Rural R&D for Profit Program

Adaptive area-wide management of QFly using SIT: Guidelines for efficient and effective pest suppression and stakeholder adoption
Final Report

Horticulture Innovation Australia Limited

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Area-Wide Management (AWM) is a proven management approach for mobile pests around the world, employing a united strategy to target all pest habitats within a well-defined area or region to reduce the total pest population. These guidelines will help you understand AWM, how to get started implementing it for Queensland fruit fly, and the opportunities to implement Sterile Insect Technique (SIT) once AWM has been successfully implemented.
To work properly, Area Wide Management requires input from the whole community – so we've created three different sets of steps in implementing AWM, depending on whether you're a coordinator, a commercial grower or a backyard gardener. Simply choose who you are from the options below...

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Plain English summary

The three-year Queensland fruit fly area-wide management (QFAM) project was undertaken with the aim to support the successful incorporation of Sterile Insect Technique (SIT) into the management of Queensland fruit fly (Qfly). Qfly is a major pest of Australian horticultural crops, currently causing millions of dollars-worth of damage across Australia and it presents a major barrier to market access. Broad goals of the project were to ensure a thriving and sustainable horticulture sector; realise improved productivity and profitability for producers; remove the limitation that Qfly poses to commercial production and market access; and establish a framework for Area-wide Management (AWM) uptake of SIT within AWM for Qfly (SITplus). To achieve these broad goals, two key project goals were met: 1) Communities have an informed basis of current best technology to consider SIT as part of AWM in Qfly management; 2) Guidelines for SIT incorporation into AWM of Qfly are workable and accepted.

The research focused on study regions in southern Australia (Sunraysia, Murray/Goulburn Valley [MGV] and the Riverland). The results of the project have been extended over a larger region, including into northern NSW and southern Queensland. The multidisciplinary nature of the project incorporated diverse research methods to undertake the activities, including interviews, discussion groups and surveys for the social science and economics research, as well as expert elicitation, spatial simulation modelling and field studies for the biophysical research.

Within the scope of this research three potential economically-viable implementation strategies for AWM including SIT of Qfly under Australian conditions include: outbreak eradication (and potentially maintenance of area freedom, should legislation allow); spatially-isolated contexts (including in support of industry-specific market access); and more effective management in an urban context than existing ad hoc approaches. Before SIT deployment each region should be considered in the context of landscape, suppression potential and economic impact. There are likely to be significant gains from applying AWM and SIT for pest outbreak eradication in designated pest free areas. However, while modelling has shown AWM will lead to pest suppression, the broad economic study showed that management of established populations across very large areas using SIT within an AWM approach appears unlikely to be an appropriate objective, given that the time to see financial returns from new market access (dependant on eradication) is uncertain. There are a number of other assumptions behind this conclusion, particularly relating to pesticide use and impacts, based on our assessment of the current situation (as of May 2017). The results are sensitive to our findings of negligible production losses due to Qfly once managed and the estimated time taken to realise future benefits. We also recognize there are uncertainties, including the time taken to realise future benefits, the potential for market access and changes to chemical controls going forward. Nevertheless, market access will clearly be an issue for some regions with sensitive products or markets (e.g. Tasmania and cherries) and SIT may play a role in supporting this. Also to note, this assessment was made in isolation of the management of multiple pests in these regions; understanding the introduction of SIT in the context of Integrated Pest Management (IPM) may provide some overall benefit that outweighs the cost.

When it comes to deployment strategies for sterile flies, our research indicates that it will be of benefit to work with fruit industry bodies and/or a committee comprising an amalgam of government and industry organizations (with an important role for local councils in urban areas, which the general public tend to look to for leadership) in implementing AWM and SIT. These are the institutions most

trusted by communities to manage Qfly and can enable coordination and communication of actions. Although there was evidence of inertia and a preference for maintaining the status quo for growers across all three regions, there was also positive and large willingness to pay (WTP) among growers for Qfly management in towns as well as a SIT program component. Urban residents also exhibited a positive WTP.

In terms of releases, our biophysical research has generated valuable risk maps for three case study regions (Sunraysia, MGV and Riverland). Such maps are essential to the development of a future tool or system for planning releases, as well as for ongoing AWM and monitoring programs. We also highlight the need to consider that complex landscapes, containing a higher diversity of hosts that fruit across different seasons, will pose greater challenges in achieving population suppression and require adoption of AWM strategies in readiness for SIT to be incorporated into an AWM program. Urban areas pose a significant challenge, as these areas provide a reservoir of flies throughout the year with potential to move into nearby crops. Our biophysical models can identify potential hotspots and bottlenecks in space and time which can be used to develop more targeted and effective SIT release strategies. Year round efforts provide greatest benefit (Figure 8), but when resources are limited the modelling showed that an urban treatment is most effective when reducing populations in late winter/early spring before they can move into the agricultural area.

The outcome of the project has been to integrate transdisciplinary research to deliver two key outputs for industry: 1) Guidelines for adaptive area-wide management (AWM) using Sterile Insect Technique (SIT) (see www.area-wide-management.com.au), and 2) the present report for SITplus (KPI 6.4, Appendix 8), which identifies the next steps needed to produce and deploy sterile males for managing Qfly populations. In addition to the research findings and Guidelines cited above, material outputs of the project for industry also include i) risk maps; ii) a quantitative assessment of willingness to pay that can be scaled on a per capita basis; iii) a scalable methodology by which the economic costs and benefits of implementing AWM and SIT can be assessed; and iv) a spatial simulation model which allows a mechanistic exploration of the effects of management practices on pest suppression outcomes across space and time, which is easily adaptable to different locations and management settings. Together, these outputs can assist in decision-making for AWM of Qfly including SIT going forward.

With regard to the next steps for SIT, we advise that there is a clear ongoing need to engage expertise in AWM in order for the technology to be effective. Specifically, there is a need to coordinate actions and follow the steps of our AWM Guidelines: in regions with fly populations making release decisions in relation to the landscape context, which are informed by the results of monitoring the effects of management, and which are based on socio-economic analysis;. The logical next step to support releases for SITplus is therefore to put in place the tools with which both strategic and tactical decisions for effective release can be made, informed by the findings of this project and building on the Guidelines and materials produced. Practical learnings may then identify low cost and high effectiveness implementation strategies and socially responsible pathways, which could support SIT in more complex and larger landscape settings. This would allow for releases to be managed strategically and efficiently.

The Adaptive Area Wide Management of Qfly using SIT project is delivered by Hort Innovation in partnership with CSIRO, and is supported by funding from the Australian Government Department of Agriculture & Water Resources as part of its Rural R&D for Profit program. Further partners include QUT, Agriculture Victoria, NSW Department of Primary Industries, PIRSA, SARDI, Wine Australia and BioFly. This project is part of the SITplus partnership.

Abbreviations and glossary

Ag Vic: Agriculture Victoria

AWM: Area-wide Management. See also https://area-wide-management.com.au/about/these-guidelines/

BMP: Best Management Practice

DAWR: Department of Agriculture and Water Resources

NSW DPI: NSW Department of Primary Industries

IPM: Integrated Pest Management

MAT: male annihilation technique

MGV: Murray/Goulburn Valley

NNSW; northern NSW

NPV: Net Present Value

PFA: Pest Free Area

QFAM: Queensland Fruit fly Area-wide Management (refers to this project)

Qfly: Queensland Fruit Fly, *Bactrocera tryoni*

SDM: species distribution model

SIT: Sterile Insect Technique

SITplus: https://horticulture.com.au/what-we-do/sitplus/ the research consortium established to deliver SIT and associated knowledge and practices to assist in the management of the major horticultural pest Queensland fruit fly.

WTP: willingness to pay

1 Project rationale and objectives

The project was undertaken with the aim to support the successful incorporation of Sterile Insect Technique (SIT) into the Area-wide Management (AWM) of Queensland fruit fly (Qfly). Qfly is a major pest of Australian horticultural crops, currently causing millions of dollars-worth of damage to horticultural crops across Australia, presenting a major market access barrier.

The broad goals to which the project contributes were established during the early phase of the project, following a program logic framework. These were to: ensure a thriving and sustainable horticulture sector; realise improved productivity and profitability for producers; remove the limitation that Qfly poses to commercial production and market access; and establish a framework for Area-wide Management (AWM) uptake of SIT within AWM for Qfly (SITplus). To focus the project towards these broad goals, two key project goals were also established:

> **1) Communities have an informed basis of current best technology to consider SIT as part of AWM in Qfly management;**
>
> **2) Guidelines for SIT incorporation into AWM of Qfly are workable and accepted.**

To meet these goals, the project focused on four broad activities:

a) Identifying and filling gaps in biophysical knowledge, developing risk maps and developing a simulation model to test management scenarios in different landscape contexts;
b) An economic analysis for individual vs area-wide management including SIT and willingness to pay;
c) An analysis of social barriers and enablers of adoption of AWM and SIT, including strategies for promoting adoption;
d) Regionally focused extension for BMP and AWM incorporating SIT.

These activities developed an understanding within the project team of biophysical, financial, social and institutional barriers and enablers to adoption of SIT as part of AWM, in order to produce regionally-specific Guidelines for AWM incorporating SIT for Qfly.

The following outputs from the project are summarized in this report:

- Output 1: Project management
- Output 2: Identifying social and economic challenges and constraints to successful SIT implementation;
- Output 3: Identifying biophysical challenges and constraints to successful SIT implementation;
- Output 4: Demonstrating Best Management Practice (BMP);
- Output 5: Developing area-wide fruit fly Guidelines;
- Output 6: Communicating the Guidelines and identifying next steps.

2 Method and project locations

The research was divided into three components: social, economic and biophysical. The research undertaken was facilitated by and AWM Coordinator, who acted as a conduit between researchers and stakeholder engagement. Each of these components followed component-specific research methodologies, with communication across the research components and the activities of the AWM Coordinator throughout the project.

Social methods

Scoping interviews and discussion group sessions were conducted to identify social and institutional barriers or facilitators of commercial uptake for AWM using SIT, across the various study regions, industries and sub-industries. Subsequently, community-wide surveys were conducted to test the barriers and facilitators identified in the context of AWM and SIT acceptance. The survey also examined intentions of both growers and the general public to adopt AWM and SIT, and to determine the predictors of adoption.

Economic methods

The economics component elicited information on production loss, on-farm Qfly management activities (distinguishing between new and amended activities) and access to various markets as experienced by growers. The farm-scale activity costs were aggregated to region-wide costs by summing across adoption, crop type, market, Qfly state by region (generalized aggregate model). Farm scale activity costs were combined with estimates of the willingness to pay of horticultural producers and communities (estimated from survey data using a choice modelling approach) to identify overall costs and benefits of Qfly in the case study regions. Region-wide AWM and SIT costs were estimated via structured scenarios that frame the transition process from the current baseline to the adoption of AWM using SIT. The scenario approach accommodated estimations of the time taken for grower adoption (social element), Qfly population management (biophysical), and the realisation of benefits from reduced Qfly pressure. This analysis structure provides a framework for bio-economic modelling of AWM and SIT which can be amended and updated as new information becomes available.

Biophysical methods

Both modelling and empirical research was undertaken to answer biophysical questions about Qfly distributions and behaviours, after initial review of key gaps in knowledge. A species distribution model (SDM) of Qfly was developed for the case study regions, based on expert elicitation and published literature. This allowed us to generate both habitat suitability (annual timeframe) and habitat susceptibility (seasonal timeframe) maps. A spatio-temporal simulation model with landscape and management scenarios was generated and applied to assess Qfly population dynamics and the implications of different management strategies in a range of landscape types. Data gaps were identified through an initial literature review and then prioritised in consultation with the modellers, after which behavioural ecologists conducted empirical studies to fill these gaps using a combination of field-based and laboratory methods.

AWM Coordinator methods

Baseline stakeholder information was collected at the start of the project via an online survey, and networks were established and maintained throughout the project. A contact point for the coordination of research activities on-the-ground was engaged across all regions, with initial communication and awareness raising of this project along with other Qfly management initiatives conducted by the AWM coordinator for the project. Extension and community engagement principles and activities were developed as required, most notably the website communicating our Guidelines for AWM using SIT.

Project locations

Research was undertaken by scientists based at CSIRO in Brisbane, Canberra, Adelaide and Perth, in partnership with Hort Innovation, QUT, Agriculture Victoria (Ag Vic), NSW Department of Primary Industries (NSW DPI), PIRSA, SARDI, Wine Australia and BioFly (Israel).

Three study regions were selected in southern Australia (Riverland, Sunraysia and Murray/Goulburn Valley [MGV]), on which we focused the bio-physical modelling scenarios and socio-economic studies, with results that translate beyond these regions (Figure 1).

Three study regions were selected in southern Australia (Riverland, Sunraysia and Murray/Goulburn Valley [MGV]), on which we focused the bio-physical modelling scenarios and socio-economic studies, with results that translate beyond these regions (Figure 1). These regions were selected on the basis of their economic importance to the horticultural industry in Australia. By value, SA, Vic, and NSW contribute 73% of Australia's fresh horticultural exports (Australian Horticulture Statistics Handbook 2016/17). Sunraysia's (Vic/NSW) major crops of citrus and table grapes collectively amounted to 216,596 t (with over half exported internationally); Sunraysia and MGV collectively produced 102,240 t of stone fruit (mostly for the domestic market; only 9,552 was exported internationally); and the Riverland produced a large amount of citrus (157,236 t), with much smaller production of table grapes (4,827 t) and stone fruit (11,280 t), which are also all mostly for the domestic market (54,066 t, 683 t and 207 t respectively went to international markets).

Within these regions, the socio-economic component of the project carried out their research activities in Loxton, Renmark, Waikerie, Mildura, Irymple, Merbein, Swan Hill, Tooleybuc, Shepparton, Tatura, Barooga, and Cobram. Area-wide management Guidelines arising from the project and communications were extended over a larger region, incorporating the scientific study regions as well as Riverina, Young/Orange, northern NSW (NNSW) and southern Queensland (SQ) (Figure 2).

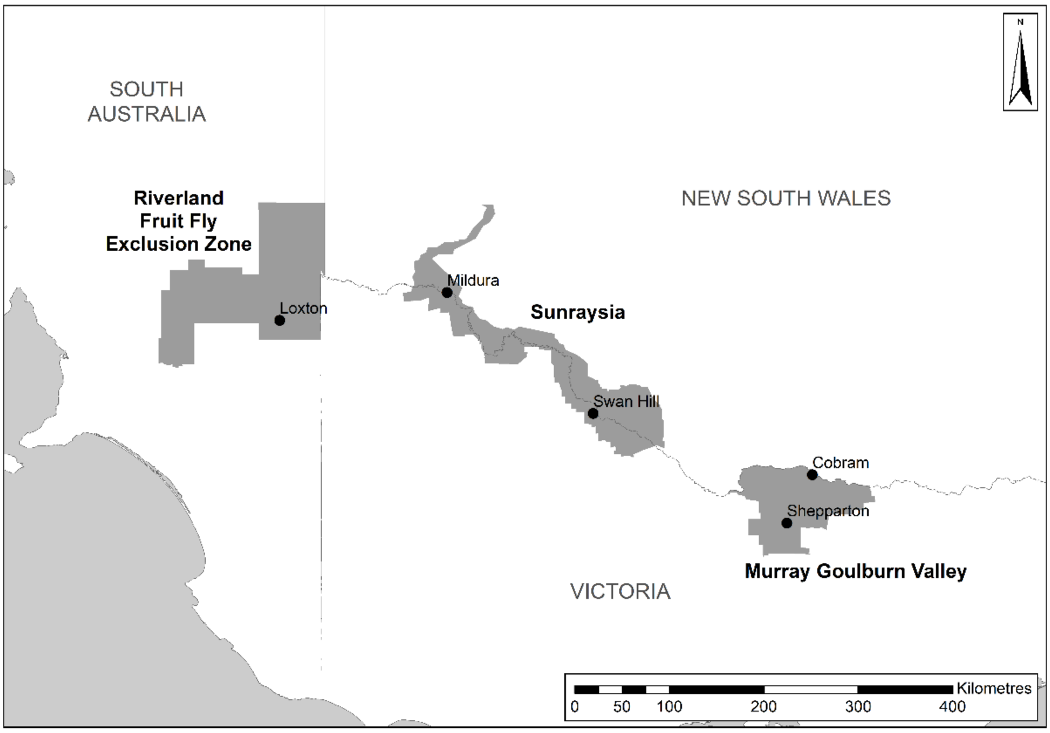

Figure 1: Map of the three study regions for scientific research, with the five survey locations for the socio-economic studies indicated.

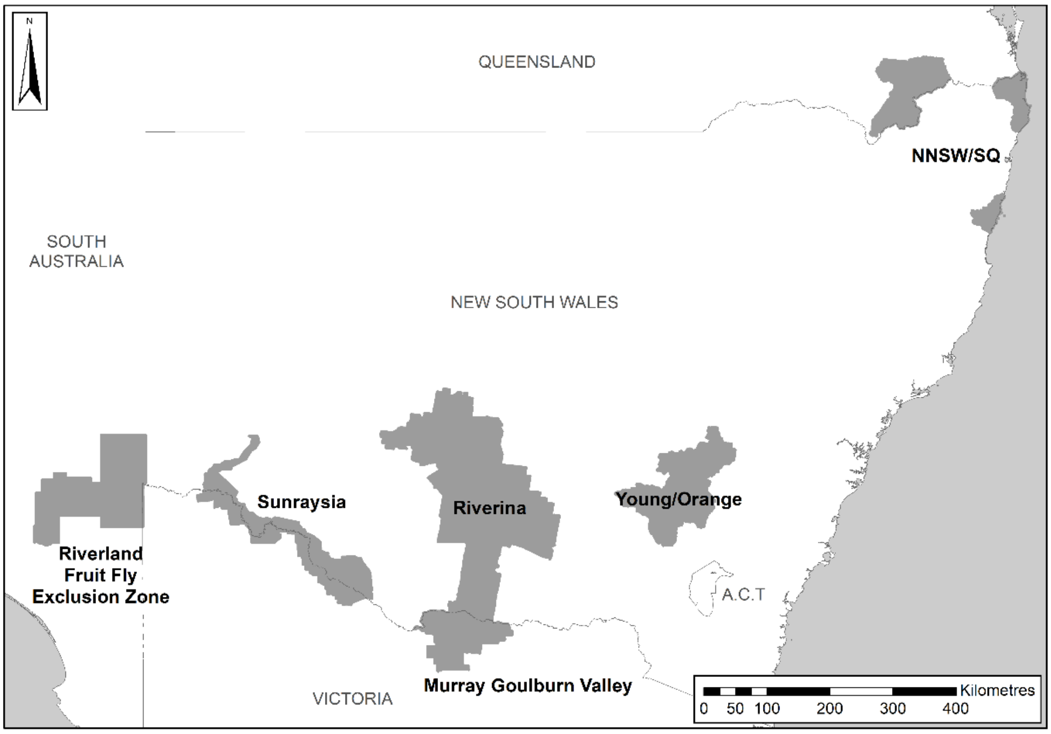

Figure 2: Map of the seven regions for extension of the area-wide management Guidelines and stakeholders

3 Project Outcomes

3.1 Project level achievements

Note that this report follows the Milestones and KPIs as agreed in the deed of variation of 9th May 2016.

3.1.1 Project initiation and management

The project developed a solid governance structure, appointing sub-project leaders to facilitate the delivery of the project who worked closely with the project leader and also the AWM coordinator. Partner organizations contributed throughout the project, both in-kind (Biofly, NSW DPI, Ag Vic, Wine Australia) and as sub-contractors (QUT and PIRSA), as per the agreements (KPI 1.2). Project team meetings were held regularly, both telephone and face-to-face, and meetings with the Stakeholder Committee (KPI 1.3) also took place more than once a year. We were guided by an M&E plan (KPI 1.1) based on project logic developed by the team at the first face-to-face meeting, and by the stakeholder engagement and communication plans. We had a thorough publications approvals process. Milestone reports, including financial reports, were delivered in a timely manner through the duration of the project (KPI 2.1, KPI 4.1 and KPI 6.1), and an independent mid-term review was conducted (KPI 3.1) with a report provided to the department. Attached to this report is an end of Project evaluation report (KPI 6.2).

3.1.2 Identify social and economic challenges and constraints to successful SIT implementation

Within the first six months of the project, a pilot scoping study to refine the social research objectives was conducted (Output 2a/KPI 1.5). Telephone interviews were conducted with a total of 34 participants, comprised of 19 fruit growers, nine fruit industry association representatives, four agronomists/field officers, three state government officers, three local government representatives, and one community gardening group leader across the three case study regions: Riverland (n = 5), Sunraysia (n = 12) and Murray/Goulburn Valley (MGV; n = 13), with an additional four fruit industry association representatives providing a national perspective.

At the end of the first year of the project, the results of the pilot scoping study were analysed to inform the larger study (Output 2a). These results comprised qualitative broad themes found in the interview data: barriers and facilitators of AWM and SIT (assuming a male-only release, the aim of other projects within the SITplus consortium), as well as perspectives on general acceptance of AWM and SIT. Barriers were identified as: cost and sustainability; lack of knowledge; apathy/perceived lack of relevance; integration with current practice; and lack of cooperation/compliance. Facilitators were identified as: market access guarantee; community champions; involvement of packing sheds; and contextual evidence of success. In general, growers believed they were already carrying out AWM (likely linked to an inconsistent definition of AWM). Growers were willing to be involved as long as everyone was seen to be involved, and believed that the general community would accept AWM as long as personal involvement was easy to understand, cost effective, and did not require much effort. SIT was generally viewed as another potential tool for management, complimenting existing BMP, although with a potential cost barrier.

The results from the pilot study provided a good baseline understanding of the types of social issues that were important to stakeholders and, in particular, how growers were perceiving the Qfly threat, AWM and SIT. These data also provided a springboard from which to launch focus groups and explore topics identified as barriers and facilitators further, including additional perspectives from the general public. This led to the development of a framework for stakeholder interviews (Output 2c/KPI 3.2) by the mid-term of the project (18 months).

After two years, stakeholder interviews had been conducted (Output 2c/KPI 4.2) and a summary of outcomes was provided to Department of Agriculture and Water Resources (DAWR). A comprehensive analysis of 1,027 survey participants gave us a confident understanding of the barriers and facilitators to AWM and SIT in the focal regions, and the relationships between these factors in the context of intention and acceptance. Fairness was found to be the strongest predictor of acceptance for AWM and intention to implement, with a trend towards some regions to be more receptive than other regions (i.e., Sunraysia showed higher acceptance than MGV). All participants from the three regions felt morally responsible for helping their region manage Qfly. Besides perceived fairness, perceived severity of the Qfly threat, self-efficacy, and a belief that AWM would be effective in managing the Qfly pest, provided insight into intentions of individuals to implement AWM and their perceived moral obligation to do so. Acceptance of SIT was most likely if an individual believed an 'important other', such as a family member, would also give their approval. It was also important for the SIT process to be easy to understand. Fruit Industry Bodies received the highest rating of trustworthiness for managing Qfly, followed by a committee comprising a mix of government and industry organisations. For details see research paper 'Psychosocial barriers and facilitators for area-wide management of fruit fly in southeastern Australia' and book chapter 'Social and institutional factors important in the area wide management of insect pests' (Appendix 7.1.1).

During the first year of the project a discounted cash-flow analysis was conducted to compare grower benefits of SIT with other fruit fly management approaches (Output 2b/KPI 2.2). The economic analysis assessed current (baseline) Qfly costs in major south-eastern Australian horticultural industries in the three case study regions. The expected costs of Qfly management, production loss and whether there was likely to be loss of market access were estimated for the Sunraysia and MGV, and the costs of an outbreak in the Riverland Pest Free Area (PFA) region, were also estimated. We also looked at factors which would influence these costs, including regional differences in crop mixes, pest status, market access rules, monitoring and management methods and future trends in management. In addition we identified the costs of an AWM management program and the consequent future reductions in cost/increase in benefits to landholders.

The total (baseline future) cost of Qfly for each of the three regions was estimated as the sum of: on farm management cost, post-harvest treatment cost, and production losses resulting from produce not able to be harvested, sold or rejected consignments. The annual future cost of Qfly under a business as usual scenario where Qfly is already established was estimated at $6.7m/Yr in Sunraysia, $4.5m/Yr in the MGV. For the Riverland which remains Qfly free it was estimated at $5.6m/Yr (assuming the total $5m/yr SA costs of maintaining Qfly freedom in SA apply to the Riverland). Implementation of AWM and SIT to manage the already established Qfly populations in Sunraysia and the MGV requires more intensive management of Qfly on farms and in surrounding urban and peri-urban areas. Evaluating these costs and benefits over the next 20 years (net present values) we find that the Sunraysia region is worse off by $30m under a best case (faster control of Qfly) scenario, or $37m under a worse case (slower control of Qfly); and similarly, in the MGV under the best case control scenario the region is worse off $29m, or $40m under the worst, compared to the mature baseline, Table 1. In the Riverland the counterfactual for analyses is a 'lose control' scenario where Qfly become established costing an estimated $118m in present values (which incorporates an early high cost phase with production losses during the pest establishment phase and a lower cost maintenance phase once landholders integrate Qfly management into their programs). The comparison for the Riverland contrasts maintaining Qfly-freedom over this higher alternative future cost, delivering substantive benefits: a Net Present Value

(NPV) of $58m using historic outbreak likelihoods and a lower NPV of $45.9m under an increased rate of outbreaks (incurring higher costs of preventing establishment; Table 1). This result supports the typical economic narrative that it is more cost effective to prevent a pest from establishing than to attempt to remove it later. For details see research paper 'Characterizing the costs of Queensland fruit fly and benefits of Area Wide Management to growers: case studies in south-east Australia' (Appendix 7.1.1).

Table 1: Economic scenario results - cumulative Present Value (PV) cost over 20 years for increased Qfly control (lost control in the Riverland)

Scenario/Cost	**Sunraysia (gain control)**	**MGV (gain control)**	**The Riverland (lose control)**
Baseline $m	70.9	47.4	60.8 (57.7 better off with current incursion rates)
Best case $m	100.4 (29.5 worse off)	76.0 (28.6 worse off)	72.5 (45.9 better off with higher incursion rates)
Worst case $m	107.9 (37.0 worse off)	87.3 (39.9 worse off)	118.4 (cost of Qfly establishment)

Note: Discount rate = 7%

After two years, a bio-economic model was developed (Output 2d/KPI 4.3), building on the baseline assessment conducted in the first year. This identified and costed the relevant scenarios in delivering SIT, including individual and area-wide cost frameworks, and their impact for producers on yield and the market. The main narratives from this work were reported to DAWR, and are also summarized in the present report on KPI 6.4 in relation to the feasibility of AWM and SIT objectives (see Appendix 8). We show that there are three potential economically-viable implementation strategies for AWM including SIT: outbreak eradication (and potentially maintenance of area freedom, should legislation allow); direct substitution for existing sporadic management in spatially-isolated contexts (including in support of industry-specific market access); and more effective management in an urban context than existing adhoc approaches.

The willingness to pay study was completed six months before the end of the project (Output 2d/KPI 4.4). Choice modelling surveys were used to examine the willingness to pay (WTP) by growers and residents for AWM and SIT across the three case study regions. The total number of growers invited to participate in the survey was uncertain, due to the multi-method approach employed to reach as many growers as possible. The response rate across the 600 paper surveys handed out via grower groups and growers associations was 30 completed paper surveys, giving a response rate of 5%. The response rate across 53 growers contacted by the online survey company and given the hyperlink to the survey was 36 growers yielding a response rate of 68%. A total of 1,556 residents were invited to complete an online-only survey. Out of the 648 residents who responded to the invitation, 389 completed the survey. Therefore, the total response rate was 25%.

Although there was evidence of inertia and a preference for maintaining the status quo for growers across all three regions, there was also positive and large willingness to pay among growers for Qfly management in towns as well as a SIT program component. This is likely to be in part as these activities are beyond an individual grower's control and are perceived as reducing risk on their farms. Overall, growers also perceived the aggregate benefit of AWM to be greater than the inconvenience of change when several AWM program components were bundled together, but not all bundles were perceived as beneficial.

Residents exhibited a positive WTP for each of the proposed AWM program components. For example, residents would be happy to pay for an on-property tree removal service alone as part of an AWM activity in the town. Support for SIT was strong among residents across all three case study regions. Second to SIT, residents demonstrated a positive WTP and preference for the distribution of organic traps in the vicinity of $40 to $55 per household, and no real preference for tree netting over tree removal, indicating that both are acceptable and substitutable. Residents also exhibit strong WTP for a SIT program and less so for reduced chemical usage (which could potentially be achieved via a successful SIT program anyhow). There exists preference heterogeneity among growers and residents across the three regions, likely due to differences in socio-economic (e.g. age and gender), social (e.g. how many non-family members the respondent interacts with regularly or involvement in organized groups such as sports teams), attitudinal (e.g. sense of belonging in a region) and farm characteristics (e.g. crop type) (note: Riverland respondents were asked to answer based on an imagined scenario of Qfly presence in the region). WTP estimates for the preferred package containing Qfly management and SIT are given in Table 2**Error! Reference source not found.** below, by region. Conventional use of WTP data suggests a conservative approach to extrapolation, therefore it is advisable to rely only on the conservative extrapolation rate of 25% of the total horticultural land. For details see research paper 'Willingness to pay for area-wide management and sterile insect technique to manage fruit flies' (Appendix 7.1.1).

Table 2: Annual regional total WTP estimates for the entire community (at different extrapolation rates) for the preferred Qfly management and SIT package: status quo + AWM in town + SIT, in the three case study regions.

Region	Annual total WTP ($) Extrapolation rate (% of total horticultural land)			
	25%	50%	75%	100%
Riverland	970,881	1,941,762	2,912,642	3,883,523
Sunraysia	1,112,335	2,224,670	3,337,005	4,449,340
MGValley	938,283	1,876,565	2,814,848	3,753,130

3.1.3 Identify biophysical challenges and constraints to successful SIT implementation

In the first year of the project, knowledge was integrated and reviewed on the effects of land use on the distribution and dynamics of Qfly, as well as the anticipated benefits of SIT adoption to crop production, quality and market access (Output 3a/KPI 2.3). In first examining the literature, key findings were that although SIT could be a highly effective and benign pest management strategy as part of an AWM approach, it is also well recognized as costly, requiring optimal targeting in space and time to maximize benefits. The poor knowledge on the field ecology of Qfly then poses a challenge to SIT for Qfly in Australia, with studies to date focused on mechanics of release rather than timing and locations. The use of multiple hosts across the year and sensitivity to temperature, and also to some extent rainfall, mean that Qfly is not equally abundant at all times or in all places. Although some knowledge already existed on seasonal habitat use and dispersal there was a lot of uncertainty about dispersal behaviour and the role of some potentially important habitats, such as urban areas and waterways. Thus, while some aspects of the small-scale foraging behaviour of Qfly were known, and the large-scale regional and seasonal scale patterns of abundance were perhaps known or predictable, the intermediate level of ecology (i.e. how populations behave in specific agricultural landscape) was largely unknown. Further review of the literature revealed key biological parameters and existing modelling approaches for the population dynamics modelling of Qfly and a study exploring the measurement of insect fitness with Near Infra-Red Spectrometry (NIRS) was undertaken to explore a potential novel technique that would allow us to measure Qfly health and body condition in different environments. Unfortunately this did not reveal a method we could employ in the field studies. A full report in the form of a literature review of the landscape ecology of fruit flies was submitted to DAWR at the mid-term of the project. The latter work was not published as a stand-alone document as it was considered that there is insufficient depth in the primary literature to justify a formal scientific review. However, contents of the review informed, and were subsequently utilised within, other publications from the biophysical component.

An expert elicitation workshop was conducted in Brisbane with 12 participants (a mix of entomologists and land managers with interests in Qfly) in February 2016 (

Table 3, KPI 2.5), supplemented by smaller elicitation engagements with regional experts who were not able to attend. This enabled us to construct a habitat suitability model using a Bayesian Network methodology, incorporating key factors that determine the suitability and susceptibility of habitat according to the experts (Output 3a and 3c). This was initiated in the first year of the project (KPI 2.4) and preliminary results were provided to DAWR (Figure 3 and Figure 4).

Table 3: Workshop participants that attended the 2-day ecology workshop for Qfly on 10-11th February 2016.

Expert	Organisation	Experience with Qfly
Olivia Reynolds	NSW DPI	Ecology & management, SIT, biological control; Stanthorpe, Riverina
David Williams	Ag Vic	Goulburn Valley, Sunraysia; fruit fly management
Tony Filippi	Integrity Fruit	Sunraysia, Goulburn Valley; fruit fly management; are-wide management
Peter Crisp	SARDI	South Australia, monitoring & eradication, sterile insect technology
Dan Papacek	Bugs for Bugs	Private consultant, Sunraysia, Goulburn Valley, Qld
Craig Hull	DAWR	Commonwealth fruit fly coordinator; PhD fruit fly
Paul Cunningham	QUT/Ag Vic	Insect ecology & behaviour, lure baits, Stanthorpe
Peter Leach	Qld DAF	Northern Queensland, Asia/Pacific
Stefano De Faveri	Qld DAF	Senior entomologist; Mareeba
Lara Senior	Qld DAF	Entomologist
Brendan Missenden	Qld DAF	Entomologist; fruit fly management
Daniel Mansell	Ag Vic	Domestic quarantine & market access
Tony Clarke	QUT	Behaviour, ecology & management; Stanthorpe

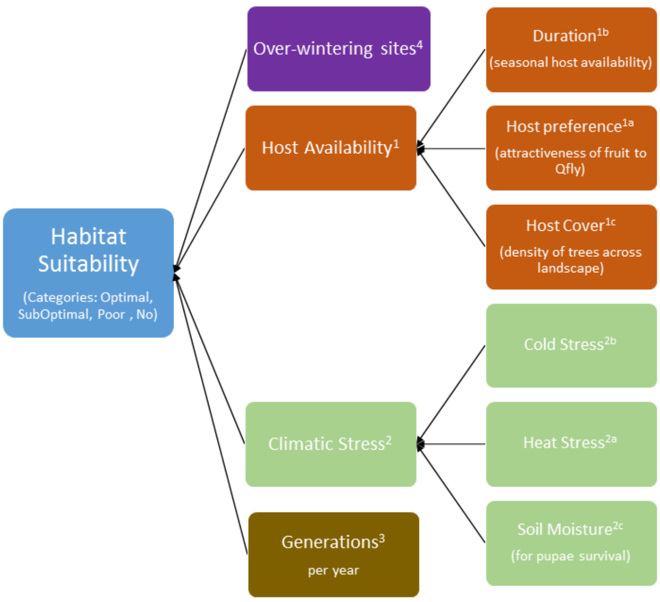

Figure 3: Conceptual diagram of the habitat suitability model for Qfly developed in the expert workshop.

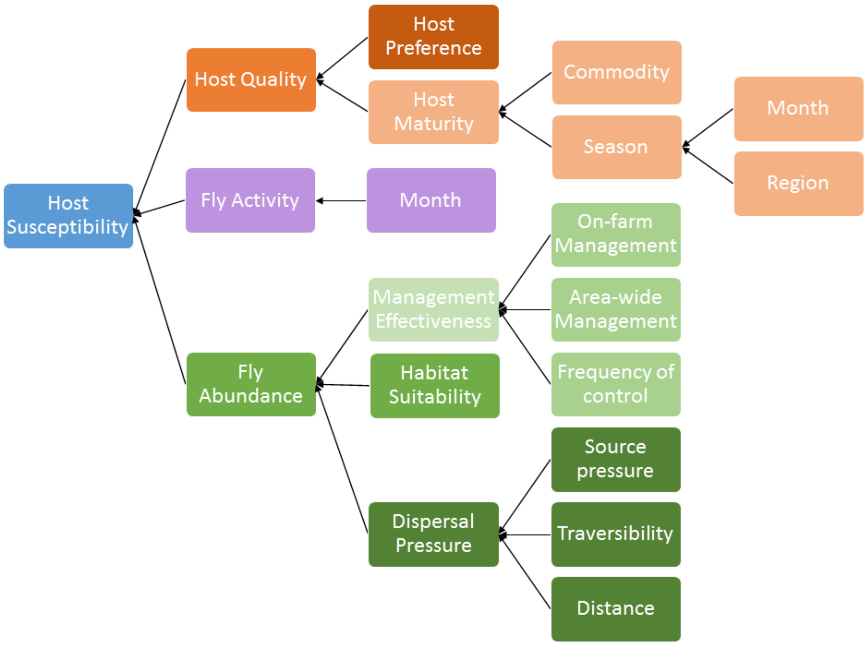

Figure 4: Conceptual diagram of the susceptibility model for Qfly developed in the expert workshop.

The following biophysical knowledge gaps were identified during the first year of the project (Output 3b), framed as suggested research opportunities for the then newly appointed ecology post-doctoral fellow:

- Collection of observational data on proportional changes in *B. tryoni* abundance in key habitat types or areas at key times in the season.
- Preference-performance trials for potential hosts of fruit fly.
- A resource-foraging study.
- A dispersal study to determine where flies go in a complex landscape, including urban/peri-urban habitat.
- Confirmation as to whether post-teneral dispersal is a behaviour present in Qfly.

Following the full literature review conducted by the mid-term of the project, these research recommendations were refined to the following two key focus areas where gaps were identified, forming the research objectives for the field ecology post-doc:

1) Research *B. tryoni* behavioural foraging rules to better understand, and so allow more accurate modelling, of *B. tryoni* local movement within the landscape.
2) Research on how *B. tryoni* survives winter periods in temperate Australia where temperature and lack of fruit hosts may be expected to depress local populations.

After two years, the two research objectives of the field ecology post-doc were undertaken, and the project was able to begin to fill some of the knowledge gaps of fruit fly requirements (Output 3(b and c), KPI 4.5). Key results on the field studies were presented during the final year of the project, including in the present report (Appendix 9), with some further analysis required. Key research findings were:

1) The foraging study revealed that there is a higher likelihood of individual fruit being infested on a tree with few fruit than a tree with many fruits, and a short period of exposure can result in an equal amount of infestation compared to a longer period. This means that the few fruit remaining on trees post-harvest may still become infested, and that in the context of AWM treatments shouldn't leave this window of opportunity for fly breeding. Similarly, backyard or feral trees with just a few fruit are potentially significant sources of fruit flies to the local population. Further research (Appendix 9) explored these foraging behaviours further, testing specific predictions of the simulation modelling.
2) The overwintering study revealed that, in northern NSW, fruits on trees over winter harbour Qfly eggs and larvae, but the number of flies emerging from infested fruit during the winter is very low. In NSW the increasing number of emerging flies towards the end of winter and early spring suggests that removing fruit from the orchard at the start of the winter season may help to reduce fly numbers in early spring. The sudden peak in emerging flies in late August highlights the importance of managing the early spring populations. Nothing in the study was at odds with older literature which reported that adult overwintering is the most likely overwintering mechanism for most of the *B. tryoni* population. For details of the over-wintering research see research papers '"Overwintering" phenology of a polyphagous, tropical fruit fly (diptera: tephritidae) at the sub-tropical/temperate interphase' and '*Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) over-wintering: a mini-review' (Appendix 7.1.1).
   While not a target question of the over-wintering study, regular sampling of fruit during the late-autumn and early winter in northern NSW detected very high Qfly parasitism levels, commonly well over 50%. Qfly parasitoids are not generally considered to exert this level of population mortality, but this study, and a more detailed parasitoid phenology carried out, shows that Qfly parasitism increases during the season, peaking in late autumn. While not a core component of the current project, it is a valuable 'spin-off' finding which can be further pursued in the support of Qfly AWM.

Also after two years, further elicitation of regional experts for model calibration (four per region) was complete and risk maps were generated, with feedback received from community and industry representatives (Output 3(b and c), KPI 4.6). Although experts saw no discrepancies with the models, they had concerns over the communication of the maps (particularly the seasonal susceptibility maps, not shown here), given the sensitivity of the underlying data. Experts saw significant value in the models: at the industry level to show where risk has been identified for broad-scale prevention, management and eradication, and at a more local scale to identify specific management needs to reduce Qfly numbers. The maps of habitat suitability (annual timeframe) are shown in Figure 5 for the three case study regions. For details see research paper 'Developing spatially explicit risk maps for *Bactrocera tryoni* (Diptera: Tephritidae) in southern Australia to facilitate area-wide management' (Appendix 7.1.1).

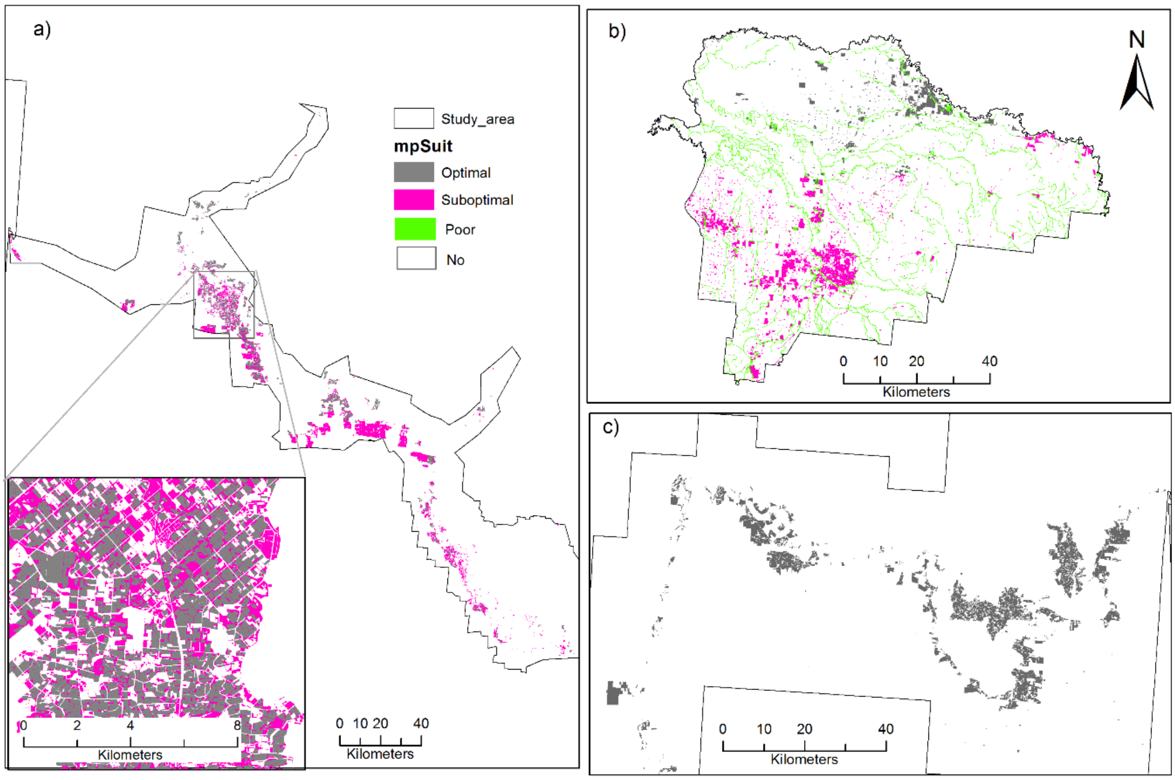

Figure 5: Habitat suitability maps for a) Sunraysia (with insert showing an area in finer detail), b) MGV, and c) Riverland regions. 'mpSuit' shows the level of suitability of habitat across the region on an annual basis, as estimated by the model (see text).

3.1.4 Demonstrate best management practice (BMP)

An AWM Coordinator was appointed to the project within the first six months (Output 4d/KPI 1.6). The coordinator undertook network and relationship building activities (Output 4d/KPI 1.7), including face-to-face and phone engagement, as well as popular press articles. Information about Qfly management practices was gathered in the different regions, and an overview of fruit fly research in Australia was compiled.

By the end of the first year of the project, a review of current management practices had been completed (Output 4a/KPI 2.6) with a consideration of how SIT could be integrated into management programs (Output 4b/KPI 2.6). This was achieved through a comprehensive consultative process, and a survey targeting horticultural producers: the survey included 180 growers, with responses from SA, Vic, NSW and Qld. Best management practices were discussed with the project's Stakeholder Committee, with industry association representatives and specific fruit fly community groups, and formed part of the survey. Currently, management options for Qfly fall under 2 broad categories; on-farm management and AWM. It was difficult to evaluate effectiveness of individual tools within these options, but the general consensus was that bait-spraying and male annihilation technique (MAT) are complementary, and hygiene is a key component (particularly in areas of high infestation). The survey results supported this, with the majority of growers familiar with, and using, these practices, but with room for improvement. The results of the survey also showed that the potential for good management of Qfly using available on-farm methods is high and that growers are aware and accepting of the reality of the Qfly problem currently faced in each region. The biggest concern for most growers was the off-farm pest population. Two results from the survey are given below, showing the current perception of the Qfly problem by growers (Figure 6) and also the range of management strategies currently employed to manage the pest (Figure 7).

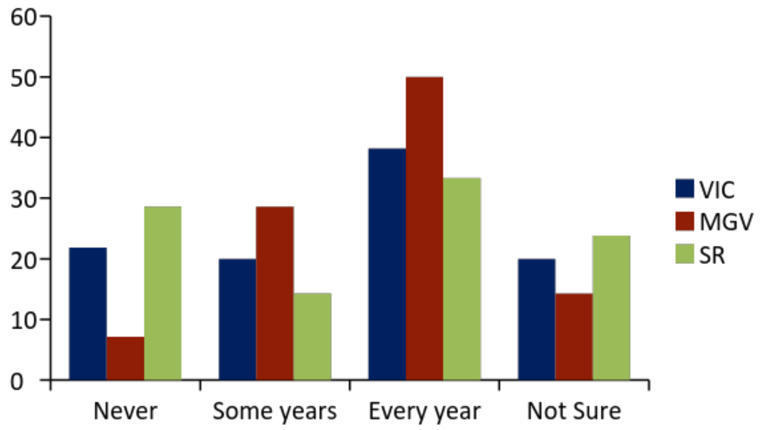

Figure 6: The percentage of Victorian (VIC), MGV and Sunraysia (SR) growers that see Qfly on-farm at different time periods.

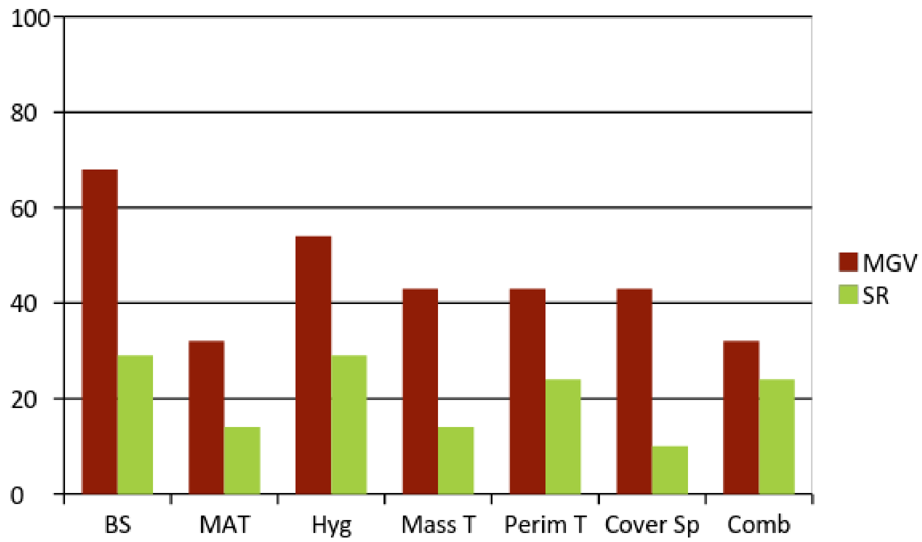

Figure 7: The percentage of growers using different Qfly management options (bait-spraying, male annihilation technique (MAT), hygiene, mass trapping, perimeter trapping, cover sprays and a combination of strategies)

At the mid-term of the project (18 months), progress had been made in informing and tailoring management programs in the Victorian case study regions (Output 4c and 4d/KPI 3.3), with BMP Guidelines packaged and delivered and information on the benefits of area-wide coordination of Qfly management communicated by the AWM Coordinator for the project to regional councils, industry groups, horticulture agronomists, consultants and growers across all of the project regions in South Australia, Victoria, and New South Wales.

A total of 17 project materials were produced (Appendix 7.1.5 and 7.1.8) and 33 engagement activities (Appendix 0 and 7.1.4) were undertaken during the first half of the project, using various communication formats; written articles, presentations, meetings, workshops and discussions. A literature review was conducted to unearth the success factors for AWM approaches from around the world. This review led to the development of a capability matrix and guided the identification and addressing of regional needs for improving AWM activities. The matrix could be used as a self-assessment tool for AWM capability readiness, and has additionally helped inform the development of area-wide fruit fly Guidelines that address all aspects of an AWM approach.

Using this knowledge, progress continued in bolstering management programs in the case study regions (Output 4c/KPI 4.7), by focussing on the integration of both on-farm and off-farm efforts within an area. This was aided further by bringing the findings of the social, economic and biophysical components into extension efforts. For example, the results from the social component helped explore the potential role of local council in AWM approaches. Engagement tips were well received, especially the advice regarding keeping activities simple and providing simple messages in order to make participation easy, as evidenced by the increase in the simple messages seen in the social media communication from regional groups in the last year. More recently, understanding the costs involved in AWM programs for regions, along with the 'willingness to pay' results have helped regions consider costs, benefits and explore various funding models. The biophysical modelling that shows pest suppression under AWM, and the influence of the predominant landscape (continuous hosts) has confirmed the assumption that urban treatments are important. The biophysical field work showing the potential for few fruit to be infested and produce similar fly numbers to having many fruit available and infested has reinforced the need for good hygiene and postharvest clean up in orchards. These results all underpinned the Guidelines that were developed for AWM using SIT.

By the end of two years, 41 project materials had been produced (Appendix 7.1.5, 7.1.7, 7.1.8 and 7.1.9) and 47 engagement activities (Appendix 0 and 7.1.4) had been undertaken in total.

3.1.5 Develop Guidelines for AWM of Qfly

During the first six months the project identified a need to appoint a post-doctoral research fellow to conduct the Qfly simulation modelling work (Output 5a/KPI 1.8). We interviewed candidates from across the globe, and appointed a highly suitable scientist from Germany, who commenced work on the simulation model in January 2016.

By the end of two years, significant progress had been made in this activity. A Qfly spatially-explicit population dynamic simulation model had been developed (Output 5a/KPI 4.8) and a report on scenario modelling in different landscape contexts (Output 5b/KPI 4.8) was provided to the Department. Key results from the simulation model focus on two areas:

1) The effects on population dynamics of resource continuity and movement strategy;
2) Area-wide management: How, where and when to manage.

With regard to understanding the effects of resource continuity and movement strategy, key results from our simulation modelling work suggest that continuity, not abundance, of available oviposition sites is the main determining factor for large and persistent populations. This finding extends explicitly to continuous low level resources such as backyard trees in urban areas (supported by validation against monitoring data from the field). We also showed that knowledge gaps in the density dependence and the directedness of Qfly movement impede more detailed predictions. A directed movement strategy of Qfly and the sequential use of hosts leads to larger and more persistent populations, possibly overriding resource effects. Analysis of the final field study data will give insights into the landscape level population dynamic of Qfly which will help to fill this gap and validate and refine model assumptions. For details see research papers ‘Resource continuity and movement strategy shape Queensland Fruit Fly population dynamics.’ and ‘Area-wide management of Queensland Fruit Fly: How, where and when to manage’ (Appendix 7.1.1).

In terms of area-wide management, the model indicates that management actions that kill the adult female fly have the highest effect on population densities. Methods that reduce offspring have to be very efficient to achieve a similar result. When it comes to management effectiveness in a range of different complex landscapes, we could show that an increase of on-farm BMP can reduce populations and detections. However, this effect is landscape dependent: in areas with a single crop, on-farm BMP effects are highest. The most challenging areas to manage are the ones with multiple crops close to an urban area; these generally support the highest population densities as determined by our first study, due to the continuity of hosts throughout the year. However, when incorporating these urban areas into an AWM programme, suppression can be achieved in these areas as well. As an example, we showed that a well conducted and complete urban trapping programme in combination with a 60% on-farm BMP adoption across a landscape can reduce the number of hotspots drastically. We also showed that a three month urban trapping programme would be most effective in winter/early spring when you would expect these areas to be a refuge for the overwintering population (Figure 8), compared to the same applied at other times of year.

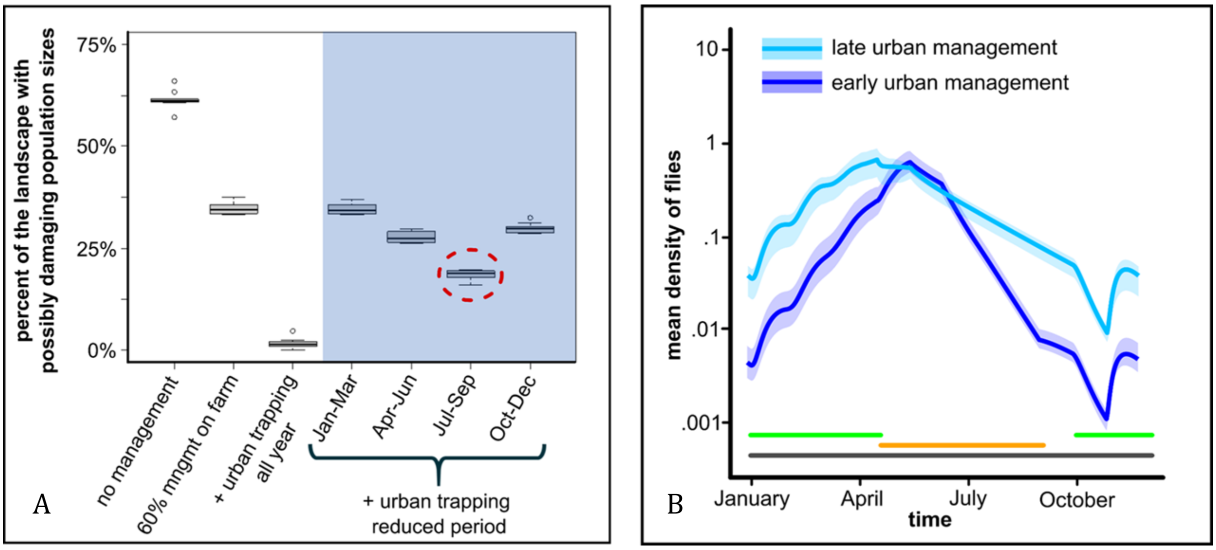

Figure 8: Simulated effects of management type and timing on Qfly populations in landscapes containing urban habitat. Simulations were run across ten replicate artificial landscapes with the same properties, and the graphs show variation between these landscapes (A: mean (line) and interquartile range (box); B: mean (darker shade) and range between maximum and minimum (lighter shade) at each time step). The most effective urban trapping program when resources are limited is indicated by the red circle. Different host availability over time is indicated by the green and brown lines.

The model results, along with other scientific findings from across the project, were communicated directly with stakeholder groups (Output 5c/KPI 5.1). The Chief Investigator and three sub-project leaders/representatives conducted a roadshow Aug 30-Sept 1 2017 (nine months before the end of the project), accompanied by the AWM Coordinator. This comprised three events with two hours of talk/discussion presenting the work of the entire project team in each of Shepparton, Mildura and Loxton. Several radio, television and newspaper articles were produced either promoting the roadshow prior to the events, or reporting on them afterwards, and the events themselves were attended by local media.

Following the presentation of, and valuable feedback from, the project roadshow, along with information gained from the ongoing and substantial activities of the AWM Coordinator, and the Stakeholder Committee, the activities of the entire project came together to produce draft Guidelines for AWM of Qfly incorporating SIT (Output 5d/KPI 5.2). The collation and development of the material was a significant combined effort from the project team, led by the AWM Coordinator. The draft Guidelines were discussed with and approved by the project stakeholders and DAWR before further refining and developing into a website.

3.1.6 Communicate Guidelines and identify next steps

This activity has built on all other activities of the project and is delivered in this current milestone. Guidelines were communicated to stakeholders and feedback incorporated (Output 6a/KPI 6.3) during a face-to-face meeting with project stakeholders in February 2018. The decision to develop the Guidelines as a website https://area-wide-management.com.au/, which went live at the beginning of April 2018, was a decision that evolved during the project in discussion with stakeholders who showed strong preference for this, so long as it could be housed somewhere that provided longevity, accessibility, was reputable and could be updated. Prior to establishing the website, an exploration and review of existing websites and web-based materials was conducted. This highlighted a gap in AWM support; while the project found numerous sites with integrated pest management (IPM) principles, and case studies (and support materials) for AWM programs around the world, a high-level step-wise approach to embarking on AWM was not found.

In developing the Guidelines and website format, the Stakeholder Committee advised that: using steps would be helpful; messaging should be consistent; all information required for embarking on an AWM approach should be provided, including support materials and engagement tips. A multi-media, web-based format as a means to communicate the Guidelines, along with associated materials (downloadable from the website) was considered to be the most effective means to widely disseminate the Guidelines; ongoing user statistics will be monitored by Hort Innovation who will have custody of the website into the future, and will update as required.

Activities during May 2018, and beyond, to communicate the Guidelines are:

- Regional visits and workshops to showcase the website (Yarra Valley, Swan Hill, Mildura, Griffith, Coffs Harbour)
- Presentation to the Fruit Growers Tasmania Biosecurity Conference (Tasmania)
- Promotion at the Cherry Growers Australia Export Workshop (Canberra)
- Promotion at the Hort Innovation and CSIRO trade stands at Hort Connections, Brisbane
- Suite of materials packaged for local governments
- Social media promotion plan

The website was also promoted in the media coverage of SITplus' first releases of sterile flies over Adelaide.

At this final milestone we also provide an important report on the next steps needed to produce and deploy sterile males for managing Qfly (Output 6b/KPI 6.4): see Appendix 8, as part of this final project report (Output 6c/KPI 6.5). The report gives our research findings on: 1) the general target areas that are appropriate for SIT releases; 2) objectives that are appropriate for SIT releases; and 3) the deployment strategies that would need to be taken into account in order for SIT to be successful in meeting objectives in a target area.

Overall, we advise that there is a clear ongoing need to engage expertise in AWM in order for the technology to be effective. Specifically, there is a need to coordinate actions and follow the steps of our AWM Guidelines: making release decisions in relation to the landscape context, which are informed by the results of monitoring the effects of management, and which are based on socio-economic analysis; it is not enough simply to produce and deploy the flies for SIT to be effective. However, a top-down, labour-intensive approach like that of BioFly in Israel is not something that is likely to be viable for SITplus in Australia without large government subsidies. The logical next step to support releases for SITplus is therefore to put in place the tools with which both strategic and tactical decisions for effective release can be made, informed by the findings of this project and building on the Guidelines produced. Practical learnings may then identify low cost and high effectiveness implementation strategies and socially responsible pathways, which could support SIT in more complex and larger landscape settings. Ideally, this would allow for releases to be managed strategically and efficiently, but not in a labour intensive or highly subsidised manner.

3.2 Contribution to program objectives

This project realised a significant increase in knowledge on the impact and management of Qfly at the biophysical, social and economic levels. The results of the project have been extended to a breadth of stakeholders (growers, councils, fruit fly coordinator groups, urban residents) in the Riverland, Sunraysia, Murray/Goulbourn Valley, Riverina, Yarra Valley and NSW and southern Queensland. Communities have been informed in person on current best technology to consider SIT as part of AWM in Qfly management. The Guidelines for SIT incorporation into AWM of Qfly were produced following significant input from the project Steering Committee, comprising representative growers, local councils, and state and federal government stakeholders.

The biophysical research has generated risk maps that provide invaluable knowledge for planning SIT releases, as well as for ongoing AWM and monitoring programs. The project highlights the challenges and opportunity for AWM in managing complex landscapes (e.g. a diversity of hosts that fruit across different seasons, such as those in or close to urban areas), and the biophysical models identify potential hotspots and bottlenecks for targeted SIT release strategies.

The knowledge generated by the project has made a significant contribution to the SITplus program. The biophysical, social and economic data generated by this project provide strategic insights into where, when and how SIT Qflies can be most effectively released as part of an AWM program. As such, the project contributes to and extends the research in other SITPlus projects within the consortium. Moreover, the research partnerships strengthened in this project, overlap with other projects in the SITplus consortium (and beyond), which has in turn furthered opportunities for transdisciplinary research into effective, holistic pest management in horticulture. Not only will AWM of Qfly improve infield management and therefore productivity, it is critical for building and maintaining access to domestic and international markets, leading to greater productivity for growers.

The final independent review of the project is in the Appendix (Section 7.3).

4 Collaboration

The project was initiated as a collaborative project between the main partners, Hort Innovation and CSIRO, and other partners that included QUT, PIRSA and SARDI, Agriculture Victoria, NSW DPI, Wine Australia and BioFly. This also includes the SITplus Consortium managed by Hort Innovation.

Further partnerships were established during the project by including other groups in the project Stakeholder Committee (regular meetings): Local Government (Loxton Waikerie, Berrigan), COSTAS, Yarra Valley Pest Free Place of Production, Greater Sunraysia Pest Free Area Industry development Committee and Cobram District Fruit Growers Association, and a DAWR representative (Craig Hull).

Throughout the project extensive regional engagement by the AWM Coordinator occurred. This included regular engagement with the regional fruit fly groups supported by the Victorian Fruit Fly Action Plan in Yarra Valley, Sunraysia and MGV and their respective regional coordinators, Bronwyn Koll, Deidre Jaensch and Ross Abberfield, as well as the Victorian Fruit Fly Coordinator Cathy Mansfield. In NSW regular engagement occurred with Local Land Services fruit fly Officer Tammy Galvin.

National linkages in the fruit fly space included regular interaction with the DAWR Plant Export Division, and National Fruit Fly Coordinator, Craig Hull, In addition, the AWM Coordinator regularly liaised with the Manager of the National Fruit Fly Council, to ensure consistent messaging around AWM, and attended and presented at selected National fruit Fly Council Meetings.

Engagement with the Australian academic research community for Tephritid Fruit Flies was achieved by at least one member of the project team attending the twice-yearly meeting 'Biology of Tephritid Fruit Flies' and presenting the work of the project throughout the three years. These meetings were a good ongoing networking opportunity and provided visibility for the project within the fruit fly research community in Australia, with participants including researchers from CSIRO, QDAF, NSW DPI, Western Sydney University, Macquarie University, University of Adelaide, Murdoch University, Ag Vic and QUT. Joint supervision of two new PhD students commenced during the course of the project (CSIRO-QUT). The students are funded under the ARC Industrial Transformational Training Centre for Fruit Fly Biosecurity Innovation and both are working on fruit fly questions evolving from the current project.

International collaboration with BioBee/BioFly (Israel) was strengthened and formalized throughout the project: 1) by teleconference (chaired by Olivia Reynolds) and a visit in September 2016 by Nancy Schellhorn and Florian Schwarzmueller (with Dan Ryan, SITplus Director) to view their full SIT operation from factory to field in Israel; 2) by the visit of Gal Yaacobi to Brisbane and Adelaide/Port Augusta in February 2018. Collaboration over data sharing with Biofly took a long time, and although some data has been shared this unfortunately remains incomplete at the close of the project.

In addition to the international collaboration established with Gal Yaacobi of Biofly, we also established international connections with Roger Vargas (USDA). Roger visited Brisbane to engage with the project in May 2018, in particular to give feedback on our Guidelines and research outcomes from an international perspective. A visit to the International Atomic Energy Agency (IAEA) in Siebersdorf and Vienna strengthened the relationship between globally recognized experts in AWM and SIT and some project members (Aditi Mankad and Olivia Reynolds) participated as panel experts in the IAEA Conference in Vienna. The face-to-face meetings allowed for feedback on our project activities, and further building of the network of experts. Florian Schwarzmueller visited Professor James Carrey (UC

Davis) in August 2017, a well-known expert on fruit fly invasions in California and fruit fly demographic ecology. They discussed the fruit fly situation in California and what we might learn from it for the case of South-East Australia.

The expert elicitation workshop conducted by the project provided an opportunity for getting Qfly experts together and engaged with the project, including the majority of the Queensland experts that were not already part of the project.

Likelihood to extend collaborations beyond the duration of the project

Among the project partners

We anticipate to continue to work with Biofly to complete the integration of their data into the modelling research outputs that will be published in the academic literature in the next few months.

Applications of the risk maps will depend on future data use agreements with Ag Vic and NSW DPI, which we hope will be feasible. There are certainly some clear opportunities to apply these maps (e.g. with the Sunraysia PFA) and they give an important understanding of the landscape advised in our Guidelines for AWM and our present report on the next steps needed to produce and deploy sterile males for managing QFly (see Appendix 8). In relation to this, a joint proposal was submitted to Ag Vic by CSIRO and the Sunraysia PFA in early 2018 to explore the opportunity for Qfly pest forecasting in the region, building on the work of this project.

With the SITplus Consortium

It is anticipated that the AWM Guidelines and present report for KPI 6.4 (see Appendix 8) will inform strategic planning for the deployment of sterile flies in Australia. SIT is not a stand-alone tool, and the legacy of this project (the website) will be helpful for ongoing SITplus efforts. The AWM Coordinator will continue to have a role in SITplus, ensuring that the outputs and outcomes of the AWM project are incorporated into future thinking.

With academic partnerships established

The joint students (CSIRO-QUT) will continue fruit fly collaborations well beyond the life of the current project.

5 Extension and adoption activities

The high level objective for the project is “Communities have an informed basis of current best technology to consider SIT as part of AWM in Qfly management”. In this case, success could be defined by the collaborative development of Guidelines for using SIT as part of AWM of Qfly on a regional scale. For effective collaboration, extension to key stakeholders within a community requires (a) identification of key stakeholders and (b) the optimum extension approach for those stakeholders, in order that communities understand how AWM will work within a region.

A comprehensive stakeholder analysis was undertaken in order to identify and define ‘community’. However, as the project had a regional focus, the stakeholders within each region varied and the resulting ‘community’ differed slightly from region to region. The Hort Innovation Queensland Fruit Fly brochure was extension material that focussed grower’s efforts; more than 1000 brochures were voluntarily taken by growers and grower groups during the project.

The type and level of engagement was based on well-known matrices, described in the engagement plan. However, given the seasonality of different crops, the high number of industry-specific events, and the varied time frame of project results becoming available it was difficult to achieve a long-term plan and a high level of flexibility and adaptability was required from the coordinator, the project team and extension approach. Regionally specific workshops and focus groups were determined each year based on the current state of the project, and regional situation.

Extension materials and activities included regular R&D updates, industry articles, formal and informal workshops, regional roadshows presentations to industry and scientific conferences, meetings, a masterclass, fact sheets and posters.

The key extension material produced was the AWM Guidelines. The process to reach this stage commenced with the regional roadshow of 2017. Feedback on the roadshow from various stakeholders included:

- “Good information that backs up what we’re already doing”
- “We shouldn’t discourage local efforts by saying AWM is not worth it, it is worth it if it keeps the pressure off our crops”
- “Good to see the links between research and local structure working so well”
- “This is great, the biology stuff and urban management are key messages”
- “The guidelines should have relevance to other areas too, need to support this work with on farm management information though”
- “Will be good to have guidelines that we can use”
- “Good to see so many different sectors of the community here”
- “Hygiene seems to be very important – we can do that now”
- “Guidelines are an important next step – make them user-friendly with information to help engage with growers and community”
- “Great to see how the research has progressed”
- “Good to see local chairs and involvement”
- “So much information, will be good to have guidelines to work through at our own pace and to use the bits relevant to our situation”

The draft Guidelines were developed collaboratively by the project team in response to key stakeholder feedback (see section 3.1.5) that determined a website would be the most appropriate vehicle. Once complete, a comprehensive consultation period occurred with project partners, the SITplus consortium and DAWR before the website was designed.

The website was then circulated for final Stakeholder Committee comment and feedback. This feedback has been incorporated, and the Guidelines website endorsed and approved by the Stakeholder Committee. Furthermore, consultation and input was sought and received on the support materials provided on the website; these can be considered endorsed as well given that regional orders to date for posters has exceeded 8000 posters.

The shed posters were designed based on feedback to provide:

- a snap shot of management options as a reminder to all on the property
- a consistent 'look' to reinforce the AWM concept (everyone is doing this)
- evidence of management knowledge to visitors (auditors)

While still linking to specific crop types.

The Qfly ID poster was designed to:
- Stand out and be predominantly visual;
- Be useful for areas with, or without, flies.

The website URL is provided on all support materials, so the Guidelines will be promoted in grower sheds across the country along with a reinforcement of management practices and Qfly awareness and identification. Specific fact sheets developed for table grape grower education sessions also provide the Guidelines website URL. These sheets were developed in consultation with state and federal regulators and the Australian Table Grape Association.

Multiple requests for' engagement tips' that help regions communicate and connect with both commercial growers and backyard gardeners have been made to the AWM coordinator. It is anticipated that these support materials will be used widely.

Further adoption of the project outcomes, in particular "Communities have an informed basis of current best technology to consider SIT as part of AWM in Qfly management" could be achieved by

- Public endorsement of the Guidelines by key regional identities (champions) and/or fruit fly experts that are held in high regard
- Linking to the AWM Guidelines website from other related, reputable and frequently-accessed websites such as "Prevent Fruit Fly" and industry association sites
- Positive public promotion of successes arising from undertaking AWM in south eastern Australia
- Continued relationships with SITplus and incorporation of SIT release information into the website

These recommendations are all currently being progressed.

6 Lessons learnt

By its multidisciplinary nature and large scope the project faced significant challenges in building a shared understanding and effective collaboration. A number of actions throughout the project helped to facilitate this:

- Implementing a clear project structure, especially the establishment of sub-project leaders and clarification of the roles and responsibilities across the project, made it easier to progress key activities by streamlining workflows. For example, the sub-project leaders in each of social science, ecology and economics played an active and important role in conducting a successful science roadshow in the regions and translating our science into 'Guidelines for AWM and SIT'.
- Active measures were taken to build trust amongst researchers and between researchers and stakeholders. This was particularly important for a multidisciplinary group that was not co-located.
- Annual face-to-face researcher meetings were important, and a great reminder of the collaborative nature of the project where a multi-disciplinary approach can achieve more that isolated silos.
- Regular all-project teleconferences at the start of the project helped to keep all team members informed of activities early on. This was complimented by a shared space for files and project information. However, as time went on there was a clear need to modify this mode of interaction as responses were slow, and communications shifted following restructuring of the project team to a more hierarchical format, with sub-project leaders established who met very regularly as a group with the Project Leader and AWM Coordinator. This pushed progress of the research forward at a higher rate and helped resolve project issues faster, as well as helped coordinate the clear communication of results with the AWM Coordinator (rather than ad hoc and direct interaction with individual researchers).
- On reflection the project may have benefitted from an additional face-to-face research meeting early on, to strengthen internal project relationships and collaborations. Working well together as a truly collaborative multi-disciplinary team took some time and effort to achieve.

The nature of the project was very applied, with the two main goals to 1) provide communities with an informed basis of current best technology to consider SIT as part of AWM in Qfly management, and 2) to develop workable and accepted Guidelines for SIT incorporation into AWM of Qfly. Achieving these goals was facilitated by our engagement with industry and stakeholders in the regions:

- Early engagement with Horticulture Industry bodies and hosting the inaugural Stakeholder Committee early in the project was beneficial to establishing effective links on-the-ground quickly. Subsequently involving the Stakeholder Committee in planning extension events and research activities was helpful; comments and suggestions were considered and insightful.
- The role of AWM Coordinator for the project was very valuable to the project, for example in recruiting interviewees for socio-economic studies and providing direct insights into the nature of the problem in the regions, as well as ensuring communication of results to stakeholders at the earliest opportunity.
- Due to the need for growers and industry to have intense focus on their production during summer, it became evident that participatory activities should be avoided at that time, if at all possible. This extends to any ground-truthing activity, model validation and verification.
- Also, it is best to avoid survey fatigue by loading multiple surveys onto the same groups. If multiple surveys are required, concise surveys are likely to be better received, certainly if they follow other surveys.
- Spending time with BioFly in the field in Israel (N Schellhorn & F Schwarzmueller) and the visit of BioFly to Australia (G Yaacobi) provided a strong example of an efficient and effective SIT program, which contributed to our modelling scenarios and enabled reflection on the challenges SIT may face to be implemented in Australia (given a very different biophysical, socio-economic and political situation).

- The delays in project commencement and changes in staff had several impacts. Firstly, the planning and coordination of on-the-ground activities: it was sometimes difficult to ensure participation of external parties as lead time was short. Secondly, it also impacted on the ability to provide research outcomes to stakeholders as results were delayed, which tested their goodwill towards the project. Such delays need to be carefully managed to ensure they don't impact on a project's success.

Our communication of sometimes complex and challenging project results and outcomes to a wide audience helped refine our messages and achieve impact on-the-ground:

- Presentation of the modelling work at a range of forums, including academic conferences and to growers, helped refine and improve the models in terms of both ecological realism and usefulness.
- The expert elicitation process engaged a wide range of Qfly experts beyond the project team and beyond the focal regions of the project.
- During our attempt to further examine interactions between cover sprays, IPM, and MRLs (and implications for Qfly management effectiveness), we spoke to Dave Williams (in-kind contributor to this project) and learned that much of the information needed on the biophysical impacts of pesticides for assessing other impacts is no longer routinely collected for new pesticides. This represents an area of future biophysical research that would be useful for assessing environmental, health, IPM and trade impacts of new pesticides.
- We advise to be careful how much information is hinted at being produced during engagement activities before project outcomes are released, in order to avoid disappointment if sensitive data are not released to the wider community.

With regard to data, it is worth noting here that data sharing and a lack of clear, up-front agreements was problematic, particularly for the biophysical research:

- A lack of an up-front data sharing agreements in the contract, in addition to a lack of clarity in collaboration expectations (particularly for in-kind), hindered the sharing of data between project partners and the core project team. It was thus extremely difficult to obtain spatial data of a fine scale suitable for the habitat modelling, especially for crop survey and fruit fly trapping data. Data from overseas (Biofly) was also not forthcoming despite a large, but non-specific, in-kind agreement. Data that could be obtained from private consultants (host distributions) is difficult to acquire as they demand a premium for the data: this was not budgeted for in the project planning.
- Also in relation to data, we found that dealing with highly sensitive data and market access issues will always be problematic when presenting results in any format. Use of sensitive data (in this case, crop survey data) ensures highly specific model outcomes, but restricts access to results. Non-sensitive data (such as broad land-use categories) allows no restrictions to presenting results, but significantly less specificity in model outcomes. The lessons learnt here are to be clear from the start the limits for each approach and what is expected from the funding agency in making a decision on what data to use, including how the model results will be used at the end and where the limits will be around presenting the results.
- If sensitive data are chosen in order to provide more specific results, then a lengthy process of negotiation should be allowed for in project timelines, and ongoing hurdles should be expected in communicating results from the data.

7 Appendix - additional project information

7.1 Project, media and communications material and intellectual property

7.1.1 Scientific papers and book chapters

Listed in the table below are scientific papers from the project that are either published or in an advanced stage of preparation/submission (as indicated). Abstracts for the papers follow the summary table.

Title	Target Journal/Book	Authors	Status
Psychosocial barriers and facilitators for area-wide management of fruit fly in southeastern Australia	Agronomy for Sustainable Development	Mankad A, Loechel B, Measham P	Published *2017 Issue 37(6)*
Social and institutional factors important in the area wide management of insect pests	In J. Hendrichs, R. Pereira and M. Vreysen, *Area-wide Integrated Management of Insect Pests*	Mankad A, Loechel B, Measham P	In Review
Characterizing the costs of Queensland fruit fly and benefits of Area Wide Management to growers: case studies in south-east Australia	Land Use Policy	Tam M, Capon T, Whitten S, Tapsuwan S, Kandulu J, Measham P	Submission ready
Willingness to pay for area-wide management and sterile insect technique to manage fruit flies	International Journal of Pest Management	Tapsuwan S, Capon T, Kandulu J, Tam M, Measham P, Whitten S	Submitted
Developing spatially explicit risk maps for *Bactrocera tryoni* (Diptera: Tephritidae) in southern Australia to facilitate area-wide management	Agriculture Ecosystems and Environment	Murray J, van Klinken R, Clarke A	Submission ready
Resource continuity and movement strategy shape Queensland Fruit Fly population dynamics.	Journal of Theoretical Biology	Schwarzmueller F, Schellhorn N and Parry H	Submission ready
Area-wide management of Queensland Fruit Fly: How, where and when to manage	Journal of Applied Ecology	Schwarzmueller F, Reynolds O, Schellhorn N and Parry H	In prep

Title	Target Journal/Book	Authors	Status
"Overwintering" phenology of a polyphagous, tropical fruit fly (diptera: tephritidae) at the sub-tropical/temperate interphase	Journal of Pest Science	Merkel K, Schwarzmueller F, Hulthen A, Schellhorn N, Williams D, Clarke AR	Submission ready
Bactrocera tryoni (Froggatt) (Diptera: Tephritidae) over-wintering: a mini-review	Austral Entomology	Clarke AR, Merkel K, Hulthen A, Schwarzmueller F	Submission ready

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

Journal: *Agronomy for Sustainable Development 2017 Issue 37(6)*

Authors: *Mankad A, Loechel B, Measham P*

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 areawide 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.

Social and institutional factors important in the area wide management of insect pests

Book: J. Hendrichs, R. Pereira and M. Vreysen, *Area-wide Integrated Management of Insect Pests*

Authors: *Mankad A, Loechel B, Measham P*

The area-wide management (AW-IPM) of highly mobile insect pests such as tephritid fruit flies requires an integrated understanding of technical, social and institutional processes that drive a coordinated approach within a defined area. Furthermore, the success of an AWM programme is dependent upon the coordinated efforts of key stakeholders within the designated area (e.g. growers, community members). Yet, public views regarding AWM may not reflect those views held by scientists or stakeholders; public considerations for acceptance are likely varied and multidimensional. A series of qualitative (phase 1-2) and quantitative (phase 3) studies examined stakeholder and community attitudes towards AWM to control Queensland fruit fly *Bactrocera tryoni* (Froggatt) and the novel use of the sterile insect technique (SIT) as a possible component of AWM. Research was conducted over three regions of varying pest prevalence, ranging from zero to endemic; participants included growers, extension officers, industry and government representatives, and members of the general public. Participants in this research were asked to consider potential barriers and facilitators to the widespread uptake of AWM integrating the SIT, including any relevant institutional-level factors. Combined data revealed potential social barriers to AWM and SIT uptake. Most notably, there were perceptions of low efficacy in successfully coordinating key social groups for the purposes of an AW-IPM approach, and a concern for the possibility of 'free-riders' within an area-wide system. On the other hand, innovation complexity and observability of outcomes were important factors contributing to acceptance of AWM. Importantly, all participants were influenced by the attitudes and behaviours of important others. Participants also identified key facilitators that could assist in the uptake of AWM using the SIT, such as the importance of trustworthy information sources and harnessing the persuasive influence of community champions and central packing houses on commercial growers. Overall, there was high stated acceptance for the SIT, both on-farm and in towns, as long as SIT application was found to be economically feasible at individual farm or household level and the community was adequately consulted.

Characterizing the costs of Queensland fruit fly and benefits of Area Wide Management to growers: case studies in south-east Australia

Target Journal: *Land Use Policy*

Authors: *Tam M, Capon T, Whitten S, Tapsuwan S, Kandulu J, Measham P*

The Queensland Fruit Fly has become established in historically Qfly free major horticultural growing regions in Australia. Area Wide Management (AWM) incorporating the Sterile Insect Technique (SIT) is an internationally recognized method of insect pest control that is often cited as delivering an economic net benefit and reducing chemical usage. This study conducts grower and expert elicitation to characterize: 1) the baseline cost of Qfly for growers in endemic regions; 2) the potential benefits to growers and impact on chemical usage under AWM; and 3) the benefit of maintaining control in pest free areas. We conduct scenario analysis to quantify the cost to growers in the current state and under AWM. Results indicate a net benefit from maintaining control in pest free regions. In endemic regions, the economic benefits of AWM to growers are low due to high upfront costs and discounted future benefits from avoided management costs. Growers have an incentive to manage on-farm if they perceive any risk of Qfly incidence in their crop. Although Qfly can cause significant damage if unmanaged, growers respond to these private incentives with management options which are identified as effective in reducing their risk. Only eradication supporting high level international government negotiations would support benefits from market access through recognition of pest free area status and avoided post-harvest treatment. In addition, given the variety of pests that growers are managing for, it is not clear that AWM and SIT for Qfly would result in reduced chemical usage. In the alternative, chemical usage does pose a risk to trade through Maximum Residue Limits. The potential loss of an effective chemical through changes to regulations or resistance build up may result in significant damage rates. Policy supporting reductions in chemical usage for all pests could instead support environmental, health, and trade benefits.

Willingness to pay for area-wide management and sterile insect technique to control fruit flies

Target Journal: *International Journal of Pest Management*

Authors: *Tapsuwan S, Capon T, Kandulu J, Tam M, Measham P, Whitten S*

Fruit flies are a biosecurity threat to international trade of horticulture produce around the world. Area-wide management (AWM) of fruit flies offers a promising solution to coordinate farmer's activities to fight against the spread of this pest. The addition of sterile insect technique (SIT) helps supress fruit fly population going into the future. This paper presents findings from a choice experiment survey to ascertain the willingness to pay (WTP) for non-market benefits of a suite of AWM features and SIT. These features include the benefits from 1) coordinated on-farm fruit fly monitoring, 2) coordinated on-farm inhalation of male fruit flies, 3) management of fruit fly in residential areas, and 4) coordinated release of sterile files. This is the first study of its kind to assess the WTP for AWM and SIT in a developed country context. Results suggest that growers are willing to pay for SIT and coordinated fruit fly management in residential areas, but are not willing to pay for other coordinated services that they are already doing on their farms.

Developing spatially explicit risk maps for *Bactrocera tryoni* (Diptera: Tephritidae) in southern Australia to facilitate area-wide management

Target Journal: *Agriculture Ecosystems and Environment*

Authors: *Murray J, van Klinken R, Clarke A*

Identifying areas at risk within a management district is key to designing successful area-wide management (AWM) campaigns for pest suppression. Such risk maps need to account for the target species' ecological relationships within the local ecosystem, including daily resource foraging movement. We used expert elicitation and a spatially explicit approximate Bayesian network computational approach with moving window analysis to develop a habitat suitability model for a mobile horticultural pest insect *Bactrocera tryoni* in south-eastern Australia, a region currently being targeted for area-wide management. We used a multi-scale perspective to identify key environmental variables for *B. tryoni* which identified areas where fly populations could persist despite seasonally fluctuating resources within a daily foraging distance of 200 m. Host fruit availability was the strongest driver for species persistence, while climatic stress and overwintering potential did not limit reproduction in our model. Within large horticultural production areas isolated by natural barriers of non-habitat, as might be *a priori* deemed suitable for launching AWM, we produced risk maps to identify local areas of high fruit fly risk. We used trapping data to verify these predictions and showed that the model provided a good fit to the data. The model provided a useful mechanism to incorporate the multi-scale drivers of *B. tryoni* persistence and evaluate the complexity fo the landscape through a mobile pest perspective. The resultant risk maps, particularly their visual output, can encourage stakeholder engagement across all levels to improve AWM and the application of AWM tools, such as the Sterile Insect Technique.

Resource continuity and movement strategy shape Queensland Fruit Fly population dynamics

Target Journal: *Journal of Theoretical Biology*

Authors: *Schwarzmueller F, Schellhorn N, Parry H*

Animal populations are often highly variable in time and space. The dynamics in these systems are often driven by the landscape structure (availability of resources) and the movement of animals in response it. When animals rely on multiple resources that are not constantly available, this creates a highly dynamic system. The movement mechanisms and the resulting ability of animals to track resources in a landscape will then influence population growth and survival. Knowledge about these structuring processes is crucial to predict spatial population dynamics but it is complicated to mechanistically address this at a landscape level in empirical studies.

Here we introduce a spatially explicit model for Queensland Fruit Fly (QFly, *Bactrocera tryoni*) to systematically look at the effects of different temporally dynamic resource landscapes and the population stability under different movement strategies. With fruit trees being the main resource (oviposition), the seasonal availability of fruit was suggested to be a main driver of QFly dynamic and persistence. We found that the continuity of the resource landscape was the main contributing factor for large and persistent populations. This explicitly included the presence of continuous low density resources such as fruit trees in urban areas. Analysis of trapping data from South East Australia supported this finding by showing similar trends. We also found a strong effect of movement strategies with directed movement supporting higher population densities. This suggests that animal species that are able to track resource availability in a landscape can persist even in environments where resources are scarce.

The results of this study give insight into structuring processes of spatial population dynamics when it comes to the interaction of landscape structure and animal movement. Understanding a resource landscape from the animal's perspective will help to improve the forecasting of spatio-temporal hotspots and bottlenecks and will, in the end, enable a more targeted population management.

Area-wide management of Queensland Fruit Fly: How, where and when to manage

Target Journal: *Journal of Applied Ecology*

Authors: *Schwarzmueller F, Reynolds O, Schellhorn N, Parry H*

Management of insect pests often has to go beyond property borders as populations often expand across these. This Area-Wide Management (AWM) utilizes different management techniques and incorporates multiple stakeholders in a region. Apart from social and economic questions on how to get people involved and at what costs, the biggest ecological question is about the effectiveness of different AWM strategies in terms of pest control. In this paper, we used a recently published model of spatial population dynamics of Queensland Fruit Fly to explore the effectiveness of different management strategies. We were asking "How, where and when do we need to manage?" in order to make it effective. We applied this question to the case study of South-Eastern Australia where the horticultural areas are facing increased pest pressure likely due to multiple factors including the collapse of the Fruit Fly Exclusion Zone (FFEZ). We found that existing technologies that kill adult females (i.e. mass trapping, bait spraying or cover sprays) are the most effective single strategy in reducing populations. We also found that the combination of management strategies, that is considered current on-farm Best Management Practice (baiting, male annihilation, hygiene), can significantly reduce fly numbers and detections when adopted by enough growers (>60% of the area). This result, however, is landscape dependent, with non-managed urban areas potentially having a huge negative impact on AWM success. An additional urban treatment (mass trapping) is most effective when applied early in the season. Having such a predictive model that can give some indication of management effectiveness will help to advise region specific AWM strategies and manage expectations. Incorporated into an appropriate socio-economic strategy, this can potentially increase the buy-in into an AWM.

“Overwintering” phenology of a polyphagous, tropical fruit fly (diptera: tephritidae) at the sub-tropical/temperate interphase

Target Journal: *Journal of Pest Science*

Authors: *Merkel K, Schwarzmueller F, Hulthen A, Schellhorn N, Williams D, Clarke AR*

Tropical tephritid fruit flies from the genus *Bactrocera* are generally accepted to be confined to the tropics and subtropics because of cool temperature climate limitations. However, a few species presently expanding their range into temperate regions are showing flexible strategies to adapt to cold temperatures. The Queensland fruit fly, *B. tryoni*, exhibits seasonal population depression in temperate regions driven by low temperatures, while declines in its tropical range are due to a lack of hosts for breeding. However, what drives the population phenology in the subtropical interphase is unknown. Using a subtropical field-site, with host fruits continuously available, we sought to determine if wild fly populations continued to oviposit during winter, or if there was over-wintering break, and what was the emergence pattern of next-generation adults from infested fruit both in the field and laboratory. Female flies continued to lay eggs during the winter and juveniles successfully developed and emerged as adults from the soil, albeit with much higher levels of field mortality than experienced in fruits returned to constant warm conditions. The development time of the immature stage in the field was prolonged, presumably due to cooler ambient conditions, but a day-degree population model fitted with mean daily field temperatures consistently overestimated development times. Our results indicate that in the subtropics the decline in *B. tryoni* populations during winter is only partly driven by temperatures. We classify *B. tryoni* as a climate generalist, which may deploy physiological as well as behavioural mechanisms to achieve broad climatic tolerance ranges.

Bactrocera tryoni **(Froggatt) (Diptera: Tephritidae) over-wintering: a mini-review**

Target Journal: *Austral Entomology*

Authors: *Clarke AR*, *Merkel K, Hulthen A, Schwarzmueller F*

The Dacini fruit flies (Diptera: Tephritidae) are tropical and subtropical insects for which a winter diapause is largely unknown. However, some pest dacines have extended their geographic ranges into temperate areas where winter temperatures may be limiting. During the 1900s, *Bactrocera tryoni* (Froggatt) extended its endemic tropical range to include temperate southern Australia. Starting nearly 100 years ago, several research teams have spent considerable effort understanding how 'tropical' *B. tryoni* survives temperate winters: this review summarises that research. Across three study areas (Sydney and surrounding districts, NSW; Melbourne and surrounding districts, Victoria; Stanthorpe, south-eastern Queensland), there is highly consistent data showing that the fly overwinters almost exclusively in the adult form. Eggs, larvae and pupae generated in late autumn or early winter either fail to develop due to lack of sufficient day-degree accumulation, or if immature development is successful and adults emerge then those adults do not become sexually mature until the spring. Females which are already sexually mature when entering winter resorb some or all of their eggs. During winter, adults rest in sheltered locations and will forage for food on warm days. In field-cages, mortality of adults is approximately 8% per week during winter, and so quite significant adult over-wintering mortality occurs. Based on laboratory studies, adult survival at cool to cold temperatures is increased if the fly undergoes a gradual acclimation process, rather than subjected to a sudden drop in temperature. Early climate change modelling suggests that a decrease in the number of extreme cold-events (i.e. hard frosts), is more likely to lead to improved fly survival in temperate areas than the overall mean temperature increase. Gaps in knowledge include: quantification of what makes a preferred over-wintering site; how climate change over the last 30 years, when the last detailed experiments were done, have modified over-wintering phenologies; and where on the Australian east coast does temperature become limiting such that year-round breeding ceases.

7.1.2 Academic Conference papers

The titles of presentations (papers) and posters given at academic conferences are listed below, along with the name of conference, authors and date.

International

- Fighting Queensland Fruit Fly in-silico: modelling an insect pest to inform management strategies, 102nd Annual Meeting of the Ecological Society of America, Oregon, USA (F. Schwarzmueller)
- Area Wide Management – plenary talk, Science Protecting Plant Health, Brisbane, 2017 (N. Schellhorn, F. Schwarzmueller, A. Mankad)
- Fighting Queensland Fruit Fly in-silico: modelling an insect pest to inform management strategies, Science Protecting Plant Health 2017, Brisbane, 2017 (F. Schwarzmueller)
- Evaluating costs and benefits of AWM using SIT for Qfly, *B. tryoni*: links to spatial population simulations, Third FAO–IAEA International Conference on Area-wide Management of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques, Vienna 2017 (N. Schellhorn, H. Parry, T.Capon, M. Tam, S. Whitten, J, Kandulu, F,. Schwarmueller, P. Measham)
- Poster - Third FAO–IAEA International Conference on Area-wide Management of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques, Vienna 2017 (A. Makad, B. Loechel, P. Measham)
- Poster -Third FAO–IAEA International Conference on Area-wide Management of Insect Pests: Integrating the Sterile Insect and Related Nuclear and Other Techniques, Vienna 2017 (A. Mankad, B. Loechel)
- Spatially-explicit modelling of ecological processes in complex agricultural landscapes: connecting 'artificial' landscapes with 'reality', 22nd International Congress on Modelling and Simulation (MODSIM2017) Tasmania 2017 (F. Schwarzmueller, A. Hulthen, J. Murray, and H. Parry)

Domestic

- Economics of Qfly AWM and SIT, Tephritid Fruit Flies Meeting, 2017 (S. Whitten)
- Economics of Qfly AWM and SIT, Western Economic Association International meeting in Newcastle 2018 (S. Whitten, T. Capon)
- Modelling the risk of Queensland fruit fly across diverse agricultural regions, Tephritid Fruit Flies Meeting, 2017 (J. Murray)
- Modelling fruit fly populations, CSIRO PostDoc Convergence, 2017 (F Schwarzmueller)
- Willingness to pay for AWM in south eastern Australia, Australian Agricultural and Resource Economics Society, 2017 (S Tapsuwan)
- Cost-benefit Analysis of AWM, Australian Agricultural and Resource Economics Society, 2017 (M Tam)
- Social and Institutional factors of AWM, Tephritid Fruit Flies Meeting, 2016 (B. Loechel)
- Qfly Population Modelling, Combined Australian Entomological Society 47th AGM & New Zealand Entomological Society Conference, 2016 (F Schwarzmueller)
- Qfly spatially explicit models of population, Tephritid Fruit Flies Meeting, 2016 (F Schwarzmueller)

7.1.3 Industry (and other) presentations

Presentations given to industry and other stakeholders. All presentations were given by AWM Coordinator, unless otherwise indicated.

- Area Wide Management of Qfly, Fruit Fly Roadshow, Mooroopna, 2017
- Area Wide Management of Qfly, Fruit Fly Roadshow, Mildura, 2017
- Area Wide Management of Qfly, Fruit Fly Roadshow, Loxton, 2017
- Spatially explicit simulation modelling of QFly: How models can inform management strategies, Persimmon Conference, 2017 (F. Schwarzmueller, N. Schellhorn, H. Parry)
- Evaluating costs and benefits of AWM using SIT for Qfly, Persimmon Conference, 2017 (M. Tam, S. Whitten, T. Capon, P. Measham, J. Conner)
- AWM and SIT – a national framework for regional outcomes, Citrus Technical Forum, Mildura, 2017
- AWM and SIT – cost benefit Analysis, Citrus Technical Forum, Mildura, 2017
- AWM – the role of local government, Combined Riverina, Murray River and Goulburn Group of Councils, Jerilderie, 2017
- AWM and SIT – an overview, Persimmon Conference, Barooga, 2016
- AWM and SIT – is this new? Riverina Biosecurity, Yanco, 2016
- Area wide management in Victoria, Goulburn Valley Fruit Fly Task Force, Tatura, 2016
- A new approach to Qfly management, Tasmanian Biosecurity, 2016
- The role of AWM of Qfly, National fruit Fly Council, Melbourne, 2016
- Social barriers and facilitators of AWM, DEDJTR Centre of Excellence Conference, Tatura, 2016
- Institutional factors in AWM, DEDJTR Centre of Excellence Conference, Tatura, 2016
- IPM in Victoria (including AWM), DEDJTR Centre of Excellence Conference, Tatura, 2016
- Qfly Mnagement, DEDJTR Centre of Excellence Conference, Tatura, 2016
- SIT as a component of AWM, DEDJTR Centre of Excellence Conference, Tatura, 2016
- AWM and SIT – a new approach, Murrumbidgee Group of Councils, Coleambally, 2016
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Waikerie, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Mildura, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Swan Hill, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Tatura, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Griffith, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Young, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Bundaberg, 2015
- Area Wide Management of Qfly, Hort Innovation Fruit Fly Roadshow, Coffs Harbour, 2015
- AWM – National framework, regional approach, NSW Farmers Federation, 2015
- Queensland Fruit Fly and Horticulture, Fruit Growers Tasmania extension day, 2015

7.1.4 Workshops

All workshops were delivered by the AWM Coordinator.

- AWM workshop, Young 2017
- AWM workshop, Yarra Valley, 2017
- AWM and SIT – where are we now? – Young, 2017
- AWM and SIT – where are we now? – Griffith, 2017
- AWM and SIT – where are we now? – Mildura, 2017
- AWM and SIT – where are we now? – Cobram, 2017
- AWM and SIT – where are we now? – Shepparton, 2017
- AWM and SIT – where are we now? – Renmark, 2017
- AWM principles in Qfly management and prevention, Box Hill Institute Qfly Master Class, Lilydale, 2017
- Qfly management for growers, Mildura, 2016

- Qfly Management for growers, Euston, 2016
- Qfly management – agronomists, Euston 2016
- AWM workshop, Wandin, 2016
- AWM workshop, Young 2016
- AWM Capability workshop, Cobram, 2016
- AWM Capability workshop, Coffs Harbour, 2016
- AWM Capability workshop, Shepparton, 2016
- AWM Capability workshop, Mildura, 2016
- AWM workshop and Field day, Coffs Harbour, 2016
- Biosecurity Workshop, the role of AWM and SIT, Loxton, 2016
- Biosecurity Workshop, the role of AWM and SIT, Renmark, 2016

7.1.5 R&D updates

These were communications that were prepared by the project team (predominantly by the AWM Coordinator) and sent out to industry associations for dissemination.

- #1 Area wide management – what is it? (Measham)
- #2 Area wide management – trapping (Measham)
- #3 Expert workshop – where are the flies? (Measham)
- #4 Area wide management – working together (Measham)
- #5 Fly responses to environment and impact on population (Measham and Schwarzmueller)
- #6 The cost of Qfly (Measham and Whitten)
- #7 Exploring the cost of AWM (Measham and Whitten)
- #8 How does Qfly survive winter? (Measham and Clarke)
- #9 Community engagement in AWM(Measham and Mankad)
- #10 Implications for funding AWM programs (Measham and Tapsuwan)
- #11 New website to help communities combat Queensland Fruit Fly – preparing for SIT

7.1.6 Press/magazine articles

These were derived from the R&D updates, above.

- How does Qfly survive winter? The Cherry Magazine, 2017
- Engaging your community, The Cherry Magazine, 2017
- How does Qfly survive winter? Implications for temperate regions, The Vine 2017
- How does Qfly survive winter – what it means in temperate regions, Citrus magazine, 2017
- How does Qfly survive winter? Tree Crop Magazine, 2017
- Calls for community engagement in AWM, Apple and Pear Magazine, 2017
- Controlling Fruit Fly' (within Sunraysia PFA Update), The Vine 2017
- Where are the flies? Living Lychee 2017
- Counting the cost of Qfly, Cherry Magazine 2017
- AWM approach bearing fruit globally, Citrus Magazine, 2017
- Identifying hurdles for AWM of Queensland Fruit Fly, Cherry Magazine 2016
- Understanding Qfly behaviour, Apple and Pear Magazine 2016
- Cost of Qfly, Apple and Pear Magazine 2016
- Stopping Fly Migration, Australian Stone Fruit Grower, 2016
- AWM update, The Vine 2016
- Area wide management and SIT, Australian Stone Fruit Grower, 2016
- AWM and SIT in Australia, SA Apple and Pear Newsletter, 2016
- Area wide management of Qfly using SIT, NSW DPI Orchard Plant Protection Guide, 2016
- Area wide management, Cherry Magazine, 2016
- Area wide management, The Vine, 2016

7.1.7 Factsheets

On website

- Management of Qfly – Hygiene
- Management of Qfly – MAT
- Management of Qfly – Bait spraying

Others – for table grape growers

- What is AWM and SIT?
- AWM - Monitoring
- AWM – Hygiene
- AWM – Bait Spraying
- AWM – MAT
- AWM – Qfly ID and Lifecycle
- AWM – Why should I manage Qfly?
- AWM – why is Qfly a challenge?

7.1.8 Posters

Sterile Insect Technique Factory Opening Event 2015 (and available at https://horticulture.com.au/what-we-do/sitplus)

- Adaptive Area Wide Management Research To Practice (P. Measham)
- Benefits and costs of AWM using SIT for Queensland Fruit Fly (M. Tam)
- Where is the Qfly hotspot risk? (J. Murray)
- Informing Qfly management strategies using spatially-explicit simulation modelling (F. Scwarzmueller)
- Social barriers and facilitators for area wide management of QLD fruit fly (A. Mankad)

On website

- Qfly management in citrus
- Qfly management in grape
- Qfly management in cherry
- Qfly management in pome fruit
- Qfly management in summer fruit
- Qfly management in berries
- Qfly management in vegetables
- AWM – what is that?
- Is that Qfly?

7.1.9 Website

Measham, P; Parry, H; Clarke, A; Mankad, A; Whitten, S; van Klinken, R; Capon, T; Darc, A; Kandulu, J; Loechel, B; Merkel, K; Murray, J; Navarro, J; Schellhorn, N; Schwarzmueller, F; Reynolds, O; Tam, M, Tapsuwan, S and Williams, D (2018) Guidelines for adaptive area-wide management for Queensland fruit fly using Sterile Insect Technique https://area-wide-management.com.au/ Hort Innovation, created 2/4/2018

7.2 Equipment and assets

List of all equipment or assets created or acquired during the period covered by the project. N/A

7.3 Monitoring and evaluation

Clear Horizon

Final Review Report

Adaptive area-wide management of Qfly using SIT: Guidelines for efficient and effective pest suppression and stakeholder adoption ('AAWM Project')

Prepared for Horticulture Innovation Australia

15 April 2018

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Document review and authorisation

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Disclaimer

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Acronyms

AAWM	Adaptive area-wide management [phrase from project title]
AWM	Area-wide management
BMP	Best management practice
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAWR	Department of Agriculture and Water Resources
Hort Innovation	Hort Innovation Australia Limited
KEQ	Key evaluation question
KPI	Key Performance Indicator
NSW DPI	New South Wales Department of Primary Industries
SARDI	South Australian Research and Development Institute
SIT	Sterile Insect Technology
QUT	Queensland University of Technology
R&D	Research and Development

Executive Summary

This document presents the Final Review of the *Adaptive area-wide management of Qfly using SIT: Guidelines for efficient and effective pest suppression and stakeholder engagement project (the 'AAWM' project).* The AAWM project was contracted by the Department of Agriculture and Water Resources (DAWR) to Hort Innovation, who partnered with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for the delivery of the project. Other partners included the Queensland University of Technology (QUT), South Australian Research and Development Institute (SARDI), New South Wales Department of Primary Industries (NSW DPI), Agriculture Victoria, Wine Australia and the Israeli company, Bio-Fly. The AAWM project aimed to develop guidelines for adaptive AWM of Qfly that identify the constraints and challenges to implement best management practice (BMP) that can include the delivery of SIT as a way to promote the adoption of area-wide management (AWM) using SIT. The AAWM project was funded by DAWR for $2.585M over three years (June 2015 – June 2018).

The purpose of the Final Review was to assess the overall performance of the project as it approached completion. The primary focus of the review was on project effectiveness. The review also assessed aspects of relevance, appropriateness, efficiency of the project's processes, return on investment and identified lessons learned. The review methodology included a desktop review of project documentation and interviews with nine key stakeholders. The review took place in April 2018.

Review findings

Achievements against performance measures and expected outcomes

The review found that the project successfully delivered guidelines for AWM of Qfly that include opportunities for using SIT. The guidelines are web-based, which was not part of the initial project design but followed advice provided by project stakeholders during project implementation. The decision to use a web-based platform for the guidelines was made to maximise access to all interested stakeholders and to allow guidelines to be efficiently updated and improved over time. The desktop review of the website content found that at the time of reporting, the website has extensive information about AWM and best management practices for Qfly control. It also contains some information about opportunities to implement SIT and how to access habitat and risk maps for an area where a community might be considering AWM.

The review found the published guidelines to be of good quality although is it too early to assess the likelihood of uptake. The majority of interviewees positively described the quality of the AWM guidelines and some were optimistic about their usefulness. The evidence indicates there had been positive feedback from the regions about the fact sheets and other best management practice (BMP) extension materials that were distributed through the project and are now available through the AWM website.

The review found that the potential acceptance and utility of the guidelines is supported by the incorporation of research findings into the guidelines. Ecological studies described how AWM and SIT will lead to pest suppression, and the willingness-to-pay studies described how community members would be willing to contribute to reduced pest pressure. Stakeholder Committee interviewees appreciated how the social science research has been able to provide industry with a holistic understanding of barriers and enablers for AWM. Project team interviewees recognised the value of the social science and willingness to pay studies to help develop key parts of the guidelines around engagement of commercial growers and backyard gardeners for AWM. However, concern was expressed by several interviewees that Qfly SIT acceptability investigated in the social science studies was based on male-only sterile flies, which are not yet available in Australia. Qfly SIT sterile fly production is outside the control of this project.

The project outputs demonstrate extensive engagement by the project with industry, government and the scientific community to develop the guidelines and distribute information on BMP for Qfly control. Some of the scientific research completed during the project has already been published and additional publications are expected later in 2018. The evidence provided by interviewees indicates that the outputs of the project were of sufficient quality and scientific rigour.

The review found that the project developed regionally specific information to support the adoption of SIT in AWM, and incorporated this information into the guidelines. This information includes habitat and risk maps and differences in management approaches between endemic and pest free regions, as well as between areas with and without known flies in endemic regions. There is potential for spatially explicit population models incorporating economic findings to help inform decisions for AWM and SIT in a defined area, however this has not yet been developed into a practical tool for industry use.

The evidence indicates the project contributed to increased industry awareness about Qfly and SIT. However, there was a mixed response regarding the overall relevance of the outputs to industry given their limitations, and uncertainty remains about how AWM of Qfly will be carried out.

The project met all KPIs for activities 1-5, as evidenced in project milestone reports. These activities were 1) project initiation and management, 2) identify social challenges and constraints, 3) identify biophysical challenges and constraints, 4) demonstrate best management practice (BMP) and 5) develop area-wide fruit fly guidelines.

The review identified a number of significant efforts to improve efficiency during project implementation. These included: a review and subsequent changes to the project management structure; an increase in the full-time equivalent (FTE) allocation to project management and coordination; the introduction of regular reviews of resourcing; the introduction of a cloud-based collaboration tool; and, not least, the significant efforts of Stakeholder Committee members to act as champions for the project.

The project achievements described above were realised despite significant challenges that arose from the project's complex governance arrangements and difficulties inherent in coordinating multidisciplinary and geographically dispersed teams.

Other outcomes

The review identified positive, unintended outcomes related to increased collaboration across disciplines and industries. The evidence suggested the project had built greater transdisciplinary capacity, linkages and communication channels between regional groups and between stakeholders in NSW and Victoria.

Project delivery

The review found that communication between the project team and Stakeholder Committee members significantly positively influenced the project. The majority of interviewees commented positively when asked to describe the communication between the project team and the Stakeholder Committee, although there was also a range of views about how it could have worked better.

The evidence shows the project was well received by stakeholders engaged in the targeted regions. Stakeholder Committee interviewees observed that industry responded well to roadshows and that there was interest from growers to attend and to listen and understand what was going on. Interviewees positively described the AWM coordinator's role as a conduit between the research and communities.

Return on investment

Demonstrated or expected quantifiable return on investment for the project could not be determined from available data.

Lessons learned

Eleven lessons learned were identified by the review and cover a number of issues including future collaborations, management of in-kind contributions, the delivery of SIT and the role of DAWR.

1. Introduction

This report describes the approach to, and results of, the Final Review of the *Adaptive area-wide management of Qfly using SIT: Guidelines for efficient and effective pest suppression and stakeholder engagement* project (the 'AAWM project'). The report is structured as follows:

- Section 1: Introduction, including a description of the AAWM project
- Section 2: Approach to the Final Review
- Section 3: Findings, including lessons learned
- Appendices:
    - Appendix 1: Program logic for the AAWM project
    - Appendix 2: Overview of KPI achievements
    - Appendix 3: Data sources
    - Appendix 4: Interview guide

1.1. About the AAWM project

Hort Innovation received funding for the AAWM project from Round 1 of the Australian Government's Rural Research and Development (R&D) for Profit program. This program was set up to boost funding for nationally coordinated, strategic research that will deliver outcomes for Australian producers. The AAWM project was funded by the Department of Agriculture and Water Resources (DAWR) for $2.585M over three years (June 2015 – June 2018).

The AAWM project aims to tackle the major pest issue for Australian horticulture that also represents a barrier to international market access: Queensland fruit fly (Qfly). The release of sterile male flies as part of the Sterile Insect Technique (SIT) embedded into an Area Wide Management (AWM) program has proved successful overseas, but is yet to be implemented in Australia. This project brought together a number of partners to support the commercial delivery of SIT for the Qfly in Australia. The project was designed to support the business case for the commercial production and delivery of sterile male Qfly to protect production and secure and grow market access for Australian horticultural produce. The project has been implemented between 2015 and 2018 and is approaching completion.

Recognising that successful Qfly suppression requires the alignment of bio-physical and socio-economic factors, the project focussed on three broad integrated activities:

- cost-effective delivery and release of sterile male flies
- strategy to maximise uptake of the commercial service
- regionally focussed extension for best management practice (BMP) and incorporating SIT

These activities have been carried out by a multi-disciplinary team from several organisations, including CSIRO, QUT, SARDI, NSW DPI, and Agriculture Victoria with additional input from Wine Australia and the Israeli company Bio-Fly. The project coordinator from Hort Innovation played a key role liaising with various stakeholders in Australia and overseas.

2. Approach to the Final Review

2.1. Purpose and audience

The purpose of the Final Review was to provide an assessment of the overall performance of the project as it approached completion. The Final Review is a requirement under the Grant Agreement between the Department of Agriculture and Water Resources (DAWR) and Horticulture Innovation Australia (Hort Innovation) and is recognised and planned for in the project's Monitoring and Evaluation Plan (M&E) developed in 2015 (ST15014 AAWM ME plan).

The audience for the review includes:

- the AAWM project team
- Hort Innovation
- CSIRO
- Department of Agriculture and Water Resources (the funder).

Specifically, the review was required to:

- describe whether the planned outputs were delivered and expected outcomes were achieved
- assess how well resources were used
- identify lessons relevant to delivery of the wider SIT program, the role of DAWR in the project, and future collaborations.

The primary focus of the review was on the overall project effectiveness, based on the program logic developed for the project (see Appendix 1 of final review

Program logic for AAWM project). The review also assessed aspects of relevance, appropriateness and efficiency of the projects' processes and identified lessons learned. In terms of the balance between accountability and lessons learned, accountability was the primary driver for the Final Review.

2.2. Review questions

Hort Innovation required the review to be framed against the Hort Innovation Project Investment Level Key Evaluation Questions for *effectiveness, relevance, process appropriateness and efficiency*. In addition, Hort Innovation and the project management team were interested in identifying any lessons learned for the design and implementation of future projects.

Given these requirements and the areas of enquiry described in the RFQ and at the inception meeting (26 March 2018), and considering the purpose and audience for the review, the key questions and sub-questions guiding the Final Review were:

1. To what extent has the project developed workable and accepted guidelines for using SIT in AAWM?
    a. What has been achieved against performance measures and intended outcomes?
    b. How effective were the collaborations between service providers within and between sub-projects and organizations?
    c. How well were stakeholders engaged?
    d. How relevant were the project's activities and outputs to industry?

2. What are the expected and/or quantifiable returns on investment?
3. What, if any, unintended outcomes (positive or negative) have resulted from the project?
4. What efforts did the project make to improve efficiency?
5. What are the lessons learned to inform future collaborations and delivery of SIT?

Table 1 below shows how the Final Review key questions can be mapped to address the Hort Innovation Project Investment Level Key Evaluation questions.

Table 1: Final Review key questions mapped to Hort Innovation KEQs.

Level/domain	Hort Innovation Key Evaluation Questions	Final Review key questions
Effectiveness	To what extent has the project achieved its expected outcomes?	1a, 1b
Relevance	How relevant was the project to the needs of the beneficiaries?	1d, 2, 3
Process appropriateness	How well have the intended beneficiaries been engaged in the research process?	1c
	To what extent were engagement processes appropriate to the target audience/s of the project?	1b,1c
Efficiency	What efforts did the project make to improve efficiency?	4

2.3. AAWM project performance expectations

The Grant Agreement describes KPIs for each milestone, organised against six project activity areas:

1. Project initiation and management
2. Identify social challenges and constraints
3. Identify biophysical challenges and constraints
4. Demonstrate best management practice (BMP)
5. Develop area-wide fruit fly guidelines
6. Communicate guidelines and identify next steps.

The KPIs were at the activity/output level. No other performance expectations were established for the AAWM project, for example, at the outcome level. The regular milestone reports produced by the project team to DAWR focussed on meeting accountability requirements and provided a key source of data for the Final Review, along with stakeholder interviews.

2.4. Final Review methodology and limitations

The following methodology was used for the Final Review:

- A desktop review of existing project documentation (e.g. milestone reports and other relevant documented information as shown in Appendix 2). Information gaps were identified and where possible addressed through stakeholder interviews.
- Nine interviews with key stakeholders (the project team, key researchers and members of the Stakeholder Committee) to complement information identified through the desktop review and fill information gaps (see Appendix 3 for list of interviewees and Appendix 4 for the interview guide).
- Interviews were analysed using thematic coding and cluster analysis.
- Evidence from the desktop review and interviews were synthesised against review questions to form the basis of review findings.
- Development of the Final Review report.

2.5. Limitations

Return on investment findings

The analysis of expected and/or demonstrated quantifiable return on investment was limited to collation of evidence provided by project documentation and interviews with six members of the project team and three members of the Stakeholder Committee.

Breadth of stakeholder interview data

Twelve potential interviewees were approached, but only nine could contribute in the time frame of the Final Review. While three Stakeholder Committee members were interviewed, only one of these was from horticultural industries.

Recent publication of guidelines

Guidelines for AWM of Qfly were published on the internet[1] in April 2018. As a result not all interviewees had an opportunity look at the website before contributing to this review. Nevertheless, all interviewees were given the opportunity to review the content prior to its publication on the website.

[1] https://area-wide-management.com.au/

3. Findings

This section describes the findings of the final review of the AAWM project, arranged under the following headings:

- Summary of overall project performance
- Achievements against performance measures
- Achievements against expected outcomes
- Other outcomes
- Program delivery
- Return on investment
- Lessons learned

The findings include illustrative quotations from interviewees consulted for the review. When illustrative quotations are used, the sources of quotations are identified by interviewee category (Stakeholder Committee member = *SH1, 2 etc.* Project team member = *PT1, 2, etc*.) The full list of interviewees can be found in Appendix 3 of final review: Data sources for the Final Review. To protect anonymity, the list does not match the numbering codes.

3.1. Summary of overall project performance

The review found that the project successfully delivered guidelines for AWM of Qfly that include opportunities for using SIT. The guidelines are web-based, which was not part of the initial project design but followed advice provided by project stakeholders during project implementation. The decision to use a web-based platform for the guidelines was made to maximise access to all interested stakeholders and to allow guidelines to be efficiently updated and improved over time. The desktop review of the website content found that at the time of reporting, the website has extensive information about AWM and best management practices for Qfly control. It also contains some information about opportunities to implement SIT and how to access habitat and risk maps for an area where a community might be considering AWM.

The review found the published guidelines to be of good quality although is it too early to assess the likelihood of uptake. The majority of interviewees positively described the quality of the AWM guidelines and some were optimistic about their usefulness. The evidence indicates there had been positive feedback from the regions about the fact sheets and other best management practice (BMP) extension materials that were distributed through the project and are now available through the AWM website. However, some interviewees expressed doubt about the overall utility of the guidelines, observing that they are not specific or not practical enough.

The review found that the potential acceptance and utility of the guidelines is supported by the incorporation of research findings into the guidelines. Ecological studies described how AWM and SIT will lead to pest suppression, and the willingness to pay studies described how community members would be willing to contribute to reduced pest pressure. Stakeholder Committee interviewees appreciated how the social science research has been able to provide industry with a holistic understanding of barriers and enablers for AWM. Project team interviewees also recognised the value of the social science and willingness to pay studies to help develop key parts of the guidelines around engagement of commercial growers and backyard gardeners for AWM. However, concern was expressed by several interviewees that Qfly SIT acceptability investigated in the social science studies was based on male-only sterile flies, which are not yet available in Australia. Qfly SIT sterile fly production is outside the control of this project.

The project outputs demonstrate extensive engagement by the project with industry, government and the scientific community to develop the guidelines and distribute information on BMP for Qfly control. Some of the scientific research completed during the project has already been published and additional publications are expected later in 2018. The evidence provided by interviewees indicates that the outputs of the project were of sufficient quality and scientific rigour.

The review found that the project developed some regionally specific information to support the adoption of SIT in AWM, and incorporated this information into the guidelines. This information includes habitat and risk maps and differences in management approaches between endemic and pest free regions, as well as between areas with and without known flies in endemic regions. There is potential for spatially explicit population models incorporating economic findings to help inform decisions for AWM and SIT in a defined area, however this has not yet been developed into a practical tool for industry use.

The evidence shows the project was well received by stakeholders engaged in the targeted regions. Stakeholder Committee interviewees observed that industry responded well to roadshows and that there was interest from growers to attend and to listen and understand what was going on. Interviewees positively described the AWM coordinator's role as a conduit between the research and communities.

The evidence indicates the project contributed to increased industry awareness about Qfly and SIT. However, there was a mixed response regarding the overall relevance of the outputs to industry, given their limitations, and uncertainty remains about how AWM of Qfly will be carried out.

The review found that communication between the project team and Stakeholder Committee members significantly positively influenced the project. The majority of interviewees commented positively when asked to describe the communication between the project team and the Stakeholder Committee, although there was also a range of views about how it could have worked better.

The project met all KPIs for activities 1-5, as evidenced in project Milestone Reports. These activities were 1) project initiation and management, 2) identify social challenges and constraints, 3) identify biophysical challenges and constraints, 4) demonstrate best management practice (BMP) and 5) Develop area-wide fruit fly guidelines.

The review identified a number of significant efforts to improve efficiency during project implementation. These included: a review and subsequent changes to the project management structure; an increase in the FTE allocation to project management and coordination; the introduction of regular reviews of resourcing, the introduction of a cloud-based collaboration tool; and, not least, the significant efforts of Stakeholder Committee members to act as champions for the project.

The project achievements described above were realised despite significant challenges that arose from the project's complex governance arrangements and difficulties inherent in coordinating multidisciplinary and geographically dispersed teams.

3.2. Achievements against performance measures

Performance expectations for the AAWM project were described as Key Performance Indicators (KPIs) at the activity and output level. No other performance measures were established for the AAWM project, for example, at the outcome level. Achievements against expected outcomes are described in Section 3.3.

The review found that the project met all KPIs for activities 1-5, as evidenced in project Milestone Reports. These activities are:

1. Project initiation and management
2. Identify social challenges and constraints
3. Identify biophysical challenges and constraints
4. Demonstrate best management practice (BMP)
5. Develop area-wide fruit fly guidelines.

The KPIs for these activity areas and the sources of evidence for their achievement are provided in Appendix 2 of final review: Overview of KPI achievements. A summary of project outputs is presented in Table 2.

These outputs represent evidence of extensive engagement by the project with industry, government and the scientific community to develop the guidelines and distribute information on BMP for Qfly control. Some of the scientific research completed during the project has already been published and additional publications are expected later in 2018. The evidence provided by interviewees indicates that the outputs of the project were of sufficient quality and scientific rigour.

For the final project activity, *Activity 6 - Communicate guidelines and identify next steps*, KPIs have been partly achieved. There is evidence that the web platform content has been shared with stakeholders and feedback incorporated into the published guidelines. Two other remaining KPIs for the project were being addressed at the time the Final Review was being conducted: a report on next steps to produce and deploy sterile males for managing Qfly, and the final project report, both due in May 2018.

Table 2: Summary of outputs delivered during the AAWM project

Output area	Activity type	2015-16		2016-17		2017-18	Project total
		MR1[a]	MR2	MR3	MR4	MR5	
Collaboration between service providers	Face to face project meetings			5[b]	4	1[c]	**10**
Engagement with stakeholders	Face to face Stakeholder Committee meetings		2	2	2	1	**7**
Engagement with industry, government and scientific community	Scientific articles					5[d]	**5**
	Scientific presentations				5	5	**10**
	Industry / government / public presentations		13[e]		7[f]	5[g]	**25**
	Industry articles		4	7[h]	7	4	**22**
General engagement events	Total engagement events[i]			~80	~80	>50	**>210**

Table Key:

[1] Outputs not reported on in Milestone Report 1, as reporting period covered planning phase

[b] 7 project meetings over teleconference were also reported

[c] 2-day project meeting

[d] 1 published peer review conference paper; 2 scientific articles in press; 2 in submission

[e] 7 industry presentations; 1 industry conference presentation; 1 industry conference paper; 1 government presentation; 3 industry consultation meetings

[f] Industry presentations

[g] Industry/government presentations

[h] Additionally, at date of publication, these articles were accepted for publication to five industry magazines

[I] Estimates as stated in Milestone Reports

3.3. Achievements against expected outcomes

Publication of guidelines for AWM of Qfly and opportunities to implement SIT

The program logic for the AAWM project describes a higher level outcome that "*Guidelines for SIT incorporation into AWM of Qfly are workable and accepted*." The project published these guidelines in April 2018 on a website titled "*Guidelines for AWM of Qfly and opportunities to implement SIT*"[2].

[2] https://area-wide-management.com.au/ The website presents three related sets of guidelines targeted at the three key 'actors' in AWM; coordinator, commercial grower and backyard gardener.

The review found the published guidelines to be of good quality although is it too early to assess the likelihood of uptake. The majority of interviewees positively described the quality of the AWM guidelines. Three interviews expressed optimism about the usefulness of the guidelines.

> *"Overall, I think the guidelines are really very good on the whole. In the context of what the project was trying to achieve, I think the guidelines are good and provide something useful. I think they are workable." (PT1)*

Another project team interviewee reported there has been positive feedback from the regions about the fact sheets and other extension materials that were distributed through the project and are now available through the AWM website. A Stakeholder Committee member thought the web-based format of the guidelines was an appropriate platform for delivery.

While all interviewees were given the opportunity to review the content prior to publication on the website, not all interviewees had an opportunity look at the website before contributing to this review as there was little time between their publication and the final review. Some interviewees expressed doubt about the overall utility of the guidelines, observing that they are not specific or not practical enough.

The desktop review of the website content found that, at the time of reporting, the website has extensive detailed information on best management practices for Qfly control, but there is limited information about opportunities to implement SIT or how to access habitat and risk maps for an area where a community might be considering AWM.

Understanding of barriers and enablers to the adoption of SIT

One expected outcome of the AAWM project was improved understanding within the project team of barriers and enablers to adoption of SIT in AWM. In the program logic, this outcome is a prerequisite to the development of regionally specific information material to support extension around SIT in AWM.

The review found that the project provided an understanding of barriers and facilitators to the adoption of SIT in AWM, which improved the understanding within the project team and was used to inform the guidelines. This is supported by the positive responses from most project team and Stakeholder Committee interviewees when asked about this outcome.

Those who responded positively spoke about the quality and comprehensive information about barriers and enablers captured in the results of the social science research. Stakeholder Committee interviewees appreciated how the social science research has been able to provide industry with a holistic understanding of barriers and enablers for AWM instead of focussing just on Qfly management practices. Project team interviewees also recognised the value of this work to help develop key parts of the guidelines around engagement of commercial growers and backyard gardeners for AWM.

Concern was expressed by several interviewees that the social research was based on the release of sterile male flies, whereas male only flies are not yet available from the SIT facility. The acceptability of release of sterile bi-sex flies (i.e. sterile male flies and sterile female flies) was not investigated in the social research. One project team interviewee thought that bi-sex is less acceptable to farmers than male-only, but acceptance might still be high for bi-sex releases.

Development of regionally specific information to support adoption of SIT in AWM

The review found that the project developed regionally specific information to support the adoption of SIT in AWM, and incorporated this information into the guidelines.

The guidelines incorporate information on highly susceptible fruit fly areas and insights for fruit fly management, both produced through the expert elicitation and risk mapping project activities. Two examples of habitat and risk maps are provided in the published guidelines, together with an explanation about how habitat and risk mapping can be used to support AWM.

Region-wide surveys were conducted to find out how much growers and residents felt willing to pay for the various features of an AWM program and SIT. The results of this study, including regional differences, are presented in the published guidelines as information to support AWM planning.

Economic studies conducted by the project used three case study regions to look at where AWM and SIT could be efficient and effective and to identify the key factors needed to identify whether AWM using SIT is economically viable. The studies found there was no net benefit from AWM and SIT for large regions where Qfly is endemic (considering only grower management costs), but there may be net benefit at another spatial scale.

> *"SIT is only economically justified for outbreak eradication and special cases, primarily relatively small concentrated space where substitute SIT for chemical control – not the big areas where we got stuck into. We never designed research to look at small concentrated areas. Likelihood of really good cases is low – maybe some in the Swan Hill area. Maybe good for urban areas – willingness-to-pay work shows urban areas benefit where there is an urban SIT program." (PT5)*

Spatially explicit population models developed in the project can assess the effectiveness of different Qfly management strategies for a defined area. There is potential for this model to be combined with economic studies to help inform decisions for AWM and SIT in a defined area, however it has not yet been developed into a practical tool for industry use.

Interviewees provided mixed responses when asked how successful was the project in developing regionally specific information for AWM using Qfly SIT, while acknowledging that they do describe differences in management approaches between endemic and pest free regions, as well as between areas with and without known flies in endemic regions.

3.4. Other outcomes

Unintended positive outcomes

The review identified positive, unintended outcomes related to increased collaboration across disciplines and industries. One project team interviewee described how the project had built greater transdisciplinary capacity, which will have a flow on benefits for other investments. Another project team interviewee described the linkages and communication channels that had been built between regional groups that comprise different stakeholders and between stakeholders in NSW and Victoria. One Stakeholder Committee interviewee described how the project has helped promote a more national approach to Qfly management and a more collaborative approach across the different levels of industry, which in turn can make trade negotiations easier. One project team interviewee described how the project has gained international recognition. One Stakeholder Committee interviewee described how industry had learnt about improved trapping techniques (for monitoring) though the project and how this has presented an opportunity to commercialise a new and improved design.

Unintended negative outcomes

No unintended negative outcomes were identified by the review. However, several project team interviewees expressed concern that there is potential for the social research findings to be misinterpreted because they were based on the release of sterile male flies. These interviewees were concerned that if the social science results are inappropriately applied to bi-sex releases, this could undermine the SIT release program and trust in the technology.

3.5. Program delivery

Effectiveness of collaborations within and between teams

Project activities were carried out by multi-disciplinary teams comprising participants from CSIRO, QUT, SARDI, NSW DPI and Agriculture Victoria. **The review found that the project experienced some governance and coordination challenges, but that collaboration significantly improved with the introduction of new governance arrangements during the latter part of the project.** Evidence suggests that the project's complex governance arrangements combined with difficulties coordinating multidisciplinary and geographically dispersed teams resulted in significant challenges for collaboration. A common observation by interviewees was that collaboration improved over time as roles, expectations and accountabilities across the project were clarified. Focussing discussion on shared outcomes was seen as important. One interviewee described the importance of meeting physically and of focussing planning discussions on shared outcomes. Another interviewee observed that difficulties arose when teams focussed on reaching their own milestones rather than looking at shared outcomes.

Interviewees described sub-optimal collaboration between teams and difficulties in managing input from diverse stakeholders within the project.

> *"I have been quite disappointed how teams have got together. Sometimes interested in working together, sometimes quite separate. … Each team is trying to reach their milestones rather than looking at outcomes." (PT4)*

The sequence of the research activities was seen as important although no clear picture emerged about an optimal sequence for the project as a whole. One interviewee appreciated the results of social science coming early and first as it helped inform their activities. Another interviewee thought that if the economic results has been known earlier, it would have helped to streamline the social science research.

One interviewee observed that there was insufficient "team aesthetic" at the commencement of the project and that the approach taken was to try and pull work together at the end rather than collaborate during planning and implementation. Table 3 presents feedback on the overall integration of project activities into a SWOT analysis (strengths, weaknesses, opportunities and threats).

Table 3: SWOT analysis of overall integration of project activities

SWOT analysis of overall integration of project activities	
Strengths	• Integration of research findings into extension and engagement activities and outputs, including roadshows and into the AWM guidelines. • The multidisciplinary approach led to a better understanding of social issues. These insights were communicated externally, including to industry. • The project coordinator acted as an effective intermediary between project sub-units, Stakeholder Committee members and external stakeholders including industry. • Near-weekly meetings resulted in a more integrated approach for bio-economic modelling • Researcher face-to-face meetings helped to maintain linkages between projects components. • The collaboration within the biophysical team was identified as a strength.
Weaknesses	• Difficulties in understanding the approaches of disciplines other than your own – it takes time to establish a shared understanding. • Disagreements about suitable parameters for modelling. • Geographical separation of project team members. • The order of research was less than optimal and compromised effectiveness of each research component. • Incorporation of the economic work. • Slower than anticipated optimization of male-only sterile flies (by another project).
Opportunities	• The changes to project management including to the overall structure and personnel that were made mid-way through the project were effective and could be learnt from. • Previous lack of management managing multiple research teams was acknowledged, lessons from this project could be built upon. • Additional project management at the regional level could lead to improvements to the way stakeholders are identified and involved in the project.
Threats	• Managing the timing and level of input from project partners, particularly related to their in-kind contributions to ensure quality and commitment was maintained. • Nature of collaborative R&D projects means keeping momentum and deciding what to do next after the project ends is more difficult.

Stakeholder engagement at the Stakeholder Committee level

The review found that communication between the project team and Stakeholder Committee members significantly positively influenced the project. The majority of interviewees commented positively when asked to describe the communication between the project team and the Stakeholder Committee, although there was also a range of views about how it could have worked better.

Project team interviewees valued the input from the Stakeholder Committee, in particular that it was useful to get feedback and advice from the committee about what would work. There is evidence that input from stakeholders at the committee level positively influenced the development of the AWM guidelines.

> *"The face to face meetings were the most effective in terms of listening to opinions from the group – a good opportunity to do it and the way it was handled encouraged open and frank advice from the group." (SH2)*

> *"Stakeholder engagement at the committee level was pretty good. Key people in industry took time and effort to work with us. Without that the project could not have succeeded." (PT5)*

One Stakeholder Committee interviewee commented that the AWM coordinator liaised effectively between the research teams and industry, both at the committee level and in the regions. Another Stakeholder Committee interviewee observed that the project has led to much better collaboration between industry groups.

> *"I think it* [stakeholder engagement] *has been exemplary – it was very well done with the coordinator role filled – [they] did a very good job about being the go-between of the hard core science of CSIRO and industry involvement." (SH1)*

One Stakeholder Committee interviewee observed that the potential for local and state government to be more actively involved in the meetings was not realised. This was seen as significant given the emerging importance of these groups in AWM and the potential use of SIT.

Interviewees identified some shortcomings to do with engagement at the Stakeholder Committee level. One project team interviewee observed that the Stakeholder Committee could have performed more of a steering committee function to support outcome-focussed collaborations. The same interviewee thought that the Technical Advisory Committee of SITplus could have been more actively coordinating all SIT related projects, including this one, in order to improve effectiveness.

Stakeholder Committee interviewees noted that less time could have been given to long scientific presentations and more time given to discussions. One Stakeholder Committee interviewee noted a level of fatigue among industry over the three year time frame of the project. Two Stakeholder Committee interviewees noted that it would have been useful to have more industries represented, while acknowledging that this can be difficult given the fragmented nature of horticultural industries.

Stakeholder engagement in the targeted regions

The evidence shows the project was well received by stakeholders engaged in the targeted regions. A majority of interviewees made positive comments relating to the regional roadshows and their role in regional engagement. Stakeholder Committee interviewees observed that industry responded well to roadshows and that there was interest from growers to attend and to listen and understand what was going on. Interviewees positively described the AWM coordinator's role as a conduit between the research and communities.

Interviewees had mixed views on the overall level of participation at roadshows. There was varying stakeholder interest that did not always match expected relevance to the local or regional community.

Relevance to industry needs

The evidence indicates the project contributed to increased industry awareness about Qfly and SIT. However, there was a mixed response regarding the overall relevance of the outputs to industry, given their limitations, and uncertainty remains about how AWM of Qfly will be carried out.

Two Stakeholder Committee interviewees thought the project was highly relevant to industry because of current outbreaks and the potential for further spread and impacts on production and trade. The AWM guidelines are a source of practical information for AWM and best management practices. One project team interviewee thought the guidelines website provides a useful platform for providing practical information for growers and groups and represents a useful communications channel around Qfly.

The majority of interviewees described some limitations about the relevance of project activities and outputs to industry. One project team interviewee observed that industry heterogeneity made the operation of a business subscription model difficult. The same interviewee thought that the case study framework, based on whole regions, was too large. Another project team interviewee noted that the lack of a regional economic argument was an opportunity that was missed. A project team interviewee thought that the spatially explicit population model is not yet in a useful form for industry.

Stakeholder Committee interviewees expressed uncertainly about how industry is going to use AWM and SIT, describing the challenges inherent in user-pays scenarios. There was a view that uptake and interest would be highly varied across regions, industries and businesses. One Stakeholder Committee interviewee expressed concern about a lack of information about how SIT is going to be trialled and introduced. The project's extension activities have raised awareness and interest in Qfly SIT, however information in the guidelines is limited to general information about SIT and how it can be used to reduce Qfly numbers further after AWM (using best management practices) has already reduced Qfly to a low level.

One Stakeholder Committee interviewee described how there are a range of expectations among various stakeholder groups about how SIT is going to be implemented. Industry stakeholders do not have a clear understanding about the potential for SIT to help keep Qfly populations at a low level and the potential to eradicate the pest so that an area can regain a pest free status.

3.6. Return on investment

Demonstrated or expected quantifiable return on investment for the project could not be determined from available data. As described in Section 3.3 the economic studies found there was no net benefit from AWM and SIT for large regions where Qfly is endemic (considering only grower management costs), but there may be net benefit at another spatial scale.

The two milestone reports described how BMP extension activities conducted by the project together with the publication of AWM guidelines are helping prepare growers for implementation of AWM. The extension activities and guidelines also promote BMP for commercial growers and backyard gardeners, whether or not these audiences are part of AWM. These benefits were not analysed by the project.

Evidence provided by interviews and the economic studies indicated that a high return on investment would be expected if this project contributes to preventing Qfly incursion in the Riverland PFA or contributes to successful eradication of a future incursion in the Riverland PFA. However, there was little evidence about how this could be done.

3.7. Lessons learned

Interviewees provided a broad range of ideas to inform future projects. They have been grouped into 11 lessons arranged under five themes.

Future collaborations

1. Two project team interviewees pointed to challenges with collaboration between natural scientists and social scientists resulting from natural scientists' unfamiliarity with social science methodologies. It was suggested that collaborative work between different disciplines requires individuals to be willing to recognise to the validity of the methodologies involved and to trust the expertise of others. Another project team interviewee described the need to strengthen relationships within the project through explicit efforts to build trust between researchers, and how this is especially important for a multidisciplinary group that is not co-located.
2. The role of a project coordinator to liaise between scientists and industry stakeholders was seen as critical for the success of collaborative projects like the AAWM.

3. Several interviewees noted the importance of establishing a shared understanding and clarity about roles, expectations and accountabilities and overall direction of a project. Interviewees said that a clear structure and hierarchy is needed from the start of the project and that time should be invested in creating a leadership team to plot out the research process at the commencement of the project before commencing research activities. Ideally this team should then work together for the life of the project.
4. Three interviewees made suggestions about how stakeholder engagement and industry involvement could be improved for projects involving regional case studies. Of these, one respondent said regional management roles were required in addition to the good will of Stakeholder Committee members acting as champions and sources of on-ground information.
5. The use of non-sensitive data for modelling allows unrestricted presentation of results but less specificity of model outcomes. The use of sensitive data ensures highly specific model outcomes, but restricts sharing of results. It is important to be clear from the start about the limits for each approach and what is expected from a project (Milestone Report 5, p. 13).

In-kind contributions

6. Three interviewees described how future projects would benefit from greater clarity about expectations in managing in-kind contributions. Clarity around both expectations and commitments of in-kind contributors at the start of the project was seen as very important. Such commitments need to be recognised at both the project level and organization level.

Delivery of SIT

7. One project team interviewee described how the project has identified a need for decision support in producing and deploying flies, and a need for tools to support this. This is seen as a gap moving forward that will impact the sustainability of SIT technology for Qfly.
8. Another lesson for the delivery of Qfly SIT is the importance of appropriate application of the social science results from this project (based on the male ST releases) so that bi-sex releases do not undermine community trust in the technology.

Role of DAWR

9. The involvement of a DAWR representative on the Stakeholder Committee was considered important to help manage risks around international trade sensitivities.
10. One project team interviewee suggested the financial reporting requirements of DAWR could be more streamlined. Expectations for financial reporting could be communicated up-front to help facilitate this. The requirement to report expenditure by individual activity was viewed as impractical by a project team interviewee.

Other risks to industry

11. One project team interviewee described how the integrated management of multiple pests in an area (including other trade-sensitive pests) needs attention. Campaigns that focus on a single pest can increase other risks to industry, including pest and chemical risks to trade and the emergence of pesticide resistance.

Appendix 1 of final review

Program logic for AAWM project

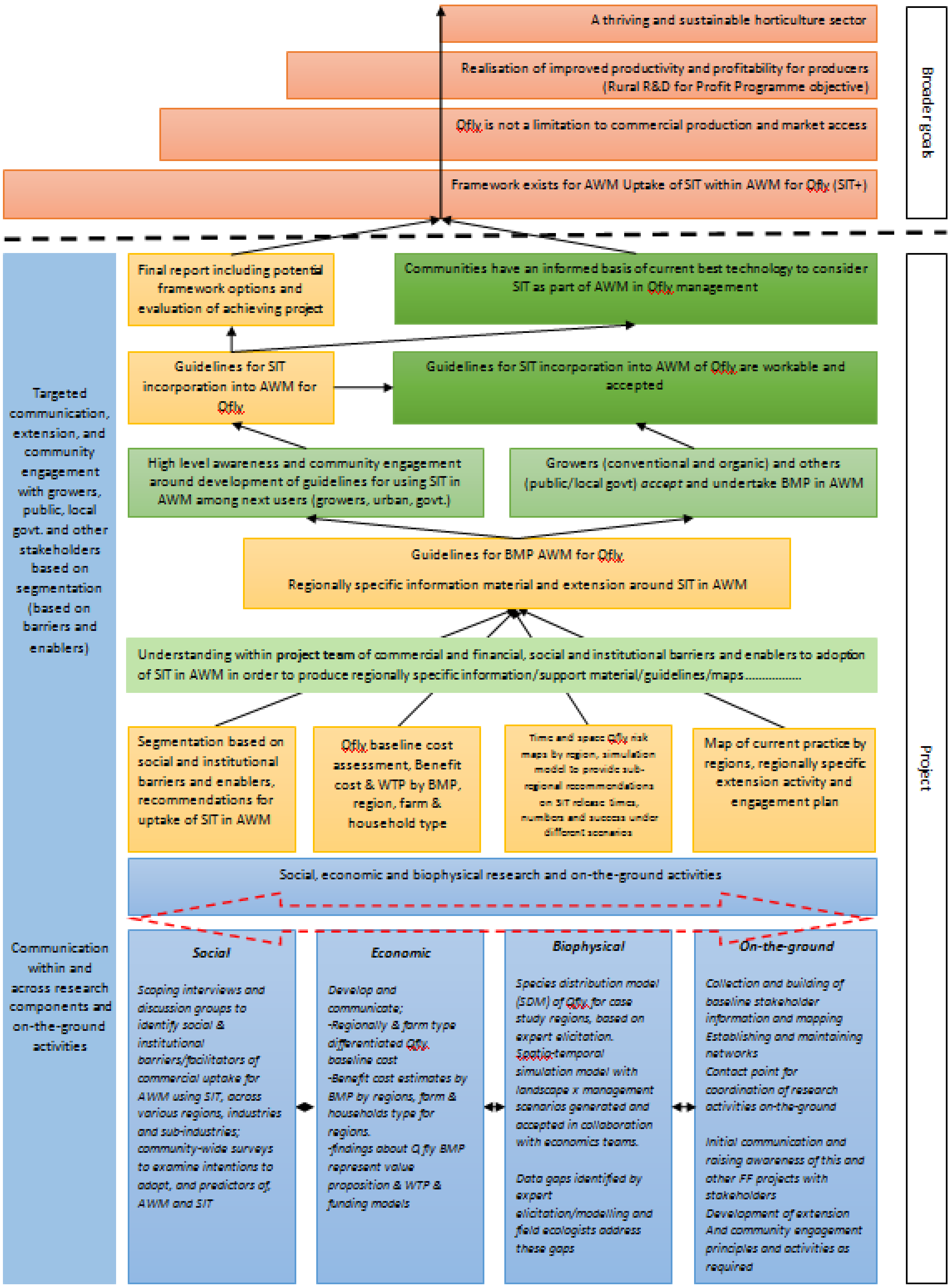
A program logic model for the AAWM project is provided in **Error! Reference source not found.** (next page).

The model shows that the AAWM project expects to contribute to the framework for AWM uptake of SIT within AWM for Qfly (SIT+) by developing guidelines for adaptive AWM of Qfly. The guidelines are expected to identify the constraints and challenges (social and bio-physical) to achieve and implement best management practice (BMP), including through the effective delivery and management of SIT.

The guidelines are expected to identify and determine the availability of optimal commercial delivery pathways of Qfly SIT, and establish strong effective networks at a regional level for Qfly management (industry and community) capable of undertaking AWM. It is expected that communities will have an informed basis of current best technology to consider SIT as part of AWM in Qfly management as a result of the project.

To achieve meaningful and accepted guidelines, the research team needs to produce meaningful models, and all stakeholders within a defined area, or region, need to be identified and involved in the development of the guidelines. The success of the project, therefore, depends on there being sufficient data to develop meaningful models, and on community engagement and effective communication. These are amongst the key assumptions of the AAWM project.

Program logic model for the AAWM project



Appendix 2 of final review: Overview of KPI achievements

Activity area	Key Performance Indicator	Source of evidence of achievement	Year achieved	Comments
1. Project initiation and management	Monitoring and evaluation plan and communication plan completed and provided to the Department	Milestone Report 1	2015	Completed on schedule
	Advise the Department of executed agreement with partner organizations	Milestone Report 1	2015	Completed on schedule
	Advise the Dept. of the establishment and appointments to the Steering Committee	Milestone Report 1	2015	Completed on schedule
	Advise the Dept. of any new partnerships or contributions toward the Project[3]	Milestone Report 1	2015	Completed on schedule
	Financial Report covering the period from execution of the funding agreement to the submission of Milestone Report 2	Milestone Report 3	2016	Completed behind schedule
	Independent mid-term review conducted by Clear Horizon	Milestone Report 3	2016	Completed on schedule
	Financial report covering the period from submission of Milestone report 2 to submission of milestone report 4	Milestone Report 5	2017	Completed on schedule
	End of project evaluation report			Due for completion May 2018
2. Identify social challenges and constraints	Pilot scoping study to refine research objectives and a summary provided to the Department	Milestone Report 2	2016	Completed behind schedule
	Report on discounted cash flow analysis completed and provided to the Department	Milestone Report 2	2016	Completed on schedule
	Framework for stakeholder interviews developed	Milestone Report 3	2016	Completed on schedule

[3] No new partnerships had been identified at the point of reporting

Activity area	Key Performance Indicator	Source of evidence of achievement	Year achieved	Comments
	Stakeholder interviews conducted and summary of outcomes provided to the Department	Milestone Report 4	2017	Completed on schedule
	Bio-economic model developed	Milestone Report 4	2017	Completed on schedule
	Willingness to pay assessment complete and report provided	Milestone Report 5	2017	Completed behind schedule
3. Identify biophysical challenges and constraints	Analysis of habitat suitability for Qfly initiated and preliminary results provided to the Department	Milestone Report 2	2016	Completed on schedule
	Elicitation workshop of Qfly Ecology experts and planning for elicitation workshop of Regional experts	Milestone Report 2	2016	Completed on schedule
	Review and integrate knowledge completed and a summary provided to the Department	Milestone Report 3	2016	Completed behind schedule
	Elicitation of regional experts complete; risk maps generated	Milestone Report 4	2017	Completed on schedule
	Knowledge gaps of fruit fly requirements identified and filled	Milestone Report 5	2017	Completed behind schedule
4. Demonstrate best management practice	Advise the Department of the appointment of an extension co-ordinator	Milestone Report 1	2015	Completed on schedule
	Advise the Department of the network and relationship building activities undertaken	Milestone Report 1	2015	Completed on schedule
	Review current management practices completed, embed SIT practices and a summary provided to the Department	Milestone Report 2	2016	Completed on schedule
	Report on progress tailoring management programs in the three case study regions	Milestone Report 3	2016	Completed on schedule
	Report on progress implementing management programs in the 3 case study regions	Milestone Report 4	2017	Completed on schedule
5. Develop area-wide fruit fly guidelines	Advise the Dept. on progress developing Qfly simulation models	Milestone Report 1	2015	Completed on schedule
	Qfly spatially-explicit population dynamic simulation models developed and report on scenario modelling	Milestone Report 4	2017	Completed on schedule

Activity area	Key Performance Indicator	Source of evidence of achievement	Year achieved	Comments
	Communication of output from model scenarios conducted with stakeholder groups and summary of activities	Milestone Report 5	2017	Completed on schedule
	Area-wide fruit fly guidelines developed and approved	Milestone Report 5	2017	Completed on schedule
6. Communicate guidelines and identify next steps	Guidelines communicated to stakeholders and feedback incorporated; final guidelines	www.area-wide-managment.com.au and interviews	2018	Completed on schedule
	Report on next steps to produce and deploy sterile males for managing Qfly			Due for completion May 2018
	Final project report			Due for completion May 2018

Appendix 3 of final review: Data sources for the Final Review

Project documents reviewed

Milestone reports
MR1: Milestone Report 1, Hort Innovation MS103 (30 November 2015)
MR2: Milestone Report 2, Hort Innovation MS 104 (27 May 2016)
MR3: Milestone Report 3, Hort Innovation MS 105 (29 November 2016)
MR4: Milestone Report 4, Hort Innovation MS 106 (29 May 2017)
MR5: Milestone Report 5, Hort Innovation MS 107 (27 November 2017)
Research team meeting notes
RN1: QFAM Researchers Workshop Meeting Notes (20-21 June 2017)
Stakeholder committee meetings
SCM1: Qfly Area Wide Management Stakeholder Committee Meeting Minute (6 November 2016)
SCM2: Qfly Area Wide Management Stakeholder Committee Meeting Minutes (29 February 2016)
SCM3: Qfly Area Wide Management Stakeholder Committee Meeting Minutes (29 June 2016)
SCM4: Qfly Area Wide Management Stakeholder Committee Meeting Minutes (8 September 2016)
SCM5: Qfly Area Wide Management Stakeholder Committee Meeting (3 March 2017)
SCM6: Qfly Area Wide Management Stakeholder Committee Meeting (21 April 2017)
SCM7: Qfly Area Wide Management Stakeholder Committee Meeting (3 August 2017)
Evaluation documents
ER1: Mid-term Review Final Report Adaptive area-wide management of Qfly using SIT (22 August 2016)
AWM guidelines
"Guidelines for AWM of Qfly and opportunities to implement SIT" at https://area-wide-management.com.au/

List of interviewees

Name	Organisation	Role in AAWM project
Adam Upton	Yarra Valley, Victoria.	Stakeholder committee (Industry member)
Dr Aditi Mankad	CSIRO	Lead, Social Science sub-project
Brenda Kranz	Hort Innovation	Project Manager
Dr Craig Hull	DAWR	Stakeholder committee
Dan Ryan	SITPlus	Director SIT plus Program
Dr Hazel Parry	CSIRO	Chief Investigator
Merran Socha	Local Government Berrigan, AS	Stakeholder committee
Dr Penny Measham	Hort Innovation	AWM Project Coordinator
Stuart Whitten	CSIRO	Lead, Economics Science sub project

Appendix 4 of final review: Interview guide

Hello, my name is [*interviewer name*] from Clear Horizon Consulting. We have been contracted by Horticulture Innovation Australia to undertake the final review of the Adaptive area-wide management of Qfly using SIT ('the project'). [*Provide more detailed description of project if needed*]

The purpose of the final review is provide an assessment of the overall performance of the project to assess its effectiveness, relevance, process appropriateness and efficiency and to identify any lessons learned for the design and implementation of future projects. Your name has been provided to me by Hort Innovation. The purpose of the interview is to ask you to draw on your experience and perspectives to reflect on the implementation and success of the project to date.

The information you provide will be analysed together with other interviews and used to develop a final review report for Hort Innovation. While you will not be identified by name in the report, identification may be possible by reason of the small number of interviewees (approximately 12). If there are any comments you would not like to be associated with please let me know so that I can ensure confidentiality. Is this ok with you? This interview is expected to take about 30-45 minutes. Are you happy to proceed?

Introductory questions

I'll start with some background and general questions.

1. Could you tell me your role/how have you been involved, in the AAWM project to date?
2. Do you have any overall comments would you make about the AAWM project?

In the following section I ask you about the outcomes the project is hoping to achieve.

Outcomes

3. The project aimed to develop workable and accepted guidelines for uptake of SIT within AAWM or Qfly. How successful do you think the project has been in developing these guidelines?
4. How well do you think the project provided an understanding of the barriers and enablers to adoption of SIT in AWM? (Prompt: why/why not – what made you answer in that way?)
5. In your opinion, how successful was the project in developing regionally specific information for AWM using Qfly SIT?
6. Again, in your opinion are the outputs of the project of sufficient quality and scientific rigour?
7. How effective do you think the collaborations within the project have been (Prompt: between sub-projects and between organisations)?
    a. What worked well?
    b. What could have worked better?
8. How would you describe the communication between project teams?
    a. What worked well?
    b. What could have worked better?

9. How would you describe the communication between project teams and the Project Steering committee?
    a. What worked well?
    b. What could have worked better?
10. How was the level of stakeholder engagement in the program at the Stakeholder Committee level?
    a. What worked well?
    b. What could have worked better?
11. How was the level of stakeholder engagement in the program in the target regions?
    a. What worked well?
    b. What could have worked better?

Relevance

12. In your opinion, how relevant do you think were/are the project's activities and outputs to industry?
    a. What are the ways in which the activities and outputs will benefit / be used / by industry? (possible to quantify? anything you can draw on to quantify those benefits)
    b. How likely do you think that these guidelines will be used? Why do you say that?

Efficiency

13. Are you aware of efforts to improve the efficiency of the project during its implementation? What were they?

Unintended outcomes

While projects are generally managed to achieve their expected or promised outcomes, it is not unusual for projects to have other effects, both positive and negative. These questions are intended to capture those, where they exist, and their implications/significance.

14. Outside of what the project was expected to achieve, are there any effects (either positive or negative) you observed?
15. What are the implications of this? (*significance; why important to capture*)

Lessons learned

The next question asks you to think about how you would go about this project differently based on what you have learned, and lessons for future collaborations and delivery of SIT.

16. If you were managing this project, what do you think could be done better (or what would you do differently) given what you know now?
17. Are there any specific lessons:
    - for the success of future collaborations?
    - for the delivery of SIT?
    - about the role of DAWR?

Closing comments

18. We have reached the end of the interview questions, but are there any other comments you would like to make before we finish up?

Thank you for your time and for your comments, they have been most useful.