*Proceedings of the Sixth International Conference on Urban Pests*
*William H Robinson and Dániel Bajomi (editors), 2008*
*Printed by OOK-Press Kft., H-8200 Veszprém, Pápai út 37/a, Hungary*

# DISTRIBUTION AND POPULATION DYNAMICS OF *BLATTELLA ASAHINAI* IN SOUTHERN ALABAMA AND GEORGIA, USA

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**Abstract** The Asian cockroach, Mizukubo, was discovered in large numbers in southeast Alabama in 2003. We surveyed southern Alabama and Georgia to determine the distribution of this species. We found that was established in 7 counties in Georgia and 8 counties in Alabama. Basic ecology and behavior studies were conducted in Florida, and basic biology was conducted in a laboratory setting. No reported studies have been conducted in South Alabama on the field population dynamics of We examined three different populations of in Dothan, Houston County, Alabama during 2005 and 2006. We tracked life stage and populations visually, and by sweep net and Berlese samples. We plotted this against time of year to evaluate the population dynamics in the established populations of in the field. Populations started to increase in early May and reached their zenith in August to September when they sharply declined. Populations retreated by burrowing down into the substrate during conditions of low temperature and low moisture.
**Key Words:** Asian cockroach, distribution records, peridomestic pest

## INTRODUCTION

Since the introduction of the Asian cockroach into central Florida in 1986 (Brenner et al., 1987), its range has increased dramatically. Originally, was described from three counties in central Florida, but by 1999, it had spread to 48 counties throughout Florida (Koehler, 1999) and by 2005 had reached the Florida panhandle county of Santa Rosa (Donahoe, 2005). This species reportedly has the potential to spread up the East coast and as far West as California and Washington limited only by cold temperatures (Koehler and Patterson, 1987). During the warm summer months, has the potential to build up large populations and become a peridomestic pest problem for homeowners (Brenner et al., 1987). Unlike the German cockroach, (L.), with which it may be easily confused, the Asian cockroach is phototaxic, a strong flier, and lives outdoors in leaf litter. This species will fly at night to light sources and then find its way into the home where it may become a nuisance for homeowners. If not identified properly the wrong pest control strategies (e.g., use of insecticides indoors rather than outdoors) may be used yielding little or no control.

In August 2003, a county agent in Dothan, AL (Houston County) encountered what he described as a flying German cockroach and called Auburn University for information. The cockroach in question was identified as the Asian cockroach. After several visits to Dothan, AL, it was determined that a large field population was established in this area (Hu et al., 2005). Since there are no previously published studies of the distribution of outside the state of Florida, this finding represented a new distribution.

There has not been a systematic distribution study of conducted outside of Florida except a report of populations of on Kiawah Island, South Carolina (Sitthicharoenchai, 2002) and one report from Brunswick, Georgia (Grush, 2003). Because was established in the wiregrass area of South Alabama, we decided to determine how far and to what extent it had increased its range in Alabama, if it was also established in the bordering state of Georgia, and how its distribution might have expanded. The purposes of this study were; 1) to define the distribution of field populations in southern Alabama and Georgia by sampling counties in those two states, 2) to map the distribution of and 3) to examine how it has expanded its distribution so rapidly.

Since the introduction of the Asian cockroach into Florida in 1986, there has been little field work other than some basic ecology and behavior (Brenner et al., 1987). Basic biology studies were conducted in the laboratory to determine the mean development time (Atkinson et al., 1999). In 1999, Atkinson et al. found that mean development and adult longevity of at 25°C with 50% RH were 67.8 and 103.5 d for females and 65.7 and 48.5 d for males. Environmental factors and anthropogenic factors such as low temperature or low humidity may skew developmental time of in the field. Brenner et al. (1987) used numerous traps place at ground level around a home, and examined distribution patterns and habitat preferences. showed a preference for shady areas with abundance of leaf litter (Brenner et al., 1987). Populations of can reach between 30,000-205,000 per acre in Florida (Richman, 2005). In 1990, Brenner reported that adults were not present in field populations during January and December, and again in June and July. This suggests there are two broad generations per year in central Florida. Since has expanded its range into southern Alabama and Georgia (Snoddy and Appel, 2007) there have been no published studies on population dynamics in these states. Since temperature and anthropogenic factors may influence cockroach population, and the climate of Alabama and Georgia is different than that of central Florida, and the dynamics of field populations of may be different. There are differences in the dynamics of foraging among stages (Cloarec and Rivault, 1991). Younger, immature stages of will not forage as far as adults, this may also be true for, especially since has the ability to fly and cannot.

The objective of this study was to determine the population dynamics of in the field. We compared the seasonal abundance of populations and developmental stages (means per $m^2$) and the distribution of different stages of in peridomestic habitats.

## MATERIALS AND METHODS

### Survey Methods

A visual survey for was conducted in the spring and summer of 2005 and 2006. The survey was conducted along main federal and state highways, stopping every 10 km, making periodic checks of habitats that could harbor populations of. This survey was conducted on sunny days from afternoon to sunset to facilitate the observations. Since it is likely that populations spread by “hitching” rides on vehicles, we examined those places frequented by travelers such as motels, fueling stations, rest areas, and state parks. These locations had extensive landscaping including the use of leaf litter mulch, primarily pine straw. Leaf litter and shady areas are the most likely areas to harbor populations of (Brenner et al., 1987). We sampled at least two locations, or every 10 km depending on the size of the county, unless was found at the first site. The sampling method consisted of examining the site visually for flying adults of, as they fly readily when disturbed. We also disturbed leaf litter or mulch as well as turning over any objects that could serve as harborage such as logs, and landscaping timbers. We spent no longer than 30 min at each sampling site unless we found, then we sampled until at least two adult males were collected for identification in the laboratory. Adult males were collected and preserved in 70% ethanol for transfer back to the laboratory for examination. We recorded only established populations of, i.e., if all developmental stages were present. If a county contained populations of then all counties contigous to that county were sampled. In Alabama, we sampled by starting on US Highway 431/231 in Houston County at the Florida state line and traveling north. We also traveled along US Highway 231 northward when it split from US Highway 431. We also sampled all major cities in Alabama with populations of over 100,000 since they could be destinations for people traveling to and from Florida.

In Georgia, the survey of was conducted by starting on Interstate I-75, which enters the state from Florida, and traverses the state from South to North continuing to the Tennessee line. We traveled along Interstate I-75 and made two stops per county, or every 10 km, depending on the size of the county. If the presence of. was established, we sampled the surrounding counties until a county was reached that did not have. From I-75, each county adjacent to one with was sampled on both sides of the interstate. Interstate I-85 was surveyed from the Alabama state line across Georgia to the South Carolina state line. Interstate I-20 was examined from the Alabama state line north to the South Carolina state line. We examined Interstate I-95 from the South Carolina border south to the Florida state line. This span includes Brunswick, Georgia, where Grush (2003) reported finding . We also examined US Highway 84, 82, and 80 that run East to West in Georgia. We recorded the location of each collection site using a TomTom model GO 700 (TomTom USA, Concord, MA) navigation device. GPS coordinates were confirmed using the Google Earth software system (Google 2006).

### Identification

Because species descriptions for the genus  are based on the morphology of adult males (Roth, 1986), only specimens of adult males were used to confirm the identification of Field populations were positively identified by examination of the male dorsal abdominal tergal glands (Roth, 1986). The male tergal glands of  differ considerably from those of , its closest relative, in shape and the presence or absence of posterior margins of the tergal gland. In  the posterior margins curve cephalad and may or may not join with the anterior margins (Mizukubo, 1981). In , the margins are joined anteriorly but the hind margins are widely separated and do not extend anteriorly. Once a suspected field population of  was detected, adult males were collected and transported to the laboratory for confirmation. The abdomens of the specimens were removed, cleared, and the tergites mounted on a microscope slide for examination following the methods of Roth (1986). Morphology of the tergal glands was used for species identification rather than other external morphological characteristics such as wing length, coloration, number of hind wing veins (Lawless, 1999) because these characters are only useful for separating  from . There are other  spp. with similar appearance and behavior as  [e.g.,  (Brunner) and  (Walker)] for which there are no macroscopic external characters described that could definitively differentiate among species.  Therefore we determined species identifications using tergal gland morphology following the taxonomic key to species presented by Roth (1986).

### Population Dynamics Methods

Three sites were selected based on habitat and location in Dothan, Houston County, AL that had established populations of. All sites were public parks owned by the City of Dothan. Site I was selected because it contained predominately pine straw mulch and no litter. Site II was selected because it contained predominately turf habitat and a moderate amount of litter. Site III was selected because it was covered with predominately hardwood leaf litter and heavily littered with residential trash. The sites were sampled for  every 14 d starting on 26 MAY 2005 and were sampled continuously until September 2006 when populations plummeted due to the onset of cool weather. Sample intervals were reduced to every 30 d during winter months when was relatively inactive. Three random locations were sampled at each site consisting of population counts of all stages of . In each of the random samples, three areas were sampled: vegetation, ground surface, and leaf litter. Ambient temperature and relative humidity, as well as time of day, and weather conditions were recorded at each site. A digital hydrothermograph with a probe (Model 3700, Cole-Palmer, NJ) was used to record the temperature and RH.

A sweep net was used to sample vegetation for ; five sweeps of the vegetation for each sample. Next, a standard white 5-gallon (~19 L) plastic paint bucket (Lowe's Home Improvement, Opelika, AL) was used to sample the ground surface and leaf litter. We removed the bottom of the bucket and sharpened the sides to produce a sampling device. For sampling, the bucket was placed on the ground and driven into the leaf litter. This procedure allowed  to fly from the enclosed leaf litter to the sides of the bucket and to run upwards on the inside walls. The cockroaches and other arthropods could then be counted. Nymphs of  would also run up the side of the bucket and could be easily counted. Driving the bucket into the leaf litter assured an accurate count of  in that confined space with a minimum of escapees. Temperature and relative humidity readings were taken under the leaf litter inside the bucket. The probe was inserted and temperature and RH readings recorded at the mulch-soil interface. Next, the leaf litter enclosed by the bucket was placed in plastic bags, labeled, and returned to the laboratory in a cooler. The bucket was left in place and a 1 min 30 sec visual count was taken for cockroaches in a 1-meter radius circle. Leaf litter samples were placed in a Berlese funnel for complete collection of the cockroaches in that sample. A screen mesh was placed over the top of the funnel to contain the cockroaches. Leaf litter samples were exposed to a 60-watt light bulb for 48 h and the specimens were collected into 70% ethanol. Specimens of  were categorized according to sex of the adults, and size of the nymphs. Nymphs from 1-3 mm were categorized as small, 4-7 mm as medium, and > 7 mm were considered large nymphs.

### Data Analysis

All data were converted to cockroaches/$m^2$ for comparisons using an Excel spreadsheet. Population means (± SE) were correlated with temperature and RH using SAS software (SAS Institute, 2007). Results of data analysis were plotted using SigmaPlot (ver. 9.0) software.

## RESULTS

### Distribution

We sampled a total of 32 counties (96 sample sites) in Alabama, and 62 counties (186 sample sites) in Georgia. These counties account for 48% and 39% of the total counties in those states, respectively. We detected populations of  in 7 counties in Alabama, and 8 counties in Georgia. Counties in Alabama that contain populations of  and the coordinates of the collection sites were: Baldwin, Barbour, Coffee, Dale, Geneva, Henry, and Houston. These counties are all located in the southeast corner of the state known as the wiregrass area except for Baldwin County that is located in the Mobile Bay area in the southwest corner of the state. These counties are classified primarily as being in the coastal plain region, which is dominated by sandy-loam soils, pine trees, and herbaceous plants (Kush and Meldahl, 1998). No populations of  were found North of Barbour County. The northern most established population of  in Alabama was at Lake Point State Park, Barbour County.

Counties in Georgia that contain populations of  and the coordinates of the collection sites were: Cook, Crisp, Dooly, Houston, Lowndes, Tift, Turner, and Worth. These counties are all located on US Interstate I-75 that runs through the middle of Florida to Tennessee. Every county on I-75 from the Florida line to Perry, Georgia contained populations of . The northern most population of  in Georgia was at the Georgia State Fair Grounds, in Perry, Houston County. Every county along I-85 was sampled and no populations of were detected. Interstate I-20 from Atlanta to the South Carolina state line was sampled and no populations of  were detected. Interstate I-95 from the South Carolina state line south to the Florida state line was also sampled and no populations of  were detected.

### Population Dynamics

For the 2 yr of this study (2005-2006), all sampling methods and sampling sites, a total of 1,173 were collected. Overall, the collections consisted of 24% adult females, 16% adult males, 10% small nymphs, 28% medium nymphs, and 22% large nymphs. In 2005, there were a total of 725  collected which consisted of 20% adult females, 14% adult males, 9% small nymphs, 33% medium nymphs, and 24% large nymphs (Figure 2). In 2006, only 448 total  were collected which consisted of 32% adult females, 20% adult males, 10% small nymphs, 19% medium nymphs, and 19% large nymphs (Figure 2).  had a positive correlation with temperature ($P< 0.0001$) for total stages. However, when examined as independent stages small nymphs were the only stage that didn't have a significant correlation ($P=0.09$) with temperature. During the 2005-2006 sampling periods, average daily temperatures ranged from 8.9°C to 28.5°C (AWIS, 2005 and 2006).

## DISCUSSION

The land area of Alabama and Georgia that had identified populations of  was 14,075 $km^2$ and 7492 $km^2$, respectively. Figure 1 illustrates the distribution ofin Alabama and Georgia during 2005 and 2006. Of the 15 total counties in Alabama and Georgia that contained field populations of , all but one (Houston County) represents new distribution records. The advancing northern distribution of  is not a broad, uniform advancement, instead, what appears are finger-like projections of advancing distribution into southern Alabama and Georgia (Figure1).

By overlaying the major highways in Alabama, Georgia, and Florida on the distribution map of  it is evident that  distribution is coincident with major interstates and highways (Figure 1). It is likely that transportation vehicles facilitate the distribution. Interstate I-75 that transverses most of Florida and all of Georgia (North to South) is a major transportation route for tourists and commerce. Since major production of fruits and vegetables, as well as many horticultural and ornamental crops occurs in Florida (Smith, 2006), there is a large movement of commercial open flatbed trucks that are capable of transporting  unknowingly into other states throughout the year. Interstate I-10 that traverses Florida (East to West) in the Florida panhandle is a major transportation route that again would facilitate transportation of  into other states. Interstate I-10 also passes through Baldwin County, AL, where an established population of  was detected. Interstate I-10 proceeds west from Florida through Alabama, Mississippi, and Louisiana, and also passes through Houston, Texas. Mr. Jeffery Tucker submitted a specimen to us for positive identification in 2006. The  specimen was collected behind a car dealership on Interstate I-10 in Houston, Texas (Tucker 2006). Although we confined this study to Alabama and Georgia, there is no reason why should not be present along I-10 from Florida West through Alabama, Mississippi, Louisiana, and Texas.

We propose that the field populations of  in southeastern Alabama originated in Florida and entered Alabama via US Highway 431/231. This is a major transportation route for tourists that visit the crystal white sand beaches of the Gulf of Mexico. Tourists that come from Georgia, Tennessee, or farther north must use US Highway 431/231 to access the Gulf of Mexico beaches. Specimens could be unknowingly collected in nearby areas and transported into Alabama. From Dothan, AL US 431/231 splits but both routes continue in a northerly direction facilitating further dissemination of  into different areas of Alabama.

In Alabama, has not advanced as far North as it has in Georgia, and this may be due, in part, to the winter temperatures. The South Georgia costal plain climate is more humid and warmer in winter than the northern sections because it is influenced by both the Atlantic Ocean and the Gulf of Mexico (Figure 1). The wiregrass area of Alabama, where field populations of  are most prevalent, is influenced only by the Gulf of Mexico (Figure 1) (AWIS, 2005). Despite the report by Grush (2003), we found no populations along I-95 that traverses the coast of Georgia from Florida and into South Carolina. This may be due, in part, to the predominately salt marsh habitat that is found along this interstate. It is possible that the  reported from Brunswick, Georgia (Grush, 2003) located along I-95 were introduced, but did not become established.

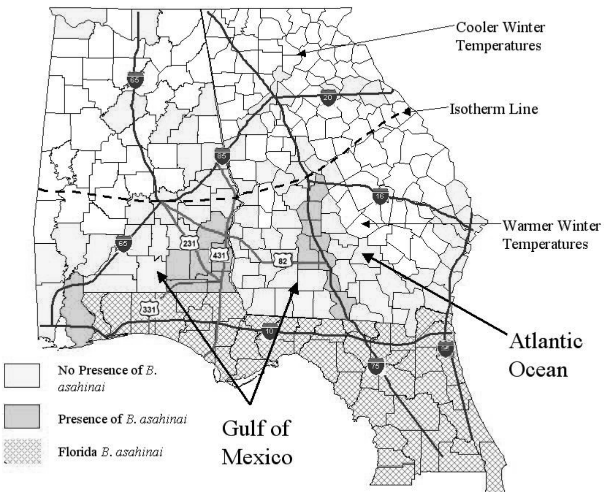


**Figure 1.** Distribution of the Asian cockroach, *B. asahinai* in Alabama, Georgia, and Florida with major transportation routes, an isotherm line, and temperature differences indicated.

There is an established population of  on Kiawah Island, South Carolina, which, is believed to have been introduced in pine straw mulch (E. P. Benson, personal communication) from Florida. The South Carolina coast is south of the isotherm line (Figure 1) where all other established populations of  have been detected. We propose that  ranges farther north in Georgia than in Alabama because of the more moderate winter climate. Other insects, which have similar distributions, include Love bugs,  (McCann et al., 1996), and Eye Gnats,  (Payne et al., 1977).

From 2005-2006 we observed no northerly shift in the range of past Houston County, Georgia; this again, is probably due to seasonal temperature differences between North and South Georgia. The winter is colder in North Georgia with temperatures as much as 4°C lower in the north than the south (AWIS 2005). The temperature in North Alabama is also cooler in the winter than in South Alabama (AWIS 2005). Based on our field surveys in 2005 and 2006, it appears that at this time  is restricted to the costal plains and gulf coasts regions of the continental United States.

The movement of other invasive insects has been facilitated by human transport, and limited by cold temperatures. For example, the red imported fire ant,  Buren, is an introduced invasive species that entered this country at the Port of Mobile in the 1930s (Vinson, 1997). Since its introduction,  has expanded its distribution throughout the southeastern United States, and is only limited by climatic conditions (cold temperatures) (Vinson, 1997). The red imported fire ant is typically moved or transported in soil, but mated wing females have been detected in open beds of trucks (Vinson, 1997). Similarly, the Formosan subterranean termite  Shiraki was introduced into the United States during WWII on ships returning from war. This species was first recorded at Mobile, Alabama in 1985, although it had probably been there for some time (Hu and Oi, 2004). The Formosan subterranean termite has advanced its range to 13 counties in Alabama, all of which are associated with one of the 5 major interstates in Alabama (Hu and Oi, 2004). Since its introduction into Florida in 1986, has expanded its distribution to four additional states in just 11 years. It was originally thought that  would be limited in range by temperatures of -12.3°C, but more recently the estimate has been lowered to -17.8°C (Vinson, 1997). Under favorable environmental conditions  could range along the Atlantic coast as far north as Maryland, and as far West as California and the Pacific coast of Washington (Koehler and Patterson, 1987). With the recent detection of  in AL, GA, and Houston, TX, it is likely that the distribution of this species is facilitated by mechanical transportation. Based on the ability to utilize transportation, a spread of ca. 1579 km in ca. 20 yr, a relatively direct transportation route (Interstate I-10), and similar habitats and climates, we could observe populations of  in California by 2017. Similar to , climatic conditions and suitable habitats should be the only major parameters governing the distribution of in the continental United States.

During 2005 and 2006, females populations were larger than males, and medium nymphs were the predominate stage of immature (Figure 2). During 2005 and 2006, mean visual populations of all stages of  reached their zenith in late August-early September (Figure 3). All visual counts were at ground level; was never observed or collected in sweep net samples. When disturbed  would fly to escape, and when an individual encountered vegetation it would land, but quickly return to ground level. In 2005 mean visual populations for all stages of  started increasing in early May with overlapping generations observed before populations declined sharply with the onset of cool weather in September (Figure 3). In 2006, mean visual counts of all stages of  began to increase in early May but dropped sharply in early June (Figure 3). It is possible that the sudden decline in counts was in part due to a prolong absence of rainfall (± 8 weeks) (AWIS, 2006). Data show a concurrent increase in Berlese counts at this time in June. By late June 2006, when normal precipitation resumed, mean visual counts of all stages of  resumed their growth rate and reached their zenith in late August, and then decline sharply with the onset of cool weather (Figure 3). During 2005-2006 there was a significant positive correlation between total means of and temperature ($P < 0.0001$). There was also a significant positive correlation between total means of and RH ($P < 0.0001$).

In early May 2005,  populations were predominately adults (50% females and 25% males), with some nymphs (25%), and higher populations of nymphs occurring in the next two generations (Figure 3). Again in 2006, we observed a similar adult to nymph ratio during the same time period (Figure 3). Interestingly, during the drought conditions of June 2006, when we observed a sharp decline in visual counts of all stages of , there was a sharp increase in Berlese counts during the same time period (Figure 5). The increase in Berlese sample counts demonstrates that all stages of  moved from the ground level surface habitat and leaf litter into a cooler and moister habitat. This movement demonstrates that  has the ability to escape adverse environmental conditions (e.g., temperature and low RH) buy burrowing down into cooler and moister leaf litter and into the soil. In the 2005-2006 bucket samples, we observed distributions and population sizes similar to those of the 2005-2006 visual means (Figure 4). In contrast to the visual and bucket means we observed higher population numbers of the different stages of  during the colder months of 2005-2006 in the Berlese samples (Figure 5). This demonstrates again that  has the ability to burrow down into the soil when faced with cold temperatures during the winter months.

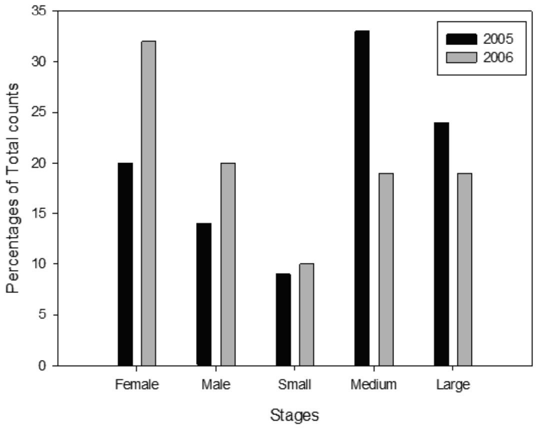


**Figure 2.** 2005-2006 Percentage by stage of counts of *B. asahinai* in Dothan, Alabama.

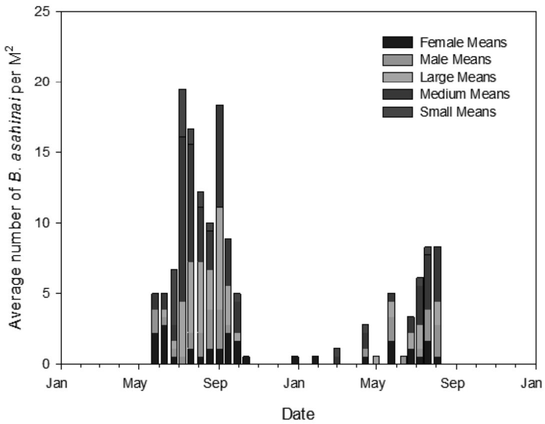


**Figure 3.** 2005-2006 Visual population means of all stages of *B. asahinai* in Dothan, Alabama.

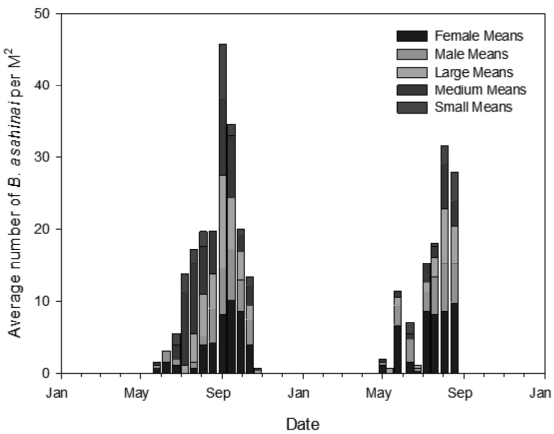


**Figure 4.** 2005-2006 Bucket Sample means for all stages of *B. asahinai* in Dothan, Alabama.

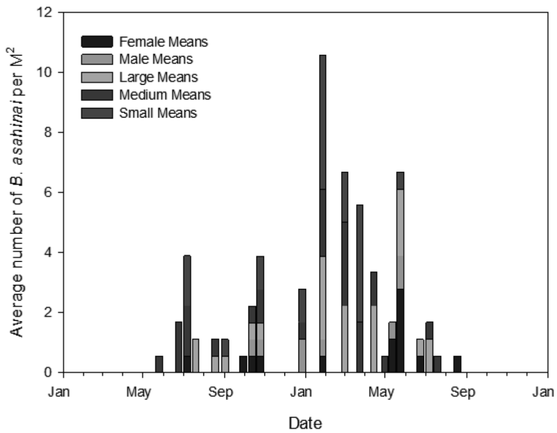


**Figure 5.** 2005-2006 Berlese sample means for all stages of *B. asahinai* in Dothan, Alabama.

We observed that laboratory and field populations of different stages of  have the ability to acclimatize and acclimate to their environment (Snoddy 2007 Masters Thesis, unpublished). Temperature sensitivity varies with environmental temperatures; higher environmental temperatures result in higher CTMax and CTMin values. Lower environmental temperatures result in lower CTMax and CTMin values. Acclimation enables  to better tolerate increasing or decreasing ambient temperatures (Snoddy, unpublished).

The Berlese samples were highly skewed towards the nymphal stages (Figure 5). Berlese samples suggest that when  is faced with adverse environmental conditions such as low temperature and low humidity, they will burrow into the substrate to escape those conditions. By recording the different stages of  using three different sampling methods, we were able to show the stage distributions as they occur over time in the field. During January through June the population of  is skewed towards adult females and nymphs (small, medium, and large). Populations build from early May through late August when they decline sharply; females and nymphs (small, medium, and large) over-winter in the substrate. In January, populations are

~10% adults and ~90% nymphs, but his changes into ~100% nymphs from February through May, when the large nymphs go through eclosion into adults. During January, can only be detected in Berlese samples, since they over winter in the leaf litter and soil. As temperatures warm in the spring, Berlese sample counts start to decline and visual counts start to increase. There is an overlap between the Berlese samples and visual counts during the transition into warmer weather in the spring, as adults are much more mobile than nymphs, and adults are picked up more frequently in the visual and bucket samples at that time.

Field observations during 2005 and 2006 suggest that may have two generations per year in Alabama, which is similar to the observations of Brenner et al. (1987). Visual and bucket counts were absent of adults during certain times of the year. But concurrent Berlese samples detected some adult populations. Brenner et al. (1987) examined a microhabitat whereas our observations were recorded from three different macrohabitats. The ability of to acclimatize and burrow to avoid adverse conditions would allow to expand and colonize new habitats that are similar. With multiple generations per year, has the ability to rapidly expand and colonize new ranges in the coastal plains and gulf coast regions

## ACKNOWLEDGMENT

We thank Micky D. Eubanks and Xing Ping Hu, Auburn University for their many helpful comments of earlier versions of this manuscript.

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