The effects of climate change on ant population dynamics and ant-plant mutualisms
Short-term visit 3/14/2010 – 3/19/2010 of Judith Canner (NCSU)
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Summary Report: For ant colonies, seasonal regulation of egg, brood and worker numbers is critical to ensure that there are enough foragers when food is abundant and to minimize death when conditions are unfavorable (e.g. when it is excessively hot or cold, during dry seasons, or when the food supply is limited). At the same time, within-colony dynamics and, in particular, the onset of ant foraging and the peak in forager numbers can have a significant impact on the myrmecochorous plant community, many of which time dehiscence to coincide with the early spring appearance of ants. To understand the factors controlling the seasonal abundance of ants, we developed a stage-structured model of colony dynamics, using a McKendrick-von Foerster PDE (MvF) formulation. More specifically, we constructed a modified MvF to include development and mortality rates that vary both by season and by life stage (egg, larva, pupa, worker/alate). We then used this model to predict the temperature driven seasonal abundances of eggs, brood, pupae and workers. In contrast to others who have worked with the MvF model, our model considers a fixed number of breeding females (the queens) with temperature sensitive fecundity rates. Moreover, we incorporated temperature and stage dependent development and mortality rates and SB determined an analytic solution under the simplifying assumption that fecundity, development and mortality vary linearly in time. We also wrote a model that incorporates the effect of food availability on development and mortality rates at each life stage, though we have not determined an analytic solution for the full model. In addition to the MvF model for ants, JC developed a model of plant fruiting phenology that we will later incorporate into the extended MvF model as an additional, high quality, food source that affects the growth and survival of larvae and thus indirectly alters both worker-to-reproductive and male reproductive-to-female reproductive ratios. Finally, in collaboration with KS, we acquired, through a literature search, the data necessary to parameterize and test our model for the invasive fire ant, *Solenopsis invicta* as well as data for other common ant species, specifically seed-dispersers.

Future Work: We are currently coding the model in Maple and Matlab in order to simulate colony dynamics driven by seasonal changes in temperature. We will fit the model for *S. invicta* in order to test the predictive power of the model for a single species. Once we get a working model, we will then fit the model for a suite of species "types", where we differentiate types by variation in life history traits (diapauses, multiple queens, stage-specific temperature tolerances). In theory, we should be able to predict the seasonal community composition along a temperature gradient in terms of species types. We will then consider current estimates of climate change in order to make predictions about the possible effects of global climate change on ant colony dynamics and perhaps even ant community dynamics. Finally, using models developed by JC for plant community dynamics, we will couple our ant colony model with the plant community model to make predictions about the future coupling and population dynamics of ants and plants under different climate change scenarios. In each step, we will also consider stochastic extensions of the deterministic models we developed, specifically environmental stochasticity. In total, we hope to produce two publications from this research over the next year. The first will be an introduction to the model, with qualitative and quantitative analysis, and a realization of the model for fire ants. The second will be a paper on the effects of temperature changes on the seasonal abundances of different seed-dispersing ants and how this will affect the myrmecochorous plant community.

Final Summary: We developed a temperature dependent model of ant colony dynamics, using an extension of the McKendrick-von Foerster PDE. We determined the analytic solution of the model assuming linear changes in fecundity, development and mortality rates through time. We also synthesized the available literature on the invasive fire ant, *Solenopsis invicta*, in order to parameterize and test the model. Finally, we developed two possible extensions of the model, one that incorporates food availability/quality and another that incorporates the effects of elaiosome consumption on larval survival and colony sex-ratios.

Below we show a sample simulation from our initial exploratory work. In this figure, we consider a newly mated queen at the beginning of the spring, and track the changes in the number of eggs, brood, pupae and workers throughout the course of the first year. For this simulation, we assumed that developmental rates increase and decrease through the spring and fall respectively, but remain constant through the summer and winter. Similarly, we assumed that worker mortality increases in the spring/summer (due to foraging risks, etc.), but that egg and pupae mortality increases in the fall/winter (intolerance to extended periods of freezing). We assume very little change in larval mortality over the entire year.