SPATIAL POPULATION DYNAMICS AND OVERWINTERING BIOLOGY OF THE GLASSY-WINGED SHARPSHOOTER IN CALIFORNIA'S SAN JOAQUIN VALLEY

Project Leaders:

Marshall W. Johnson
Department of Entomology
Univ. of Calif., Riverside
Kearney Agric. Center
Parlier, CA 93648
mjohnson@uckac.edu

Kent Daane
Department of ESPM
University of California
Berkeley, CA 94720
daane@uckac.edu

Russell Groves
Department of Entomology
University of Wisconsin
Madison, WI 53706
groves@entomology.wisc.edu

Elaine Backus
USDA, ARS, PWA
SJVASC
Parlier, CA 93648
ebackus@fresno.ars.usda.gov

Cooperators:

Youngsoo Son
Department of Entomology
Univ. of Calif., Riverside
Kearney Agric. Center
Parlier, CA 93648
yson@jps.net

David J.W. Morgan
Calif. Dept. Food & Agric.
Mt. Rubidoux Field Station
Riverside, CA 92501
drmorgan@jps.net

Kris Lynn-Patterson
Kearney Agricultural Center
Parlier, CA 936348
krislynn@uckac.edu

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ABSTRACT

The purpose of this project is to define and quantify specific environmental constraints that influence the population dynamics and overwintering success of glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis* (formerly *coagulata*), and to field-test our laboratory findings. Using data collected in our laboratory tests and field studies, we developed a "cooling degree-day" (CDD) model to estimate the impacts of winter field temperatures on GWSS survival throughout California. Work on better understanding the feeding behaviors of GWSS at various temperatures is underway using an electrical penetration graph (EPG). Initial results from these studies indicate that GWSS adults may continue feeding during the two hours after the air temperature falls below 50ºF (= 10ºC) (i.e., our estimated feeding threshold), but eventually stop. Feeding activity data are currently being analyzed. Field studies on GWSS overwintering were initiated by releasing field-collected insects into the double-protected cages in secure areas in late November 2006 in the areas of Bakersfield (Kern County) and Riverside (Riverside County). Weekly monitoring was completed in February 2007. The caged GWSS adults at Bakersfield experienced 100% mortality in mid-January 2007 whereas 8.4% of GWSS at Riverside remained alive at that time. The number of surviving adults at Riverside in late February was equal to 0.4% of the initial cohort placed in the cages in early December 2006. Using the data from these field studies and those conducted by Don Luvisi, *Emeritus* Farm Advisor, during the winter season 2001-2002 in the Bakersfield area, we found that a non-linear model provided a good estimation of the impact of accumulated CDD on GWSS mortality. One hundred percent GWSS mortality was estimated when accumulated CDD reached 215 CDD.

INTRODUCTION

Climate appears to play a significant role in the geographic distribution of diseases caused by *Xylella fastidiosa* (*Xf*) in California and throughout the southeastern U.S. (Purcell 1997). Similarly, populations of glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, in the southeastern US appear to be constrained by climatic factors that limit the pest's establishment and persistence (Hoddle 2004). Presently, limited information exists on the overwintering biology and ecology of GWSS in the San Joaquin Valley of California. Our earlier results from this project indicated that survival and feeding activity of GWSS adults were significantly influenced by temperature and exposure duration. In particular, low temperatures caused rapid mortality. Access to host plants for feeding was a critical factor for survival at high temperatures (≥ 20°C). We developed models to approximate the influences of temperature on GWSS survival with changes in exposure duration. Additional studies focused on the impacts of temperature on GWSS feeding rates with the aim of determining the thresholds below which feeding stops and to further determine the critical duration of time spent in this non-feeding state, which may result in increased mortality. The results below advance our ability to define the specific environmental constraints that influence GWSS population dynamics and overwintering success by increasing our present understanding of the overwintering requirements of GWSS with a focus on critical environmental factors that may limit population distribution in the Central Valley of California.

OBJECTIVES

1. Identify the critical environmental constraints that influence the spatial population dynamics and overwintering success of GWSS in California's Central Valley.
2. Characterize the impact of host plant species succession on the overwintering survivorship of GWSS populations that constrain the insect's ability to become established and persist throughout the San Joaquin Valley.

RESULTS

Objective 1

Sub-objectives on a) temperature dependent-survival of GWSS under different feeding conditions; b) survival under diurnal temperature cycles, and c) xylem excreta production bioassays have been completed with respect to data collection and analysis. A manuscript describing temperature dependent-survival of GWSS under different feeding conditions is being prepared for submission to *Environmental Entomology*. A second manuscript combing the results of the latter two sub-objectives will be produced and submitted for publication.

Variable temperature Electrical Penetration Graph recordings

Given difficulties in obtaining lab-reared GWSS individuals during the winter months, Electrical Penetration Graph (EPG) recordings were conducted using field-collected GWSS adults held within field cages. A GWSS adult was individually tethered to each Japanese euonymus plant used in the study (four replicates). To qualify and quantify real-time responses of GWSS feeding, environmental conditions (i.e., light intensity, temperature) were monitored using a data-logger (HOBO Pendant) to record climatic parameters. Recordings of EPG-generated waveforms were visually interpreted using the Windaq software program. Data analysis for the EPG experiment is in progress. A waveform (see Figure 1) may be categorized into pathway (p), ingestion (c), interruption (n), and baseline (z) (Joost et al. 2006). Preliminary results are provided below (Table 1, Figures 2B, C). Environmental conditions (i.e., light intensity and temperature) during the recording duration were presented in hourly means (Figure 2A). The waveform duration (mean ± SEM) of feeding activity (p and c waveform of four test insects) was also presented in hourly units (Figures 2B, C). During the EPG recording, temperatures ranged from 6.7 to 29.8ºC (mean SEM = 14.7 ± 0.4ºC) with an approximate photoperiod of 11:13 (L:D) hours. During the 24-hour period, GWSS adults spent 2.23 hours (133.8 min) feeding with substantial feeding occurring during the mid-night hours following initial set-up. Feeding intervals continued for two hours after the temperature fell below 10ºC. However, once stopped, feeding took about nine hours to resume as the temperature increased to greater than 10ºC. Following arsine data transformation $[X' = (X + 0.5)^{1/2}]$, feeding activity (expressed as percentage of the observation time) was compared using a *t*-test for the period when temperature was above 10ºC versus below 10ºC. Overall, the GWSS adults spent less time feeding when temperatures were less than 10ºC, and three of the four test-insects did not feed during that time. GWSS spent approximately two-fold more time feeding when the temperature was above 10ºC, although the results were not significantly different. Waveform analysis should be completed by April 2008.

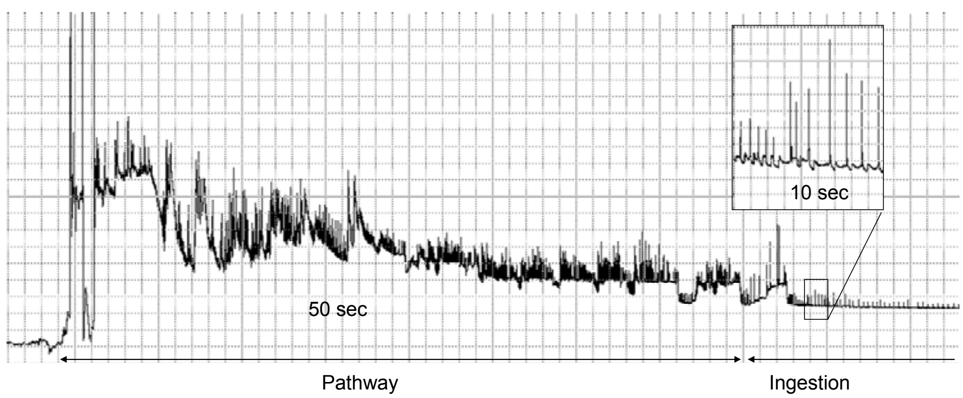

Figure 1. This chart represents a small interval of a 24 hr-recording of adult GWSS feeding at 30ºC. A typical EPG waveform is shown that represents two components of GWSS feeding activity: Pathway (p) and Ingestion (c). The larger output shows GWSS probing and continuous ingestion (p + c), and the enlarged portion of the output (enlarged box on right side of graph) shows the ingestion waveform (c) in finer scale.

Table 1. Duration (min and %, mean ± SEM) of feeding activity (Pathway = P; Ingestion = C) of GWSS in 24 hr-EPG monitoring under fluctuating temperature cycles.

Waveform	Waveform duration[a]	Temperature in daily cycle[b]		Total
		< 10ºC	> 10ºC	
P	Minutes	0.4 ± 0.4	12.1 ± 8.3	12.5 ± 8.6
	Percentage	0.1 ± 0.1	1.2 ± 0.8	0.9 ± 0.6
C	Minutes	20.2 ± 20.2	101.1 ± 77.1	121.3 ± 75.5
	Percentage	5.0 ± 5.0	9.8 ± 7.5	8.4 ± 5.2
C + P	Minutes	20.6 ± 20.6	113.2 ± 79.07	133.8 ± 79.4
	Percentage	5.1 ± 5.1	10.9 ± 7.6	9.3 ± 5.5

[a] Minutes indicate the waveform duration when temperature is above or below 10ºC and % indicates the percentage of waveform duration in a given time.
[b] As shown in Figure 2, temperatures below 10ºC occurred between 0040 and 0720 hours (405 min) and remained above 10ºC during the rest of time (1035 min).

Objective 2

Field study of GWSS overwintering survival

Survival of overwintering GWSS adults (using field-cages) and accompanying environmental conditions (using mini data-loggers) were monitored at two test sites in 2006-2007: Bakersfield (Kern County Extension Office at Mount Vernon Ave.) and Riverside (Agricultural Operations, UC Riverside). Test plants were maintained within fenced secured zones and were double-caged with yellow sticky traps and imidacloprid-treated citrus plants in the outer cages to reduce the chances of insects escaping. Field-collected GWSS adults were obtained from the CDFA Arvin Field Station. In late November 2006, 50 GWSS adults were released into each test cage, which enclosed potted grapevine and citrus plants. Weekly monitoring was conducted from December 2006 through February 2007. In each large cage, three smaller, test cages and one data-logger (HOBO Pendent Temperature/Light) were installed to record temperature data. The number of live adults per cage was monitored weekly. Insects were checked during the afternoon period (1300-1400), when the maximum daily temperatures (> 10ºC) permitted adults to feed on plants. Dead insects were usually found near the base of the plant or on the soil surface. There was a substantial reduction in the number of surviving adults at both sites during the first week after release. The high mortality appeared to result from stress induced during the preparation process (i.e., field-collection, aspiration, and anesthesia using CO_2, and transfer), and was similar to that commonly observed in field-collected colonies under laboratory conditions. Over the entire monitoring period, the number of surviving adults per cage was not significantly different between Riverside and Bakersfield (Repeated measures ANOVA, $P > 0.05$). However, all adults at the Bakersfield site died in mid-January 2007 whereas 8.4% of GWSS at Riverside still remained alive. In late February, the number of surviving adults in Riverside decreased to 0.4% of the original number. GWSS egg masses were observed in March 2007 in one Riverside cage.

Estimation of Cooling Degree-Days

Using the site-specific temperature data obtained from the data-loggers and monitoring data from two seasons (2001-2002 in Bakersfield conducted by Don Luvisi and 2006-2007 in Bakersfield and Riverside by this project), a cooling degree-day model was developed to describe the relationship between temperature condition and GWSS survival. The models provided good estimates of the percentage of GWSS overwintering mortality associated with accumulated CDD (Figure 3). The nonlinear model provided a better estimate than the linear model (r^2 of non-linear method > r^2 of linear method). The nonlinear model predicted that 90 and 100% of GWSS mortality would occur at 143 and 215 CDD, respectively. The linear model predicted that 90 and 100% of mortality would occur at 148 and 175 CDD, respectively. Given that the non-linear model does not account for ca. 24% of the variation, room for improvement exists. However, given that we only need to estimate those areas where 95 to 100% mortality occurs, the non-linear model may well serve our needs. Results from the non-linear model could potentially be mapped using GIS methods to provide a visual estimate of the impact of winter temperatures on GWSS survival.

CONCLUSIONS

Findings from our studies clearly indicate that survival and feeding activity of GWSS adults are significantly influenced by cool temperatures and exposure duration. In particular, low temperatures (< 10°C) caused rapid mortality. This project has generated significant new information regarding the thermo-biology of GWSS in California. Models generated from these data will permit spatial estimation of GWSS overwintering success to be expressed via GIS generated maps. These maps should be a valuable resource for individuals making decisions on where to apply pesticidal treatments to suppress spring populations of GWSS within California.

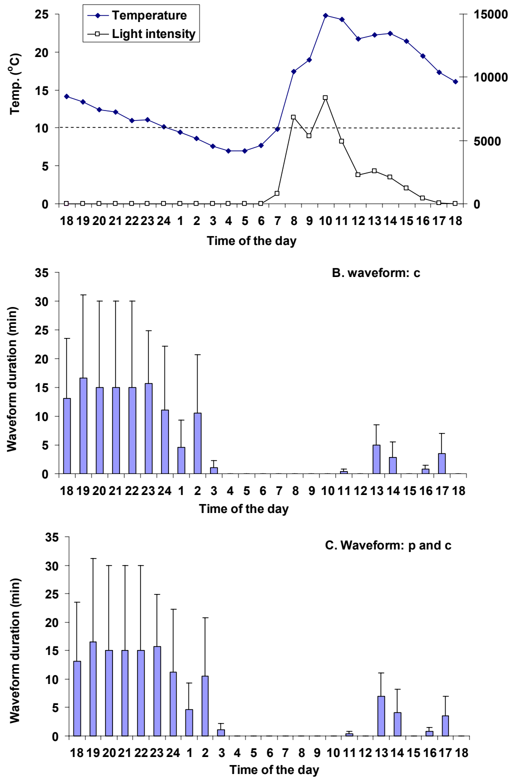

Figure 2. EPG waveform and environmental condition during 24-hr recording under outdoor condition: (A) hourly temperature (ºC) and light intensity (lum/ft^2), (B) duration in minutes of ingestion waveform (c) duration in hourly intervals, and (C) duration in minutes of feeding activity waveform (p and c) in hourly interval.

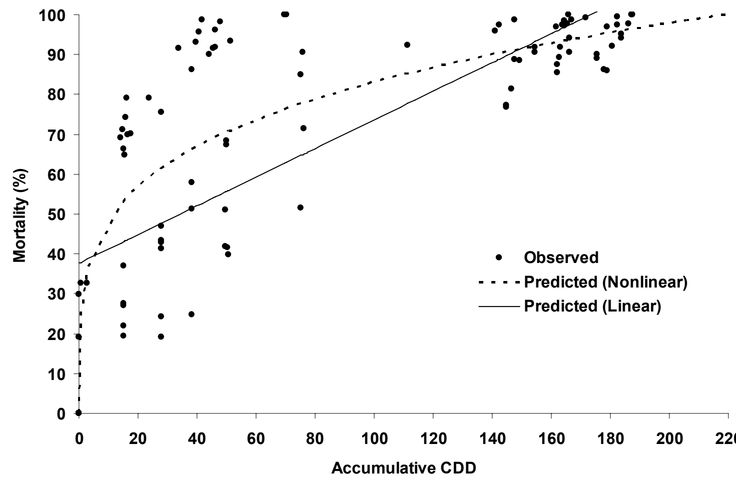

Figure 3. Linear (solid line) and non-linear (dotted line) regression models to predict the mortality (%) of GWSS adults based on cooling-degree days (CDD).

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