IMPROVED DETECTION, MONITORING, AND MANAGEMENT OF THE GLASSY-WINGED SHARPSHOOTER

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ABSTRACT
Efficient and precise methods for detection of new colony infestations and for monitoring glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis* (Germar) population dynamics on a temporal and spatial basis for IPM related decision-making are lacking. This proposal provides an approach that will address the detection and monitoring needs as well as develop a new strategic approach to management of GWSS.

INTRODUCTION
The glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis* (Germar), as a vector of *Xylella fastidiosa* (*Xf*) remains a threat to grapes, almonds, stone fruit and oleander and impacts citrus and nursery crops throughout much of California. It remains an important quarantine pest for the Napa and Sonoma Valleys and other uninfested areas. Due to the unique biology and behavior of the xylophagous GWSS which is driven by plant xylem chemistry and nutrition, conventional detection and monitoring approaches may not provide the necessary statistical precision needed by the regulatory and producer community for management decisions. This proposal provides an approach that will address the detection and monitoring needs as well as develop a new strategic approach to management of GWSS.

OBJECTIVES
Overall: To determine the most efficient and cost effective trapping system to detect and monitor GWSS population dynamics and the potential to manage GWSS populations.
1. Evaluate and summarize previous sampling and trapping efforts for GWSS.
2. Trap configuration and number: Determine the potential and optimize the number of traps that are most efficient and cost effective in detecting and estimating GWSS populations.
3. Determine the effects of host plants in combination with traps: Determine the potential and the optimization of a combination of GWSS host plants in sentinel plots to detect, estimate and manage GWSS population dynamics.

RESULTS AND DISCUSSION
Since the initiation of the Pierce's Disease-Glassy-winged Sharpshooter Research Program, a number of investigators have addressed sampling methodology for estimating population parameters of GWSS. Here we discuss trap and related sampling methodology with potential for the development of effective monitoring and detection of GWSS (**Figure 1**) and summarize the results to date. We do not include all of the literature that used traps to sample GWSS or the literature tangentially related to sampling methodology, such as marking methods for mark-recapture studies. However, new effective methods have been developed within the program (Hagler et al. 2005).

Turner and Pollard (1959) first used sticky board traps (size not described) at 3 heights 0.6, 1.8 and 3 m above ground. Traps at these three heights captured 23, 37 and 42% of the GWSS captures, respectively. Ball (1979) used masonite board traps (27 × 13.5 cm) and screen traps of yellow, white and red covered with either Tack Trap™ or Stickem Special™ in peach orchards in Monticello, FL to trap GWSS and *H. insolita* (Wlk). Traps were placed at 1 and 1.3 m above the ground and data were collected for three years. Yellow boards captured the highest number of leafhoppers of both species. Results relative to brands of stickem were equivalent. The 1.3 m trap height captured 61% of the GWSS, however, the 0.6 m traps captured significantly more *H. insolita*. GWSS populations began to appear on the traps in late March–early April, peaked in June-July and disappeared in late September-early October. Leafhopper populations fluctuated by an order of magnitude from year to year.

Blua et al. (2002) compared yellow sticky cards, beat-net sampling and timed counts to estimate GWSS nymph and adult populations in citrus compared to total tree counts of GWSS obtained with knockdown (pyrethrin canister) pesticide applications. They also estimated trap efficiency as a function of the number of GWSS already on the traps which addressed the physical function of the trap. However, a potential effect on trap attraction due to reduced visual stimulation or trap active distance was not discussed, but may have been involved. A significant inverse relationship ($Y=6.584-0.0022X-8E\text{-}05X^2$, $R^2=0.71$, $P<0.001$) was detected between number of GWSS already present on traps and subsequent trap catch. No correlations were observed for nymph or adult GWSS counts between beat-net samples, timed counts or stick card samples. GWSS adult sticky card samples did not correlate with any other sampling method. Absolute counts of GWSS nymphs correlated significantly ($P=0.035$) with timed counts. For nymphs, adults and total GWSS, beat-net samples correlated significantly ($P<0.01$) with timed counts. Blua and Redak (2003) compared trapping methods in small citrus trees versus large commercial trees. Adult counts showed significant correlations between all methods tested. In large commercial trees about 50% of variation was explained by a regression of GWSS sticky card counts on total counts. Beat-net and visual counts were less accurate. In small trees, beat-net and visual counts of nymphs had a correlation with total counts near to or greater than 80%.

Blackmer et al. (2002, 2004, 2006) conducted a mark-recapture study using cylindrical traps (40 × 60 cm sheet rolled into a cylinder of 16 cm dia.) at three heights (ground level , 2-3 m and 6-7 m relative to alfalfa and citrus canopies) to determine the dispersal rate and distance of GWSS as well as *H. liturata*. While trap comparison was not part of the studies, a number of parameters that could affect GWSS trap capture rates were evaluated. Pertinent findings included: higher numbers of GWSS were collected on traps at heights below 3 m, 95% of released GWSS were captured within 90 m of the release point in alfalfa and within 31-150 m in citrus, GWSS peak flight activity occurred between 1000 and 1400 h and trap capture was rare at temperatures below 18 ^{0}C. Wind speeds above 3 m/sec decreased flight activity. No flight activity was observed between 2200 and 0600 h and this was similar to observations in Florida (Mizell et al. 2008).

Bartels et al. (2002) used Seabright (Seabright Labs, Emeryville, CA) yellow traps (36 cm^2 trapping surface) at 2 m in height to trap GWSS in several types of crop habitats in Kern County, CA. Grape, peach/nectarine, almond and cherry orchards were sampled at 11 locations using a grid approach where traps were placed in 3 transects 24 m apart on the exterior and interior of the habitats. Traps were checked weekly. GWSS were captured throughout the year. An early season peak was observed in citrus but not in the other crops. From July-October most GWSS captures were found in grape and cherry while the organic grape location had the most GWSS. Late in the year GWSS peaked in peach/nectarine.

Hix (2002, 2003) trapped GWSS in wine grape vineyards that were either organically or minimally farmed in Temecula, CA. Commercially-available yellow traps, and plate and nymph traps (not described) in a number of colors were tested and compared against visual counts of GWSS life stages. Adult GWSS trap captures and oviposition in adjacent vegetation (3 sets of 25 vines) were correlated. Also, the number of nymphs found in July-September was strongly correlated to the number of captured female GWSS. The relationship between nymphs and females was described ($y=b_1(X) - b_0)$): number of nymphs per search = 3.4 GWSS females-2.4 ($R^2 = 0.97$, F=379, P =0.003). Yellow plates captured higher numbers of GWSS than commercial yellow traps. Orange plate traps also captured more GWSS than the Seabright trap. Seabright traps configured as a cylinder did not capture more GWSS than regularly configured (two-sided) traps. Four trap sizes (125, 249, 499 and 998 cm^2) were compared and trap catch increased with size. However, the trap size of 499 cm^2 captured higher numbers on an area/trap basis. Two types of sticky material were also tested but without manifesting differences in trap captures. GWSS phenology in Temecula grapes was characterized with peak numbers occurring in August-September. Using trap color comparisons, it was demonstrated that GWSS were behaviorally attracted to both yellow and orange.

Blua and Morgan (2003) used Pherocon AM/NB (18 × 25 cm, two sides) (Trece', Salinas, CA) to sample GWSS for 21 months in grape-growing areas of southern California. Their methods consisted of trapping the areas between citrus and grape plantings and 0-40 m into the vineyard interiors along with surrounding vegetation consisting of natural coastal sage scrub and riparian areas. They also investigated the effect of trap height on GWSS capture rate. They reported that >97% of GWSS trap captures occurred at trap heights at or below 5 m. Citrus harbored higher numbers of GWSS than the other vegetation types, especially during winter months, but unlike most native leafhopper vectors in CA, GWSS were detected far into the interior of the vineyards. Peak GWSS trap captures were observed in August-September in all vegetation types with citrus exhibiting an additional peak in December.

Castle and Naranjo (2008) compared yellow sticky trap captures of GWSS using four sampling methods: D-Vac, A-Vac, pole-bucket and beat-net for their ability to estimate relative densities of GWSS in citrus. Similar estimates of GWSS distribution and phenology were produced by each of the methods, however, precision, accuracy and relative cost differed between methods. While a male bias was indicated in the sampling method data, female counts correlated well ($R^2 = 0.95$) with yellow sticky trap captures. The pole bucket was judged using precision and costs as the criteria to be the best overall sampling method for both nymph and adult GWSS.

CONCLUSIONS

With the notable exception of the results reported for citrus by Blua and Redak (2003) and Castle and Naranjo (2008) that compared four sampling methods useful to estimate GWSS population parameters in citrus groves, trapping methods for GWSS remain ill defined with respect to relative cost, accuracy and precision for both regulatory and management purposes. Yellow sticky traps available commercially from either Seabright or Trece' remain the primary method for detection and monitoring GWSS. However, "homemade" or non-commercial traps of various sizes, including dinner plates (Hix 2003), painted a bright hue of yellow or orange have been shown to be behaviorally attractive to and equally effective for the leafhoppers vectors.

The quantification of sampling efficiency and efficacy remains incomplete for crops and habits other than citrus. In grape, Hix (2003) did report significant correlations between trap captures of nymphs and adults at specific times of the season as well as correlations of GWSS numbers in the vineyard with those captured on exterior vegetation. Investigations from a number of perspectives with the objective of trap improvement are ongoing. Unlike many other insect pests, GWSS behaviors involved in mating and host plant selection do not appear to be predominantly mediated by olfactory cues. Patt and Sétamou (2007) investigated the response of GWSS nymphs and adults to visual and olfactory cues in the laboratory. They reported that host odors changed the orientation behavior of both nymphs and adults and likely functions as stimulant for enhanced visual attraction to hosts. Potential exploitations of these findings remain to be elucidated. Unfortunately, GWSS is a strong flyer capable of long range dispersal whose nutritional requirements force it to use different host plants over its long lifetime (Mizell et al. 2008). It has demonstrated the ability to spread and establish in non-native habitats in CA and in other parts of the world. Therefore, efficient methods for detection and monitoring remain important tools that need further development to facilitate suppression of this leafhopper vector of *Xf*-caused diseases. A number of behavioral, biological and ecological factors conceptualized in **Figure 1** may perhaps be exploited to further address the problem and these are being investigated.

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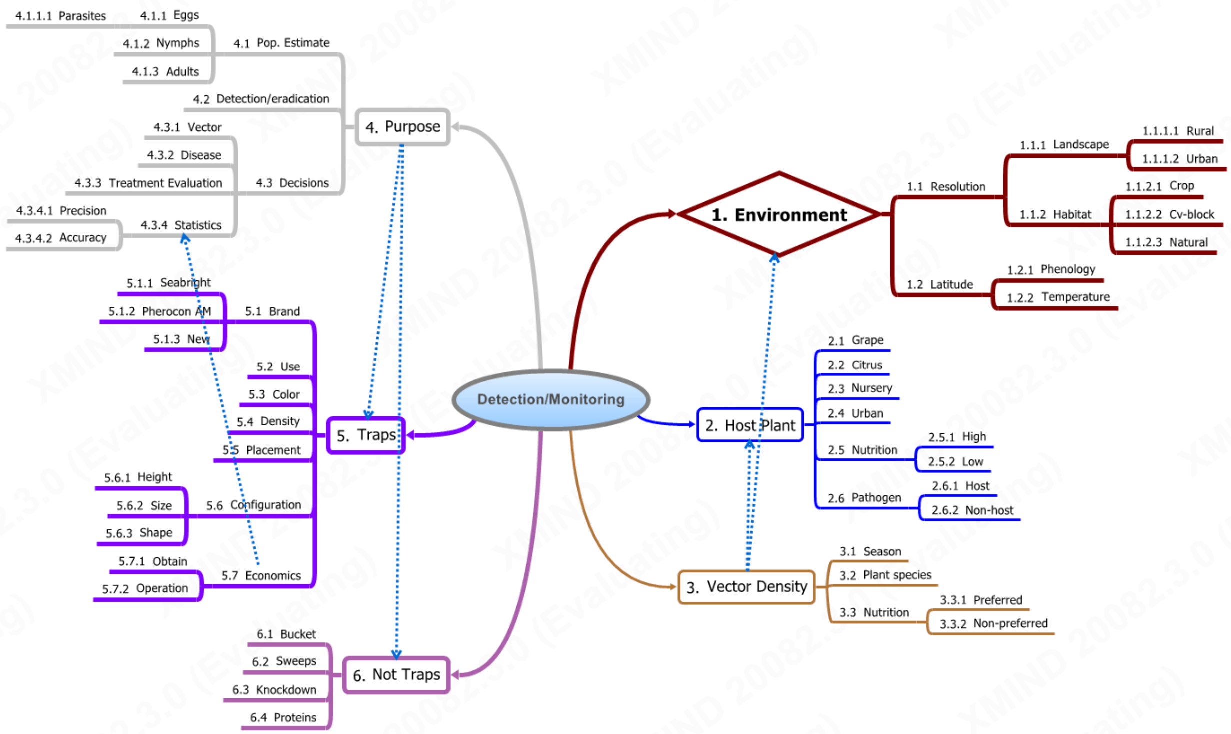

Figure 1. A conceptual "mind map" model of the parameters and potential relationships involved in detection and monitoring of the glassy-winged sharpshooter, *Homalodisca vitripennis.*