Project Final Report presented to: The Pest Management Foundation Board of Trustees

Project Title: Effects of house and landscape characteristics on the abundance and diversity of perimeter pests

Principal Investigators: Arthur G. Appel and Xing Ping Hu, Department of Entomology and Plant Pathology, Auburn University

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Executive Summary:

The overall goal of this project was to expand and refine our statistical model that estimates Smokybrown cockroach abundance from house and landscape characteristics to include additional species of cockroaches, several species of ants as well as subterranean termites. The model will correlate pest abundance and diversity with house and landscape characteristics. These results could ultimately be used to better treat and prevent perimeter pest infestations.

Since the beginning of the period of performance (August 1, 2017), we have hired two new Master's students, Patrick Thompson and Gökhan Benk, to assist with the project. Both students will obtain degrees in entomology with a specialization in urban entomology with anticipated graduation dates of summer-fall 2019. We have developed and tested several traps designs for rapidly collecting sweet and protein feeding ants, purchased and modified traps for use during a year of trapping, and have identified species of ants, cockroaches, and termites found around homes in Auburn Alabama.

House and landscape characteristics have been measured at 62 single-family homes or independent duplexes. These homes range in age from 7 to 61 years and include the most common different types of siding (brick, metal, stone, vinyl, wood), different numbers/types of yard objects (none to >15, including outbuildings, retaining walls, large ornamental rocks, old trees, compost piles, etc.), and different colors. Thirty homes were selected for trapping.

As expected, both the abundance and diversity of ant and cockroach pests increased around homes with increasing environmental temperature. Argentine ants were the most abundant species followed by red imported fire ant and little black ant. For cockroaches, American, smokybrown, and Asian were the most abundant with pale bordered and woods cockroaches also in high abundance. In general, rain reduce the foraging behavior of ants and cockroaches resulting in lower trap catch, however, traps catch increased the day after a rain. After 2 months, only 16% of termite traps were positive.

Our statistical results indicate a strong positive relationship between house age and the diversity of ant and cockroaches trapped, but a strong positive relationship between large yard objects and termites trapped. There are more traditional peridomestic pests, e.g., Argentine ants, red imported fire ants, American cockroaches, and smokybrown cockroaches, at older brick sided homes with many objects in the yards. Asian cockroaches that were not present in the Auburn area until recently (2015) are becoming increasingly abundant throughout the city.

Introduction:

Perimeter pest insects (peridomestic) live and reproduce outdoors, particularly around the foundation of homes, but can move indoors to feed and drink. Primary perimeter pests in the southeastern United States include the American, *Periplaneta americana* (L.), Smokybrown, *Periplaneta fuliginosa* (Serville), and oriental, *Blatta orientalis* L., cockroaches; invasive Argentine*, Linepithema humile* (Mayr), red imported fire ant, *Solenopsis invicta* Buren, and little black ant, *Monomorium minimum* Buckley; and the Eastern subterranean, *Reticulitermes flavipes* (Kollar). Additional pests include the Formosan*, Coptotermes formosanus* Shiraki and various native ant and cockroach species.

Cockroaches are economically important pests because they contaminate food and food preparation surfaces with their feces. They also can spread disease-causing microorganisms such as *Salmonella* spp., one important cause of food poisoning. Hundreds of medically important pathogens and parasites have been identified from cockroaches (Roth and Willis 1957, 1960). Cockroaches and their body parts are also potent human allergens, causing respiratory distress and hives (Brenner et al. 1990, Kang 1990). In addition, cockroaches are repulsive to the average homeowner.

Like cockroaches, many ant species thrive in the warm and humid Southeastern U.S. While the fire ant bites and stings, the other species can be an annoyance because of their periodic invasions indoors. All of these ant species can mechanically transmit bacteria and are allergenic to sensitive people. Outdoors, these species interact with honeydew producing plant pests such as aphids and scale insects resulting in plant diseases and costly replacement of landscape plants.

Termites, particularly Formosan*, Coptotermes formosanus* Shiraki, and Eastern subterranean, *Reticulitermes flavipes* (Kollar), are also important perimeter pests. They usually originate outdoors and, using mud tubes and tunnels, gain entry into homes. These termite species often nest outdoors while foraging indoors. Termites may also damage some live landscape plants and will feed on landscape timbers and wooden fences.

A comprehensive integrated pest management (IPM) system for perimeter pests does not currently exist in the U.S. Management depends almost entirely on chemical control, with either a band of insecticide applied around the perimeter of the home or the application of granular or liquid baits to fire ant mounds or around the perimeter of the home. Recommended sprays cover a 10-foot wide band around the home and the lower 3 feet of the home's exterior. This strategy allows high densities of perimeter pests to develop only a few feet away from the home. Limited success has been obtained by combining an insecticide application with structural modifications such as caulking holes and cracks (Thoms and Robinson 1987). Protection of the structure, however, does not control pests outdoors. High densities of perimeter pests can develop outdoors and serve as a reservoir for infestation of homes. Loss of insecticidal effectiveness occurs quickly in the Southeastern U.S. because high daily maximum temperatures in the summer rapidly degrade most insecticides (e.g., Harris 1972). Our previous studies have shown that banded applications are ineffective less than 10 days after treatment (Smith et al. 1993abc). Consequently, infestation of homes occurs repeatedly throughout the summer.

Based on our previous research, we developed a predictive model for Smokybrown cockroaches and an IPM system that integrated present control methods with management of house and landscape characteristics. (We believe that similar IPM systems could be developed for ants and termites based on model predictions and correlations.) We tested the system in four different trials. The tactics included

in our system were: sprays targeted at cockroach hiding places and points of entry; gel and pellet baits for residual control; insecticidal smoke to kill cockroaches inside hiding places such as outbuildings and crawl spaces; sanitation (removing junk piles); and removal of mulches and living ground covers next to homes and replacement with garden stones. We compared our IPM system with three treatments: a standard perimeter spray of chlorpyrifos, trapping out cockroaches, and a no-treatment control. The IPM system reduced cockroaches faster and to lower levels than the other treatments while lasting 50% longer and using 75% less insecticide than perimeter treatments.

Materials and Methods:

Homes

Over 100 homes in the Auburn-Opelika, Alabama area were visited to determine their suitability for the project. Of those 62 were selected for house and landscape characterization. Each house was visited by 2-4 researchers and the following information recorded: Trees: species, diameter at breast height, diameter of canopy cover, presence and number of tree holes, distance from house, light intensity under canopies measured under standardized conditions. Shrubs: species, volume, distance from house. Mulches: specific type of mulch, area covered, average thickness, distance from house. Objects: type of object (woodpile, masonry grill, outbuilding, tree stumps, etc.), area covered, volume, distance from house. Lawn cover: area, percent coverage of total area. Cardinal direction of the front of the house. Thirty home were selected for trapping based on owner and occupant agreement and stability (i.e., no upcoming modifications to the home or landscape)

Trapping

Perimeter pest abundance was measured beginning in May 2018 and concluding in June 2019. Homes were trapped biweekly March through October and monthly from November through February. To reduce the effects of weather and insect population dynamics, homes were trapped for three consecutive days at each sampling period (Smith et al. 1995). Wide-mouth glass jars (0.95-L) were used to measure cockroach abundance. Jars were baited with fresh white bread and coated on the upper inside surface with petroleum jelly to prevent escape of cockroaches. The outer surface of all traps was be covered with nylon stockings to permit small nymphs and oriental cockroaches to enter traps (Granovsky 1983, Smith et al. 1995). The opening of each jar was covered with a piece 0.5-inch metal hardware cloth (to prevent entry of birds and rodents) and secured in place with a metal band. Each trap was also covered with a plastic cap with holes to allow insects to enter while preventing rain from entering Fig. 1). Five jar traps were used at each house during each sampling period; 500 traps were set for every collection cycle.

Since ant species may have different feeding preferences, we developed a protein and sweet feeding ant trap that we used around the homes. The trap consisted of a 15 ml plastic centrifuge tube (12.7 cm long and 2.5 cm diameter) baited with several drops of honey and a small piece of beef hotdog. Uncapped tubes were positioned on their side around each house and property. Five centrifuge traps were used at each house during each sampling period; 500 traps were set for every collection cycle. All traps were placed against a vertical surface such an exterior wall, fence, tree, or shrub to maximize trap catch.

Cockroach trap catch was counted *in situ* and the age class of individuals recorded. Cockroaches were released immediately after counting to avoid biased population estimates due to removal or trapping-out effects. Ant traps were tightly capped and returned to the laboratory. Species were identified and the number of foragers recorded. Because ant species names and identifications are constantly being revised, we used the keys found at: https://mississippientomologicalmuseum.org.msstate.edu/Researchtaxapages/Formicidaepages/faunal. lists/Common_Pest_Ants.html for identification. The Auburn University curator of Insects, Dr. Charles Ray, confirmed identifications.

Termites were trapped using open-bottom underground traps described by Hu and Appel (2004); traps consisted of bottomless plastic buckets 18 cm high with an internal diameter of 13 cm provisioned with 6 pieces of cut pine. Traps were dug into the ground at the corners of each house, near the air conditioning compressor, outbuilding, and at the base of a nearby tree or tree stumps.

Data and statistical analysis

Data were transcribed into Microsoft Excel 2016 spreadsheets, sorted, and summary statistics (means, standard deviations, etc.) generated. Count data were further analyzed using SAS software (2011). Pearson correlation analysis was used to relate ant and cockroach abundance with house and landscape characteristics and to determine relationships between pairs of species.

House and landscape characteristics as well as trap count data were transformed to normalize each variable. We used the transformations described by Smith et al. (1995): typically ln(x + 1) for most habitat and trap count data. Simple correlation analysis (SAS Institute 2011) was used to determine general relationships among all pairs of transformed data, followed by canonical correlation to analyze the relationship between landscape characteristics and ant or cockroach abundance. However, it was possible that some of our house and landscape characteristics might be redundant. We detected redundant characteristics using cluster analysis with a minimum of 75% of variation explained by cluster components. The variable, within a cluster, with the lowest correlation retained, and the others discarded as redundant (PROC VARCLUS, SAS Institute 2011). We then used canonical correlation to relate house and landscape characteristics to ant and cockroach abundance.

Figures were developed using SigmaPlot 14 (SYSTAT software).

Results and Discussion:

House and landscape characteristics

The 62 single-family homes or independent duplexes ranged in age from 7 to 69 years (mean = 30 years) and represent different types of siding (brick, metal, stone, vinyl, wood), different numbers of yard objects (none to >15, including outbuildings, brick walls, large ornamental rocks, large trees/stumps, etc.), and different colors white to red brick). Each property was surveyed and measured extensively to determine the number, species, and distance from the structure of all major plant material (bushes, trees) and yard objects. Some plant material has been sent to our Horticulture Department for identification. We have also photographed all sides of each property, determined the type of construction, and noted the position and condition of vents, screening, soffits, roofing, and gutter systems. The number of residents and number and type of pets was also recorded.

The house to property area ratio was calculated as a measure of the proximity of homes to each other; larger ratios indicate homes that close together. House/property area ratios ranged between 0.02 and 0.54 (mean = 0.21). More than 75% of the homes had brick exteriors with the balance wood, stone, or a combination of materials.

Weather

During the sampling period from the beginning of June 2018 through the beginning of June 2019, the mean high temperature was 76.91°F (24.95°C) and the mean low temperature was 57.89°F (14.38°C). The highest temperature during the sampling year was 97°F (36.11°C) and the lowest was 26°F (-3.33°C). Rain occurred during 23.7% of the sampling days and, in general, rain reduce the foraging behavior of ants and cockroaches resulting in lower trap catch. However, trap catch generally increased the day after a rain. Rain wet soil that stimulates termite foraging activity and wet wood that attract termites.

Ants

Species diversity

A total of 16 ant species were identified from the >200,000 ants collected from 30 homes during the 2018-2019 sampling year (Table 1). Species included the common Argentine, *Linepithema humile* (Mayr) and red imported fire ant, *Solenopsis invicta* (Buren) as well as two species with no common names: *Temnothorax pergandei* (Emery) and *Ponera pennasylvanica* (Buckley).

Abundance

At least one ant species was collected at every sampling period during the one year trapping season. Argentine ants were the common and abundant species at the sampled homes. As many as 1644 Argentine ants were trapped (in 5 tube traps) at a single property over a single night. Overall ant abundance was: Argentine > red imported fire > little black > native fire > pharaoh > odorous house > acrobat > all others. Infestations were consistent in that homes with many Argentine ants at the beginning of the sampling period also had large populations at the last sampling period reported. Mean ant trap catch for the species of major abundance are illustrated in Figs. 3-5. Argentine ant abundance and big headed ant was the lowest (0) in early March and peaked in late June (mean = 48.05 ants/trap for Argentine ant and mean = 4.15 ants/trap for bigheaded ant) (Fig. 3). Similarly, the lowest catch of red imported fire ants was in early March and the greatest catch in early June. Maximum trap catch of thief, reddish carpenter ant, pyramid ant was in early August; mean = 4.39, 0.03, and 0.009 ant/trap for thief, reddish carpenter ant, and pyramid ant, respectively. The false honey ant (winter honey ant) was caught only in winter and has been previously reported from Alabama (http://entnemdept.ufl.edu/creatures/misc/ants/Prenolepis_imparis.htm).

Species interactions

Using correlation analysis for all possible pairs of ant species and all species combined, there were significant (P<0.05) positive correlations between the total number of ants collected and the numbers of Argentine, red imported fire, acrobat, pyramid, odorous house, thief, little black, big headed, and dark rover ants. These correlations are due to the large numbers of individuals of these species collected during the sampling period. More interesting, was the significant negative correlation between the

abundance of Argentine and red imported fire ants (-0.063, P=0.0001). These results indicate that the abundance of one species reduces the abundance of the other species and supports the idea that these two species compete for similar resources and can competitively exclude each other from a particular area.

The abundance of Argentine ants was significantly (P<0.05) negatively correlated with the abundance of acrobat, dark rover, big headed, little black, thief and pyramid ants. Argentine ants clearly competitively exclude a number of different ant species. However, abundance of red imported fire ant was only significantly correlated with a reduction (negative correlation) in abundance of big headed ants. These results seem to indicate that red imported fire ants do not directly compete or do not successfully compete with other ant species, except Argentine ants.

Cockroaches

Species diversity

Seven different cockroach species were identified from the 1,604 cockroaches collected from 30 homes during the 2018-2019 sampling year (Table 2). Species included the large American, *Periplaneta americana* (L.) and smokybrown, *P. fuliginosa* (Serville), cockroaches as well as the smaller little yellow, *Cariblatta lutea* (S. & Z.), and Asian, *Blattella asahinai* Mitzukubo, cockroaches.

Abundance

Cockroach abundance was: Asian > smokybrown > American > woods > all others. Pale bordered and woods cockroaches were also quite abundant. Woods cockroaches included several *Parcoblatta* spp. As with ants, infestations of cockroaches were relatively consistent among houses. Cockroach numbers and species diversity generally increased during the summer. Mean ant trap catch for the species of major abundance are illustrated in Figs. 6-7. Maximum trap catch of the native cockroaches including the pale bordered and woods, occurred in June. Maximum catch of Asian cockroaches was in late July, American cockroaches in early August and smokybrown cockroaches in late August. Smokybrown cockroaches were trapped at all sampling periods except January (Fig. 7).

As reported for smokybrown cockroach alone, total cockroach abundance (each species and combined) was positively correlated with house age. Total abundance was also positively correlated with house to property area ratios and the number and size of objects on the property including out buildings.

Species interactions

Using correlation analysis for all possible pairs of cockroach species and all species combined, there were significant (P<0.05) positive correlations between the total number of cockroaches collected and the numbers of all seven species. There were no significant negative correlations among cockroach species or for all species combined. There were no significant correlations between the numbers of any individual cockroach species or all combined species and the numbers of ants present in traps except for Asian cockroaches. The numbers of ants and Asian cockroaches were positively correlated (P=0.004).

Asian cockroach abundance was correlated positively with only the abundance of wood cockroaches (P=0.0035); there were no other significant correlations with this species. Abundance of American and smokybrown cockroaches was positively correlated with wood and pale bordered cockroaches as well with each other.

Termites

Of the 150 termites traps, only 10 (6.67%) were infested with subterranean termites at the end of the one-year sampling. These traps were generally located away from the footprint or perimeter of the homes and either against tree stumps in wooded areas or near outbuildings. All termites trapped were Eastern subterranean. There was no seasonal pattern of termite infestation; the number of traps infested increased over time. It is likely that termiticide treatments under and around the structures were toxic or repellent to termites, and prevented the traps there from being infested. Traps located away from the structures were very likely not treated with termiticides. These results indicate that even though structures may be protected currently, there is termite activity nearby and if termiticide 'barriers' breakdown, infestations are possible.

Relationships between pest abundance and house and landscape characteristics

Simplified models relating house and landscape characteristics with pest ant and cockroach abundance were developed for Argentine and red imported fire ants and Asian, American, and smokybrown cockroaches (Table 3). These species were most abundant in the trapping study and we were able to get reasonable model coefficients. Modeling of each species was done individually and no multi-species interactions were considered. There are clearly species interactions as noted above, so more complex and accurate modeling is indicated. As described by Smith et al. (1993c and 1995), the canonical correlation models were simplified and adjusted to yield 'user friendly' numbers. For a particular species, characteristic house and landscape items (age of home, brick exterior, etc.) are multiply by coefficients to determine number of 'points'. 'Points' for all items are added and if the total is <1.7 then populations are low, 1.7-3.0 then population levels are average, and >3 population levels are high. Note that the model does not predict exact numbers of ants or cockroaches; it predicts high, medium, and low population sizes.

Ant models were more difficult to develop than cockroach models, probably because ants are eusocial, live in large colonies, and recruit to food sources and therefore our traps. Professional pest control (baits and perimeter sprays) strongly influenced ant population estimates. Both Argentine and red imported fire ants are successfully controlled with bait products, especially the red imported fire ant. The number of trees on a property strongly influenced the populations of Argentine ants whereas the number of hardwood trees reduced red imported fire ant population. This probably because red imported fire ants prefer sunny edges and disturbed areas with little shade and the hardwoods in this study were generally large and shaded the area beneath the trees. Argentine ant populations were also strongly influenced by the percentage of the house to property area. A larger percentage represents more of a property covered with a house and usually closer proximity to neighboring houses and additional resources. Red imported fire ant populations were least affected by the number of residents at a property. This may indicate that human-based resources are less important to red imported fire ants than they are to other species and that natural resources, such as insects and worms, are a more important part of their diet that human trash. Compost piles and garden/potted plants are a major location of Argentine ants; compost piles and heavy leaf litter are closely associated with the larger cockroaches

Both the Asian and American cockroach models were similar to the previously developed model for smokybrown cockroaches (Smith et al. 1995). Asian cockroach population estimates were strongly influenced by professional pest control. This species is easily controlled with a variety of products and our laboratory experiments indicate that they are not significantly resistant to any insecticide (Snoddy

and Appel 2014). In addition, unlike the larger cockroach species, Asian cockroaches were least influenced by the percentage of the house to property area. This is probably because of the very different behavior of Asian cockroach adults that readily fly 10-20 m during the photophase. Although the American and smokybrown cockroaches can fly, they do so only during the scotophase and in high humidity conditions. Pale boarder cockroaches are closely associated with compost piles, leaf litter, and bushes.

For American and smokybrown cockroaches, the number of hardwood trees positively influenced cockroach populations. However, the influence of pine tree density on was 10-times less for American cockroaches. It is possible that pine trees and pine straw do not repel American cockroaches, as they do smokybrown cockroaches (Appel and Smith 1996).

Continuing studies:

The amount of data collected during this study is almost overwhelming and changeling to analyze. The large number of samples and replicates increases the possibility of 'finding' significance due to the statistics alone. In addition, we analyzed species population models individually without any interactions. We have consulted with several statisticians who are interested in the data and in developing new modeling techniques to address interaction effects properly. We have been told that "machine learning" approaches should be used.

In addition to further data analysis, we intend to investigate behavioral interactions between species in laboratory assays. We will also investigate the water relations and temperature sensitivity of the species we have identified around homes. Finally, with additional funding, we can investigate the preferences of individual species for various insecticidal bait formulations and placements that can reduce pest pressure around home.

Impact:

Funding from this project has partially supported two MS urban entomology students (Patrick Thompson and Gokhan Bent) in the Department of Entomology and Plant Pathology at Auburn University. Mr. Thompson graduated with a M. Ag. (non-thesis) degree in May 2019 and Mr. Bent will graduate in August 2019 with a MS in entomology. Results obtained during this study have been presented at pest management and scientific meetings:

Appel, A. G. 2018. Using Landscape Management to Achieve Long-Term Pest Control, National Pest Management Association, Memphis, Tennessee.

Appel, A. G. 2018. Department and Urban Entomology Research 2018 Update. Alabama Pest Control Association Winter meeting, February 8-9, 2018, Auburn, Alabama.

Appel, A. G. 2018. Using landscape features to predict and manage pest pressure. National Pest Management Association, PestWorld 2018, Orlando, Florida.

Appel, A. G. 2019. Using landscape features to predict and manage pest pressure. Alabama Pest Control Association Winter meeting, February 7-8, 2019, Auburn, Alabama.

Benk, G., A. G. Appel, and X. P. Hu. 2019. Temporal variation in abundance and diversity of ant species (Hymenoptera: Formicidae) around homes in Auburn, Alabama. Entomological Society of America, Southeastern Branch, Annual meeting 3-6 March 2019, Mobile, Alabama. (Poster)

We anticipate that at least four scientific publications will be submitted based on the research results from this study. The Pest Management Foundation will be acknowledged on all presentations and publications.

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Table 1. Ant species collected around homes in Auburn, Alabama 2018-2019.

No.	Common name*	Species name
1	**Argentine ant**	*Linepithema humile* (Mayr, 1868)
2	Acrobat ant	*Crematogaster pilosa* (Emery, 1895)
3	**Big Headed ant**	*Pheidole dentigula* (Smith, M.R., 1927)
4	Black carpenter ant	*Camponotus pennsylvanicus* (De Geer, 1773)
5	Crazy ant	*Nylanderia* sp. (Emery, 1906)
6	**Dark rover ant**	*Brachymyrmex patagonicus* (Mayr, 1868)
7	False honey ant	*Prenolepis imparis* (Say, 1836)
8	**Little black ant**	*Monomorium minimum* (Buckley, 1867)
9	Odorus house ant	*Tapinoma sessile* (Say, 1836)
10	Pyramid ant	*Dorymyrmex bureni* (Trager, 1988)
11	**Red imported fire ant**	*Solenopsis invicta* (Buren, 1972)
12	Reddish carpenter ant	*Camponotus castaneus* (Latreille, 1802)
13	Robust crazy ant	*Nylanderia bourbonica* (Forel, 1886)
14	**Thief ant**	*Solenopsis molesta* (Say, 1836)
15	No common name	*Temnothorax pergandei* (Emery, 1895)
16	No common name	*Ponera pennasylvanica* (Buckley, 1866)

*Most common species in **bold** collected over season.

Table 2. Cockroach species collected around homes in Auburn, Alabama 2018-2019.

No.	Common name*	Species name
1	**American Cockroach**	*Periplaneta americana* (L.)
2	Little Yellow Cockroach	*Cariblatta lutea* (S. and Z.)
3	Wood Cockroach	*Parcoblatta* spp.
4	Pale Boarder cockroach	*Pseudomops septentrionalis* Hebard
5	**Asian Cockroach**	*Blattella asahinai* Mizukubo
6	**Smokybrown cockroach**	*Periplaneta fuliginosa* (Serville)
7	Brown wood cockroach	*Ischnoptera deropeltiformis* (Brunner)

*Most common species in **bold** collected over season.

Table 3. House and landscape items and coefficients from correlation model for estimating relative pest ant and cockroach populations around homes.

Item	Argentine ant	Red imported fire ant	Asian cockroach	American cockroach	Smokybrown cockroach*
Age of house (years)	0.01	0.02	0.01	0.04	0.03
Brick exterior (yes=1, no=0)	0.08	0.01	0.4	0.8	0.7
Number of objects on the property (1, 2, etc.)	0.19	0.08	0.11	0.31	0.26
Number of pets (1, 2, etc.)	0.21	0.19	0.30	0.21	0.18
Professional pest control (yes=1, no=0)	-56.8	-78.90	-34.1	-1.0	-0.77
Number of residents (1, 2, etc.)	1.6	0.09	1.8	2.2	-0.19
Number of hardwood trees >15 feet	90.36	-0.89	78.91	67.34	95.17
Number of pine trees	89.96	23.01	34.78	-31.9	-331.7
Percentage of house area to property area (0.1-0.95)	8.09	2.63	1.20	6.67	4.98

* Based on and compared with Smith et al. 1993c.

For each individual species, multiply item number by coefficient to determine number of 'points'. Add points and if total is <1.7 then populations are low, 1.7-3.0 then population levels are average, and >3 population levels are high.

Figure 1. Assembled cockroach trap.

Figure 2. Ant trap with sweet and protein bait.

Figure 3. Seasonal abundance of Argentine, red imported, big headed, and thief ant around homes in Auburn, Alabama 2018-2019.
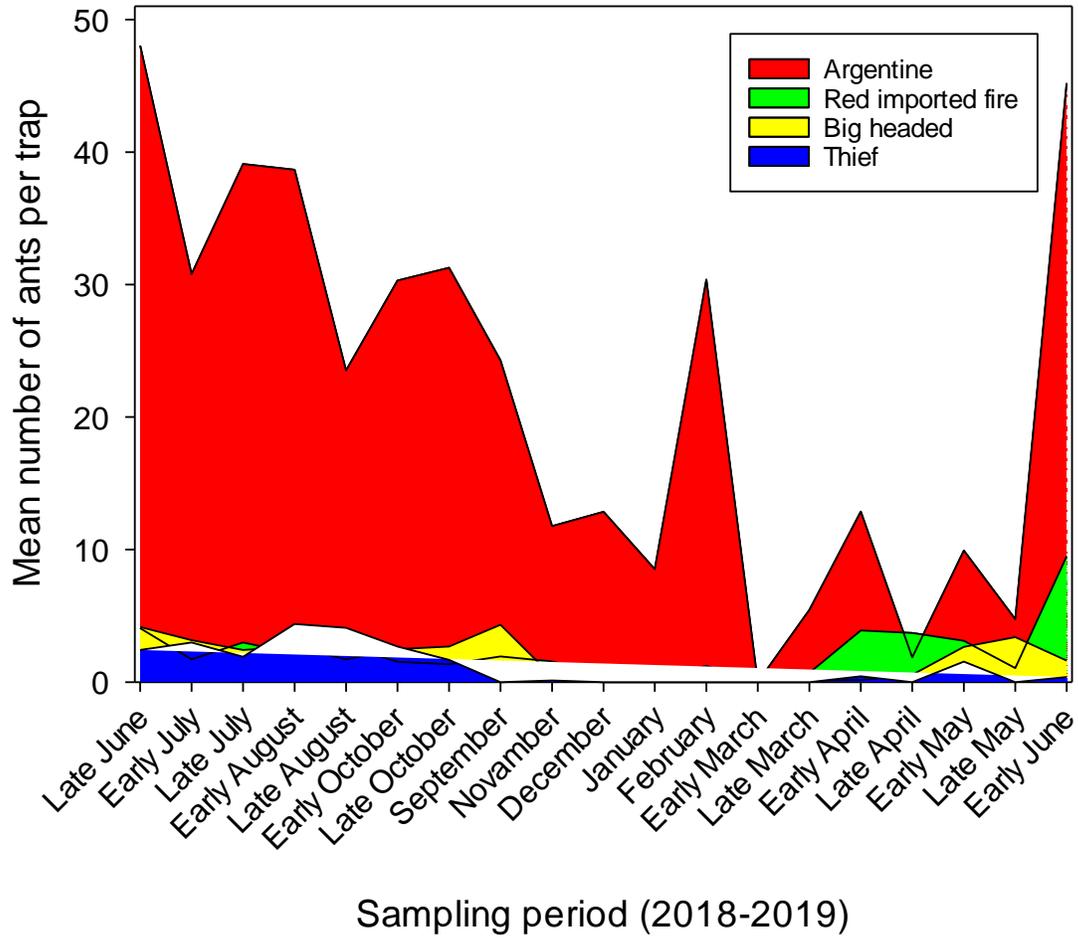
Figure 4. Seasonal abundance of dark rover, little black, acrobat and *Temnothorax pergandei* ants around homes in Auburn, Alabama 2018-2019.
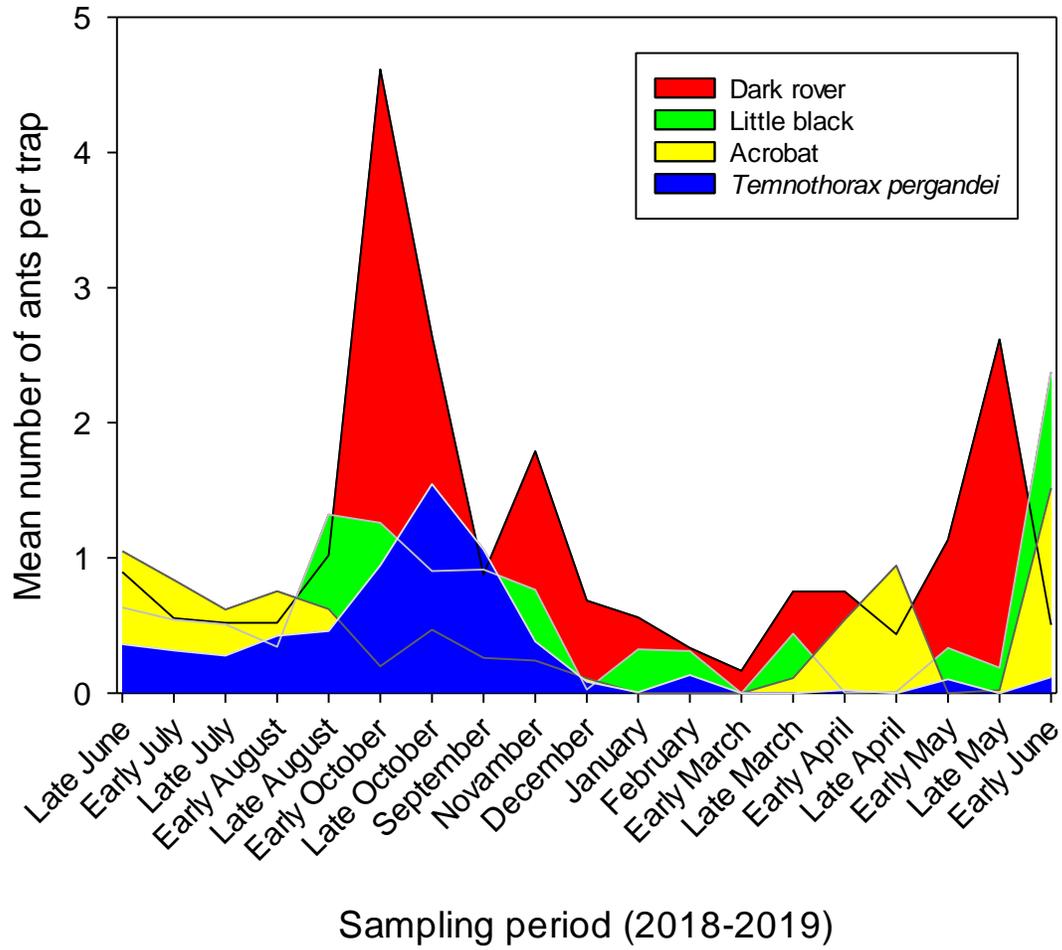
Figure 5. Seasonal abundance of reddish carpenter, pyramid, crazy, and *Ponera pennsylvanica* ants around homes in Auburn, Alabama 2018-2019.
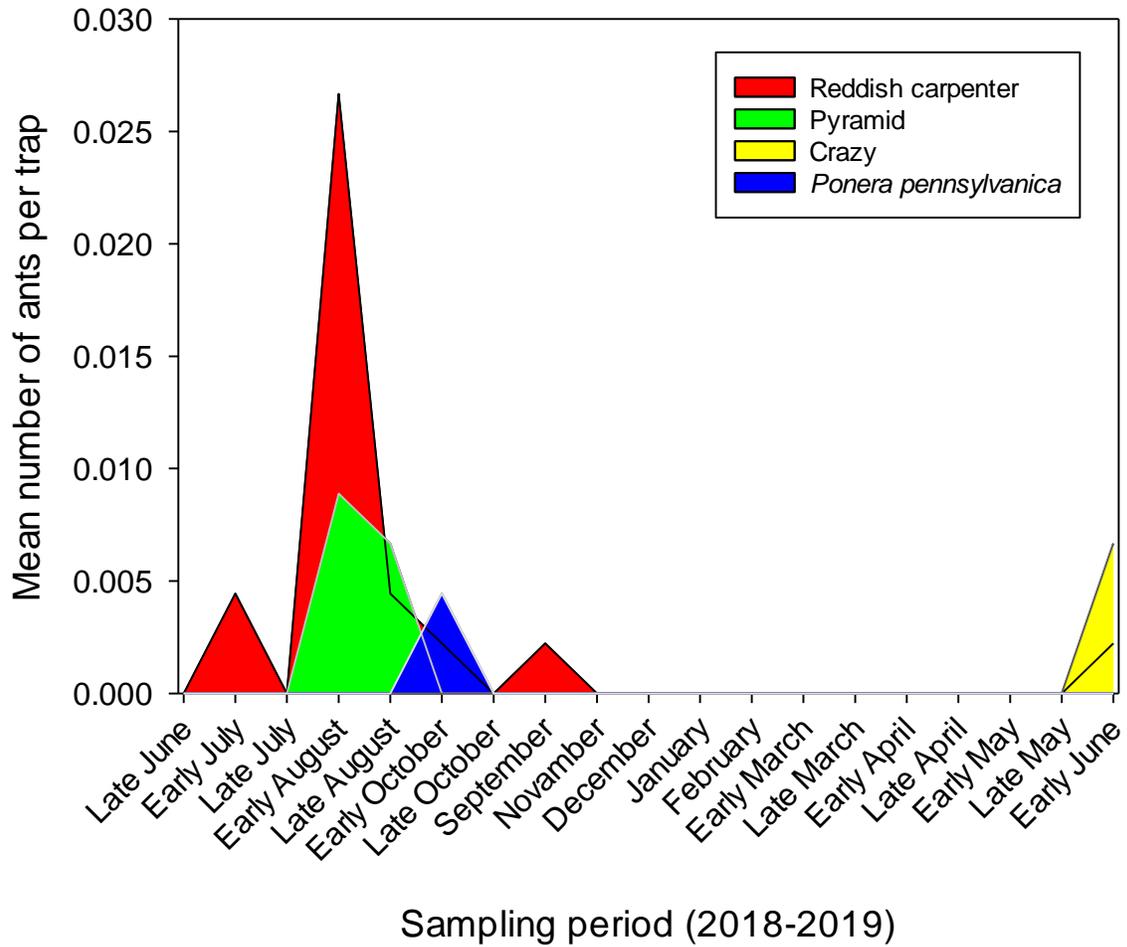
Figure 6. Seasonal abundance of American, Asian, brown wood, and little yellow cockroaches around homes in Auburn, Alabama 2018-2019.
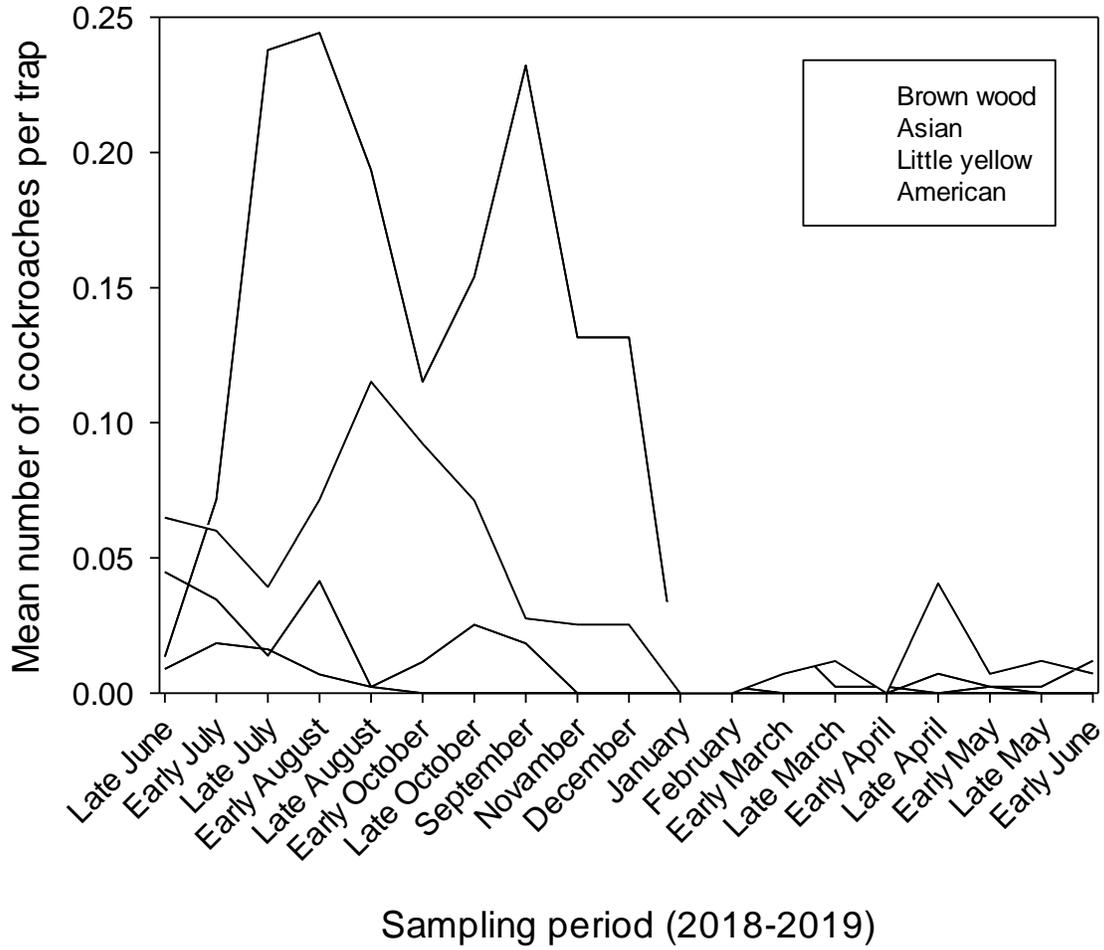
Figure 7. Seasonal abundance of American, Asian, brown wood, and little yellow cockroaches around homes in Auburn, Alabama 2018-2019.