National Fruit Fly Research, Development and Extension Plan

CRC PLANT biosecurity

Acknowledgements

This plan has been prepared by the Plant Biosecurity Cooperative Research Centre (PBCRC), with advice from the National Fruit Fly Advisory Committee and the National Plant Biosecurity Strategy Implementation Committee. Numerous individuals and organisations provided input to the National Fruit Fly RD&E Plan during its development and consultation phase.

This National Fruit Fly Research, Development and Extension (RD&E) Plan is a component of both the National Plant Biosecurity RD&E Strategy (itself a component of the National Primary Industries RD&E Framework) and the National Fruit Fly Strategy (NFFS) (PHA 2008). This plan was endorsed by the National Fruit Fly Advisory Committee in February 2015. This Plan provides direction on the research, development and extension required to fully implement the NFFS.

Further information

National Fruit Fly Strategy
http://www.planthealthaustralia.com.au/national-programs/fruit-fly/draft-national-fruit-fly-strategy/

National Plant Biosecurity RD&E Strategy
http://www.npirdef.org/cms_strategy/20

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Contents

Background

Nearly 60,000 people are employed in the Australian horticultural sector, growing fruits and vegetables for domestic and export markets. Australia's horticultural industry is the nation's third largest agricultural industry, with the total value of Australian horticultural production in 2012-13 being over $9 billion.

Due to a combination of regulatory withdrawal of key insecticides and climate driven changes in pest abundance, Australia's horticultural sector is currently under serious threat from a group of horticulture specific pest insects, the tephritid fruit flies.

Fruit flies lay their eggs directly into near-ripe and ripe fruits and vegetables, where the eggs hatch into maggots which feed upon the fruit flesh. Over 75% of Australia's fruit and vegetable exports, valued at around $640 million in 2012-13, are susceptible to fruit fly.

An inability to control fruit fly will see the decline and potential loss of some horticultural communities, a reduction in the amount and quality of fresh produce available to Australian consumers and the loss of international markets.

The National Fruit Fly Strategy and a Fruit Fly RD&E Plan

The Draft National Fruit Fly Strategy (NFFS) (Plant Health Australia 2008) provides a comprehensive assessment of Australian fruit fly challenges, and a specific set of recommendations and strategies to address those challenges: the Strategy has been widely endorsed. The NFFS remains current in most respects, although the urgency of the fruit fly problem has become significantly greater.

As part of the NFFS, this National Fruit Fly Research, Development and Extension (RD&E) Plan establishes the future direction for improving the focus, efficiency and effectiveness of fruit fly RD&E for Australia's horticultural industries.

The Fruit Fly RD&E Plan recognises a wide range of stakeholders, from individual growers, through specialist RD&E funders and providers, to the State and Australian governments. These stakeholder groups were involved in the development of this Plan, either through representation on the expert writing group or through a national consultation process.

Queensland fruit fly (*Bactrocera tryoni*) is a significant horticultural pest which can infest many varieties of fruit and vegetables - photo by Jaye Newman.

Vision of the National Fruit Fly RD&E Plan

The vision of this Plan aligns with that of the NFFS: ***Fruit flies are not a constraint to sustainable production or a significant barrier to national and international market access.***

Consistent with this vision, the Plan identifies the RD&E investments areas required to manage the risks to the economy, industry, and community, of (i) exotic fruit fly pests entering and establishing; and (ii) of endemic species limiting production and market access. The Plan is driven by the principles that fruit fly RD&E needs to benefit growers and allow them to maintain viable businesses; and that fruit fly RD&E is not just a grower issue but needs to involve the whole community.

This RD&E Plan has two major components. The first half of the document identifies broad areas of RD&E needs, to manage fruit fly both now and in the future. The second half of the document provides detailed, specific recommendations for RD&E investment areas, which are broken down into seven themes:

- Theme 1: Managing Exotic Risk
- Theme 2: Pre-harvest Controls
- Theme 3: Post-harvest measures
- Theme 4: Market access and regulatory issues
- Theme 5: Social issues
- Theme 6: Capacity
- Theme 7: Core science

The broad RD&E needs identified in the first half of the document are linked to the detailed RD&E investment areas.

Key recommendations

The following recommendations align with the five major areas for fruit fly RD&E investment within this plan:

- Coordination
- Extension, Community and Capacity
- Controlling Fruit Flies
- Trade and Market Access
- Future Issues

This Plan recommends that;

1. National coordination for fruit fly RD&E and improved resourcing is urgently needed to maximise the benefits gained from RD&E investment and to ensure consistent information is provided to growers and other end-users. A coordinated National RD&E Plan is integral to the successful delivery of the NFFS and, as such, the National Fruit Fly Advisory Committee should investigate the different contemporary models by which such coordination and resourcing could be achieved and seek to implement the most appropriate.
2. There is a major need for regional development and extension of fruit fly research, including working directly with growers to trial and develop control strategies optimized for local regions and crops. Urgent consideration should be given to the models for provision of fruit fly development and extension services in Australia's major horticultural production areas, including by the private sector.
3. R&D support continues to be provided for biosecurity preparedness and quarantine activities targeted at preventing the entry and establishment of offshore fruit fly threats. Particular focus should be applied to mitigating the risk posed by Oriental fruit fly.
4. RD&E activities targeting rapid replacement options for dimethoate and fenthion should focus on the registration of new chemicals and new uses for existing registered chemicals, and optimisation of existing controls such as MAT, protein bait spray, crop hygiene and mass trapping.
5. RD&E activities targeting medium to long-term fruit fly infield controls should work within an integrated pest management framework, which will decrease the need and reliance on synthetic pesticides. Such control or eradication strategies include Sterile Insect Technique, mass trapping, crop hygiene, eradication, protein baiting, MAT and use of natural enemies. The combination of these techniques into a systems approach can be used for market access.
6. An R&D focus be applied to fruit fly eradication technologies (such as SIT, MAT and protein baiting), to make the eradication of fruit flies technically easier and hence economically more justifiable.
7. R&D targeting medium and long-term outcomes for fruit fly disinfestation should focus on the development of new methodologies and statistical approaches which can provide the same importer confidence and regulatory approvals as currently achieved, but with reduced logistical effort, time and/or cost.
8. Standardised approaches for market access RD&E and field operations should be developed and implemented to ensure international acceptance of Australian fruit fly market access datasets for fresh commodities. This includes updating national codes of practice for fruit fly.
9. RD&E focus is applied to the 'other' fruit fly pests of Australia, including resolving the systematics and taxonomy of the *Bactrocera tryoni* complex and developing biological data sets (including confirmed host lists) and management tools for native fruit fly species other than *B. tryoni* and *C. capitata*.
10. Systematic and taxonomic research should be carried out to develop accurate and user-friendly diagnostics to separate native pest fruit flies from native non-pests and exotics.
11. The National Fruit Fly Advisory Committee coordinates and implements this Plan, supporting an audit of activity, a prioritisation process and exploring resourcing arrangements via existing and/or new funding mechanisms.

Australian horticulture

The horticultural industries contribute significantly to the prosperity of people living in rural and regional Australia, while providing the fresh fruit and vegetables which all Australians take for granted. Australia's horticulture industry has long enjoyed a domestic and international reputation for quality, primarily due to our high standards across all stages of the supply chain, from farm to consumer. Nearly 60,000 people are employed in Australia, predominantly through small enterprises, to grow fruit, vegetables and nuts for the domestic and export markets. A further 6,250 are employed in fruit and vegetable processing (DAFF 2013). In 2011-12, based on gross value of production, Australia's horticultural industry was the nation's third largest agricultural industry and the sector is growing.

Fruit flies and horticulture

Australia's horticultural sector is currently under serious threat as a result of one group of pest insects: the tephritid fruit flies. Fruit flies lay their eggs directly into near-ripe and ripe fruit, where the eggs hatch into maggots which feed upon the fruit. The negative impact of fruit fly is caused by two issues. Firstly, direct crop loss, and hence product available for sale, is caused by maggot feeding, the introduction of decay organisms, and premature fruit drop. The second problem of fruit fly is that their presence in production areas can lead to very significant market access loss, as fruit flies are considered by all our trading partners as major quarantine pests. The Minister for Agriculture recently noted that the total value of Australian horticulture production in 2012-13 was over $8 billion. It was also noted that over 75% of Australia's fruit and vegetable exports, valued at around $640 million in 2012-13, are susceptible to fruit fly.

Australia has two serious fruit fly pests, the native Queensland fruit fly (*Bactrocera tryoni*), found in most (but not all) non-arid areas of the Northern Territory, Queensland, New South Wales and Victoria; and the introduced Mediterranean fruit fly (*Ceratitis capitata*) established in Western Australia. These are only two of approximately 90 fruit infesting fruit flies within Australia, but of these 90 fewer than 10 have been recorded from commercial fruit. The Oriental fruit fly (*Bactrocera dorsalis*), arguably the world's worst fruit fly pest, occurs in Indonesia and Papua New Guinea and continuously threatens to enter Australia through the north. If it did enter, it could rapidly spread through nearly all Australian production areas.

The National Fruit Fly Strategy

The Draft National Fruit Fly Strategy (NFFS) (Plant Health Australia 2008) provides a comprehensive assessment of the Australian fruit fly challenge, and a specific set of recommendations and strategies to address those challenges: the Strategy has been widely endorsed. The NFFS remains current in most respects, although the urgency of the fruit fly problem has become significantly greater. Within the NFFS, recommendations 13, 14 and 15 deal explicitly with R&D, and most others implicitly.

- Recommendation 13: Maintain and enhance fruit fly research capability, capacity and resources.
- Recommendation 14: Develop a process for ongoing prioritisation of fruit fly research and development activities to provide clear direction for current scientific activities and proactively identify emerging research needs consistent with the directions of this strategy.
- Recommendation 15: Develop and strengthen fruit fly research and development collaborations and linkages, nationally and internationally, and ensure these cover the different sectors involved in fruit fly management.

In mid-July 2014, The Hon. Barnaby Joyce MP, Federal Minister of Agriculture, called for a reinvigoration of the NFFS through the creation of a new National Fruit Fly Advisory Committee. Under the guidance of the National Fruit Fly Advisory Committee, PBCRC was charged with taking a key role in coordinating a national approach on fruit fly research and building an enhanced and collaborative research capacity to the benefit of all states, territories and affected industries.

The National Plant Biosecurity RD&E Strategy

In April 2007, the Primary Industries Ministerial Council, with support from all research and development corporations (RDCs) and the Australian Council of the Deans of Agriculture, agreed to establish a National Framework for Primary Industries Research, Development and Extension. The Framework aims to facilitate greater coordination among the Australian Government, state governments, CSIRO, RDC, industry and university sectors to better harmonise their roles in RD&E related to primary industries and ensure that they work together effectively to maximise net benefits to Australia. It supports a strong culture of collaboration and coordination between the bodies, strengthens national research capability to better address sector and cross sector issues and focuses RD&E resources so they are used more effectively, efficiently and collaboratively, thereby reducing capability gaps, fragmentation and unnecessary duplication in primary industries RD&E.

The Framework has produced 14 sectoral strategies and eight cross-sectoral strategies, each led by a relevant government and industry body. The Plant Biosecurity RD&E Strategy was endorsed in November 2013 and identified the development

and implementation of a national fruit fly RD&E plan as an important early activity. The National Plant Biosecurity RD&E Strategy Implementation Committee, formed in August 2014 and hosted by Plant Health Australia, has identified fruit fly as the first pest to be worked through as part of the Strategy's vision for building a fully integrated national plant biosecurity system. This twenty year National Fruit Fly RD&E Plan thus constitutes a component of both of the NFFS and the National Plant Biosecurity RD&E Strategy.

The changing fruit fly challenge

Fruit flies are nothing new to Australian horticulture, having first been recorded as causing economic losses in the 1880s (Tryon 1889). However, since the publication of the NFFS in 2008 there has been a major increase in concern about fruit flies due to two key issues.

The first is the regulatory withdrawal of the organophosphate pesticides dimethoate and fenthion (D&F) for many fruit fly susceptible commodities. D&F have been used since the early 1970s to both control fruit flies in the field and as post-harvest treatments for disinfestation. Unfortunately, the organophosphate insecticides have been linked with both human and environmental health issues and independent reviews by the APVMA have seen them withdrawn from postharvest use for all fruit fly affected commodities except tropical and subtropical fruit with inedible peel.

The second key issue is the loss of fruit fly area freedom over most of south-eastern Australia. Currently, at the state level, only Tasmania, Western Australia and South Australia are considered free of Queensland fruit fly, and the maintenance area freedom of the important Riverland horticultural production district of South Australia requires significant investment. The loss of area freedom was brought about by repeated outbreaks and increasing population densities of Queensland fruit fly in south-east Australia; under climate change this situation will almost certainly continue.

The combination of chemical withdrawal and loss of area freedoms has placed huge economic and management imposts on producers of fruit fly susceptible commodities in nearly all parts of Australia. The profitability, and indeed sustainability, of a number of horticultural sectors are threatened and both emergency and long term responses are required to ensure that fruit fly does not permanently limit the Australian horticultural sector.

> *"Please act!*
>
> *The consequences of inaction will be catastrophic.*
>
> *This issue belongs not only to growers and industry, but to all Australian people who want to eat readily available, reasonably priced and clean food."*
>
> **Stone-fruit grower, Riverland S.A., 30 September 2014, consultation response.**

Mediterranean fruit fly (*Ceratitis capitata*)- photo courtesy of the Agricultural Research Service Photo Unit at the United States Department of Agriculture.

Stakeholders

There are large numbers of stakeholders associated with fruit fly RD&E in Australia and the complexity of the stakeholder arrangements is illustrated in Figure 3.1 of the NFFS. The following stakeholder groups are critical to this RD&E Plan – to both its inputs and outcomes.

Australian Government: The Australian Government's activities in fruit fly are focused on regulating the Australian border and managing the risk of exotic fruit flies entering and establishing. The Australian Government is responsible for the conduct of pest risk analyses to assess the likelihood of fruit flies of quarantine concern entering, establishing and spreading within Australia through various pathways, and establishing appropriate risk mitigation measures to reduce the pest risk to an acceptably low level. From a product certification perspective, the Australian Government is also responsible for negotiating market access, ensuring that Australian exports meet importing country requirements, and that any pest free area requirements or fruit fly treatments have been fully met. As part of general surveillance and preparedness activities, the Australian Government is also involved in fruit fly survey and/or response activities in Northern Australia through the Northern Australia Quarantine Strategy, the Torres Strait through the Torres Strait Fruit Fly Strategy, and in Australia's near neighbours through the International Plant Health Program. These programs are delivered in partnerships with state and international agencies.

State governments: All Australian state governments maintain active fruit fly RD&E. Tasmania, as the state least affected by fruit fly, maintains a trapping network to demonstrate fruit fly freedom but few other activities. All other states maintain fruit fly surveillance, research, development, extension and regulatory activities, including the accreditation and maintenance of pest free areas. While some states have withdrawn certain aspects of their fruit fly RD&E support in recent times, other states have increased theirs, and overall they remain key players in fruit fly RD&E. The states both invest heavily in, and have very significant expertise in fruit fly RD&E.

Industry: The horticulture industry is diverse, both in the number of individual members and administrative structures. The basis of the industry is the individual growers, who generally run small to medium enterprises, but the horticultural industry also includes large production enterprises, cooperatives, packers and exporters. Individual growers may be represented by, or participate within local or regional grower groups and peak industry bodies. The industry is both the largest user and funder of RD&E.

Plant Health Australia: Plant Health Australia is a not-for-profit company which liaises between the Australian Government and plant-based industries to enhance plant biosecurity. It has an important extension role and also carries out development activities. As the host of the National Fruit Fly Strategy and the National Plant Biosecurity Strategy it has a unique stakeholder role in fruit fly RD&E.

Specialist RD&E investors: This group of stakeholders includes Horticulture Australia Ltd (now Horticulture Innovation Australia Ltd (HIAL)), The Rural Industries Research and Development Corporation, the Australian Centre for International Agricultural Research, State funding agencies and the Australian Research Council. Of these, HIAL is particularly important as an investor of joint Australian Government and horticulture grower levy monies.

Specialist RD&E providers: This group of stakeholders includes CSIRO, the states, the universities, Cooperative Research Centres, agricultural development companies and private crop consultants. The universities and CSIRO fund R&D from both internal sources and through external grants; while PBCRC funds and carries out research through one large grant: all organisations run largely not-for-profit. The rapidly growing private agricultural RD&E sector consists largely of small and medium size enterprises (SMEs) which carry out development and extension for profit.

Broader community: The broader Australian community are important stakeholders with respect to fruit fly RD&E. When implementing regional fruit fly management, the community need to be engaged in fruit fly control through the management of their backyard trees and by not carrying fruit between regions. Local governments have the ability to levy rates and employ local staff who can be involved in area-wide management campaigns. Community perceptions and acceptance are also of importance in the development of controls and treatments such as irradiation and genetically modified products.

An expert writing group was brought together by the Plant Biosecurity CRC, the organisation tasked by the Minister to develop this plan, between June and November 2014.The expert writing group has many years of experience with fruit fly, with expertise covering fruit fly research and development, regulatory market access, grower experience/needs, RD&E funding, and project management. Additional specialist support was sought for input on market access research and social science RD&E. Some members of the writing group were also members of the National Fruit Fly Advisory Committee and the National Plant Biosecurity Strategy Implementation Committee. The writing group chair, Anthony Clarke PhD FRES, is Professor and Chair of Fruit Fly Biology and Management at the Queensland University of Technology, a co-appointed position with the Plant Biosecurity CRC.

The first step of developing the Plan was to review the NFFS (PHA 2008) and the NFFS Implementation Plan to understand the RD&E recommendations and strategies, and identify and specific gaps or changes since those documents were drafted.

As the second step of Plan development, the group consulted with industry, government and the research community. Consultation was largely online and through letters of invitation to growers, grower groups, peak industry bodies, researchers, relevant CRCs and RDCs. The invitation to contribute was widely repeated through the rural media and a website was created to capture online responses. Members of the writing group also consulted directly and spoke to growers, individual researchers, research agencies, regulators and research managers. Forty-two formal submissions were received, additional to the hundreds of conversations held over the period. All responses were assessed, considered and incorporated as appropriate.

Alignment to national Rural Research and Development Priorities

This Plan supports the following national Rural Research and Development Priorities.

- *Productivity and adding value*: Improve the productivity and profitability of existing industries and support the development of viable new industries.
- *Supply chain and markets*: Better understand and respond to domestic and international market and consumer requirements and improve the flow of such information through the whole supply chain, including to consumers.
- *Climate variability and climate change*: Build resilience to climate variability and adapt to and mitigate the effects of climate change.
- *Biosecurity*: Protect Australia's community, primary industries and environment from biosecurity threats.
- *Supporting the Rural Research and Development Priorities*: Improve the skills to undertake research and apply its findings.

The vision and objectives of this Plan align with those of the National Fruit Fly Strategy.

Vision

Fruit flies are not a constraint to sustainable production or a significant barrier to national and international market access.

Objectives

- To reduce the risk of fruit fly incursions from overseas and the spread of economically significant species within Australia as far as practicable.
- To optimise early detection and response to non-endemic and economically significant endemic fruit flies to minimise their impact.
- To manage fruit fly through effective and efficient use of tools, technology and people in order to establish, maintain or modify the fruit fly status of an area to support trade and sustainable production.
- To raise awareness of biosecurity generally and fruit flies specifically to empower growers, industry, government and community to work collaboratively to minimise the impacts of fruit fly on production, environment and trade.
- To establish and maintain an intelligence network that imparts information to target risks and threats, supports the risk assessment process and facilitates development and ongoing implementation of the fruit fly management system.

New areas of priority

Since the publication of the NFFS in 2008, new priority areas for fruit fly have emerged and these are also dealt with in this Plan.

- *Improved controls*: The loss of dimethoate and fenthion has put emphasis on the short-term refinement and extension of existing fruit fly controls, and on the medium to long-term development of novel controls.
- *Eradication*: In regions where fruit flies are under regulatory control, or where they are not naturally endemic, eradication of outbreaks or newly established populations is a priority control strategy for growers, exporters and regulators. Renewed focus needs to be placed on the science and practice of fruit fly eradication.
- *Northern Australia*: Both Australian and relevant state governments have placed emphasis on the development of agriculture in tropical Australia. Fruit flies will impact negatively on tropical horticulture, while a dramatically enlarged northern production will offer a 'stepping-stone' for the entry of exotic fruit flies. RD&E for tropical and exotic fruit flies thus increases in importance.
- *Grower focus*: Innovative rural research and development is essential for profitability and productivity improvements in agriculture. Outputs of fruit fly R&D must be of commercial benefit to growers either directly, or indirectly through reduced risk (for example by border quarantine).

"R&D makes a very significant contribution to growth in agricultural productivity. This [rural R&D] programme provides grants for collaborative research that will lead to better returns for producers and support continued innovation across Australian agriculture."

The Hon. Barnaby Joyce MP, media release 15 October 2014.

"If the intention of the RD & E is for the benefit of the rural community, then the ability of the producer to manage fruit fly cost effectively to remain in business should be the ultimate goal. As prices received per unit of produce have been stagnant for 20 years, the cost of management of fruit fly needs to be no more, or preferably lower than it has been. If it is greater, then it means that fruit fly can be controlled, but for whose benefit; researchers?"

Queensland grower, 18 September 2014.

Consistent with its vision and aims, the Plan identifies RD&E investment areas required to manage the risks to the economy, industry, and community, of (i) exotic fruit fly pests entering and establishing; and (ii) of endemic species limiting production and market access. The Plan is driven by the principles that fruit fly RD&E needs to benefit growers and allow them to maintain viable businesses; and that fruit fly RD&E is not just a grower issue but needs to involve the whole community.

The following section recommends five major areas for fruit fly RD&E investment:

- Coordination
- Extension, community and capacity
- Controlling fruit flies
- Trade and market access
- Future issues

Each major area is further divided, as appropriate, and linked to the detailed RD&E investment areas.

1. Coordination

1.1 The need for national coordination and resourcing

Both growers and researchers report that fruit fly management in Australia is badly hampered through there being no single body coordinating research, development and extension. Currently RD&E coordination roles are being undertaken by Plant Health Australia, Horticulture Innovation Australia Ltd, the Plant Biosecurity CRC, the NFF Advisory Committee, the National Plant Biosecurity Strategy Implementation Committee, Primary Industries Standing Committee, and the SITplus initiative. This confusion is very obvious at ground level, and a consistent message from growers, grower groups and researchers throughout the consultancy period was the need for a single, national body responsible for fruit fly management. In addition, it is recognised that the fruit fly management situation has become increasingly difficult over the past decade and that historic funding levels are not sufficient to maintain a 'status quo'. To address this relative decline and deliver against this Plan, adequate resourcing is required for priority RD&E projects and initiatives.

Link to RD&E investment areas: Theme 6, sub-theme 6.5.

> *"Amalgamation of all fruit fly related bodies into one force with action, not talk, heading the agenda."*
>
> **State researcher, 4 September 2014.**

> **KEY RECOMMENDATION**:
>
> National coordination for fruit fly RD&E issues and improved resourcing is urgently needed to maximise the benefits gained from RD&E investment and to ensure consistent information is provided to growers and other end-users. The National Fruit Fly Advisory Committee should investigate the different models by which such coordination and resourcing could be achieved.

2. Extension, Community and Capacity

2.1 The need for regionally based fruit fly biosecurity officers

The loss of capacity in regional entomology and local horticultural extension has directly and negatively affected fruit fly management. As an immediate priority, investment needs to be made to support regionally based professionals who can carry out on-station and on-farm trials to adopt and extend primary research to the needs of local growers. Such staff also need to work with local growers, the local community, local government, rural sellers of insecticides and others to develop and implement both on-farm and area-wide IPM strategies which best fit the need of that community. These officers will also act as intermediates between specialist researchers and growers, providing a two-way information exchange between groups. Ideally the biosecurity officers would not be working in isolation, but as part of a larger, nationally coordinated effort. The Australian grains industry regional biosecurity officers are a working example of how this system might operate.

Link to RD&E investment areas: Theme 6, sub-theme 6.1.

> *"The information is largely there, communicating it to growers has been the difficulty in WA. Wider industry communications have not proven to be effective (websites, newsletters, flyers), growers are looking for one-on-one discussion and support. One-on-one extension programs for at least two years."*
>
> **WA grower, 7 September 2014.**

> **KEY RECOMMENDATION**:
>
> There is a major need for regional development and extension of fruit fly research, including working directly with growers to trial and develop control strategies optimized for local regions and crops. Urgent consideration should be given to the models for provision of fruit fly development and extension services in Australia's major horticultural production areas, including by the private sector.

2.2 Fruit fly is not just a grower issue

This was a thematic issue which came through in many responses; i.e. that the wider community in towns must be part of the fruit fly solution and growers cannot do it all on their own. Fruit fly is as much a socio-political and ethical issue as it is a biological one, and there is a requirement for shared responsibility between levels of government, industry and the wider community.

However, what exactly 'shared responsibility' means with respect to fruit fly, and how to gain and maintain engagement from different participants, is not easily addressed and needs new research. Local fruit fly biosecurity officers would play an important role in community engagement.

Link to RD&E investment areas: Theme 5, sub-themes 5.1 & 5.2.

> *"Public education media program to notify public to clean up fruit in backyards and unoccupied orchards/orchards that have fallen into disuse. Make links with local shires, growers' cooperatives and other agencies selling supplies to horticulturalists, to engage their help to deliver this message."*
>
> **WA grower, 11 September 2014.**

2.3 Regional differences

Fruit fly is not the same problem in all parts of Australia. Mediterranean fruit fly is the dominant pest species in Western Australia, while Queensland fruit fly is the major pest species in eastern Australia. Similarly, growers in the tropics have a suite of pest species which do not occur in temperate areas. Even geographically close communities have different issues. For example, growers in South Australia are still concerned with maintaining area freedom, while growers just across the border in Victoria and southern NSW are concerned with regaining area freedom. This Plan is national and does not prioritise specific RD&E recommendations for these regional differences, although it does recognise the biological and economic differences between production regions. Individual regions can develop their own RD&E priorities using this plan based on local issues, and for some R&D (e.g. SIT, lure technology) there will be existing information available that needs to be applied through good local extension. Thus the RD&E investment areas identified will need to be prioritised by region, horticultural industry and resources available.

Link to RD&E investment areas: no specific RD&E investment recommendations made, but this acknowledgement of local differences is linked to recommendation 2.1 on the need for regional biosecurity officers.

2.4 Capacity

Regardless of how good the RD&E Plan is, nothing will be achieved to control fruit fly over the next twenty years without the capacity, both human and physical, to do so. Capacity in fruit fly RD&E is shared by the Australian Government, CSIRO, the state departments of agriculture and a small number of universities. Notably, state agriculture departments have reduced their development and extension capacity in recent years, and while some of this capacity has been taken over by the private sector in terms of IPM scouts and horticulture consultants, a renewed investment is urgently needed to develop local R&D capacity and grower networks. Changes in funding cycles are also required to provide more secure career pathways for research and technical staff.

Link to RD&E investment areas: Theme 6, sub-themes 6.2, 6.3 & 6.4.

2.5 Core science

'Core science' covers those research disciplines (molecular biology, insect physiology, behaviour and ecology, modelling, statistics) which provide the underpinning science upon which operational research and development are based. Core science also provides the 'blue-sky' or discovery-science which is the basis for the over-the-horizon controls which are currently difficult or impossible to predict. By supporting core science disciplines, fruit fly R&D will be able to provide the innovative research required develop and maintain novel fruit fly controls. Clearly 'core science' and 'capacity' are closely aligned: the core science will only get done if appropriate capacity is maintained and funded.

Link to RD&E investment areas: Theme 6, sub-themes 6.2, 6.3; Theme 7, sub-theme 7.1.

3. Controlling fruit flies

3.1 Managing exotic risk

Fruit flies are a global agricultural issue, with nearly all regions of the world having different native fruit fly species; these different pest species can and do invade other regions. For Australia, the threat of offshore pests entering and establishing is substantial. This is particularly the case as tropical agriculture develops; northern Australia will become a stepping stone for invasive fruit flies from Asia and PNG. A recent study has shown that one Asian species, the Oriental fruit fly (Bactrocera dorsalis), is the single greatest plant biosecurity threat facing Australia, with an estimated impact cost of over $1 billion if it enters and establishes (Cook et al., 2010). Beyond Oriental fruit fly, there are over forty other exotic fruit fly species with the potential to have significant economic and pest management impacts. Australia needs to maintain active surveillance and an RD&E Plan to proactively manage the very significant risk posed by offshore fruit flies.

Link to RD&E investment areas: Theme 1, sub-themes 1.1 to 1.5.

> *"Six fruit fly species are repeatedly detected in the Torres Strait which threaten to cross to mainland Australia. These incursions pose a potential threat … To ensure this effort remains as effective as possible, research also needs to target strategies to best manage this issue."*
>
> **Peak Industry body, 17 October 2014.**

KEY RECOMMENDATION:

R&D support continues to be provided for biosecurity preparedness and quarantine activities targeted at preventing the entry and establishment of offshore fruit fly threats. Particular focus should be applied to mitigating the risk posed by Oriental fruit fly.

3.2 Immediate dimethoate and fenthion replacements

On 16 October 2014 the APVMA removed fenthion from all uses for fruit fly control except as a postharvest dip for tropical and subtropical fruit with inedible peel. Along with the earlier withdrawal of dimethoate, this leaves all fruit fly affected industries, except the tropical fruit industry, without effective pesticide controls. Numerous alternative controls do exist for fruit fly management, but these currently have limited uptake and development for many horticultural commodities. Emergency development and extension needs to be undertaken to provide short-term alternatives to dimethoate and fenthion.

Link to RD&E investment areas: Theme 2, sub-themes 2.2, 2.4 & 2.6.

"Please do it quickly as there are NO proven adequate methods of commercial scale control available when Fenthion is taken away from growers - or ridiculous withholding periods imposed."

NSW grower, 28 September 2014.

KEY RECOMMENDATION:

RD&E activities targeting rapid replacement options for dimethoate and fenthion should focus on the registration of new chemicals and new uses for existing registered chemicals, and optimisation of existing controls such as MAT, protein bait spray, crop hygiene and mass trapping.

3.3 Eradication

In states which are currently fruit fly free, districts which have recently lost area freedom, and very isolated production areas (such as in WA), eradication is a preferred control option. Fruit flies are a group of insects for which eradication is highly feasible and which has been repeatedly demonstrated (Suckling et al., 2014). R&D is needed to refine current surveillance and eradication tools, and to develop new tools which would increase the efficiency of eradication programs.

Link to RD&E investment areas: Theme 1, sub-theme 1.5; Theme 2, sub-theme 2.1, 2.4, 2.8, 2.9 & 2.11.

KEY RECOMMENDATION:

An R&D focus be applied to fruit fly eradication technologies (such as SIT, MAT and protein baiting), to make the eradication of fruit flies technically easier and hence economically more justifiable.

3.4 Integrated Pest Management and Area-wide Integrated Pest Management

In the absence of effective cover sprays, Australian fruit fly management will need to rely on a suite of control tools applied within an integrated pest management (IPM) framework. As fruit flies are mobile pests, which move around a cropping district to new hosts as they come into season, fruit fly control is best done at an 'area-wide' (A-W) level, where the 'area' may be a whole cropping district, or a well-defined geographic area (e.g. a river valley). IPM and A-W IPM integrate individual control tools including the Sterile Insect Technique, although A-W IPM can operate in the absence of SIT. Developing A-W IPM for fruit fly control in Australia will require addressing a complex suite of RD&E, not the least of which is community engagement. To be sustainable for the grower, fruit fly IPM needs to be integrated as one component of their whole crop IPM.

Link to RD&E investment areas: Theme 2, sub-themes 2.1, 2.4, 2.5, 2.7, 2.8, 2.9, 2.10; Theme 4, sub-theme 4.2; Theme 5, sub-themes 5.1, 5.2; Theme 6, sub-theme 6.1. (see also below 5.4, 'A future without pesticides').

"The loss of key chemicals such as Fenthion and Dimethoate has meant growers now rely on Area Wide Management (AWM), which involves monitoring, sanitation, lures, and baits, to manage fruit fly. AWM, however, has variable and limited success in managing fruit fly and stronger control strategies need to be developed. Improved extension programs would support the wider adoption of AWM to improve its effectiveness."

Peak Industry body, 17 October 2014.

KEY RECOMMENDATION:

RD&E activities targeting medium to long-term fruit fly infield controls should work within an integrated pest management framework, which will decrease the need and reliance on synthetic pesticides. Such control or eradication strategies include Sterile Insect Technique, mass trapping, crop hygiene, eradication, protein baiting, MAT and use of natural enemies. The combination of these techniques into a systems approach can be used for market access.

4. Trade and Market access

4.1 Disinfestation tools

Industry is seeking improved post-harvest control options for fruit fly, specifically treatments that have a rapid turnaround, are efficacious, cost-effective, non-damaging, do not adversely affect product quality and are suitable for both sea and airfreight.

Link to RD&E investment areas: Theme 3, sub-themes 3.1 to 3.5.

> *"Currently NSW [citrus] growers have to ship fruit under cold sterilisation. This costs $4.00 per carton and when a carton ranges between $5 to $15 back to a grower it is a significant cost. It also shortens the shelf life of fruit and there is always the risk of container temperature failure which can result in dumping of the fruit in a foreign land, and that can be a very costly exercise. An alternative to Cold Sterilisation is needed by NSW Growers."*
>
> **Industry Policy Advisor, NSW Farmers, 29 September 2014.**

> **KEY RECOMMENDATION**:
>
> R&D targeting medium and long-term outcomes for fruit fly disinfestation should focus on the development of new methodologies and statistical approaches which can provide the same importer confidence and regulatory approvals as currently achieved, but with reduced logistical effort, time and/or cost.

4.2 Evidence-based regulations

To guarantee market access opportunities for Australian commodities, be they domestic or international markets, market access negotiators need to have the scientific evidence to argue market access cases with their counterparts in importing states or countries. Research and development is required to deliver market access disinfestation data packages which are consistent and based on the best scientific knowledge. Standard operating procedures for pest management are also required for growers targeting export markets so as to facilitate the gaining and maintaining of market access.

Link to RD&E investment areas: Theme 3, sub-theme 3.4; Theme 4, sub-themes 4.1 & 4.2.

> **KEY RECOMMENDATION**:
>
> Standardised approaches for market access RD&E and field operations should be developed and implemented so as to ensure international acceptance of Australian fruit fly market access datasets and fresh commodities. This includes updating national codes of practice for fruit fly.

5. Future Issues

5.1 Northern Australia development

The Australian Government, Queensland, the Northern Territory and Western Australia have all identified increased growth and investment in tropical agriculture as priority areas. A greatly increased tropical horticultural industry will require more knowledge of Australia's endemic tropical pest fruit flies, including detailed hosts lists, both for infield control and for market access. These new productions areas will also create a stepping-stone for new exotic fruit flies to other areas. Australia's most serious exotic fruit fly threats are all found to our north, and increased production of tropical horticultural crops will increase the likelihood of those flies finding suitable breeding sites if they should enter.

Link to RD&E investment areas: Theme 1, sub-themes 1.1 to 1.5; Theme 4, sub-theme 4.1.

> **KEY RECOMMENDATION**:
>
> RD&E focus should be applied to the 'other' fruit fly pests of Australia, including resolving the systematics and taxonomy of the *Bactrocera tryoni* complex and developing biological data sets (including confirmed host lists) and management tools for native fruit fly species other than *B. tryoni* and *C. capitata*.

> **KEY RECOMMENDATION**:
>
> Systematic and taxonomic research be carried out to develop accurate and user friendly diagnostics to separate native pest fruit flies from native non-pests and exotics.

5.2 Climate change

Under predicted climate change scenarios, it is anticipated that flies currently restricted to the tropics and sub-tropics will move south, while species already in the temperate zone may increase in abundance and their active seasons lengthen. Tasmania and New Zealand will also be under much greater risk of fruit fly invasion. From a market access view point, markets such as northern Europe which are currently less concerned about fruit fly because of climate unsuitability may become more fruit fly aware. Preparedness for climate change will involve the generation of new control and market access datasets for the tropical species, and better modelling of the distributions of all species.

Link to RD&E investment areas: Theme 2, sub-theme 2.7; Theme 4, sub-theme 4.1.

5.3 A future without pesticides

While pesticides, if they are available, remain a preferred control option for many growers, experience from Europe and North America is clearly illustrating that within the next twenty years traditional pesticides will either be entirely banned, or used as only one component of more complex, integrated strategies (i.e. integrated pest management). The European Union has already directed that all pest management undertaken in its member nations should be done as integrated pest management (European Union 2009), and the USA has a national framework for promoting IPM (USDA ARS 2013). Australia will almost certainly have to follow this path, if only to gain access to these lucrative markets.

Link to RD&E investment areas: Theme 2, sub-themes 2.1, 2.3, 2.5, 2.7; Theme 3, sub-theme 3.5; Theme 6, sub-theme 6.2, 6.3; Theme 7, sub-theme 7.1.

Situation analysis and Audit

A full audit of current fruit fly RD&E activities needs to be undertaken in 2015. Previous audits are now dated, do not cover research activities unless funded by publically reported grants (this misses, for example, activities funded internally by the states and university postgraduate research), and miss the many extension activities by peak industry bodies and regional grower groups.

Prioritisation process

Once this Plan is endorsed, a prioritisation process needs to be undertaken in 2015, concurrent with the capacity audit, to prioritise all areas. This should involve consultation with all stakeholders identified in the Plan. As identified in the NFFS (Recommendation 14), this process should be undertaken on a regular basis in order to maintain currency. It is expected that this will be a core function of the NFF Advisory Committee, supported by the Plant Biosecurity CRC.

Resources

The full implementation of the NFFS and this RD&E Plan will need significant new investment from government and industry if its outcomes are to be achieved.

The case for investing in all aspects of fruit fly management has been made by the NFFS and subsequently costed in independent cost-benefit analyses (Harvey et al. 2010; Abdalla et al. 2012; White et al. 2012; Florec et al. 2013). Depending on the analysis undertaken, it has been found that return on investment for fruit fly management ranges from 8.3:1 to 15.6:1 (PHA 2009, ABARES 2012). The economics of investing in fruit fly RD&E has not been assessed independently of other fruit fly investment areas, but the average return on rural RD&E in Australia is 11:1, with additional social and environmental non-cash benefits (Rural RDC 2008). There is no obvious reason why fruit fly RD&E would vary greatly from this average.

> *"Long-term funding (20 years) would be required to achieve the objectives of the NFFS and implementation plan and to ensure projects are not abandoned. We would long like to see a long-term commitment that it be progressed and supported well into the future."*
>
> **Peak Industry body, 29 September 2014.**

Existing investment mechanisms

HIA: The newly created Horticulture Innovation Australia Limited is a not-for-profit, grower-owned Research and Development Corporation (RDC) for Australia's horticulture industry. Replacing the previous Horticulture Australia Ltd (HAL), HIA invests grower levy and voluntary contribution funds matched with Commonwealth Government funds.

PBCRC: The Plant Biosecurity Cooperative Research Centre Ltd is a company limited by guarantee with an independent, skills-based board of directors. Its participants are both plant biosecurity research providers and research users, whose contributions to the PBCRC are matched by Commonwealth funding under the Cooperative Research Centre scheme.

ARC: The Australian Research Council's discovery and linkage programs can fund university based researches, although the schemes are highly competitive and focus on more fundamental aspects of fruit fly biology.

RIRDC: The Rural Industries Research and Development Corporation is the second RDC with capacity to invest in fruit fly RD&E. Under its 'New and Developing Plant Industries' portfolio there are a number of crops for which fruit fly management will be required.

Voluntary levies or fees: At state, regional or area-wide levels, support for fruit fly RD&E can be generated. Current examples of such voluntary fees include grower levies in Sunraysia in Victoria and Carnarvon in Western Australia.

New investment mechanisms

While the economic and social benefits of increasing investment in fruit fly management have been made clear, the mechanisms by which those investments can be made are still unclear. This section suggests some possible mechanisms as a basis for discussion.

Australian Fruit Fly Commission: An Australian Fruit Fly Commission, with a role of both national coordination and implementation, could be funded by Australian and state governments and an industry levy for its core coordination and operational/extension activities. The Fruit Fly Commission would engage external research agencies and leverage third-party funding to achieve its research objectives.

Landcare model: Landcare Australia Limited (www.landcareonline.com.au/) was formed by the Commonwealth Government in 1989 as a private non-profit company to manage the national public awareness and sponsorship campaign for the Decade of Landcare. The operation of community Landcare recognises the effectiveness of community groups in promoting self-reliance, developing social capital and social norms for positive landcare outcomes: this participatory approach has become the dominant policy paradigm in Australia. Many horticultural production communities have already formed, or are forming, local fruit fly management groups in response to the problem and a Landcare model would logically flow from grower driven initiatives.

Key Centre: From time to time the Government funds one-off centres, often with matching or leveraged money. There are several mechanisms by which this can, or has been achieved:

- ARC Co-funded Centres (http://www.arc.gov.au/ncgp/ce/ce_2014/2014_coe_funding.htm) Centres of Excellence (e.g. Centre of Excellence for Biosecurity Risk Analysis).
- ARC Special Research Initiatives (e.g. SRI for Tropical Health and Medicine - http://www.arc.gov.au/ncgp/sri/Tropical_Health.htm).

Biosecurity levy arrangements: Many industries have in place levy arrangements under the Emergency Plant Pest Response Deed, as well as research and development levies. It is possible these levies could be matched by the Australian Government for fruit fly RD&E. An alternative arrangement has been developed in Sunraysia where the Greater Sunraysia Pest Free Area Industry Development Committee, comprising two members each from the table grape, citrus and stone fruit industries, is funding fruit fly management and eradication efforts through a grower levy initially set at $3 a tonne with a contribution from the Victorian Government on a 70% industry/30% government basis.

Mixed models: It is important to recognise that solving the fruit fly problem in Australia has many facets, ranging from discovery science, through to regulatory harmonisation, to implementing practical management options for growers. A single funding scheme is unlikely to meet all these needs. It is thus reasonable to seek different mechanisms for different purposes. For instance, grower-based funding might be sought to fund field-based extension officers or entomologists, for which growers can see a direct and immediate return for their investment. The annual HIAL funding call may remain the most appropriate mechanism to fund developmental research, while an ARC Key Centre or similar may fund more basic and strategic research.

KEY RECOMMENDATION:

The National Fruit Fly Advisory Committee coordinates and implements this Plan, supporting an audit of activity, a prioritisation process, and exploring resourcing arrangements via existing and/or new funding mechansims.

RD&E investment areas

RD&E investment areas

Theme 1: Managing exotic risk

Theme Overview: Fruit flies are a global agricultural issue, with almost all regions of the world having different native fruit fly species. These different pest species can, and do invade other regions: for example the Oriental fruit fly has spread and established in Africa and parts of the South Pacific, while the American eastern cherry fruit fly has recently invaded Europe. For Australia, the threat of offshore pests entering and establishing in Australia is very significant. This is particularly the case as tropical agriculture develops, as northern Australia will become a stepping stone for invasive fruit flies from Asia and Papua New Guinea. One such Asian species, the Oriental fruit fly (*Bactrocera dorsalis*), is the single greatest horticultural threat facing Australia, with an estimated invasion cost of $1.26 billion (Cook et al. 2010). If established in Australia, international experience suggests that Oriental fruit fly may displace all existing fruit fly pests, rapidly becoming our single most important pest species, requiring new market access protocols to be negotiated and agreed. The entry and subsequent eradication of an exotic fruit fly is expensive; when Oriental fruit fly invaded north Queensland in the mid-1990s (then under the name of Asian Papaya fruit fly), the eradication cost was $36 million and the grower cost approximately $100 million (Cantrell et al. 2001).

Australia needs to maintain an active RD&E Plan to proactively manage the very significant risk posed by offshore fruit flies. This includes developing tools, capacity and professional networks which can; (i) better predict threats, for example through better pathway analysis and the development of formal international networks which share knowledge of emergent threats; (ii) strengthen border protection through optimised surveillance and rapid fruit fly identification; and (iii) increase the likelihood of successful eradication in event of an exotic fruit fly incursion.

Aligns with NFFS recommendations 4, 5, 6, 7 & 8 and NFFS Implementation Strategy Projects 2 & 3.

Sub-theme 1.1	Entry pathways
Need	Trade in fruit fly susceptible commodities is tightly regulated around the world because of the perceived risk of fruit fly movement, yet informal analysis of most exotic incursions suggest they are through non-commercial fruit movement by tourists. Good quantification of such analyses would greatly change the emphasis on where and how pathways are controlled.
Outcome	Better targeted investment in managing pathways through which exotic fruit flies might enter Australia, and hence reduced risk of pest entry.
Outputs	Tools and techniques for the identification of new and emerging fruit fly pests and pathways.
Alignment to NFFS & NFFS Implementation Plan	5.2, 5.3, 7.2, PR2
RD&E investment areas	**1.1.1 Pathway analysis** **Output: Pathways analysed for potential global fruit fly incursions** **Description and actions:** Improve upon our current level of preparedness through a comprehensive analysis of how, when and where fruit fly pests that have caused serious impact to industry and the environment arrived (by dispersal or mutation). This vulnerability analysis will frame our understanding of future threats by determining historical rates of incursions by these high-impact species. Time to impact: 3-5 years
	1.1.2 Pest prioritisation **Output: Tools created for fruit fly pest prioritisation** **Description and actions:** Biosecurity pest prioritisation approaches have been developed by groups such as CEBRA. Determine if such models can be used as predictors for potential invasive fruit fly pests, and so improve the quantification of incursion and establishment success. Time to impact: 3-7 years

	1.1.3 Wind-borne threats **Output: Improved preparedness and response to wind-borne fruit fly threats** **Description and actions:** Improve preparedness and response to wind-borne fruit fly incursions. Pest fruit flies absent from Australia occur in our near northern Asian and western Pacific neighbours. Initial analysis shows that, at least for the Torres Strait, increased incursions may be linked to seasonal wind patterns. Better assessment of wind dispersion of fruit flies will improve pre-border surveillance and post-border preparedness, particularly in light of the proposed intensification of agriculture in northern Australia. Time to impact: 3-7 years

Sub-theme 1.2	Surveillance
Need	The ability to eradicate an exotic fruit fly is very tightly linked to how early that entry is detected. If an exotic fly is detected soon after entry, then eradication is more likely to be technically feasible and economically viable. If the pest is already well established and widespread when first detected, then eradication may be neither technically nor economically viable. An efficient border surveillance program is central for rapid detection of exotic pests, while efficiency of a surveillance program is needed to ensure that operational costs are minimised while maintaining effectiveness.
Outcome	Better ability to detect exotic fruit flies which enter Australia, so increasing the chance of their subsequent eradication.
Outputs	New technology and better community engagement for surveillance of fruit fly pests.
Alignment to NFFS & NFFS Implementation Plan	6.2, 7.1, 7.5, 7.6, 7.7, PR2
RD&E investment areas	**1.2.1 New lures** **Output: Lures available for monitoring currently 'non-lure' responsive fruit fly species** **Description and actions:** Fruit flies are generally detected using traps baited with the male lures methyl eugenol and cue-lure. Several important pest fruit flies species do not respond to either of these two lures. New lures, such as has been found with zingerone for *B. jarvisi*, are urgently required for these traditionally 'non-lure responsive' species. Time to impact: 3-5 years
	1.2.2 Optimising trap placement **Output: Guidelines available for optimising fruit fly trap placement with respect to trapping efficacy and efficiency** **Description and actions:** Large area grid based pattern trapping programs are widely regarded as inefficient, yet the national standards currently call for grid based fruit fly trapping at ports of entry. Using biological data and modern analytical approaches as the basis for designing new trapping arrays, both the efficacy and efficiency of fruit fly surveillance could be increased. Time to impact: 2-5 years
	1.2.3 Within commodity detection **Output: Tools available for automatic detection of the presence of fruit fly in imported commodities** **Description and actions:** Very large amounts of fruit fly susceptible fresh commodities enter Australian ports every day. Automated means of detecting fruit fly infestation in those importations, most likely through 'smart nose' technology, would greatly strengthen border quarantine. Time to impact: 5-10 years

	1.2.4 Smart traps **Output: Automatic detection and reporting tools available for fruit fly surveillance traps** **Description and actions:** Currently, all fruit fly surveillance traps need to be manually collected and sorted. This generally constitutes the greatest part of surveillance costs. Economically viable remote traps which could detect, identify and then report on fruit fly captures of biosecurity concern would greatly streamline the national surveillance system. Time to impact: 5-15 years
	1.2.5 Community surveillance **Output: Remote communities engaged with fruit fly surveillance, so strengthening border security** **Description and actions:** The greatest threat of exotic fruit fly entry is in northern Australia, over very large remote areas. Increased engagement with traditional owners on fruit fly and other issues of biosecurity concern would greatly strengthen northern Australian surveillance. Time to impact: 3-20 years

Sub-theme 1.3	Invasion biology
Need	A great many exotic fruit fly species have the potential to enter Australia, but this does not mean that all would become pests, or, if they were pests, how significant they would become. If they do enter, we currently cannot predict how far they might spread, or what their preferred habitats might be within a local area. This type of information is needed to prioritise surveillance efforts and design emergency responses. We include in this section research on the Spotted Wing Drosophila, *Drosophila suzukii*, which, while not a tephritid species, shares a similar biology and potential impact to many of the true fruit flies.
Outcome	Better ability to prioritise surveillance activities against individual fruit fly pests, and to prioritise the need for and size of an emergency response in the event of an incursion.
Outputs	Detailed data sheets on the potential pest status of exotic fruit fly species, including likely affected commodities and industries, potential rate and range of spread, potential infestation levels in affected commodities, and likely interactions with other fruit fly species and the local environment.
Alignment to NFFS & NFFS Implementation Plan	5.2, 5.3, PR2
RD&E investment areas	**1.3.1 Climate matching of exotic fruit flies** **Output: New knowledge to inform risk assessments on the ability of exotic fruit flies to acclimate to Australian environmental conditions** **Description and actions:** Many fruit fly species of threat to Australia are currently tropical and subtropical species, and therefore largely of quarantine concern to the far north. However, the potential of such species to spread more widely into temperate production areas under climate change will greatly increase their likely pest status. Such spread, as shown for Queensland fruit fly, will also be influenced by both their ability to adapt to new conditions and their innate environmental tolerances. Research is required on environmental tolerances and adaptation abilities of fruit flies. Time to impact: 4-15 years
	1.3.2 Host matching of exotic fruit flies **Output: New knowledge to inform risk assessments on the host and habitat preferences of exotic fruit flies** **Description and actions:** Knowing host use patterns of exotic flies and their preferred environmental conditions are key issues, both for designing surveillance arrays and targeting controls in event of an incursion. Such information is unknown, or known only at a superficial level (e.g. a simple, unranked host list) for most exotic fruit flies of concern to Australia. Time to impact: 4-15 years

	1.3.3 Life histories of exotic fruit flies **Output: New knowledge to inform risk assessments on the reproductive, dispersive and competitive capacity of exotic fruit flies** **Description and actions:** Fruit flies vary greatly in their reproductive, dispersive and competitive capacity, greatly influencing their overall invasive capacity. Working with offshore colleagues, more basic biology of this type needs to be gathered for fruit flies which threaten Australia, so their true invasive capacity can be determined. Time to impact: 4-15 years
	1.3.4 Offshore research **Output: New knowledge to inform risk assessments and incursion management** **Description and actions:** Most exotic fruit flies of threat to Australia come from countries where funding for research is highly limited or absent. In such cases Australia can gain much benefit by funding offshore research. This is particularly the case where the information needed by Australia is not the same as might be needed for local crop protection (for example trialling novel lures, or gathering general life-history data, or testing control strategies).

Sub-theme 1.4	Diagnostics
Need	There are over 4000 species of fruit fly, but only approximately 100 of these are pests. Separating pest from non-pest species is the core component of any surveillance program, and the area of greatest challenge to Australia. Australia no longer has an employed fruit fly taxonomist, while the standard molecular 'barcodes' which are meant to support quarantine in the absence of specialist taxonomists are notoriously inefficient for fruit flies. The field is further complicated by the fact that standard taxonomy of fruit flies is based on adult characters, but it is the maggots which are intercepted in commodity trade and these remain essentially unidentifiable.
Outcome	Better ability to accurately identify both adult and immature fruit fly species, be they exotic or endemic to Australia, through improved collaboration between fruit fly taxonomy researchers and front line diagnosticians.
Outputs	Faster, cheaper, more accurate identification of fruit flies.
Alignment to NFFS & NFFS Implementation Plan	7.5, 7.6, 8.2, 8.3, PR2, PR3
RD&E investment areas	**1.4.1 Fruit fly systematics** **Output: A robust systematic framework, including resolution of pest species complexes, providing the basis for accurate fruit fly diagnostics** **Description and actions:** Robust diagnostics is built upon sound taxonomy, which itself should be built upon a systematic framework. Much fruit fly taxonomy, particularly in the genus Bactrocera, does not have a systematic basis. This is particularly problematic for species complexes, such as the Oriental fruit fly, Banana fly and Bactrocera tau complexes, all of which contain species of great economic importance but for which the relationships between taxa are unknown. Systematics in fruit flies not only needs a molecular approach, but for very closely related species also requires quantification of traits such as pheromones, mate compatibility and others, collated within an integrative systematic framework. A well-populated and robust systematic phylogeny for fruit flies will form the basis for all future fruit fly diagnostics. Time to impact: 3-6 years
	1.4.2 Fruit fly key **Output: Diagnostic keys which can be used by non-specialists to identify unknown fruit fly specimens** **Description and actions:** Identifying an unknown fruit fly specimen is extraordinarily difficult. Adult keys are either non-existent or effectively unusable to all except a rapidly diminishing handful of experts. New generation multi-entry, comprehensively illustrated keys, built as applications for mobile devices, would greatly aid fruit fly surveillance and quarantine. Time to impact: 3-6 years

	1.4.3 Diagnostic standards **Output: Approved national diagnostic standards which can be used to confirm the identity of both adult and larval pest fruit fly species** **Description and actions:** Development of molecular diagnostic tools for adult and larval fruit flies has been greatly impeded by the absence of a comprehensive phylogenetic framework, lack of adequate sample sizes to work upon, and confusion around species limits within fruit fly species complexes. As these issues are resolved, robust diagnostic markers, which work for both adult and immature fruit flies, need to be developed and implemented for front line diagnosticians as part of SPHDS approved National Diagnostic Standards. Time to impact: 4-10 years
	1.4.4 Rapid sorting and identification **Output: Tools available for the rapid sorting and identification of large fruit fly trap catches** **Description and actions:** Sorting through hundreds or even thousands of specimens from a single trap is a logistical problem in areas with high endemic fruit fly numbers. Machine learning with robotic sorting could greatly reduce this logistic constraint. Time to impact: 5-15 years

Sub-theme 1.5	Response
Need	Despite the best efforts of pre-border and border protection, Australian and international experiences show that one or more incursions by exotic fruit fly pests are highly likely within the next twenty years. If responded to quickly, fruit flies are a group of insects for which it has been shown that eradication is achievable (Suckling et al. 2014). Having well developed emergency response protocols in the event of an incursion is highly desirable. If an incursion is not eradicated, then industry needs to deal with the new pest and pest management plans are needed.
Outcome	Better preparedness (emergency response protocols) to respond to an exotic fruit fly incursion through eradication or, if unsuccessful, through detailed industry pest management plans.
Outputs	Sharper responses to fruit fly incursions through development of fruit fly emergency response and incursion response plans.
Alignment to NFFS & NFFS Implementation Plan	4.2, 4.4, PR1, PR2
RD&E investment areas	**1.5.1 National incursion response strategies** **Output: Regularly updated national incursion response strategies for both lure and non-lure responsive fruit fly species** **Description and actions:** Review Australian and international eradication and response procedures for fruit flies and develop, in collaboration with appropriate Australian, State and industry bodies, and in alignment with the Emergency Plant Pest Response Deed, incursion response strategies for exotic fruit flies detected in Australia. Time to impact: 1-20 years
	1.5.2 Industry biosecurity plans **Output: Up-to-date fruit fly incursion contingency plans and control methods incorporated into industry biosecurity plans** **Description and actions:** While fruit flies are listed very highly as threats in industry biosecurity plans, there is often little or no additional information on the industry's response to fruit fly in the event of an incursion. Working with PHA and respective industries, embed detailed fruit fly response strategies into industry biosecurity plans. Time to impact: 1-20 years

Theme 2: Pre-harvest controls

Theme Overview: Fruit flies are the primary pre-harvest insect pests of horticulture in all Australian states except Tasmania and South Australia (where they are absent). Estimates of the direct production loss costs of fruit fly vary significantly, but with the total annual international and domestic export value of Australian fruit fly susceptible horticultural production valued at approximately $1.5billion (NFFS), then even a highly conservative 2 per cent loss across the industry is worth $30million/annum. The real costs of fruit fly are much more, as this estimate does not include the crop protection costs, without which most fruit fly susceptible industries could not produce commercially acceptable crops. Since the release of the draft NFFS in 2008, the regulatory withdrawal of the organophosphate insecticides dimethoate and fenthion for most fruit fly uses, and the almost entire collapse of area free (and associated buffer) zones in south-east Australia, has severely exacerbated the fruit fly problem. Several industries are now at significant risk of failure due to fruit fly; the low-chill stone fruit industry in far northern NSW and south-east Queensland is one such example.

The loss of cover-sprays and area freedom present extreme challenges for the entire fruit fly stakeholder community, the brunt of which is borne by growers. To meet this crisis, a range of RD&E strategies need to be put in place, so that alternative treatments can be offered to growers in the immediate term, while strategic research and development consolidates the options for new controls in the medium and long term. A key aspect of the RD&E Plan for pre-harvest control is that it will never be as easy as it was in the past. Growers could achieve high levels of infield fruit fly control through a small number of late season sprays. Previous spray regimes required little biological understanding of the pest, while still giving very good control. Even if replacements for dimethoate and fenthion are found, the global pattern in pest management is that traditional pesticides are being phased out and alternative strategies, based on more environmentally ‘friendly’ tools, will become the norm. The European Union has already directed that pest management within its member nations should only be undertaken through an Integrated Pest Management approach (European Union 2009). Integrated Pest Management does not exclude the use of pesticides, but they become only one component of a larger management toolbox. For pre-harvest fruit fly control in Australia, over a twenty year timeframe, this means that; (i) fruit fly control will invariably use multiple techniques within an integrative framework; (ii) management is likely to be applied at the level of multiple farms or whole production districts; and (iii) the application of control tools will require much more sophisticated knowledge of the physiology, biology and ecology of the target organisms. This will need to be supported, both immediately and into the longer term, by a much strengthened extension program; this is dealt with later in this document.

Aligns with NFFS recommendations 7, 9, 10, 18 & 19 and NFFS Implementation Strategy Projects 3, 4 & 5.

Sub-theme 2.1	**Monitoring and detection**
Need	Nearly all aspects of infield pest control should rely on knowing how many of the target organisms are present. In some respects fruit flies are well suited for monitoring, as many *Bactrocera* species and Medfly respond to lures. Despite these positives, there are many weaknesses with respect to fruit fly monitoring in Australia. Not all pest species respond to lures, existing lures vary in their effectiveness based on local variables, relationships between trap catch and infestation are not known, and so on. As a basis for more effective and efficient infield fruit fly controls, key R&D issues around monitoring need to be resolved.
Outcome	Better infield control of pest fruit flies through better ability to match controls with population numbers.
Outputs	A knowledge base around fruit fly monitoring which will better link trap catch with real population numbers, and new or improved lures with better attraction to target fruit flies.
Alignment to NFFS & NFFS Implementation Plan	7.5, 7.6, 7.7, PR3, PR4, PR5

RD&E investment areas	**2.1.1 Better lures** **Output: More effective lures available for monitoring and controlling fruit flies** **Description and actions:** The standard fruit fly lures, cue-lure and methyl eugenol, vary in their attractancy to different species and local weather conditions (e.g. temperature and humidity). Chemical analogues of cue-lure show great promise as better fruit fly attractants; developing these chemicals, and understanding how they operate in the field, is a key first step in improving monitoring. This investment area is also directly relevant to subtheme 2.4 'Better lure and kill'. Time to impact: 2-5 years
	2.1.2 Optimising traps **Output: A trap design which maximises fly capture** **Description and actions:** Many different fruit fly trap types are currently in use in Australia. These traps have been designed for different operational and commercial purposes, and this has resulted in traps of varying efficiency. R&D is needed to compare the efficiency of existing traps under standard conditions, and to develop a new trap design if required. Time to impact: 2-5 years.
	2.1.3 Optimising trap placement **Output: Guidelines available for optimising fruit fly trap placement with respect to trapping efficacy and efficiency** **Description and actions:** As for border surveillance (see sub-theme 1.2), significant gains in efficiency can be made by optimising trap placement, rather than relying on standard trapping grids. Time to impact: 3-5 years
	2.1.4 Smart traps II **Output: Automatic detection and reporting tools available for fruit fly monitoring traps** **Description and actions:** For non-endemic areas where fruit fly populations may be low, automated sampling and reporting will significantly decrease costs and increase response times. Use of the National Broadband Network and digital image technology will greatly advance this area, as might the automated chemical or wing-beat recognition of target flies. Time to impact: 3-6 years
	2.1.5 Infestation detection **Output: A mobile tool which allows the detection of fruit fly eggs and larvae in fruit and vegetables** **Description and actions:** Current fruit fly surveillance methods target adult fruit flies, but fruit infestation levels may be more meaningful to a grower. Hand-held devices which can detect eggs or young maggots in fruit with high confidence are needed for this to occur. Time to impact: 5-10 years
	2.1.6 Low density monitoring **Output: Statistical tools which allow estimation of true fruit fly population numbers when trap catches are very low** **Description and actions:** Great controversy exists around the world with respect to 'trapped below detectable limits' versus 'eradication'. As Australia is likely to seek to renew area freedoms through eradication, statistical and experimental approaches need to be applied to the question of true population size and biosecurity risk, when populations are very low. Time to impact: 3-5 years
	2.1.7 Working key **Output: A diagnostic tool which can be used by non-specialists to identify Australia's fruit fly fauna** **Description and actions:** Australia has nearly 100 species of endemic, fruit infesting fruit flies. No workable diagnostic tool exists for these species and this negatively impacts on the ability to determine the fly species caught in traps, especially in endemic areas. New generation diagnostics need to be developed for Australian pest and non-pest fruit flies. Time to impact: 3-5 years (see also sub-theme 1.4)

Sub-theme 2.2	Cover sprays
Need	The regulatory loss of the long-serving cover sprays dimethoate and fenthion for most infield fruit fly control purposes has left a huge hole in Australian fruit fly management. While alternative controls exist and can be improved, insecticides still play a fundamental and important role in insect pest management. Urgent research is needed to generate permits for alternative existing chemicals, and longer term focus needs to be given to finding new chemical controls.
Outcome	Better infield control of pest fruit flies.
Outputs	Commercial pesticide products which can be applied as part of the control 'toolbox' for infield control of fruit flies.
Alignment to NFFS & NFFS Implementation Plan	None identified.
RD&E investment areas	**2.2.1 Registration** **Output: Registration available for existing active ingredients** **Description and actions:** In the short term, urgent research is needed to gain registration for existing agricultural chemicals which are not currently permitted for fruit fly control. Research is needed not solely for registration, but also for infield research on how best these chemicals can be applied within the cropping cycle. Time to impact: 1-3 years
	2.2.2 New pesticides **Output: New active chemical ingredients available for the control of pest fruit flies** **Description and actions:** The development of new active pesticide ingredients is a long term process beyond the likely scope of research funded under this Plan. Nevertheless, fruit fly researchers need to remain cognisant of new active compounds being developed and ensure they are trialled against fruit flies at the earliest opportunity. Collaborations with the chemical companies are a key element of this action. Time to impact: 5-20 years
	2.2.3 Non-lethal chemical treatment **Output: Registration permits available for chemical treatments which protect the crop through means other than poisoning** **Description and actions:** Products exist which can protect the crop through means other than poisoning. Agricultural oils, for example, have been shown to decrease fruit fly oviposition in experimental situations, and other repellent/deterrent chemicals are likely to exist. Research is needed to operationalise existing treatments in this class, and to develop new ones based on fruit fly behaviour studies.

Sub-theme 2.3	Natural enemies and biological control
Need	In Australia, natural enemies have not traditionally been used as part of the fruit fly control toolbox. This is contrary to the situation internationally, where there is quite significant research, development and implementation associated with fruit fly natural enemies. The natural enemies of fruit flies considered here include free-living specialist parasitoids, pathogenic organisms which can be applied as biopesticides, and internal microorganisms which negatively influence the fitness of flies.
Outcome	Better infield control of pest fruit flies.
Outputs	For biopesticides, commercial products which can be applied as part of the control 'toolbox' for infield control of fruit flies. For free living agents, the development of manipulative strategies which lead to general depression of fruit fly populations at an area-wide level.
Alignment to NFFS & NFFS Implementation Plan	None identified.

RD&E investment areas	**2.3.1 Parasitoids** **Output: Parasitoids able to be used as part of area-wide management or SIT against fruit fly** **Description and actions:** Opiine braconids are free living egg/larval/pupal endoparasitoids of fruit flies. Research is needed in all aspects of the biology and ecology of these wasps, particularly with respect to how wild populations might be manipulated to help suppress fly populations, and how cultured populations might be mass-reared to be released alongside SIT flies. Time to impact: 3-10 years
	2.3.2 Parasites **Output: Parasites used as part of long-term, sustainable control of pest fruit flies** **Description and actions:** Fruit flies carry a number of internal parasites which can negatively affect their fitness, the best known of which are *Wolbachia*. Manipulating *Wolbachia* for fruit fly control is a long term, high risk research path, which if successful, could lead to very dramatic control gains. Time to impact: 10-15 years
	2.3.3 Pathogens **Output: Pathogen-based products registered as biopesticides for the control of pest fruit flies** **Description and actions:** There is some very scattered literature showing that both adult and pre-pupal fruit flies are susceptible to pathogenic fungi, viruses and nematodes. This work has been exploratory in Australia, but is more developed internationally. Focused research and development in this area could lead to rapid gains and the development of commercial biopesticides against pest fruit flies. Time to impact: 3-10 years

Sub-theme 2.4	**Lure-and-kill**
Need	'Lure-and-kill' is a generic pest management term which describes any control technique in which pests are attracted to a specific location by some form of lure, at which point they are killed (commonly with a pesticide). Lure-and-kill techniques are highly suitable for organic agriculture, as the pesticide is generally contained (e.g. within a trap) and so the crop is not exposed to the chemical. There are several well established lure-and-kill approaches for fruit flies and further development and refinement of these approaches is central to the ongoing pre-harvest management of fruit fly in Australia.
Outcome	Better infield control of pest fruit flies
Outputs	A range of new and/or improved, commercially available control tools to be used as part of the control 'toolbox' for infield control of fruit flies.
Alignment to NFFS & NFFS Implementation Plan	9.8
RD&E investment areas	**2.4.1 MAT** **Output: The Male Annihilation Technique (MAT) optimised for use by growers against pest fruit flies** **Description and actions:** The MAT approach uses cue-lure baited wicks or wafers, mixed with an insecticide, to lure and kill male *B. tryoni*. Further research is needed to find more attractive cue-lure analogues, determine the attractive distance of the lures under different conditions, and to optimise the density of MAT devices in a production area. Immediate term research is needed to test the efficacy of different commercial MAT devices against each other. Time to impact: 1-5 years

	2.4.2 SPLAT and other carriers **Output: Specialised Pheromone & Lure Application Technology (SPLAT) tested and optimised under Australian conditions and available for commercial use** **Description and actions:** SPLAT is a proprietary, wax-based product produced in the USA. It is considered to have many benefits as a carrier of both the 'lure' and 'kill' components of lure-and-kill against fruit flies. Research needs to be finalised to validate SPLAT against Medfly and Qfly in Australia under different environmental and commercial conditions. Products similar to SPLAT also need to be tested. Time to impact: 2-3 years
	2.4.3 Protein bait spray **Output: Protein bait spray technology optimised for use by growers against pest fruit flies** **Description and actions:** Along with MAT, protein bait spray is the second standard lure-and-kill approach used to control fruit fly. It operates on the premise that fruit flies, especially females, need protein to sexually mature and lay eggs. This physiological requirement is manipulated through the application of spot or strip sprays of poisoned yeast derived protein, to which females come to feed and so are killed. There are many problems with the use of protein bait sprays; current proteins are only weakly attractive, mature Qfly females may require much less protein than originally thought, current application technologies require weekly reapplication, and protein may burn foliage or mark fruit in some crops. Research to overcome all these operational weaknesses, for both Qfly and Medfly, is required. Time to impact: 2-6 years
	2.4.4 Bait stations **Output: Bait station technology optimised for use by growers against pest fruit flies** **Description and actions:** Bait stations follow the same principle of protein bait spray, but the bait is contained and so physically separated from the crop. This has advantages for organic production, negates phytotoxic effects to the crop, can allow strategic placement of the lure, and with the right attractant can be long lasting. Research is needed to optimise bait stations, through the development of long-lasting attractants and killing agents, the safe use of killing agents, the development of stronger female attractants and improved bait station devices that are ideally biodegradable. In terms of procedures, densities and deployment should be optimised and evaluation must be based on fruit infestation levels (IAEA 2009).
	2.4.5 Female lures **Output: Commercially available traps which target mature, gravid female fruit fly** **Description and actions:** In the lure-and-kill tool box for Qfly, lures are available for males and immature females but not the egg laying mature female. Female lures based on fruit based odours and visual fruit mimics offer potential as commercially viable control options, as do lures based on bacterial metabolic volatiles. This is a complex R&D area in which only initial research has been undertaken so far. Time to impact: 4-8 years
	2.4.6 Better male lures **Output: More effective lures available for monitoring and controlling fruit flies** **Description and actions:** The standard fruit fly lures, cue-lure and methyl eugenol, vary in their attractancy to different species and local weather conditions (e.g. temperature and humidity). Chemical analogues of cue-lure show great promise as better fruit fly attractants; developing these chemicals, and understanding how they operate in the field, is a key first step in improving use of MAT. Time to impact: 2-5 years
	2.4.7 Trap crops **Output: Commercially viable recommendations on the use of trap crops and sentinel trees as part of a management tool-box for pest fruit flies** **Description and actions:** Some particular fruit types (e.g. guava) are highly attractive to fruit flies. The appropriate planting and management of flies on those plants could act as a population 'sink' for local fruit flies. Next generation research could investigate GM plants which are both attractive and toxic to the flies. No research has been done on either the biology or implementation of such controls for fruit fly management in Australia. Time to impact: 3-15 years

	2.4.8 Repellents/deterrents **Output: Commercially available products which can be used by growers to repel or deter fruit flies from their crops** **Description and actions:** While the opposite of attractants, repellents and deterrents logically fit within thissub-theme. Just as fruit fly's complex chemical ecology suggests several novel avenues for attracting flies, the same complex ecology suggest novel approaches for finding chemical deterrents to push flies away – for example some bacterial odours are known to deter fruit flies from oviposition sites. Both attractants and repellents can be used together in 'push-pull' management strategies.
	2.4.9 Chemosterilants **Output: Commercial chemosterilants available as a registered product for area wide fruit fly control** **Description and actions:** Chemosterilants act in the same way as SIT, by sterilising wild male flies so that mated wild females become infertile. Chemosterilants have been researched for 50 years, but have had little or no uptake due to human health concerns (early products) or operational issues in distributing the chemosterilant in the field. New generation chemosterilants need both further research and development to make them commercially viable.

Sub-theme 2.5	Host plant and host fruit interactions
Need	Adult male and female flies rest, feed and shelter on plants, both crop and non-crop, while the female lays her eggs into fruit where the larvae develop. Fruit resistance breeding, manipulating roosting sites and understanding provisional non-host status for market access are all applied outcomes which follow from understanding these interactions. Australia needs to explore and exploit these areas of fruit fly weakness.
Outcome	Better infield control of pest fruit flies.
Outputs	New commodity cultivars which are more resistant to fruit fly attack, grower guidelines for manipulating fruit fly abundance in the field by modifying canopy and crop architecture, approved regulations for market access based on non-host and provisional non-host status.
Alignment to NFFS & NFFS Implementation Plan	7.7, 9.4
RD&E investment areas	**2.5.1 Conditional non-host status** **Output: Technically justified guidelines on the use of conditional non-host status as a market access tool available for relevant fruit fly affected commodities** **Description and actions:** Several crops (e.g. banana, papaya) have conditional non-host status for market access based on ripeness at picking (i.e. hard green). More research is required to generate conditional non-host status for other potential crops. Time to impact: 2-10 years
	2.5.2 Non-host status **Output: Technically justified guidelines on the use of non-host status as a market access tool available for relevant fruit fly affected commodities** **Description and actions:** New definitions of host status testing are likely to be approved under the IPPC in the next two to three years. Once this international agreement is in place, non-host status can be tested and confirmed for market access purpose. Time to impact: 3-7 years

	2.5.3 Varietal resistance **Output: New varieties and GM lines available in which fruit fly resistance is incorporated as a selected trait** **Description and actions:** It is well recognised that different species and varieties of fresh commodities show varying susceptibilities to fruit fly damage. While this is observed, and in some cases resistance mechanisms identified, in Australia such traits have never been incorporated into breeding programs. Both traditional breeding and new generation plant biotechnology manipulation have the potential to lead to fruit which are fruit fly resistant; this should be a major new research thrust. Time to impact: 5-20 years
	2.5.4 Canopy architecture **Output: Recommendations available for canopy pruning/training and orchard design that minimise fruit fly attack** **Description and actions:** Fruit flies use host plants not only to lay eggs but also for sheltering. Changes in canopy and orchard architecture have been shown to change the abundance of pest fruit flies (Balagawi et al. 2012), but only minimal research has been done on this topic in Australia. Given that orchardists already change pruning regimes and orchard layout for a number of reasons, including knowledge of how this might influence fruit fly attack (for better or worse) would be valuable. Time to impact: 5-20 years

Sub-theme 2.6	**Physical barriers**
Need	If flies can be physically stopped from reaching fruit to oviposit then the fruit fly problem is solved. In some countries this is achieved though individual fruit bagging, but except for non-commercial purposes this approach is unlikely to be viable in Australia because of high salary costs. Other types of physical barriers may work and should be researched as part of the fruit fly tool-box.
Outcome	Better infield control of pest fruit flies.
Outputs	Recommendations for commercially suitable products and practices which limit fruit fly access to fruit.
Alignment to NFFS & NFFS Implementation Plan	9.8
RD&E investment areas	**2.6.1 Whole orchard netting** **Output: Commercially available whole-orchard netting available for controlling fruit fly in high value crops** **Description and actions:** Full orchard netting has been shown to provide excellent fruit fly control. However, such netting is expensive, can be prone to storm and hail damage, and needs to be appropriately managed to allow access to pollinators and natural enemies, while not promoting the build-up of other pests, such as scales. Development opportunities exist for commercial companies to make whole orchard fruit fly netting a viable option for high value crops. Time to impact: 3-5 years
	2.6.2 Fencing **Output: Recommendations available on the use (or non-use) of fences as a commercially viable control tool for fruit fly** **Description and actions:** Very little is known about the role which fences may play in limiting fruit fly movement. If flies did not fly over fences of a given height, then it may be possible to simply fence orchards or crops with appropriate netting. All research and development remains to be done for this topic. Time to impact: 2-4 years

	2.6.3 Border plantings **Output: Recommendations available on the use of border plantings as part of the on-farm tool-box for fruit fly control** **Description and actions:** Border plantings are unlikely to physically block flies to a crop (although this is possible if fences are found to work), but research has shown that flies may leave a crop to roost in border plantings where they could then be targeted for pesticide or bait-spray control. Some important international research has been done in this area but Australian research is just beginning. Time to impact: 3-6 years
	2.6.4 Kaolin clays **Output: Recommendations available on the use of kaolin clays as a protective fruit barrier against ovipositing fruit flies** **Description and actions:** Kaolin clays are used in several industries to prevent sun burn of fruit. Laboratory work has shown kaolins will deter female fruit fly from ovipositing, but field trials were less successful and removal of the kaolin may be damaging to some commodities. Development is needed to see if kaolin clays can be made to work in appropriate crops. Time to impact: 3-6 years
	2.6.5 Mineral and botanical oils **Output: Recommendations on the use of mineral and botanical oils as protective fruit barriers against ovipositing fruit flies** **Description and actions:** Mineral oil deposits display repellent and other behavioural effects on fruit flies. The responses to hydrocarbons are possibly related to quite specific molecular structures which 'mimic' natural repellents, but this needs to be tested. Oils can cause damage to crops and any research needs to take a holistic view on the benefits and costs. Time to impact: 5 years

Sub-theme 2.7	Phenology and distribution models
Need	Australian agriculture is precision based, with growers having access to detailed predictive modelling for nearly all aspects of their orchard management, from watering regimes to flowering time. In contrast, even researchers do not have access to a population phenology model for pest fruit flies which works. Predictive geographic models work only at a continental level and model the impact of abiotic variables. As an underlying component of most infield control strategies – from MAT to SIT – there is an urgent need for a suite of integrated fruit models which can inform both researchers and growers. For researchers they will offer new ways to answer difficult research issues; for growers they will help optimise the application of control tools.
Outcome	Better infield control of pest fruit flies.
Outputs	A suite of computer models which can guide both researchers and growers in how they manage fruit flies. Models with appropriate 'dash boards' customised to end user needs.
Alignment to NFFS & NFFS Implementation Plan	7.5, 7.6, 9.4, 9.7, PR4
RD&E investment areas	**2.7.1 Ecological data** **Output: Biological data available for informing the development of predictive models for fruit fly management** **Description and actions:** Developing models for Australia's fruit fly pests is problematic because much basic data is absent or inadequate for modelling purposes. The type of data needed includes, but is not limited to; constant temperature development rates; impact of low and high temperatures on the development and mortality of all life stages and on the activity of adult flies; seasonal abundance; abundance with respect to landscape features; clarification of the impact of rainfall on activity and mortality of adult flies; identifying and defining the cues that trigger the onset and the termination of over-wintering. The generation of such data should be done in conjunction with modellers. Time to impact: 1-7 years

	2.7.2 Predictive modelling I **Output: A suite of predictive models which can be used by different stakeholders, ranging from growers to researchers, to inform and predict fruit fly management decisions** **Description and actions:** 'Modelling' is a generic term and different models serve different purposes, while the underlying assumptions of different models vary dramatically. At a minimum fruit fly stakeholders need; (i) predictive phenology models which take into account both local biotic and abiotic variables, and imposed control treatments; (ii) landscape models within a GIS framework; and (iii) large scale distribution models. Other more specialist models include those which can optimise trap placement for surveillance and monitoring, and those which aid incursion management and eradication. The generation of such models should be in conjunction with data gatherers. Time to impact: 1-7 years
	2.7.3 Predictive modelling II **Output: New information available for growers, regulators and researchers which will improve fruit fly management** **Description and actions:** Once validated models have been created there are number of key activities which can be undertaken using them. These include the application of models to; (i) determine the distribution boundaries of fruit fly species, including how they might change with season, or how they might change in respect to climatic conditions and climate change; (ii) determine appropriate outbreak and reinstatement calendars for a specific region; (iii) accurately predict winter windows; and (iv) be integrated into on-farm decision support tools to optimise timing of management. Time to impact: 3-10 years

Sub-theme 2.8	Population source control
Need	A large part of solving the fruit fly problem relies on reducing or eliminating source populations, be that source an earlier crop, feral trees, abandoned orchards, or native hosts. Despite this importance, relatively little is known about the contribution that feral trees or abandoned orchards, for example, make to the size of a local fruit fly population. Similarly, mechanisms for implementing orchard hygiene which are suited for modern farm management need to be developed. Good RD&E in this area will greatly help reduce pest fruit fly populations at both the farm and area-wide levels.
Outcome	Less fruit fly damage due to lower fruit fly population levels.
Outputs	Commercially justified recommendations for reducing fruit fly populations through crop hygiene and the management of non-commercial trees.
Alignment to NFFS & NFFS Implementation Plan	12.4
RD&E investment areas	**2.8.1 Crop hygiene** **Output: Commercially justified recommendations for the need and practice of crop hygiene in major horticultural crops** **Description and actions:** Crop hygiene, the destruction or removal of fallen fruit within an orchard, is a cornerstone of most fruit fly management packages. The required information to support this practice is, however, lacking, as are commercially acceptable mechanisms by which it can be achieved. There is little doubt that for some highly susceptible crops, hygiene will be critical, but for crops which are very poor fruit fly hosts then practicing hygiene may impose a cost which is not biologically justified. If crop hygiene is found to be critical, then recommendations and engineering solutions need to be found as to how to operationalise the practice in a commercially viable form; these may include post-harvest orchard sprays, soil treatments, or mechanical fruit collection. Time to impact: 3-6 years

	2.8.2 Feral and wild sources **Output: Commercially justified recommendations for the need to control feral fruit trees and other wild sources of fruit fly** **Description and actions:** A standard recommendation for area-wide management is the removal of feral and other unmanaged trees. As for crop hygiene, the science behind such recommendations is lacking, despite the costs involved in carrying out the recommendation. The contribution that fruit from feral or wild hosts make to a total local fly population is likely to vary dramatically depending on the fruit type, time of ripening, the number of trees involved, how heavily parasitised are the maggots, and so on. Research is needed to make justifiable recommendations on feral tree management. Time to impact: 3-5 years
	2.8.3 Urban, peri-urban and abandoned orchard sources **Output: Reduced fruit fly damage in orchards by managing fruit flies in urban trees** **Description and actions:** It has been known for a long time that the greatest sources of fruit flies are from untended fruit trees in backyards, peri-urban small holdings and abandoned orchards. Particularly in districts where area freedom or area of low pest prevalence status is being targeted, regulatory and social interventions are required to ensure individuals manage their fruit trees, or allow them to be removed. This action should also be extended to interventions targeting abandoned orchards. Time to impact: 5-10 years

Sub-theme 2.9	Sterile Insect Technique
Need	The Sterile Insect Technique is a well-developed control approach in which mass reared, sterilised males are released into the environment. Females mated with such males lay infertile eggs, and as long as there are enough sterile males to outcompete the wild male population, suppression and eradication can follow. SIT is regarded around the world as a core tool in area-wide management of fruit flies. The development of a commercially viable SIT program producing adequate sterile flies to meet demand will greatly increase the likelihood of long term, sustainable fruit fly control in Australia.
Outcome	Better infield control of pest fruit flies, including eradication and enhanced emergency response.
Outputs	Commercially sustainable SIT production and distribution systems in Australia, fully integrated with local A-W IPM programs.
Alignment to NFFS & NFFS Implementation Plan	9.8, 10, 19
RD&E investment areas	**2.9.1 Male-only line** **Output: A *Bactrocera tryoni* male-only line which can be used in commercial SIT** **Description and actions:** In SIT only the males are needed. Producing females doubles factory production costs, while released sterile females can potentially still damage fruit by ovipositing; for these reasons a male only strain is considered essential in SIT. Both traditional selection and genetic engineering approaches can be applied to the generation of a line in which females can be selectively removed. Time to impact: 3-5 years
	2.9.2 Male fitness **Output: Mass reared, sterile males which have high levels of genetic and physical fitness compared to wild males** **Description and actions:** Mass released males need to be able to survive in the wild once released and out-compete wild males for access to females; together this constitutes male fitness. The study of male fitness focuses on several areas of both physiological and sexual fitness and all areas need to be addressed. Time to impact: 3-5 years

	2.9.3 Liquid larval diet **Output: A liquid larval diet developed and in use in a *B. tryoni* mass rearing facility** **Description and actions:** In fruit fly rearing factories, the use of liquid diets over solid diets offers numerous advantages in terms of space and handling. Making a liquid diet which works for flies, and which can be up-scaled to factory level, requires both entomological and engineering research components. Time to impact: 3-5 years
	2.9.4 Pre-release supplements **Output: Pre-release supplements for adult male *B. tryoni* fully researched and operationalised for use in commercial SIT** **Description and actions:** Male fitness can be increased through chemical and dietary supplements which decrease the time a fly needs to reach maturity and which make them more sexually competitive. There has been some small scale research done on this for *B. tryoni*, but not research taking lab findings to factory scale. Time to impact: 3-5 years
	2.9.5 Release strategies **Output: Strategies optimised for releasing sterilised male *B. tryoni* as part of commercial SIT** **Description and actions:** 'Release strategies' within SIT cover both the physical mechanism of fly release and the integration of SIT as part of larger control strategies. There are numerous physical release technologies developed internationally, including semi-automated aerial release, and different release strategies, e.g. micro-SIT or AW-SIT. Significant investment needs to be made into SIT fly physical release mechanisms and the integration of SIT as a component of eradication or AW-IPM programs. Time to impact: 5-10 years
	2.9.6 Male discrimination **Output: The ability to discriminate between wild males and SIT males with 100 per cent confidence** **Description and actions:** SIT males need to able to be told apart from wild males for regulatory and operational purposes. Traditional dye marking is prone to error and new methods, which would allow automated reporting, are needed. Time to impact: 3-5 years

Sub-theme 2.10	**IPM and Area-Wide IPM**
Need	In the absence of effective cover sprays, Australian fruit fly management will need to rely on a suite of control tools applied within an integrated pest management framework. As fruit flies are mobile pests which move around a cropping district to new hosts as they come into season (including non-commercial, feral and wild native hosts), fruit fly control is best done at an 'area-wide' level, where the 'area' may be a whole cropping district or a well-defined geographic area (e.g. a river valley). IPM and A-W IPM primarily integrate the individual control tools covered previously but there are also specific RD&E issues associated with combining these approaches. With respect to the Sterile Insect Technique, SIT is considered internationally as a key element of area-wide management. However, as demonstrated in the Central Burnett citrus production area, area-wide management can occur successfully in the absence of SIT. R&D for area-wide management should therefore not wait until SIT is fully mature in Australia but be developed concurrently with the national SIT program.
Outcome	Better infield control of pest fruit flies.
Outputs	An integrated fruit fly control 'toolbox' which optimises the mix of individual control tools for individual growers, commodities and production areas.
Alignment to NFFS & NFFS Implementation Plan	9.3, 9.4

RD&E investment areas	**2.10.1 IPM model** **Output: A grower usable, model-based tool which supports the integration of multiple fruit fly control tools within an IPM framework** **Description and actions:** Integration of a robust, predictive fruit fly phenology model with efficacy data from separate control tools (e.g. MAT, SIT, protein bait spray), such that the best combination and timing of treatments can be determined for commodity, region, and season. Time to impact: 3-10 years
	2.10.2 Working AWM models **Output: A formalised assessment of AWM in Australia, with international comparisons, to determine what aspects of fruit AWM work for Australian producers and which do not, to inform subsequent RD&E** **Description and actions:** AWM for fruit fly has both succeeded and failed previously in Australia, as it has done in other countries. A review needs to be undertaken to examine both successful and unsuccessful AWM cases in Australia to determine which aspects worked, and which didn't. Comparisons with a limited number of international cases would also be appropriate.
	2.10.3 Landscape ecology **Output: Knowledge on the landscape ecology of fruit fly which can be used to inform area-wide IPM** **Description and actions:** In area-wide control, it is recognised that flies breed at sites away from managed crops. Such sites may include abandoned orchards, feral plants, non-commercial plantings and wild native hosts. Flies may also use other aspects of the landscape for sheltering, locating mates, obtaining moisture, etc. The landscape ecology of fruit flies in Australia is essentially unknown and must be researched if area-wide controls, such as SIT, are to work most effectively. Time to impact: 3-10 years
	2.10.4 Community engagement **Output: Engagement strategies which maximise the likelihood of participation in area-wide programs by all members of the community** **Description and actions:** It has been demonstrated many times both internationally and domestically that area-wide controls cannot be applied in the absence of grower and rural community engagement. Any serious development of area-wide management approaches for fruit fly control in Australia must be accompanied by social science research and extension to maximise community engagement. Time to impact: 3-10 years
	2.10.5 Management systems **Output: Effective management systems to ensure successful area-wide IPM** **Description and actions:** A common denominator of all successful AW-IPM programs, irrespective of the combination of tactics used or the degree of centralised coordination, is an effective management structure. Managerial challenges (Hendrichs et al. 2007) include: (1) obtaining the commitment of all private and public stakeholders to support, participate in and finance the AW program, (2) carrying out appropriate feasibility studies, (3) developing a professional business plan for the program, (4) establishing an effective and dedicated organisation with full time staff to coordinate and implement the program, (5) implementing a training program, (6) establishing communication mechanisms among all rural and urban stakeholders, (7) establishing a system of program evaluation, and (8) obtaining research support for the program.

Sub-theme 2.11	Regional eradication
Need	Complete eradication of fruit fly from a region is without doubt the best form of fruit fly management. Numerous tools exist which make fruit fly eradication technically feasible, as has been demonstrated many times in Australia and internationally. Regaining area freedom for production districts which have recently lost this status is an RD&E area of high importance, as is eradication of Medfly from production areas in WA.
Outcome	Unrestricted market access and nil infield control costs due to an absence of fruit fly.
Outputs	Operational, economic and regulatory tools to guide investment and action in fruit fly eradication programs.
Alignment to NFFS & NFFS Implementation Plan	18, 19
RD&E investment areas	**2.11.1 Economics of eradication** **Output: Economic guidelines available for assessing the economic feasibility of eradicating Medfly and Q-fly from production areas** **Description and actions:** While technically feasible, eradication over very large areas is costly. Cost-benefit analyses of such eradication programs generally only focus on direct costs and production benefits, without consideration of flow-on benefits (e.g. private householder production, regional employment/unemployment). Such feasibility studies would better inform policy makers of the value or otherwise of eradication. Time to impact: 1-3 years
	2.11.2 Eradication **Output: Operational guidelines available for implementing Medfly and Qfly eradication from production areas** **Description and actions:** Technologies for eradicating fruit flies are well known but their implementation is largely reliant on personal expertise. National guidelines should be developed for fruit fly eradications, including both operational fruit fly controls (e.g. SIT, bait sprays, etc.) and regulatory controls (e.g. fruit movement restrictions, grower awareness, etc.). Time to impact: 1-3 years

Theme 3: Post-harvest measures

Theme Overview: In areas where fruit flies are present, post-harvest treatments which reduce the risk of fruit fly infestation in picked fruit to a level acceptable to a trading partner remain the strategies easiest to develop, justify and implement for gaining and regaining domestic and international market access; as such they are a core component of any fruit fly RD&E Plan. They are also needed if a pre-harvest market access program (e.g. area freedom, AWM or systems approach) fails. The need for research and development in post-harvest measures is as urgent as in any other area of fruit fly management. International and domestic loss of long-used post-harvest chemical treatments (e.g. methyl bromide, fenthion) are restricting available treatments; traditional experimental approaches to generating post-harvest data sets are becoming prohibitively expensive; human capability is rapidly declining; while traditional funding models have not allowed for innovation to help address these problems.

Research is required to deliver market access disinfestation data packages and treatments in a much shorter timeframe. Industry is seeking improved post-harvest control options for fruit fly that have a rapid turnaround, are efficacious, cost-effective, non-damaging, do not adversely affect product quality and are suitable for both sea and airfreight. Given this, the following sub-theme areas recommend RD&E areas which focus on new and improved single step disinfestation treatments, research on combination treatments, and 'blue sky' research which offers the potential of totally new treatments, or at least novel ways to improve current treatments.

Aligns with NFFS recommendations 1, 7 & 9 and NFFS Implementation Strategy Project 8.

Sub-theme 3.1	Refinement and improvement of existing treatments
Need	A large number of actual and potential disinfestation treatments are available. Some are already operational and simply need refinement, some are still under development and need more research to operationalise. Making these existing technologies work is the key first step in a post-harvest RD&E program. While largely a technical R&D program, social science research is also required. Irradiation is widely regarded by post-harvest researchers as the ideal post-harvest treatment, yet broader societal acceptance of this approach is largely lacking, as it may be for microwave treatments. Social scientists need to work with both the broader community and fruit fly researchers to understand and find solutions to these societal barriers to adoption.
Outcome	Better post-harvest control measures for fruit fly.
Outputs	A suite of new and improved post-harvest disinfestation treatments for fruit fly, which have high treatment efficacy, commercial viability, and broad public acceptance.
Alignment to NFFS & NFFS Implementation Plan	1.2, 9.6, PR8
RD&E investment areas	**3.1.1 Fumigation** **Output: Fumigant-based treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Producers and exporters are becoming increasingly reliant on fumigation to provide effective non-damaging control of pests to access markets. The research need includes a replacement for methyl bromide, development of quarantine treatments based on fumigants, research of low dose methyl bromide and evaluation of other possible fumigants including ethane dinitrile, ethyl formate and phosphine. Time to impact: 5-10 years
	3.1.2 Heat treatment **Output: Heat treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Covers post-harvest heat treatments to eliminate fruit fly and other pests of quarantine concern without injuring the host materials. Includes high temperature forced air, vapour heat and hot water treatments. Heat treatment data sets have been completed for current Australian pest species. Time to impact: N/A

	3.1.3 Cold treatments **Output: Cold treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Cold temperature treatments to eliminate pests of quarantine concern associated with fruits and vegetables without harming the condition or quality of the commodity. Includes cold disinfestation at; 0°C, 1°C, 2°C, 3°C and higher. Research is required to improve present export protocols and develop cold treatments within a shorter time frame. Time to impact: 5-10 years
	3.1.4 Irradiation **Output: Irradiation treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Research is required to gain Food Science Australia New Zealand (FSANZ) generic or product specific approval for various tropical and temperate fruit as well as raspberries, blueberries and passionfruit. Lower irradiation dose research for fruit fly is required. Time to impact: 5-7 years
	3.1.5 Chemical treatment **Output: Chemical treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** With the loss of a number of post-harvest chemicals, there is a research need to investigate 'generally regarded as safe' (GRAS) alternatives. This area also includes short term APVMA approvals and permits for dimethoate and fenthion dip treatments, low concentration fenthion treatment and development of other pesticides. Time to impact: 1-5 years
	3.1.6 Atmospheric manipulation **Output: Atmospheric manipulation treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Reduction of oxygen, or used with mixtures of CO2 or other gases, or combined with heat or cold. Includes controlled atmospheres, modified atmospheres, plastic wrapping, active wrapping, SO2 liners and low pressure disinfestation. Research is needed to develop new combination treatments that will satisfy international trading partners. Time to impact: 5-10 years
	3.1.7 Microwave treatments **Output: Microwave available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Research is currently underway to prove microwave technology for use as a residue free disinfestation method to kill pests of quarantine concern. Microwave is another form of heat treatment and needs research on efficacy and product tolerance. Research is required to address even heating of product, to produce new microwave heat data sets to kill fruit flies, and to develop commercial treatment equipment for stakeholder use. Time to impact: 10-15 years.
	3.1.8 Combination treatments **Output: Combination treatments available for the fruit fly disinfestation of fresh commodities** **Description and actions:** Use of two or more end-point treatments in combination to reduce treatment times and/or kill pests of quarantine concern. Includes low pressure and thermal treatments, ethyl formate and cold treatment, controlled atmosphere temperature treatments (CATTS) and post-harvest systems approaches. New effective multiple or combination treatments are needed that will satisfy international trading partners. Possible combination treatments include cold and controlled atmosphere, cold and low dose Methyl bromide, cold and high/low pressure, cold and ethyl formate. Time to impact: 5-10 years.

Sub-theme 3.2	Protection
Need	Many market access protocols require physical protection of the picked crop from fruit fly, through the packing shed and in the supply line. The biological basis for this requirement is not well justified and may be fruit fly species and/or commodity dependent.
Outcome	Better post-harvest control measures for fruit fly.
Outputs	Research which justifies the need or otherwise for physical protection of the crop from fruit fly after harvest, and operational guidelines for installing protection barriers if required.
Alignment to NFFS & NFFS Implementation Plan	None identified
RD&E investment areas	**3.2.1 Need for protection** **Output: Biological data to support the need, or otherwise, of protecting picked fruit from fruit flies** **Description and actions:** The biological need for protection of the crop after harvest, i.e. do fruit flies sting fruit after picking, is not known and relies largely on anecdotal observation. Documenting the propensity of fruit fly to attack harvested fruit would inform the need for protection and what parts of the post-picking chain need that protection. Issues to address would include fly species, commodity type and location in the chain (e.g. picker to shed, shed to pallet). Time to impact: 1-3 years
	3.2.2 Protection methods **Output: Commercially viable recommendations and products to protect picked fruit from fruit flies** **Description and actions:** If picked fruit needs to be protected from flies, development research needs to be undertaken on protective mechanisms, e.g. physical barriers, air-curtains. Time to impact: 3-5 years
	3.2.3 Hygiene **Output: Commercially viable and biologically justified recommendations on the safe disposal of reject fruit** **Description and actions:** All commercial sheds have dumps for fruit rejected on the packing line. The risk these pose as sources of fruit fly are not understood and need to be studied, and implications for managing the dumps described. Time to impact: 1-3 years

Sub-theme 3.3	Detection
Need	Disinfestation protocols are required because it is currently not possible to accurately determine if a fruit piece is infested when only eggs or young larvae are present. If it were, such fruit could be culled in the packing shed, guaranteeing only clean fruit was packed. The ability to detect eggs and larvae in fruit would, with subsequent automatic culling of that fruit, be a 'holy grail' in post-harvest treatments.
Outcome	Better post-harvest control measures for fruit fly.
Outputs	A commercially usable detection device, integrated with packing shed sorting and culling equipment, which can detect and cull fruit fly infested fruit with 100 per cent confidence.
Alignment to NFFS & NFFS Implementation Plan	7.7

RD&E investment areas	**3.3.1 Packing shed detection** **Output: A commercially usable detection device, integrated with packing shed sorting and culling equipment.** **Description and actions:** Detection methodologies will almost certainly be based on 'smart nose' technology and will be required to work instantly, at very high sensitivity, and in an environment rich with fruit and inorganic odours. Once an operational detection device is developed, developmental engineering will be required to retrofit the equipment to commercial packing lines. Time to impact: 5-10 years

Sub-theme 3.4	**New research and data protocols**
Need	Regardless of the disinfestation methodology used, gathering post-harvest data suitable for market access negotiations requires labour intensive trials involving many thousands of individual fruit treatments/samples. The cost of generating the new data required for a single market access protocol can now easily reach $1 million. Such costs are increasingly prohibitive to both government and industry. New R&D is needed to develop more efficient and effective experimental protocols and analytical approaches which supply data of the same confidence to importers and market access negotiators, but which are cheaper and quicker to implement.
Outcome	Better post-harvest control measures for fruit fly.
Outputs	New experimental and analytical protocols for post-harvest assessment which can generate data of high confidence to importers and market access negotiators, and which are more efficient than current approaches.
Alignment to NFFS & NFFS Implementation Plan	PR8
RD&E investment areas	**3.4.1 Review of protocols** **Output: A justified basis for the regulatory and trade requirements associated with market access datasets** **Description and actions:** The type of data considered 'suitable' for market access negotiations has developed over time and often appears more stringent than is needed for biological risk reduction. A review of current standards, undertaken within a combined historical, biological, statistical and regulatory framework, is necessary to determine how much of current practice is justified, versus the simple result of unjustified progressive change over time. Time to impact: 5-10 years
	3.4.2 New disinfestation protocols **Output: More efficient and effective disinfestation protocols** **Description and actions:** Current post-harvest disinfestation experiments are still largely based around Probit analysis, a statistical technique which requires very large sample sizes to generate a high degree of confidence in a specified Probit value (= the treatment response or mortality within a given population). New analytical approaches, such as Bayesian techniques, should be developed for post-harvest data to determine if the experimental protocols can be made more efficient, while providing the same level of confidence. Time to impact: 5-10 years

Sub-theme 3.5	Biology of death
Need	Most post-harvest treatments focus on death, i.e. causing mortality to eggs and maggots in fruit. Despite this focus, we know very little about the actual cause of death resulting from different treatments. For example, in heat treatments, is death caused by thermal shock, or very rapid aging, or a combination of both? Knowing the answers to such questions could help optimise treatments, allow the study of sub-lethal effects, identify novel mortality inducing mechanisms and so on. Essentially this is a discovery research area with the potential to open as yet unrecognised avenues for post-harvest controls.
Outcome	Better post-harvest control measures for fruit fly.
Outputs	Strategic basic research which studies the physiological basis of death in fruit flies, providing the scientific basis for novel post-harvest controls in fruit fly.
Alignment to NFFS & NFFS Implementation Plan	None identified.
RD&E investment areas	**3.5.1 Heat shock proteins** **Output: A molecular based approach which will make the development of new thermal disinfestation treatments more rapid** **Description and actions:** Heat-shock proteins are one of the most conserved gene families across all animals and are very well studied. For heat and cold disinfestation treatments, the study of heat shock proteins offers a way of examining treatment effects at the molecular and cellular lethal, allowing for better focused treatments. Time to impact: 5-10 years
	3.5.2 Stage dependent sensitivity **Output: A predictive method which will make the development of new disinfestation treatments more rapid** **Description and actions:** Most post-harvest treatments impact different live stages (i.e. eggs, three larval instars) differentially. Why this should be is unknown, but the ability to predict this without running full trials for all life stages would greatly benefit the development of new post-harvest treatment protocols. Time to impact: 5-10 years
	3.5.3 Modes of action **Output: A scientific approach which may lead to entirely novel disinfestation treatments** **Description and actions:** The mode of action, i.e. what causes death, for nearly all post-harvest treatments is unknown. Only one research laboratory in the world, based in Florida, is doing this type of research. Understanding mode of action, based on molecular, cellular and whole organism physiology, offers a way of developing new control tools. Time to impact: 5-15 years

Theme 4: Market access and regulatory issues

Theme Overview: Being able to control fruit flies and demonstrate risk reduction strategies (e.g. systems approaches or post-harvest disinfestation treatments) are not in themselves sufficient to guarantee market access opportunities for Australian commodities. For this to happen growers and exporters need to be aware of new and changing market opportunities so that new commercial export opportunities can be targeted; while market access negotiators need to have the scientific evidence required to argue market access cases with their counterparts in importing countries or interstate. Such evidence may exist but may not be collated in a way which is easily accessed by relevant parties, while new biological data may also need to be gathered for some data sets. The provision of market access data sets for both international and domestic trade is a very important component of both the NFFS and the NFFS Implementation Strategy; the R&D components of providing such data sets are addressed here.

Aligns with NFFS recommendations 1, 9 & 12 and NFFS Implementation Strategy Projects 8, 9, 10, 11 & 13.

Sub-theme 4.1	Market access data sets
Need	Market access for fruit fly affected commodities requires different information for exporters and regulators. Industries and exporters need trade statistics, market intelligence and more in order to respond promptly to changing market requirements and new market opportunities. Both domestic and international market access negotiators need data sets which identify the potential biological risks associated with an export commodity, as well as the risk reduction methods associated with reducing those risks. Having both data sets available and regularly updated positions Australian growers for prompt, positive action in highly competitive market places.
Outcome	Increased market access opportunities for Australian fruit fly susceptible commodities.
Outputs	Current and regularly updated market access data sets available to Australian horticultural industries, exporters and market access negotiators which can be used to both identify and then rapidly respond to new or changing market opportunities.
Alignment to NFFS & NFFS Implementation Plan	1.2, 1.3, PR13
RD&E investment areas	**4.1.1 Tropical and 'lesser' flies** **Output: Data sets on Australian fruit flies other than Qfly and Medfly available for market access negotiations** **Description and actions:** International markets are increasing requesting information on Australia's pest fruit flies other than Queensland fruit fly and Mediterranean fruit fly. Basic biological information to carry out import risk analyses on these approximately ten species is almost entirely lacking – and this deficiency may see the eventual closure of some markets. New information needs to be generated and collated into market access data packages for Australia's 'other' fruit fly species.
	4.1.2 Queensland fruit fly complex **Output: The biological species status of taxa within the Queensland fruit fly complex confirmed to support market access negotiations** **Description and actions:** Queensland fruit fly is one of four taxonomically closely related species, the others being *B. neohumeralis*, *B. aquilonis* and *B. melas*. Uncertainty exists over the biological species status of the latter two species, which may be taxonomic synonyms (i.e. the same species) of *B. tryoni*. Some trading partners are increasingly requesting information for these other members of the complex, and an integrative taxonomic approach is needed to resolve the species limits.
	4.1.3 Trade information **Output: Commodity specific export data packages available to exporters and producers to support international market access** **Description and actions:** As part of supporting the total production system, data sets containing trade statistics, changing market requirements and opportunities should be collated and made available to horticultural industries.

Sub-theme 4.2	Protocols
Need	As a signatory to both the World Trade Organisation Agreement of Sanitary and Phytosanitary Measures and the International Plant Protection Convention, management of Australian fruit fly susceptible crops destined for international markets is most appropriately done under the formal operating guidelines of the IPPC's International Standards for Phytosanitary Management (ISPMs). There are ISPMs both specifically and generally applicable to fruit fly, but implementing these in Australia as a basis for subsequent international market access requires targeted local research. Similarly the domestic equivalents of the ISPMs, the Interstate Certification Assurance protocols, need regular updating or writing.
Outcome	Increased market access opportunities for Australian fruit fly susceptible commodities.
Outputs	Domestic and international market access cases for fruit fly susceptible commodities based on the best possible science, following and implementing internationally agreed protocols.
Alignment to NFFS & NFFS Implementation Plan	1.1, 1.4, 2.2, 9.6, 12.5, PR9, PR10, PR11
RD&E investment areas	**4.2.1 Systems approaches** **Output: Accepted methodologies and approaches to the use of systems approaches for gaining market access by fruit fly affected commodities** **Description and actions:** Systems approaches (as defined in ISPM 35) require the integration of two or more independent treatments to reduce plant biosecurity risk to a level acceptable to the importing nation. While a logical approach, there are significant operational and statistical issues with applying it and there are very few currently approved international systems approaches for fruit fly. Research needs to be done on both the basic science of systems approaches (e.g. collating different types of data into a single end point 'value') and specific field examples leading to market access which can be used as exemplars.
	4.2.2 Area freedom **Output: Research findings to develop accepted regulatory and operational guidelines for maintaining, and as required regaining, market access for fruit fly affected commodities through the use of area freedom** **Description and actions:** Specific research issues around area freedom(as defined in ISPM 4 and ISPM 26) include determining the size of containment zones, the likelihood of fly populations persisting below detectable limits and the best combination of treatments to eradicate outbreaks.
	4.2.3 Areas of low pest prevalence **Output: Research findings to develop accepted regulatory and operational guidelines for maintaining, and as required regaining, market access for fruit fly affected commodities through the use of areas of low pest prevalence** **Description and actions:** Areas of low pest prevalence (as defined under ISPM 29) offer a very significant opportunity for Australian producers, especially those in southern states where fruit flies may be naturally rare or seasonally absent. However, ISPM 29 is silent on what number of flies constitutes 'low pest prevalence'. Answering this is a complex question, as it centres on the relationship between adult fly abundance and infestation in a particular crop. This will vary depending on the crop, other hosts in the environment, season and fruit fly species. To answer this will require collection of targeted biological data combined with phenological and landscape modelling. The existing Codes of Practice for Qfly and Medfly are effectively systems for ALPP and these documents provide the basis for implementing ALPP.

	4.2.4 Protocols for Pest Free Areas and Areas of Low Pest Prevalence **Output: Accepted regulatory and operational guidelines for using PFA and ALPP as market access tools for fruit fly affected commodities** **Description and actions:** Both the USA and NZ have standard national protocols for growers/exporters who are seeking to gain markets through the use of pest free areas or areas of low pest prevalence. Using data gained from investment areas 4.2.1 – 4.2.3, and developed in conjunction with market access negotiators, develop nationally agreed production manuals for export orientated crops.
	4.2.5 Codes of Practice **Output: Up-to-date Codes of Practice for Qfly and Medfly** **Description and actions:** The National Codes of Practice for Queensland fruit fly and Mediterranean fruit fly need to be updated on a regular basis, taking into account changes in national cost sharing arrangements, species distributions and scientific knowledge.
	4.2.6 ICAs **Output: Interstate Certification Assurance available to allow interstate trade of fruit fly affected commodities** **Description and actions:** The Interstate Certification Assurance (ICA) scheme supports the domestic trade of fruit fly affected commodities. Ongoing research and development is needed, on a regional and commodity specific basis, to ensure new ICAs are available to support domestic trade.

Theme 5: Social issues

Theme Overview: Solving the fruit fly problem is not only dependent on solving a biological pest problem. Fruit fly is a socio-political and ethical issue, with a requirement for shared responsibility between government, industry and the wider community. Failure of any one sector to fully engage is likely to lead to failure of the whole system. However, what exactly 'shared responsibility' means with respect to fruit fly, and how to gain and maintain engagement from different participants, is not easily addressed and needs new research. Factors need to be identified that withhold growers and the broader community from being 'full' partners in addressing fruit fly related issues; novel methods need to be investigated to empower local governments in the fruit fly arena; and reiterative evaluation needs to be made of awareness and education activities to ensure change practices have occurred. Institutional issues, such as policy settings and regulations versus incentives, also need to be examined to best achieve desired outcomes.

Aligns with NFFS recommendations 3 & 6.

Sub-theme 5.1	Fruit fly as a socio-political issue – *A shared responsibility*
Need	It is widely recognised that managing fruit fly will require input from the entire fruit fly stakeholder community; growers, researchers, the general community, exporters and government at all levels. But what does 'shared responsibility' or 'a working partnership' between government, industry and the community mean in the context of fruit fly? What does an 'enabling government' for fruit fly control look like with limited resources? For example, a grower said "*I don't want government hand-outs, but I need government to be the support worker, not the policeman, because at the moment government is a policeman only* (enforcer of regulation)". And what, for example, can realistically be asked from town residents to control fruit fly and how does this differ between towns? For instance, can we expect more community support in small towns that are highly dependent on horticulture, versus a large regional centre that has a broad agriculture and non-agricultural economic base? These types of questions need to be addressed and the answers incorporated into a solution if fruit fly is to be managed effectively.
Outcome	Greater engagement by all fruit fly stakeholders in managing the fruit fly problem.
Outputs	Strategies and engagement mechanisms which help build linkages between the different members of the fruit fly stakeholder group.
Alignment to NFFS & NFFS Implementation Plan	3.1, 3.3, 6.1, 6.3
RD&E investment areas	**5.1.1. Engaging the broader community** **Output: Communities more engaged with helping solve the fruit fly problem** **Description and actions:** What is the appropriate role for the broader community? Do they need to be engaged in the decision-making and agenda setting process (implied in the word partnership) or are they simply an extension of the 'industry-government' apparatus to address fruit fly issues in order to gain market access?
	5.1.2 Regional industry voice **Output: Individual growers and grower groups with greater participation in setting the fruit fly RD&E agenda** **Description and actions:** How do regions get a voice? Often national industry bodies are less concerned about issues, including fruit fly, that do not affect most growers of the relevant commodity. However, fruit fly might be of paramount importance for a regional industry. Who is industry? There appears to be a lot of emphasis on industry bodies, but many growers are not members of industry bodies for a range of reasons. Are they still 'partners'? How do we deal with 'partners' who are not taking up their responsibilities?

	5.1.3 Local government **Output: Shire and other local governments empowered to actively assist in fruit fly management** **Description and actions:** As fruit fly can have a significant impact on the economic well-being of a local shire if the region is dependent on fruit fly-sensitive crops, there is a need for local capacity to set enforceable rules. A logical candidate in this space seems to be local government, however local government has no power to issue legislation. This means that at a local level there is often limited capacity to set enforceable rules for backyards, derelict orchards, absentee landholders, etc., even as a back-up measure if other engagement strategies fail. Are there ways to overcome this, such as giving more power to local government?

Sub-theme 5.2	Growers and the community as 'full' partners
Need	Growers are the primary stakeholders in fruit fly management, but due to the distributed nature of Australia's horticulture industry growers may have the smallest voice. There is an urgent need to identify and mitigate the factors that withhold growers (and the broader community) to be 'full' partners in addressing fruit fly related issues.
Outcome	Growers and the wider local community better engaged and empowered to manage fruit fly.
Outputs	Strategies and engagement mechanisms which strengthen grower and local community leadership in fruit fly research, development and extension issues.
Alignment to NFFS & NFFS Implementation Plan	3.1, 3.3, 6.1, 6.3
RD&E investment areas	**5.2.1 Grower and industry groups** **Output: Local fruit fly action groups with strong support from both growers and government.** **Description and actions:** Some local and regional fruit fly/grower bodies seem to lack resources and capacity to be responsive and deliver on local needs. In other cases regional bodies struggle to achieve good grower attendance at meetings. In some cases, there are individuals who have good relationships with individuals in state or federal government, which benefits local progress. What can we learn from various experiences and literature about what works and doesn't work in this context and how can those elements that work well be encouraged and supported? Are there ways that industry can have more input in trade negotiations about market access protocol, to ensure they are practical on-farm and still meet the importing countries' requirements?
	5.2.2 Grower perceptions **Output: Growers who understand current regulatory and government operational conditions and can optimise their work practices within them** **Description and actions:** What are growers' perceptions of 'the fight against fruit fly'? For example, research suggests that many growers and residents do not understand the shift that plant biosecurity has undergone in the last few decades. Many still see state departments of agriculture and the federal Department of Agriculture as primarily responsible for addressing many biosecurity related issues such as fruit fly control and expect government to be highly responsive to local needs, as in the 1960s. Hence they feel deserted by government, which affects their trust in and perception of government. Many don't seem to understand that due to the change in the international 'rules of the game', Australia needs to spend a large amount of resources to abide by international conventions under the World Trade Organisation and International Plant Protection Convention in order to ensure it remains a 'reputable player' in the international scene, an important condition for a healthy export industry. Such perceptions need to be understood and either modified or worked around.

	5.2.3 Participatory research **Output: Growers better engaged with adapting new research and development outputs** **Description and actions:** Outcomes from research investment are often undermined by a lack of uptake by growers and others. Participatory research involves engaging growers from the start in the research process, including shaping the research focus. Growers become active participants in the research process, such as allowing and undertaking research-related activities on their land. Although not named that way, this is in broad terms what happened in Central Burnett when Queensland DAFF partnered with the local industry to implement AWM in the region. DAFF staff consulted with growers and local consultants about the research project. The research design included research questions put forward by growers. Locals mentioned this process as an important factor in the success of AWM in Central Burnett. Ideally participating growers meet regularly with each other and researchers to interpret findings and direct future activities (social learning). Due to the high level of ownership, findings from such research holds far more credibility and hence uptake than bringing in research findings from elsewhere. This approach can be extended to citizen science, where town residents can also be engaged in the research process, for example schools or people from gardening clubs might be willing to monitor new traps or other technologies in their school grounds/ backyards. This has the potential to expand manpower, increases awareness of the pest and results in better uptake of results.

Theme 6: Capacity

Theme Overview: Regardless of how good the RD&E Plan, nothing will be achieved to control fruit fly over the next twenty years without the capacity, both human and physical, to do so. Historically, capacity in fruit fly RD&E has been shared by the Australian Government, CSIRO, the state departments of agriculture and a small number of universities. CSIRO and the universities carried out predominantly discovery and strategic research, while the states had responsibility for research, development and extension, and the Australian Government for border protection and market access negotiations. Since its formation in the 1980s the Australian Centre for International Agricultural Research (ACIAR) has continuously funded offshore fruit fly research and development in Asia and the Pacific and has thus played an important role in maintaining both regional and Australian fruit fly capacity.

The current situation in capacity still reflects part of this historical pattern, but with some significant differences. Notably state agriculture departments have greatly reduced their development and extension capacity, especially in regionally located extension staff and field entomologists who serviced a particular production area or crop type. Some of this regional capacity has been taken over by the private sector, in terms of IPM scouts and horticulture consultants. In order to maintain a viable and effective national capacity in fruit fly RD&E, a capacity which has the potential to cover the full spectrum of required activities from discovery science to grower support, the following issues need to be addressed.

Aligns with NFFS recommendations 13, 15 & 17

Sub-theme 6.1	Regional support
Need	The loss of capacity in regional entomology and local horticulture extension capacity has directly and negatively affected fruit fly management. Both as an immediate priority, and in the future, investment needs to be made to support regionally based professionals who can carry out on-station and on-farm trials to adopt primary research to the needs of their local growers. Such officers need to work with local growers and their community to develop and implement both on-farm and area-wide IPM strategies which best fit the need of that community.
Outcome	Better ability for growers to make informed fruit fly management decisions, leading to more viable and sustainable local horticultural communities.
Outputs	Enhanced capacity for the outputs of fruit fly R&D to be communicated to growers in forms tested for local production areas, and for growers to provide information and feedback to the fruit fly R&D community.
Alignment to NFFS & NFFS Implementation Plan	No identified alignment.
RD&E investment areas	**6.1.1 Regional fruit fly biosecurity (research and extension) officers** **Output: Regionally based professionals who can optimise fruit fly controls for local production areas and crops, while facilitating networks of growers, local government and the wider local community** **Description and actions:** Regionally based entomologists and extension staff have historically played a pivotal role in the fruit fly RD&E system. Through professional networks they have had access to new research and development, while being regionally based they have had first-hand knowledge of their local growers needs, as well as grower trust, and have been able to test new controls under local conditions. This key role, in the form of fruit fly 'biosecurity officers' urgently needs to be reinvigorated, with the appointment of dedicated professionals for key horticultural production areas around Australia. The model of regional biosecurity officers as used by the grains industry could be easily adopted for fruit fly.

Sub-theme 6.2	**Research and Development capacity**
Need	Capacity to carry out fruit fly R&D currently exists in Australia, but this situation will change over time. Increasingly, laboratories around Australia are running largely on contracted staff, commonly linked to a specific research project with great uncertainty of continuing employment. Within the state governments, only a few research entomologists are specifically allocated to fruit fly research and most share their fruit fly work with research on other pests or plant biosecurity problems. The situation is the same in universities, where research fellows and postdocs are funded for specific projects, and most continuing academics have 'day jobs' (i.e. teaching, supervision, administration) which limit their ability to contribute to long term R&D. Importantly, this impacts on the ability of researchers to invest in fundamental research and biological investigations, and hence the ability to pursue novel solutions. To attract the best skills to fruit fly R&D there needs to be a clear opportunity for researchers to establish a career and an interesting/engaging RD&E program.
Outcome	High quality and innovative R&D outputs which support growers' needs for fruit fly management.
Outputs	A stable professional community capable of support fruit fly R&D needs into the future.
Alignment to NFFS & NFFS Implementation Plan	13.1
RD&E investment areas	**6.2.1 Strategic research staff** **Output: A stable fruit fly research community engaged in discovery and strategic research for the development of novel fruit fly management tools** **Description and actions:** In addition to field entomologists, a viable fruit fly R&D community requires stable research teams focusing on the 5-20 year R&D objectives. To achieve this, current fruit fly specific appointments need to be supported and new ones created.
	6.2.2 Changed funding cycles **Output: A more stable fruit fly research community, especially for professional officers and early career researchers** **Description and actions:** Funding cycles of one to three years lead to great job insecurity for staff appointed through such projects. A change of funding cycles for strategic R&D initiatives from three years to five years would give greater employment stability for contract staff and opportunity for individual and team development.

Sub-theme 6.3	**Professional networks**
Need	The fruit fly problem concerns all states and territories of Australia, as well as most countries around the world. For this reason fruit fly RD&E professionals are dispersed both nationally and globally and strategies need to be put in place to ensure that networks exist through which information can be exchanged and collaborative RD&E undertaken.
Outcome	Stronger professional linkages nationally and internationally, maximising domestic R&D collaborations and ensuring Australia stays current with international developments.
Outputs	A more efficient and effective fruit fly R&D community.
Alignment to NFFS & NFFS Implementation Plan	15.1

RD&E investment areas	**6.3.1 International symposiums** **Output: Australian fruit fly R&D professionals linked to world best practice** **Description and actions:** The four yearly International Symposiums of Fruit Flies of Economic Importance (ISFFEI) are the primary international fruit fly meetings. Presentations cover all areas of applied fruit fly management. Funding of Australian fruit fly RD&E professionals to participate within the ISFFEI would create valuable networks and ensure Australia stays current with international trends.
	6.3.2 TAAO **Output: Australian fruit fly R&D professionals actively participating in regional fruit fly activities** **Description and actions:** The Tephritid Workers of Asia, Australia and Oceania (TAAO) is a recently reinvigorated regional network of fruit fly workers. Australian support for TAAO will help build regional linkages, strengthening research on all *Bactrocera* fruit flies.
	6.3.3 National meetings **Output: Maximised collaboration and minimised duplication within the Australian fruit fly RD&E community** **Description and actions:** While the 'core' Australian fruit fly workers all know each other, there is a much wider community of RD&E professionals who work with fruit flies who are not part of this group. National fruit fly RD&E meetings, held at least once every 18 months and attended by as wide a representation of the RD&E community as possible (including regionally based scientists, border protection staff, students and postdocs) would significantly strengthen the national fruit fly effort.

Sub-theme 6.4	Physical Infrastructure
Need	The physical infrastructure for fruit fly RD&E in Australia currently lies within the individual R&D organisations involved. Some countries, e.g. Mexico, are moving towards single national fruit fly RD&E facilities as a way of coordinating research efforts. This strategy is unlikely to work in Australia given the size of the nation and the diversity of horticultural systems involved. A distributed physical network, either built around existing facilities or with new facilities, would be better suited to Australian situation.
Outcome	A sustained fruit fly RD&E capacity in Australia.
Outputs	A network of regional laboratories capable of undertaking fruit fly R&D and informing extension.
Alignment to NFFS & NFFS Implementation Plan	15.1
RD&E investment areas	**6.4.1 R&D network** **Output: A national coordinated, but distributed R&D network consisting of a small number of research hubs.** **Description and actions:** Arrangements need to be made for national prioritisation and funding of critical research and operational infrastructure for fruit fly R&D. Discussions should be held as part of Primary Industries Standing Committee strategies.

Sub-theme 6.5	Managerial Infrastructure
Need	Fruit fly RD&E in Australia is currently greatly weakened by the lack of a permanent administrative infrastructure with a clear line of reporting and financial responsibility. At the moment several groups have administrative and or financial coordination roles for at least some part of the national fruit fly effort. These include the National Fruit Fly Advisory Committee, the Plant Biosecurity CRC, Horticulture Innovation Australia Ltd, Plant Health Australia, the National Plant Biosecurity RD&E Implementation Committee, Primary Industries Standing Committee and the SITplus Consortium. These groups are additional to the internal management structure of every organisation within Australia which employs at least one person involved in fruit fly RD&E. Given this crowded situation it is not surprising that confusion and duplication exists. This confusion is very obvious at the ground level, and a consistent message from growers, grower groups and researchers throughout the consultancy period was the need for a single, national body to be responsible for fruit fly management, e.g. "*Amalgamation of all fruit fly related bodies into one force with action, not talk, heading the agenda*." Several different models exist for how this might be achieved and these need to be explored, and the preferred option implemented, as soon as possible.
Outcome	Better management of all aspects of fruit fly RD&E in Australia.
Outputs	A single, national body charged with coordinating and implementing fruit fly RD&E in Australia.
Alignment to NFFS & NFFS Implementation Plan	Nearly all recommendations of the NFFS could be better achieved through the existence of a single, national coordination centre.
RD&E investment areas	**6.5.1 National fruit fly coordination** **Output: A single, national coordination centre for all aspects of fruit fly RD&E.** **Description and actions:** Creation of a single, national body with a role of both coordinating and implementing fruit fly RD&E. Development of such a body should be considered by both the NFF Advisory Committee and the National Plant Biosecurity Strategy Implementation Committee.

Theme 7: Core science

Theme Overview: Throughout the RD&E themes above are several disciplines considered by the writing group as 'core science'. We refer to 'core science' as those broad research disciplines which provide the underpinning science upon which operational research and development are based. Core science also provides the 'blue-sky' or discovery-science, which are the basis for the over-the-horizon controls which are currently difficult or impossible to predict. Given this, we list core science as a separate theme to recognise the ongoing need for basic and strategic-basic research in fruit fly management.

Aligns with NFFS recommendations 13 & 14

Sub-theme 7.1	Core science
Need	While it is possible to predict future fruit fly R&D needs, anticipated advances in science and technology make it difficult, if not restrictive, to predict how those needs are best met. By supporting core science disciplines, fruit fly R&D will be able to provide the innovative research required to develop and maintain novel fruit fly controls.
Outcome	The best possible fruit fly management in Australia for the next twenty years.
Outputs	Innovative science solutions for fruit fly management.
Alignment to NFFS & NFFS Implementation Plan	13.1, 13.2, 14.2
RD&E investment areas	**7.1.1 Molecular biology** **Output: Active fruit fly R&D programs utilising molecular biology approaches** **Description and actions:** In the last two decades no field of biological research has developed as rapidly as molecular biology, and there is every sign that this progress will continue. The current potential of molecular biology is best seen in the human health sciences, where targeted medications are being designed to fight disease and illness based on our knowledge of individual genes. This depth of knowledge and application is still only rarely applied to insect systems, but there are already areas for which it is considered unacceptable to work without a molecular basis (e.g. systematics and diagnostics), while nearly all subthemes in Themes 1-4 do, or in the future will, benefit from molecular biology research. As we move into the five, ten and twenty year timeframes of this Plan, molecular biology will become a routine R&D tool, and also the most likely provider of truly novel fruit fly controls.
	7.1.2 Physiology and behaviour **Outputs: Active fruit fly R&D programs utilising insect physiological and behavioural approaches** **Description and actions:** Fruit flies are behaviourally complex organisms with complex neural, circulatory, respiratory and reproductive systems. An understanding of fruit fly physiology and behaviour can aid R&D objectives as diverse as predicting geographic range changes under climate change (e.g. how well can the insect survive extreme temperature events?), predicting the success of SIT (e.g. how competitive is sperm produced by SIT flies?), and designing new generation lures (e.g. how are plant volatile chemicals processed in the brain?). Physiological and behavioural studies, using both traditional and molecular based approaches, will remain a long term core science for fruit fly management. Both physiological and phenological understanding also can deliver direct improvements in fruit fly control, including understanding when populations emerge and become a risk to commercially grown produce.

	7.1.3 Ecology **Outputs: Active fruit fly R&D programs utilising insect ecology approaches** **Description and actions:** Ecology is the study of organisms in the environment. A robust ecological knowledge of the Australian fruit fly species has been repeatedly identified as a key gap in our ability to control these insects. Examples of the type of questions for which ecological answers are needed include; what drives the abundance of flies in the field and how does that abundance change during the year; where do flies mate in the field so we can target SIT releases; how do flies move around the landscape and where do they come from before entering an orchard? All such knowledge will help focus the development and application of controls. Ecology should be based upon an understanding of the insect's physiology, and relies heavily on tools provided by molecular biology, modelling and statistics.
	7.1.4 Modelling **Outputs: Active fruit fly R&D programs utilising modelling approaches** **Description and actions:** A very broad term covering a multitude of approaches, we refer to modelling here as the development and application of computer based tools which help us summarise and combine knowledge, understand observed mechanisms and patterns, and predict answers to questions relevant to fruit fly management. Examples of models (and the type of questions they can answer) needed for fruit fly include; (i) phenology models (when are flies in my orchard?); (ii) landscape models (where are flies in my orchard coming from?); and (iii) exotic pathway models (what is the highest risk entry point?). Modelling is a way of summarising and presenting RD&E outputs for all themes in this Plan and provides user-accessible tools to leverage and apply research. Models can also be refined to provide continuous improvement as underpinning research is completed.
	7.1.5 Statistics **Outputs: Active fruit fly R&D programs utilising advanced statistical approaches** **Description and actions:** The statistical sciences are concerned with the development and application of appropriate analytical tools to knowledge, and then using those tools to supply formal confidence statements about the inferences which can be drawn from that knowledge. To put it less formally, statistics helps us make decisions within a repeatable framework. Statistics is a core discipline to all branches of science and is used to analyse data, but also to inform how that data is best collected. Strong statistical support is needed for all RD&E themes in this Plan. A strong understanding of the statistics of risk also help define the necessary level of protection for commercial pathways and assists in providing assurance that fruit fly control measures, or combinations of measures can achieve this level.

ABARES (2014). Benefit-cost analysis of the long term containment strategy for exotic fruit flies in the Torres Strait. ABARES, Canberra.

Abdalla A., Millist N., Buetre B.& Bowen, B.(2012). Benefit–cost analysis of the National Fruit Fly Strategy Action Plan. ABARES report to client prepared for Plant Health Australia, Canberra.

APVMA (2010). Human Health Risk Assessment of Dimethoate. Australian Pesticides and Veterinary Medicines Authority, Canberra.

APVMA (2011). Dimethoate Residues and Dietary Risk Assessment Report. Australian Pesticides and Veterinary Medicines Authority, Canberra.

APVMA (2012). Fenthion Residues and Dietary Risk Assessment Report. Australian Pesticides and Veterinary Medicines Authority, Canberra.

Balagawi S., Jackson K., Hamacek E.L. & Clarke A.R. (2012). Spatial and temporal foraging patterns of Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae), for protein and implications for management. *Australian Journal of Entomology* **51**: 279-288.

Bateman M.A. (1991). *The Impact of Fruit Flies on Australian Horticulture*. Horticultural Policy Council, Report No. 3, Report to the Honourable John Kerin, Minister for Primary Industries and Energy, Canberra.

Cantrell B., Chadwick B. & Cahill A. (2001). *Fruit Fly Fighters: Eradication of the Papaya Fruit Fly*. Collingwood, Vic: CSIRO Publishing.

Clarke A.R., Powell K.S., Weldon C.W. & Taylor P.W. (2011). The ecology of *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae): what do we know to assist pest management? *Annals of Applied Biology* **158**: 26-54.

Cook D., Hurley M., Liu S., Siddique A., Lowell K. & Diggle A. (2010). Enhanced risk analysis tools. Final project report for the Cooperative Research Centre for National Plant Biosecurity, Canberra. Pp 479.

DAFF (2013). *Australian Food Statistics 2011-12*, Department of Agriculture, Fisheries and Forestry, Canberra.

Dominiak B.C.& Ekman J.H. (2013).The rise and demise of control options for fruit fly in Australia. *Crop Protection* **51**: 57-67.

El-Sayed A.M., Suckling D.M., Byers J.A., Jang E.B. & Wearing C.H. (2009).Potential of "Lure and Kill" in long-term pest management and eradication of invasive species. *Journal of Economic Entomology* **102**: 815-835.

European Union (2009). Directive 2009/128/ EC Establishing a framework for Community action to achieve sustainable use of pesticides. http://www.pcs.agriculture.gov.ie/regulations/Directive_2009_128_%20EC.pdf

Florec V., Sadler R.J., White B. & Dominiak B.C. (2013). Choosing the battles: The economics of area wide pest management for Queensland fruit fly. Food Policy 38: 203–213.

Growcom (2011). Food security issues for the Australian horticulture industry. A report prepared for HAL project AH09009.

Ha A., Larson K., Harvey S., Fisher B. & Malcolm B. (2010). *Benefit-cost analysis of options for managing Queensland fruit fly in Victoria*. Evaluation Report Series 11, Department of Primary Industries, Melbourne.

Hafi A., Arthur T., Symes M. & Millist N. (2013). Benefit-cost analysis of the long term containment strategy for exotic fruit flies in the Torres Strait. ABARES Report to client prepared for the National Biosecurity Committee, Canberra.

Harvey S., Fisher B., Larson K. & Malcolm B. (2010). A benefit cost analysis on management strategies for Queensland Fruit Fly: methods and observations. 54th Annual Conference of the Australian Agricultural and Resource Economics Society.

Hendrichs J., Kenmore P., Robinson A.S. & Vreysen M.J.B. (2007). Area-wide integrated pest management (AW-IPM): principles, practice and prospects. Pp 3-33 in: Area-wide Control of Insect Pests (M.J.B.Vreysen, A.S. Robinson & J. Hendrichs eds). Springer, AA Dordrech, The Netherlands.

Horticulture Australia Limited (2010). Review of Rural Research & Development Corporations. Response to the Productivity Commission Issues Paper.

IAEA (2009). Development of Bait Stations for Fruit Fly Suppression in Support of SIT. IAEA, Vienna.

Lloyd A.C., Hamacek E.L., Kopittke R.A., Peek T., Wyatt P.M., Neale C.J., Eelkema M. & Gu H. (2010). Area-wide management of fruit flies (Diptera: Tephritidae) in the Central Burnett district of Queensland, Australia. *Crop Protection* **29**: 462-469.

Madge P., Mobbs P., Bailey P. & Perepelicia N. (1997). Fifty years of fruit fly eradication in South Australia. Primary Industries and Resources South Australia. Pp 69.

Mumford J.D., Knight J.D., Cook D.C., Quinlan M.M., Pluske J. & Leach A.W. (2001). Benefit cost analysis of Mediterranean fruit fly management options in Western Australia. Imperial College, Ascot.

PHA (2008). Draft National Fruit Fly Strategy, Plant Health Australia, Canberra.

PHA (2009). Economic assessment of the implementation of the proposed National Fruit Fly Strategy: Part 1, Plant Health Australia, August, Canberra.

PHA (2010). National Fruit Fly Strategy Implementation Action Plan, Plant Health Australia, Canberra.

PHA (2010). National Plant Biosecurity Strategy, Plant Health Australia, Canberra 2010

Plant Health Committee (2013). Review of the Long-term Containment Strategy for Exotic Fruit Flies in Torres Strait. Canberra.

Rural RDC (2008). Measuring economic, environmental and social returns from Rural Research and Development Corporations' investment. Rural R&D Corporations, Canberra.

Sharma V. & Alam A. (2013). Current trends and emerging challenges in horticulture. *Journal of Horticulture* 1: e101. doi:10.4172/horticulture.1000e101.

Suckling D.M., Stringer L.D., Stephens A. E.A., Woods B., Williams D.G., Baker G. & El-Sayed A.M. (2014). From integrated pest management to integrated pest eradication: technologies and future needs. *Pest Management Science* **70**: 179-189.

Suckling D.M., Kean J.M., Stringer L.D., Cáceres-Barrios C., Hendrichs J., Reyes-Flores J. & Dominiak B.C. (2014).Eradication of tephritid fruit fly pest populations: outcomes and prospects. *Pest Management Science*: in press.

Sutherst R.W., Collyer B.S. & Yonow T. (2000). The vulnerability of Australian horticulture to the Queensland fruit fly, *Bactrocera (Dacus) tryoni*, under climate change. *Australian Journal of Agricultural Research* **51**: 467-480.

Tryon H. (1889). Inquiry into diseases affecting the fruit-trees and other economic plants in the Toowoomba district. Parliamentary Paper, Brisbane.

USDA ARS (2013). National road map for integrated pest management. http://www.ipmcenters.org/Docs/IPMRoadMap.pdf

White B., Sadler R., Florec V. & Dominiak B. (2012). Economics of Surveillance: a bioeconomic assessment of Queensland fruit fly. Contributed paper 56th AARES Annual Conference, Fremantle, Western Australia, Feb 7-10, 2012.

Wissemann A., Rogers J. & Duffield B. (2003). Changing roles for a state agriculture department: Driving forces and organisational responses in the 21st century. *Australian Journal of Public Administration* **62**: 59-69.

Acronym	Meaning
ALPP	Areas of low pest prevalence
APVMA	Australian Pesticide and Veterinary Medicines Authority
A-W	Area-wide
A-W IPM	Area-wide integrated pest management
AWM	Area wide management
CRCs	Cooperative Research Centres
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
D&F	Dimethoate and fenthion
FSANZ	Food Safety Australia New Zealand
HAL	Horticulture Australia Limited
HIAL	Horticulture Innovation Australia Limited
ICA	Interstate Certification Assurance
IPM	Integrated pest management
ISFFEI	International Symposiums of Fruit Flies of Economic Importance
ISPM	International Standard for Phytosanitary Management
MAT	Male annihilation technology
Medfly	Mediterranean fruit fly or *Ceratitis capitata*
NFFS	National Fruit Fly Strategy
NSW	New South Wales
PBCRC	Plant Biosecurity Cooperative Research Centre
PHA	Plant Health Australia
Qfly	Queensland fruit fly or *Bactrocera tryoni*
R&D	Research and development
RDCs	Research and Development Corporations
RD&E	Research, development and extension
SIT	Sterile insect technique
SME	Small and medium size enterprise
TAAO	Tephritid Workers of Asia, Australia and Oceania
WA	Western Australia