ARE GLASSY-WINGED SHARPSHOOTER POPULATIONS REGULATED IN CALIFORNIA? LONG-TERM PHENOLOGICAL STUDIES & CONSTRUCTION OF MULTI-COHORT LIFE TABLES FOR THE GLASSY-WINGED SHARPSHOOTER IN CITRUS ORCHARDS

Project Leader:
Mark S. Hoddle
Department of Entomology
University of California
Riverside, CA 92521
mhoddle@ucr.edu

Reporting Period: The results reported here are from work conducted March 2002 to August 2006.

ABSTRACT
Glassy-winged sharpshooter (GWSS; *Homalodisca vitripennis*; formerly *H. coagulata*) population densities have been steadily declining over a 4.5 year period in organic lemons grown in an experimental study plot at University of California, Riverside Ag. Ops. Peak adult GWSS populations in August 2006 were just 32% of those observed around August 2002. It is uncertain if egg parasitism, which has consistently averaged ~ 20% per year of GWSS egg masses, is responsible for the observed decline. Density dependent analyses of time series data are planned once data sets are large enough. Phenological observations are being complimented with recently initiated multi-cohort stage frequency life tables to provide greater insight into GWSS population dynamics and identification of life stages most susceptible to mortality factors.

INTRODUCTION
In California, there is a guild of natural enemies attacking the glassy-winged sharpshooter (GWSS; *Homalodisca vitripennis*; formerly *H. coagulata*). The dominant parasitoid attacking GWSS in California is *Gonatocerus ashmeadi* followed by *G. morrilli*. *G. triguttatus* from Texas and *G. fasciatus* from Louisiana have been released in California, but widespread establishment is uncertain. Completion of recent studies investigating the effect of varying temperatures on development, survivorship, and reproductive output coupled with GIS modeling, strongly suggests that climate is a major limiting factor for *G. triguttaus* in California, while *G. ashmeadi* is more robust to California's varying climatic conditions (see article in this Proceedings). Other minor parasitoid species include *G. novofasciatus*, *Ufens* sp., and *Zagella* sp. Together, this guild of parasitoids provides an average of ~15% parasitism of GWSS eggs laid during the spring generation and ~20-25% of GWSS eggs laid during the summer generation in commercial citrus orchards. The average year round parasitism level of ~20% falls short of the 33-36% level determined necessary for successful classical biological control (Hawkins and Cornell, 1994). However, data collected from bi-weekly monitoring over the last five years from an organic commercially-managed citrus orchard in Riverside indicates that GWSS populations are declining steadily each year (Figure 1). It is uncertain what the significance is of parasitism of GWSS eggs by mymarid parasitoids to this downward population trend (Figure 2). There are at least four possible reasons for low seasonal parasitism levels in California: (1) competitive exclusion amongst members of the GWSS parasitoid guild is reducing effective biological control. (2) An extremely aggressive and efficacious natural enemy that can dominate the system to the almost total exclusion of all current parasitoids has not been established in California and is needed for successful biological control of GWSS. (3) The absence of resource subsidies such as nectar provided by flowering plants in agroecosystems may limit parasitoid efficacy because longevity and fecundity is significantly reduced when parasitoids can not access carbohydrates. Understorey management may be an important cultural strategy to benefit parasitoids if it can be demonstrated not to enhance GWSS and *Xylella* populations. (4) Climate, in particular, prolonged cool periods over winter when GWSS eggs are unavailable probably has a severe affect on parasitoid reproductive success. There are two general approaches to investigating population phenomena in the field: (1) long-term phenology studies which can be used to tease out density-dependent and density-independent factors affecting population dynamics, and (2) life tables that dissect populations by life stage to determine the magnitude of change between developmental stages, and if possible elucidation of factors impacting survivorship within life stages. Both approaches need to be conducted concurrently in the same field plots using standardized methods to better understand mechanisms underlying long-term population fluctuations for GWSS in California.

OBJECTIVES
1. Construct multi-cohort life tables for glassy-winged sharpshooter nymphs and adults in citrus orchards.
2. Continue the 3 years of bi-weekly surveys of GWSS eggs, nymphs, and adults, and associated rearing of parasitoids from harvested egg masses in citrus at Ag Ops, UC Riverside.

RESULTS
The population monitoring study and measures of percentage parasitism clearly indicate that GWSS densities have continued to decline steadily at the long-term monitoring plot (Figure 1) and percentage parasitism have remained relatively constant over this time period (Figure 2). Detection of density-dependent mortality from sequential census data such as that presented here is notoriously difficult and the results of analytical models differ in outcomes depending on assumptions made even when dummy data sets have been constructed to show density dependent mortality. One of the major problems with these

types of analyses is serial correlation, where densities at N_t directly influence the population at N_{t+1}. Recent developments in analyses of time series data, such as those we are collecting for GWSS are now providing much more robust tests that overcome autocorrelation problems. The Partial Rate Correlation Function is a relatively new statistical procedure specifically designed for time series analysis of biological populations to detect density dependent feed back. Literature searches so far indicate that PRCF is the best of the extant techniques for analyzing long-term population counts. Consequently, census data collected from GWSS monitoring will be subjected to PRCF once we have data for a minimum of 10 consecutive years to determine if density dependent or density independent feed back is responsible for observed fluctuations from generation to generation. Detection of density dependent mortality will indicate that populations are being regulated, and could suggest that natural enemy populations are responsible. Currently, our data set is too short to determine if parasitoid activity is providing density dependent mortality and is subsequently responsible for decreasing GWSS densities at the study site. There are several techniques that are amenable to constructing life tables for GWSS using stage frequency data from field surveys. GWSS motiles are relatively easy to classify based on developmental stage. Therefore the numbers in each developmental stage can be determined and the data used to estimate numbers entering a life stage, survival rates in a stage, life stage duration, and numbers successfully entering the next stage. The Kiritani-Nakasuji-Manly (K-N-M) method has been used to construct life tables for insects with discrete generations from regularly collected census data of field populations. The ideas behind this model are simple and robust. The area under a life stage frequency curve is determined by: (1) the number of individuals entering that life stage through time; (2) a survival parameter that determines the numbers exiting the life stage to enter the next developmental stage, and (3) the length of time that particular life stages last for. The K-N-M model can be applied to the spring and summer generations of GWSS as the amount of over lap between life stages across generations are minimal. Work is ongoing for the K-N-M life tables and too few data have been collected this summer for any meaningful analyses.

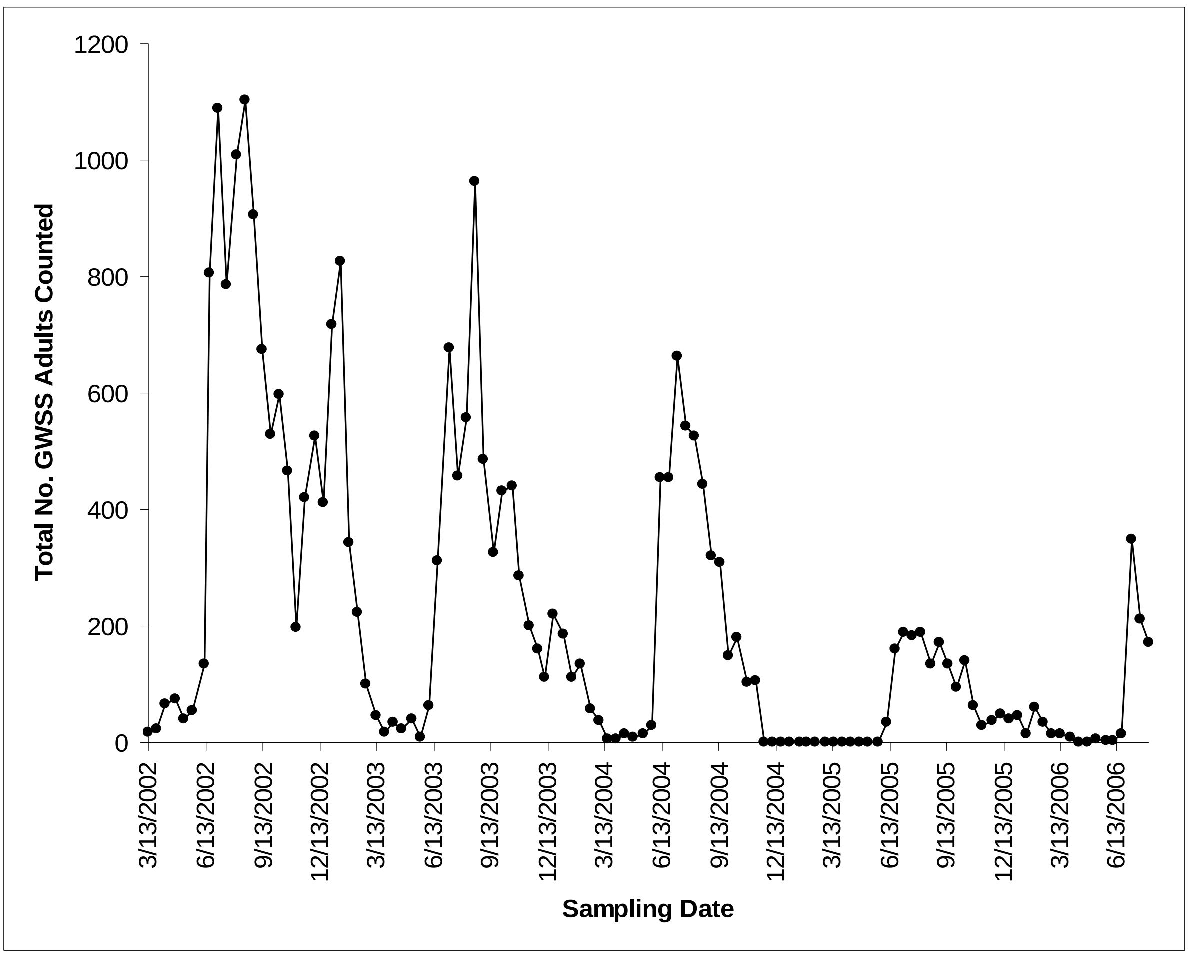

Figure 1. Phenology of adult GWSS in Eureka lemons. Data are total counts from timed five minute surveys made every two weeks of 10 mature lemon trees at Ag. Ops. University of California, Riverside.

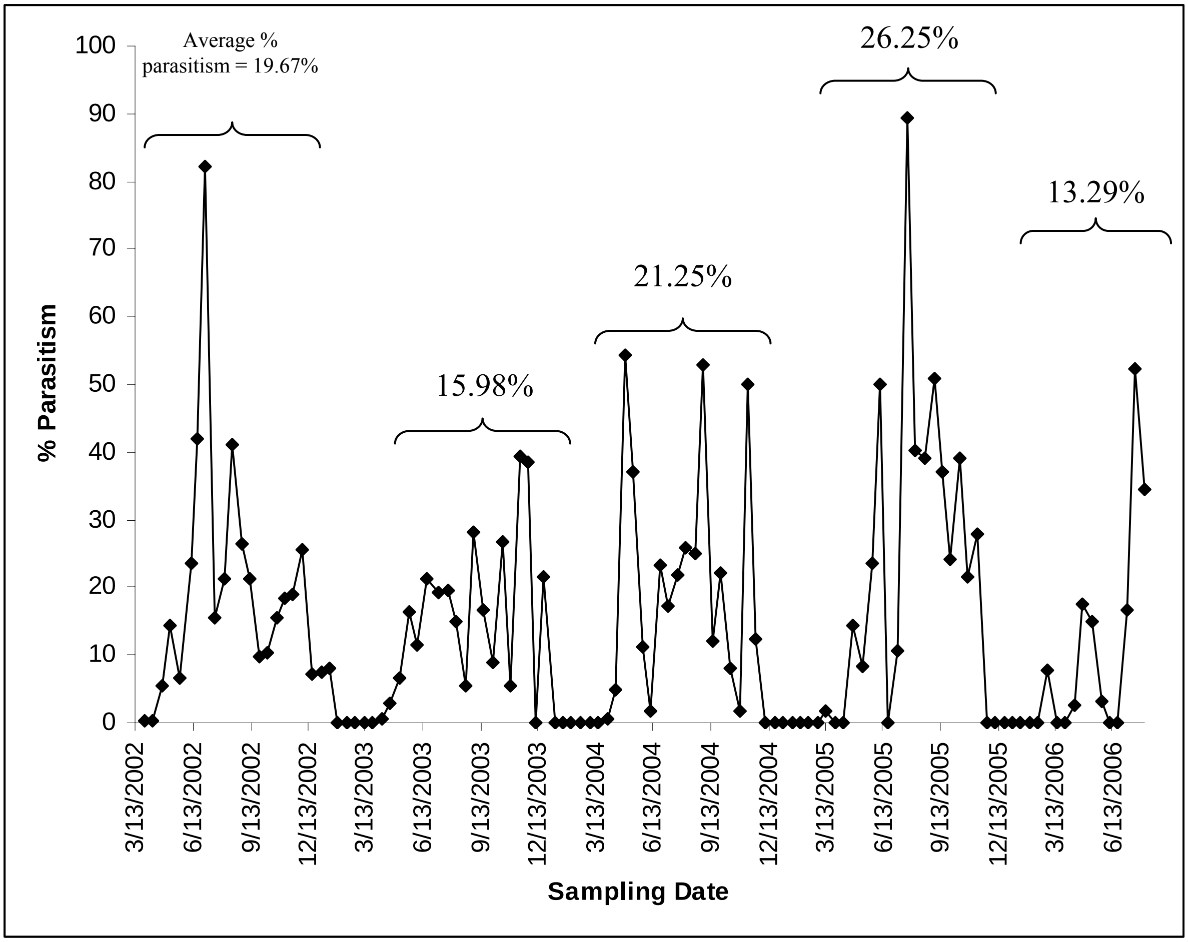

Figure 2. Percentage parasitism estimates of GWSS eggs in Eureka lemons. GWSS egg masses are collected from timed five minute surveys made every two weeks of 10 mature lemon trees at Ag. Ops. University of California, Riverside. Harvested leaves are returned to the laboratory, the number of eggs per egg mass are counted and parasitoid emergence and species identity per egg is determined. Overall average egg parasitism = 19.34%

CONCLUSIONS

GWSS populations appear to be showing a steady annual decrease in numbers in an organic lemon orchard at the University of California, Riverside. Percentage parasitism of GWSS eggs by mymarid parasitoids, in particular, *G. ashmeadi*, has remained relatively constant from year to year at ~20%. It is unknown if this level of parasitism is sufficient to have caused the steady decline in GWSS numbers observed over the past five years. The construction of the K-N-M life table from multi-cohort sampling data is incomplete as just one summer's worth of data has been collected. The life table aspect of the project is ongoing.

REFERENCES

Berryman, A, P. Turchin. 2001. Identifying the density-dependent structure underlying ecological time series. Oikos 92: 265-270.

Hawkins, B.A., and H.V. Cornell. 1994. Maximum parasitism rates and successful biological control. Science 266: 1886.

Holyoak, M. 1993. The frequency of detection of density dependence in insect orders. Ecological Entomology 18: 339-347.

Manly, B.F.J. 1990. Populations, Sampling, Analysis, and Simulation. Chapman & Hall, London.

Turchin, P. 1990. Rarity of density dependence or population regulation with lags? Nature 344: 660-663.

Turchin, P. 1995. Population regulation: Old arguments and a new synthesis. In: Population Dynamics: New Approaches and Syntheses (Eds: N. Cappuccino & P.W. Price), pp.19-40. Academic Press, San Diego.

FUNDING AGENCIES

Funding for this project was provided in part by the University of California Agriculture Pierce's Disease Grant Program, and by the CDFA Pierce's Disease and Glassy-winged Sharpshooter Board.

DETERMINING THE DAY-DEGREE REQUIREMENTS FOR GLASSY-WINGED SHARPSHOOTER DEVELOPMENT AND QUANTIFICATION OF DEMOGRAPHIC STATISTICS AT FIVE TEMPERATURES

Project Leader:
Mark S. Hoddle
Department of Entomology
University of California
Riverside, CA 92521
mhoddle@ucr.edu

Reporting Period: The results reported here are from work conducted July 2006 to August 2006.

ABSTRACT
Glassy-winged sharpshooter (GWSS; *Homalodisca vitripennis*; formerly *H. coagulata*) developmental and reproductive biology has received very little attention from researchers investigating management strategies for this pest. This is a major impediment to rearing this insect for experimental work, developing management plans, understanding interactions with natural enemies, predicting incursion risk into new areas, and spread in recently inoculated areas. Field-oriented management plans for GWSS, if they are to be effective, need solid data on day-degree accumulations to predict pest developmental times, number of expected generations per year, and estimates of expected longevity and fecundity. The purpose of this grant is to generate these fundamental biological data for GWSS to assist pest management programs, biological control efforts, and incursion risk management. Work investigating the developmental and reproductive biology of GWSS at 20°C and 30°C is underway and should be completed by the end of the year (i.e., December 2006).

INTRODUCTION
Completed studies have comprehensively quantified the day-degree requirements of *Gonatocerus ashmeadi* and its demographic statistics across five temperatures (Pilkington & Hoddle, 2006a). These temperature derived data were modeled and equations generated were put into a GIS model built from 381 weather stations in California (CA). Geographic Information System (GIS) output using temperature data and relationships between *G. ashmeadi* development and population growth predicted the "intensity" of generational turnover and population growth throughout CA for this parasitoid. These results may indicate where *G. ashmeadi* can be expected to invade in California should its host, the glassy-winged sharpshooter (GWSS; *Homalodisca vitripennis*; formerly *H. coagulata*), invade these areas too (Pilkington & Hoddle, 2006b). Similar work has been completed and submitted for publication on *G. trigutattus* (Pilkington & Hoddle, 2006c, d). However, these analyses for parasitoids and GIS application are moot unless they can be overlaid and compared with similar predictions for GWSS from comparably generated and analyzed data on its developmental and reproductive biology. Consequently, the intent of this project is to develop estimates of reproductive output at five different temperatures, and time to complete development at these experimental temperatures. Together these data will enable GIS modeling to predict incursion risk and intensity of population growth of GWSS in different areas of California and these models can be compared to similar data and GIS models for *G. ashmeadi* and *G. triguttatus*.

OBJECTIVES
1. Develop day-degree models for GWSS by quantifying the developmental biology at 5 different temperatures (15, 20, 25, 30, & 33°C).
2. Quantify reproductive biology and generate demographic statistics from $l_x m_x$ life tables at five experimental temperatures.
3. Use day-degree data (Objective 1) and demographic estimates (Objective 2) in GIS to predict the geographic range of GWSS within California, and intensity of population turnover in areas vulnerable to incursion. These predictions will be compared to those generated for two egg parasitoids of GWSS, *G. ashmeadi* and *G. triguttatus*.

RESULTS
This work is ongoing and results for 20°C and 30°C are not yet available but work should be completed by the end of 2006 for these two temperatures.

CONCLUSIONS
This work is ongoing and will be completed by the next PD Symposium in 2007.

REFERENCES
Pilkington, L.J., N.A. Irvin, E.A. Boyd, M.S. Hoddle, S.V. Triapitsyn, B.G. Carey, W.A. Jones, and D.J.W. Morgan. 2005. Introduced parasitic wasps could control glassy-winged sharpshooter. California Agriculture 59: 223-228.
Pilkington, L.J. and M.S. Hoddle. 2006a. Reproductive and developmental biology of *Gonatocerus ashmeadi* (Hymenoptera: Mymaridae), an egg parasitoid of *Homalodisca coagulata* (Hemiptera: Cicadellidae). Biological Control 37: 266-275.