TREATMENT THRESHOLDS FOR THE GLASSY-WINGED SHARPSHOOTER BASED ON THE LOCAL EPIDEMIOLOGY OF PIERCE'S DISEASE SPREAD

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ABSTRACT
The current treatment threshold for the glassy-winged sharpshooter (GWSS) as a vector of Pierce's disease (PD) is one insect per tree in citrus. We developed a model to evaluate how the threshold might change in relation to various biological and ecological factors. The model was designed to determine the number of GWSS required to cause a single PD infection in grape. The primary model parameters were the proportion of GWSS carrying PD, GWSS transmission efficiency of PD, proportion of GWSS that will move from citrus to grape, the number of grapevines that a single GWSS will visit, grape varietal susceptibility, and the probability of an infection event resulting in disease. As these factors varied in the model, the GWSS treatment threshold changed. A major limitation of implementing treatment thresholds calculated from the model is that key data for some parameters are lacking. The model is a useful tool for identifying research areas that are needed to further refine a GWSS treatment threshold.

INTRODUCTION
The current treatment threshold recommended to prevent glassy-winged sharpshooter (GWSS) transmission of Pierce's disease (PD) is one GWSS per tree in citrus. This threshold was implemented in Kern County, and was reported to successfully reduce GWSS densities (Wendel et al. 2002). In winter 2003, this threshold directed treatment of almost all citrus acreage in the Temecula and Coachella Valleys. The initial threshold has provided a good start towards refining management criteria for GWSS. However, in the current California budget crisis, it is doubtful that funds will be available to sustain the level of areawide insecticide applications required to respond to this low action threshold. We believe that field-specific thresholds can be developed and we have begun work on a model for this purpose.

In refining the GWSS treatment threshold, the primary question becomes, what is the relationship between insect density and disease incidence? If we can develop this relationship, then we have a much better reference for developing a treatment threshold that will prevent disease transmission. The challenge is that the number of insects required to cause disease will change under different circumstances, therefore, a model is a helpful tool for estimating a threshold number based on key parameters.

In our approach to establishing treatment thresholds we are developing a model that incorporates biological and ecological data. It is common in entomology to calculate a treatment threshold based on the economic injury level (EIL). In a traditional EIL, injury is defined as the amount of injury per pest and is typically expressed in terms of amount of plant tissue consumed per insect (Higley and Pedigo 1996). In a system where an insect transmits a pathogen, injury can be interpreted as the number of plants infected per insect vector.
Currently, there is no tolerance for GWSS-transmitted PD. Therefore, we must assume that the treatment threshold is the number of GWSS required to cause a single PD infection. However, as more information is gained about the GWSS/PD relationship in California, we are learning that the likelihood of GWSS successful transmission of PD will vary under different conditions and therefore the threshold should vary as well.

OBJECTIVES
1. Develop a model to describe the epidemiology of GWSS transmission of PD to provide a framework for organizing data and examining relationships between data from different research projects.
2. Use the model to develop field-specific treatment thresholds to prevent GWSS transmission of PD.

RESULTS AND CONCLUSIONS
Model Components:
The first challenge in developing the model was to identify the primary parameters affecting the number of insects required to cause a single PD infection. We identified a list of these primary factors and they are listed in Table 1.
The assumption

Table 1. Components of the model for a treatment threshold of an insect vector of plant disease.

Symbol	Description	Parameter Value Range	Reference
T_v	number of insects required to cause a single infection	calculated from model	none
C	proportion insects carrying pathogen	0.00–1.00	none
R	insect transmission efficiency of pathogen	0.01–0.35	Almeida and Purcell 2003
M	proportion insects that will move from sample area to feed on host plant of interest	0.00–1.00	none
P	number of plants a single insect will visit	5–15	none, values estimated
S	plant varietal susceptibility to disease expressed as a proportion	0.04–1.00	Raju and Goheen 1981
E	probability of infection event resulting in disease	0.00–1.00	none

Model Assumptions:

The following assumptions were made for the model:

- GWSS will be monitored by sticky traps in citrus.
- Treatment of GWSS will be applied to citrus.
- The relationship between sticky-trap catches and an absolute population estimate of GWSS is known.

Model Design:

A discrete, dynamic, deterministic model was developed using the model variables described in Table 1. The mathematical relationship between the primary model variables was arranged to yield a threshold result of the number of vectors required to cause a single PD infection:

$$T_v = \frac{1}{C \times R \times M \times P \times S \times E}$$

Model Simulation:

In a model simulation run, we varied two parameters across a range of values from 0.00–1.00 to examine the effect on the GWSS treatment threshold (Figure 1). In this simulation, as the proportions of GWSS carrying PD and moving to grape increased, the threshold decreased. As expected, the threshold was greater than one when these proportions were lower. For example, when the proportions GWSS carrying PD and moving to grape were approximately 0.25 and each GWSS visited five vines (Figure 1A); the treatment threshold was at least 10. When the proportions were very low (<0.05), the threshold increased greatly to over 3,000 GWSS (Figure 1A). The thresholds remained lower over a greater range of proportions when the number of grapevines visited per GWSS was increased to 15 (Figure 1B).

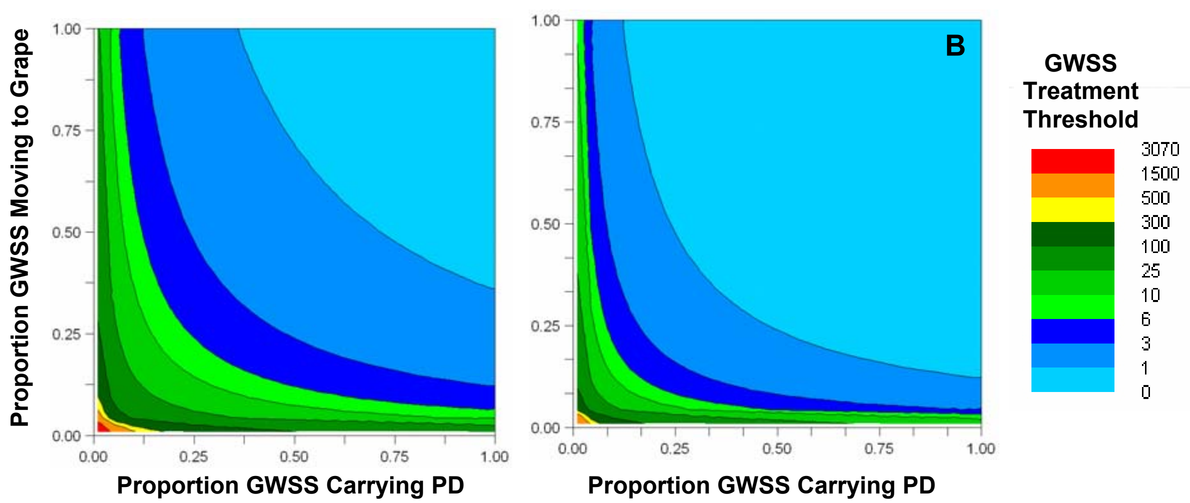

Figure 1. Glassy-winged sharpshooter treatment threshold at varying proportions of GWSS moving to grape and GWSS carrying PD at two different levels of grapevines visited per GWSS: A) 5, and B) 15. Other model parameters were constant: transmission efficiency = 0.35, varietal susceptibility = 0.80, and probability of infection event resulting in disease = 1.00.

The initial threshold model is a useful tool for exploring the effect of various epidemiological parameters on the relationship between GWSS density and PD incidence. However, the primary limitation to implementing treatment thresholds based on the model is that key data are lacking. The model has helped to identify several areas where more research is needed including:

- The relationship between sticky-trap catches and an absolute population estimate of GWSS.

- Methods for determining the percentage of GWSS carrying PD in the field.
- Preference of GWSS to move from citrus to grape.
- Grape varietal susceptibility to PD for common cultivars, especially table grapes.
- Various data on phenological and environmental circumstances under which a *Xylella fastidiosa* infection event leads to PD development.

We will continue to refine the model as additional simulation runs are performed. Additional parameters may be added to the model and others removed if their importance is found to be negligible. Some mathematical relationships may change as more data become available. Realistic model parameters will be evaluated in the model as they become available through current research.

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