The Effect of Climate Change on the Vegetative Dieting Habits of Argentine Ants: A Study on Preference of Sucrose Concentration

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Climate change is causing unnatural temperature increase around the world, and as a result of this, there is a projected increase in droughts and wildfires in California. These effects threaten ecosystems, and over 3,000 species in California are expected to face reductions in habitat and population (United States Environmental Protection Agency, 2016). Of these threatened species are ants; ants play a key role in ecosystems, and any impact on them will cause a huge ripple effect on other organisms in their habitat. Furthermore, ants rely on sustenance from vegetation surrounding their hills, and as this vegetation diminishes with climate change, it becomes harder for ants to optimally forage for food. It is important to study the effects of climate change on ants and their habitats in order to better understand how to combat damage to natural ecosystems.

*Linepithema humile* is an invasive ant species found in California. Commonly called Argentine ants, *L. humile* is a small, dull brown species, native to South America, and responsible for invading temperate regions across the world. Argentine ants are omnivorous, however they mainly eat nectar from flowers and honeydew from aphids and scale insects; they are also known to eat human food (particularly sweets), when available (Miner, 2014). In fact, Argentine ants are known to prefer sugar water to other forms of sweet carbohydrates or proteins (Nyamukondiwa and Addison, 2014). Furthermore, previous research has found that sucrose solutions of intermediate concentrations were consumed by *L. humile* at higher and faster rates than sucrose solutions of high concentration; additionally, high concentration sucrose solution resulted in detrimental foraging activity, including extended feeding times and low intake rates (Sola and Josens, 2016).

This study focuses on settling the following questions: Does *Linepithema humile* have a preference in specific concentrations of sugar solution? Is this preference based on the amount of vegetation surrounding Argentine ant hills? In order to determine this, we will examine the foraging activity of several Argentine ant hills with abundant surrounding vegetation and several with scarce surrounding vegetation. We will place four solutions of different sucrose concentrations (0%, 5%, 25%, 50%) equidistant and in close proximity to active hills. Sucrose solutions will be used because previous research has shown that Argentine ants diet on sweet substances. All the conditions of each replication in this experiment, except for surrounding amount of vegetation, will be controlled. Preference of the ants to sugar solution will be measured by the number of ants on the solution.

Previous research has shown that *L. humile* prefers sucrose solutions of intermediate concentrations more than those with high concentrations. According to this and according to optimal foraging theory, we hypothesize that a significantly greater amount of Argentine ants will consume the intermediate, 25% sugar solution in both vegetatively abundant and scarce habitats. We hypothesize that more Argentine ants, overall, will consume the intermediate solution in vegetatively scarce habitats than in vegetatively abundant habitats, because ants in abundant habitats have a lower need for extra sources energy, due to their nutritionally rich environment. For this same reason, we also hypothesize that the recruitment time of the Argentine ants will be shorter in vegetatively scarce habitats than in vegetatively abundant habitats.

**Study System**

*Linepithema humile* is an invasive ant species found in California. Ant hills located at the Bernard Field Station (BFS) were sampled for this experiment in 2018. All habitats of the
sampled ant hills contained sandy and rocky soil and were not close to water sources. The amount of vegetation surrounding each ant hill varied, with vegetatively abundant ant hills being on the upper trails at the BFS and scarce ones being on the lower trails. The type of surrounding vegetation at all ant hills was the same, and included *Ribes aureum* (golden currant), *Eriodictyon crassifolium* (yerba santa), *Crassula connata* (pygmyweed), *Amsinckia menziesii* (rancher’s fireweed), and various *Cryptantha* species (popcorn flower).

**Experimental Setup**
Ten Argentine ant hills — five hills surrounded by abundant vegetation and five surrounded by scarce vegetation — were sampled over the span of a week (the following method was replicated ten times). Four coins were placed equidistantly around each ant hill opening, within 2 inches of the mound. We pipetted five drops of 0% (water), 5%, 25%, and 50% sucrose solutions onto separate coins around the hill. We controlled for the type of coin used, texture of soil around the ant hills, light exposure to the mounds, and the time of day of the experiment.

**Data Collection & Measurements**
Argentine ant activity at the four coins around a given hill was observed and recorded for sixty minutes. We counted the number of ants on each coin at ten minute intervals. We also recorded ant recruitment time, or the time it took for ten ants to reach each bait. For treatments where less than ten ants were recruited, recruitment time was estimated by dividing the number of ants by sixty minutes, and finding the equivalent proportion that gave the recruitment time of ten ants per minutes. The environmental surroundings of each ant hill were diagrammed and described.

**Statistical Analysis**
Our independent variable, or the different concentrations of sugar solutions (0%, 5%, 25%, 50%), was categorical. Our dependent variable, measured by the number of ants at each bait over ten minute intervals, was continuous. Therefore, we analyzed our results with ANOVA to compare the mean number of ants among the four nominal categories; we conducted one ANOVA analysis for ant hills with abundant vegetation and a separate ANOVA analysis for ant hills with scarce vegetation. We analyzed our results with a Chi-squared test to determine if Argentine ants do have a preference for a specific concentration of sucrose solution. We also analyzed the time it took ten Argentine ant to visit the baits with a t-test in order to determine if there was a difference in recruitment times among vegetatively abundant and vegetatively scarce habitats.

**Results**
The number of total Argentine ant visits to all baits in vegetatively abundant habitats was 62; the number of total ant visits to all baits in vegetatively scarce habitats was about thirteen times greater, totaling 856 ant visits (Figure 1).
Figure 1. <Linepithema humile> – total number of ants on all baits – the relationship between vegetatively abundant and vegetatively scarce habitats and number of ants visits.

At 17 visits on average, the number of ant visits to 25% sucrose concentration baits largely exceeded the number of visits to other baits in vegetatively abundant habitats; the average number of ant visits for other baits ranged from 0 to 3 (Figure 2). There was no significant difference in number of ant visits among treatments at vegetatively abundant habitats (ANOVA, $p = 0.13$, $F = 2.56$, df = 3,8). There was a significant difference in Argentine ant visits to each treatment; preference for a specific concentration of sucrose at vegetatively abundant habitats is indicated ($\chi^2(3, n = 62) = 111.29$, $p < .01$).

Figure 2. <Linepithema humile> – number of ants on bait – the relationship between sucrose concentrations of bait and number of ant visits in vegetatively abundant habitats on upper trails at the BFS ($n = 3$, mean ± SE).

At 122 visits on average, the number of ant visits to 25% sucrose concentration baits exceeded the number of visits to other baits in vegetatively scarce habitats; the average number of ant visits for the 0%, 5%, and 50% sucrose treatments were 0, 11, and 81, respectively (Figure 3). There was a significant difference in number of ant visits among treatments at vegetatively
scarce habitats (ANOVA, p < .01, F = 38.71, df = 3,12). There was a significant difference in Argentine ant visits to each treatment; preference for a specific concentration of sucrose at vegetatively scarce habitats is indicated ($\chi^2(3, n = 856) = 756.41, p < .01$).

![Bar graph showing the number of ants on bait for different sucrose concentrations.](image)

**Figure 3.** *Linepithema humile* – number of ants on bait – the relationship between sucrose concentrations of bait and number of ant visits in vegetatively scarce habitats on lower trails at the BFS (n = 4, mean ± SE).

**Table 1.** *Linepithema humile* – recruitment times in minutes for treatments at vegetatively abundant and vegetatively scarce habitats (n = 11, mean ± SE, * indicates p < 0.05)

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Treatment (Sucrose Concentration)</th>
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<tbody>
<tr>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>Vegetatively abundant</td>
<td>--</td>
</tr>
<tr>
<td>Vegetatively scarce</td>
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Whereas Argentine ants formed a recruitment at only the 25% treatment in vegetatively abundant habitats, they formed three recruitment trails (at 5%, 25%, and 50% treatments) in vegetatively scarce habitats (Table 1). All average recruitment times in vegetatively scarce habitats are quicker than those in vegetatively abundant habitats, with no overlap from standard error. The average recruitment times in vegetatively abundant habitats fall within the range of 30 to 34 minutes, whereas the average recruitment times in vegetatively scarce habitats fall within the approximate range of 11 and 26 minutes (minimum value at 11.62 and maximum value at 26) (Table 1). There was a significant difference between recruitment times of ants to 25% sugar solutions in vegetatively abundant and scarce habitats (t-test, t = 4.77, df = 4, p = 0.01).
Discussion
The focus of this study is to determine if *Linepithema humile* has a preference for specific concentrations of sugar solution, and, secondarily, to determine if this preference is based on the amount of vegetation surrounding sampled ant hills.

We hypothesized that a significantly greater amount of Argentine ants will consume the 25% sugar solution in both vegetatively abundant and scarce habitats; for the most part, our results support this hypothesis. While a significantly greater amount of Argentine ants visited and consumed the 25% sugar solution in vegetatively scarce habitats, there was no significant difference in number of ant visits among treatments at vegetatively abundant habitats. On the other hand, preference for the 25% sugar solution was shown by Argentine ants at both habitat types; this preference is shown because, according to optimal foraging theory, the 25% solution provides the ants with maximum energy benefits while minimizing expenditure. Overall, our results indicate that, at the upper trail ant hills of the BFS, Argentine ants are able to successfully forage for nectar and other forms of sustenance in the rich surrounding vegetation. However, at the lower trails of the BFS, Argentine ants are experiencing the effects of climate change and are not able to optimally forage for sustenance. This is why our results indicated a great amount of ants consuming 25% and 50% sugar solutions; in order to obtain the most energy, and at the risk of inefficient expenditure of energy, the ants in scarce habitats consumed higher sucrose concentration solutions.

We also hypothesized that more Argentine ants, overall, will consume the intermediate 25% solution in vegetatively scarce habitats than in vegetatively abundant habitats. Our results support this hypothesis. On average, 17 ants from vegetatively abundant habitats consumed the intermediate 25% solution; meanwhile, 122 ants from vegetatively scarce habitats — about seven times more ants than the abundant habitats — consumed the same solution. This occurred because ants from habitats with scarce vegetation (due to climate change effects) cannot forage efficiently. These ants have a greater need for energy than ants from vegetatively abundant habitats. Therefore, the intermediate solution was more consumed by Argentine ants from the lower trails than the upper trails.

Lastly, we hypothesized that the recruitment time of the Argentine ants will be shorter in vegetatively scarce habitats than in vegetatively abundant habitats. Our results support this hypothesis. Not only did the vegetatively scarce habitats find recruitment for two treatments more than vegetatively abundant habitats, but also the average recruitment times of the former habitats were, overall, approximately 5 minutes faster than the latter habitats. Additionally, the quickest recruitment time (about 12 minutes) in the vegetatively scarce habitats took approximately one-third of the time of the quickest recruitment in vegetatively abundant habitats (30 minutes). The ranges of the recruitment times differ between habitat type because, once again, Argentine ants in the vegetatively scarce habitats have a greater need to obtain energy than ants in vegetatively abundant habitats. Additionally, in terms of the intermediate sucrose solution, it took ants from abundant habitats a significantly greater amount of time than ants from scarce habitats to form recruitment.

Previous research has shown that sucrose solutions of intermediate concentrations were consumed by *L. humile* at higher rates than sucrose solutions of high concentration (Sola and Josens, 2016). Our experiment supports this with ant hills in both abundant and scarce habitat types, as, on average, more Argentine ants consumed the 25% sucrose solutions than the 50% solutions in order to minimize expenditure of energy. Previous research has also found that detrimental ant foraging activity is associated with consumption of high concentration sucrose
solution (Sola and Josens, 2016). Our results also support this because Argentine ants from vegetatively scarce habitats are not able to optimally forage for sustenance due to climate change effects. Additionally, in our experiment, 81 ants consumed the 50% sucrose solution, despite the associated risk of inefficient expenditure of energy. Overall, our study slightly deviates from these other studies in that our analysis demonstrates how the magnitude of ant preference for sugar solutions differs among vegetatively abundant and scarce habitats.

Specifically examining Argentine ants and their habitats, our study and findings demonstrate the damaging effects of climate change on the natural ecosystem. Diminishing vegetation surrounding ant hills makes it difficult for ants to optimally forage for food, leading to inefficient expenditure of energy. Instead of devoting resources to other beneficial activities, such as developing nests or attacking neighboring ant colonies, Argentine ants in scarce habitats are forced to expend excessive amounts of energy harvesting sustenance. Further studies may be carried out on other ant species to investigate if diminished vegetation and sources of sustenance impacts their foraging activity. It may also be of interest to examine how increased foraging activity of Argentine ants affects competition between other ant species with similar dieting habits.
Works Cited

