Dynamics of Fire Ant Raft Mergers

[redacted]

I. Introduction

Fire ants, Solenopsis invicta, are a resilient species originating in South America but spread to Asia and North America and are classified as an invasive species as they are able to compete with native ant species [1]. They have a complex social structure and are one of the many species that exhibit cooperative behavior in order to accomplish complex tasks. One such behavior is the formation of a raft when the fire ant's habitat is flooded [2]. The raft is a stable structure that can persist for months. Many species, for example water striders and fire ants, capable of biolocomotion have plastrons which are pockets of air trapped by hairs on their limbs due to them being slightly hydrophobic [3]. This effect is capable of not only supporting a single ant but a raft with multiple layers. It has been found that the hydrophobicity of ants' cuticle aid in trapping air which decrease its effective density by up to 75% [2]. This also allows ants to remain buoyant even after they are submerged in water leading to a robust structure.

Additionally, it has been determined that ants actively grip each other in the raft, with their tarsal claws with a force of about 620 dyn [2]. The construction rafts from an initial spherical conglomerate structure has also been analyzed and demonstrated that ants actively join the edge of the raft [2]. All of this points that the formation of rafts is not by accident and that cooperative perhaps altruistic behavior underlies this behavior [4].

We seek to investigate this behavior further by studying the merger of two different rafts, specifically if rafts from two colonies would merge in a similar manner to rafts from the same colony. On land, ants from different colonies typically fight and we aim to investigate if such behavior would be observed during a merger of two rafts or if a larger raft would be formed. We chose to measure the construction rate by determining the total area of the raft in order to characterize these dynamics.

II. Methods

A. Experimental Setup

The ants from multiple colonies were obtained from the vicinity of Georgia Tech. Two separate colonies were obtained. For each trial, about 50 ants were used for each raft prior to merger. Because of difficulties with counting the exact number of ants, groups of ants were weighed to ensure that they were of comparable weight. For trials with ants from different colonies, ants from one of the colonies were painted with a white oil-based paint. To prevent the paint from blocking trachea or coating the ant's cuticle, the paint was only applied on the abdomen as shown below:

A tub, approximately 0.7m by 0.4m dimensions, was filled with water 10cm deep. After two groups were placed on the water, they were allowed to equilibrate for five minutes. This length was chosen in accordance with observation and previous studies that showed asymptotic behavior in construction rate of rafts after 3 minutes. They were then brought together and observed for 20 minutes with an overhead camera.

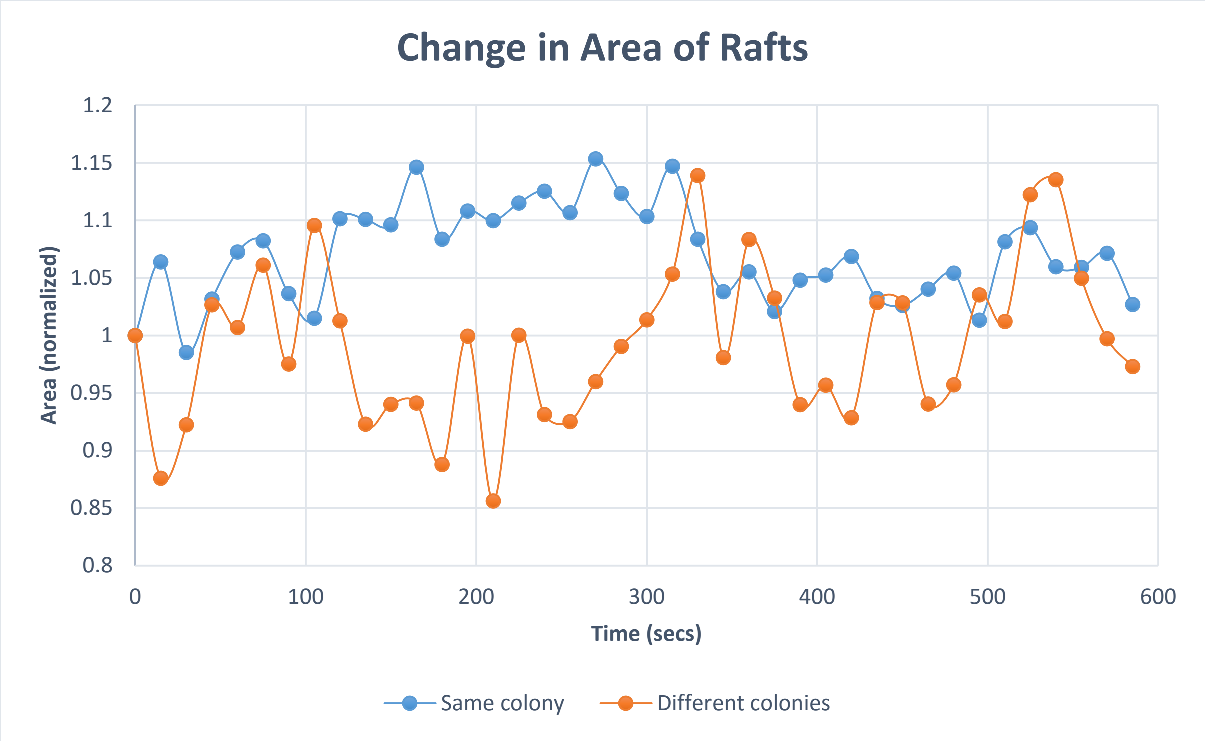
B. Image Analysis

Still frames from the recorded video were used for data analysis. Pictures are taken every fifteen seconds for up to ten minutes for both the different colonies and the same colony cases. The picture is then opened up in ImageJ for measurement. The ant raft is enclosed by a circle, then ImageJ calculates the area enclosed. Below is a screenshot of one measurement:

We then normalize the measurement with the initial area of the raft to track the changes through time. Our hypothesis is that the different colonies raft merger will fluctuate more than the same colony case.

III. Results

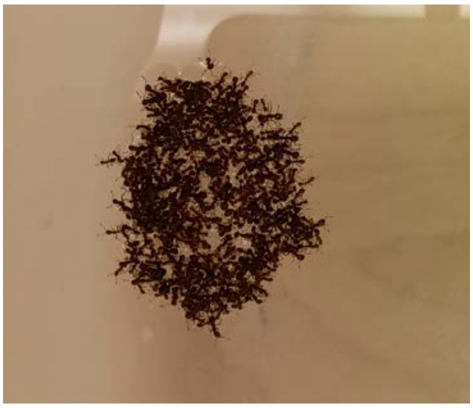
Below is the plot obtained from our data:



We can see that there is fluctuation in both cases. This is expected, as the rafts are in water and the ants are constantly maneuvering to stay afloat. However, in the same colony case, we see that the ants equilibrate and fluctuate less after some time (around 5 minutes). After equilibrating, the raft tries to retract to a constant value after some expansion. In the different colonies case, there is not a clear trend in the raft's fluctuation. Interestingly, in the same colony case, we don't see the resulting raft constantly retracting pass the initial area, whereas the resulting raft from the different colonies fluctuate both above and below the initial point. Quantitatively, the data from the same colony case has standard deviation of 0.0415, where the different colonies case has standard deviation of 0.0677, confirming our hypothesis that the different colonies raft fluctuates more than the same colony one.

Moreover, we also observed splitting of the resulting raft in the different colonies case on a few occasions, as seen here:

whereas the same colony resulting raft flattens out to a nice pancake shape:



IV. Discussion

We observed qualitatively different behavior in different colony mergers along with their areas decreasing after the merger. The different colony mergers were generally more chaotic and had a higher height even after 20 minutes. However, a quantitative measure of the height difference wasn't obtained, as we only recorded straight overhead. While tracking of individual ants is an open problem because of the high density of ants within the raft structure, Particle Image Velocimetry methods could be used in order to capture ant movement to perhaps model ants as a flow or diffusive process. There were things we could have done better as well, such as painting ants in the same colony case, or conduct more experiments. However, we are still glad we were able to obtain interesting data even with a small number of ants in our rafts (~100 vs ~1000 in referenced papers).

V. Conclusion

We learned a lot about ants through this project, and it was fun playing with ants. Though we kept the project simple, we realize there are many ways we could expand the project. Possible ways to expand the project include observing only two single ants, or observing how different factors may alter ants' behavior, such as when the queen is present. We hope that a future group in the class will choose to work with fire ants as well.

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References

1. Sanford D. Porter and Dolores A. Savignano, “Invasion of Polygyne Fire Ants Decimates Native Ants and Disrupts Arthropod Community”. Ecology 71:2095–2106. http://dx.doi.org/10.2307/1938623 (1990)

2. Nathan J. Mlot et al. , “Fire ants self-assemble into waterproof rafts to survive floods”.
PNAS 2011 108 (19) 7669-7673 . (2011)

3. Bush JWM and Hu DL, “Walking on water: Biolocomotion at the interface”. Annu Rev Fluid Mech. 38:339–369. (2006)

4. Stuart A. West et al. , “Evolutionary Explanations for Cooperation”. Current Biology. Volume 17. Issue 16. R661-R672. (2007)