GLASSY-WINGED SHARPSHOOTER'S (GWSS) POPULATION DYNAMICS AS A MEANS OF GAINING INSIGHT INTO THE MANAGEMENT OF GWSS POPULATIONS

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ABSTRACT
Our results indicate that:
1. Glassy-winged sharpshooter (GWSS) populations in untreated groves at University of California, Riverside (UCR) Agricultural Operations have been declining steadily since the beginning of 2002 through mid 2005 when sampling ceased. Current population densities are only 10% as dense as those during 2001-2002.
2. Forecast analysis indicates that, if current trends continue, untreated GWSS populations should decrease to their minimum densities sometime after winter 2008 and prior to summer 2013, depending on the *Citrus* species on which they are feeding.
3. Forecast analyses indicate that adult GWSS densities are cycling around an equilibrium density of 600 adults per Valencia tree and 950 adults per lemon tree when left untreated.
4. Population analyses indicate that 30% of the first instar nymphs survive to become fifth instar nymphs and less than 15% become adults on the citrus cultivar. Egg mortality is not included.
5. Current estimates of GWSS' impact on citrus production and fruit quality is an overestimate because the GWSS densities under which these measurements were made are 9 to 25 times more dense per tree than those that currently prevail in most untreated commercial orchards.

INTRODUCTION
In late 1989, the GWSS, *Homalodisca coagulata* (Say) (Hemiptera: Cicadellidae), was detected in Irvine, California, most likely having arrived from the southeastern US as egg masses on imported ornamental plants (Sorensen and Gill 1996). Following its initial detection, GWSS spread throughout the inland coastal valleys of southern California (Orange, Riverside, and Ventura Counties) and, by 1997, had spread to the southern San Joaquin Valley, where it was first detected east of Bakersfield, Kern County, CA (Hill and Hashim 2004). Incipient populations were also detected at several San Joaquin and Sacramento Valley locations between 2000 and 2002, areas that encompass or are near several important table and wine grape growing regions in northern California. Of particular concern was the coincident distribution of GWSS in central and northern California with a portion of the distribution of *Xylella fastidiosa* (*Xf*) (Wells et al.), the causative agent of Pierce's disease (PD).

Citrus is considered to be the main source of GWSS adults migrating into the vineyards (Perring et al. 2001, Blua and Morgan 2003). In southern and central California, *Citrus* spp. is an important over-wintering host for GWSS, generating substantial GWSS populations on this host each spring (Coviella et al. In review). Using mark-release-recapture data obtained during June and July, 2001, Coviella et al. (In review) estimated that 1.2 million adult GWSS occurred per ha at a San Joaquin Valley citrus grove (Kern Co.) and 2.2 million adult GWSS occurred per ha at a southern California citrus grove (UCR, Ag Ops, Riverside Co). GWSS has two annual generations on citrus: one in late winter through spring and a second beginning in early summer and lasting through late autumn (Al-Wahaibi 2004, Coviella et al. In review). It is the adults arising from the spring generation produced on citrus that then disperse to the adjacent vineyards which has become of great concern to grape growers (Blua and Morgan 2003). The adult GWSS produced in autumn are the over-wintering population that initiates reproduction during the late winter or early spring, principally on citrus (Covella and Luck unpubl. data).

To prevent PD epidemics, GWSS population densities must become extremely scarce if PD's spread and transmission are to be disrupted. Thus, identifying whether critical periods in GWSS' two annual generations occur in which an appropriately timed treatment will drive GWSS nearly extinct while minimizing disruption of the associated citrus arthropods is an important pest management concern. Similarly, assessing the impact of established and/or introduced egg parasitoids on GWSS population dynamics is also an important issue. It is with these issues in mind that we began a sampling program to determine GWSS' population dynamics on untreated citrus. We sought to determine whether GWSS densities were remaining static or decreasing during our three and a half year study, and if they were decreasing what likely densities they would attain.

RESULTS
Our results to date suggest that GWSS has two major reproductive periods, one during the spring and a second during late summer-early autumn. The late summer-early autumn generation involves a dense egg population laid by GWSS females arising from the spring generation. Interestingly, very few of these eggs mature to become adult GWSS. Nevertheless the few females that do mature from this generation lay the eggs that initiate the late winter-spring generation the following year. We have measured egg parasitism ranging from 78% to 92% during this second generation, i.e. during the summer-autumn generation. In contrast, the eggs laid during the late winter early spring period appear to suffer less parasitism than those laid during the late summer or early autumn (Al Wahabi 2004). Our results also show substantial nymphal mortalities. Only about 30% of the first instar nymphs reach the last (fifth) nymphal stage, and less than 15% of the first instar nymphs survive to become adult GWSS, but this varies between the citrus varieties.

Our studies also show that the GWSS populations have declined substantially by July 2005 when compared to those in July 2002. The adult GWSS populations on orange trees at UCR Agricultural Operations in July, 2005, was 3% (= 200 GWSS per tree) of the adult GWSS population that we measured in July, 2002 (= 6,500 GWSS per tree) (Figure 1). By comparison, the GWSS population that we measured on lemons in October, 2004 was 16% (= 800 GWSS per tree) of that we measured in October, 2002 (= 5,000 GWSS per tree) (Figure 2). In general, an 80-90% decline occurred in the GWSS adult density during the last three years in Valencias and lemons. The 1.5 year period during which we sampled GWSS populations on tangerines and grapefruit is of insufficient duration to make a similar analysis of GWSS populations on these citrus varieties meaningful (Figures 3 and 4).

We also subjected the densities of the adult GWSS population densities and their trend during the 3.5 year sampling period on Valencia oranges to a forecast analysis (Figure 5). We also conducted a forecast analysis for the GWSS population densities and trend on lemons (Figure 6). We plotted the total adult and the newly emerged (red-veined) adult densities using a logarithmic scale. We then applied a forecasting technique to the GWSS adult density data from Valencia and lemons separately. Figures 5 and 6 show the results of this analysis if current trends were to continue and these density trends are extrapolated until they reach zero. Although these values will never reach zero, we use the plots to estimate a minimum and a maximum "extinction" date. The two extinction dates (defined by the points where the lines cross the X-axis in each graph) encompass the time period (interval in years) during which we estimate that GWSS adult populations will likely reach their minimum densities.

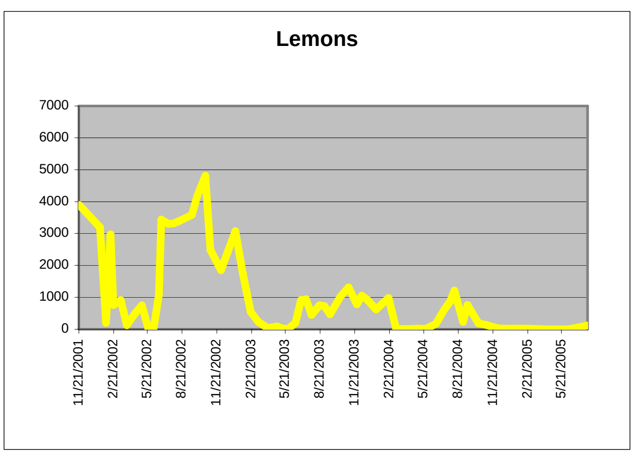

Figure 1. Actual adult GWSS densities in an untreated lemon grove (adults per tree).

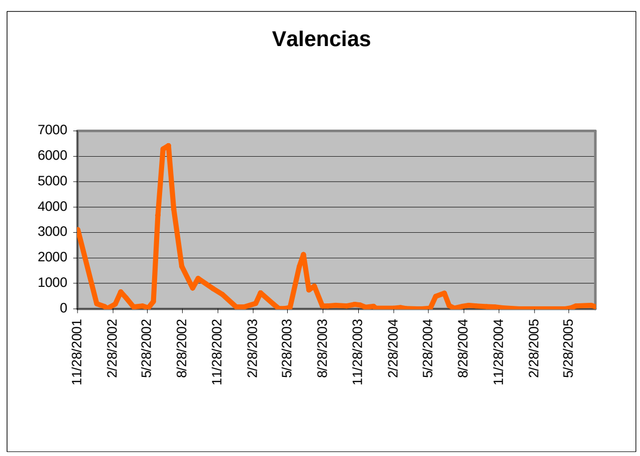

Figure 2. Actual adult GWSS densities in an untreated orange grove (adults per tree).

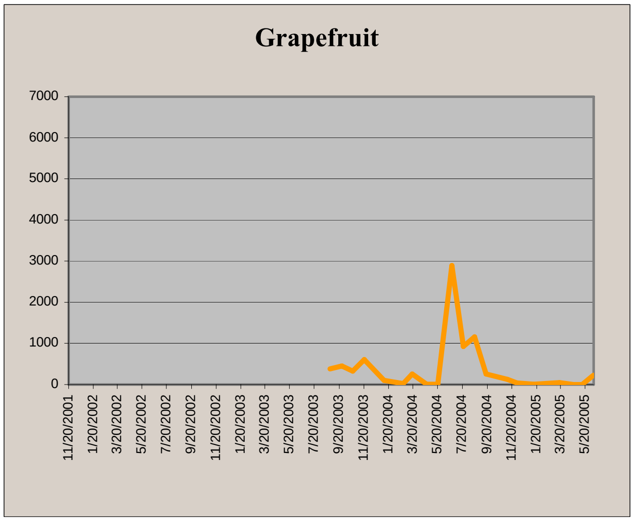

Figure 3. Actual adult GWSS densities in an untreated grapefruit grove (adults per tree) since fall 2003.

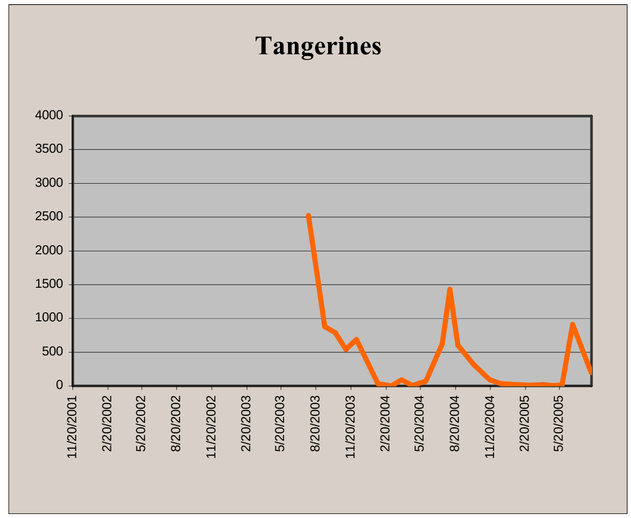

Figure 4. Actual adult GWSS densities in an untreated tangerine grove (adults per tree), since fall 2003.

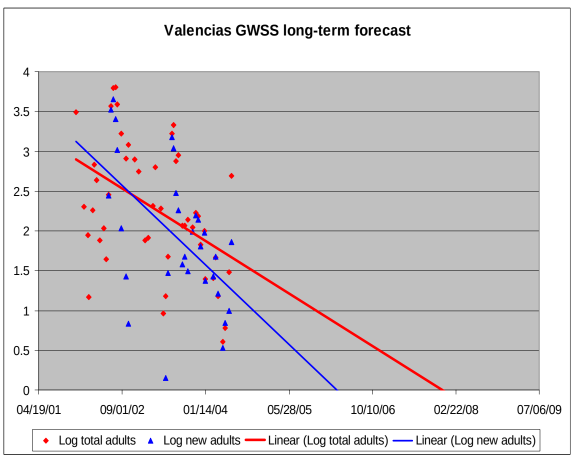

Figure 5. Logarithm of total and new adults with trend lines showing expected "zero density" dates (Valencia).

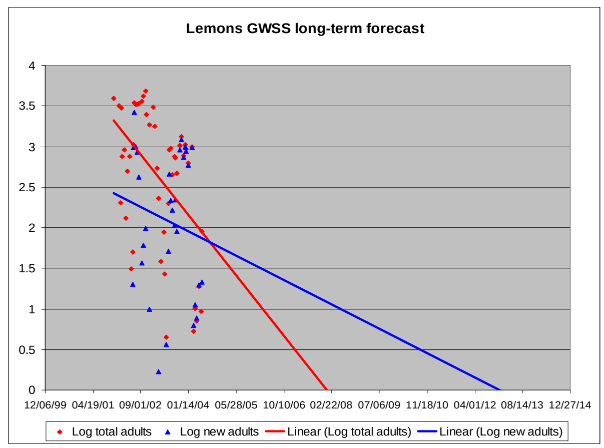

Figure 6. Logarithm of total and new adults with trend lines showing expected "zero density" dates (lemons).

If current trends continue, we estimate that the adult GWSS densities will reach their minimum densities within the next three to six years. We can also use a second and even more powerful technique to analyze the GWSS dynamics; a phase diagram (Figures 7 and 8). Each phase diagram shows a plot of adult GWSS densities during the current time interval as a function of their density during the previous time interval. In our case, it is the density of adult GWSS during a given week as a function of their density two weeks prior. The plotting is continued for each successive pair of sample dates and we obtain a phase diagram that shows whether the GWSS population density is cycling, and if it is cycling, an estimate of the density around which it will likely cycle. Figure 7 shows the phase diagram for Valencias.

The point at which the two diagonal lines cross indicates the equilibrium density, that is, the density around which the adult GWSS population is estimated to cycle, generation after generation. It is the density at which the population will occur generation after generation. For Valencias, this equilibrium density is about 600 adults per tree; for lemons (Figure 8), it is about 950 adults per tree. The analysis indicates that GWSS will never reach "zero density," rather it will cycle above and below this density at different times of the year and in different years. The actual density in any given year can be as high as a thousand GWSS adults per tree or as low as 100 or less. GWSS population data for tangerines and grapefruit encompass too few generations to allow forecasting analysis to be applied to GWSS population using these hosts. We will need at least another year of GWSS data before we can conduct this analysis for these two citrus varieties.

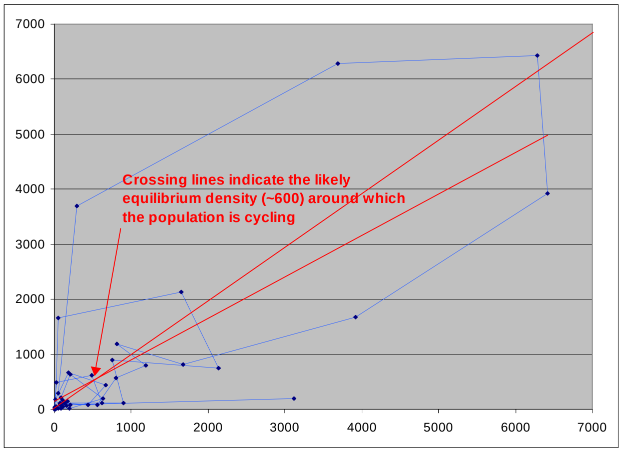

Figure 7. Phase diagram for adult GWSS dynamics in Valencias (see text).

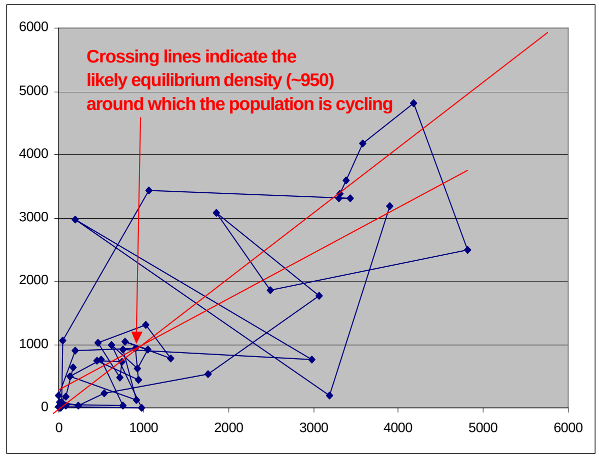

Figure 8. Phase diagram for adult GWSS dynamics in lemons (see text).

CONCLUSIONS

Our results clearly show that the adult populations of GWSS have declined substantially during the 3.5 years of this study. In early summer of 2005, the 200 GWSS adults per tree were only 3% as dense as they were per tree in 2002 on untreated Valencia orange trees at UCR Agricultural Operations. Similarly, at this same location in 2005, the 800 adults were only 16% as dense as they were per tree on untreated lemon trees in 2002. These densities are estimated by enclosing the entire crown of a sample tree in two parachutes, fogging the enclosed tree with a pyrethrum insecticide, and, after vigorously shaking the tree, collecting all of the GWSS adults and immature nymphs on a ground cloth 24 hours after fogging the tree. Each sample date (twice a month) involved three replicate sample trees per citrus cultivar.

Our results also show that GWSS has two generations per year. The first generation comprises the GWSS adults which mature in the autumn and survive the winter to initiate egg-laying the following spring. The adults arising from this generation lay their eggs during the summer-fall period of the same year which give rise to the GWSS adults that over-winter and initiate oviposition the following spring period. Parasitization of the eggs laid during the spring is less than that which occurs to the eggs laid during the summer-autumn generation (Al Wahabi 2004). The autumn egg generation suffers between 78% (lemons) and 92% (Valencia) parasitism.

Currently, the suppression tactics directed against GWSS seeks to prevent emigration of the adults from a citrus grove to nearby vineyards. Movement of GWSS adults poses a risk of spreading PD to the vineyard and among the vines within a vineyard (Hill and Hashim 2004, Perring et al. 2001). If the immigrant GWSS adults also oviposit in the vineyard, then the immature nymphs may also spread PD among the vines. Thus, citrus growers are encouraged to treat the spring GWSS generation to prevent this movement. They are also compensated for these treatments. However, treating citrus during the period is highly disruptive of a sustainable pest management program that has been developed for citrus in California (Forster and Luck 1997; Luck et al. 1997). Pesticide applications during the spring period pose a dilemma for citrus growers practicing sustainable pest management. Such spring treatments often disrupt natural control and prevent the use of augmentative releases of natural enemies for control of California red scale, *Aonidiella aurantii* (Maskell) (Diaspididae: Hemiptera) (Forster and Luck 1997; Luck et al. 1997). Thus, a grower is often faced with an additional pesticide application because the timing of the GWSS treatment disrupts the natural control present in a grove under sustainable pest management or prevents the augmentative release of natural enemies. Thus a grower faces additional costs for which he/she does not receive compensation.

Lastly, even though GWSS densities are much lower than three years ago, data from June-July 2005 show that untreated citrus groves still sustain GWSS densities which peak at 13,000 (oranges), 20,000 (lemons), 12,000 (grapefruit), and 90,000 (tangerines) adults per acre. The uncertainty with the declining GWSS populations, especially in orange, lemon, and grapefruit, is whether these densities will decrease fruit quality as has been suggested by Hix et. al. (2003). Their untreated trees supported 1,149-4,999 GWSS per tree in 2002 which converts to 114,900 to 499,000 if one assumes 100 trees to the acre. This ranges between 9.5 and 25 times more GWSS adults per acre than we measured at the peak GWSS densities in 2005. If the densities we measured in our experimental plots in 2005 are typical of those to which GWSS will decline, then we strongly suspect that the estimated impact of GWSS feeding is over estimated and is unlikely to be economic in the absence of citrus variegated chlorosis (the *Xf* induced disease in citrus). Thus experiments conducted by Hix et al. (2003) are unlikely to be relevant to untreated GWSS population densities in citrus if the GWSS population densities that we have measured are typical of those that will prevail in the presence of the GWSS egg parasitoids.

REFERENCES

Al-Wahaibi, A. K. 2004. Studies on two *Homalodisca* species (Hemiptera: Cicadellidae) in southern California: Biology of the egg stage, host plant and temporal effects on oviposition and associated parasitism and the biology and ecology of two of their egg parasitoids, *Ufens* A and *Ufens* B (Hymenoptera: Trchogrammatidae). Ph.D. Thesis, University of California, Riverside, 435 pp.

Blua, M. J. and D. J. W. Morgan 2003. Dispersion of *Homalodisca coagulata* (Hemiptera: Cicadellidae) a vector of *Xylella fastidiosa* into vineyards of southern California. Jour Econ Entomol. 96: 1369-1374.

Coviella, C. E., J. F. Garcia, D. R. Jeske, R. A. Redak and R. F. Luck. In Review. The feasibility of tracking within field movements of *Homalodisca coagulata* (Say) (Hemiptera: Cicadellidae) and estimating its densities using florescent dusts in mark-release-recapture experiments. Jour. Econ. Entomol. 28 ms pp.

Forster, L. D. and R. F. Luck. 1997. The role of natural enemies of California red scale in an IPM program. Proceedings of the International Society of Citriculture VIII International Citrus Congress, May 12-17, 1996, Sun City, South Africa. 1:504-507.

Hill, B. L. and J. Hashim. 2004. Epidemiological assessments of Pierce's disease and monitoring and control measures for Pierce's disease in Kern County. Proceed. Pierce's Disease Research Symp. Dec 7-10, 2004, Coronado, Calif. pg. 260-3.

Hix, R. L., M. L. Arpaia, C. Lovatt, B. Grafton-Cardwell, and P. Philips. 2003. Glassy-winged Sharpshooter impact on orange yield, fruit size and quality. Proceed. Pierce's Disease Research Symp. Dec 8-11, 2004, Coronado, Calif. pg. 217-220.

Luck, R. F., L. D. Forster, and J. G. Morse. 1997. A ecologically based IPM program for citrus in California's San Joaquin Valley. Proceedings of the International Society of Citriculture VIII International Citrus Congress, May 12-17, 1996, Sun City, South Africa. 1:499-503.

Perring, T. M., C. A. Farrar, and M. J. Blua. 2001. Proximity to citrus influences Pierce's disease in Temecula Valley vineyards. Calif. Agric. 55; 13-18.

Sorensen, J. T., and R. J. Gill. 1996. A range extension of *Homalodisca coagulata* (Say) (Hemiptera: Clypeorrhyncha: Cicadellidae) to southern California. Pan-Pacific Entomol. 72: 160-161.

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