Abstract

Emergent group behaviors were observed which point toward a certain degree of cooperation by antlions. The donut theory, the forerunner in describing antlions' spatial distribution, asserts that the insects form a ring to capture ants approximately equitably. Similar "cooperative" behavior was observed, with the antlions remaining under the soil when the surface was overpopulated (demonstrable by a significantly lower number of pits forming in smaller trials). The donut theory was confirmed by the observed spatial distribution because antlions often stuck to the side of the trial area despite there being significant available space on the inside of the circle where an individual could gain competitive advantage. The hypothesis that they exhibit more extreme behaviors under space constraints was confirmed because, proportional to the number introduced, especially in the 8x7 trial, cannibalism and non-formation of pits increased significantly—likely as a compensatory mechanism to ensure that a stable "surface group" could still safely exist. Additionally, territory (measurable by the Voronoi diagrams and by nearest neighbor) decreased towards the later trials, and the patterns didn't merely display the same structure scaled down—rather, antlions accepted more dense conditions by increasing pit density. This likely corresponds to natural conditions (especially in hatcheries) where some proportion of the antlions remain on the surface (increasing with population density because it's understood to mean a prevalence of food), and as the surface antlions become adults (sometimes fed through cannibalism), new larvae emerge to take their place and sustain the species' propagation.

Guiding Question, Hypothesis, and Variables

Question Statement:

How do antlion spatial patterns, such as pit depth, width, and nearest neighbor, as well as behaviors, such as cannibalism and eating habits vary with respect to spatial constraints and temporal change?

Hypothesis:

As the space available to antlion groups decreases, each claims less territory, and the populations tend towards more extreme behaviors, such as cannibalism and reclusivity, to limit competition for ants as an emergent feature of individual interactions.

Independent and Dependent Variables:

Throughout the experiment the independent variable was the size of the container, which changed from trial to trial, but did not change due to any other variable. Furthermore, the dependent variable throughout the experiment was the settlement patterns and behaviors of the antlions, which was quantified through the nearest neighbor calculation, pit depth and width, and the number of cannibalized antlions. The control trial of the experiment was the 32x32 trial, as it shows the spatial patterns and behaviors of the antlions with the most available space, limiting the effect of competition on settlement patterns, which qualifies it to be a good control group.

Materials And Procedure

Materials:

1. A 32x32 Container
2. A barrier to reduce the 32x32 container to a 24x23 Container
3. A barrier to reduce the 32x32 container to a 16x15 Container
4. A barrier to reduce the 32x32 container to a 8x7 Container
5. 4 bags of Quartz sand (200 Pounds of Sand)
6. 40 Antlions
7. 41 Medium Circular containers, about 6 inches in diameter
8. A meter stick
9. 40 Toothpicks
10. Tape
11. A Ruler (With Cm)
12. 160 Ants
13. A small plastic cup, about 2 inches in diameter
14. A sharpie
15. 1 Sieve

Procedure:

1. A meter stick was used to mark the sides of the 33x32 container with inch markers starting from the bottom right of the container on its lid
2. 4 antlions were introduced to the container every 24 hours until all remaining antlions had been introduced, s
3. Toothpicks were inserted next to pits to signify there presence. Following the introduction of all 31 antlions a 24 settling period was allotted
4. The location of each antlion was measured using the grid system created earlier and the number of total pits and dead antlions was taken, the pit depth and width was also measured (In centimeters) using a 6 inch ruler
5. All antlions were taken out and placed in temporary pits
6. Steps 2-5 were carried out again with enclosure sizes of 24x23, 16x15, and 8x7, which were reduced by using cardboard barriers and tape to real off parts of the enclosure

Data Analysis

The patterns created by antlion groups are emergent: they don't exhibit top-down structure like a highly regular tiled or even consistent polymorphism across trials. However, the antlions did cluster somewhat but regardless maintained sufficient area to capture food, either of the cannibalistic or regular sort. The Voronoi diagrams are the primary source which exhibits these traits: scaled down to the window of the trial area which antlions populated, the area claimed by each individual antlion is somewhat consistent, explicable by a selfish algorithm: each antlion wants to optimize its area of ant capture (represented by "claimed" regions on the Voronoi diagrams), so the area was shared about equally by the group. Also, average distance to nearest neighbor decreased with lesser trial area: from 5–6cm on average in the 33x32cm trial down to 3–3.5cm in the 8x7cm trial, the graph in Figure 3 demonstrates a clear correlation, with a notable (but inconclusive) p-value of about 8%, between territorial area and total area.

Data Analysis Continued

Weekly feedings helped maintain the natural analogue to scarce ant feedings, so the antlions had to create their pits as determined by the density of the environment (simulated by a small area). This caused them to create significantly smaller pits in smaller containers (in terms of depth and width) because the antlions were aware that ants would have a better chance of falling into the pits if numerous small pits were created. This is in contrast to the 33x32 where none of the antlions formed pits shallower than 1.1cm and one pit was 4.2cm wide. Throughout the study a clear increase in extreme behaviors was noted, which is shown by Table 1 (Appendix B, Figure 4), which shows that the initial 33x32 trial size had a 19.35% fatality rate among the 31 antlions involved in the trial, compared the last 8x7 trial size which had a 33.33% fatality rate. This resulted in a 13.9785% increase in deaths throughout the study, which falls within a p value of below 0.05, making the results statistically significant. The observed cannibalism of antlions supported the hypothesis that extreme behaviors would increase as trial size decreased, as antlions are known to resort to cannibalism in times of environmental and biological stress.

Background Research

To design the experiment and understand the organisms' underlying behaviors which might affect it, extensive background research was required---specifically on their spatial distribution patterns. First, a previous study analyzing the spatial patterning and structure of termite mounds in an African savanna was examined to better understand the procedure of the experiment. This study examined how different termite colonies in the African savanna positioned themselves in relation to one another, and helped guide the procedure of our experiment. Next, several studies regarding the anatomy and behavior of antlions were used in order to better understand the insects. These studies determined that antlions stay in their larva form, in which they make pits, for 6-8 weeks and develop slower when exposed to less food. This helped determine the timeline of the experiment and determine the intervals at which the antlions would be fed. Lastly, a series of studies about antlion dispersal pattern called the "Doughnut theory" were examined to better understand the current scientific knowledge surrounding antlion dispersal patterns. These papers determined that antlions naturally position themselves in a "doughnut", in which a ring of antlions circle a center point or food source to limit competition for ants.

Conclusion

Pit depth and width correlate strongly with trial area, as demonstrated by graph one, which relates the two. The pit positioning of antlions (as a group and as individuals) likely varies solely to maximize ant capture. Therefore, this phenomenon is observed because antlions' pits don't need to be as big when the main constraint on ants falling into the pit is simply having a pit available for them to fall into. This is also observable by the trials' decreasing number of visible pits (versus total antlions introduced) with respect to size: they start to hide underground because rather than simply having smaller pits than stronger antlions, they have to rest underground, possibly to preserve group wellbeing. Graph 2 indicates a similar trend---antlions' territory as described by the nearest neighbor calculation is much lower in smaller containers. This is the natural consequence of less area being available but demonstrates that the effects of hiding don't completely level the density of antlion pits based on population per area. Additionally, deaths remain minimal even in highly crowded conditions like the 8x7, which means that deaths are probably accidental at worst and antlions work to preserve the group's chances of surviving. The earlier hypothesis was proven to be correct, as the correlation between a smaller trial size and more extreme behaviors (such as cannibalism and reclusiveness) is supported by the data, as an increase in cannibalism was seen in lower treatment groups, hinting towards more aggressive behavior at lower trial groups, thereby proving the hypothesis.

Works Cited

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