To what extent does a plant's distance (metres) from a trekking path influence the damage and pathogenic infection done to the plant?

Introduction:

The influence of tourism and human interference has devastated many sites where nature once flourished. Litter, garbage and the physical actions of humans all affect the environment of a forest as it can often introduce pathogens and other foreign entities into the habitat of plant life, disrupting their survival. The exact effects of tourism and human influence upon the environment has long been investigated, with many nature sites such as Boracay Island in the Philippines (Aquino, 2019) and Maya Bay in Thailand (Wipatayotin, 2019) closing down access to tourists because of deaths in surrounding living organisms or the damaging of the environment, which is all a result of human waste and behaviour.

Throughout my own personal experiences, I have had a firsthand account of the negative effects of humans on the environment in my own day-to-day life; I have seen an abundance of trash and litter along the paths that I take whilst hiking, and the trampling of plant life that situate themselves near a walking path. Additionally, defence systems of animals and humans have been consistently drilled into my head in school, with different lines of defence such as white blood cells acting as macrophages and lymphocytes, or the skin acting as a physical barrier against pathogens.

In contrast, not once have I ever learned about plants' defence systems in any of my syllabi, but plants certainly have their own methods to combat foreign entities, or else they would be extinct. Dirty environmental conditions can introduce a lot of pathogens to humans, so it would be sensible to assume plants would also be negatively affected by these conditions. On many of the hiking trails, I have seen plants with discolouration, disease and physical abnormalities. I questioned, has the influence of humans in the region contributed to this damage? I have personally investigated this topic in my Duke of Edinburgh expeditions by comparing areas that have had a large amount of human interaction to areas that have been barely touched by humans, but a lot of the data that I had was qualitative. Thus, this is an excellent opportunity for me to investigate both defence systems of plants as well as effects of humans on plants in deeper detail, and to see if I could quantifiably evaluate the exact effects of humans on plants.

Background Information:

The presence of a path has many implications that could affect flora's health. The creation of a path will already mean that damage has been done due to the destruction of plant and wildlife habitat (Pickering and Hill, 2019). The path would also have to be consistently maintained, leading to long term damage and consistent damage of the surrounding environment.

Sun and Walsh also found that food and energy sources for plants will be negatively affected as plants are destroyed to make way for cement pavements (Sun and Walsh, 1998), thus leading to a greater vulnerability to the plant life that are next to the path. The path is then transversed by organisms like humans which could introduce a variety of factors which could cause damage, such as acting as vectors carrying pathogens which bring disease to kill plant life, or other hazards to physically damage the plants around the path.

The path itself is also a whole new habitat which could help other living organisms thrive and thus kill off plants nearer to the path due to the survival of these organisms which could damage the plants, for example from absorbing nutrients in the soil to deplete the plants' resources, leading to the growth of weeds which invade the living environment of these other plants.

The soil itself can be affected from the path; a study found that when comparing vegetation and soils between areas near a road and areas with native vegetation and minimal infrastructure, the soil in these road verges had significantly lower levels of nutrients and higher levels of pH (Johnston and Johnston, 2004). The effects of a road can be inferred to be similar to a path, as both are transversed by organisms however a path is not usually utilised by vehicles. These less than optimal conditions make plants more susceptible to attacks by pathogens.

A study found that the incidence of a plant pathogen, *Phytophthora cinnamomi*, was higher as the plants gets closer to the path (Worboys and Gadek, 2004). Symptoms of plants with disease include wilting, yellowing, blight, powdery mildew, leaf cankers and loose bark (Riley, Williamson and Maloy, n.d.; Dieback of Trees and Shrubs, 2018) Studies have also found that there is an asymptotic, curvilinear relationship between the use of a path and the damage to plants (Frissell and Duncan, 1965; Cole, 1981; Monz, 2002)

Thus, theoretically, there should be an inverse relationship between the distance of the plant from the walking path and the number of plants with damage; as we stray further from the path into the forest, we should see a uniform percentage or frequency of damage to plants because the path's effect on the environment of the forest should be negligible.

Therefore, I will investigate the damage done to plants through the number of plants that have damage on their leaves within a quadrat, as this will give me a numerical value which lets me be able to compare different areas with different distances from the path in Tasek Maikuching. Through this, I can analyse the effect of human influence on plant life more specifically through the damage done to the plants around the path.

Hypothesis:

H_1 - As the distance of the plant from the walk path increases, the number of plants with damage will increase.

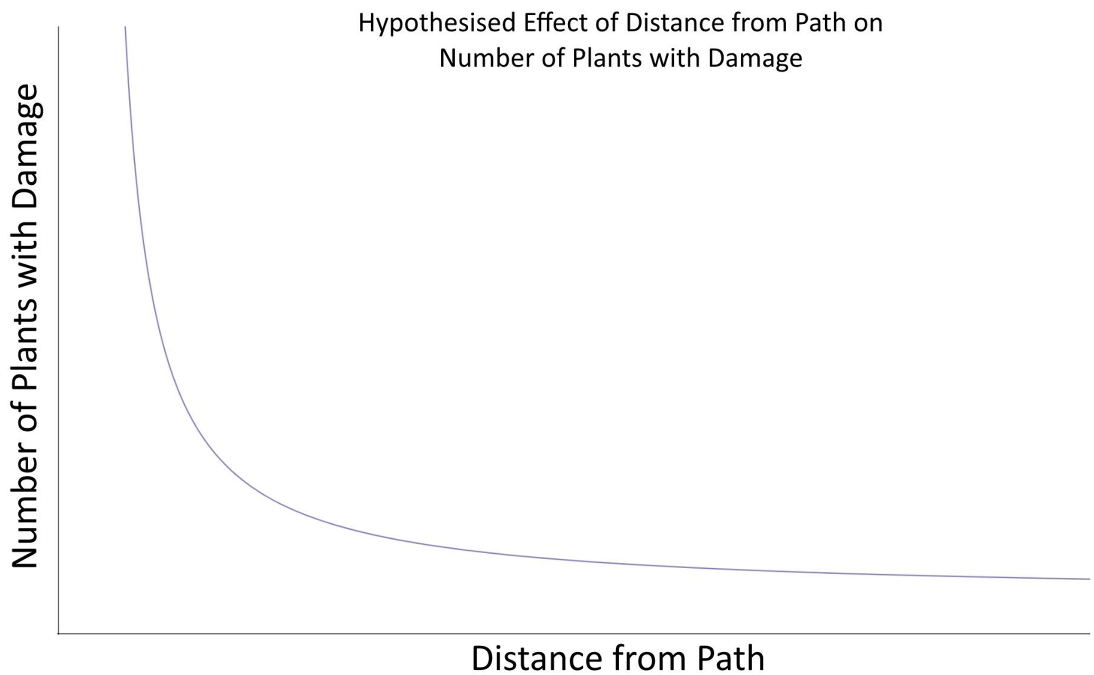

Figure 1: Distance of Path against Number of Plants with Damage

Variables:

Variables	Likely impact upon the investigation	How the variable will be changed/ measured/controlled
<u>Independent variable</u> Perpendicular distance away from the path	Perpendicular distance away from the path will change the number of plants with damage because it changes the influence of the path on the plant life and wildlife.	5 points along a path, 20 readings each 500 mm apart. This is to increase the reliability of the data as I have more repeats, as well as 20 readings to increase the range of my data.
<u>Dependent variable</u> Number of plants with damage & percentage of leaves with damage	Number of plants with damage and percentage of leaves with damage is a good measure because it can be used to compare between different distances away from the path.	The number of plants within the quadrat with any damage will be recorded. The percentage of leaves with damage within the quadrat will be recorded by measuring how many squares it occupies.
<u>Control variables</u> - Time period of readings - Moisture level	If the investigation occurs in different time periods, then our data will be less reliable because events may have occurred such as a large animal trampling on the plants. Plants need water to survive and thrive therefore if we have fluctuations in moisture level, it affects the plant's survival rate against foreign dangers.	Choose an area with consistent moisture level, then record all the data at the same time period.
<u>Uncontrolled variables</u> - Pressure - Altitude - pH - Temperature - Type of plant	Pressure, Altitude - Can affect the air quality and life that survive in the environment. Moisture level - Living organisms need water to survive, different quantities can change survivability. Temperature, pH - Affects the effectiveness of enzymes in living organisms Type of plant - Different plants have different susceptibilities to damage, thus while a certain plant may be damaged from a pathogen, an immune species of plant may be resistant and appear to not have any damage.	The effect of these variables will be minimised by recording measurements around the same geographical region, which would mean similar pressure, variety of plants, altitude, moisture, pH and temperature levels.

Apparatus:

- 2 quadrats, 500 mm by 500 mm, with 50 mm wide squares.
- 2 line transects that also function as tape measure, at least 10 metres long.
- Identification booklet for plants

Method:

1. Start with a path that is roughly the same altitude and height along the trek. This controls the variables of plant growth so that the regions have approximately the same conditions for growth. Make sure to choose an area that can keep the uncontrolled variables as constant as possible.

2. Lay out a line transect along the path in 10 metre intervals, plotting 5 points along, which should be 2 metres equidistant from each other. This makes it so that there is no bias when attempting to find a spot to start recording data, as such systematic sampling can occur where we can record several spots without bias.

3. At the first point, lay out another line transect perpendicular to the direction of the first line transect. Extend this 10 metres out. This will be the sampling range for the first area.

4. Put a quadrat on the first point. Do not flatten the plants in the quadrat so that the percentage coverage of the plant can be taken more realistically within the quadrat.

5. Use the identification booklet to identify the plant, to observe whether or not the abnormality present in the plant is actually damage inflicted by pathogens. Count the number of individual plants that have any sort of damage to their leaves and record it, and then count the number of squares in the quadrat that are occupied by the damage of the leaves. Calculate the percentage coverage as each square is 1% of the total area.

6. Put another quadrat right in front of the quadrat and repeat the recording process. After recording, put the previous quadrat right next to the current quadrat, measuring the number of plants again.

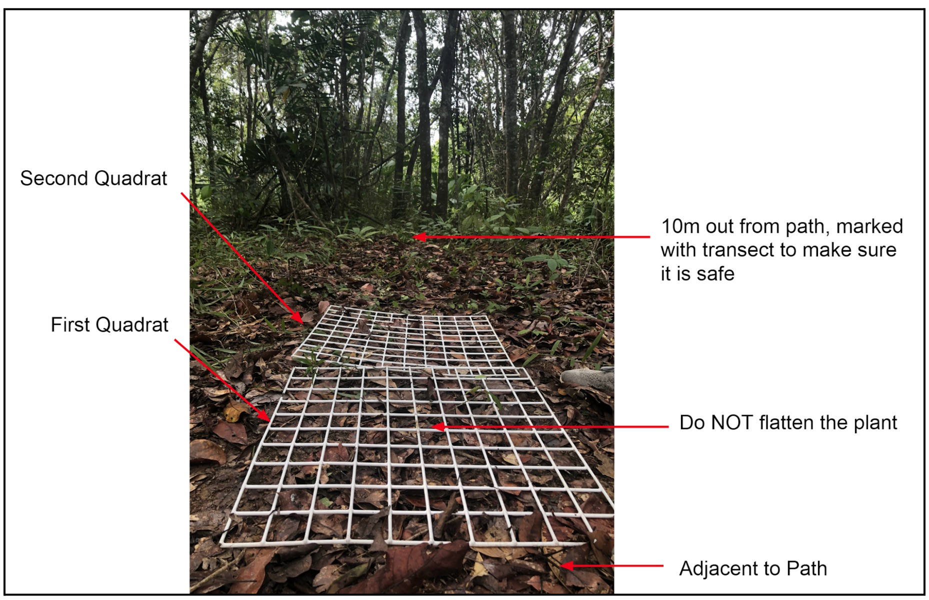

Figure 2: Diagram of Experimental Setup

8. Keep putting the quadrats next to each other and recording results until 20 readings have been done. This means we can have more accurate and valid data.

9. Go to the next point of the line transect in the path and repeat the recording process, laying out another line transect 10m out perpendicular to the path and record 20 more readings. Repeat this until 5 points along the path have 20 readings. This allows us to increase the reliability of the investigation because there is a wider range of data, comparing the results which can allow us to spot anomalies.

10. Tabulate and graph the data.

Preliminary Testing and Improvements:

My final method is different from my initial preliminary testing methods. Firstly, I had planned 20 metres outwards from the path to make the results more clear and accurate, so that the correlation could be more clear-cut. However, given the environment I was measuring in, after 10 metres, most of the forest would be too thick to go through, or there would be water which would be a hazard.

I also originally measured with 1 quadrat at a time, however, it took a lot of time to carry out the experiment. Thus, I changed it so that 2 measurements could happen at the same time to reduce the time needed to prepare the quadrat.

The identification booklet for plants was also an improvement from the initial method, because I found it useful to identify the plants so the type of damage could be measured more accurately since I could compare the growth habits of certain plants and whether or not they were actually infected by pathogens.

Safety and Ethical considerations:

- Do not harm any plants in the process of recording, making sure not to damage the leaves or kill plants to ensure minimal impact on the wildlife in the habitat. Be careful with handling plants when putting them through the quadrat holes.

- Do not harm the wildlife and micro-organisms present, watching closely where to step and avoiding areas where there are a lot of organisms such as insects to minimise impact.

- Do not choose an area near a large water source because it could be a hazard as the ground becomes slippery or animals in the water may be affected by the experiment.

- Choose an area that is not near sharp objects (branches, roots) or near poisonous plants and wildlife because walking through these objects may lead to injuries as hazards.

- Do choose an area that is not near any wild animals, such as snakes, monkeys or hogs. This minimises impact on the wildlife, but also minimises injuries as these animals can attack.

Analysis:

Qualitative Data

Directly adjacent to the path, there is a minimal amount of plants. This means the environment is quite sparse with little to no plants. In my observations, I noticed that even if there were a few number of plants adjacent to the path, they would very likely have damage on their leaves, either through trampling or other organisms. As we went further along the line transect, there would be a larger number of plants present in the quadrat, so whilst most would be healthy, there were bound to be some plants with damage on their leaves, contributing to the number of plants with damage. As seen from my quantitative data, many data points far from the path will have similar numerical values as data points directly adjacent to the path. Therefore, while both samples may have similar values, their causes are different. Figure 3 below is an example, where it can be seen that adjacent to the path, there is a sparse distribution of plants but they have damage, whilst further away from the path, there is a more concentrated distribution of plants in the area but a few of them have damage.

Figure 3: Third point along the path

Some areas were also quite moist and humid compared to other recorded areas, which could mean that the test was not as fair as it could have been; however due to my method of systematic sampling I still chose to record my data within the areas to avoid biases in my data collection. Additionally, there was a wide variety of plant species observed throughout the data collection, so it means that different plants have different adaptations which would make each plant differ in their defence mechanisms against damage from pathogens and other living organisms. Three examples are shown below of the different kinds of plants contained in the quadrats.



Quantitative Data

Table 1: Averaged Results			Standard Deviation for number of plants with damage
Distance from Path (mm) ±5	Number of plants with damage ±1	Percentage of quadrat occupied with damage to leaves (%)	
0	1	2	1.00
500	2	3	1.10
1000	4	5	1.67
1500	6	8	2.41
2000	2	5	2.28
2500	5	8	1.95
3000	6	10	2.74
3500	4	11	2.28
4000	6	11	1.89
4500	4	5	3.70
5000	4	7	3.70
5500	5	7	2.87
6000	3	5	0.89
6500	3	12	1.10
7000	4	8	1.92
7500	4	11	1.73
8000	2	5	1.48
8500	2	3	0.50
9000	2	9	0.84
9500	2	5	1.10

Using my results for the 5 different areas along the path into Tasek Maikuching, I produced an average number of plants with damage and an average percentage of quadrat coverage of damaged leaves for each distance from the path, as well as the standard deviations for the number of damaged leaves, all tabulated into Table 1.

Next, to interpret the data and visually represent my results, I plotted my data points for distance from path against number of plants with damage. I connected the data points together, extrapolating a trend line between the different data points to show where my results are tending towards. This graph can be seen below in Figure 4. However, I chose not to graph the results for the percentage of quadrat occupied with damaged leaves because there were a lot of fluctuations between different data points in the different areas along the path, so I decided to disregard these results as they varied too much.

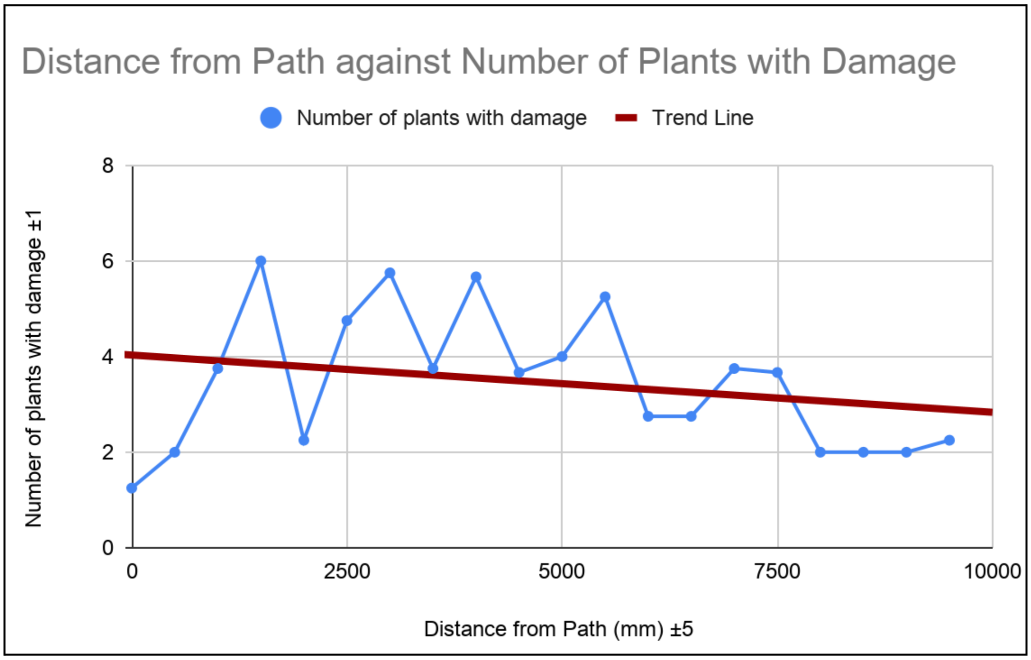

Figure 4: Graph of Distance from Path against Number of Plants with Damage

As shown in Figure 4, the trend line has a negative gradient, which suggests an inverse relationship between distance from path and the number of plants with damage. This could suggest that as the distance from the path increases, the number of plants with damage decreases. This supports our main hypothesis, however this result could possibly be skewed and we could misinterpret the data due to the manipulation of the scale of the graph. Thus, we should test the hypothesis H_1 and investigate whether or not there is a strong negative correlation between distance from the path and the number of plants with damage.

Therefore, I will be carrying out Spearman's rank correlation test, to investigate if there is any correlation between my two variables, and if so, the strength of such a correlation.

Spearman's Rank Correlation Test

Our null hypothesis is that there is no correlation between distance from the path and the number of plants with damage. The alternative hypothesis is H_1 which states that there is a negative correlation between the distance from the path and the number of plants with damage.

In Spearman's Rank Correlation Test, I will have to find Spearman's rank correlation coefficient, denoted as r_s. The closer it is to the absolute value of 1, the stronger the correlation between the two variables. Adversely, the closer the coefficient is to 0, the weaker the correlation between the two variables. With this value I can investigate the correlation between the distance from the path and the number of plants with damage. I can also use this r_s value to test against my hypothesis, to see whether or not it is statistically significant enough to reject my null hypothesis and accept the alternative hypothesis. With biological data, it is universally accepted to adopt a 0.05 significance level. Since I have 20 pairs of data, my critical value for Spearman's rank correlation will thus be 0.450.

The formula to calculate r_s is as follows:

$$r_s = 1 - \frac{6\Sigma D^2}{n(n^2 - 1)}$$

where D denotes the difference of the rank number of plants and distance and n denotes the number of pairs of data.

To calculate r_s, I have compiled a table to include the calculations I made in order to find the value for D. In the Spearman's rank correlation test, I allocate a rank for each set of paired data, for the distance from path and the number of plants with damage. The lowest value is given the rank value of 1, and the next lowest value in the data set is given the rank value of 2. If two values are the same, such as if a variety of distances have the same number of plants with damage, then it means that the next ranks for the number of plants with damaged are averaged out, and these values will have the same rank numbers of plants. This table can be seen in the next page in Table 2.

D is the difference between rank number of plants and the rank distance, where I will square each pair's D value and sum all 20 values together to find ΣD^2 so that I can substitute it into the formula to evaluate r_s.

Distance from Path (mm) ±5	Rank Distance	Number of plants with damage ±1	Rank Number of Plants	Difference between rank number of plants and distance (*D*)	***D***^{2}
0	1	1	1	0	0.00
500	2	2	4.5	2.5	6.25
1000	3	4	12.5	9.5	90.25
1500	4	6	19	15	225.00
2000	5	2	4.5	-0.5	0.25
2500	6	5	16.5	10.5	110.25
3000	7	6	19	12	144.00
3500	8	4	12.5	4.5	20.25
4000	9	6	19	10	100.00
4500	10	4	12.5	2.5	6.25
5000	11	4	12.5	1.5	2.25
5500	12	5	16.5	4.5	20.25
6000	13	3	8.5	-4.5	20.25
6500	14	3	8.5	-5.5	30.25
7000	15	4	12.5	-2.5	6.25
7500	16	4	12.5	-3.5	12.25
8000	17	2	4.5	-12.5	156.25
8500	18	2	4.5	-13.5	182.25
9000	19	2	4.5	-14.5	210.25
9500	20	2	4.5	-15.5	240.25
ΣD^2					1583

Table 2: Calculations for Spearman's rank correlation coefficient

Now that there are values for all variables in the formula to calculate r_s, simply input them into the formula.

$r_s = 1 - \frac{6\times1583}{20(20^2-1)}$ which is equal to -0.190 (rounded to 3 significant figures)

This means that there is a very weak negative correlation between distance away from the path and the number of plants with damage. The r_s value is very close to zero, which suggests that there is only a slight correlation between the two variables.

Additionally, when comparing the r_s value of -0.190 to the critical value of 0.450, the absolute value of my Spearman's rank correlation coefficient is less than the critical value, which means that the data is not statistically significant enough to reject H_0. Even if I used a significance level of 0.1 instead, the critical value would be 0.377, which is still greater than the absolute value of my r_s value. Thus, there is insufficient evidence to reject the null hypothesis.

However, with more evidence I may be able to prove a stronger correlation as I only recorded 5 different areas with only 20 pairs of data. I would have more reliable data if I made more measurements, and this variance in data can be seen in Table 1, where my largest standard deviation for a given measurement was 3.70. This means that the data points varied a lot from the mean, suggesting that there was either an anomaly, or that there was not enough data points to evaluate a reliable average.

My qualitative data might have also impacted my findings as the variations in plant species means that different plants have different susceptibilities to different types of damage, thus if I kept plant species constant, I may have been able to see a stronger correlation between distance away from the path and the number of plants with damage, because there would be less variation. Furthermore, the qualitative data makes it more difficult to come to a valid conclusion because of the fact that there is a sparse distribution of plants, this means that there are a variety of numerous damaged plants for different reasons.

Conclusion:

To address my research question of "to what extent does a plant's distance from a trekking path influence the pathogenic infection and damage done to the plant?" I do not have enough evidence to prove my hypothesis that as the distance between a plant and a trekking path increases, the number of plants with damage in the particular area decreases. My results are not statistically significant enough to accept this hypothesis, however through my statistical tests I found that there is indeed a very weak negative correlation between these two variables. If I used a higher significance level, then my hypothesis could possibly be accepted, however I adopted the conventional significance level of 0.05 at the beginning of the experiment, so I kept the value constant and consistent throughout my investigation.

Based on the theory laid out in my introduction, through my qualitative data there was a clear influence of humans on the vegetation of the environment, as there was only a small amount of plants present directly adjacent to the trekking path, and as the distance from the trekking path increased, there was a larger number of plants present in the area. Trampling and damage to plants were evident as the absence of plants in the first place suggest that damage has already been done to the plants near the trekking path.

Additionally, many plants had blisters, blights, wilting and rotting. There was clear evidence of pathogenic infections, however it may be correct to actually assume that humans and animals did not act as significant vectors of plant disease in my investigation. There is not a large human population using the path, therefore the effect of vectors bringing plant disease may be negligible because there is not a lot of people using the path. Additionally, there were no wild animals such as snakes or monkeys as it was not deep into the jungle, which meant that they did not really act as vectors anyway. Thus, the low correlation may be due to the fact that the impact of the path was negligible, which explains the fluctuations in data.

While I may not have sufficient evidence to prove my hypothesis, the weak negative correlation can be investigated more in-depth and detail with a more widely-used path to explore whether or not there is truly a negative correlation, and if so the reasons behind why there could be one.

Evaluation, improvements and next steps:

Evaluation of experimental errors		
Weakness/source of error	Possible effects on data and magnitude of weakness/error	Suggested Improvements
<u>Independent variable</u> ● Not enough range of values, insufficient sets of data.	This weakness makes my data less reliable and increases the magnitude of error in my measurements. Had I chosen to make more measurements, my significance level would be lower.	Instead of only recording 5 areas, record 10 similar areas along the path. Furthermore, instead of only making 20 measurements along a line transect, extend it to 40 so that a trend line is more concise and clear.
<u>Dependent variable</u> ● Inaccurate method of measurement.	As shown with my qualitative data, the measurements of numbers of damage plants were seen to be due to different reasons as distance increased, thus my data could be inaccurate or invalid as there were a variety of distributions of plants within particular distances.	Instead of recording the number of damaged plants, I could have measured the number of plants in the quadrats. This would insinuate that the absence of plants in the quadrats will be due to damage caused by the path.
<u>Control variables</u> ● Collected data in different time periods	I was unable to collect all my data in a single day so I conducted my data collection between two days. While it is unlikely that damage done to plants will have changed drastically in a 24 hour time-span, it still may have changed.	Record all data in the same day, at the same time of day.
<u>Uncontrolled errors</u> ● Unable to effectively monitor environmental conditions with proper equipment.	Without being able to accurately monitor uncontrolled variables such as pressure, altitude, pH, temperature and type of plant, these may have influenced the experiment and caused differences in number of plants that have damage, as variables such as pH could influence how well a plant is able to defend itself from foreign organisms and attacks.	Use a PASCO Data logger to monitor environmental conditions, such as the pH levels of the soil and temperature of the surrounding air around the plants.

Given more time, I would like to have repeated the investigation and made these improvements to the method, so that the dependent variable is measured more accurately, as well as increasing the accuracy and reliability of my data by carrying out more repeats as I collect more data. Furthermore, I would also want to measure environmental conditions such as the pH, water content, nutrients, minerals in the soil, to observe whether or not these factors affect the changes of plant distribution.

Appendices:

Appendix 1: Area Recordings

Area #	Reading #	Distance from Path (cm)	Frequency of plant with damage	Percentage of quadrat occupied with damage (%)
1	1	0	0	0
	2	50	1	1
	3	100	6	6
	4	150	4	6
	5	200	0	0
	6	250	2	2
	7	300	3	4
	8	350	5	23
	9	400	4	6
	10	450	3	4
	11	500	3	5
	12	550	7	7
	13	600	3	5
	14	650	1	16
	15	700	4	6
	16	750	3	7
	17	800	2	4
	18	850	2	2
	19	900	2	5
	20	950	1	3

Area #	Reading #	Distance from Path (cm)	Frequency of plant with damage	Percentage of quadrat occupied with damage (%)
2	1	0	1	1
	2	50	3	3
	3	100	3	7
	4	150	4	7
	5	200	5	13
	6	250	6	9
	7	300	6	7
	8	350	6	14
	9	400	5	6
	10	450	0	0
	11	500	4	13
	12	550	1	1
	13	600	4	6
	14	650	3	6
	15	700	6	11
	16	750	-	-
	17	800	2	7
	18	850	2	4
	19	900	2	6
	20	950	4	12

Area #	Reading #	Distance from Path (cm)	Frequency of plant with damage	Percentage of quadrat occupied with damage (%)
3	1	0	2	2
	2	50	3	5
	3	100	2	4
	4	150	8	8
	5	200	0	0
	6	250	7	14
	7	300	5	13
	8	350	1	1
	9	400	8	20
	10	450	-	-
	11	500	0	0
	12	550	6	11
	13	600	2	3
	14	650	3	15
	15	700	2	8
	16	750	6	21
	17	800	4	8
	18	850	2	3
	19	900	1	20
	20	950	2	3

Area #	Reading #	Distance from Path (cm)	Frequency of plant with damage	Percentage of quadrat occupied with damage (%)
4	1	0	2	3
	2	50	1	1
	3	100	4	4
	4	150	8	10
	5	200	4	5
	6	250	4	8
	7	300	9	14
	8	350	3	6
	9	400	-	-
	10	450	8	12
	11	500	9	10
	12	550	7	7
	13	600	2	4
	14	650	4	11
	15	700	3	7
	16	750	2	5
	17	800	0	0
	18	850	-	-
	19	900	3	3
	20	950	2	2

Area #	Reading #	Distance from Path (cm)	Frequency of plant with damage	Percentage of quadrat occupied with damage (%)
5	1	0	0	0
	2	50	1	2
	3	100	2	4
	4	150	3	5
	5	200	2	12
	6	250	4	8
	7	300	2	3
	8	350	1	1
	9	400	4	5
	10	450	7	15
	11	500	0	0
	12	550	-	-
	13	600	2	2
	14	650	3	12
	15	700	1	1
	16	750	3	3
	17	800	3	5
	18	850	1	2
	19	900	3	10
	20	950	2	7

Bibliography:

2018. *Dieback Of Trees And Shrubs*. [online] Available at: <http://www.ladybug.uconn.edu/FactSheets/tress-and-shrubs--dieback.php> [Accessed 25 December 2019].

Aquino, M., 2019. *Why Boracay Is Closed For Tourism: Everything You Need To Know*. [online] TripSavvy. Available at: <https://www.tripsavvy.com/boracay-philippines-island-closed-for-tourism-4165709> [Accessed 2 December 2019].

Cole, D., 1981. Managing Ecological Impacts at Wilderness Campsites: An Evaluation of Techniques. *Journal of Forestry*, 79(2), pp.86-89.

Frissell, S. and Duncan, D., 1965. Campsite Preference and Deterioration in the Quetico-Superior Canoe Country. *Journal of Forestry*, 63(4), pp.256–260.

Johnston, F. and Johnston, S., 2004. Impacts of Road Disturbance on Soil Properties and on Exotic Plant Occurrence in Subalpine Areas of the Australian Alps. *Arctic, Antarctic and Alpine Research*, 36(4), pp.201-207.

Monz, C., 2002. The response of two arctic tundra plant communities to human trampling disturbance. *Journal of Environmental Management*, 64(2), pp.207-217.

Pickering, C. and Hill, W., 2019. *Impacts Of Recreation And Tourism On Plants In Protected Areas In Australia*. [online] Sustainable Tourism Cooperative Research Centre, pp.5-9. Available at: <https://www.researchgate.net/publication/281444557_Impacts_of_Tourism_on_Plants_in_Protected_Areas_in_Australia> [Accessed 26 October 2019].

Riley, M., Williamson, M. and Maloy, O., n.d. *Plant Disease Diagnosis*. [online] Available at: <https://www.apsnet.org/edcenter/disimpactmngmnt/casestudies/Pages/PlantDiseaseDiagnosis.aspx> [Accessed 25 December 2019].

Sun and Walsh, 1998. Review of studies on environmental impacts of recreation and tourism in Australia. *Journal of Environmental Management*, 53(4), pp.323-338.

Wipatayotin, A., 2019. *Maya Bay To Remain Closed Until Mid-2021*. [online] https://www.bangkokpost.com. Available at: <https://www.bangkokpost.com/thailand/general/1674364/maya-bay-to-remain-closed-till-mid-2021> [Accessed 2 December 2019].

Worboys, S. and Gadek, P., 2004. *Rainforest Dieback: Risks Associated With Roads And Walking Track Access In The Wet Tropics World Heritage Area*. [online] Rainforest CRC. Available at: <http://www.wettropics.gov.au/site/user-assets/docs/rainforestDiebackRoads%26WalkingTracks.pdf> [Accessed 25 December 2019].