Behavioral idiosyncrasy in division of labor in common eastern bumblebees (*B. impatiens*). ***Claire Guérin***

ABSTRACT

The study of social insects holds a key role in the field of sociobiology for their social organization has repetitively proved ecologically successful, and as such, is crucial for enlightening our understanding of evolutionary theory in general. Behavioral syndromes have recently been identified in common eastern bumblebee (*Bombus impatiens*) colonies, with a small number of workers undertaking the majority of foraging activity. In this project, I will combine theoretical and experimental approaches to disentangle functions and mechanisms underlying personality differences among workers and their role in structuring patterns of task allocation in bumblebee colonies.

QUESTIONS

What are the proximate mechanisms driving behavioral syndromes among bumblebee workers?

What are the ultimate consequences of behavioral syndromes for colony success in bumblebees?

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An efficient division of labor in eusocial insects is critical to their ecological success [1]. In social insects, task allocation can be determined by a diversity of environmental factors and evolutionary mechanisms [2]. While early work in the field focused on the importance of discrete and morphologically-distinct castes for efficient division of labor [3], distinct worker castes are only found in a minority of social insect species, and recent work has questioned the early emphasis on the importance of division of labor for the evolution of social insects [4]. Even in species that lack a clear differentiation between worker castes, however, individual workers display considerable behavioral specializations, known as animal personalities, or behavioral syndromes [5]. Bumblebees (*Bombus* spp.), for example, live in small colonies that lack discrete worker castes, yet workers still display strong inequalities in foraging activity (as well as other behaviors) among workers, with the majority of foraging work performed by a minority of workers (Crall, in prep.). The importance of such behavioral syndromes for social insects lacking distinct castes remains unclear, however. In this project, I will use a combination of theoretical and empirical approaches to investigate the proximate origins and ultimate consequences of behavioral syndromes in bumblebee colonies.

MODEL PREDICTIONS

Mechanistic – I will investigate differences in foraging activity among bumblebee workers using response-threshold models, extending previous work by modeling continuous distributions of thresholds among individuals. Theory predicts that low-threshold individuals need a lower level of stimulus in order to engage in a task than high-threshold individuals. If the task is performed, the individual threshold stimulus should decrease, while it should increase when the assignment is not performed [6]. This can generate task specialization among workers, since low-threshold individuals regularly perform the task, keeping the stimulus-level below the threshold necessary to activate high-threshold individuals. By modulating active versus idle foraging workers ratio in the model, I will be able to draw predictions on the impact of social structure disturbance on behavioral syndromes in bumblebee colony.

Adaptive – If time and resource allow, I would like to investigate the ultimate reasons for behavioral variation among workers in bumblebee colonies. I would develop an evolutionary model linking heterogeneity in threshold within colonies and individual or colony success. This model should take into account the conflict arising between two levels of organization in the system: (1) the colony as a whole entity and (2) the individuals within the colony. Indeed, what can be evolutionary advantageous for a colony in terms of global foraging activity doesn't necessarily match individual's interest (why would a single bumblebee forage when others make all the work?). I will use this model to explore the stability of individual behavioral strategies within colonies, as well as modeling the reproductive success of each behavioral type or of colonies composed of different behavioral types. This will allow me to investigate the selective forces driving behavioral variation among workers within colonies. A main conceptual issue faced by the scientific community with eusocial insects, is the entanglement of costs and benefits between colony and individual level in such models of evolution [1].

EXPERIMENTAL VALIDATION

To parameterize and test the predictions of the theoretical models described above, I will conduct experiments on a bumblebee colony in an indoor environment. Each worker in the colony will be marked with a unique BEEtag, which allows automatic tracking of the movements of each individual in the colony, while both foraging and performing nest work, using a digital video camera [7].

Mechanistic – I will use this laboratory system to validate the response-threshold models of foraging activity described above. First, I will perform forager-removal experiments to investigate the colony responses to disturbance. I expect "lazy" individuals to take over the labor previously done by actively foraging bumblebees, as the level of food brought into the nest dramatically decreases after eviction of active individuals, thus reaching out the sensitivity threshold of lazy bees, and triggering them into taking on foraging tasks. The BEEtag enables continuous monitoring of both nest behavior and foraging activity, providing the means for ascertaining the prior behavior of high-threshold individuals who took over foraging activity. One possible outcome is that novel active foragers are the ones already actively handling other tasks within the nest (brood care, cleaning, etc.). In addition to forager removal experiments, I will also perform a series of experiments directly manipulating potential foraging stimuli (i.e. in-colony pollen [8] and nectar stores [9]) to elucidate the specific cues that workers respond to when switching to foraging activity. I also anticipate that when the removed individuals are reintroduced into the colony, the system will not recover the same state as originally, especially with an increasing time of separation of the individuals from their community. Indeed I hypothesize that a parallel can be made between disturbance in bumblebees social structure and ecological succession, as the structure of the bee society would be profoundly affected by the removal of active foragers, even though the latter are put back in the nest later on.

Adaptive – Finally, I will experimentally investigate the consequences of behavioral variation among workers for colony success, testing the predictions from the models described above. I will artificially create 3 sets of bumblebee colonies, composed of either (1) a natural mix of high- and low threshold individuals, (2) only high-threshold individuals, or (3) only low-threshold individuals respectively. I will then account for each colony's success (approximated by colony growth) over time. I predict that colonies that contain a mix of behavioral types will outperform colonies composed of a single behavioral types, providing evidence for an adaptive value of behavioral syndromes at the colony level.

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