

**QUANTIFYING VINE MEALYBUG (*PLANOCOCCUS FICUS*) SPATIOTEMPORAL DYNAMICS:
ASSESSING INVASION RISK TO REFINE MANAGEMENT STRATEGIES**

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INTRODUCTION

Geospatial analyses and niche-based/species distribution modeling have previously been used to characterize plant, aquatic invertebrate, amphibian, and insect invasions. Results of these and similar investigations have been applied, with varying degrees of success, to develop early detection strategies, identify and prioritize management in high risk areas, and minimize monitoring expenditures (Thuiller et al. 2005, Bradley et al. 2010, Venette et al. 2010, Jiménez-Valverde et al. 2011, Vincente et al. 2016). An intriguing possibility is that information gained from geospatial analyses of invader spread and niche-based/species distribution modeling of suitable habitat for invaders may be used to simulate invader dispersal and predict invader distributions. Ensuing predictions of invader distributions could then guide detection and management efforts, as well as be evaluated and refined using field-collected data on invader occurrence. Here we use such tools to improve response to an important invasive insect in California, the vine mealybug (VMB; *Planococcus ficus* [Signoret]).

The vine mealybug is a severe vineyard pest that contaminates fruit, debilitates vines, and transmits plant pathogens such as *Grapevine leafroll-associated virus-3* (Daane et al. 2012; Almeida et al. 2013). Management of VMB has proven challenging and often requires the use of multiple tactics, including biological control, mating disruption and insecticides (Daane et al. 2008). Management can be particularly complicated in coastal wine grape-growing regions where climatic conditions are favorable and Argentine ants (*Linepithema humile* [Mayr]) disrupt biological control (Daane et al. 2007, Gutierrez et al. 2008). Management costs may range from \$300 to \$500 per acre, per year; and due to the aggressive nature of VMB populations, these practices cannot be neglected.

Vine mealybug was first reported in California from vines in the Coachella Valley (Gill 1994) and soon spread throughout much of the state, likely on infested nursery stock (Haviland et al. 2005). It is currently found in most California grape-growing regions (Godfrey et al. 2002; Daane et al. 2004a, 2004b). However, despite the continued expansion of VMB in California, its current distribution in Napa County and areas at risk of VMB introduction in this region are not well characterized.

OBJECTIVES

Given the ongoing expansion of the vine mealybug (VMB; *Planococcus ficus*) in California and continued risk of its introduction into new areas, a better understanding is needed of what is driving its invasion. The overall goal of this research is to characterize the factors associated with VMB establishment and spread in Northern California vineyards, which will be addressed via the following objectives:

- 1) Quantify the spatiotemporal patterns in VMB occurrence to identify invasion hot spots and patterns of spread
- 2) Characterize the landscape, climatic, and anthropogenic factors associated with current VMB occurrence to predict areas at risk to invasion
- 3) Validate and update predictions of VMB risk via in-field monitoring

RESULTS AND DISCUSSION

All activities related to the first two objectives were completed during the prior project period, which are summarized in past reports. Here, we report just ongoing activities related to the third objective.

Objective 3

Work on Objective 3 is leveraging the results of Objectives 1 and 2 to evaluate the accuracy of predictions of habitat suitability and risk of VMB infestation via in-field monitoring. To do this we have identified more than 300 unique vineyard properties from throughout Napa Valley that collectively represent a large range in both estimated habitat suitability values (Obj. 2) and distance to VMB trap detections in the prior year. We will confirm the status of the vineyard with respect to VMB presence, for as many of these sites as possible, via one of three means. First, we are interviewing the growers and vineyard managers who oversee these properties to determine whether VMB is established at that site, and if so, what year the site was first invaded. Second, for more than a dozen independent sites so far, growers or vineyard managers have reported suspected VMB infestations, which we have confirmed via field visits. Finally, at a subset of sites for which growers or managers believe VMB is not present or are not sure, we are conducting detailed monitoring. The monitoring includes timed visual inspection of 250 vines spread throughout up to approximately 4 acres, including inspection under the bark and on leaves. If any of the vines have evidence of VMB presence, that site is being treated as infested (i.e. presence/absence).

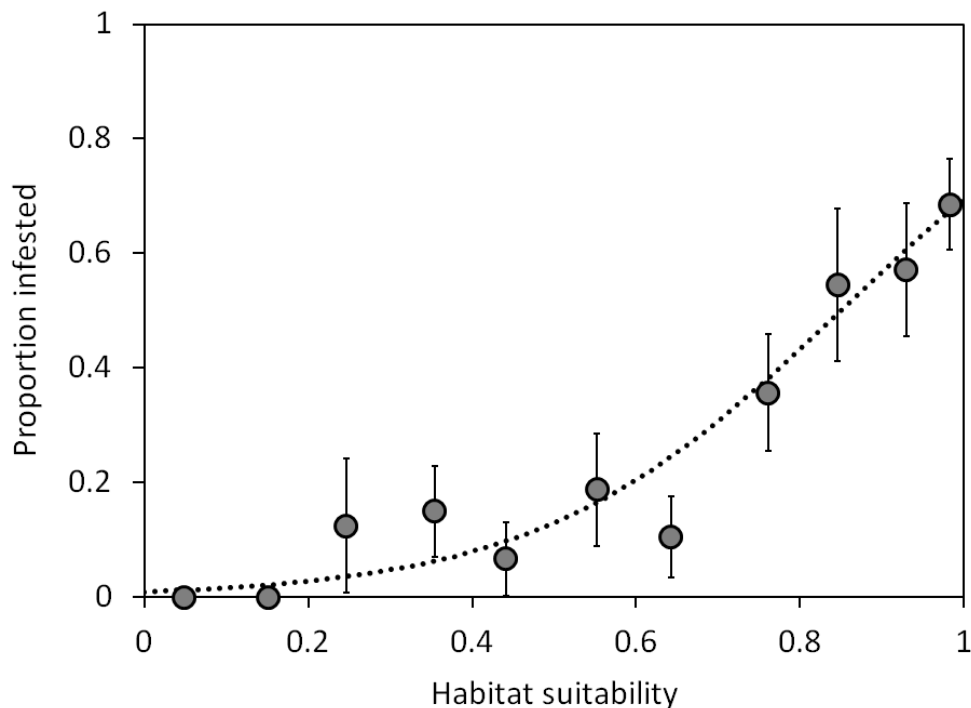


Figure 1. Proportion (\pm SE) of vineyards with VMB infestations as a function of estimated habitat suitability. The dotted line denotes the fit of a logistic regression.

Thus far we have documented VMB infestation status for approximately 220 of vineyard blocks, via a combination of grower interviews, confirmation of suspected infestations, and in-field monitoring. Collectively, these sites have estimated habitat suitability values ranging from 0.02 to 0.99, and distances to the nearest trap detection the prior year ranging from 0 to more than 4,500 m. Overall, nearly 29% of sites have been invaded by VMB since 2015, with invasion rate strongly tied to habitat suitability and distance to prior trap detections. Preliminary analysis with a logistic regression indicates that habitat suitability is significantly and positively related to the proportion of vineyards with VMB infestations (Fig. 1). Conversely, distance to the nearest trap detection is significantly negatively related to the proportion with VMB infestations (Fig. 2). A few aspects of these preliminary results are noteworthy. First, the very strong positive association with habitat suitability indicates that the suitability modeling in Objective 2 is robust, and likely a useful indicator of the risk of VMB infestation in the near future at sites in the study region that are not already invaded. Second, although the effect of distance from prior trap detection is more variable, the nature of the effect is biologically plausible (i.e. greater distances = lower probability of infestation), and may be useful in refining further estimates of VMB dispersal distances from known infestations. Finally, given that almost all of the sites with distances to prior trap detections

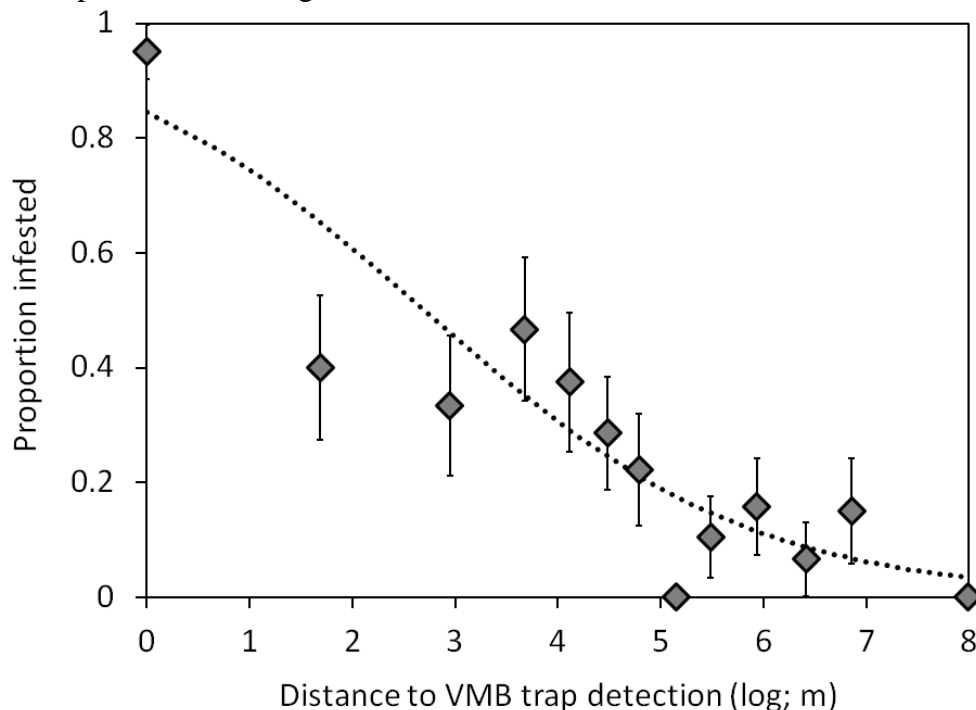


Figure 2. Proportion (\pm SE) of vineyards with VMB infestations as a function of distance to the nearest trap detection the prior year (natural log[x+1] transformed). The dotted line denotes the fit of a logistic regression.

near 0 m were invaded suggests that trap detections are a reliable indicator of a VMB infestation in the immediate area of a trap. In other words the network of traps in the study region, which forms the basis for the suitability modeling, appears to be capturing accurately the true distribution of VMB in the region. For the remainder of the project, we will collect additional information at the rest of these vineyard sites to determine whether these preliminary results hold.

PROJECT PUBLICATIONS AND PRESENTATIONS

Nothing to report

RESEARCH RELEVANCE STATEMENT

Better understanding of the factors driving VMB invasion is needed to curtail its ongoing range expansion in California, continued risk of introduction into novel regions of the US, and expense of management efforts. For this research project, survey data on 2012-17 VMB occurrence are being used to quantify spatiotemporal patterns in VMB occurrence, identify factors underlying hot spots of VMB occurrence/activity, characterize factors associated with VMB establishment, and clarify pathways that contribute to VMB spread in Napa County, California. This work will thereby help explain infestation patterns of this pest and identify areas at risk of infestation in the future. An improved understanding of the directionality and rate of VMB spread, as well as the pathways by which this insect disperses naturally or is moved by human activity, also will inform regulatory steps and direct educational efforts toward mitigating spread by targeted risk reduction strategies. Ultimately, such information is critical for developing a statewide response to this important vineyard pest.

LAYPERSON SUMMARY OF PROJECT ACCOMPLISHMENTS

Analysis of trapping records in Napa County indicate that the area affected by VMB's invasion continues to increase, with more than a 3-fold increase in the number of traps recording VMB between 2012 and 2017. Estimates of yearly spread range from approximately 100 to nearly 900 m, with patterns of spread that are highly idiosyncratic. Areas of VMB infestation are also highly clustered, with hotspots in activity within the central portion of Napa Valley between Napa and St. Helena that are increasing over time. Moreover, geospatial modeling suggests that the locations of these hotspots are not random. VMB infestation level depends on vineyard environmental characteristics (e.g., elevation, precipitation) and on factors associated within human activity (e.g., proximity to vineyards). These analyses have been used to predict those areas of Napa County not currently

affected that are at highest risk to VMB infestation in the near future, the results of which have been shared with the Napa County Winegrape Pest & Disease Control District to guide their ongoing VMB monitoring efforts.

STATUS OF FUNDS

All activities for the first two objectives were completed in the last project period. After a delay in initiating activities for Objective 3, resulting in an extension on funds to complete that work, activities and spending for are on track.

SUMMARY AND STATUS OF INTELLECTUAL PROPERTY ASSOCIATED WITH THE PROJECT

No intellectual property is anticipated associated with the project.

CONCLUSIONS

Our findings indicate that VMB invasion of Napa County is well beyond the initial invasion stages and is actively spreading throughout this region. Future VMB spread may continue to occur via natural and/or human-assisted pathways at rates upwards of 850m per year. We detected substantial heterogeneity in both the distribution of statistically significant hotspots of VMB detections and estimated habitat suitability for VMB over the study region. The amount of precipitation in the driest month, elevation, and trap distance to nearest winery were identified as the most important and strongly associated predictors of habitat suitability for VMB. Thus far, results from the in-field monitoring both indicate that the predictions of the habitat suitability modeling are robust and may help to refine further estimates of VMB dispersal rate.

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