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Growers' risk perception and trust in control options for huanglongbing citrus-disease in Florida and California

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ABSTRACT

Citrus huanglongbing disease (HLB) is an acute bacterial disease that threatens the sustainability of citrus production across the world. In the USA, the Asian citrus psyllid (ACP) is responsible for spreading the disease. Successful suppression of HLB requires action against ACP at large spatial scales, i.e. growers must cooperate. In Florida and California, the citrus production regions have been split into vector-management areas and growers are encouraged to coordinate spraying of insecticide across these (to achieve area-wide control). We surveyed growers from Florida and California, obtaining samples of opportunity at grower meetings, to assess the consensus of

opinions concerning issues that influence HLB management. Our results show that a grower's perception of the risk of disease infection and their trust in control options are central to the decision on whether to join an area-wide control program. Growers' perceptions on risk and control efficacy were found to be influenced by information networks and observations about the state of the HLB epidemic and psyllid populations. Within the growers' information networks, researchers and extension agents were reported to have the largest influence on these perceptions. Differences in opinion between California and Florida growers as to the efficacy of treatments could be explained as a function of experience: growers from areas with lower densities of ACP were associated with rating insecticide control more positively than those where psyllids population density was higher. Thirty percent of growers identified the expected lack of participation by other growers as a reason why they themselves would not participate in area-wide control.

Keywords: Huanglongbing citrus-disease, area-wide control, grower surveys, Asian citrus psyllid, grower cooperation

1. Introduction

Plant diseases collectively account for annual losses in the order of 12–15% of global crop production (Savary et al., 2012), however, diseases that completely threaten the production of specific types of crop at a global or regional scale are relatively rare. Citrus huanglongbing (HLB) disease is one of that category of rare, acute plant diseases that threaten the sustainability of citrus production across all citrus producing regions of the world (Gottwald, 2010).

The disease is caused by a fastidious bacterium, *Candidatus* Liberibacter spp., with three species known to be associated with HLB symptoms in different regions. In the USA the Asian Citrus Psyllid (ACP, *Diaphorina citri*) is the invasive vector that is responsible for spreading *Candidatus* Liberibacter asiaticus (CLas) (Gottwald, 2010). The disease is now widespread in Florida and is causing significant economic losses (see Box 1). The disease was found in California in 2012 and now it has been identified in over 300 trees in residential areas of Southern California but has not yet been detected in commercial trees (see Box 2). Disease control programs in both states are coordinated around spatially organised groups of growers who take coordinated actions on psyllid control. We refer to this approach to control as an area-wide control program. For detail on the organisation see Box 1 and Box 2.

When one considers the dynamics of HLB epidemics at state or regional scales it is apparent that human behaviour has a major impact on the rate of disease spread. It is recognized that successful suppression of HLB requires action at large spatial scales (Gottwald, 2010). In most settings, and certainly in both Florida and California, the effective area over which coordinated action is required exceeds the area of a single plantation and vector control, thus,

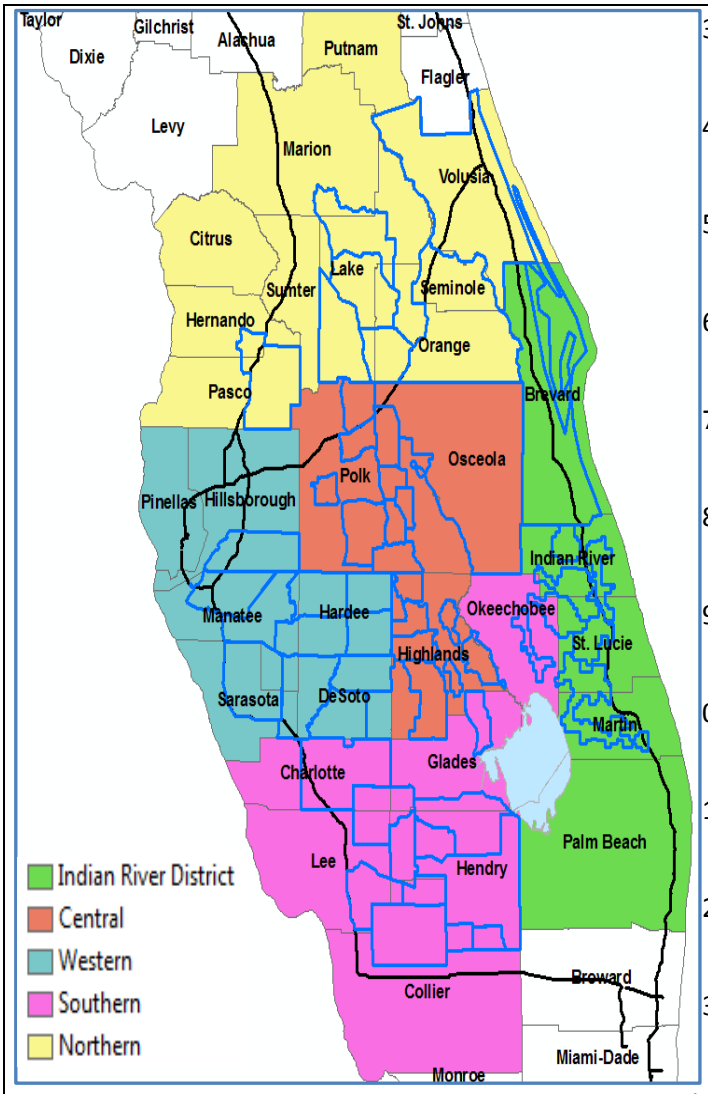
entails coordination among several-to-many growers or crop managers. Furthermore, in both states control of HLB also involves coordination and cooperation between growers and state and federal government agencies, introducing another point of dependence on human behaviour in the overall dynamics of the disease.

Although the importance of the human element in plant disease epidemics in agriculture has long been recognized (Zadoks and Schein, 1979) and has received renewed attention in recent years (Breukers et al., 2012; McRoberts et al., 2011; Hillis et al., 2016; Hillis et al., 2017; Sherman and Gent, 2014; Singerman et al., 2017) the management of HLB forces attention onto those human and social aspects perhaps more than any other. In that light, the ongoing epidemics in Florida and California offer a unique case study into growers' attitudes to the disease at two very different stages of the epidemic. In addition to the insights that can be gained about growers' beliefs and preferences with regards to the specific case of HLB, an analysis of attitudes to HLB management among citrus growers is also likely to be informative about the issue of cooperation in disease management; a topic that has much wider relevance.

We report on the findings from surveys among Florida and California citrus growers on the topic of HLB and ACP management. The surveys were conducted to assess how growers perceived the risk of their orchards becoming infected with HLB, and their perception of the efficacies of methods to control ACP and HLB: in particular, their attitudes towards area-wide control. Both the actual situation with respect to HLB and its control, and the growers' perceptions have consequences for the actions that may be needed by government and industry bodies who are attempting to manage the disease. We hypothesized that differences in attitude

between growers from California and Florida would be consistent with the different durations of the epidemics in these two states and the level of damage caused by HLB.

BOX 1



A map of Florida with the areas used to categorise where the participants' orchards were located.

Huanglongbing citrus-disease in Florida. The ACP was first detected in Florida in 1998 and spread rapidly throughout the state. *Candidatus* Liberibacter asiaticus (CLas) was confirmed to be present in Florida in 2005. In the intervening 12 years from that detection until now, HLB has spread through all of Florida's citrus producing acreage. The disease has caused approximately a 75% reduction in citrus production while more than doubling the cost of production per acre. A recent

analysis by Mitchell (2017) estimated the net loss of consumer and producer economic surplus at $466M per year since HLB was first detected in Florida.

In Florida coordination of disease management into area-wide programs is based on Citrus Health Management Areas (CHMAs). CHMAs were purposely constructed with known vector and disease prevalence in mind and using information on the known dispersal capability of the vector to establish the required physical extent over which coordinated treatment is needed to achieve local population suppression. Information on the level of grower participation in CHMAs and the size of the ACP population (estimated using tap-sampling of trees) is gathered every 3-weeks and is available through a website maintained by the University of Florida (www.flchma.org). Singerman et al. (2017) give a recent account of economic reasons why CHMAs differ in level of performance in suppressing ACP populations and preventing spread of HLB.

BOX 2

A map of Central and Southern California with the counties used to categorise where the participants' orchards were located. The map is from the UCANR website http://ucanr.edu/sites/ACP/Distribution_of_ACP_in_California/ (last accessed September 2017).

Huanglongbing citrus-disease in California. The ACP was first confirmed in San Diego county California in 2008. The first confirmed case of HLB occurred in 2012 in Hacienda Heights in the greater Los Angeles metropolitan area (California Department of Food and Agriculture, 2012), since which time the number of confirmed cases has increased to >300 (as of January 2018), spread through a band of residential areas east of Los Angeles. The entire area of southern California, is under quarantine for ACP, and numerous smaller quarantine areas exist in northern California, around locations where ACP have been detected. At the time of writing (January 2018) there are still no confirmed cases of HLB in commercial citrus in

California. An extensive program of surveying, treatment, and regulatory enforcement of tree removal is in place in residential properties.

In California, Pysllid Management Areas (PMAs) are constructed by considering the social network among growers. Individual PMAs are defined by groups of up to approximately 20 growers who communicate and coordinate through a PMA "Captain". When coordinated treatments are required in an area the relevant PMA captains contact their group of growers and make them aware of the treatment schedule. At a county level the PMA networks are facilitated by a group of "grower liaisons" (typically experienced crop consultants or pest control advisers). Overall management of the liaisons is the responsibility of the Citrus Pest and Disease Prevention Committee (CPDPC), a grower body that operates in collaboration with California Department of Food and Agriculture (CDFA) and has regulatory authority to impose mandatory measures to control both ACP and HLB.

2. Materials and methods

We held three workshops in California and two in Florida. Participants were asked to fill in questionnaires about ACP and HLB in citrus. The Californian data were collected at citrus grower extension meetings organized the University of California Cooperative Extension. These meetings are an annual fixture on the calendar for the citrus industry, with the topics covered varying from year to year, but with an identical format and speakers in all locations each year. The meetings were held in June 2015 at Exeter (Central Valley), Palm desert (south-east California) and Ventura (coastal California). At the time, only one case of HLB had been reported in the state: a single tree in Hacienda Heights in the Los Angeles metropolitan area. In total, there were 225 participants. The Florida workshops were held in January 2016 at Fort Pierce in a small group setting at the USDA-ARS research station and at the Florida Citrus Show in Fort Pierce later in the month. In total, there were 102 participants.

Each workshop began with an introductory talk in which the aims of the survey activity were explained, and the protections to individual identity under Institutional Review Board (IRB) compliance were explained (followed by the opportunity to opt-out). The data represent a 'sample of opportunity' collected from participants who had gathered to attend meetings on HLB. We note, therefore, that the sample may have inherent bias, in as much as, it was gathered from individuals who were engaged enough in the citrus industry to attend extension meetings and industry gatherings. The questionnaire was presented using the Turning Point add-on for Microsoft PowerPoint with each individual using a unique handset to respond to the series of questions. A summary of the responses to each question was instantly relayed to the participants

in the form of a bar chart projected in the meeting auditorium via LCD projector, and so they could see the proportion of participants who selected each option. While there is a possibility that the opportunity to see other peoples' results before submitting their own might influence choices, there is no systematic evidence, in our experience that this happens (McRoberts, unpublished data). Generally, respondents focus on the handset to make their choices without looking at the room display and then check to see what the overall results look like; the majority of responses occur within 30 seconds of the question being posed. The availability of the results in real-time maintains audience interest.

2.1 Questionnaires

Because there was a large difference between the exposure of the California and Florida participants to HLB, and smaller differences in infrastructure and culture, the questionnaires used in each state were slightly different. Table 1 shows a summary of the questionnaire (see Supplementary materials S1 for full details of all questions and possible responses). The questions fell broadly under five themes. The first group of questions described the individuals. The next group targeted awareness of HLB and the perception of risk of becoming infected. The third group of questions were concerned with the interactions between individuals and the sources of information they used to form opinions on HLB and its control. There was a set of questions relative to participation in PMA/CHMA's. The last group of questions assessed the perception of participants about the efficacy of the most common ACP management practices.

Table 1

A summary of the grower survey

Descriptive questions
• Where are your orchards/orchard located (see Boxes 1 and 2)? • How many acres of citrus do you grow or manage?
Awareness of HLB and the perception of risk of becoming infected
• When did you first become aware that HLB was present in your state? • When you first found out HLB was in your state, how likely did you think your orchards would become infected soon after? • How do you feel now? Do you think your orchard/orchards will be infected by HLB within 5 years from now? (California only)
Interactions between individuals and the sources of information they used to form opinions on HLB and its control
• How did you find out HLB was present in your state? • What factors made you realize HLB was a serious threat to your orchard/orchards? • Who or what has made you think it is a good idea to join a CHMA (Citrus health management area) or PMA (pysllid management area)?
Participation in area-wide control
• Have you joined a PMA or CHMA? • If you have not joined a PMA, are you planning to join one? (California only)

• When did you join? (Florida only) • What is your biggest concern about PMAs? (California only)
Perception of participants about the efficacy of the most common ACP management practices. • Rate the following ACP management practice: Area-wide control, spraying independently, and tree removal.

There were no open-ended questions in the questionnaires, rather, the participants were asked to select the response or responses that most closely represented their thoughts from a list projected on the auditorium screen. This made the implementation of the survey using the clicker system straightforward and provided a means to analyse the results statistically. Where questions asked how likely an event was (i.e. infection of their orchard), the list of possible responses comprised a list of calibrated phrases and associated probability intervals (as recommended by Budescu et al., 2009).

2.2 Method of analysis

We analysed the responses to each of the questions and, also looked for significant associations between the responses of questions. We constructed contingency tables (e.g. Table 2) in which the rows are responses to one question and the columns the responses to the other. Under our null hypothesis the responses are independent, and so the same distribution of responses is expected across each row and column. Under the null hypothesis the expected

number of responses in a cell is the product of the respective marginal (row and column) totals divided by the total number of responses in the table. If the expected number of responses in the ith cell (out of N) is e_i and the observed number is o_i we then compute the familiar statistic

$$\chi^2 = \sum_{i=1}^{N} (o_i - e_i)^2 / e_i$$

to measure the evidence against the null hypothesis. In principle under the null hypothesis, and with n_r rows and n_c columns in the table, χ^2 is distributed by $\chi^2$with $(n_c - 1)(n_r - 1)$ degrees of freedom, but the fact that o_i is an integer introduces an approximation when the o_i over many cells is small. For this reason, we obtain a p value for the χ^2 under the null hypothesis by the permutation method (Payne, 2011). Here we reject the null hypothesis if $p < 0.05$.

Table 2.

A contingency table of the location of orchards in California and the participants' perception of risk of infection within 5 years of the survey date. Counties Madera, Fresno, Tulare or Kern comprising the main citrus growing area located in the southern San Joaquin Valley, are denoted MFTK, and San Bernardino is denoted SBR.

	Counties					
	MFTK	Ventura	SBR	San Diego	Imperial	Others
Very unlikely	15	1	1	0	1	1
Unlikely	12	8	2	0	0	0
Possible	70	18	7	1	2	4
Likely	40	13	11	3	4	5
Almost certain	12	4	8	2	5	3

In cases where the null hypothesis is rejected, further investigative analyses were used to understand the associations between the responses to the questions; either by comparing the values of the contributions $(o_i - e_i)^2/e_i$ or by using a correspondence analysis (Benzecri 1973). The advantage of correspondence analysis is that it provides a graphical representation to aid the understanding of the nature of the association. The aim of the method is to reduce the number of dimensions in the data by projecting and visualizing the multivariate data on a subspace formed by orthogonal axes (usually two to three dimensions) on which the total χ^2 value represented in the low-dimension subspace is maximal (see Greenacre, 1984). We used Genstat (Payne, 2011) directive CHIPERMTEST to calculate the permutation tests and the R package FactoMineR (Husson et al., 2017) for the correspondence analysis.

3. Results

The growers from California had orchards in the San Joaquin valley (MFTK) (60%), Ventura (16%), San Bernardino and Riverside (12%), San Diego (2%), Imperial (4%) and 'other' (6%) (see Box 2). Approximately half of the growers managed less than 100 acres of citrus (Fig. 1). Seventy-five percent managed conventional citrus, 5% organic and the remainder a mixture of the two. The proportions of different sized orchards and of growers that produced organic citrus were similar to values given by the state (National Agricultural Statistics Service, 2015; California Department of Food and Agriculture, 2015).

Forty percent of the Florida growers had orchards in the Indian River district, 27% in central and 24% Western, 6% Southern and 3% Northern (see Box 2). A greater proportion of the growers managed large areas (>200 ha) compared with those from California (Fig 1).

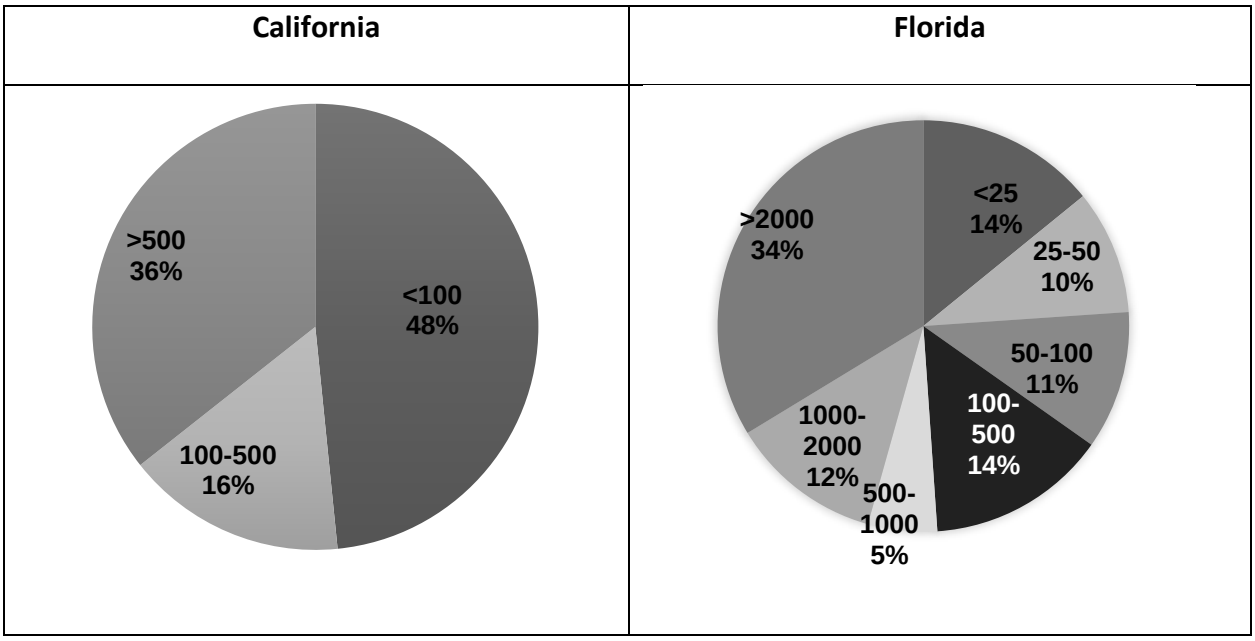


Fig. 1. The areas (acres) of citrus managed by respondents (percentage of respondents per category).

3.1 Risk perception

Sixty-seven percent of participants reported being aware that HLB had been found in California within three months of it being detected (April 2012–June 2012). The numbers of participants who became aware over the next three years decreased with time from detection (see Supplementary materials S2). The awareness of the problem was slightly slower to spread to growers in Florida with 56% reporting that they knew HLB had been detected in Florida within 5 months (August 2005–December 2005). After the devastation caused by the disease in Florida, the media and other information sources are likely to have been more responsive in spreading the news of the first infection event in California, and this would explain the difference in the rate of awareness.

Approximately half of the growers surveyed in Florida and California thought it "possible" that their orchards would become infected when they first learned of HLB (Fig. 2). The growers in Florida were reportedly slightly more pessimistic than those from California, but this difference was not significant according to the χ^2-permutation test.

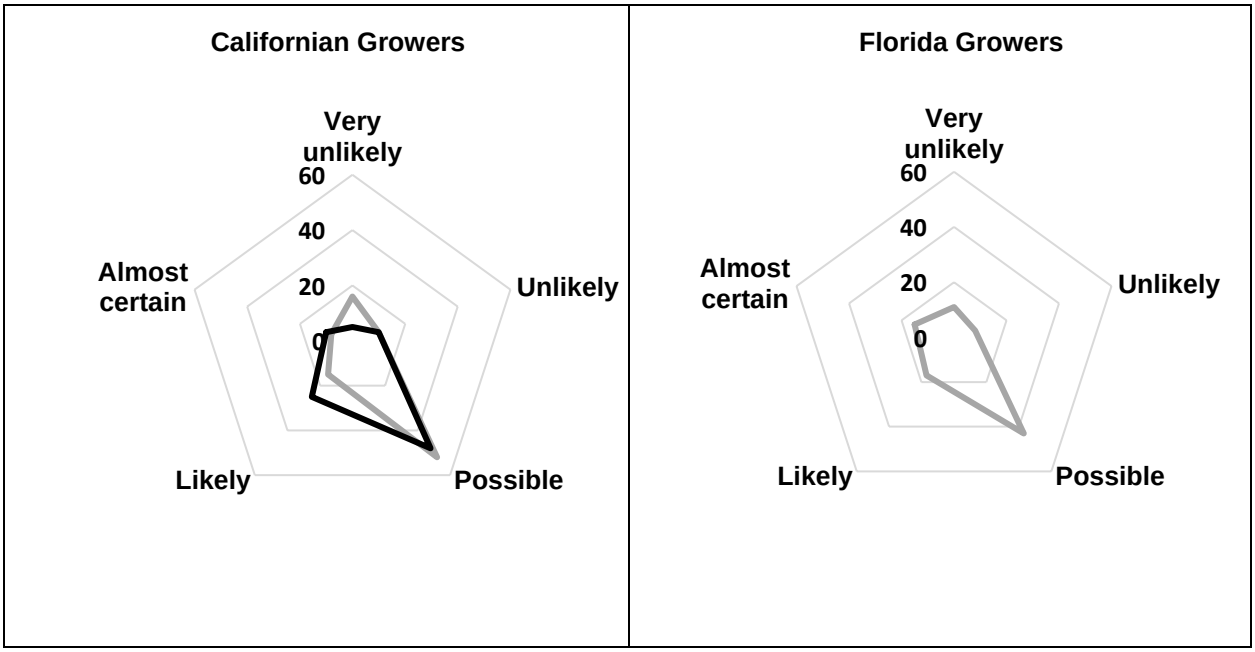


Fig. 2. The risk perception of becoming infected with HLB at the time when infections were first identified in each state (dark grey line) and at the time the survey was done (black line).

We also asked the California growers currently, how likely they felt it was that their orchards would be infected within 5 years. The results show that the growers were more concerned that their orchards would become infected with HLB than they had been when they first learned about the disease, although the evidence against the null hypothesis of no change in risk perception was not strong (p=0.063). We note that at the time of the surveys no further infection events had been recorded in California and so change in perception was not influenced

by witnessing a spread in the disease, but may have been influenced by ongoing spread of the vector .

In California, there was a significant association between the location of an orchard and the participants' perception of risk of infection within 5 years (p=0.016). More participants than expected with orchards in San Bernardino, Riverside, San Diego and Imperial counties thought they would 'almost certainly' be infected within five years, while more growers than expected from the San Joaquin Valley counties of Madera, Fresno, Tulare and Kern (MFTK) were associated with thinking infection was 'possible' or 'unlikely' (for map see Box 2). There was a slightly weaker association between growers with orchards in Ventura (Coastal California) and feeling that infection was 'possible' or 'likely', while those classified as 'others' were associated with believing infection was 'very unlikely' (see Supplementary material S3).

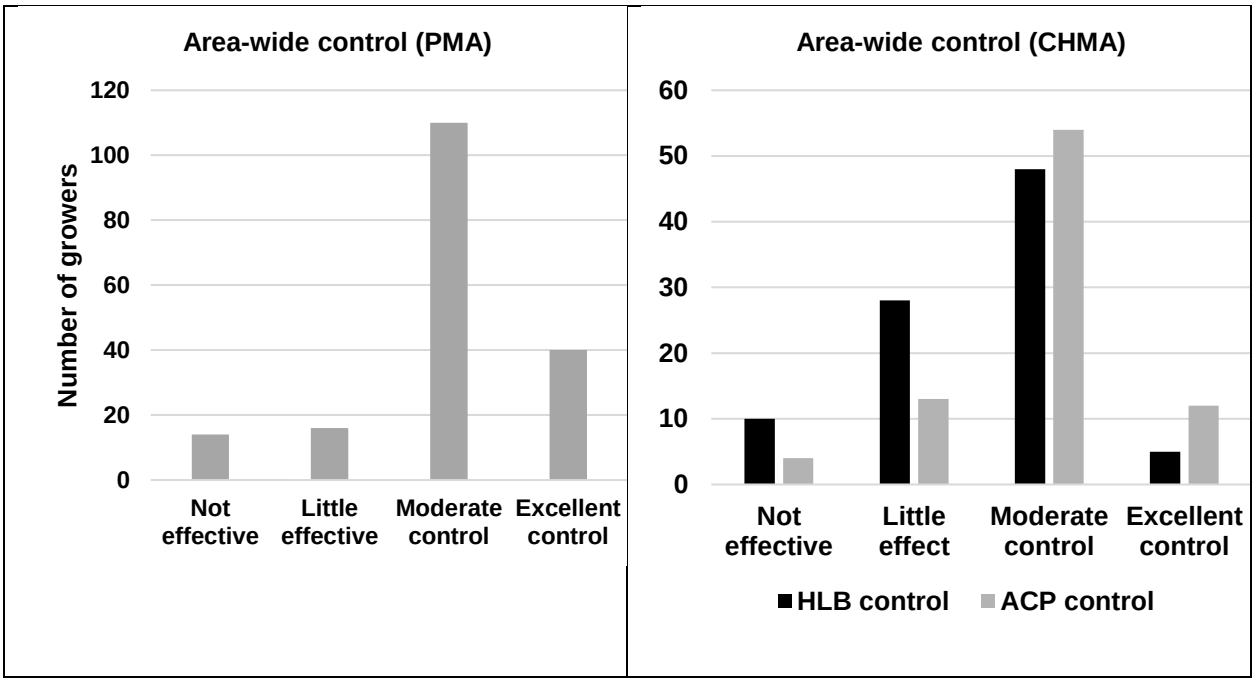
In Florida, we also found significant associations between location of the orchard and the perception of risk when growers first learned about HLB (p=0.021). More growers than expected from Northern and Central CHMAs thought it 'unlikely' or 'very unlikely' that their orchards would be infected, whilst more growers than expected from the Indian River district (central East Coast of Florida) thought it 'likely' that they would become infected, and growers from Western CHMAs were associated with believing it 'almost certain' they would become infected (for map see Box 1 and Supplementary material S3).

3.2 Trust in control options.

There was no significant difference between Florida and California in the level of trust in the effectiveness of area-wide control of psyllid populations (Fig. 3). Most growers were of the

opinion that area-wide control was moderately effective, and only a small percentage of growers consider area-wide control to be entirely ineffective.

Fig. 3**.** Florida and California grower ranking of the effectiveness of area-wide control against HLB (black) and ACP (gray).



There are, however, differences in the trust in the effectiveness of psyllid control programs. California growers had a higher trust that insecticide applications are effective than Florida growers (Fig. 4). This holds both for the lower application rate programmes of less than 4 sprays per season and for the high application rate programs of more than 4 sprays per season.

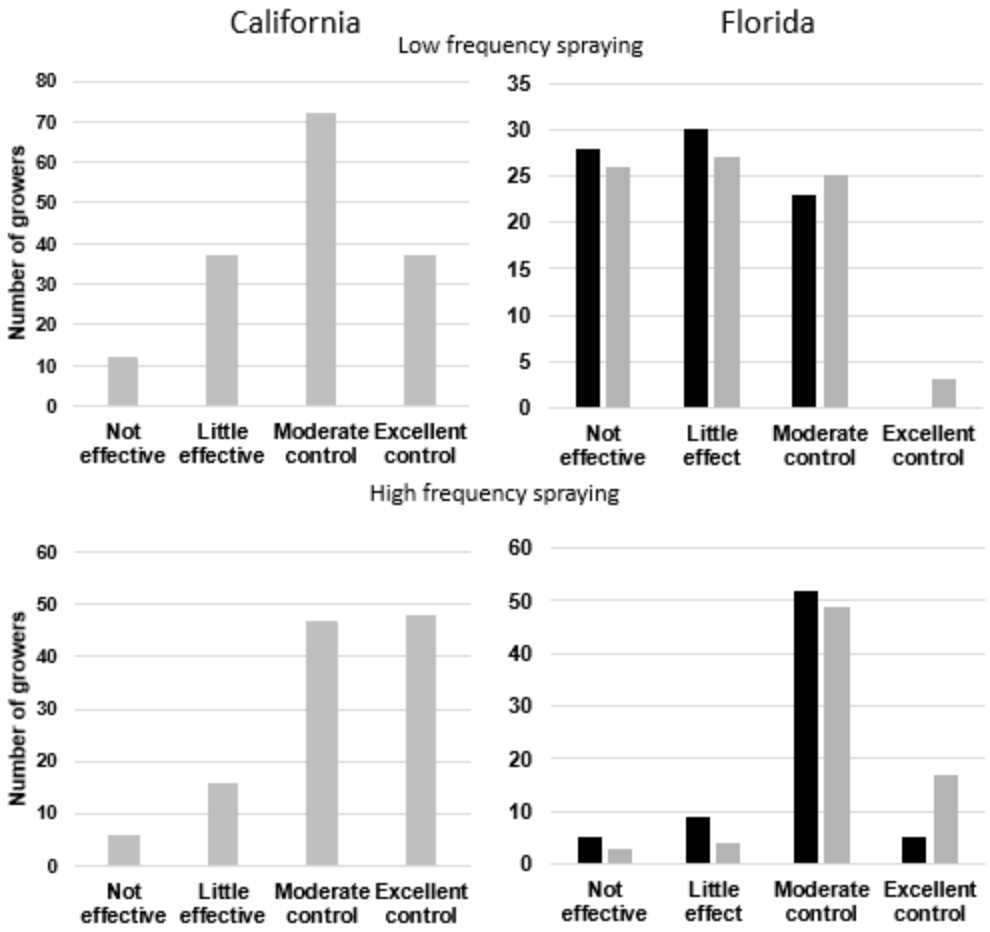


Fig. 4. Florida and California grower ranking of the effectiveness of insecticide spray treatments against HLB (black) and ACP (gray).

There were significant associations between the location of the participants' orchards and how they perceived the efficacy of spray control in California but not in Florida (contingency tables with p-values are listed in Supplementary S4). The growers in the San Joaquin Valley, where observations of psyllids were relatively sparse, had a more positive view of spraying insecticide for the control of ACP (generally rating them moderate to excellent) compared with

1 those from other counties (in particular Imperial, San Bernardo, and Riverside) where the psyllid
2 populations are consistently much greater and have been resident for several years.

3 There were significant associations between California growers who were not planning to
4 join a PMA and those that considered them ineffective, and those who were planning to join a
5 PMA that rated them effective ($p=0.05$).

6 There were significant associations between where participants learned about HLB in
7 California and how they rated control methods. Those who learned from other growers tended
8 to rate tree removal, and spraying as having 'little effect' on ACP control, whereas those who
9 learned from grower meetings where associated with rating spraying methods more positively.
10 There is also an association between poor PMA ratings and having been convinced to join a PMA
11 by other growers. There were no similar associations in the Florida data.

12 *3.3 Communication pathways*

13 Extension agents and researchers had a substantial role in disseminating the news that
14 HLB had arrived in each state (Table 3). Grower meetings (at which growers interact with
15 extension agents, researchers and peers) also played an important role. In California, the media
16 play a notable role with 35% of the responses indicating the media as a mechanism by which they
17 first learned about HLB. This starkly contrasts with Florida where only 10% of responses indicated
18 the media as a source of information.

19

Table 3

Responses to questions that relate to sources of information and interactions.

	Percentage of participants	
	California	**Florida**
How did you find out HLB was present in your state?		
Researchers or extension personnel	25	44
Crop consultants	7	14
Media	36	10
Other growers within 5 miles of my orchard	2	8
Other growers within 5-30 miles of my orchard	5	10
Grower meetings	26	14
What factors made you realise HLB was a threat?		
Researchers or extension personnel	10	14
Crop consultants	3	5
Increased media attention	8	7
Other growers	3	11
When HLB was found in Florida	26	-
When HLB was found in California	49	-
Not seen as a threat	1	-
When HLB was found within 30 miles of my orchard		15
When HLB was found within 5 miles of my orchard		6
When HLB was found in my orchard		42
Who or what influenced you to join a CHMA or PMA?		
Researchers or extension personnel	48	46
Crop consultants	9	8
Media	7	2
Other growers within 5 miles of my orchard	2	8
Other growers within 5-30 miles of my orchard	2	27
Grower meetings	32	9

The responses about which factors made growers realize HLB was a threat show a strong proximity effect (Table 3). In Florida, growers indicated finding the disease in their orchards as the most important factor, and in California the growers indicate the presence of the disease in the state. Other commonly indicated factors also involve observing the disease (i.e. when the disease was found in other growers' orchards or found in another state).

Researchers, extension agents and grower meetings played a large role in influencing the decision of growers to join area-wide control programs in both states (Table 3). Interestingly, in Florida 'other citrus growers' also play a substantial role with 35% of responses indicating this as an influence on them joining compared with only 4% in California.

There was a significant association between the participants who realized HLB was a threat through communication with other growers and participants being almost certain that their orchards would be infected within 5 years ($p=0.003$)). In other words, although the one-to-one communication is not prominent, it was significantly involved in raising awareness that HLB is a threat.

3.4Joining CHMAs and PMAs

At the time of the survey, 68% of growers in California had joined a control program. A further 8% of growers planned to join, bringing the total to just over 75%, the other groups were mostly undecided. Similarly, of the growers we surveyed in Florida, 76% said that they had joined a control program. These participation rates are similar to the estimate of the threshold for success, which is 75% (T. Gottwald, November 2015), but do not account for residential citrus. We note that when Singerman et al. (2017) surveyed a group of 123 growers from Florida only 63% stated that they participated in a CHMA.

The biggest concern about joining the control program for the California participants was the level of participation by other growers (30%), followed by costs (18%) and number of sprays required (13%).

Growers who do not see HLB as a threat and those who thought it was unlikely that they would be infected with HLB when they first found out it was in California were significantly associated with the view that joining a control program was not effective. There is also an association between growers that have a high trust that control options will be effective and the tendency to be willing to join an area-wide control program. These trends are visualised in Fig. 5. Five of the growers who had rated 'Risk of infection' as probable or greater and 'Area-wide-control' as moderate or excellent said that they would not join a PMA. These growers were in the MFTK area of California where there were very few psyllids at the time of the survey and no imminent threat of HLB.

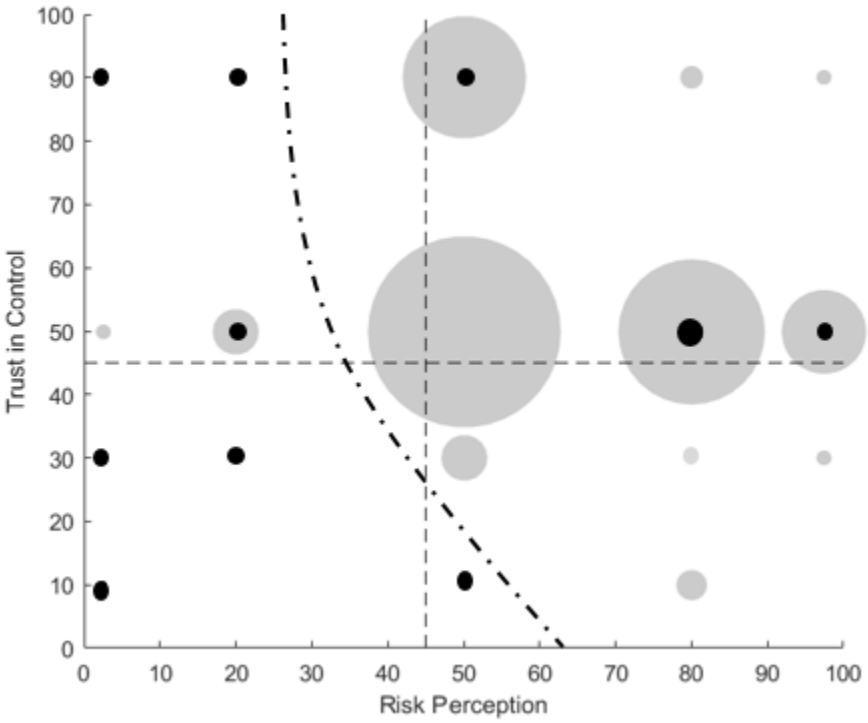


Fig. 5. Responses to the Californian surveys (113 in total) mapped onto the conceptual model for joining an area-wide control program. The grey discs represent growers who said that they had

joined a PMA or who planned to join one. The black discs represent those who said they did not plan to join. The area of each disc is proportional to the number of growers it represents. The smallest discs shown represent 1 grower. The curve line delineates the conceptual boundary between those who chose to join an area-wide control programme and those who did not.

4. Discussion

Our results lead to the conceptual model shown in Fig. 6. Risk perception and trust in control options are central to the decision by growers on whether to join an area-wide control program. The results from our survey support this, with significant associations between growers joining area-wide control programs and (i) risk perception and (ii) the ratings given to area-wide control programs (Fig. 5).

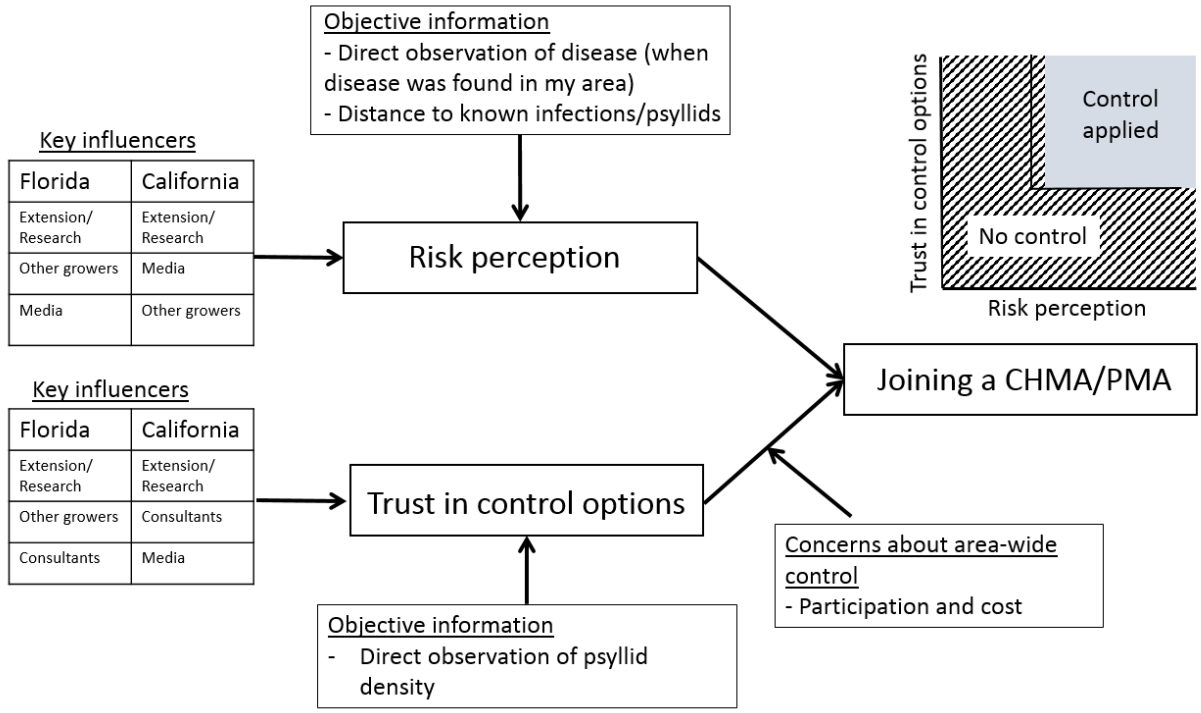


Fig. 6. A conceptual model of the decision process for whether to join an area-wide control program or not. Risk perception and trust in control options are central to the growers' decisions. Our results show that these factors are influenced by researchers and extension agents, other growers, the media and consultants. Direct observations of disease and the effectiveness of control options also influence the growers' opinions and there is a strong association between risk and proximity to disease. Concerns about participation and cost of sprays erode the growers' belief that area-wide control is or will be worthwhile.

The growers' perceptions of the two central pillars of the decision-making processes (risk perception and trust in control options) are influenced by information networks and observations

made by growers about the state of the epidemic and psyllid populations (Fig. 6). Indeed, observations that the disease was near were reported to have the largest influence on risk perception (Table 3). In both California and Florida researchers and extension agents were reported to have the largest role to play in grower awareness of the disease (Table 3). The survey results, however, suggest a stark contrast in the role of the media in the two states, with 35% of growers from California reporting this as the mechanism by which they first learned about HLB compared with 10% from Florida. This may reflect the fact that the infection in California followed on from the devastation the disease caused in Florida and so made the occurrence of the disease a more prevalent news-worthy event. Generally, across the responses to all three questions on communication networks, the grower-to-grower communications were much more influential in Florida than in California. External information sources (comprising extension, grower meetings and media) were far more important for growers from California who relied much less on other growers for information than the growers from Florida did. This contrasts with other studies in more rural areas where outsiders are sometimes mistrusted and the "one-to-one" communication pathways are favoured (Castella et al. 1999; MacDonald, 1984). The relatively high emphasis on external information sources in California may also reflect the fact that, in the absence of the disease in commercial citrus, there is little for California growers to discuss in peer-to-peer conversation. This supports our hypothesis that differences between the responses of growers from California and Florida reflect the different durations of the epidemics in the two states and the associated level of damage caused by HLB. If and when HLB becomes widespread in California we anticipate that word of mouth spread of information will become more

important; something, again, which coordinating agencies should bear in mind in developing future strategy.

Risk perceptions of citrus growers to HLB are in line with what has been found in general in the literature on risk (Severtson and Burt, 2012; Arias et al., 2017); the level of perceived threat has a strong proximity component (where proximity can be measured in space and/or time). In California, we found significant associations between levels of perceived risk and the locations of growers' orchards. Growers close to the initial infection event and in areas where ACP density is greater were associated with risk ratings of 'almost certain' and 'likely' whereas those in areas further away from the initial infection site and where ACP was at low density were associated with risk ratings of 'possible' and 'unlikely'. Similarly, in Florida we found significant associations between location of the orchard and the perception of risk when growers first learned about HLB. This result is likely to be associated with the location of the initial survey for HLB which extended from extreme south-east Florida, up the east coast north to approximately Ft. Pierce. Thus, growers in this area were exposed to the possibility that the pathogen was present in their proximity because of the survey activity early in the epidemic. This result has implications for the communication strategy that might be used by extension and regulatory agencies when attempting to update growers on the status of the disease. Because perceptions of the level of risk are connected with the proximity of disease, and because the attitudes toward the value and efficacy of control are connected with perceived risk, it is important that growers be given frequent and accurate updates on the location and intensity of disease outbreaks as well as clear information on appropriate control measures.

Opinions on control were most influenced by researchers and extension agents (Table 3). There was no significant difference between Florida and California in the level of trust in the effectiveness of area-wide control of psyllid populations (Fig. 3). This is surprising as it implies that the trust in area-wide control has not eroded during the course of the epidemic in Florida. Differences in opinion between California and Florida growers as to the efficacy of independently applied insecticide treatments (Fig. 4) can be viewed as largely a function of experience (supporting our hypothesis on this). At the time of the surveys very few California growers had extensive experience of trying to suppress ACP populations. In comparison, most, if not all, Florida growers had several years' experience. We observed that growers from areas with lower densities of psyllids were associated with rating insecticide control, in general, more positively than those where psyllids were denser. More recent anecdotal evidence suggests that the views of California growers in the southern areas of the state (where ACP populations have increased rapidly and where HLB has been found in more than 400 residential trees) are now more closely aligned with those of Florida growers, while most of the California Central Valley citrus acreage has yet to experience ACP infestation and HLB has not been detected.

Of importance for California, going forward is the finding that a large proportion of growers identified anticipated lack participation by others as a reason why participation in area-wide control might not occur. This indicates that control program effectiveness is susceptible to a classic failure of cooperation (Schneier, 2014); i.e. believing that a large proportion of others will not participate, and knowing that participation is pointless unless a sufficiently large fraction of the population does so, individuals elect not to participate, resulting in a self-fulfilling prophesy of failure. This finding highlights the importance of infrastructure to support communication and

coordination among growers. These findings from California are broadly in agreement with recent results reported by Singerman et al. (2017) for CHMAs in Florida.

A smaller proportion of growers identified negative impacts on IPM as a concern. Whether this will ultimately cause failures in the ACP control effort remains to be seen. In some areas of California growers are reporting that problems such as red scale, that have not been an issue for over a decade, are re-emerging as orchards are treated with insecticides to suppress ACP effectively eliminating the natural enemies of red scale. When a desire to retain IPM is combined with a view that the HLB risk is relatively distant, the conditions may be created for some growers to prioritize IPM at the expense of effective ACP suppression. Again, this potential highlights issues that the CPDPC should observe carefully and prepare an action plan for intervention if needed.

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