As seen in Graph 2, over a period of 20 days, there was an overall initial increase in the number of mosquito larvae, but around Day 12, there was a drop in mosquito larvae among all vegetation sites. This decrease could be due to the changes in weather pattern, as the precipitation during this time period could have washed out and severely flooded the oviposition traps, destroying the potential larval habitat inside. However, at the same time, the precipitation nourished different vegetation sources, as well as left behind more sources of stagnant water around each site, increasing the likelihood of a mosquito coming near the traps. This could account for the increase in mosquito larvae for all of the sites following Day 12.

Sample Calculations:

Calculation of Average Number of Mosquito Larvae:

Calculating the mean number of larvae found near flowers:

$$Average = \frac{28+26+29+26+28+28+22+24+23+27+28+26+29+27+28}{15} = 26.6 \text{ Mosquito Larvae}$$

Standard Deviation of the Mean Number of Mosquito Larvae:

Formula: $\sigma = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$

Using the data from the vegetation site, flowers:

$\bar{x} = 26.6$ $\quad$ n = 15

$$\sigma = \sqrt{\frac{5(28-26.6)^2 + 3(26-26.6)^2 + 2(29-26.6)^2 + (22-26.6)^2 + (24-26.6)^2 + (23-26.6)^2 + 2(27-26.6)^2}{15-1}}$$

$$\sigma = 2.13 \text{ Mosquito Larvae}$$

This standard deviation calculation is utilized for the error bars in Graph 1 above.

Running a t-test:

Multiple t-tests are conducted to determine if there is a significant difference between two vegetation sites.

Null Hypothesis: There is no association between the type of vegetation and mosquito abundance.
Alternative Hypothesis: There is an association between the type of vegetation and mosquito abundance.

Mean Mosquito Larvae and Standard Deviation for Each Vegetation Site

Vegetation Type	Mean Mosquito Larvae	Standard Deviation
Flowers	26.6	2.13
Trees	5.13	1.55
Shrubs	15.4	2.67
No Vegetation	0.87	0.74

Calculated t-values for each t-test conducted

t-test number	Group 1	Group 2	t-value
1	Flowers	No Vegetation	44.1529203
2	Flowers	Shrubs	12.704793
3	Flowers	Trees	31.5314151
4	Shrubs	Trees	12.8845644
5	Shrubs	No Vegetation	20.3286048
6	Trees	No Vegetation	9.60171475

For all of the t-tests, the degree of freedom is: $30 - 2 = 28$. Based on this degree of freedom and the p-value, which is 0.05, the critical value is 1.70. For all t-tests 1 to 6, the calculated t-value is greater than the critical value, meaning that the null hypothesis can be rejected. Hence, the idea that there is a significant difference between the means of every pair of vegetation type is accepted, and this indicates that there is an association between the type of vegetation and the number of mosquito larvae found.

However, the uncertainty of the number of mosquito larvae was $\pm\ 1$. Hence, it is necessary to evaluate whether the results of the t-tests hold true even when this uncertainty is applied and the gap between the means is smaller. Therefore, the following table provides the "extreme" means that could potentially occur within the experiment.

Mean Mosquito Larvae and Standard Deviation for Each Vegetation Site

Vegetation Type	Mean Mosquito Larvae	Standard Deviation
Flowers	25.6	2.13
Trees	4.13 OR 6.13	1.55
Shrubs	14.4 OR 16.4	2.67
No Vegetation	1.87	0.74

Calculated t-values for each t-test conducted

t-test number	Group 1	Group 2	t-value
1	Flowers (Mean: 25.6)	No Vegetation (Mean: 1.87)	40.7213462
2	Flowers (Mean: 25.6)	Shrubs (Mean: 16.4)	10.4360799
3	Flowers (Mean: 25.6)	Trees (Mean: 6.13)	28.5937056
4	Shrubs (Mean: 14.4)	Trees (Mean: 6.13)	10.3745843
5	Shrubs (Mean: 14.4)	No Vegetation (Mean: 1.87)	17.5310904
6	Trees (Mean: 4.13)	No Vegetation (Mean: 1.87)	5.10091096

Once again, the degree of freedom is 28 and the p-value is 0.05, meaning that the critical value is 1.70. All of the calculated t-values, even when extreme values for the mean are used, are greater than the critical value. This again demonstrates that the null hypothesis needs to be rejected and that even when the uncertainty is applied, there is still an association between vegetation type and mosquito abundance.

Sample Calculation for t:
Solving for t between the mean mosquito larvae found in flowers and in barren (no vegetation) areas:

$$t = \frac{|x_1 - x_2|}{\sqrt{\frac{(\sigma_1)^2}{n_1} + \frac{(\sigma_2)^2}{n_2}}}$$

$$t = \frac{|26.6 - 0.87|}{\sqrt{\frac{(2.13)^2}{15} + \frac{(0.74)^2}{15}}}$$

$$t = 44.15$$

Degrees of Freedom: $df = 30 - 2 = 28$
If $df = 28$ and $p = 0.05$, then: $critical\ value = 1.70$

$$44.15 > 1.70$$

$$t > critical\ value$$

As a result, the null hypothesis is rejected.

Conclusion:

It can be concluded that the vegetation type influences the number of mosquito larvae present near that site. As shown with the multiple t-tests conducted, because all of the calculated t-values are greater than the critical value, the null hypothesis must be rejected. This suggests that there is a significant difference between the two mean data sets for each pair of vegetation sites, meaning that there is a correlation between the vegetation type and mosquito abundance. Graph 1 supports this, illustrating the lack of overlap between the error bars of the vegetation sites. It also depicts that ground flowers had the largest number of mosquito larvae, but following this vegetation type was shrubs, trees, and barren areas that lack vegetation. With flowers as the site of high mosquito abundance and barren areas as low abundance, these results can be attributed to the importance of vegetation on mosquito growth and development. After all, vegetation is a nutrient and sugar source for mosquitoes. Flowers and shrubs have a high sugar content and are located close to the ground, making this rich source accessible to many mosquitoes. This contributes to the high number of larvae found at these sites.

Furthermore, Graph 2 charted the change in mosquito abundance for each vegetation site over a period of time. This emphasizes the impact of weather conditions on mosquito abundance. For instance, there was a decline in the number of larvae at all vegetation sites around Day 12 during the short period of heavy precipitation. However, after the rain, the number of mosquito larvae gradually increased. The initial decline could be a result of the rain washing out larval habitats, but the following increase in larvae was a product of nourished vegetation and an increased number of stagnant water sources at each vegetation site. In addition, the temperature decline during the period of precipitation was not conducive to large numbers of mosquito larvae, as mosquitoes prefer a warm environment. Hence, this also contributed to the decline in mosquito larvae during that period.

Similar investigations have been conducted. For instance, a study conducted by researchers David Roiz, Santiago Ruiz, Ramon Soriguer, and Jordi Figuerola also found a positive correlation between the presence of mosquitoes and the normalized difference vegetation index (NDVI), which quantifies the amount of vegetation.[11] Furthermore, researchers Louise Ivers and Edward Ryan found that following heavy precipitation and natural disaster events, there is an initial decrease in the mosquito population in the region due to high winds and flooding, but after the event, there is a larger amount of water-holding containers that increase the number of potential mosquito-breeding water sources, giving an increase in the population.[12] Hence, these studies validate the results of my investigation.

Evaluation:

There are other ways to collect mosquito larvae data. For example, in the dipping method, a dipper is used to collect mosquito larvae in different water sources. The *Culex*, *Aedes*, and *Anopheles* mosquito larvae are found near the surface of the water and in proximity to vegetation. Hence, when dipping, the person must approach the water source quietly and carefully, while turning towards the sun, in order to prevent disturbance of the larvae habitat and cause the larvae to dive beneath the water surface. Then, to do a shallow skim, the dipper must be angled at 45° and positioned one inch below the water's surface; the dipper must move gently across the water to collect the larvae. A complete submersion dipping method could also be used, where the dipper is quickly plunged downward and gently brought up to collect the mosquito larvae that are diving downwards.[13] Compared to the oviposition traps used in my investigation, there are strengths and weaknesses to each method. One strength of the oviposition traps is that they allowed for a clear management of control variables and for the production of favorable

---

[11] David Roiz et al., "Landscape Effects on the Presence, Abundance and Diversity of Mosquitoes in Mediterranean Wetlands," *Plos One*10, no. 6 (June 18, 2015).

[12] Louise C Ivers and Edward T Ryan, "Infectious Diseases of Severe Weather-Related and Flood-Related Natural Disasters," *Current Opinion in Infectious Diseases* 19, no. 5 (October 2006): pp. 408-414.

[13] Claudia O'Malley, "Seven ways to a successful dipping career," Wing Beats, vol. 6(4): 23-24 (1995).

conditions, such as a shady environment and use of rank and stagnant water. These favorable conditions allow for the isolation of the independent variable: vegetation type. However, compared to the dipping method, a weakness of the oviposition traps is that these traps aren't specified to a certain mosquito species. There are multiple forms of the dipping method, such as the shallow skim, partial submersion, and complete submersion, that specifically target different mosquito larvae species based on where in the water they reside. Hence, the generalized nature of the oviposition traps could result in fewer mosquitoes being attracted to the site compared to the dipping method.

Furthermore, there were other strengths and weaknesses in this investigation. One major strength was that multiple traps were used per trial for each vegetation site. This allowed for large data collection for each type of vegetation, increasing the data's accuracy and reliability. However, a primary weakness is that the experiment was conducted only in a local park as opposed to multiple parks or throughout the city. This limits the scope of the investigation to a comparably more confined space. Another weakness was that the conditions at each vegetation site were slightly altered after the short period of precipitation. Each site reacted in a slightly different manner to the influx of rain, specifically based on how much water each vegetation type requires and how many stagnant water sources were formed. This slightly alters the extent of a mosquito's attraction to the trap and vegetation site. Also, a potential limitation of this investigation was the use of multiple t-tests. Performing multiple t-tests could increase the chance of finding a false significant difference. However, because my groups were very distinct and each individual test produced t-values that were well above the critical value, this was not a primary concern and the significant difference found in the tests are valid.

There were also some random errors of uncertainty. One error of uncertainty was the way the traps were built, specifically the size and position of the holes created in the stadium cup. Because the holes were created by humans, there would be slight uncertainty in the measurement of the radius of the hole, as well as the position of the hole on the stadium cup, among the multiple mosquito traps. This would lead to miniscule differences in each mosquito trap, specifically influencing the water level in each trap by one to two inches, especially after it was flooded with rainwater around Day 12. The water depth for each trap could influence the mosquitoes' attraction to the traps, as some larvae prefer to stay on the surface or slightly below. Another error of uncertainty was the way the mosquito traps were positioned in the local park. While the traps were supposed to remain in a shady region, depending on the time of day, a little bit of sunlight would still come through at times. Because mosquitoes prefer shady conditions, this uncertainty could slightly influence the mosquitoes' attraction to the trap.

As a result, in the future, some improvements to the investigation should be made. The first major improvement would be to conduct the experiment in a series of multiple parks located throughout the city. This would expand the data set available and provide a more holistic view to the data set that could be applicable to a wider base. Furthermore, instead of using alfalfa pellets as bait, fish food could also be utilized, and the small and light flakes could allow for more bait to be placed in each trap, increasing the mosquitoes' attraction to the area. In addition, to reduce random errors, the measurements could be made multiple times and more trials could be conducted.

To further expand this exploration, I would select a mosquito species and analyze if it is attracted to a certain plant species. I would also investigate if there are specific flower species that repel mosquitoes. This could be useful in identifying areas of high mosquito abundance. Furthermore, based on the qualitative observations, in the future, I would record mosquito data throughout the entire year to mark the effect of seasonal changes in temperature and precipitation on mosquito abundance. I would investigate the influence of the type of water source (artificial or natural) on mosquito abundance; to add to this topic, I would attempt to define the time it takes for a mosquito breeding site to form, as well as how long it would last. These investigations would increase my understanding of the various factors that influence mosquito breeding and how to prevent the spread of mosquito-borne illnesses.

Works Cited

"Bear Creek Pioneers Park." Commissioner Steve Radack. Harris County, n.d. http://www.pct3.com/Parks/Bear-Creek-Pioneers-Park.

Capinera, John L. *Encyclopedia of Entomology*. Dordrecht: Springer, 2008.

Chowell, G., K. Mizumoto, J. M. Banda, S. Poccia, and Charles Perrings. "Assessing the potential impact of vector-borne disease transmission following heavy rainfall events: a mathematical framework." *Philosophical Transactions of the Royal Society B* 374, no. 1775 (2019): 20180272.

Foster, Woodbridge A. "Mosquito Sugar Feeding and Reproductive Energetics." *Review of Entomology* (1995)

Gardner, Allison M, Tavis K Anderson, Gabriel L Hamer, Dana E Johnson, Kate E Varela, Edward D Walker, and Marilyn O Ruiz. "Terrestrial Vegetation and Aquatic Chemistry Influence Larval Mosquito Abundance In Catch Basins, Chicago, USA." *Parasites & Vectors* 6, no. 1 (January 11, 2013).

Gu, Weidong, Günter Müller, Yosef Schlein, Robert J. Novak, and John C. Beier. "Natural plant sugar sources of Anopheles mosquitoes strongly impact malaria transmission potential." *PLoS One* 6, no. 1 (2011): e15996.

Ivers, Louise C, and Edward T Ryan. "Infectious Diseases of Severe Weather-Related and Flood-Related Natural Disasters." *Current Opinion in Infectious Diseases*19, no. 5 (October 2006): 408–14.

"Life Cycle." Life Cycle - American Mosquito Control Association. http://www.mosquito.org/page/lifecycle.

"Mosquito Larvae." MDC Discover Nature. Missouri Department of Conservation. December 3, 2019. https://nature.mdc.mo.gov/discover-nature/field-guide/mosquito-larvae.

Nava, Martin Reyna, and Mustapha Debboun. "A Taxonomic Checklist of the Mosquitoes of Harris County, Texas. *Journal of Vector Ecology* 41, no. 1 (June 27, 2016): 190-94.

Olena, Abby. "After Harvey, Mosquito Control Ramps Up." The Scientist Magazine®, September 15, 2017. https://www.the-scientist.com/daily-news/after-harvey-mosquito-control-ramps-up-30917.

O'Malley, C. 1995. Seven ways to a successful dipping career. Wing Beats, vol. 6(4): 23-24.

Roiz, David, Santiago Ruiz, Ramon Soriguer, and Jordi Figuerola. "Landscape Effects on the Presence, Abundance and Diversity of Mosquitoes in Mediterranean Wetlands." *Plos One*10, no. 6 (June 18, 2015).