

WHITE-FOOTED MOUSE (*PEROMYSCUS LEUCOPUS*) ACTIVITY AND GYPSY MOTH (*LYMANTRIA DISPAR*) SURVIVAL

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Abstract. How white-footed mice (*Peromyscus leucopus*) forage is important to gypsy moth (*Lymantria dispar*) population dynamics because mice are one of the main natural predators of gypsy moth pupae. I used tracking plates to measure mouse activity at the bases of trees and compared activity with mouse predation of gypsy moth pupae on those trees. Trees with high mouse activity (as measured by the number of plates with tracks) were more likely to experience predation than trees with less activity. Conversely, the presence of moth pupae had no effect on mouse activity at the base of trees.

Keywords: *Peromyscus leucopus*, *Lymantria dispar*, tracking plates, foraging, predation, activity.

INTRODUCTION

The white-footed mouse (*Peromyscus leucopus*) is a dietary generalist that feeds on a plethora of different prey items, including invertebrates, fruits, seeds (Kantak, 1983), fungi (Maser and Maser, 1987) and even bird eggs (DeGraaf and Maier, 1996). In general, mice prefer some foods over others (Kantak, 1983) but will consume many food items upon encountering them. How do mice choose one food over another when they have a number of options? Optimal-foraging, the theory that assumes organisms must compromise among different demands when energy supplies are low (Molles, 1999), has long been thought to be a good predictor of mouse activity (Vickery, 1984). Laboratory studies show that mice select prey with high energy content (Hansen and Batzli, 1978; Vickery, 1984; Yunger, 2002; Lewis et al., 2001), however, it is uncertain how these studies translate into the field.

Mouse foraging is especially crucial in the ecology of one of its preferred prey items, the gypsy moth (*Lymantria dispar*). The gypsy moth, introduced to the northeastern United States in 1869, feeds on forest trees and in years of high moth densities can defoliate large areas of forest even resulting in widespread tree mortality (Elkinton and Liebhold, 1990). Moth populations fluctuate greatly, with egg mass densities ranging between 0.1 to over 10,000 egg masses per hectare (Ostfeld et al. 1996). These fluctuations are due to many factors, including introduced control agents, weather and food availability (Sharov and Colbert, 1996). Only a handful of larvae travel a great distance from their point of origin and most stay within 20m of the egg mass (Weseloh 1985, 1997). This results in clusters of pupae within a small radius of the central egg mass. Limited dispersal should produce areas in the forest where moth pupae are locally dense and how mice interact with these areas may be important for gypsy moth control. Moths pupate in leaf litter and behind flaps of bark as an adaptation to avoid their native European predators (Campbell and Sloan 1975). However, white-footed mice are arboreal and so have little trouble finding pupae. In fact, mice are so successful at consuming moth pupae, it has been suggested that they may be important in moth population dynamics (Jones et al. 1998; Elkinton et al. 1996).

In low-density moth populations, high mouse density may restrict moth population growth (Jones et al. 1998; Elkinton et al. 1996; Campbell and Sloan 1977). Mouse removal studies have shown a positive relationship between mouse density and pupal mortality (Jones et al. 1998) and mice are the primary mortality agent for gypsy moth pupae when mice are abundant (Hastings, et al., 2002). Therefore, when mouse populations are high and moth populations are low, one might expect moths to go locally extinct. However, since moths can be locally dense around egg masses due to limited dispersal ability, perhaps such small pockets of high-density might allow

the low-density moth population to persist. How mice forage will determine the efficacy of these pockets of high moth density for promoting moth persistence. Will mice respond to patches of locally high pupal densities around a central egg mass by focusing their foraging in such patches or will they forage more evenly and not respond to local pupal densities? This paper attempts to answer these questions by taking a relative measure of mouse activity and comparing it to gypsy moth pupal survival. Two hypotheses were tested: (1) that mouse presence and activity in an area will predict the probability of local pupal mortality and (2) that the presence of gypsy moth pupae will affect corresponding local mouse activity.

METHODS

Study Site

Experiments were conducted in July and August, 2003 on two forest plots located at IES, Millbrook, NY. Tree species composition included red (*Quercus rubra*) and black oaks (*Q. velutina*), with some sugar maple (*Acer saccharum*), white pine (*Pinus strobus*) and various other trees in small numbers. Both plots are secondary growth forests with high, leafy canopies and hilly terrain with many small shrubs. Small mammal trapping in months previous indicated a large mouse population, a response to an oak masting event the previous fall. Results of recent egg mass surveys predicted low gypsy moth populations (9.8 egg mass/ha), resulting in the ideal setting to test hypotheses involving an abundant generalist predator and sparse prey.

Each forest plot was gridded (10 x 10 grid with 15m spacing) and there was a trapping station at each intersection of the grid (total 100 stations). Fifteen stations were randomly selected in each of the two grids such that stations were at least 30m apart to decrease the likelihood that mice visit more than one station. For each station, the closest tree with diameter at breast height (DBH) >20 cm was used for this study. Trees were noted for species. Thirteen were maples (*Acer* sp.), nine were oaks (*Quercus* sp.), 2 were pines (*Pinus* sp.) and 6 were white ash (*Fraxinus americana*).

Experimental Setup

Tracking plates were 5½ in. x 8½ in. acetate sheets coated with a suspension of graphite powder in ethanol. This coating is water resistant and effectively records tracks of small mammals, amphibians and other forest creatures, maintaining reasonable clarity even during periods of torrential rain. These are a modification of plates used by Greenberg (2001) with graphite substituted for talcum powder. Greenberg noted that mice tended to avoid talcum powder plates so the use of odorless graphite is an attempt to create a neutral medium. Each plate was attached to a small backing plate made of aluminum with paperclips to hold them in place. Five plates were deployed in a circular arrangement, each at an equal distance (0.2m) from the focal tree (Figure 1 - A). Tracking plates were deployed initially for 6 days in all test grids. Plates were checked each day and graphite was reapplied if tracks were found. Total number of white-footed mouse footprints on each plate was recorded. Mouse activity was scored in three ways: (1) total number of footprints per tree (2) total number of plates (out of five) with mice tracks present and (3) a score of yes or no as to whether any plates had been visited by a mouse. All of these are relative measures of activity.

After the 6-day tracking period a pupal treatment was applied to each tree. One third of the trees (randomly chosen) had 5 live gypsy moth pupae affixed to burlap panels with purified beeswax (beeswax is useful in determining the responsible predator) attached to them at a height of 1m (Experimental treatment, Fig. 1D). These were monitored daily and missing pupae were replaced. Another third of the trees had 5 burlap panels without pupae attached (Burlap control treatment, Fig. 1C). The remaining sites had neither burlap panels nor pupae (Blank control treatment, Fig. 1B). Track plates were maintained at all sites and scored as before. The pupae and track plates were monitored for 6 days.

A Chi-square test was used to determine if a relationship exists between mouse presence and pupal predation. Logistic regressions were run to compare the various quantifiers of mouse activity to the probability of predation. Data was analyzed using the statistics program SAS and Microsoft EXCEL.

RESULTS

Local Mouse Activity and its Consequences for Pupal Survival

Trees that were visited by mice on a particular day were more likely to experience pupal predation than trees that experienced no recorded mouse visits (Figure 2). A chi-square test showed this relationship was significant ($\chi^2=3.857$, d.f.=1, $p<.05$).

Logistic regression showed a significant relationship ($\chi^2=3.8594$, $p=0.0495$) between the number of plates tracked at a particular tree and the probability of predation (Figure 3). The predictive ability of the logistic regression model was good (Somers' D=0.348), although there were few trees with 4 or 5 plates tracked on one day, so more data may have improved model fit.

A logistic regression showed no significant correlation between the number of footprints at a tree and the probability of predation ($\chi^2 = 0.877$, $p=0.3586$). Number of footprints ranged from 0 to 92, and while there was a general trend towards more footprints indicating a higher likelihood of predation, it was not statistically significant.

Effects of Gypsy Moth Pupal Presence on Mouse Activity

An ANOVA showed that change in the number of plates tracked per tree between the initial period and the deployment period was significantly different from one site to the other ($p=0.002$). One site showed a large decrease in activity with pupal deployment while the other showed a minimal increase. These site differences were taken into account in other ANOVA analyses.

The presence of pupae on trees did not have a significant effect on any of the three measures of mouse activity. Activity in all three treatments decreased from the initial period to the experimental period (Figures 4-6), possibly due to weather, but there was no evident difference among treatments based on overlapping error bars in figure 4. This decrease was noted using all three measurements of mouse activity (yes/no? mouse visit, number of plates tracked, and number of footprints).

The proportions of plates tracked at each tree showed no evident differences among treatments based on overlapping error bars (Figure 7).

DISCUSSION

Local Mouse Activity and its Consequences for Pupal Survival

The correlation between a tracking plate at the base of a tree being tracked and pupae being eaten may be seen as a relationship between mouse activity and pupal survival. A mouse detected at the base of a tree by a tracking plate means that this mouse is therefore in close proximity to the pupae affixed to the tree's trunk. Pupa on trees that showed mice to be present at their base were more likely to experience predation events. This indicates that mice are more likely to find a pupa on a tree if they are near that tree. The relationship between the number of plates with tracks and the likelihood of predation is interesting because it suggests that in these instances either the mouse is covering more ground at the base of the tree or that there are multiple mice. Either way, more activity is detected and pupae are more likely to be eaten.

Tracking plates are obviously not perfect predictors of predation likelihood (as is evident from the instances where pupae are eaten and no plates are tracked), but they are at least helpful in making these predictions. A mouse footprint on a tracking plate inarguably shows that a mouse has been present in the area where the plate has been placed. We do not know exactly what this mouse is doing, nor do we know if there is more than one mouse present, but we can assume that at least one mouse is engaging in some sort of activity (i.e. running, foraging, eating, etc.). A plate that collects no tracks does not necessarily indicate that there was no mouse activity nearby that night, except to say that there was none in the area covered by the plate itself. Another assumption is that a group of tracking plates in close proximity to one another will constitute a more accurate estimation of whether mice are present and active in that area. Such is the case with the circular arrangement around a focal tree: five plates are more likely to pick up the activity of a mouse moving up and down the tree than one plate would be. Mice can still move undetected in the channels between plates, but there is an increased likelihood that they will tread on at least one. Tracking plates have an advantage over mouse trapping approaches in determining activity because they do not restrict mouse movement (Sheppe, 1965). Therefore, any assumptions about its local activity must apply to the time it spent in the area before it entered the trap, whereas a mouse running over a tracking plate has the potential to be active in that area both before and after its presence is recorded.

These findings tell us some valuable things about risk and refuge for pupae. Tracking plates set out in a forest to collect mouse prints may be able to tell us how likely it is for a pupae to be predated upon on any given night. If used over a large enough area of forest, they may even be effective as an indicator of the heterogeneity of predation risk for gypsy moth pupae. This in turn might be useful in constructing a model of risk for pupae from mice that could be used in forest management. Of course, there are many confounding factors for this approach. One is that maintaining a huge number of tracking plates is a time-consuming endeavor and another is that their use is mostly limited to flat surfaces, meaning that mice traveling over woody ground litter, a preferred travel substrate of *Peromyscus* spp. (Planz and Kirkland, 1992), would miss the plates entirely and could move around without detection. It seems that tracking plates could be used in the future to measure mouse activity as long as there were other independent measures that it could be correlated with (such as trapping).

Effects of Gypsy Moth Pupal Presence on Mouse Activity

If the deployment of pupae on trees had any effect on mouse activity, the signal was not detected by tracking plates. This test was conducted on the hypothesis that mice would learn that pupae were available on the trunks of particular trees and that they would respond by increasing their activity around those trees. This assumption is warranted based on past laboratory studies that show that mice can change their foraging habits to select for foods that are high in energy content (Hansen and Batzli, 1978; Vickery, 1984; Yunger, 2002; Lewis et al., 2001) and that moth pupae are typically high in energy content (Bernard and Allen, 1997). Since no increase in activity was documented (even in relation to the two control treatments), there was no evidence to suggest the assumption was true.

There are three possible reasons that no pattern was found. The first is that mice may have been responding to pupae but the response was too small for tracking plates to pick up. A second possibility is that the mice might have responded if the experiment had run for a longer period of time (1-2 months). Perhaps then the mice would have had time to recognize that certain trees would be consistent sources of food in the form of gypsy moths and would return to them regularly. However, this may not be appropriate in terms of emulating nature, as moth pupae are only present for 2-3 weeks of the year. The third explanation is that mice were not responding because they were not limited for food sources (or that they were limited but were optimally foraging on another source of food) and would not need to forage optimally. In this case, the pupae would have been eaten as a consequence of mice happening upon them, and not by any plan. Here the high protein content of the pupae would be a welcome treat, but not something that would necessitate repeat visits and changed foraging patterns.

CONCLUSIONS

This study has shown that mouse activity as measured by tracking plates is a good predictor of predation on gypsy moth pupae by mice. If mouse tracks are found at the base of a tree, moth pupae are more likely to be eaten. This has important implications in determining how gypsy moths may be able to survive amidst high-density mouse populations because if mouse activity patterns can be determined with respect to gypsy moth pupal presence, then predictions can be formed as to how likely it is that the moth population will sustain itself. There was no evidence in this study to indicate that mice increase their local activity around trees where moth pupae are present compared to trees where pupae are not present, which may support the hypothesis that mouse foraging does not respond to gypsy moth presence. The findings of this study should be a positive contribution to the mouse-moth dynamic and indicate that further study in the realm of mouse foraging should prove fruitful.

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APPENDIX

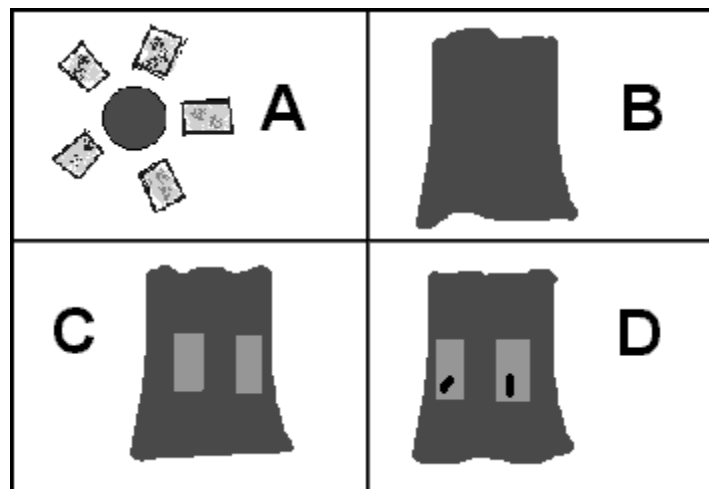


FIGURE 1. (A) Arrangement of tracking plates around focal tree. This arrangement was applied to all 30 trees; (B) 10 trees were “Blank control” with no deployment of burlap panels or pupae; (C) 10 trees were “Burlap control” with burlap panels deployed (5 per tree); (D) 10 trees were “Experimental” with pupae affixed to burlap panels (5 per tree).

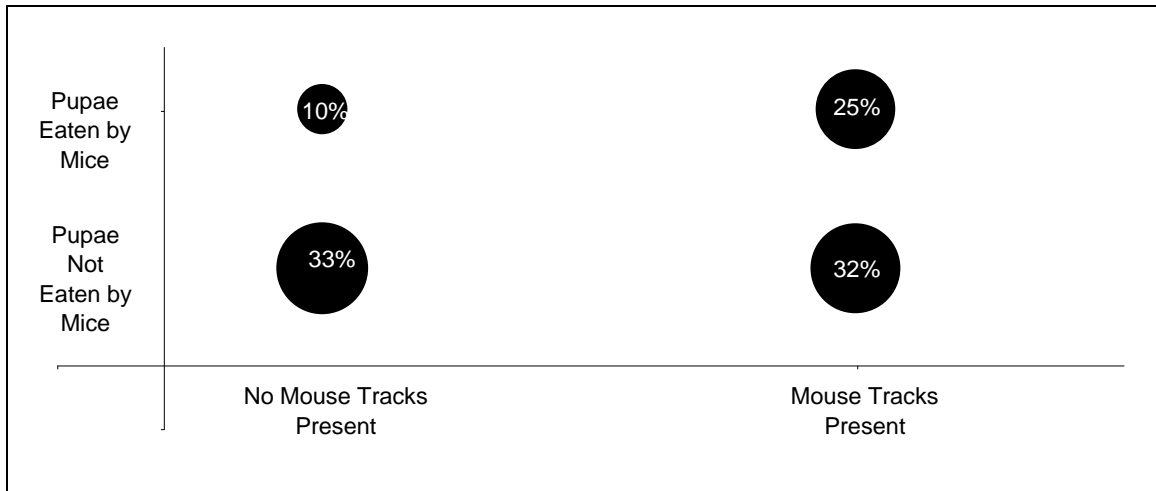


FIGURE 2. Graph showing the percentage of total events falling into each of four possible categories: yes predation and yes activity, yes predation and no activity, no predation and no activity, no predation and yes activity. The size of each circle represents the percentage of events in each category.

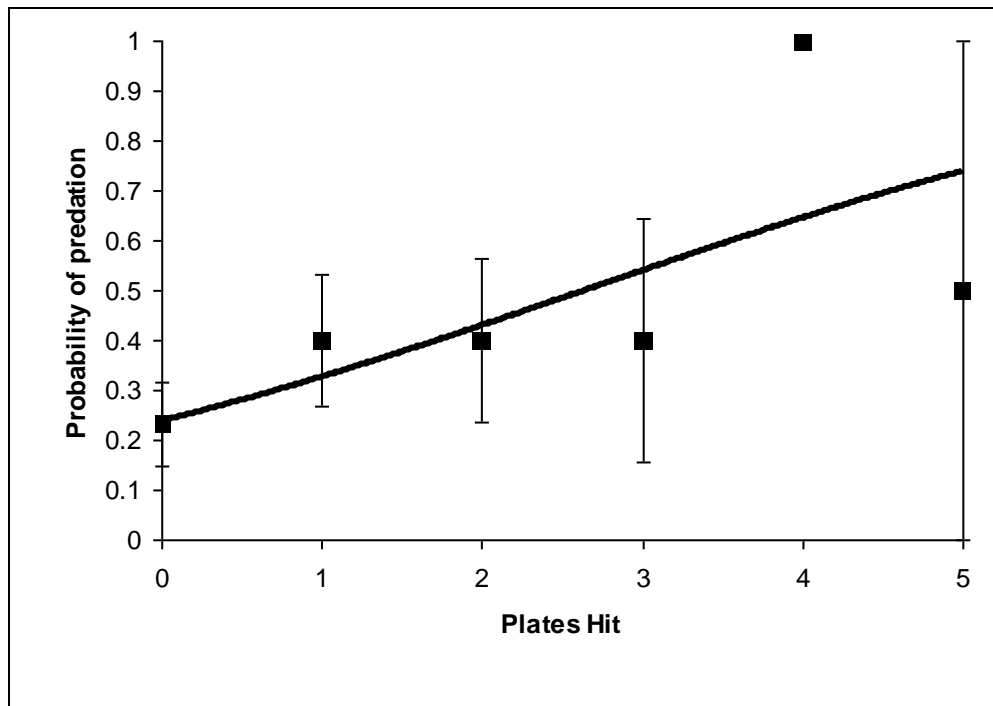


FIGURE 3. Logarithmic function showing a possible relationship between the number of plates tracked by mice at any tree on a given night and the probability of predation on gypsy moths by mice on that same tree ($p=0.0495$). Points represent actual data collected, with standard error bars.

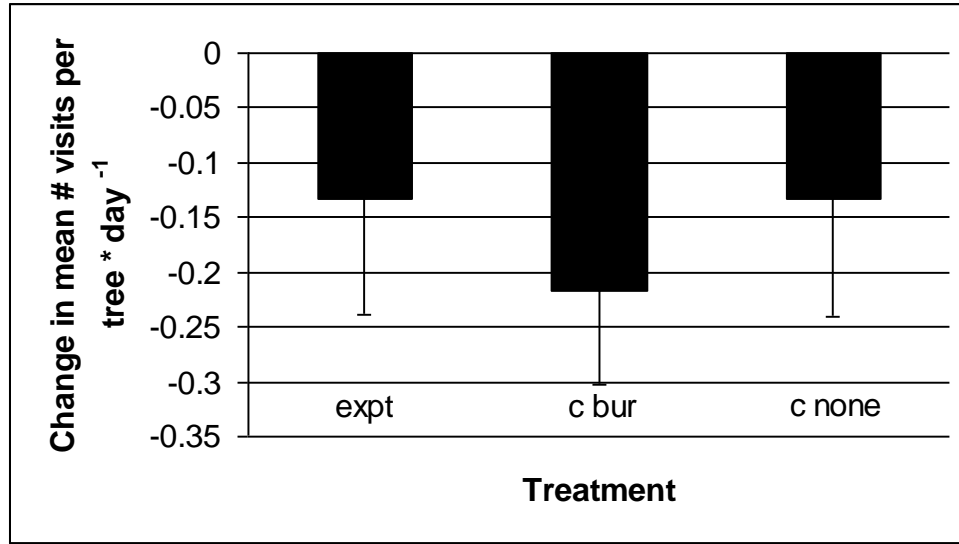


FIGURE 4. Change in mouse activity as measured by the average number of visits to trees (visit = any of the five plates with at least one footprint) by mice from the initial period to the period of pupal deployment. All treatments experienced a decrease between the two tracking periods. Error bars denote standard error.

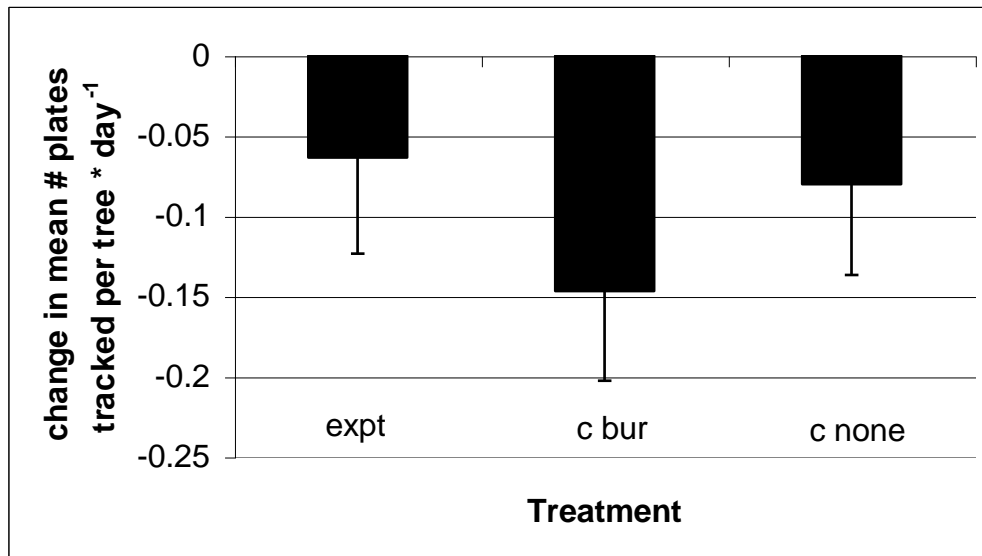


FIGURE 5. Change in mouse activity as measured by the number of plates tracked (out of five) per tree group per day from the initial period to the period of pupal deployment. All treatments show a decrease between the two tracking periods. Error bars denote standard error.

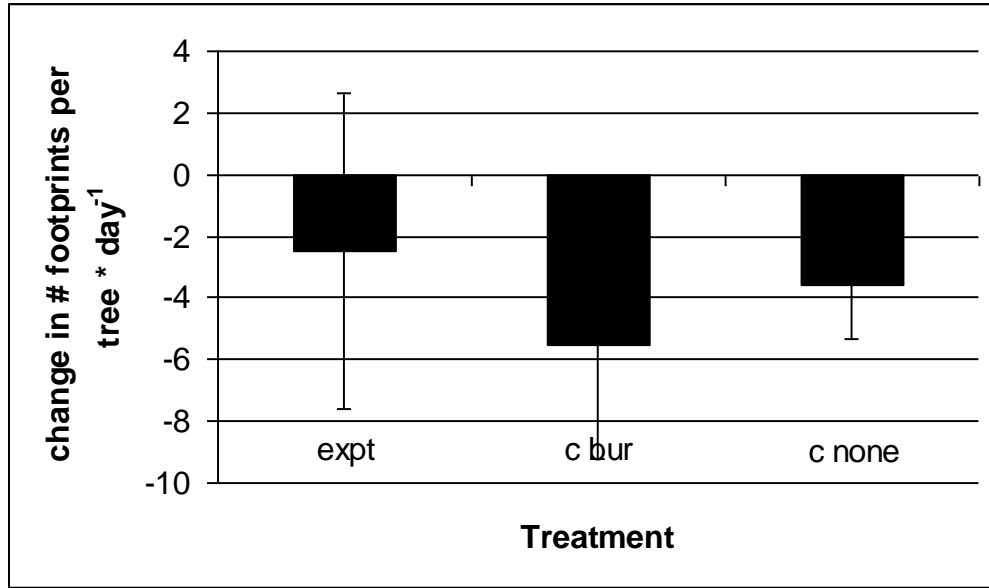


FIGURE 6. Change in mouse activity as measured by the number of mean number of footprints per tree group per day from the initial period to the period of pupal deployment. All treatments show a decrease between the two tracking periods. Error bars denote standard error.

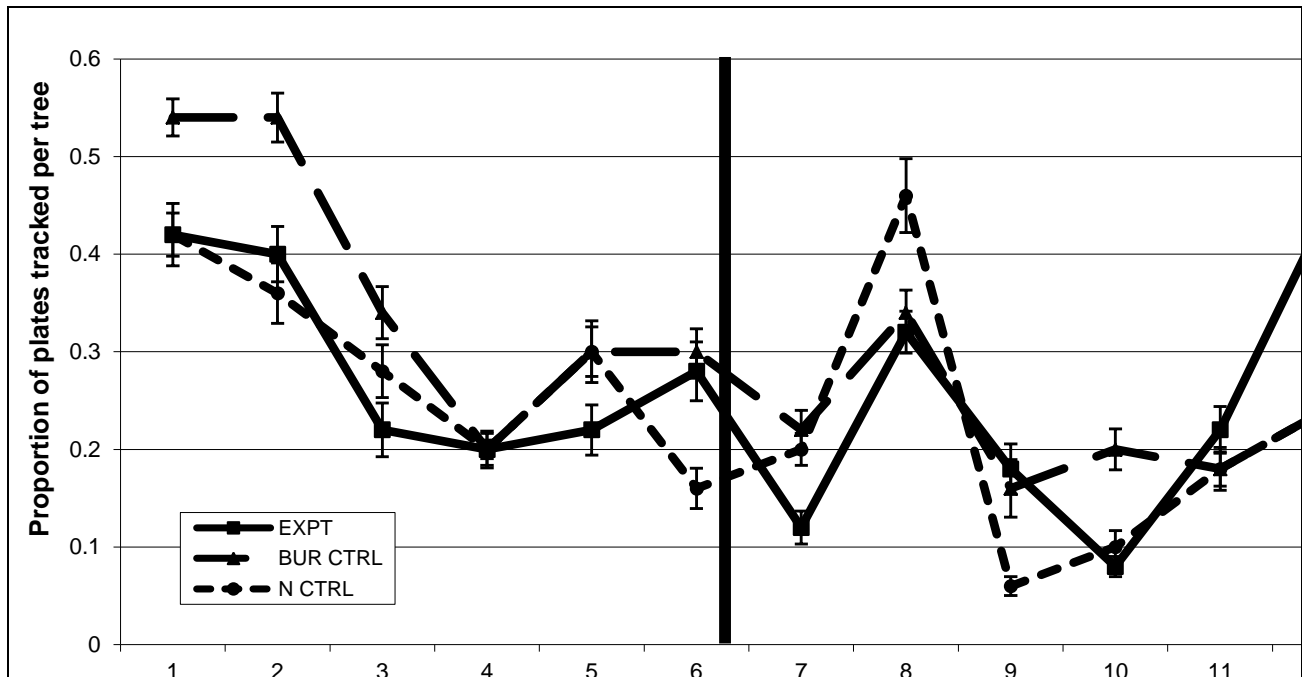


FIGURE 7. Day-by-day proportions of the mean number of tracked plates for trees in each of the three treatments. All treatments were the same until day 7, when pupae were added to trees in the experimental treatment and burlap panels were added to trees in the burlap control treatment (demarcated on the graph by the vertical black line).