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ARTHROPOD MANAGEMENT & APPLIED ECOLOGY

A Multiyear Study on Seasonal Flight Activity Based on Captures of Southern Green Stink Bug (Hemiptera: Pentatomidae) in Blacklight Traps in Central Texas

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ABSTRACT

The southern green stink bug, *Nezara viridula* (L.) (Hemiptera: Pentatomidae), is cosmopolitan in distribution and feeds on many cultivated plants. On cotton, it reduces yield and transmits fungal and bacterial pathogens that result in necrosis of the locule and boll rotting. Objectives of this study were to determine the seasonal flight activity and to assess numerical changes in the season-long captures of *N. viridula* in blacklight traps. Traps were established in a commercial farmscape where cotton and corn were the predominant crops. Minor crops grown in the area were milo, soybean, pecan, and watermelon. Study areas included four to five locations during each year from 2003 to 2011 in Burleson County of Central Texas. Frequency distribution of seasonal counts of *N. viridula* conformed to a clumped dispersion pattern when analyzed by Taylor's Power Law and negative binomial distribution as probability models. Counts transformed by a power law function, $x^{0.165}$, adequately uncoupled the mean and the variance of the data better than those transformed by log transformation. Significantly and consistently, more females than males were captured in traps. Peak captures of *N. viridula* in traps generally occurred in August. August counts of the insect declined precipitously from a monthly mean of 177 in 2003 to near zero in 2011. Results of this study demonstrate that blacklight traps are a useful sampling tool for determining *N. viridula* population numbers and to assess their seasonal flight activity in production agriculture.

In the wake of reduced application of broad spectrum insecticides for the control of heliothine insects on Bt cotton combined with the boll weevil eradication program, stink bugs have emerged as important pests of cotton in the southeastern U.S. (Bachelor and Mott, 1996; Barbour et al., 1990; Turnipseed et al., 1995). Williams (2013) estimated that stink bugs were second in importance among insect pests for causing yield reductions in cotton after *Lygus* spp. and thrips in 2012. Willrich et al. (2004) reported that in late-season cotton, southern green stink bug (SGSB), *Nezara viridula* (L), adults caused indirect harvest losses, which included rotted and hard-locked bolls, reduction in seed cotton yield, and germination of seed from harvestable bolls. SGSB infestation symptoms were exacerbated under heavy rainfall and humidity conditions, resulting in the development of boll-rotting pathogens including *Diplodia* spp. and *Fusarium* spp. (Willrich et al., 2004). Medrano et al. (2007) reported that SGSB readily ingested the opportunistic bacteria, *Pantoea agglomerans* (strain Sc 1-R) and transmitted it into unopened cotton bolls, thereby causing rotting of entire locules.

Knowledge of the seasonal activity and distribution pattern of SGSB during the cotton growing season is important in managing this pest species. The development of an integrated management program for SGSB presupposes a reliable and cost-effective sampling method to assess the activity and numerical trends of the insect during a cropping season. For example, Reay-Jones et al. (2009) sampled green stink bug, *Acrosternum hilare* (Say); brown stink bug, *Euschistus servus* (Say); and SGSB on cotton using beat cloth and sweep-net methods in South Carolina and Georgia. Hopkins et al. (2010) sampled *Euschistus* spp. in the Lower Gulf coastal region of Texas by placing the drop cloth between two adjacent rows of cotton and shaking the plants on each row adjacent to the cloth to dislodge stink bugs. Suh et al. (2012) studied species composition of stink bugs in cotton and other crops in Central Texas by using standard 40.6-cm sweep nets. Using blacklight traps, Blinka et al. (2007) sampled *A. hilare* and *E. servus* in North Carolina from mid-July to the end of August at commercial farms where corn, cotton, peanut, soybean, and tobacco were grown.

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One of the advantages of a light trap is that it captures large numbers of night flying insects by using illumination provided by the light source (Muirhead-Thompson, 1991). Stink bugs often move between host plants during the most attractive phenological phase of each plant (Panizzi, 1997), and pentatomids can be intercepted by blacklight traps during such interplant movement and thus provide a source for captures of these nocturnal insects. Nielsen et al. (2013) reported that blacklight traps proved to be a highly effective tool for monitoring *Halyomorpha halys* (Stål) populations and their spread at the landscape level. Unlike other monitoring tools such as sex pheromone traps that are sex biased, female and male *H. halys* were equally attracted to blacklight traps (Nielsen et al., 2013). Kamminga et al. (2009) reported that information using cumulative trap catch and calculated degree days could be useful in the design and implementation of a field scouting program and for determining periods of highest risk of green stink bug, *Acrosternum hilare* activity during the cropping season. Although the captures of insects in light traps are likely to be influenced by physical factors such as spectral intensity of illumination, moon phase, and weather (Bowden, 1982), it is apparent that they do represent a useful monitoring tool for determining seasonal flight activity pattern of phytophagous pentatomids. However, Bowden (1982) reported that light trap catches of insects are the result of the interactions between two physical components, natural and artificial illumination. Using the formula that light intensity decreases at a rate equal to the inverse square of distance from the light source, Bowden (1982) estimated a 12:1 ratio of background illumination to alter the captures of insects in traps.

The development of a biometrically oriented sampling technique requires an appreciation of spatial pattern of natural insect populations and the use of such distribution pattern to formulate an appropriate transformation for field counts of the insect (Harcourt, 1969; Korie et al., 2000). Aggregation or lack of it is an intrinsic property of natural insect populations and it is described by various mathematical models using random variates of insect counts (Taylor, 1961, 1984). For analyzing the dispersion characteristics of an insect species, Taylor (1961) proposed that variance (s^2) of population abundances are related to their mean (m) by $s^2 = am^b$, where a and b are parameters in a regression model.

Objectives of this study were to characterize the seasonal flight activity of SGSB relative to captures of the insect during the cotton growing season and to identify its dispersion characteristics and seasonal variations in spatial distribution pattern during numerical fluctuations of the insect in the Brazos Bottom region of Central Texas. We also sought a variance stabilizing transformation for the captures of the insect in traps to conduct parametric analysis of the data. The intent of this report also included an evaluation of likely causes that led to greatly reduced captures of SGSB in 2011 in the study locations.

MATERIALS AND METHODS

Blacklight traps were established in four to five locations during each year from 2003 to 2011 (with the exception of 2007) in Burleson County near College Station, TX. Traps were located in an agricultural landscape along Farm-to-Market Road N 50, county roads, pecan orchards, and corn and cotton fields. The acreage of each crop and the location of each crop near blacklight traps varied with years during the study period. Table 1 lists the GPS coordinates for each study area. GPS coordinates were obtained using a battery-operated Magellan® eXplorist XL portable GPS receiver (Taipei, Taiwan). Each trap was equipped with a 40-W fluorescent bulb (40 BL) mounted vertically between four baffles and above a funnel (76 cm diameter) (Hollingsworth and Hartstack, 1972). To trap live insects, the original collection reservoir was replaced with an inverted canister from a Texas cone trap (Hartstack et al., 1979). Pieces of paper bags were crumbled and placed inside the canister to provide a substrate on which the stink bugs could climb and remain separated from other insects. Traps were serviced daily in the morning, except during the weekends, rainy days, and holidays. Consecutive 2-d samples were averaged and counts were assigned to appropriate dates. Canisters containing the insects were placed in a walk-in cold room maintained at 18° C. After cooling down, the stink bugs were separated by species, placed in plastic bags and taken to the laboratory for counting. Captures of the insect from 2003 to 2006 were sorted by gender and counted, and thereafter, only total counts of the captures of SGSB were recorded.

Table 1. Blacklight trap study locations, years of operation, and GPS coordinates[z] of each study area, Burleson County, TX.

Location	Years studied	Latitude	Longitude
Mini-Lab	2003 to 2011	30.53020°N	96.42823°W
Well	2003 to 2011	30.52202°N	96.40107°W
Buffalo Ranch	2003 to 2011	30.52089°N	96.39903°W
Scarmado	2004 & 2005	30.59446°N	96.52084°W
Pecan Lab	2003 to 2008	30.52800°N	96.42892°W
Porter	2011	30.54480°N	96.45430°W
USDA	2006	30.52187°N	96.42319°W

[z] GPS coordinates were determined by a battery-powered Magellan® eXplorist XL portable GPS receiver.

Data Analysis. All data analyses were conducted using SAS version, 9.3 (SAS Inst., 2008). In total, 3217 light trap samples (653 in 2003, 665 in 2004, 433 in 2005, 335 in 2006, 364 in 2008, 271 in 2009, 275 in 2010, and 221 in 2011) were taken. Counts with zero values were coded by adding a constant (0.1). Daily counts of the insect were sorted by month and the monthly cluster of captures of SGSB was used to obtain mean densities and variances. The Taylor's Power Law parameters were estimated by the regression of $\log_{10} S^2$ on $\log_{10} m$ using the formula:

$$\ln(s^2) = \ln(a) + b \ln(m)$$

where the intercept (a) is the sampling factor related to sample unit used, and the regression coefficient b is an index of aggregation that suggests a uniform, random, or aggregated dispersion pattern when $b < 1$, $b = 1$, or $b > 1$, respectively. The b coefficients were tested for departure from unity (random distribution) using an F-test. Regression coefficients were compared using dummy variables, and the means were separated using Tukey's Studentized Range (HSD) test at the 5% probability level.

The negative binomial distribution is one of the most versatile and widely used models to describe the skewed insect counts that conform to a contagious distribution (Bliss, 1971). Binns (1986) reported that basic biological processes such as birth, death, and immigration, etc., as described by the variance-mean model of Taylor's Power Law are embedded in the negative binomial distribution, and he demonstrated a linkage between the two statistical models using mathematical formulae. As a corollary to Taylor's Power Law, we sought to determine whether or not the frequency distribution of counts of SGSB would approximate to negative binomial distribution. The adequacy of the fitness of the counts of SGSB to negative binomial distribution was determined by running the Countreg procedure. The parameter estimate, _Alpha, an estimate of dispersion, was tested for deviation from overdispersion using the *t* statistic. Counts of SGSB were transformed to $x^{0.165}$, where x is the original variate before conducting the PROC GLM procedure (See section on Data Transformation). Total variations of the transformed responses in insect counts as measured by Type III sums of squares (ss3) were partitioned into components associated with differences among month, year, location nested within year, and interactions between month and year. When *F*-values were significant ($p = 5\%$), least square means were separated at $p = 5\%$ into letter groupings using PDMIX800 macro (Saxton, 2012).

Counts of SGSB captured in blacklight traps contained a substantial proportion of zero variates and the remainder had a highly skewed distribution with heterogeneous variance (e.g., max. count = 1,626; max. $s^2 = 154{,}179.73$). The logarithmic transformation is most frequently used to achieve homoscedasticity or stability of variance of data that conform to a skewed distribution (Morris, 1955). Healy and Taylor (1962) have tabled values for a power law transformation, $z = x^{1-b/2}$, where x is the observed count and b is the slope coefficient derived from the regression of log variance on log mean. To substantially reduce error variance in the regression variates and to maximize the efficiency of parameter estimation, we conducted a weighted regression of log variance on log mean as suggested by several workers (e.g., Hayman and Lowe, 1961; Taylor, 1970; Wayman, 1959). The adequacy of the transformation was tested following transformation by calculating the correlation coefficients between the two parameters (Downing, 1979; Harcourt, 1961). Alternatively, Southwood and Henderson (2000) suggested a graphical illustration of the relationship between the variance and the mean to reveal the relative independence between the two regression variates.

RESULTS

Dispersion Pattern of Male and Female SGSB. The regression of log variance on log mean for female and male counts of the insect revealed a highly significant relationship between the regression variates. The regression equation for female counts was: $y = 0.321 + 1.809x$ with $r^2 = 0.96$ and that for male counts was $y = 0.453 + 1.768x$ with $r^2 = 0.95$. The regression coefficients and the intercepts, respectively, of each gender varied significantly from 0 ($t = 59.54$, $t = 10.09$ with df = 1, 137; $p < 0.0001$ for female; $t = 49.54$, $t = 15.55$ with df = 1, 128; $p < 0.0001$ for male). Slopes of the regression lines for female and male varied significantly from unity as well ($F = 709.11$; df = 1, 137; $p < 0.0001$ for female; $F = 463.48$; df = 1, 128; $p < 0.0001$ for male). Also, the regression coefficients of each gender did not vary significantly from each other ($t = 0.87$, df = 1, 265; $p > 0.3852$). The log s^2 and log m data for female and male SGSB were, therefore, combined and are presented in Fig. 1. The regression equation showed that 96% of the variation in the mean abundance of the insect was explained by the variance of the counts as described by the model. The slope of the regression line and the intercept, respectively, were significantly greater than 0 ($t = 77.73$, $t = 18.51$ with df = 1, 267; $p < 0.0001$). The slope coefficient also varied significantly from unity ($F = 1145.89$; df = 1, 267; $p < 0.0001$), indicating that the seasonal captures of SGSB conformed to a clumped dispersion pattern, regardless of gender.

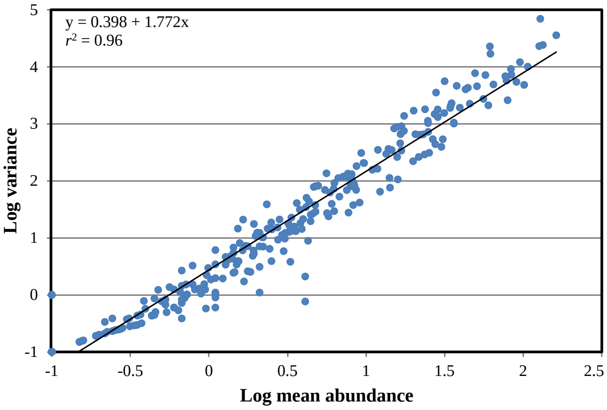

Figure 1. Relationship between $\log_{10}$ (s^2+0.1) and $\log_{10}$ (m+0.1) for *N. viridula* (males and females combined) captures in blacklight traps from 2003 to 2006.

Overall Dispersion Pattern of SGSB. The regression of log variance on log mean conducted for the entire set of data encompassing the captures of SGSB in traps during the 8-yr period revealed that 95% of the variation in mean abundance was explained by the variance of the counts as described by the model (Fig. 2). The slope coefficient and the intercept varied significantly from 0, respectively ($t = 70.35$, $t = 16.65$ with df = 1, 247; $p < 0.0001$). Furthermore, the slope of the regression line varied significantly from unity as well ($F = 855.93$; df = 1, 247; $p < 0.0001$), indicating that the captures of SGSB in light traps conformed to a highly clumped distribution pattern.

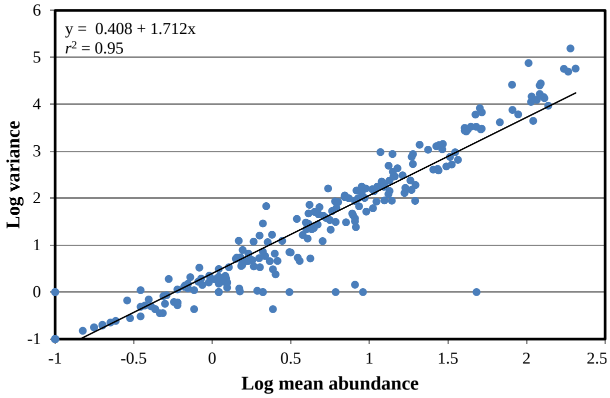

Figure 2. Relationship between $\log_{10}$ (s^2 +0.1) and $\log_{10}$ (m +0.1) for overall captures of *N. viridula* in blacklight traps from 2003 to 2011.

Year-to-Year Variation in Dispersion (Taylor's Power Law). Taylor's Power Law analysis revealed that considerable temporal variability existed in the index of clumping (Fig. 3). The slope coefficient, *b*, varied significantly among years (Fig. 3). Captures of the insect were significantly more clumped during 2004 and 2005, but the index of clumping did not significantly differ from that in 2003. Aggregation significantly declined in 2006 and remained flat thereafter through 2009. A steep decline in clumping occurred in 2010, but the index of aggregation did not significantly vary from that in 2009. The index of aggregation was near unity in 2011, and was significantly different from indices for previous years. Although the data suggest that the spatial pattern of the insect was approaching random distribution in 2011, the slope coefficient, 0.987 ± 0.004 was significantly different from unity ($t = 8.58$; df = 1, 20; $p > 0.0083$), suggesting that the distribution of the captures of SGSB in 2011 remained aggregated, although there were numerous zero values.

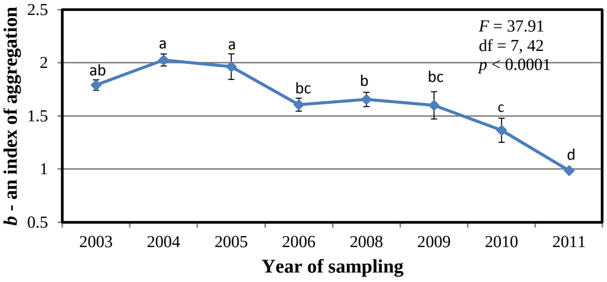

Figure 3. The index of aggregation, *b* for the captures of *N. viridula* in blacklight traps from 2003 to 2011.

Year-to-Year Variation in Dispersion (Negative Binomial Distribution). Analysis of frequency distribution of counts of SGSB using the negative binomial distribution is presented in Table 2. The dispersion parameter, _Alpha, was significantly clumped during each of the years studied ($p < 0.0001$), except in 2011 when the population of the insect declined to near zero. The statistical significance of the dispersion parameter, _Alpha, in 2011 is not determined, probably because of numerous zero values.

Table 2. The dispersion parameter (_Alpha) of negative binomial distribution fitted to counts of *N. viridula*.

Year	_Alpha ± SEM^z	*t*	*p*
2003	4.603 ± 0.49	9.39	<0.0001
2004	2.817 ± 0.305	9.24	<0.0001
2005	3.035 ± 0.424	7.16	<0.0001
2006	1.745 ± 0.349	4.99	<0.0001
2008	2.548 ± 0.426	5.98	<0.0001
2009	1.816 ± 0.414	4.38	<0.0001
2010	1.264 ± 0.36	3.51	<0.0004
2011	0.000000223^y	-	-

[z] The dispersion parameter in the negative binomial model.

[y] SEM could not be determined.

Countreg procedure (SAS, 2008) was used to fit the data using the negative binomial distribution.

Data Transformation. Figure 4 shows the weighted least square estimation, which yielded a regression equation. The slope coefficient and the intercept, respectively, were significantly different from 0 (t =70. 58, t = 19.23; df = 1, 247; p <0.0001). This relationship resulted in the transformation of the form, $z = x^{0.165}$, where x is the original count. The relationship between the mean and the variance after power transformation is shown in Fig. 5, suggesting that the power transformation adequately stabilized the variance of the data. Also, the slope coefficient, b = 0.016 was not significantly different from 0 (t = 87; p > 0.3850). Figure 6 shows the scatter plot of the same data transformed by log transformation (r^2 = 0.03; p >0.0048), suggesting that the log transformation did not adequately remove the dependence of the variance on the mean. Furthermore, the slope coefficient was significantly different from 0 (t = 2.84; p < 0.0048). The ratio of the maximum to minimum variance was 0.736/1 for the power transformation and 1.484/1 for the log transformation. The power transformation yielded a nonsignificant r^2, a nonsignificant slope, and had a lower maximum/minimum variance ratio compared to log transformation. The regression of variance on the mean in the original scale showed that the two parameters were significantly related (r^2 = 0.54; n = 249; p < 0.0001). Furthermore, the slope coefficient and the intercept, respectively, were significantly different from 0 (t = 17.16, p<0.0001; t = -3.03, p > 0.0027) with 1, 247 df).

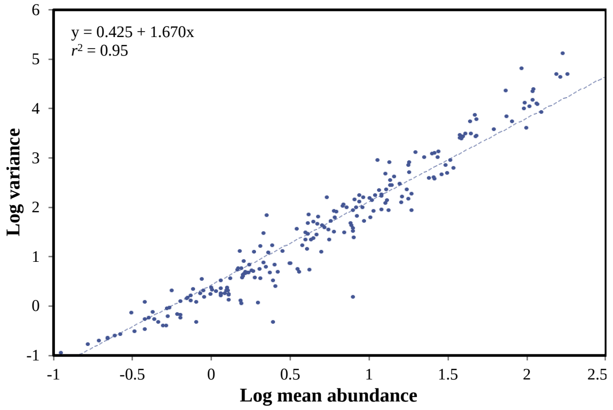

Figure 4. A weighted regression of $\log_{10}$ (s^2+0.1) on $\log_{10}$ (m+0.1) for overall captures of *N. viridula* in blacklight traps from 2003 to 2011.

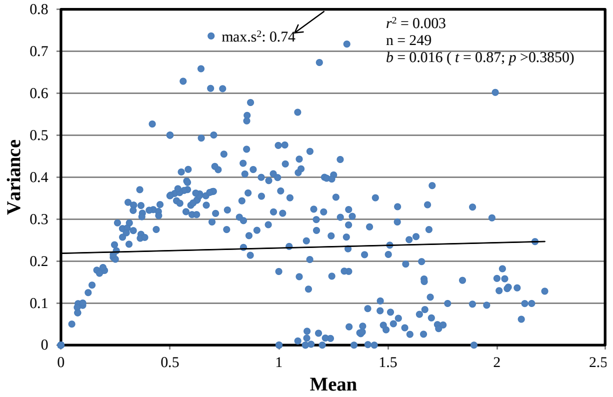

Figure 5. Scatter plot showing the relative independence of the variance from the mean after the monthly counts of *N. viridula* captured in traps were transformed to a power transformation ($x^{0.165}$), derived from Taylor's Power Law. An arrow shows the data with maximum variance.

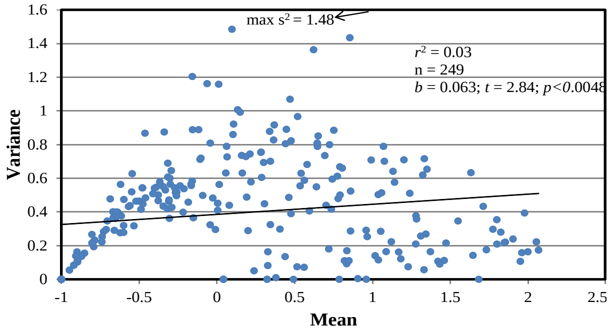

Figure 6. Scatter plot showing the relative independence of the variance from the mean after the monthly counts of *N. viridula* captured in traps were transformed to $\log_{10}$ (x+0.1). An arrow shows the data with maximum variance.

Seasonal Flight Activity of Male and Female SGSB. Figure 7 shows the mean captures of SGSB by gender in blacklight traps from 2003 to 2006. Significantly more females were captured in the traps each year compared to males. Also, significantly more females were captured each month during each year compared to males (F = 40.11; df = 8, 318; $p < 0.0001$ for 2003; F = 34.85; df = 8, 270; $p < 0.0001$ for 2004; F = 35.59; df = 5, 184; $p < 0.0001$ for 2005; and F = 13.08; df = 5, 148; $p < 0.0001$ for 2006). Also, there was no significant interaction between gender and month of capture during three of the four years of study (F = 0.80; df = 8, 318; $p > 0.6042$ for 2003; F = 0.47; df = 8, 270; $p > 0.8786$ for 2004; F = 2.27; df = 5, 184; $p > 0.0495$ for 2005; and F = 0.89; df = 5, 148; $p > 0.4874$ for 2006). Interaction between gender and the month of capture was significant only during 2005.

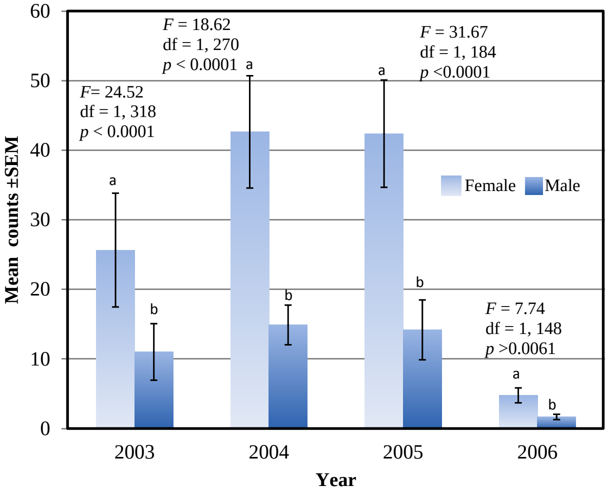

Figure 7. Mean (± SEM) counts by gender of *N. viridula* captured in blacklight traps from 2003 to 2006. Counts transformed to $x^{0.165}$ before variance analysis. Original means within each year followed by the same lower case letter are not significantly different.

Table 3 shows multiple comparisons of monthly mean captures of SGSB in blacklight traps averaged over 4 yr. Significantly more females were captured in August compared to any other month. Captures of SGSB in July were significantly less compared to those in August but the captures in September were similar to those in July. The number of SGSB decreased significantly in October and November. The seasonal activity of male SGSB relative to its captures in blacklight traps varied slightly from that of female SGSB. In contrast to females, although peak captures of males occurred in August, captures of males in September were comparable to those in August. Similar to females, captures of males declined significantly in July. However, captures of males in October and November were similar to those in July. The pattern of captures of males in March, April, May, and June were similar to that for females.

Table 3. Multiple comparison of mean (± SEM) monthly captures of female and male *N. viridula* in blacklight traps from 2003 to 2006, Burleson County, TX.

Month	Female ± SEM	Male ± SEM
March	1.33 ± 0.43cd	0.42 ± 0.26cde
April	0.79 ± 0.17d	0.49 ± 0.18cde
May	3.73 ± 0.80c	1.62 ± 0.40cd
June	3.31 ± 0.70c	0.99 ± 0.34de
July	36.23 ± 6.01b	10.74 ± 3.0b
Aug.	113.42 ± 22.29a	39.51 ± 10.09a
Sept.	49.67 ± 9.29b	23.78 ± 6.29a
Oct	6.62 ± 1.57c	3.00 ± 0.56b
Nov.	5.64 ± 2.07cd	3.45 ± 1.55bc
Dec.	0.00 + 0.0e	0.00 ± 0.00e

Data was analyzed by PROC GLM procedure after transforming the data to $X^{0.165}$. Least square means were separated at $p < 5\%$ and letter groupings were assigned using PDMIX procedure. Original means within each column followed by the lower case letter are not significantly different.

Overall Seasonal Flight Activity Pattern of SGSB. The ANOVA statistics and associated variance components for the monthly number of SGSB captured in traps during the study period from 2003 to 2011 are shown in Table 4. The yearly variation in seasonal activity of the insect relative to captures of the insect was significantly related. Monthly variations in seasonal activity of SGSB constituted the second important source of variation impinging on numerical fluctuations of the insect. Significant difference in seasonal activity of SGSB between locations within each year also persisted. There was also a significant interaction in seasonal activity between month and year. Table 5 shows mean separations for monthly captures of SGSB during each year of the study reported here. In 2003, counts of SGSB remained relatively low from April to June. Captures increased significantly in July and then peaked in August. There were no significant differences in number of SGSB captured between August and September. Captures decreased significantly in October and thereafter remained relatively low. Similar trends in seasonal counts of the insect persisted in 2004 except that peak captures occurred in July; however, the number of SGSB captured in July did not significantly differ from that captured in August. In 2005, the peak captures of SGSB persisted in August as well and the trend continued even in 2011when the population of SGSB collapsed. Data herein described indicate that the peak captures of SGSB occurred in August during each year of the study with little variation from this trend.

Table 4. Analysis of variance of counts of *N. viridula* captured in blacklight traps from 2003 to 2011, Burleson County, TX.

Source of Variation	Df	Mean Square	*F*-value	*p>F*
Year	7	1.713	6.49	<0.0001
Location(Year)	17	0.758	2.87	<0.0001
Month	11	4.359	16.50	<0.0001
Month*Year	42	1.409	5.34	<0.0001
Error	727	0.264		
Test of Hypothesis using MS for Month*Year as an Error Term *p>F*				
Month	11	4.359	3 .09	0.0040

r^2 = 0.583 ; cv % = 54.86. Counts of *N. viridula* were transformed to $x^{0.165}$.

DISCUSSION

Dispersion Pattern of SGSB. Our results are in agreement with previously reported findings by several researchers that the counts of SGSB did conform to an aggregated distribution pattern. For example, Todd and Herzog (1980) reported that the counts of SGSB on soybean conformed to a clumped pattern. In Japan, Nakasuji et al. (1965) found that the spatial pattern of male SGSB in rice fields was aggregated and they attributed this behavior to attraction to females. Lye and Story (1989) reported that in Louisiana the between-plant dispersion of SGSB fitted a negative binomial distribution with moderate aggregation on fresh market tomatoes. Recently, Pilkay (2013) found that stink bugs in commercial farmscapes in South Carolina and Georgia conformed to a clumped distribution pattern with slopes of Taylor's Power Law being significantly greater than unity in 37% of the cases.

That the _Alpha of the negative binomial distribution showed no evidence of overdispersion for the captures of SGSB in 2011 is contrary to the findings revealed by Taylor's Power Law. It appears that the estimation of clumping in 2011 by Taylor's Power Law is spurious.

Table 5. Multiple comparison of mean (±SEM) captures of *N. viridula* in blacklight traps from 2003 to 2011, Burleson County, TX.

Month	Year							
	2003	2004	2005	2006	2008	2009	2010	2011
March	-	2.0±0.6de	-	0.3±0.3bc	0.1±0.1c	-	-	-
April	1.1±0.3c	1.3±0.4e	-	1.4±0.3bc	1.0±0.5c	0.0±0c	0.0±0bc	-
May	2.3±0.9c	8.8±2.7d	-	3.4±1.5bc	13.5±4.4b	2.4±0.8bc	0.2±0.2c	-
June	4.6±1.5c	8.8±2.7cd	0.4±0.2d	1.0±0.3c	12.7±4.5b	2.3±0.4ab	0.6±0.2bc	0.0±0
July	27.6±7.3b	102.9±64.8ab	8.8±2.7c	7.0±2.5b	6.6±1.6b	0.8±0.4c	1.0±0.3b	0.0±0
Aug.	177.0±77.1a	84.4±18.5a	98.7±26.1a	27.4±5.9a	65.9±32.2a	2.7±0.8bc	4.0±1.0a	0.2±0.2
Sept.	42.8±16.8ab	29.3±8.4bc	29.2±5.1b	-	9.8±2.4ab	2.4±1.2bc	4.6±1.4a	0.1±0.1
Oct.	4.0±1.4c	5.0±1.3d	13.3±3.7c	-	10.0±5.9ab	18.3±10a	-	0.1±0.1
Nov.	6.9±2.7c	0.3±0.3e	7.0±2.5bc	-	-	-	-	0.0±0
F-value	18.65	11.62	23.46	6.42	8.87	3.40	10.20	0.79
df	8,159	8,135	5,92	5,74	7,75	6,68	5,82	5,59
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	>0.0054	<0.0001	>0.563

Data were analyzed by PROC GLM procedure after transforming the counts to $x^{0.165}$. Least square means were separated at $p < 5\%$ using PDMIX letter conversion procedure. Original means within each column followed by the same lower case letter are not significantly different.

Data Transformation. Data presented in this report suggest that the power law transformation is more effective in adequately equalizing the variance compared to log transformation by rendering the variance independent of the mean. Taylor (1970) reported that the ratio of maximum to minimum variance was185/1 for log transformation and 45/1 for power transformation vis-à-vis counts of *Aphis fabae* Scopoli on beans. Similarly, the ratio of maximum to minimum variance was 1.484/1 and 0.736/1 for log and power transformations, respectively for counts of SGSB. However, both power law and the log transformations equally stabilized the variance of several insect species (Guppy and Harcourt, 1970; Harcourt, 1961; Miller et al. 1972; Mukerji and Harcourt, 1970). Conversely, Costello and Daane (1997) found that neither power law transformation nor log transformation adequately uncoupled the variance-mean relationship for spiders in grapevine orchards. Downing (1979) also reported that the log transformation failed in some cases to stabilize the variance compared to the power law transformation for benthic population estimates made in lakes and large rivers. It seems that the selection of an appropriate transformation for insect counts varies with species, and that an analysis of the distribution pattern of an insect population might help in determining an appropriate transformation.

Seasonal Flight Activity of SGSB During August. Corroborating our data, studies conducted in Georgia showed that stink bugs began to colonize cotton at the flowering stage and peaked during the time when developing bolls were present in early August (Bundy and McPherson, 2000). On soybean, counts of SGSB increased in mid-August when the plants were at full pod without seed development and reached its peak in early September when plants were at full seed (Bundy and McPherson, 2000). The occurrence of peak captures of SGSB in light traps in August is not surprising as seasonal changes in counts of the insect are closely associated with host plant phenology.

Location of the traps is a random component of the ANOVA model and environmental heterogeneity due to temporal difference in diversity and acreage of field crops; phenology and availability of wild host plants for SGSB in each location apparently caused significant interactions among the variables. However, Blinka et al. (2007) found a statistically weak correlation for captures of the stink bug, *A. hilare* in blacklight traps established in a North Carolina farmscape comprised of corn, cotton, peanut, pasture, soybean, tobacco, and trees. These observations suggest that environmental heterogeneity did not affect *A. hilare* significantly.

Sex Ratio in Favor of Female SGSB. The data presented here indicate that the captures of SGSB were two-to-threefold greater for female than those for male. The intensity of spectral output (lumens/m^2) of blacklight traps comprised of blue-green light output at 480 to 510 nm, ultra violet light output at 350 to 370 nm and a combined output with both blue-green and ultra violet lights (Aubuchon, 2006). The spectral analysis of a 40-watt Sylvania® blacklight bulb (F40T12/350BL) measured at a distance of 60 cm showed a mean intensity of 43.46 ± 1.84 lumens/m^2 with ultra violet light peaking between 340 and 370 nm (Aubuchon, 2006). It is likely that the attractant efficiency of light traps relative to spectral intensity of illumination can vary with gender for pentatomids. Indeed, Leskey (2011) found that the capture of *H. halys* was significantly more in a pheromone-based trap with a dark visual base compared to green, white, and clear visual bases and that the response of the insect varied significantly between spectral output of light intensity. Also, Leskey (2011) found that the response of *H. halys* to spectral reflectance varied with gender.

Using harmonic radar tracking technology in an open hay field, Pilkay et al. (2013) monitored the movement of a laboratory population of SGSB and found that females flew two-fold farther than the males and that females travelled longer distances by walking and by flying than males. Whether or not this behavior caused greater captures of female than male SGSB in blacklight traps remains conjectural and needs to be investigated.

Several researchers have reported that the SGSB is capable of adjusting sex ratios in response to seasonal variations in gender mortality and overlapping generations, which facilitate selection of alleles promoting facultative sex ratios (McLain and Marsh, 1990; Mitchell and Mau, 1971; Werren and Charnov, 1978). Moreover, Schumann and Todd (1982) reported that in soybean, the sex ratio of SGSB changed during different stages of soybean development and that much larger populations of female SGSB than male SGSB were present early in the season and during reproductive stages of soybean. A fewer number of males than females might be compensated by the fact that males are more aggressive than females during the mating process and that they are polygamous, whereas females are polyandrous (Mitchell and Mau, 1969). A combination of diverse factors described herein is likely to contribute towards preponderance of females captured in light traps. More research is needed to unravel the physical and biological factors governing the captures of SGSB in favor of females.

Decline in Trap Captures of SGSB in 2011. Captures of SGSB declined from 2003 to 2011 with precipitously fewer captures in 2009 and 2010, and collapsing to near zero in 2011 (Table 5). Kamminga et al. (2009) showed that the mean weekly counts of green stink bug, *A. hilare*, in blacklight traps in Virginia were influenced by weather conditions. They (Kamminga et al., 2009) found that two weather variables, days below freezing and mean monthly precipitation from January to April sufficiently accounted for yearly fluctuations in flight activity of *A. hilare* in Virginia. Nielson-Gammon (2011) reported that Central Texas experienced extreme drought in the 2010 to 2011 field season with Palmer Drought Severity Index (PDSI) dipping below -4, a record low value for Texas since 1956. A common measurement of drought intensity is PDSI, a comprehensive index of temperature and availability of water in the soil. A record dry March through August occurred with PDSI reaching -6.05 and remained so for almost 5 months in Central Texas during 2011 (Nielson-Gammon, 2011).

Several researchers have reported that not only the agricultural host plants, but the alternate host plants as well serve as important food sources for the development of nymphs and reproduction of SGSB adults (Panizzi, 1997; Velasco and Walter, 1992), and impinge on population dynamics of the insect in the region. For example, Jones et al. (2001) found that maximum kernel damage occurred in a macadamia nut, *Macadamia integrifolia* (Maiden and Betche) orchard immediately after the decline of flowering and fruiting stages of host weeds. Studies have shown that SGSB feeds on seeds, pods, and fruits and increased populations of the insect occur when fruiting structures are present (Panizzi, 1997; Schumann and Todd, 1982; Todd, 1989). Moreover, the dispersal of the insect between wild host plants and the agricultural host plant and between different crops is a recurring phenomenon and is intricately linked to weed diversity and crop phenology as is the case apropos of the relationship between SGSB and macadamia nuts. SGSB cannot survive on macadamia nuts alone without the presence of non-host plants inside the orchards and areas contiguous to the orchards (Schumann and Jones, 1996; Shearer and Jones,1998). The severe drought in 2011 could have severely affected the weed-host plant relationship of SGSB and contributed significantly toward the decline of SGSB in the study areas.

Another likely source for the decline of SGSB was cool winter temperatures before the onset of 2011growing season in the Brazos Bottom region. Mean monthly temperature was -2.5° C for January and below freezing temperature persisted for 23 d with a minimum temperature, varying from -10.0° to -1.1° C (NOAA, http://www.ncdc.noaa.gov).

Kiritani (1964) reported that unusually low temperatures (3°C) during the winter caused greater than 97% mortality of SGSB in Wakayama, Japan and that such mortality varied between habitat conditions of the hibernacula with dense vegetative habitat protecting the insect from severe mortality. Regression of winter mortality on mean monthly temperature between 3° C and 7° C showed that winter mortality would decrease by 16.5 % with every 1° C rise in temperature (Kiritani, 2011).

Factors other than weather conditions might have influenced the flight activity of SGSB as well. With the introduction of newer Bt-engineered cotton such as Bollgard II and Widestrike varieties, which protect cotton against heliothine pests, there has been an increased need for insecticidal applications against stink bugs with growers often conducting as many as three applications per season in Central Texas (Roy Parker, personal communication). However, in the Texas coast and Blackland regions, the number of insecticidal application averaged one per acre (Williams, 2013). The common insecticides used to control stink bugs on Texas cotton are organophosphorous and synthetic pyrethroid insecticides (Parker et al., 2009). Because SGSB is highly susceptible to pyrethroid and organophosphorous insecticides compared to brown stink bug (Snodgrass et al., 2005; Willrich et al., 2003), it is likely that SGSB populations could have been significantly impaired with increased use of pyrethroid insecticides.

Although a complete collapse of SGSB occurred in 2011, our data demonstrate that there has been a gradual reduction in the captures of SGSB in blacklight traps in the Brazos Bottom region since 2004, with the decrease in captures of SGSB being most severe beginning 2009. With a gradual decline in captures of SGSB in the study area, we believe that species displacement can not be ruled out because of differential susceptibility of SGSB to synthetic pyrethroid insecticides compared to *E. servus*. Indeed, anthropogenic interference in pest management of several insects has altered the demography of several pest species globally (Reitz and Trumble, 2002). For example, Lowery et al. (2006) reported that the spirea aphid, *Aphis spireacola* Patch, displaced *A. pomi* De Geer in eastern North America, partly because *A. spireacola* was less susceptible to insecticides. Gao et al. (2012) reported that in the Hainan island of China, the leaf miner, *Liriomyza trifolii* Blanchard has displaced *L. sativae* (Burgess) apparently because of differential susceptibility to insecticides between the two species. Sun et al. (2013) reported that in China the Q biotype whitefly, *Bemisia tabaci* (Gennadius), displaced the B biotype whitefly, because Q type whitefly was less susceptible to commonly applied insecticides in the region.

Whether or not factors described here have collectively or singularly adversely influenced the captures of SGSB in blacklight traps remain speculative. We contend that more research is warranted to address this issue, especially from the standpoint of pest management. Studies are required to determine the relationship between captures of the insect in traps and the total population present in the sampling area, trap design and efficacy, changes in flight density, nocturnal insect behavior, bulb wattage, night time illumination due to lunar cycle, and the role of moonlight and moon phase (Muirhead-Thompson, 1991).

CONCLUSION

Captures of SGSB in blacklight traps conformed to an aggregated dispersion pattern. Peak captures of the insect generally occurred in August. The precipitous decline of the insect in 2011 was probably caused by several factors, including drought and unusually cold overwintering conditions. This study demonstrated that blacklight traps can be a useful sampling tool for determining seasonal flight activity of SGSB. An appreciation of the relationship between captures of SGSB in blacklight traps and infestation levels of cotton bolls might reveal whether or not the flight activity of SGSB in blacklight traps could be used to monitor activity of SGSB in lieu of field scouting. Additionally, data are needed to elucidate the physical factors affecting captures of pentatomids in blacklight traps.

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DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

REFERENCES

Aubuchon, M.D. 2006. Biological and physical factors affecting catch of house flies in ultra violet traps. Ph.D. diss. University of Florida, Gainesville.

Bacheler, J.S., and D.W. Mott. 1996. Potential utility and susceptibility of transgenic *Bt* cotton against bollworms, European corn borers, and stink bugs in NC. p. 927–931. *In* Proc. Beltwide Cotton Conf., Nashville, TN. 9-12 Jan. 1996. Natl. Cotton Counc. Am., Memphis, TN.

Barbour, K.S., J.R. Bradley, Jr., and S.J. Bachelor. 1990. Reduction in yield and quality of cotton damaged by green stink bug (Hemiptera: Pentatomidae). J. Econ. Entomol. 83:842–845.

Binns, M.R. 1986. Behavioral dynamics and negative binomial distribution. Oikos 47:315–318.

Blinka, E.L., J. Bachelor, J.R. Bradley, and J.W. Van Duyn. 2007. Stink bug distribution based on black light trap captures across North Carolina in relation to surrounding agricultural host plant ratios. p. 1711–1712. *In* Proc. Beltwide Cotton Conf., New Orleans, LA. 9-12 Jan. 2007. Natl. Cotton Counc. Am., Memphis, TN.

Bliss, C.I. 1971. The aggregation of species within spatial units. p. 311–315. *In* G.P. Patil, E.C. Pielou and W.E. Waters (eds.). Statistical Ecology Vol 1: Spatial Patterns and Statistical Distributions. Pennsylvania State Univ. Press, University Park and London.

Bowden, J. 1982. An analysis of factors affecting catches of insects in light traps. Bull. Entomol. Res. 72:535–556.

Bundy, C.S., and R.M. McPherson. 2000. Dynamics and seasonal abundance of stink bugs. (Heteroptera: Pentatomidae) in a cotton-soybean ecosystem. J. Econ. Entomol. 93:697–706.

Costello, M.J., and K.M. Daane. 1997. Comparison of sampling methods used to estimate spider (Araneae) species abundance and composition in grape vineyards. Environ. Entomol. 26:142–149.

Downing, J.A. 1979. Aggregation, transformation, and the design of benthos sampling programs. J. Fish. Res. Board Can. 36:1454–1463.

Gao, Y., S.R. Reitz, Q. Wei, W. Yu, and Z. Lei. 2012. Insecticide-mediated apparent displacement between two invasive species of leafminer fly. PloS One 7:1–7. e36622. Doi:10.1371/journal.pone.0036622.

Guppy, J.C., and D.G. Harcourt. 1970. Spatial pattern of the immature stages and teneral adults of *Phyllophaga* spp. (Coleoptera: Scarabaeidae) in a permanent meadow. Can. Entomol. 102:1354–1359.

Harcourt, D.G. 1961. Spatial pattern of the imported cabbage worm, *Pieris rapae* (L.) on cultivated Cruciferae. Can. Entomol. 93:945–952.

Harcourt, D.G. 1969. The development and use of life tables in the study of natural insect populations. Ann. Rev. Entomol. 14:175–196.

Hartstack, A.W., J.A. Witz, and D.R. Buck. 1979. Moth traps for the tobacco budworm. J. Econ. Entomol. 72:519–522.

Hayman, B.I., and A.D. Lowe. 1961. The transformation of counts of the cabbage aphid (*Brevicoryne brassicae* (L.)). New Zealand J. Sci. 4:271–278.

Healy , M.J.R., and H.R. Taylor. 1962. Tables for power law transformation. Biometrika 49:557–559.

Hollingsworth, J.P., and A.W. Hartstack, Jr. 1972. Effects of components on insect light trap performance. Trans. ASAE 15:924–927.

Hopkins , B.W., A.E. Knutson, J.S. Bernal, M.F. Treacy, and C.W. Smith. 2010. Species composition, damage potential, and insecticide susceptibility of stink bugs in cotton in Lower Gulf Coast Region of Texas. Southwest. Entomol. 35:19–32.

Jones, V.P., D.M. Westcott, N.N. Finson, and R.K. Nishimoto. 2001. Relationship between community structure and southern green stink bug (Heteroptera: Pentatomidae) damage in macadamia nuts. Environ. Entomol. 30:1028–1035.

Kamminga, K.L., D.A. Herbert, Jr., T.P. Kuhar, and C.C. Brewster. 2009. Predicting black light trap catch and flight activity of *Acrosternum hilare* adults. Environ. Entomol. 38:1716–1723.

Kiritani, K. 1964. Natural control of populations of the southern green stink bug, *Nezara viridula*. Res. Popul. Ecol. 6:88–98.

Kiritani, K. 2011. Impacts of global warming on *Nezara viridula* and its native congeneric species. J. Asia-Pacific Entomol. 14:221–226.

Korie, S., J.N. Perry, M.A. Mugglestone, S.J. Clarke, C.F.G. Thomas, and M.N. Roff. 2000. Spatio-temporal associations in beetle and virus count data. J. Agric. Biol. Environ. Statistics 5:214–239.

Leskey, T.C. 2011. Development of behaviorally-based monitoring tools and management strategies for the marmorated stink bug. USDA-ARS, Res. Rep., Appalachian Fruit Research Station, Kearneysville, WV.

Lowery, D.T., M.J. Smirle, R.G. Footit, and E.H. Beers. 2006. Susceptibilities of apple aphid and spirea aphid collected from apple in the Pacific Northwest to selected insecticides. J. Econ. Entomol. 99:1369–1374.

Lye, B.H., and R.N. Story. 1989. Spatial dispersion and sequential sampling plan of southern green stink bug (Hemiptera: Pentatomidae) on fresh market tomatoes. Environ. Entomol. 18:139–144.

McLain, D.N., and N.B. Marsh. 1990. Individual sex ratio adjustment in response to the operational sex ratio in the southern green stink bug. Evolution 44:1018–1025.

Medrano, E.G., J.F. Esquivel and A.A. Bell. 2007. Transmission of cotton seed and boll rotting bacteria by the southern green stink bug (*Nezara viridula* L.) J. Appl. Microbiol. 103:436–444.

Miller, C.D.F., M.K. Mukerji and J.C. Guppy. 1972. Notes on the spatial pattern of *Hypera postica* (Coleoptera: Curculionidae) on alfalfa. Can. Entomol. 104:1995–1999.

Mitchell, W.C., and R.M. Mau. 1969. Sexual activity and longevity of the southern green stink bug, *Nezara viridula*. Ann. Entomol. Soc. Amer. 62:1246–1247.

Mitchell, W.C., and R.M. Mau. 1971. Response of female southern green stink bug and its parasite, *Trichopoda pennipes*, to male stink bug pheromones. J. Econ. Entomol. 64:856–859.

Morris, R.F. 1955. The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. Can. J. Zool. 33:225–294.

Muirhead-Thompson, R.C. 1991. Trap responses of flying insects. Academic Press, London.

Mukerji, M.K., and D.G. Harcourt. 1970. Spatial pattern of immature stages of *Hylemya brassicae* on cabbage. Can. Entomol. 102:1216–1222.

Nakasujii, F., N. Hokyo, and K. Kiritani. 1965. Spatial distribution of three plant bugs in relation to their behavior. Res. Popul. Ecol. 7:99–108.

Nielson-Gammon, J.W. 2011. The 2011 Texas Drought. p. 1–43. A briefing packet for the Texas Legislature. Available at: https://geosciences.tamu.edu/osc_2011/files/osc_pubs/2011_drought.pdf (verified 23 Jan. 2014).

Nielsen, A.L., K. Holmstrom, G.C. Hamilton, J. Cambridge, and J. Ingerson-Mahar. 2013. Use of black light traps to monitor the abundance, spread, and flight behavior of *Halyomorpha halys* (Hemiptera: Pentatomidae). J. Econ. Entomol. 106:1495–1502.

NOAA-National climatic data center. Record of climatological observations. Station: Somerville Dam, TX. Available at: http://www.ncdc.noaa.gov (verified 23 Jan. 2014).

Panizzi, A.R. 1997. Wild hosts of pentatomids: Ecological significance and role in their pest status on crops. Ann. Rev. Entomol. 42:99–122.

Parker, R.M., M.J. Jungman, S. Biles, and D.L. Kernes. 2009. Suggested insecticides for managing cotton insects in the Southern, Eastern, and Blackland areas of Texas. E-5A. Available at: http://www.agrilifebookstore.org/product-p/e-5a.htm (verified 23 Jan 2014).

Pilkay, G.W. 2013. Ecology and management of stink bugs (Hemiptera: Pentatomidae) in southeastern farmscapes. Ph.D. diss. Clemson University, Clemson, SC.

Pilkay, G.L., F.P.F. Reay-Jones, and J.K. Greene. 2013. Harmonic radar tracking movement of *Nezara viridula* (Hemiptera: Pentatomidae). Environ. Entomol. 42:1020–1026.

Reay-Jones, F.P.F., J.K. Greene, M.D. Toews, and R.B. Reeves. 2009. Sampling stink bugs (Hemiptera: Pentatomidae) for population estimation and pest management in southeastern cotton production. J. Econ. Entomol. 102:2360–2370.

Reitz, S.R., and J.T. Trumble. 2002. Competitive displacement among insects and arachnids. Ann. Rev. Entomol. 47:435–465.

SAS. 2008. Version 9.3, SAS Inst. Cary, NC.

Saxton, A. 2012. User's guide for design and analysis SAS Macro collection DandA. Sas. Version 2.12. Department of Animal Science, Univ. Tennessee.

Schumann, F.W., and J.W. Todd. 1982. Population dynamics of the southern green stink bug (Heteroptera: Pentatomidae) in relation to soybean phenology. J. Econ. Entomol. 75:748–753.

Schumann, F.W., and V.P. Jones. 1996. Suitability of macadamia nut as a host plant of *Nezara viridula* (L.) (Hemiptera: Pentatomidae). J. Econ. Entomol. 89:996–1003.

Shearer, P.W., and V.P. Jones. 1998. Suitability of selected weeds and ground covers as host plants of *Nezara viridula* (L.) (Hemiptera: Pentatomida). Proc. Hawaii Entomol. Soc. 33:75–82.

Snodgrass, G.L., J.J. Adamczyk, Jr., and J. Core. 2005. Toxicity of insecticides in a glass vial bioassay to adult brown, green, southern green stink bugs (Heteroptera: Pentatomidae). J. Econ. Entomol. 98:177–181.

Southwood, T.R.E., and P.A. Henderson. 2000. Ecological Methods. Blackwell Science Ltd., Osnet Mead, Oxford, England.

Suh, C.P., J.K. Westbrook, and J.F. Esquivel. 2012. Species composition and relative abundance of stink bugs in cotton and other crops in the Brazos River Bottom production area of Texas. p. 880–882. *In* Proc. Beltwide Cotton Conf., Orlando, FL. 3-6 Jan. 2012. Natl. Cotton Counc. Am., Memphis, TN.

Sun, D.B., Y.Q. Liu, L. Qin, J. Xu, F.F. Li, and S.S. Liu. 2013. Competitive displacement between two invasive whiteflies: insecticide application and host plant effects. Bull. Entomol. Res. 103:344–353.

Taylor, L.R. 1961. Aggregation, variance and the mean. Nature 189:732–735.

Taylor, L.R. 1970. Aggregation and the transformation of counts of *Aphis fabae* Scop. on beans. Ann. Appl. Biol. 65:181–189.

Taylor, L.R. 1984. Assessing and interpreting the spatial distribution of insect populations. Ann. Rev. Entomol. 29:321–357.

Todd, J.W. 1989. Ecology and behavior of *Nezara viridula*. Ann. Rev. Entomol. 34:273–292.

Todd, J.W., and D.C. Herzog. 1980. Sampling phytophagous Pentatomidae on soybean. p. 438–478. *In* M. Kogan and D.C. Herzog (ed.) Sampling Method in Soybean Entomology, Springer, New York, NY.

Turnipseed, S.G., M.J. Sullivan, J.E. Mann, and M.E. Roof. 1995. Secondary pests in transgenic *Bt* cotton in South Carolina. p. 768–769. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. 4-7 Jan. 1995. Natl. Cotton Counc. Am., Memphis, TN.

Velasco, L.R.I., and G.H. Walter. 1992. Availability of different host plant species and changing abundance of the polyphagous bug *Nezara viridula* (Hemiptera: Pentatomidae). Environ. Entomol. 21:751–759.

Wayman, P.A. 1959. A least-squares solution for a linear relation between two observed quantities. Nature (London) 184:77–78.

Werren, J.H., and E.L. Charnov. 1978. Facultative sex ratios and population dynamics. Nature (London) 272:349–350.

Williams, M.R. 2013. Cotton insect losses 2012. p. 546–586. *In* Proc. Beltwide Cotton Conf., San Antonio, TX, 7-10 Jan. 2013. Natl. Cotton Counc. Am., Memphis, TN.

Willrich, M.M., B.R. Leonard, and D.R. Cook. 2003. Laboratory and field evaluation of insecticide toxicity to stink bugs (Heteroptera: Pentatomidae). J. Cotton Sci. 7:156–163.

Willrich, M.M., B.R. Leonard, and G.B. Padgett. 2004. Influence of southern green stink bug, *Nezara viridula* L. on late-season yield losses in cotton, *Gossypium hirsutum* L. Environ. Entomol. 33:1095–1101.