The Effect of Proximity to Roads on Orthoptera Populations

Anthropogenic influence is causing an increasingly apparent impact on the planet and its ecology ever since the Industrial Revolution of the 18th century (Sabine et al. 2004). Activities such as fossil fuel combustion have altered the composition of both the ocean and the atmosphere while deforestation is eliminating habitats (Sabine et al. 2004). Elsewhere, chemical pollutants such as fertilizers leach into the landscape, affecting the growth rates of floral and microbial communities (Barak et al. 1997). Because of these events, the relationship between people and their anthropogenic impact on organisms, such as Orthoptera, have been the focus of recent studies.

Orthoptera is an order of insects, notable for their ability to jump and it includes families such as Acrididae, grasshoppers, and Gryllidae, crickets. Understanding the ecological role of Orthoptera populations is important, because they are affected by anthropogenic influences to the environment yet typically remain populous enough to study (Song et al. 2018). Large numbers of these herbivorous insects are responsible for controlling the growth rate of flora in a given area and releasing nutrients from plant matter (Badenhausser et al. 2007). This makes them an influential member of the ecosystem, as they provide nutrition for predators while competing with other herbivores to keep their numbers in check (Badenhausser et al. 2007). Anthropogenic influences can alter this balance, as indicated when it was found that the Acrididae, *Ageneotettix deorum*, had a 50% higher survival rate when consuming plants that had been fertilized than populations of *A. deorum* that had not (Oedekoven and Joern 2000).

Research on roads has typically been examined from the perspective of minimizing possible impacts and not so much actual ecological consequences (Spellerberg 1998). Because of this, more studies are needed to determine if implemented solutions are actually helping the environment (Spellerberg 1998). It is known that roads are artificial heat sources and that decreases in Orthoptera populations correlate with regions of excessive temperatures (Trombulak and Frissell 2000, O'Neill et al. 2003). Despite this knowledge, Orthoptera have been studied more thoroughly in agricultural settings than along roadways, making it necessary to apply these findings to roadside ecosystems for a better understanding of ecological mechanisms. For example, reduction of vegetation from activities such as livestock grazing or mowing have been known to impact grassland-dwelling Acrididae (O'Neill et al. 2003, Gardiner and Hassall 2009). Disruptions to vegetation in this manner exposed Acrididae to changes in their microclimate including higher temperatures and increased wind velocity (O'Neill et al. 2003). Furthermore, it was found that Orthoptera populations were higher on the peripheral regions of farms where soil was disturbed less frequently from events such as ploughing (Gardiner 2007). These studies together indicate Acrididae are often driven from areas of higher temperature and winds to regions of minimal anthropogenic disturbance (O'Neill et al. 2003, Gardiner 2007, Gardiner and Hassall 2009). By acting as a heat absorbing surface, devoid of flora, roads alter the surrounding ecosystem and potentially have similar effects on the environment in the road corridor, the region adjacent to roadways (Forman and Alexander 1998). Furthermore, water is not absorbed by roads and runs off into the surrounding environment instead (Trombulak and Frissell 2000). Soil moisture affects Orthoptera life cycles as seen in a direct correlation between the number of eggs laid by the Gryllidae species, *Scapteriscus borellii* (Hertl et al. 2001). Overall, these studies suggest that Orthoptera experience negative anthropogenic impacts when residing near roadways.

In order to determine the anthropogenic impact of roads on Orthoptera, this study examined how their population abundance and species richness changes with distance from roads. Orthoptera populations were expected to rise in number with distance from any sources of anthropogenic impact. Similarly, by evaluating soil at varying increments from roads through pH and soil moisture level, it was believed that variations in anthropogenic impact could be understood. It was anticipated that points alongside roads would display lower pH levels and higher moisture levels in comparison to data collected away from roads. To test these assumptions, I based this study on the hypothesis that abiotic factors in proximity to roadways such as excess heat and pollution are detrimental to populations of Gryllidae and Acrididae.

Methods

Study organisms: The focus of this study was on the families Acrididae and Gryllidae of the order Orthoptera. Insects of this order are very successful herbivores and can be easily recognized for their large rear legs and ability to jump. Many species are also capable of flight, and use it as a means to escape predators (Knop et al. 2011). Within Orthoptera, the suborder Caelifera includes Acrididae where grasshoppers and locusts are located phylogenetically (Song et al. 2018). While this family can be found inhabiting a plethora of ecosystems on every continent, except Antarctica, they are well-known for their role in grassland biomes (Song et al. 2018). In fact, within grassland ecosystems Acrididae constitute the majority of arthropod above-ground biomass (Song et al. 2018). The second suborder, Ensifera, includes the family Gryllidae (Jost and Shaw 2006) and is distinguishable from the family Acrididae by the presence of abdominal protrusions, or cerci. Compared to Acrididae, relatively little is understood about the ecological interactions of Gryllidae in grasslands. This is partly due to difficulty in differentiating species because sexual selection has made it so characteristics are so subtle, that species can only be identified by differences in chirp signaling (Blankers et al. 2017).

Study site: Five old fields were selected as study sites and were characterized by relatively low levels of mowing and anthropogenic maintenance. Each field was located adjacent to a road. Sets of six transects, repeated in three separate trials at each field, were sampled at Heritage Park (37.243948, -80.462446), the Corporate Research Center (37.206060, -80.421514), an unnamed field on Route 460 and South Gate Drive (37.213720, -80.431782), an unnamed field on North Main Street (37.260561, -80.412192), and an unnamed field on Harding Road (37.260561, -80.412192) (Fig. 1). However, only two separate trials of transects were possible at the Harding Road site due to difficult vegetation.

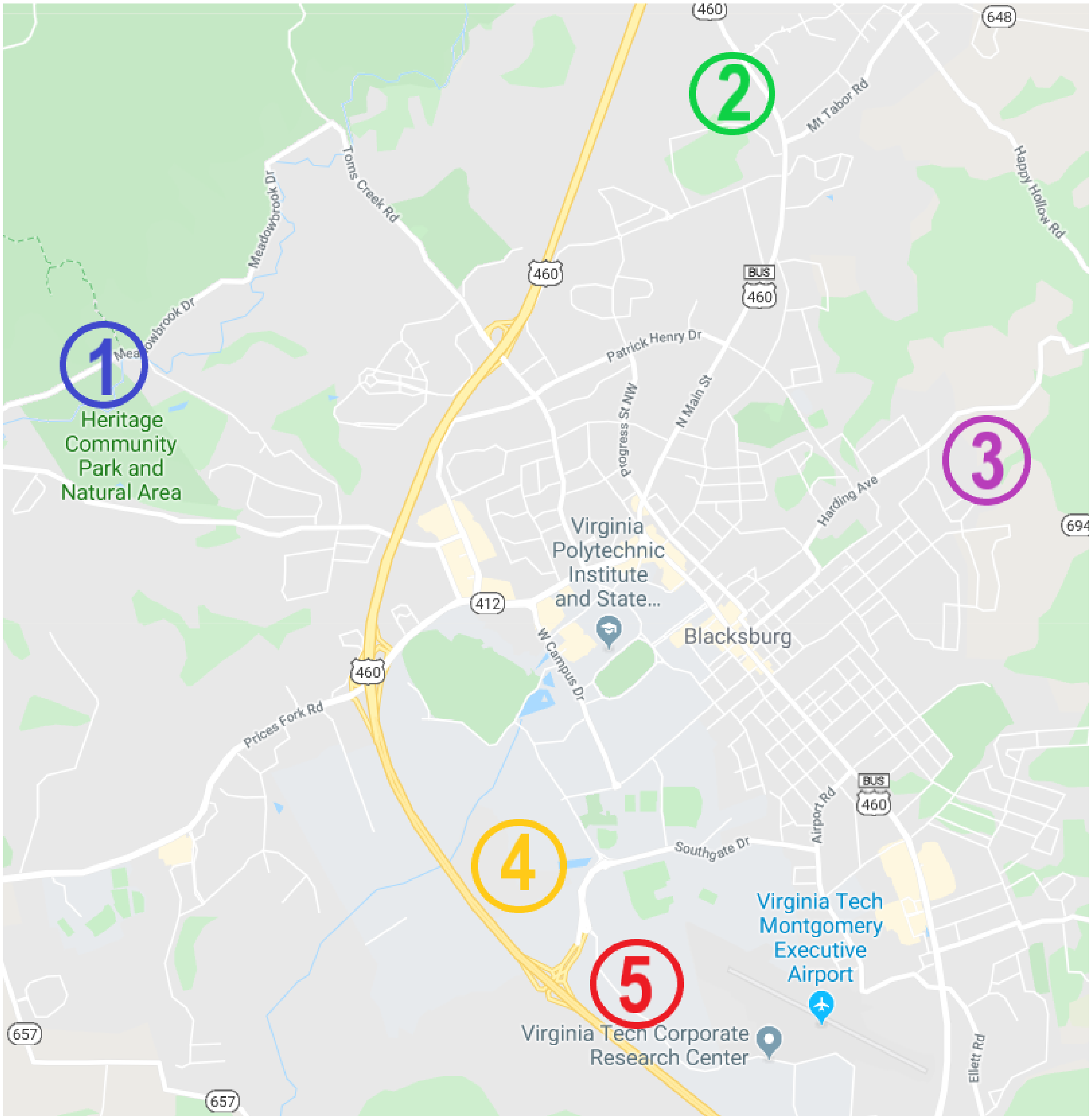

Figure 1.) This map of Blacksburg, Virginia indicates the five different locations visited over the course of this study. Site identification is as follows: 1.) Heritage Park, 2.) North Main Street, 3.) Harding Road, 4.)South Gate Drive/Route 460, and 5.) Corporate Research Center.

Study approach: This was an observational study performed by sampling Acrididae and Gryllidae present at each location to estimate population. From this data, abundance and species richness at varying distances from adjacent roadways could be estimated. Soil moisture and pH were recorded as control variables in an attempt to find significance between distribution of Orthoptera and sources of anthropogenic impact. Additionally, percent relative humidity (RH) and dew point temperature were measured to describe ambient weather conditions on the days of observation.

Study design: Observations at each site were begun by establishing transects. A 30 meter measuring tape was used to keep transects a consist 10 meters apart from each other, beginning with 0 meters at the road. Brightly colored flags were placed at the beginning and end of each transect to clearly indicate transect lines. Next, the order of transect sampling was determined randomly with a random number generator so that the same order of transects would not be performed twice. This was done to eliminate bias of Orthoptera traveling from one transect to another after being disturbed. Multiple trials were accomplished at each site by creating up to three, non-overlapping sets of transects.

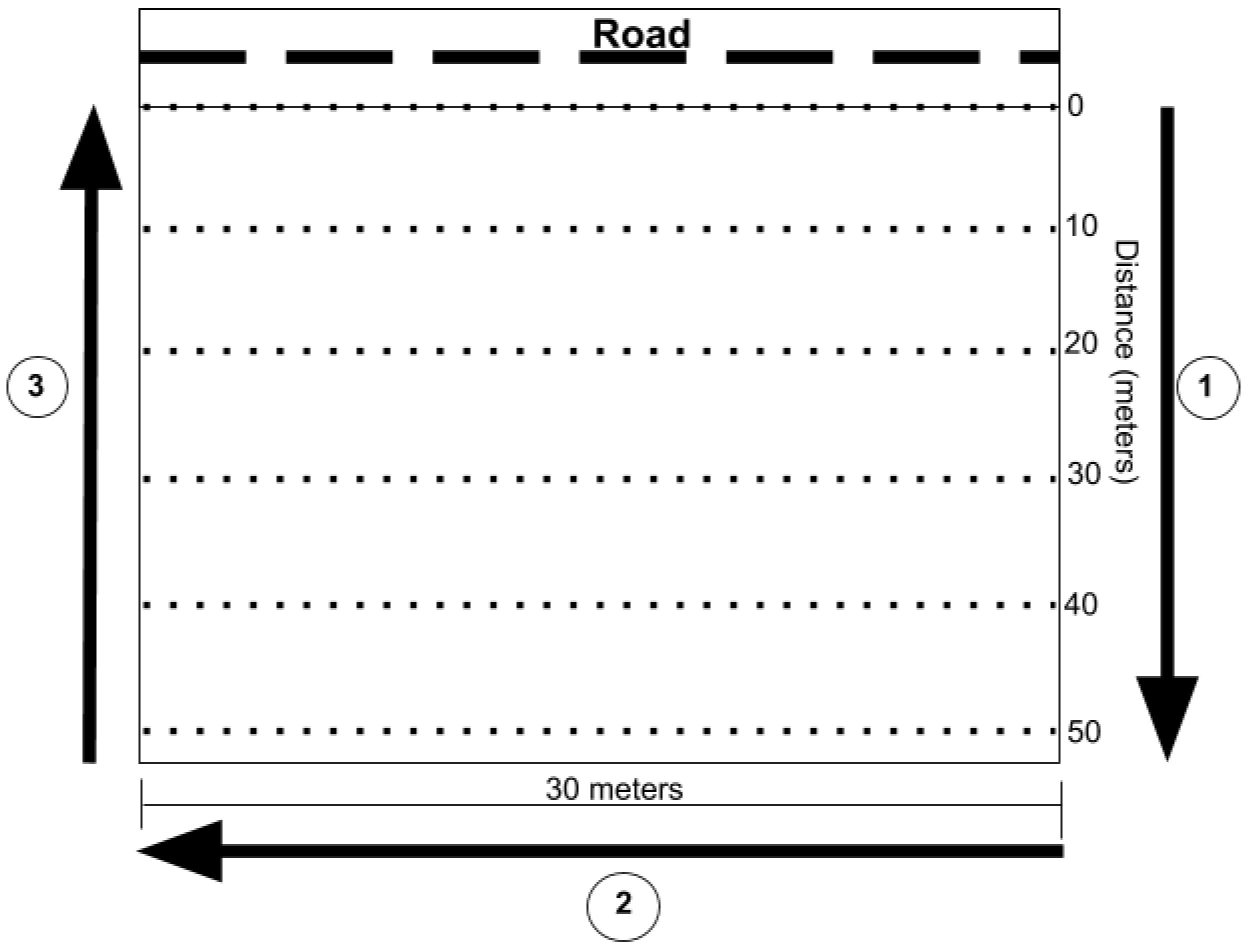

Figure 2.) This diagram illustrates the method by which transects were made. 1.) Starting on the right, 50 meters were measured from the road perpendicularly into the field. Bright flags were placed every 10 meters from 0 meters at the road until 50 meters from the road was reached. 2.) 30 meters were measured parallel to the road to find the end boundary of the transects. 3.) At this point, 50 meters were measured back to the road with flags being dropped again every 10 meters. This meant the start and end points of each transect line were visible which helped ensure straighter lines and consistent sampling sizes. This process resulted in six transect lines, parallel to the road.

Figure 3.) The above images are aerial depictions of how multiple sets of transect lines were arranged at two different sites. The image on top is of Heritage Park and the image on the bottom is on Harding Road.

Each transect began with a measurement of percent RH and dew point temperature with a humidity meter. Next, the transect was sampled with a sweep net. With each sweep, the net was brought up to approximately waist height then quickly turned back and brushed through the grass, just above the ground which served to prevent the escape of any organisms and sample again. After 30 meters, the far side of the transect was reached and the net was held closed. Organisms inside were then deposited into a clear plastic bin to observe what had been caught. Orthoptera that were clearly morphologically different from any caught before were placed in kill jars with ethyl acetate to keep for reference later, during identification. The number of Orthoptera from the families Acrididae and Gryllidae were tallied along with the number of distinct species. Following the completion of all six transects in a set, the pH and soil moisture were measured with a soil probe at the beginning and terminal points of each transect, resulting in 12 data points of each. All sets of transects were sampled following this protocol

Data Analysis: All statistical analyses were performed in R version 3.6.1 using generalized linear mixed models from the lme4 package and were plotted with the R package ggplot2. The three main relationships examined were those of the effects of road proximity, soil pH, and soil moisture on Acrididae populations. An insufficient number of Gryllidae were collected to run meaningful statistics on the family by itself. Because of this, distinct Gryllidae species were used in conjunction with Acrididae species to obtain a Shannon species diversity index with the vegan package. To test how distance from the road impacted diversity, we used a generalized linear mixed model with a gamma distribution. Shannon diversity was the response variable, distance from the road was a fixed effect, and transect set nested within location were random effects. Next, we used the same model structure with a Poisson distribution for the total counts of the family Acrididae and for the number of unique Acrididae species. Similarly, in order to examine the effects of distance from the road on abiotic factors, we used the same model structure with the Gamma distribution and soil pH or moisture as the response. After determining how these abiotic factors changed in response to the road, they were used as predictor variables in models with Poisson distributions to find any effects they may have had on total Acrididae population and species diversity.

Results

The Effect of Road Proximity on Orthoptera Abundance: Distance from road did not have a significant effect on species diversity (t=0.374, p=0.708, Fig. 4). No effects from roads were found on the total number of Acrididae (z=1.395, p=0.163, Fig. 5) or their species diversity (z=1.729, p=0.0838, Fig. 6).

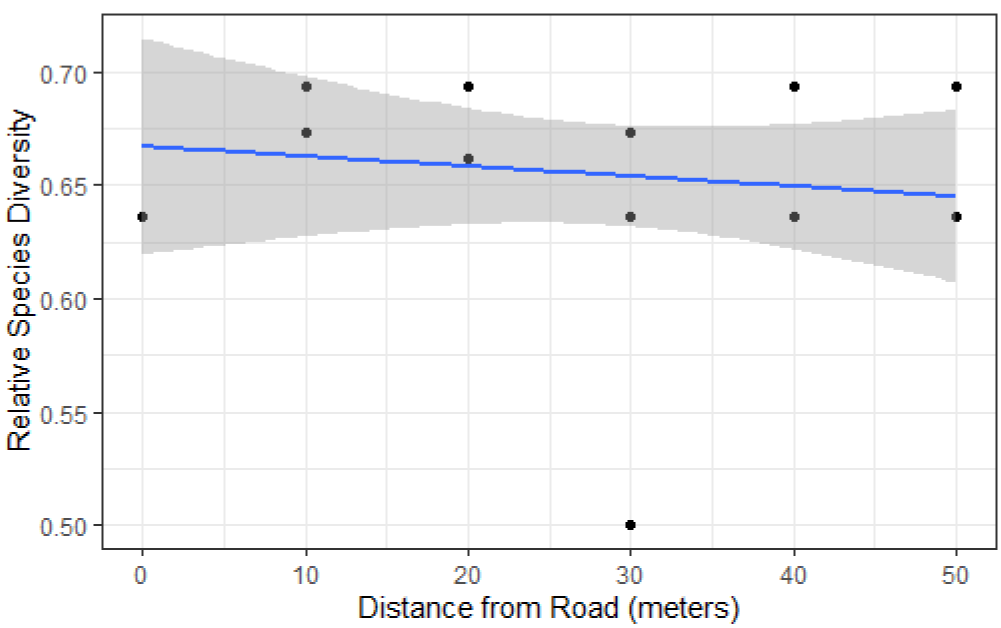

Figure 4: Shannon species diversity index displaying relative diversity of Orthoptera families Acrididae and Gryllidae at increasing distances from the roadway.

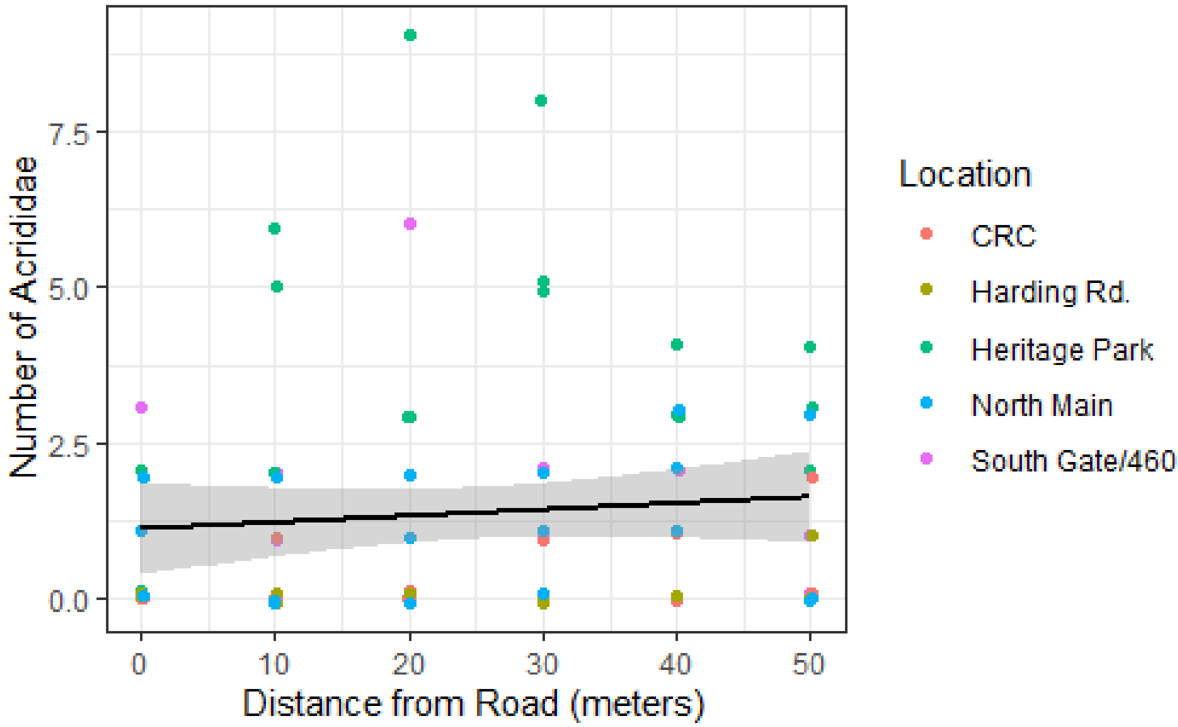

Figure 5: Effect of distance from road on total number of Acrididae caught.

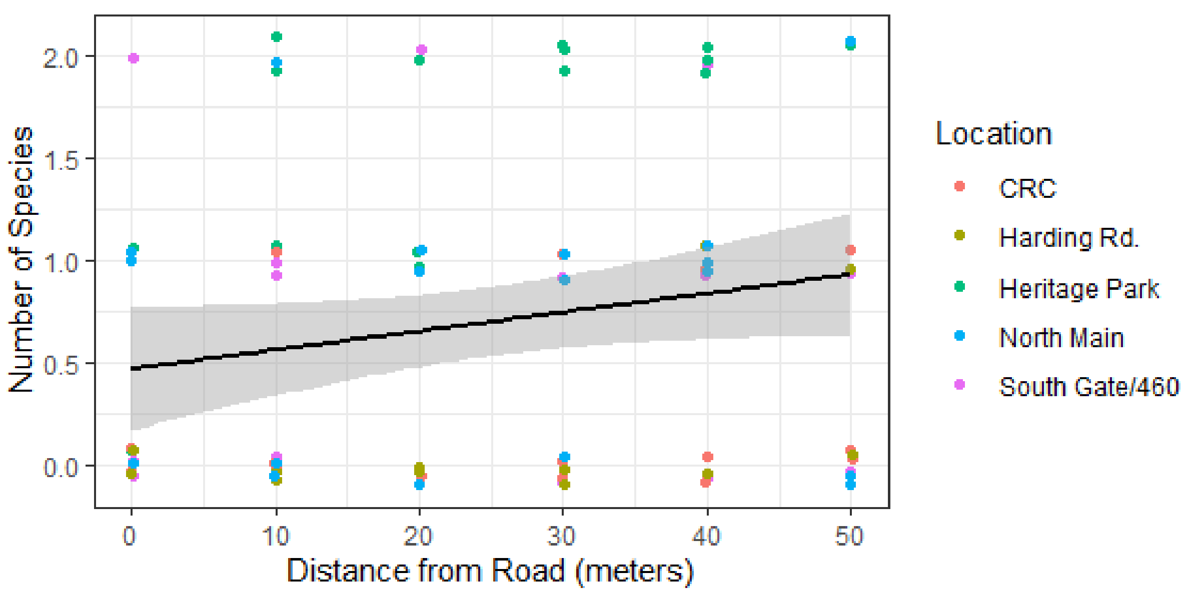

Figure 6: Change in species diversity of Acrididae at varying distances from the road.

Effect of Soil pH on Acrididae: The distance between road and measurement point showed no significant effect on soil pH (t=0.229, p=0.819, Fig. 7). This abiotic factor also failed to show a significant effect in predicting both population abundance (z=0.752, p=0.452, Fig. 8) and species diversity of Acrididae (z=0.597, p=0.550, Fig. 9).

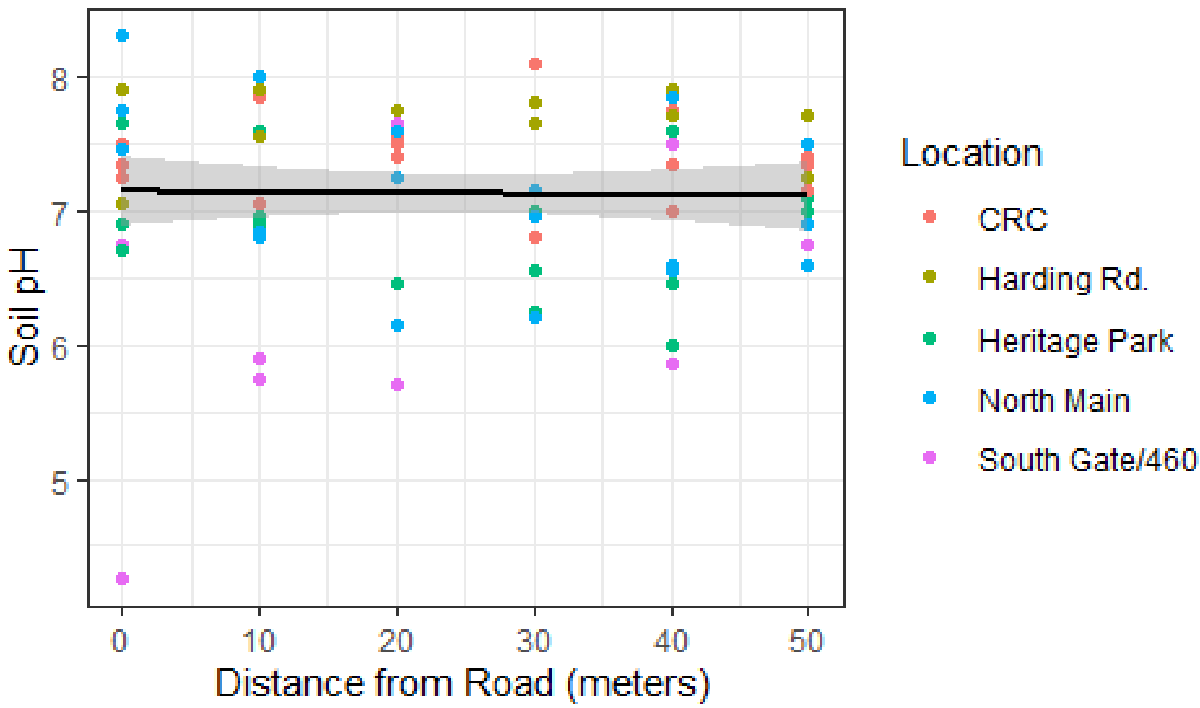

Figure 7: Effect of the road on pH levels in the soil.

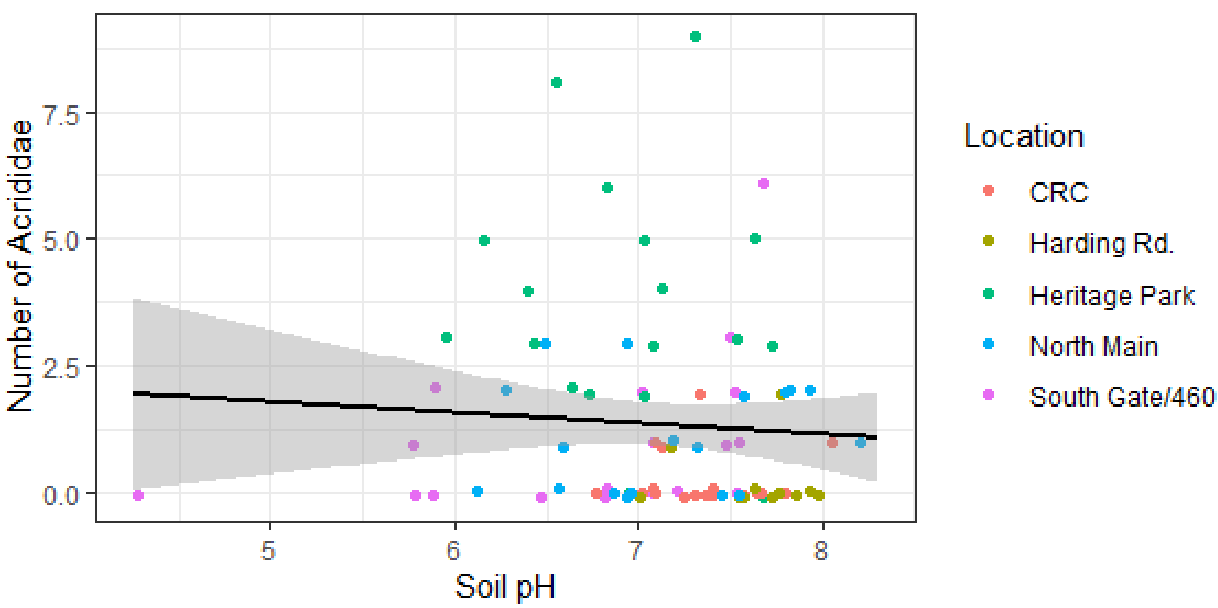

Figure 8: Effect of soil pH on changes in distribution of Acrididae.

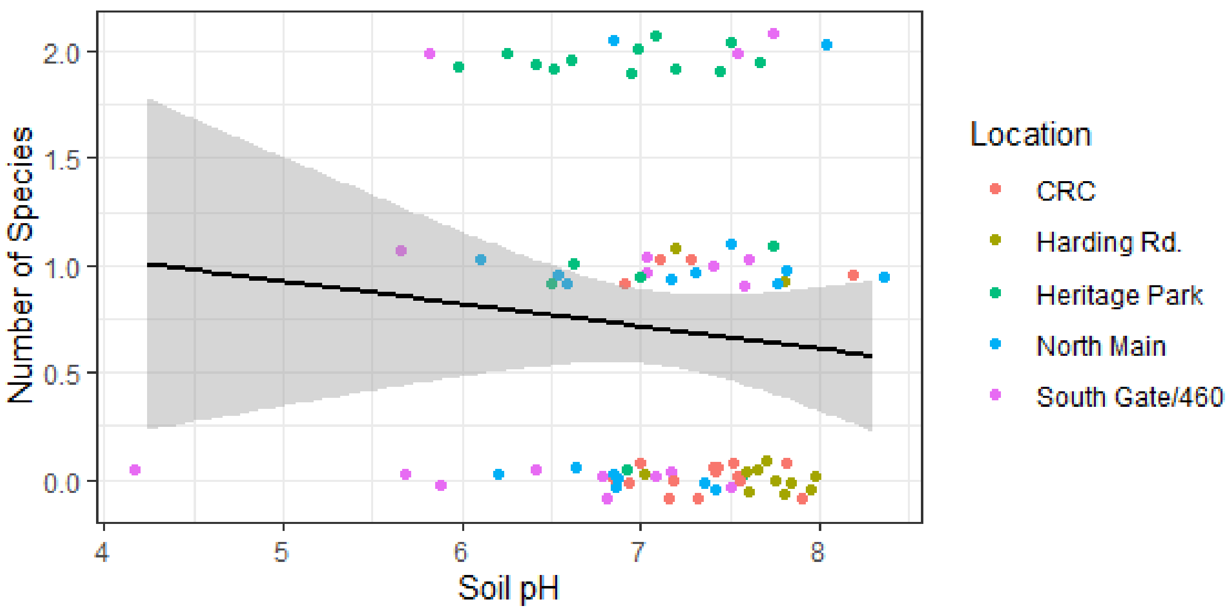

Figure 9: Effect of soil pH on number of Acrididae species present.

Effect of relative soil moisture on Acrididae: Roadways also showed no significant effect on the abiotic factor of soil moisture (t=-0.329, p=0.742, Fig. 10). No significant effect was found for soil moisture on total Acrididae (z=1.369, p=0.171, Fig. 11) or species diversity either (z=1.230, p=0.2186, Fig. 12).

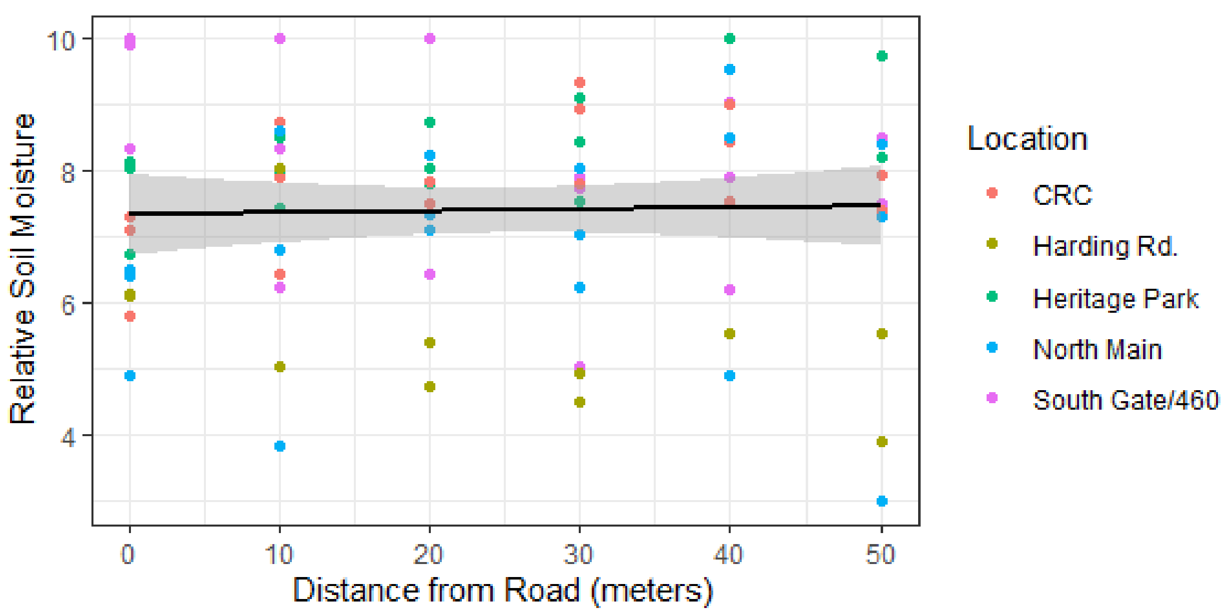

Figure 10: Effect of distance to roadway on relative soil moisture.

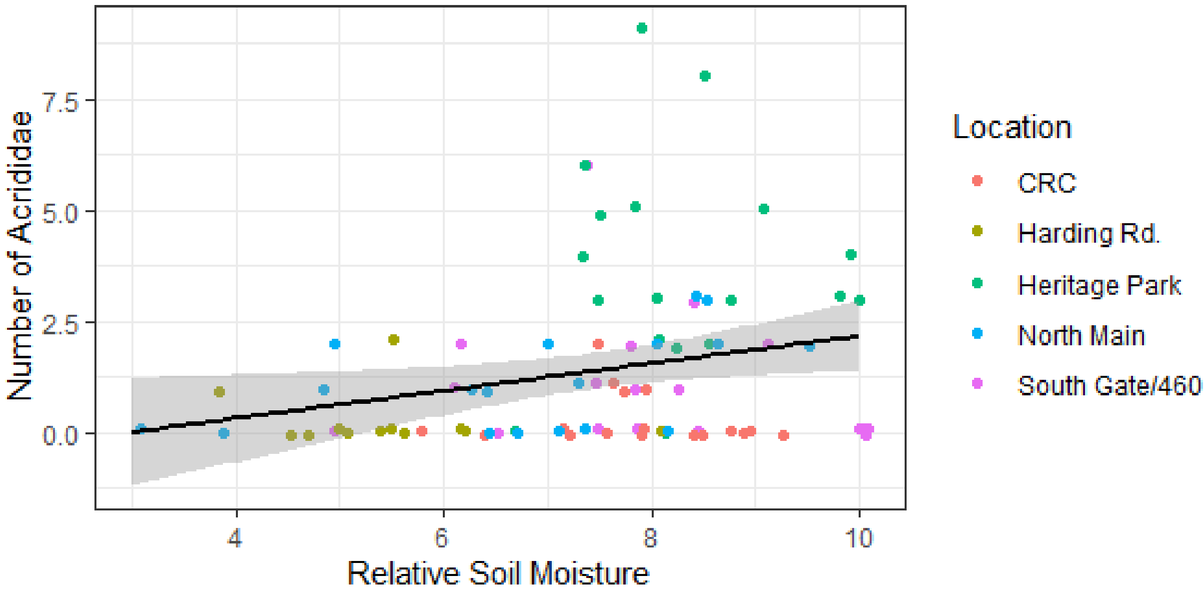

Figure 11: Change in Acrididae distribution with respect to soil moisture.

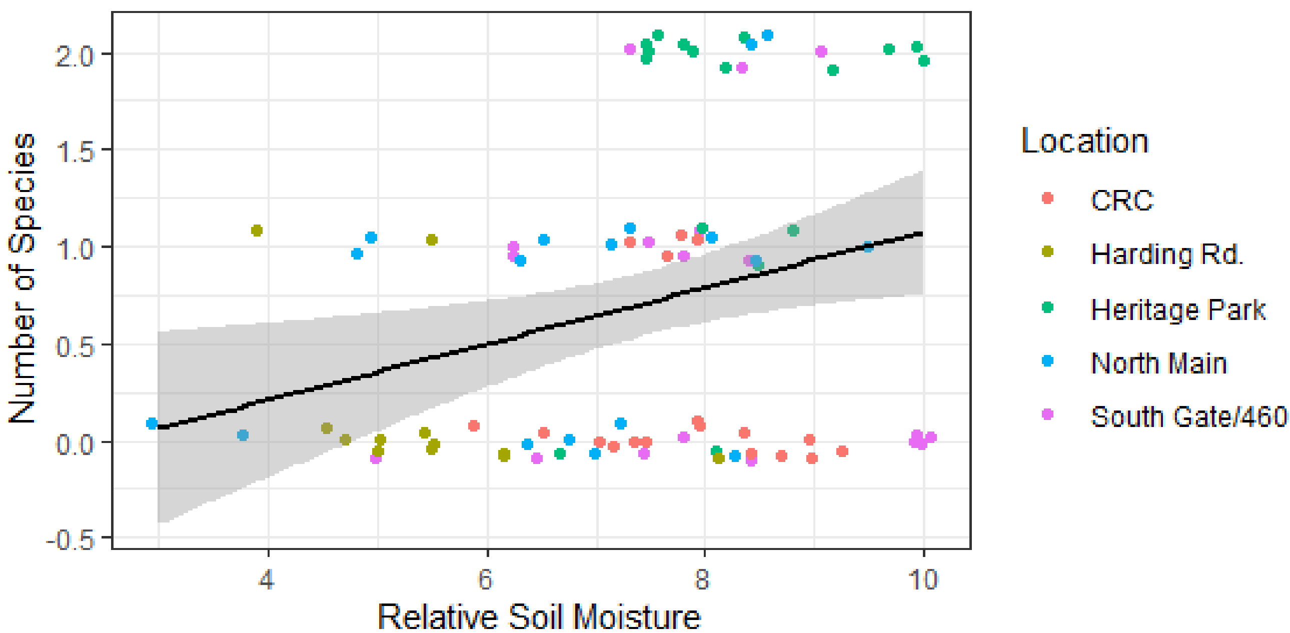

Figure 12: Effect of soil moisture on diversity of Acrididae.

Discussion

Summary: This study was conducted to determine anthropogenic impact of roadways on Orthoptera populations in adjacent fields. It was predicted that population abundance and species diversity of both Acrididae and Gryllidae would increase with distance from the road. The basis for this prediction was in the fact that roadways cause increased temperatures and high wind velocity in the surrounding ecosystem (Forman and Alexander, Lauren E.

1998, O'Neill et al. 2003). Over the course of the study, a total of six Gryllidae were found in one singular field beside South Gate Drive and Route 460. This number was too low to draw any conclusions, therefore any predictions about Gryllidae are inconclusive. Therefore, most statistics dealt with Acrididae and how their populations changed with distance from the road along with pH and soil moisture. It was found that distance from the road had no discernible effect on Orthoptera populations or abiotic factors.

Support for hypothesis: The data collected failed to support our hypothesis as roadways were shown to have little to no effect on Orthoptera populations. There was also no evidence that environmental factors including soil pH levels and relative soil moisture had noticeable effects on Acrididae. While the statistics did not show a significant effect, the relationship between soil moisture and total Acrididae and species count produced graphs with positive slopes, indicating the possibility of higher populations and greater species diversity with increased soil moisture (Fig. 11, Fig 12). Furthermore, the relationships between Acrididae and pH produced negative slopes, potentially signifying reduced abundance and fewer species with increasingly basic pH levels (Fig. 8, Fig. 9). Because pH and soil moisture themselves were not shown to be affected by distance from roads (Fig.7, Fig. 10) it is not possible to definitively call them determining factors in Acrididae population at this time. Given the relatively small sample size of this study, of five different sites with a total of 120 Orthoptera, it is plausible that relationships between factors may have been undetectable.

Comparison to past studies: A number of previous studies have examined methods by which to reduce possible negative anthropogenic impacts from roads, rather than determining the causes (Spellerberg 1998). Recently, there has been a transition in several as organizations begin focusing on studying ecological effects (Spellerberg 1998). For example, it has been determined that the total land area affected by roadways in the United States amounts to 1% of the country's total area (Forman and Alexander, Lauren E. 1998). As shown by this example, many studies still focus on only general ecological principles when studying roadways. While similar to this example, in content, the study I performed is more similar in structure to the agricultural studies that focused on specific organisms within a local area. With more research from studies such as this one, it will be possible to draw definite conclusions about the anthropogenic impact of roads on ecological systems.

Alternative explanations: The time of year during which this study was conducted was likely the determining factor of the findings. Despite a temperature of 15 to 21 degrees Celsius for four of the five days of observation, there had been frost advisories in the days leading up to the study. Organisms were difficult to locate as they were already preparing for winter. Similar studies of Orthoptera during spring and summer saw greater insect activity than this study (Gardiner 2007). Additionally, not all locations observed were equal. For example, the field along Route 460 and South Gate Drive experienced intense activity in the last couple of years as a bridge was constructed. At this site, the vegetation was short and sparse. Meanwhile, the field on Harding Road appeared to have been excused from excess anthropogenic activity for several years. Grasses grew tall and bramble patches were scattered throughout the field. Variations in anthropogenic impact and floral diversity could have been alternative factors in explaining Orthoptera distributions.

Future Studies: To properly understand Orthoptera in the context of anthropogenic impact, additional research needs to be performed. Studying Orthoptera during different seasons could reveal new biotic and abiotic relationships as organisms respond to changing weather patterns. In addition, both larger sampling sizes and larger transects would be helpful in reducing bias. Many Orthoptera are capable of flying and those with longer wings can cover greater distances (Knop et al. 2011). As a result, organisms could be present in greater numbers further from the road than observed, or travel from one side of the study area to the other.

Conclusion: While the data from this study did not reveal any significant relationships between Orthoptera and roadways, it does help to further our understanding about what factors do influence distribution. According to this study, roads do not alter abiotic factors, such as pH or soil moisture, significantly enough for there to be a responsive change in Orthoptera population. Furthermore, not all families of Orthoptera can be studied in the same fashion. Almost no Gryllidae were observed over the course of the study meaning sweep nets are inadequate for collecting them or that they do not occupy grassland ecosystems as densely as expected. Despite the data not supporting any significant effects on population, Orthoptera are ecologically important organisms as herbivores and food sources (Oedekoven and Joern 2000). For this reason, it is important to understand how their behavior in response to anthropogenic impact and habitat so we can work to preserve them and the ecosystems that depend on them.

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