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ORIGINAL PAPER

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Perceived competence, threat severity and response efficacy: key drivers of intention for area wide management

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Abstract
Area wide management (AWM) is a coordinated strategy designed to achieve effective and longer-lasting suppression of mobile insect pests, involving groups of commercial growers working together and/or with local communities to achieve control across multiple host areas. In this study, we hypothesised that intentions to carry out AWM for the control of fruit fly would be predicted by subjective knowledge of insect pests, along with protection motivation factors (perceived pest threat severity, threat vulnerability, self-efficacy, AWM response efficacy and response costs). Fruit and vegetable growers ($n = 131$) and general public ($n = 896$) living in fruit-growing regions completed a large-scale telephone survey, measuring perceptions and intentions to implement area wide management. Regression analyses tested the relationship between intention, protection motivation factors and subjective knowledge, $F(8, 1018) = 48.52$, $p < .001$, yielding a statistically significant predictive model accounting for approximately 30% of behavioural variance in intention. Self-efficacy, threat severity, response efficacy and threat vulnerability were the most influential predictors of intention. Subjective knowledge was not a strong predictor, but results did clarify that explicit knowledge of fruit fly controls, rather than tacit knowledge of fruit fly itself, was a significant predictor of intention. Understanding motivational drivers for farmer and community engagement in pest management can not only help predict uptake of novel practices, but also allude to how individual farmers and communities are articulating a pest problem. The importance of explanatory factors such as threat appraisal and self-efficacy in framing management activities can help to better target behavioural incentives.

Keywords Biosecurity · Social science · Fruit fly · Threat perception · Horticulture · Farmers

Key message

- Few behavioural models exist for improving pest management uptake, particularly for coordinated strategies.
- This study hypothesises that protection motivation variables, such as threat perception and efficacy, can be useful in predicting public engagement with pest control.
- Our model shows self-efficacy (perceived personal competence) to be most influential in predicting intention to engage in area wide pest management.
- Understanding motivational drivers for farmer/community engagement in pest control can reveal how individuals articulate a pest problem and help target shared behavioural incentives.

Introduction

Area wide management (AWM) is a control strategy for mobile insect pests that is applied across a defined 'area', targeting all pest habitats, in order to cover the entire pest population within that area (Vreysen et al. 2006). Extending pest management beyond individual farms using an AWM approach has been shown to be effective in preventing reinfestation (Lax et al. 2005). Reducing the pest population in all habitats decreases the likelihood of mobile pests

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Fig. 1 Manually inspecting fruit for signs of fruit fly larvae in Goulburn Valley, Australia. Credit: *Mia Tam*

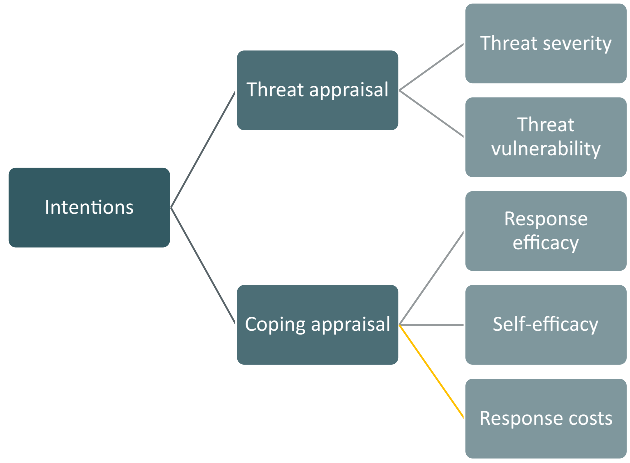

Fig. 2 A simplified protection motivation model, adapted from Rogers (1983). The orange line denotes a negative predictive relationship; grey lines indicate a positive relationship

reinfesting a treated habitat from those that have not been treated, for example, preventing farms and orchard infestation from habitats such as backyard gardens and native vegetation host areas. A comprehensive and coordinated strategy across multiple host areas can achieve more sustainable, effective and longer-lasting suppression of mobile pests, compared to individual growers seeking to control the pest on their own properties alone (Chandler et al. 1999; Vreysen et al. 2006; Vargas et al. 2010).

The specific pest control tools for fruit fly management employed within AWM programs around the world typically include on-farm hygiene (removal and/or destruction of all potential host fruit; Fig. 1), protein bait sprays (a protein attractant with an added insecticide that is sprayed on host trees to target female flies) and male annihilation technique (MAT, specially developed lures that attract and poison male flies). Additional control tools may include chemical ('cover') sprays, biological control agents and sterile insect technique (SIT) where available. Local and regional scale AWM initiatives may involve groups of commercial growers working together and with the relevant authorities in urban communities to achieve control across multiple host areas. AWM initiatives can be wholly controlled by, or via cooperation between, government entities, industry (grower) groups and third-party private sector interests (e.g. fruit processors, rural supply firms, pest management firms, farm consultants).

Past qualitative research on social barriers and facilitators of AWM found that perceived cost, lack of knowledge and apathy emerge as key barriers of uptake (Mankad et al. 2017). Incompatibility of new technologies or behaviours with existing farming practices was also noted by growers and stakeholders in the study as an important limitation to individual involvement in AWM. It is also conceivable that the general public are likely to be concerned by the compatibility (or lack thereof) of AWM activities with daily routines around the house and garden. This may stem from a lack of knowledge about controlling fruit fly at home, perceptions of the time and/or effort required to carry out new tasks, or indeed having a lack of awareness that fruit fly needs to be managed at all (Mankad et al. 2017). Limited knowledge of AWM activities may also lead to assumptions about the cost of AWM, potentially reducing intention to participate.

Protection motivation

The findings from Mankad et al.'s (2017) research reflect key factors of influence found within the protection motivation theoretical approach. Protection motivation theory proposes that intentions to engage in protective behaviours (such as implementing AWM for the prevention and/or management of fruit fly) are predicted by threat appraisal and coping characteristics (Rogers 1983; Rippetoe and Rogers 1987). The way in which individuals make decisions to protect themselves from threatening/stressful events is based on a perception or assessment of five key factors (Fig. 2). Figure 2 represents a simplified model of Rogers' protection motivation approach used in the present study; note that it is not the full protection motivation model, but a more utilitarian approach to answer our research questions. In the present study, we are interested in how the five independent factors directly predict intention, rather than testing the mediating relationship that Rogers' original model suggests.

Threat severity and *threat vulnerability* combine to form what Rogers (1983) refers to as the threat appraisal process, which is important in determining whether people feel the need to protect themselves from a risk, based on their assessment of the threat. *Threat severity* refers to the perceived seriousness or degree of harm likely to be personally experienced (e.g. 'How bad will a fruit fly outbreak be for me?'). *Threat vulnerability* is the perceived probability of the threatening event taking place and the likelihood of the threat directly impacting the individual.

Response efficacy, *self-efficacy* and perceived *response costs* comprise the coping appraisal process, as part of Rogers' model. *Response efficacy* refers to one's belief that a particular behaviour, or set of recommended behaviours, is effective in removing or preventing the threat (e.g. a belief that AWM will prevent future fruit fly outbreaks). *Self-efficacy* refers to individuals' beliefs in their ability to carry out the recommended behaviour(s), to reduce the likelihood and/or severity of the perceived threat (e.g. 'I am confident I could clean up unwanted fruit in my backyard'). Finally, *response costs* are barriers that people perceive as being negatively associated with the adoption of recommended behaviour(s) (e.g. 'I can't afford to set up a trapping grid on my farm').

In the present context, we define the *threat* as 'fruit fly outbreaks' and the *protective behaviours* as those involved in carrying out effective 'AWM'. One's intention to implement AWM activities on-farm or at home can be examined using the five predictors of protection motivation. It is also important to note that perceived costs, as part of the protection motivation model, are not only financial costs but also include the cost of time and effort in carrying out recommended behaviours as perceived by the individual.

Protection motivation frameworks have consistently been utilised in the health domain, where threat and coping appraisals have been useful in predicting intentions to engage in protective health behaviours (e.g. breast self-examinations, quitting smoking; McMath and Prentice-Dunn 2005; Fry and Prentice-Dunn 2006; Yan et al. 2014). There have been some applications of protection motivation principles in the biosecurity literature, though considerably less (Schemann et al. 2013; Mankad 2016; Cross et al. 2009).

The use of *subjective knowledge* as a predictor of protection motivation is not uncommon, and its utility in predicting uptake of on-farm biosecurity behaviours was discussed in Mankad's (2016) review of psychological influences on biosecurity. While the research is not clear as to whether subjective knowledge is a dominant predictor of intention to engage in behaviour on its own, it is clearly an important variable to consider (Martin et al. 2007). The protection motivation framing, in general, is a useful explanatory tool in the context of understanding intentions to engage in biosecurity action. Understanding motivational drivers for farmer engagement in protective behaviours can not only help predict uptake of novel practices, but also reveal how individual farmers are managing a pest problem, the explanatory importance of factors such as threat appraisal and efficacy in framing pest management, and better targeting behavioural incentives.

Present study

In the biosecurity literature, it is well understood that individual motivation and perceived competency are important drivers of protective biosecurity engagement (Kristensen and Jakobsen 2011; Mankad 2016). However, a clear limitation of past biosecurity literature in the social sciences is the lack of applied behavioural models (McLeod et al. 2015). While qualitative examinations are certainly necessary and informative in providing much needed descriptive understandings of social issues related to biosecurity action, there is a lack of predictive utility. A predictive model can help to identify which of the perceptual influences are most important in individual intentions to engage with biosecurity action and how to target interventions aimed at increasing biosecurity uptake.

In the present study, we argue that protection motivation variables—not the theory itself—can be a useful lens for predicting public engagement with AWM for the control of Queensland fruit fly (Qfly). We believe this is a first step in determining whether protection motivation constructs can be applied in an invasive species context, prior to future research that could test the full protection motivation model itself. The protection motivation approach highlights the importance of threat perception, as well as the importance of other individual factors (e.g. efficacy) in influencing coping behaviours. The psychological literature, including the protection motivation literature, has also consistently identified subjective knowledge as a key predictor of intention to carry out protective behaviours (e.g. Fishbein and Ajzen 1975; Ajzen 2001; Martin et al. 2007). Therefore, in addition to measuring the more conventional variables from protection motivation theory, we also included key variables previously found to co-predict intentions within the threat context that could influence motivation and intentions. We hypothesised that:

H_1 Growers will report a greater intention to participate in AWM than members of the general public.

Table 1 Number of survey respondents by group and region

Group	Riverland	Sunraysia	Murray–Goulburn Valley
Farmers/growers	53	47	31
General public	299	298	299
Total	352	345	330

free, but face increasing infestation risk partly driven by the spread of Qfly in Australia along with increasing people and freight movements around the nation. Alongside the increasing infestation risk, recent restrictions on control chemicals in Australia, including fenthion and dimethoate, have increased the need for alternative approaches. Due to the reliance on fruit and vegetable production industries for many regional communities in affected and at-risk areas, the involvement of all citizens—farmer and non-farmer—is imperative to achieving and maintaining area wide control of Qfly.

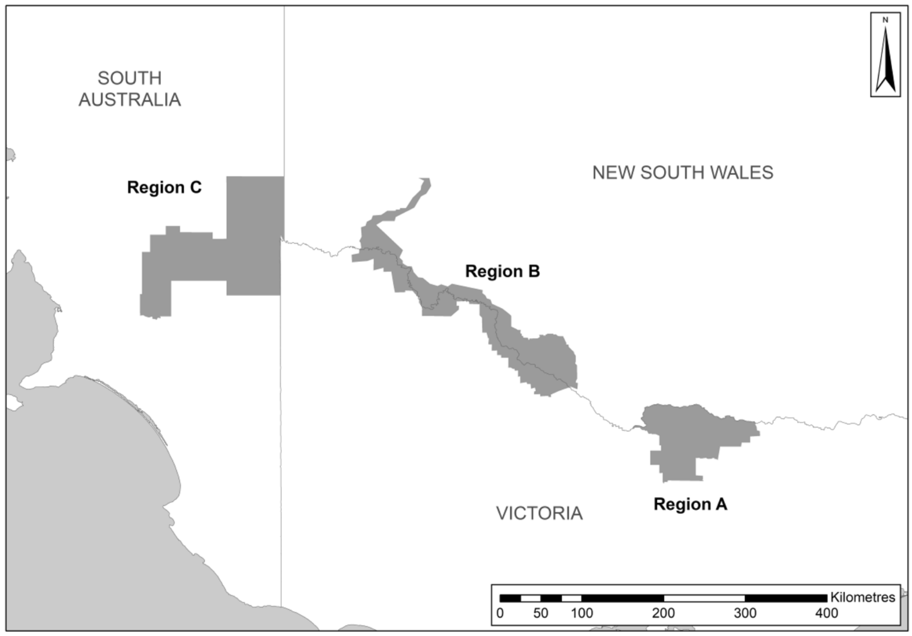

Fig. 3 Map of the three study regions targeted for social science research across south-eastern Australia: Regions A and B, both spanning New South Wales and Victoria; and Region C, on the South Australian border. *Source*: Andy Hulthen, CSIRO

H_2 Intention to implement AWM will be positively predicted by factors within the protection motivation model, as well as subjective knowledge. Perceived response costs will be a negative predictor of intention.

Situational context

The Queensland fruit fly (Qfly), native to Australia, is a potentially destructive insect pest to a wide range of fruit and vegetables in Australia and poses a significant biosecurity threat to the horticulture industry's international market access. In 2016–2017, the estimated cost of produce potentially affected by fruit fly (a large proportion of which is Qfly) was worth AU$6 billion. The annual cost for managing Qfly in Australia is approximately AU$28.5 million/year (Plant Health Australia 2019). The creation of more favourable habitat alongside movement of infected fruit over the last 5–10 years has led to the spread of Qfly throughout NSW and much of Victoria, where it is now considered established. These regions include the largest stone, pome, table grape and citrus production areas in Australia. South Australia, Tasmania and Western Australia remain Qfly

Materials and methods

Participants

The study sample comprised fruit growers and members of the general public from key horticultural regions in south-eastern Australia ($N = 1027$; see Table 1). In this study, farmers were defined as those self-identifying as 'farmers/growers' and who stated that more than 10% of their household income was derived from growing fruit.

Participants were recruited through an external market research company, using a database of residents and farmers from the key regions (Fig. 3). All participants were over the age of 18 years, with a majority of participants aged over 35 years and comprising 51% males and 49% females; however, the farmer/grower group comprised 73% males, which is representative of the farming sector in Australia.

Participants reported living in their region for an average of 31 years ($M = 31.19$, SD = 20.30), with most people having at least completed Secondary school and/or a Trade/Certificate/Diploma level education. The general public sample (i.e. regional residents not identifying specifically as *fruit or vegetable growers*) was selected to be representative of the regions surveyed (Australian Bureau of Statistics 2012). Note that it is possible, though unlikely, that farmers of other types were included in the general public sample.

Measures

Constructs from the protection motivation model were used to predict public intentions to engage in protective behaviours. In the present context, threat and coping appraisals associated with the threat of Qfly were used to predict intentions to engage in area wide pest management. As no previous research has utilised protection motivation principles in the context of pest management, items were developed based on Rogers et al.'s (1975) theory principles, as well as adapting items from past protection motivation literature (e.g. Martin et al. 2007; Mankad et al. 2013; Xu and Chen 2016) to suit the present context. Note that combining of items (throughout) was carried out using standard valid theoretical groupings from Rogers' protection motivation literature and checked using a combination of exploratory factor analyses, correlation checks and a measure of internal consistency (Cronbach's α).

Threat appraisal

A total of six items measured threat appraisal, targeting perceptions of threat severity and vulnerability specific to the threat of Qfly; the threat appraisal scale had a strong scale reliability[1] of $\alpha = .82$. Threat severity items required participants to indicate their level of agreement or disagreement to statements about how severe a threat one believed Qfly to be (e.g. 'I believe that QLD Fruit Fly has serious negative consequences', 'I believe QLD Fruit Fly is a severe problem'; $\alpha = .78$). Threat vulnerability statements asked how likely participants would be affected by Qfly (e.g. 'It is likely that I will get QLD Fruit Fly on my property', 'It is possible that I will get QLD Fruit Fly on my property'; $\alpha = .93$). Participants responded to a 10-point Likert scale (1 = strongly disagree; 10 = strongly agree). Individual items for each subscale were then combined to create a single separate score for both severity and vulnerability factors; these scores were used in subsequent analyses.

Coping appraisal

Coping appraisal comprises three distinct perceptual factors: response efficacy, response costs and self-efficacy. Perceptions of response efficacy were measured using a single item ('The AWM approach described will be effective in controlling QLD Fruit Fly'). Perceptions of response costs were measured using three items targeting perceived effort, time and financial costs associated with Qfly control activities as part of AWM (e.g. 'Getting involved in AWM would require a lot of <effort/time/money>'; $\alpha = .74$). The three items were subsequently combined to provide a single score for perceived response cost. Finally, a measure of self-efficacy included five items (e.g. 'I can easily hang up fruit fly traps on my property', 'I can easily coordinate with my neighbours for AWM'; $\alpha = .82$). Once again, the scores were combined for the five items to produce a single representative self-efficacy score, used for subsequent analyses. Participants responded to all the coping appraisal statements using a 10-point Likert scale (1 = strongly disagree; 10 = strongly agree).

Subjective knowledge

Subjective knowledge was assessed from two different perspectives: subjective knowledge of Qfly ('How would you describe your level of knowledge about Qld Fruit Fly'; 1 = I do not know anything about QLD fruit fly, 10 = I am an expert on QLD fruit fly) and subjective knowledge of Qfly control strategies ('How much do you know about controlling for QLD fruit fly on your property/farm'; 1 = I do not know anything about controlling for QLD fruit fly, 10 = I know a lot about controlling for QLD Fruit Fly).

Dependent variable: Intention

The variable being predicted in the present study was one's behavioural intention to carry out tasks required to participate in AWM (e.g. hanging traps, cleaning up unwanted fruit, coordinating with neighbours). Participants indicated their agreement to the statement 'If asked to do so, I intend to implement an AWM approach', using a 10-point Likert scale (1 = strongly disagree; 10 = strongly agree).

Procedure

Participants were recruited through a process of random sampling from residents listed in the target regions, using a professional market research company with access to residential databases. Data were collected using the

[1] Cronbach's alpha was used to calculate scale reliability (i.e. internal consistency between each of the scale items) for each of the multi-item sub-scales. An α value of over .60 is generally acceptable as a representation of a valid scale (Howell 2002).

Table 2 Independent samples *t* test, comparing mean scores between growers ($n=131$) and the general public ($n=896$) on protection motivation variables, subjective knowledge, current biosecurity and past experiences with coordinating with neighbours to address a pest problem

Variable	Means *Growers* *General public*	SD	*t*	*df*	Sig. (2-tailed)	Eta-squared
Intention	8.51 7.91	1.74 2.52	3.46	219.20	.001	.01
Threat severity	9.37 8.67	1.00 1.82	6.63	278.10	.000	.04
Threat vulnerability	6.07 4.42	2.93 3.10	5.73	1025	.000	.03
Self-efficacy	7.98 7.71	2.39 2.65	1.12	1025	.263	
Response efficacy	8.40 8.02	1.96 2.23	1.89	1025	.059	
Response costs	6.22 4.71	2.10 2.23	7.33	1025	.000	.05
Subjective knowledge—Qfly	6.98 4.99	1.93 2.75	10.40	187.43	.000	.10
Subjective knowledge—Qfly controls	6.97 4.82	2.57 3.03	8.74	187.43	.000	.07

Computer-Assisted Telephone Interview (CATI) method. Prior to commencing the CATI, informed consent was obtained from participants as per Human Research Ethics requirements; participants were provided with an explanation of the survey and provided an opportunity to ask any preliminary questions. The duration of each CATI varied between 15 and 25 min, depending on each participant. Data were transferred to an appropriate analysis file and stored securely.

Data analysis

Data in the model were analysed using a combination of general linear statistics (i.e. independent samples *t* tests), comparing average scores (means) between different groups, and multivariate statistics (i.e. hierarchical regression) where predictive relationships were tested. Importantly, our predictive statistics do not assume equal variances or sample sizes and our data do not violate core assumptions. Data were validated and analysed using the SPSS analysis program.

Results

Preliminary *t* tests and analyses of variances (ANOVAs) revealed only small effects between the two groups (farmers and general public) and across the three sampling regions; therefore, participants were combined for the final regression analysis. The sorting factor ('group') was included in the first step of the regression followed by 'region' in Step 2 of the regression, however, to account for any potential predictive differences between the two groups.

Comparisons of means between farmers and non-farmers

Independent samples *t* tests were conducted to compare growers ($n=131$) and general public ($n=896$) on their intentions to implement area wide management, as well as comparing the two groups on protection motivation factors, subjective knowledge of AWM, current biosecurity activities and past experiences in dealing with a coordinated effort for pest management (Table 2). Results showed there was a significant difference in intention scores between growers ($M=8.51$, SD = 1.74) and general public ($M=7.91$, SD = 2.52), with growers more likely to state they would implement AWM practices if asked to do so. The magnitude of the differences in the means, however, was small (eta squared = .012) which suggests that in real terms, this was only a weak difference and unlikely to be meaningful in an applied setting.[2]

The analysis also compared scores for growers and non-growers on variables that were part of the protection motivation framework, specifically threat severity, threat vulnerability, response efficacy, response costs and self-efficacy. Measures of subjective knowledge regarding Qfly and Qfly control methods were included in this grouping because of the theoretical link between protection motivation and subjective knowledge (Martin et al. 2007). Results showed a significant difference in mean scores between growers and

[2] Calculations of effect sizes (eta-squared) provide an indication of the magnitude of the difference between the two groups. Cohen (1988) suggest the following interpretations for eta-squared: .2 = 'small', .5 = 'medium', and .8 = 'large', effect sizes.

Table 3 One-way analysis of variance (ANOVA), comparing mean scores across sampling regions

Variable	*df*	*F*	Sig.
Group membership (grower vs. general public)	2, 1024	1.937	.145
Threat severity	2, 1024	13.577	.000
Threat vulnerability	2, 1024	44.972	.000
Self-efficacy	2, 1024	22.738	.000
Response efficacy	2, 1024	15.622	.000
Response cost	2, 1024	1.754	.174
Subjective knowledge—Qfly	2, 1024	13.937	.000
Subjective knowledge—Qfly controls		31.566	.000

non-growers with respect to threat severity, threat vulnerability, perceived response costs and subjective knowledge of Qfly (see Table 2 for mean values); a calculation of effect size showed that most effects were moderate. However, the difference in subjective knowledge regarding Qfly between growers and the general public was considered a large effect; that is, growers felt considerably more knowledgeable of Qfly than members of the general public.

In summary, comparisons of group means showed that all participants perceived a high level of threat severity (i.e. a belief that Qfly was a significant threat), but lower perceived vulnerability to Qfly (i.e. most people did not feel their own property was susceptible to Qfly). Growers perceived more costs associated with AWM than the general public and expressed a greater understanding of Qfly and their control methods.

Comparisons across regions

While 'region' was not of central importance in our predictive model, we did examine whether any regional differences did exist, and whether these differences were influential in predicting intention to implement area wide management. This was conducted as a manipulation check to ensure region did not unduly influence the hypothesised predictive relationship between protection motivation variables, knowledge and intention.

A one-way ANOVA was conducted to compare mean scores across regions on threat severity, threat vulnerability, self-efficacy, response efficacy, response cost, subjective knowledge of Qfly and subjective knowledge of Qfly control strategies. Differences in mean scores across the three regions did significantly differ on all variables except 'response cost' (see Table 3). This was to be expected, because of the different levels of pest pressure across different parts of the country, and the reason for multiple regions was included in the study. However, the key part of determining whether regional differences were of significance was to examine whether 'region' was an influential *predictive* factor in our intention model. We, thus, conducted a preliminary regression analysis including 'region' with 'group' and the protection motivation variables; 'region' was added at Step 2 along with group membership (given 'region' is a demographic factor). Results indicated that the unique contribution of 'region' to the prediction of intention was non-significant (Step 2: $\beta = -.053$, $p = .090$); therefore, no further action was taken to include 'region' as a predictor, and it was removed as an individual factor from the final regression model.[3]

Prediction of intention to implement AWM

A hierarchical regression was then used to assess the predictive ability of protection motivation variables and subjective knowledge in predicting intention to implement AWM. Preliminary analyses were carried out to ensure no violation of the assumptions, including examining intercorrelations between variables (Table 4), and no violations were found. Group membership (farmer vs non-farmer/general public) was entered at Step 1, to determine whether being a grower or not was enough to explain intentions to implement AWM. The result of Step 1 showed that group membership explained less than 1% of the variance in intention. After entry of the remaining threat environment variables (protection motivation variables, and subjective knowledge) at Step 2, the total variance explained by the model as a whole was 28%, $F(8, 1018) = 48.52$, $p < .001$; this represents a moderately strong predictive model (Table 5). Of the threat environment variables entered, all were statistically significant except for subjective knowledge specific to Qfly; this suggests that knowing more about Qfly itself (as opposed to knowledge of Qfly control strategies) does not predict intention on its own. Self-efficacy, threat severity, response efficacy and threat vulnerability scored the highest beta values,[4] indicating that they were the most influential predictors of intention. In particular, feelings of competence in undertaking control measures as reflected by the self-efficacy variable were by far the most dominant motivational predictor. In the full model, it was also noted that group membership was no longer significant once all the other variables in the model were included.

[3] Note that 'group' was retained as an individual variable, however, because it was a variable of significance in our hypotheses.

[4] Cohen (1992) states that standardised beta weights should be benchmarked as: 'weak' = .1, 'moderate' = .3 and 'strong' = .5.

Table 4 Correlations between independent variables in analysis ($N = 1027$)

Variables	Threat severity	Threat vulnerability	Self-efficacy	Response efficacy	Response costs	Subjective knowledge—Qfly	Subjective knowledge—Qfly controls
Threat severity	1	.303**	.199**	.241**	.136**	.363**	.358**
Threat vulnerability	.303**	1	−.017	−.018	.103**	.227**	.286**
Self-efficacy	.199**	−.017	1	.493**	−.066*	.082**	.110**
Response efficacy	.241**	−.018	.493**	1	.022	.089**	.102**
Response costs	.136**	.103**	−.066*	.022	1	.073*	.082**
Subjective knowledge—Qfly	.363**	.227**	.082**	.089**	.073*	1	.740**
Subjective knowledge—Qfly controls	.358**	.286**	.110**	.102**	.082**	.740**	1

*$p < .05$; **$p < .001$

Table 5 Coefficient table for the final model (at Step 2) of group membership, protection motivation variables, subjective knowledge, current biosecurity and past experiences with coordinating with neighbours to address a pest problem

Variable Full model $R^2 = .28$	t	Sig. p	Standardised beta β
Group membership (grower vs. general public)	.55	.585	
Threat severity	6.32	.000	.20
Threat vulnerability	4.33	.000	.13
Self-efficacy	7.43	.000	.23
Response efficacy	5.99	.000	.19
Response costs	−3.44	.001	−.10
Subjective knowledge—Qfly	−.35	.728	
Subjective knowledge—Qfly controls	2.67	.008	.11

Discussion

This study sought to understand the drivers and possible barriers of farmer and community engagement in area wide management (AWM) for the control of Queensland fruit fly. More broadly, these results highlight the key factors that influence intention to engage in biosecurity-relevant behaviour that may not directly align with one's values or directly impact one's circumstances. The cornerstone of an AWM approach is coordination in achieving a shared goal—whether that goal is pest suppression or the maintenance of an unsuitable habitat for the pest. Thus, our study endeavoured to understand why people living in fruit-growing regions would agree to participate in preventative biosecurity or pest management, and what matters most when trying to facilitate that type of proactive behaviour.

As hypothesised, growers did demonstrate a stronger intention to implement AWM compared to members of the general public (H_1), despite rating an AWM response as more personally costly. Relatedly, the general public ratings of the Qfly pest problem severity were lower than farmers' ratings of severity and this was consistent with a lower intention to implement AWM. These findings are understandable in the context that Qfly represents a threat to the very livelihood of commercial growers, with infestation costs potentially sufficient to lead to business failure. In contrast, personal costs are conceivably lower for backyard producers (e.g. reduced ability to produce one's own fruit) and are more indirect (e.g. impacts on growers will eventually flow through to impact community prosperity). For these reasons, it was expected that acceptance of, and intention to implement, AWM would be higher amongst growers than the general public.

However, in real terms, our results showed only small effect sizes for group differences between farmers and the general public with respect to intention. The most significant differences between farmers and general public had moderate effect sizes at best, including perceptions of response costs (growers perceived greater costs, though mean was mid-range), threat severity (growers perceived a more severe threat, though means were both high range) and threat vulnerability (growers perceived greater vulnerability, though mean was mid-range). This then suggests that the different groups may have unique underlying motivations for intending to carry out AWM—or, perhaps—fundamentally they have similar motivations to protect assets or benefits from the threat. For example, growers may want to maintain market access and farm profitability; the general public may want to maintain production and enjoyment of their own 'clean' backyard fruit, and, more broadly, to support protection of local fruit industries that sustain their own jobs and lifestyle in a prosperous wider community (Mankad et al. 2017; Mankad et al., book chapter in press). Thus, intention to engage in AWM is not necessarily dependent on whether one is a commercial grower or not, but rather individual motivation to implement AWM is influenced by individual-level social psychological drivers.

As predicted, intention to implement AWM was associated with factors within the protection motivation model in the direction specified by the model (H_2); however, the influence of subjective knowledge was not as strong or as straightforward as expected. In real terms, farmers likely hold vast observational knowledge and vicarious experiences of the negative impacts that Qfly infestation can inflict on producers within their respective industries and therefore hold greater general knowledge about Qfly and are likely to perceive Qfly to be a serious biosecurity threat. While 'farmer' and 'general public' groups differed in their level of general knowledge of Qfly, our data provided only qualified support for the *information deficit* narrative, which argues that more information about a problem or solution will lead to more informed opinions and thus more aligned behaviours. Instead, the data fail to clearly support the assertion that increased general knowledge of Qfly impacts predicts behavioural intention to carry out AWM. Rather, *procedural* knowledge related to carrying out Qfly control strategies was a significant predictor of intention.

It can be argued that possessing procedural knowledge of control strategies promotes greater feelings of personal *competence* which, in the psychology literature, is a fundamental driver of intrinsic motivation along with feelings of autonomy and relatedness to others (Ryan and Deci 2000). This is supported by the strong predictive power of *self-efficacy* in our model, which was found to be the most dominant predictor of intention. Self-efficacy, in addition to being a key predictor in the protection motivation model, is a core construct in social cognitive theory proposed by Bandura (1986, 2001) and is defined as situation-specific self-confidence. In the present study, self-efficacy is operationalised as one's self-confidence in carrying out tasks required for successful AWM. While self-efficacy is the more task-oriented mental evaluation of one's ability to perform a behaviour (e.g. Maddux 1995), perceived competence is a more general feeling of mastery across situations (Ryan and Deci 2000). Competence is conceptualised in Deci and Ryan's self-determination theory as the psychological satisfaction that one gets from mastering personally challenging tasks and is a necessary condition for motivation (Ryan and Deci 2006). When one experiences both a general sense of competence (e.g. subjective knowledge of Qfly control options) and a strong sense of context-specific self-efficacy (e.g. confidence in carrying out AWM activities), this will likely support greater motivation and intention to carry out the desirable behaviour(s), such as biosecurity uptake. Perhaps, then, the most important and actionable finding to come from this research is the strong influence of *subjective knowledge* and *self-efficacy* in relation to procedural solutions in predicting intentions to carry out AWM strategies. The important of both these psychological factors reflects a recognition that when these enabling conditions exist, people are more likely to deeply engage in AWM.

Other strong predictors of intention were *threat severity* and *response efficacy*, which both relate to attitudinal assessments of value and prioritisation such as 'will the threat be really bad?', 'will the recommended strategies be useful in alleviating this threat?' and, to a lesser extent, 'do I need to take action now?' Farmers typically have a long list of competing priorities on a day-to-day basis and so will prioritise based on the relevance of the problem and the viability of the solution (Liu et al. 2011; Mercer et al. 2016). Judgements as to whether the recommended approach or technology will be useful in alleviating the threat (*response efficacy*)would logically appear as a precursor step towards a broader judgement on the 'relative advantage' of a new technology, that is, whether it will provide an advantage over and above current strategies employed to deal with the threat. The concept of relative advantage of an innovation is considered within the 'adoption of innovation' literature as an attribute of the innovation that is a key influence on a farmer's decision about its uptake (Rogers 2003; Pannell et al. 2006).

A range of other attributes of innovations are considered important in influencing decisions about uptake within the 'adoption of innovation' literature. Examples include the degree of complexity involved in its application, compatibility or fit with current practices, risks related to implementation, capacity to observe and/or trial the innovation before use, and access to support resources. Further, in addition to attributes of the innovation itself, a broad array of other factors have been identified as potentially influencing adoption, including attributes of the adopter (e.g. the psycho-social factors reported here, but also demographic and social network characteristics) and system properties (the attributes of the social, organisational, technological and institutional environment within which the adopter is situated) (for overviews see Greenhalgh et al. 2004; Vagnani and Volpe 2017). Future research should look to examine these key considerations in the support and uptake of novel pest management programs such as AWM and sterile insect technique. Interestingly, in this study, participants across our different sampling regions did hold varying attitudes based on their local contexts. While not of interest in the present study, future research could look to explore differences in regional assessments of threat and the influence this may have on in-field application of area wide management.

Summary and conclusion

Farmers' understanding of and confidence in undertaking the specific Qfly control techniques included within an AWM approach influenced their willingness to implement an AWM approach. AWM is a broader or higher-level strategy that includes managerial aspects of cooperation and coordination among multiple players across space, as well as the application of specific Qfly control techniques. Clearly, AWM would be much more difficult to implement if individuals had little knowledge of Qfly control techniques specified as part of the AWM strategy. Likewise, higher response costs (perceived barriers) of implementation would likely reduce uptake of AWM. That these factors were less influential than perceived threat and response efficacy is, however, interesting. This suggests that perceptions of barriers to adoption (including the effort required to gained subjective knowledge of control techniques) may be tempered by perceptions of threat posed by Qfly. That is, when a threat is perceived as imminent and potentially severe and/or when the effectiveness of the approach is perceived as high, concerns about the amount of effort required may become less salient. Turner et al. (2016) contend that the concept of 'barriers to adoption' in itself offers too simplistic a view of farmer rationale around decision-making and is rather mediated by differences in farmer values. Prudent 'next steps' in research to better understand community intentions to carry out collaborate biosecurity activities should include an evaluation of the influence of innovation characteristics on adoption, as well as the possible impacts of complementary novel tools designed to support behaviour change initiatives such as AWM.

Author contributions

AM and BL conceived and designed research. AM conducted data collection and analyses. AM and BL wrote the manuscript. All authors read and approved the manuscript.

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Data availability The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This research was conducted in accordance with CSIRO's Human Research Ethics guidelines and the National Statement on Ethical Conduct in Human Research. The project received Human Research Ethics approval. Informed consent was obtained from all individual participants included in the study.

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