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RESEARCH ARTICLE

Psychosocial barriers and facilitators for area-wide management of fruit fly in southeastern Australia

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Abstract

Social mechanisms underpinning collaborative approaches to pest management are as important as the biological control of the pest. To facilitate the success of an area-wide management approach, social factors need to be understood and addressed. This study qualitatively analyses social, psychological and institutional barriers and facilitators for the widespread adoption of area-wide management of Queensland fruit fly, and attitudes towards the use of sterile insect technology. Interviews were conducted ($N = 35$) with fruit growers, industry representatives, agronomists, government representatives and community leaders from across the dominant horticultural regions of southeastern Australia. Transcripts were analysed and compared based on thematic organisations. Growers and stakeholders expressed high acceptance for area-wide management of Queensland fruit fly and the use of sterile insect technology. However, participants reported limited knowledge of both area-wide management and sterile insect technology. Factors found to facilitate acceptance were perceptions of increased market access, increased social awareness, operationalising community champions and value chain actors, as well as dissemination of credible scientific evidence. Trust in those individuals advocating area-wide management and sterile insect technology, and interpersonal trust between neighbours, was also seen as an important factor affecting adoption of area-wide management and sterile insect technology. Barriers to acceptance included perceptions of costs and ongoing funding needs, lack of knowledge, apathy towards control of Queensland fruit fly, compatibility of area-wide management and sterile insect technology with current practices and a lack of social cooperation amongst growers. The data show a need to increase growers' awareness of costs and benefits associated with Queensland fruit fly control and an understanding of the direct and indirect consequences of their own on-farm behaviours with respect to control. This study is the first to use a psychological lens to explore and distil grower and stakeholder attitudes towards a cooperative management approach for a pest of national significance. Results provide insight into beliefs that guide underlying biosecurity decision-making and can help improve uptake of other area-wide control techniques.

Keywords Innovation adoption · Social science · Pest management · Attitudes · Horticulture · Farmers

1 Introduction

The prevention, control and eradication of invasive species such as insect pests are often equally about the biological control of the fly and the underlying social and institutional mechanisms in place (Jang et al. 2005). These factors prepare a social and institutional environment that facilitates and optimises biological controls. Insect pests, in particular, are difficult to control because of their ability to be independently mobile and survive through winter seasons. This research examines the case of Queensland fruit fly and aims to identify and describe socially relevant barriers and facilitators for the uptake of area-wide management as a means of pest control.

Queensland fruit fly (*Bactrocera tryoni*, 'Qfly') is the most destructive *native* species of fruit fly in Australia and is

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amongst six types of fruit fly that are classed as 'pests of horticultural significance' by the Horticultural Policy Council (Jessup et al. 2007; Clarke et al. 2011). It represents a threat to over $432 million in export trade and an additional $1 billion worth of domestic produce (Dominiak and Ekman 2013). Given that Qfly is adaptable, mobile and damaging, the most reasonable method of Qfly control is to adopt an area-wide and integrated approach. Area-wide approaches have achieved success in controlling and eradicating other mobile pests around the world (e.g. Lax et al. 2005), including other fruit fly species (e.g. Allahyari et al. 2016). However, social factors need to be understood and addressed in order to ensure cooperation amongst the various players and facilitate successful area-wide management. The objective of this paper is to explore the dominant facilitators of, and barriers to, adopting an area-wide management approach for Qfly in southeastern Australia.

1.1 Area-wide management

Area-wide management (AWM) of insect pests is a control strategy applied, as the name suggests, across a defined 'area' that targets the entire pest population within it (Vreysen et al. 2007). The control tools employed in the operation of AWM programs for fruit fly management around the world are consistent and rely primarily on farm hygiene, protein bait sprays and male annihilation technique (MAT), with chemical sprays, biological control agents and sterile insect technique/technology (SIT) where available (Suckling et al. 2016). AWM for mobile pests is a sensible approach; extending pest management beyond individual farms using an AWM approach has been shown to be effective in preventing reinfestation (Lax et al. 2005). A comprehensive and coordinated strategy across multiple host areas can achieve more sustainable, effective and longer-lasting suppression of mobile pests such as Qfly (Chandler et al. 1999; Vargas et al. 2010; Vreysen et al. 2007), rather than individual growers seeking to control the pest on their own properties alone (Fig. 1).

Local- and regional-scale AWM initiatives may involve groups of commercial growers working with urban communities and relevant authorities to achieve control across multiple host areas. AWM initiatives can be wholly controlled by, or via co-operation between, government, industry (growers) and third-party private sector interests (e.g. fruit processors, rural supply firms, pest management firms, farm consultants). Therefore, the interactions and interrelationships between each of these actors within an area-wide approach need to be optimally designed to achieve the pest management objectives of AWM.

1.2 Psychology and sociology of agricultural innovation adoption

The idea of human behaviour change as being central to the adoption of a new technology or innovative practice has been strongly argued by key sociologists and economists in the agricultural domain (e.g. Pannell et al. 2006). There is sometimes an assumption that technical superiority of an innovation is enough to motivate social adoption because of the clear advantages an innovation may provide over alternatives. However, humans do not make decisions based on sound objective logic; rather, people filter selective information through unique and individualised lenses. This process attributes personal meaning and emotional connection to the information being presented to aid decision-making (Mankad 2012).

Fig. 1 Photo of a Queensland fruit fly (Qfly) trap, used for monitoring Queensland fruit fly numbers as part of a trapping grid

Social dimensions examined in the present study comprise both *psychological* (personality, cognition, motivation, personal norms, attitudes, perceptions) and *sociological* aspects (environmental context, sociodemographic factors, cultural norms, social networks, trust, institutional influences). These factors provide important mechanisms for driving *intentions* to change behaviour and ultimately facilitating *actual* behaviour change. While it is true that for many growers the final decision to adopt or not adopt a new practice or innovation is based on economic advantage, there is substantial evidence in the literature to broaden that understanding. Numerous social variables influence perceptions of this advantage and acceptance for novel innovations and applications (e.g. Simin and Janković 2014). Characteristics of an innovation, and of the required behaviour change, will also influence the probability of farmers adopting new practices (e.g. Allahyari et al. 2016). For example, Batz and Peters (1999) analysed the impact of technology characteristics on the rate and speed of adoption amongst farmers. They found that farmers were quick to adopt new behaviours if the changes promised greater utility than current methods. Further, if there was a possible *biosecurity* risk associated with non-adoption of the new innovation, then growers were sensitive to this increased risk and were more motivated to change their behaviour to reduce the chance of a biosecurity incident.

1.2.1 Attitudes and social norms

As Mankad (2016) describes, the function of attitudes and beliefs in the context of biosecurity-relevant behaviours is to guide decision-making and risk assessment. Attitudes provide evaluative information about a behaviour or context and help to determine what people do and why they do it. Farmers will likely have pre-existing ideas about pest management on their farms and strategies for examining pest risk, pest control and eradication. These attitudes have likely been formed through past experiences with a pest or management strategy, as well as through past cognitive, behavioural and emotional responses to a relevant or relatable situation. This is, of course, notwithstanding the important economic drivers of decision-making within the pest management context. Therefore, underlying attitudes about pest control, threat vulnerability and recommended behavioural responses to pest management will influence whether individuals perceive area-wide strategies as problematic or helpful.

The role of social norms can also be a significant factor in defining how people view tasks or changes in habitual practices (Godin et al. 2005). This can further highlight potential social barriers or facilitators for desirable behaviour change. Amongst farmers, there are likely to be perceptions of 'normal' or accepted behaviours that guide personal farming activities (*descriptive norms*), individual beliefs and attitudes that influence trust in information and its source, and personal expectations regarding appropriate/moral behaviour within a broader social setting (*personal norms*). The social guidance provided by descriptive norms, and the value-driven assessment of individual and group behaviour reflected in personal norms, is particularly important in the context of area-wide management. AWM works best when those involved trust each other, perceive a shared commitment to change and have similar goals to ensure that pest management behaviours are implemented correctly and coordinated across multiple individuals. As Vanclay et al. (2006) describe, the social nature of farming is such that social norms are an inherent part of farming culture. Further, if members of the broader group believe that one or two others within the group are not contributing to the joint task, then attitudes and descriptive norms will come into play (Kruger 2016). These cognitive drivers will dictate whether individuals continue their involvement in shared activities because their attitudes compel them to (for gains or altruism), or whether they too engage in social loafing (i.e. free-riding) because it is deemed acceptable to do so. Social and psychological factors such as attitudes, beliefs and social norms will also likely influence farmers' interpretations of biosecurity risk.

AWM also requires a significant amount of social cooperation across diverse individuals, businesses and communities, and sometimes across multiple industries that may or may not have shared interests in controlling a pest (Kruger 2016). The joint effort between different individuals and groups in the context of AWM essentially reflects a binding social contract whereby each party agrees to abide by the principles of AWM in order to manage the biosecurity threat (Karami and Keshavarz 2010). Therefore, in order to encourage widespread adoption of recommended AWM behaviours, an understanding of the perceived barriers and facilitators amongst individuals *and* groups involved is essential to mitigating non-adoption behaviours.

1.2.2 Institutional factors

Psychological factors such as personal attitudes and norms help to explain individual-level barriers and facilitators of AWM and resultant behavioural change. The relationships between groups at various levels of organisation are explored through an examination of institutional factors. At a broader level, these are the formal and informal rules, arrangements and systems that govern human behaviour and interactions (Barnett et al. 2011; Young 1999). They include mechanisms (from 'hard' to 'soft') such as legislation, laws and regulations, policies and programs, contracts, guidelines, procedures and standards, and norms and conventions of behaviour. The present study will discuss various institutional factors (e.g. leadership, community engagement, knowledge creation and transmission) from a psychosocial perspective and how these factors are likely to influence innovation adoption and behaviour change. We will not, however, engage in a comprehensive institutional examination in this paper.

1.3 Present study

The purpose of this study is to qualitatively explore social, psychological and institutional factors influencing widespread adoption of area-wide management of an insect pest, from the perspective of growers and industry stakeholders. The study further examines attitudes towards the use of SIT, a relatively novel agricultural innovation in the test regions. SIT, in the present example, would be used as a supplementary control tool in the context of AWM. Key themes were identified as being either barriers or facilitators of AWM adoption. We will discuss the implications of these factors and provide recommendations to address barriers and facilitate drivers for implementation of AWM. We believe the results from this research will have global implications for understanding social and institutional barriers and facilitators for improved uptake of mobile pest management initiatives.

2 Materials and methods

2.1 Participants

Participants ($N = 35$) comprised fruit growers, fruit industry representatives, agronomists and field officers, state government representatives and community/local

government representatives (see Table 1). In some cases, participants belonged to more than one participant group; the typical example being a grower who was also a representative of a fruit industry association. Participants were recruited through a designated project coordinator and a snowball technique was further employed, to gain additional participants.

All interviewees were over the age of 18 years and the majority were male (83%). This gender discrepancy was expected in a male-dominated industry (> 70% of farmers in Australia are men) (Australian Bureau of Statistics 2012). Participants were recruited from three horticultural regions across southeastern Australia: the Murray-Goulburn Valley and Sunraysia, which fall primarily within Victoria but extend into NSW; and the Riverland of South Australia. Each region varied with respect to Qfly population status, with the Riverland of SA a recognised pest-free area (PFA), Sunraysia a pest-regulated region and Murray-Goulburn Valley an endemic pest region.

2.2 Procedure

A semi-structured interview guideline was developed to encourage participants to talk about

- General thoughts regarding, and experiences with, Qfly
- Area-wide management and related behaviours
- Sterile insect technology as a potential additive tool to target Qfly

Due to the novelty of SIT, particularly in terms of its commercial availability, which is still the subject of research and development in Australia, only a general definition of the concept could be provided to participants, in the absence of specific details on likely costs, release methods and program funding strategies. Rather, their understandings and preferences for the application of SIT were sought to ascertain potential barriers and enablers for acceptance.

Interviews were audio-recorded with permission from interviewees and transcribed verbatim by an external transcriber. After informed consent was obtained from the participants, the content portion of the interview commenced. One-on-one telephone interviews were conducted with most participants; however, in some cases, the interviewees brought along one or two colleagues to participate also. This was determined unproblematic, as participants felt the discussion content did not highlight any conflicts of interest. This research study received ethical clearance from the relevant Human Research Ethics committee.

2.3 Data analysis

Transcripts were coded and analysed by two researchers who were part of the project team. Participants' interview content was categorised independently by the coders and then compared based on thematic organisations, also known as inductive category development (Hsieh and Shannon 2005). Words and statements were grouped based on their context and thematic relevance. Inter-rater comparisons were made to validate the analysis procedure and reduce interpretational bias; differences between coders were resolved through discussion (Weber 1990).

3 Results and discussion

The data presented in Table 2 represent the two broad categories of results: (1) barriers to the uptake of AWM and SIT and (2) facilitators of adoption of AWM and SIT. Results are based on the content analysis of interview transcripts, and Table 1 includes key quotes to illustrate the emergence themes.

Table 1 Breakdown of interview participants by region and occupational or sectoral category

Category	Murray-Goulburn Valley	Sunraysia	Riverland	Multi-regional^	Total
Fruit growers	8*	7*	4*		19*
Fruit Industry Association	1*	2*	2*	4	9*
Agronomists/field officers	3	2	0	1	6
State government	0	2	1		3
Local government	2	1	0		3
Community group	1	0	0		1
	13*	12*	5*	5	35

*These figures include participants who provided contributions in more than one category (typically, a fruit grower who was also a fruit industry representative); hence, the figures often sum to more than the column totals

^Some participants, mainly national-level fruit industry association representatives, but also a company field officer, operated across more than one region

Table 2 Broad themes found in interview data, comprising barriers and facilitators of AWM and SIT, emerging across all three (3) horticultural regions targeted. Direct example quotes are given from the interview data for illustrative purposes

Barriers	Examples
Cost	"The biggest [barrier] is the cost and their own situation…growers are struggling with their backs to the wall and would do as little as they can and try not spend any money… they're reluctant to do anything at all. And it hurts everyone else but that's the reality of it"
Lack of knowledge	"The first time we saw a fly in Cobram was three years ago, but growers were sceptical that it was here. They couldn't identify them properly because they didn't know exactly what they look like, didn't want to spend money on chemicals"
Apathy	"You know what growers are like, they don't want to admit that there is anything wrong, and to have a shared approach you have to admit there is a problem." "It's unfortunate but a lot of growers don't give a [curse] until it affects their pocket" "The old story, 'I'm too busy', 'when it happens I'll deal with it'. That's what generally happens"
Incompatibility	"Changing custom of practice can be a very difficult process. I think there would be a real challenge in some areas to ensure that if the sterile insects are introduced that they are not going to be knocked out by indiscriminate use of chemical control"
Lack of cooperation	"There is an attitude amongst a lot of growers that 'the neighbours can do it and I'll get the benefits'" "Usually things have got to get pretty bad before they'll get forced to work together"
Facilitators	Examples
Market access	"I think if you look at the benefits associated with market access for citrus and table grapes, that is a key motivator in itself"
Awareness	"I think with a little bit more education everybody knows that to eradicate these pests you've got to do it very very rigorously. You can't almost do it. You have to absolutely do it."
Leadership	"I think if you got the big growers on-board, a lot of the small recalcitrant ones will look at the big fellows and say, 'they're doing it so I probably should be'… There will be a certain segment of the growers that will refuse to do it because they have been told to do it" "There are always innovators, leaders, then followers and anchors in every community… in our region here there are all of those…"
Supply chain actors	"They [packers] are just a really effective conduit to growers" "There are a lot of growers who don't do their own fruit packing anymore and a lot of them supply three major packing sheds… each one of those packing sheds may have 30 suppliers and right there you have 90 growers which is a fair portion of the industry. What I'm saying is that maybe those packing sheds, particularly the buyers of the fruit, maybe they can influence the growers"
Credibility	"If they see damage then they really get on board pretty quick. Then it just comes down to the cost of treatment. As long as it's not outrageous then they will get on board"

3.1 General acceptance of AWM and SIT

Participants, overall, indicated high acceptance for AWM and SIT. Interestingly, there was a strong perception amongst growers that they were already carrying out AWM. This was aligned with researchers' observations that many interview participants, particularly growers, held inconsistent definitions of AWM. Most had a limited understanding of current definitions for AWM; for example, limited knowledge of what constituted a defined area as it related to AWM, who needed to be involved in AWM, and what individual and group involvement would actually 'look' like as part of an area-wide approach. Participants made little mention of coordination with others within a defined area. When participants did consider AWM to involve coordination or cooperation with neighbours, it was usually qualified with a provisional statement relying on joint commitment. Growers were willing to be involved in a coordinated AWM effort as long as everyone was involved (e.g. neighbours, towns) and saw cooperation, or lack thereof, as their only personal barrier. The further emergence of social loafing and conditional participation as potential factors limiting widespread adoption of AWM will be presented in more detail within Section 3.2.5. Growers and stakeholders alike believed that the general community would be accepting of AWM if they were given appropriate information. Further, area-wide activities would need to be simple and require little investment at the individual level, such as time and cost.

General acceptance for AWM and SIT was high amongst stakeholders. However, participants had many questions about the Qfly pest itself and, in particular, the possibility of SIT availability and use. These questions seemed to be driven by a curiosity about SIT amongst participants, rather than a desire to question the legitimacy of the technology. Participants considered SIT to be a preferable method of Qfly control over spraying and trapping, but assumed it would be an expensive option requiring high up-front investment costs, particularly for farmers. Unexpectedly, many growers indicated that they believed there was no real need for consultation if SIT were to be introduced, at least amongst the

farming community. Growers felt that SIT was a simple concept to explain and anything to combat Qfly was better than nothing, given the significant threat Qfly posed. If SIT were available, then there was a strong belief that it should be implemented as soon as possible because Qfly was a genuine, significant and present threat to many growers' businesses. Some expressed frustration that SIT was not already being used in the interview regions, given all the publicity surrounding SIT and its use with other insect pests.

Perceptions of broad community acceptance of SIT were positive amongst growers and stakeholders. Most stakeholders believed the community/general population would offer little resistance to the introduction of SIT if (a) the implementation of SIT did not require any additional effort from members of the general public and (b) if the sterile flies were imperceptible to townspeople. However, some participants cautioned that managing expectations related to what SIT could offer all stakeholders would be key to ultimately introducing AWM and SIT as Qfly management strategies. The clear communication of accurate advantages and disadvantages of both AWM and SIT might ensure that potential consumers would hold realistic expectations of efficacy, and not view SIT as a panacea.

3.2 Barriers

3.2.1 Cost

Cost was the dominant barrier cited amongst participants with respect to uptake of AWM. Specifically, stakeholders had concerns around additional costs that AWM and, in particular, SIT might impose at the grower level. There was a consistent view amongst participants that if relative costs of AWM and SIT were seen to be prohibitive, then this would be the largest barrier to widespread involvement in AWM with SIT. However, it was also clear that barriers associated with AWM response costs (including time and money) could be managed if relevant parties perceived a value for money (e.g. the business value of SIT versus gains from traditional trapping and monitoring only). Many growers stated they would be happy to overcome certain financial limitations if they were provided with evidence of reductions in wild fruit fly numbers and related market benefits. However, at the time of data collection, the perceived effectiveness of trapping and monitoring on-farm was high amongst growers and, thus, a clear value proposition for using SIT would need to be made. Suckling et al. (2016) showed that as area under management increases, so does the associated cost; however, decreasing size puts likelihood of success at risk. The economic benefits of AWM programs have been widely described (e.g. Mumford 2005) but can take several years to be successful (Suckling et al. 2016).

A second concern raised by participants was the long-term viability of AWM and SIT programs and infrastructure. Once implemented, participants were keen to know how the AWM approach using SIT was to be maintained in the long-term and from where it would receive its consistent funding. Growers particularly believed that a limiting factor for grower involvement would be if a stable model of AWM and SIT funding could not be guaranteed. Growers seemed wary of new initiatives that promised change but, in the end, did not have a sustainable funding model and, thus, broke down.

3.2.2 Lack of knowledge

Working definitions of AWM and understanding of the integrative nature of AWM were limited, particularly amongst growers. It was common for participants in this sample to take a literal and individualistic interpretation of what AWM was, defining it as area-wide pest management on individual properties. Thus, many growers explained that they were already carrying out excellent AWM on their own properties. This lack of knowledge highlighted poor awareness amongst growers of the potential behavioural and managerial changes that may need to occur to enable pest management within an AWM framework. Stakeholders (e.g. industry representatives, agronomists, government representatives) demonstrated greater understanding of the AWM definition. They expressed a concern that most growers and members of the general public were unlikely to be aware of the true meaning of AWM and this could be a barrier to key aspects of AWM, such as coordinating pest management activities across defined areas (e.g. ensuring all growers align management strategies to pest biology in a timely manner, or provided a platform to share information).

Other topics that growers felt less knowledgeable about, and believed that the general public would be less knowledgeable about, were specific to Qfly. This included the knowledge required to identify a fruit fly and understand its behaviours (e.g. preferred host fruits, contextual nuances, life cycle, flight). As a result, participants felt that asking growers and the general public to take part in AWM would, in effect, be asking them to make decisions based on incorrect or limited knowledge of the topic. There was evidence to suggest that there was low perceived importance of Qfly amongst growers of non-preferred host fruit. This was expressed as a belief that Qfly would not affect their fruit because there were other options for the fly. However, many of those growers were likely more susceptible than they realised and did not have accurate knowledge on the host susceptibility status. Some participants indicated that the deprioritisation of Qfly amongst some growers may stem from trying to efficiently manage the enormous attentional demands and day-to-day stresses experienced by growers. Growers were so inundated with multiple pest management issues on a daily basis that only those

experiencing an immediate threat from Qfly would likely be proactive in carrying out AWM strategies. Others likely lacked any 'spare' resources to invest in managing a pest that may not be causing immediate economic impacts and, thus, was seen to be less important.

3.2.3 Apathy

There was a perception amongst participants that a significant proportion of growers in the region believed Qfly control was irrelevant to their circumstances. Participants saw this view of irrelevance as stemming from an assumption by some growers that the type of produce they were growing was a non-preferred host. Apathy and/or disinterest can lead to a lack of drive to protect oneself and others from the threat of Qfly and a shifting of responsibility in AWM participation. The potential for apathy as a barrier to widespread uptake of AWM likely arises as a result of limited knowledge, more specifically limited knowledge of Qfly as a relative risk to one's crops and the broader industry. Participants explained that they were aware of mixed beliefs amongst peers with respect to individual susceptibility to Qfly and the economic threat Qfly posed to one's business. For example, present data suggested that there was a perception amongst table grape growers that their fruit was not a preferred host for Qfly. Consequently, it was believed these growers lacked motivation to engage in any type of Qfly control and redirected their efforts to other pests they believed were a greater threat. While it may be true that table grapes are probably less attractive to fruit flies when compared to a soft peach, it does not mean that fruit fly will not target table grapes if no suitable alternative presents itself (Dominiak 2011; Englefield 2016). While producers with sufficient information may be able to make informed choices about the relative costs and benefits to themselves of Qfly control, the danger lies in inadequate information about true threat. Notably, the relative preference of Qfly for one crop over another is less important when considering Qfly control in the broader context of AWM of a fruit fly infested or endemic area. The area-wide nature of control strategies would mean that *all* properties and host types within a designated area participate in the scheme and not just the highly susceptible ones.

3.2.4 Incompatibility

An important barrier to the uptake of an AWM initiative is the perception that AWM does not fit in with current practices. Participants noted that most growers had tailored routines for managing their farms and their most significant pests. In introducing an AWM approach, it would be important to ensure that the AWM activities that growers would need to undertake would, as much as possible, be compatible with existing on-farm behaviours. Further, it would be necessary to time SIT releases to suit growers' other key timings, such as spraying and harvesting. The issue of compatibility was also highlighted as being particularly relevant in regions or areas where several different crop types were being farmed, and the complications associated with coordinating the timings of AWM activities considering all different crops.

The potential barrier of incompatibility is probably more relevant in the case of general public participation in an AWM approach. While farmers are accustomed to modifying pest management behaviours such as pest surveillance, members of the general public are unlikely to have similar experiences. Interview data highlighted a perception amongst growers and stakeholders that many of the town centres situated in close proximity to the dominant fruit-growing regions were likely to be aware of the importance of the fruit industry in those regions. Further, many residents were likely to grow backyard fruit themselves and have an emotional and recreational investment in maintaining a good level of pest control in the town. Thus, 'invested' residents would likely be motivated to participate in AWM. However, similar to growers, residents saw the need for AWM activities to be compatible with daily household routines and have a low perceived cost associated with them (with respect to time, money and effort).

3.2.5 Lack of cooperation

Finally, but perhaps most crucially, lack of cooperation was seen to be a significant barrier to uptake of AWM amongst participants. There was a belief amongst participants that some growers simply did not prioritise or care enough about their role in the broader horticultural and social systems. Rather, these individuals were viewed as likely in denial about their public responsibilities and more likely to display apathy or displacement of responsibility when asked to consider a shared approach. According to some theorists, in order to activate a value-driven association with AWM and personal behaviours, it is important that affected individuals such as growers and members of the general public (a) have an awareness that environmental conditions threaten what they value and (b) that the individual can act to mediate the threat (i.e. ascription of personal responsibility) (Dominiak and Coombes 2010; Steg et al. 2005). Research has previously found that those who value outcomes beyond their own interests are more likely to engage in desirable community-level behaviours (e.g. Nordlund and Garvill 2003). However, while value orientations do not have a strong *direct* influence on behaviour, values influence the activation of personal norms, which *do* have a strong and direct influence on behaviour. Personal norms are individual beliefs about moral obligation and correctness and have been shown to strongly predict intentions and behaviours (e.g. Pretty and Smith 2004). Future research examining the role of personal norms in predicting adoption of AWM and SIT would be a useful way to further

our understanding of grower behaviours. Certainly, data from the present study suggest that strong feelings of moral obligation amongst participants to control Qfly for the good of the horticultural industry positively influenced acceptance of AWM and SIT—but only if the implementation conditions were perceived as workable.

There was also a concern amongst participants that while they themselves might be willing to coordinate with others and be amenable to AWM, they all knew of other growers in their respective peer groups who would probably not work well together. Many thus felt that if an insufficient proportion of growers in an area achieved cooperation, then the approach would not be fair or particularly effective, providing little incentive for those already involved to continue to adhere to an AWM program. This highlighted feelings of potential inequity amongst participants, specifically the concern that those 'free riding' the system would still benefit from AWM and SIT without any investment in time, effort or cost (Markwell and Ames 1979). This economic phenomenon of 'free riding', known as 'social loafing' in psychology, is integral to the collective action problem (Kruger 2016; Karau and Williams 1993). Participants indicated that fairness in participation was important to their decision to participate. Therefore, the ultimate success of an AWM program would likely depend on how these perceptions of free riding would be managed. Participants called for administrators and institutional bodies to address this fear/concern of non-compliance in a satisfactory way. They indicated that it would be important to determine a social 'threshold' of non-cooperation that would be deemed acceptable to those involved. Participants also suggested that no AWM or SIT program could ever be acceptable, in practice, without some formal means or mechanisms for ensuring consequences existed for those 'free riding' the system. Some participants tended to view potential solutions to increase cooperation in terms of the need for interventions by external authorities to ensure compliance. Yet, there is considerable work showing that voluntary, self-organised collective action can also be effective in achieving cooperation under certain conditions (Ostrom 2010). These approaches utilise institutional design elements that enable members to collectively develop, monitor and enforce their own agreed-upon rule-sets. Kruger (2016), for example, has examined the application of such institutional design elements, in the context of AWM, and demonstrated some potential for success.

Interestingly, negative feelings associated with other free riding were not as pronounced amongst those who were strongly driven to protect themselves from Qfly. Negative feelings were greater and a more significant concern, however, amongst those looking to be *persuaded* to engage with an AWM program. This is a key attitudinal distinction that can help to understand the psychology of those potentially disengaged in the cooperative uptake of AWM. For example, greater effort or resources may need to be allocated to target groups who might indirectly benefit from the AWM of Qfly and highlight their potential gains. Or, alternatively, develop ways to encourage people to act altruistically or in a morally obliged way. Nevertheless, a lack of cooperation for AWM potentially represents a significant psychological barrier to cooperative uptake of AWM. It is also a crucial limitation to the successful implementation of SIT.

3.3 Facilitators

3.3.1 Market access

Increased market access was the most frequently cited facilitator of grower uptake for AWM and SIT. Growers, in particular, cited a persistent belief that managing Qfly and reducing its numbers significantly would deliver greater access to elusive domestic and international markets. The attraction of potentially increased market access was also seen as a uniting cause amongst growers from varying industries. Growers indicated that many of them were limited in their export endeavours due to the presence—or threat—of Qfly within the region, whether they were growing preferred host fruits or not. The desire amongst growers to market their product from a recognised 'pest-free area' was a strong motivator. Individuals stated a willingness to work together and coordinate for the communal benefit of eradicating Qfly, to access export markets previously closed to them and increase revenue in the long term.

Unfortunately, the reality of gaining greater market access, especially to coveted international markets, would likely involve high-level government negotiations and complex changes to existing trade protocols (e.g. Smith and Webster 2017). Yet, the perception of gaining greater market access was a significant lure for many participants to state an intention to participate in AWM and SIT. Even gaining an increased ability to trade produce interstate, to domestic markets that exclude fruit from non-pest-free areas, was considered highly desirable amongst growers from Qfly affected regions (Jessup et al. 2007). While implementing AWM and SIT would certainly hasten the process of gaining access to domestic markets, this would still involve high-level negotiations at the state government level to realise market gains.

Given market access limitations, many stakeholders cautioned that there needed to be a clear plan for addressing institutional limitations of domestic and international trade. They further cautioned that not all growers would be interested in exporting their produce domestically (interstate) or internationally. Therefore, the lure of market access would not necessarily have the same motivational effect on all growers. Alternative market-based incentives would need to be identified and targeted to motivate individuals beyond the lure of greater market access.

3.3.2 Awareness

A consistent theme to emerge amongst both growers and stakeholders was the perceived need to increase awareness of issues related to Qfly amongst growers and the general public. Some of the strategies offered by participants, to increase social awareness, were the following: developing local campaigns targeting the whole community (general public and growers), raising the profile and salience of Qfly control, and developing targeted education for sub-populations within the community (e.g. specific to growers, specific to children, specific to gardening groups). Another strategy to increase awareness on the ground was to teach growers about key Qfly behaviours (e.g. preference for host plants, overwintering habits) and how Qfly numbers might directly and indirectly affect their business. Stakeholders expressed frustration at those growers who assumed that they were external to the Qfly management process because they grew non-preferred fruits. This was thought to stem from their lack of Qfly knowledge and reluctance to know more about a low priority pest. Thus, it was suggested that an effective facilitator for increasing participation in AWM would be to provide more pertinent information to all growers within a region about Qfly detection. Specifically, how Qfly could set off a chain of events that ultimately 'hit their back pocket'. Further, teaching growers contextually relevant strategies for controlling Qfly given their unique circumstances would encourage greater uptake of desirable control behaviours. It was clear that greater emphasis needed to be made on clearly articulating the more indirect effects of Qfly in low susceptibility environments. The importance of extracting and messaging financial and social incentives to participate in the wider control of Qfly was also thought to be a key facilitator of AWM uptake (Mankad 2016).

3.3.3 Champions

Participants highlighted the need for AWM advocates to foster trust amongst growers and the local community. This would be particularly important for those who might be more trusting of local leaders and peers, rather than formal authority. Stakeholders believed that it would be necessary to identify farmers in target regions who were seen as local leaders. These individuals could help to facilitate uptake of AWM by 'championing' an AWM initiative, effectively influencing their peers and setting an example for others to follow. Growers, too, cited the persuasive influence of larger or more successful growers and modelling of their habits, which often influenced others' personal behaviours. It was believed that the general public could be similarly persuaded to action AWM behaviours if there were key individuals within a community who served as 'advocates' or project managers for AWM within townships. This could build a layer of control and ownership within the community, as well as emphasising shared community goals and working towards a mutually beneficial outcome. The role of champions, in effect, would be as a 'social tool' to normalise activities involved in an area-wide approach and introduce SIT as a natural progression from AWM using trusted community leaders.

Often, the importance of community leaders is to set up a descriptive norm surrounding participation in AWM activities, from a behavioural perspective. This means that 'champions' socially/publicly endorse desirable patterns of behaviour around Qfly management. They create an impression that others are also behaving in a similar way, and convey an expectation that others should follow suit (Nolan et al. 2008). From an institutional perspective, community opinion leaders or champions can play an important role in establishing and maintaining new initiatives, and increasing uptake of novel technologies. This can be achieved through enhanced trust and credibility effects, which facilitate initial participation as well as ongoing commitment of other social players (Greenhalgh et al. 2004). These leaders were also seen as particularly useful in disseminating important information about Qfly to people who were disengaged from more authoritative or formal communication channels. Community segment leaders could provide more contextualised information about the Qfly problem for diverse social groups (e.g. growers, backyard horticultural enthusiasts, tenants, home owners). Specifically, tailoring information on how Qfly could directly affect livelihoods and quality of life and, importantly, how increased threat or higher numbers of Qfly could directly and indirectly have economic impacts.

The importance of champions also highlights the value of trust in positively influencing uptake of new practices and innovations, such as AWM and SIT. This includes trust in those advocating AWM and SIT, as well as interpersonal trust between neighbours. Participants cited other key conduits for information, including local agronomists, processor field officers and packing sheds. These groups were perceived as having regular contact with the growing community and were trusted advisors and sources of information. Packing sheds already had a role in helping growers comply with other trade protocols. Therefore, using them to champion AWM principles was seen as a reasonable extrapolation. Scientists were also viewed as trusted sources of trusted information, with participants citing the importance of on-ground evidence of success and credible scientific results being disseminated to growers, in particular, were seen as, but also given their existing role.

3.3.4 Supply chain actors

Similar to the persuasive influence of local champions, the role of some supply chain actors such as fruit packing sheds and processors was identified as a potential facilitator for

uptake of AWM. These organisations were identified as key regulators of fruit quality control. Many fresh fruit growers utilised a service provider to pack their fruit, while fruit for canning went to a processing company. Thus, it was suggested that packing and processing companies could serve as key partners in effectively enforcing micro-level regulations and sanctions, if necessary, in the context of adherence to AWM protocols. Some respondents believed that involving parts of the supply chain to implement minimum requirements for pest management protocols, fruit quality and crop management could be a way to solve the free rider problem. For example, Packing Shed A could stipulate that a company requirement for accepting fruit would be for growers to also submit trapping and monitoring data for the season, alongside their fruit. This type of approach would likely involve negotiating key institutional and governmental mechanisms (Smith and Webster 2017). Yet, participants believed that utilising parts of the supply chain to somehow 'enforce' greater participation in AWM, particularly amongst more recalcitrant individuals.

Enforcing control guidelines or rules, such as asking growers to provide trapping data or incorporating a certification process for growers, could facilitate the widespread adoption of AWM strategies. However, it was noted by some participants that there are limitations to this approach. There are usually a number of different packing sheds that growers could utilise within in a region (although they generally had no alternative for processing their fruit). Thus, growers may be able to avoid this 'regulatory net' if some packing sheds—in order to increase their 'market share' in terms of numbers of growers supplying them in the region—declined to impose AWM requirements on growers. Further, if packing sheds were to engage in setting formal regulations, they would likely need to invest in some form of policing arrangements to ensure their guidelines were being adhered to and not being circumvented. Therefore, consideration may need to be given to mechanisms that would ensure sufficient cooperation across all packing shed supplier groups and their grower suppliers. While an industry-driven and agreed approach would be desirable, it may be that a mix of industry and government measures may be required to achieve full compliance.

3.3.5 Credibility

The final theme that emerged as a facilitator for adoption of AWM was the need for credibility. Participants cited the need for (a) evidence of a credible Qfly threat, (b) evidence that local strategies for managing the pest using AWM and SIT would be effective and (c) scientific evidence that a sterile fly would indeed be sterile. Growers believed that they, and their peers, would be more likely to accept and engage in AWM or SIT if they could observe firsthand the presence of the fly. More specifically, people would be more convinced of a Qfly threat if they could see the damage it could do. Growers were also keen to understand why an AWM approach would be better than what growers were currently achieving with their own pest management practices. Similarly, stakeholders believed that industry would react more quickly in endorsing matters of Qfly management if they had evidence of what Qfly control and non-control meant for their grower base, both socially and economically. A perceptible shift in market access as a result of AWM would also have important implications for the credibility of a proposed AWM program. Some stakeholders expressed wariness of benefits that AWM and SIT could offer growers with respect to market access, because of their pre-existing knowledge of complex and ongoing trade protocol negotiations at the federal level. Overall, participants were keen for SIT to become widely available and urged trials to begin as soon as possible. There was also a general consensus amongst participants that growers were becoming increasingly impatient with the lack of action regarding improved ways of managing Qfly; to delay any potential solutions would result in lower grower engagement and a loss of trust and credibility for those advocating Qfly control. This was seen to potentially hinder any future engagement in AWM or SIT by growers.

4 Conclusion

This study has sought to identify some of the key issues important to achieving effective AWM for controlling Qfly, including through the use of SIT, in the study regions. While generally a high level of acceptance was found for the concepts of AWM and SIT, potential barriers were also identified in the form of costs, limited knowledge, apathy, perceptions of incompatibility and lack of cooperation between growers. Many of these problems were ultimately linked back to an insufficient or inaccurate understanding of Qfly control practices in general and AWM in particular. Potential facilitators that could improve public uptake for AWM and SIT were also identified, including the following: the possibility of increased market access, increased awareness and knowledge about Qfly control methods and AWM/SIT, the influence of community champions and opinion leaders, the role of supply chain actors in influencing on-farm practices and the availability of credible information related to all aspects of the issue.

Overall, two issues stand out as key influencers of effective adoption of AWM and SIT. Firstly, greater awareness, knowledge and understanding of issues related to Qfly control, particularly amongst growers and in relation to the specific requirements of AWM and SIT, were needed. Secondly, there was a need for either formal or informal mechanisms ensuring social cooperation by all land managers, particularly between neighbouring growers, in a defined AWM area. The first issue points to a greater need for continuing, and perhaps enhancing, current education and awareness raising initiatives in the

study regions. It is apparent that considerable efforts have already been made in this regard, but clearly more needs to be done to address the identified knowledge gaps. A coordinated strategy across multiple industry groups that targets the diversity of grower types and contexts is recommended. The second issue appears somewhat more difficult to overcome. 'Free riding' or 'social loafing', and other conditional participation scenarios, represents fundamental problems in collective action theory that do not have easy solutions. Further, effective AWM of Qfly requires not only the cooperation of all those who would benefit from Qfly control, but also of those who would not. This is because some growers (and other land managers) may contribute to the problem by providing Qfly host vegetation but may incur no benefits, only costs from Qfly control. This could be because the host vegetation is not saleable (e.g. abandoned orchards, 'wild' fruit trees), or its saleability or market price will not be improved by Qfly control (e.g. fruit destined to be dried or juiced, many vegetable crops). Further research to identify mechanisms that increase cooperation from such 'non-benefiting risk contributors' would therefore appear particularly useful. For example, some form of incentive or compensation for resources expended in undertaking Qfly control could potentially be provided by those who benefit.

In whatever form an AWM approach takes for the control of Qfly, it is clear that various attitudinal and group-level factors need to be considered and addressed in order to promote high levels of participation and adherence. Diverse individuals and groups within a community will all have different beliefs and reasons for participating (or not). Therefore, appropriate AWM programs should incorporate social engagement plans for communication direct and indirect outcomes for all involved.

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