Final Report

Sustainable Management of Medfly without cover sprays

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Contents

Summary

- Since the 1960s, dimethoate and fenthion have been used by apple and pear, stone fruit, and mango growers for pre-harvest (cover spray) and post-harvest (dips, flood sprays) control of Mediterranean fruit fly (medfly, *Ceratitis capitata*). The loss of these insecticides in 2011 and 2015 respectively will make medfly more difficult to control in highly susceptible crops such as summer fruit.
- Several pre-harvest control tactics were developed or tested during the project, including an area-wide approach (AWM). Facets of an AWM program were tested in pome and stone fruit orchards in Jarrahdale in the Perth Hills, and mass trapping was trialled in an area within the Jarrahdale town-site.
- Trapping grids were installed in Jarrahdale and other areas within Perth Hills commercial production areas to determine when and where medfly is abundant, and to assess the efficacy of control measures.
- Monitoring and degree-day modelling showed that medfly survived winter in the adult and immature stages in all Perth Hills areas. A study of the crop phenology provided evidence that suitable hosts are available throughout the year, particularly citrus (lemon, orange, mandarin). Citrus provides shelter and food (e.g. honeydew from scale insects), and females are able to lay eggs into oranges and mandarins in winter when temperatures exceed 10ºC.
- There are two main periods of medfly abundance: summer and autumn. Spring infestation of commercial orchards was attributed to overwintered flies, rather than an influx of adults from nearby areas such as towns. Abundance increases during summer, peaking in late December/January as summer fruits ripen.
- In autumn, medfly adults disperse into surrounding areas to search for suitable over-wintering sites coinciding with ripening of pome fruit. Late autumn baiting is recommended to curb these dispersing adults, coupled with strict orchard hygiene to eliminate overwintering eggs and larvae.
- AWM with bait sprays was highly effective at suppressing medfly (< 1 f/t/d), and was effective with as few as 1-3 growers. New techniques including attract-and-kill devices (MagMED®, Probodelt Conetrap) and the sterile insect technique did not reduce the medfly population below the economic threshold of 1 f/t/d when used alone. However, these techniques were effective when combined with bait spraying. Trap and lure components were identified that growers could use to develop their own mass trapping system, as well as lures to improve monitoring of male medfly.
- The neonicotinoids Samurai Systemic Insecticide™ (clothianidin) and Calypso® (thiacloprid) currently available for use under an APVMA permit, killed medfly eggs and larvae when fruit was treated 7 days after medfly had been allowed to lay eggs. They are both possible replacements for fenthion.

Keywords

Area wide management, mass trapping, lure and kill, Mediterranean fruit fly, sterile insect technique, suppression, bait spraying, cover spraying, clothianidin, thiacloprid, spinetoram, male-targeted trapping, female-targeted trapping.

1. Introduction

Fruit flies are one of the most economically important pests worldwide, attacking a wide range of fruits and vegetables. Australia has two major pest species: the Queensland fruit fly (Qfly, *Bactrocera tryoni* Froggatt), found in parts of the Northern Territory, Queensland, New South Wales and Victoria, and the Mediterranean fruit fly (medfly), *Ceratitis capitata* Wiedemann (Diptera: Tephritidae), in Western Australia (WA). First detected in WA in 1895, medfly is well established in commercial fruit growing districts from Donnybrook through to Carnarvon, but absent from isolated production areas such as the Ord River Irrigation Area in northern WA, where area freedom is maintained. Annual outbreaks of medfly occur in South Australia and occasionally in the Northern Territory, and are considered to originate from WA.

During the last few decades, medfly populations have increased in south western WA due to warmer winters coupled with increasing rural sub-division (De Lima 2008). This has led to reliance on cover sprays to control medfly in highly susceptible crops such as apricots, nectarines and peaches. In particular, the organophosphates - dimethoate and fenthion are regarded to be 'silver bullets' by commercial growers, with the Hills Orchard Improvement Group stating that 'without fenthion commercial production is not possible' (Commonwealth of Australia 2014). First developed in the 1950s, these insecticides have been registered since 1960 to control medfly and Qfly (Shedley 1960; Sproul 2001).

In 1994, fenthion and dimethoate were nominated for review by the Australian Pesticides and Veterinary Medicines Authority (APVMA), the national authority responsible for registering and reviewing all pesticides sold in Australia. In 2011, dimethoate was suspended from use due to public health concerns (APVMA, 2011). In October 2015, fenthion will be removed due to public health, occupational health and safety, and environmental concerns (APVMA, 2015). Maldison (malathion) and trichlorfon, currently used in bait and cover sprays, are being reviewed by the APVMA and are also likely to be removed from use in the future.

Wherever possible, pesticides removed from use are being replaced with safer, narrow-spectrum pesticides. However it is unlikely that either fenthion or dimethoate will be replaced with one of equivalent efficacy. This is due to the economics of developing new pesticides, with the total cost per new product estimated $256 million US in 2005-2008 (Phillips McDougall 2013), coupled with higher standards of safety (Casida and Quisad 1998), with the number of new active ingredients in development dropping from 70 in 2000 to 28 in 2012. In the absence of new cover sprays, different approaches to fruit fly control are required. Area-wide integrated pest management (AWM-IPM) is promoted internationally as a sustainable approach for managing highly mobile insects such as fruit flies (Klassen 2000; FAO 2005).

AWM-IPM is defined as '*IPM applied against an entire pest population within a delimited geographic area*' (FAO 2005). The approach requires coordinated efforts between two or more growers, rather than individual growers applying intensive pressure against small segments of the total population. Another feature of AWM-IPM is that multiple control techniques are used to suppress the population.

Tactics that can be used in a fruit fly AWM-IPM program include:

- mass trapping/lure and kill,
- male annihilation technique (mainly for *Bactrocera* species),
- bait spraying,
- hygiene, and
- the sterile insect technique (SIT),
- biological control (mainly the release of Braconid wasps that attack the egg and larval stages),

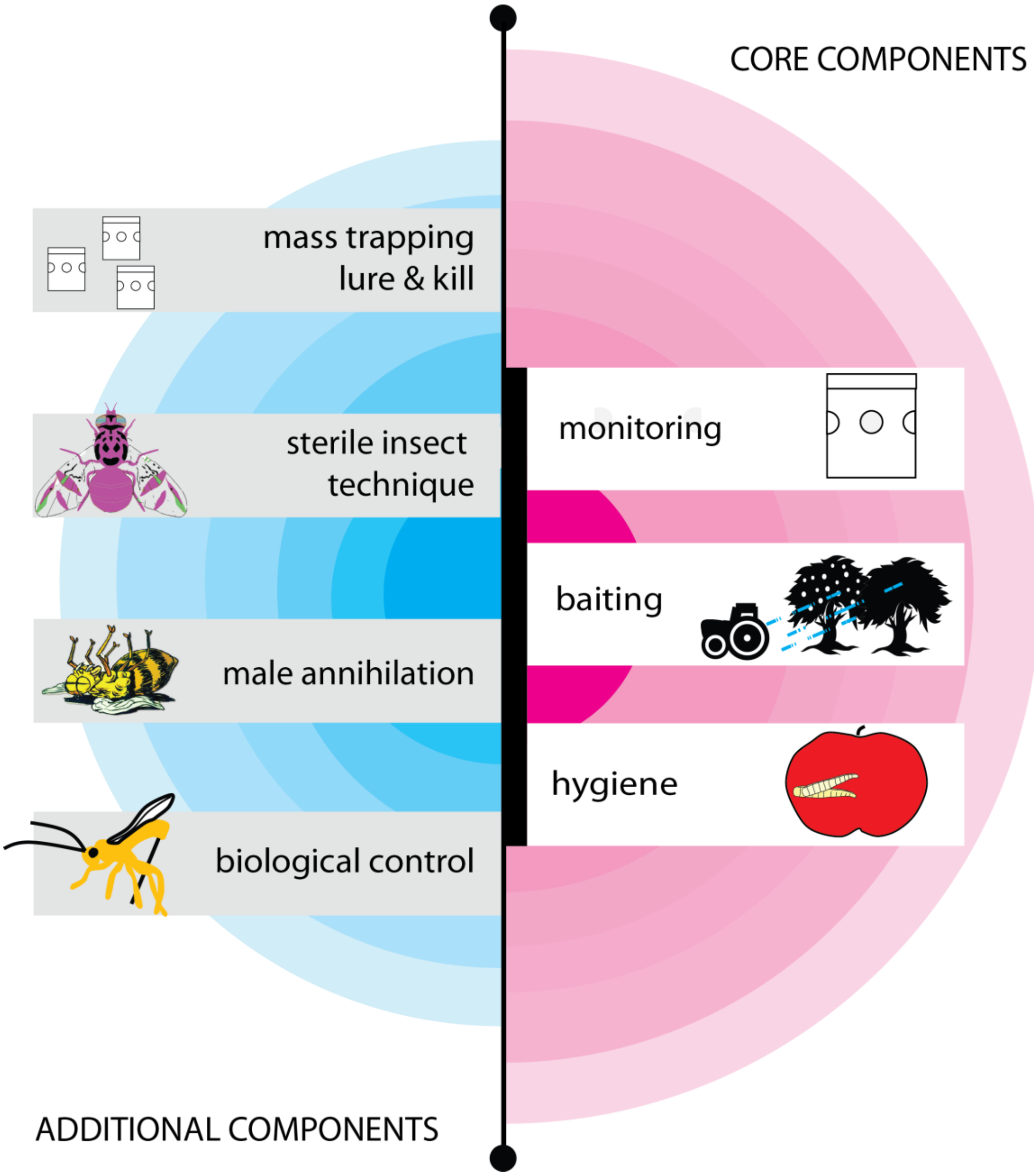

Figure 1.1. Components of a generalised fruit fly area wide management program. Note that the male annihilation technique is only currently available for tephritid species that respond to cue lure and methyl eugenol.

Recent examples of successful AWM-IPM programs include Hawaii against medfly, melon (*Bactrocera cucurbitae* (Coquillet) and oriental fruit fly (*B. dorsalis* (Hendel)) using field sanitation, male annihilation, bait spraying, and biological control (Vargas *et al.* 2010). In Australia, AWM is being applied against Qfly. Examples include the Central Burnett program (Queensland), using bait sprays and male annihilation (Lloyd *et al.* 2010), and Stanthorpe (Queensland) using sterile insects, male annihilation and bait spraying (Reynolds 2014). In the

Greater Sunraysia Area (Victoria, New South Wales), outbreaks of Qfly are being managed with mass trapping, male annihilation and bait spraying (C. Bain, pers. comm. 2015).

From September 2012 through to May 2015, we carried out a demonstration AWM project in Jarrahdale (Perth Hills) in pome and stone fruit orchards. The main tactic applied was bait spraying, with high density trapping within the town-site. Our intention had been to progress the trial to other areas, but due to lack of funding were unable to do so.

To ensure that the project also produced usable outputs for growers in other fruit growing areas within WA, we tested new control tactics (mass trapping, lure and kill, sterile insect technique). In addition, we collected information on the biology and temporal distribution of medfly in the Perth Hills, the effect of host type and phenology on abundance, and the effect of uncontrolled medfly populations such as towns and small landholder properties on commercial orchards in Jarrahdale.

2. Methodology

2.1 Target area selection for AWM trial

The Perth Hills is located on the Darling Plateau east of Perth. It has one of the highest endemic populations of medfly in WA due to a wide range of hosts, a favourable climate, rural subdivision, and the proximity of urban areas to orchards. Commercial fruit production occurs in Bickley, Carmel, Jarrahdale, Karragullen, Pickering Brook and Roleystone, with most fruit produced for the domestic market. Stone fruit crops mature and are harvested in summer (December–May), and pome fruit in autumn-winter (April-June; Fig. 2.1). Most orchards have several varieties of fruits that ripen in succession over 4-5 months.

The region has a Mediterranean type climate with hot, dry summers (December–February) and cool, wet winters (June–August). Mean monthly daily air temperatures range from 16.2–18.2ºC (min) to 22.3–39.0ºC (max) in summer, and 0–13.6ºC (min) to 19.3–25.7ºC (max) in winter; most rainfall is received in June-August (>100 mm/month) (BOM 2015).

2.1.1 Demonstration site

Jarrahdale was chosen by a project team consisting of DAFWA and Fruit West, as it had large medfly populations with an urban area located within 1 km of commercial orchards. Located 45 km south-east of Perth, the commercial production area of 72 hectares of pome (apples, pears) and stone fruit (apricots, nectarines, peaches, plums) is spread across 8 commercial orchards, with an average orchard size of 7.96 Ha (range 5.2-10.9 Ha; Appendix 1, Fig. 2.1). In addition, three growers produce fruits for local grower markets. Near or adjacent to commercial orchards are five lifestyle blocks with pome, stone fruit and citrus (Fig. 2.1). Other land use in Jarrahdale includes grazing, horses and a winery.

The town-site covers 88.1 Ha with an average block size of 0.1 Ha. The oldest settlement area with 114 dwellings is 0.7 km north-east of commercial orchards, and has the highest density of mature fruit trees. Surrounding Jarrahdale is state forest consisting of woodland and open forest of native Jarrah (*Eucalyptus marginata* Sm.) and Marri (*Corymbia calophylla* (Lindl.).

Though no citrus is grown commercially, mandarins, oranges and lemons are grown for personal use by some commercial, non-commercial and backyard growers.

2.1.2 Orchard treatments prior to project commencement

Cover sprays of fenthion or dimethoate were the main method used to control medfly in pome and stone fruit in the Perth Hills. The introduction of AWM required that bait spraying be adopted, and applied over each orchard at least a weekly basis. All growers were responsible for the cost and implementation of control methods on their own orchards. Most growers applied baits consisting of 1-2 L Cera Bait (Bioiberica, Spain; 360g/L hydrolysed protein), mixed with 435 mL maldison/100 L (Hy-mal®, 1150 g/L maldison).

Cover sprays of fenthion (Lebaycid®) were permitted during the trial period under APVMA permit 13840. This allowed fenthion to be applied to apples and pears two times, 14 days apart at the rate of 75-100 mL/100 L. Nectarines and plums could be sprayed a maximum of three times, 10 days apart at75 mL/100L. Minor use permits were also issued by the APVMA for Samurai Systemic Insecticide™ (500 g/L clothianidin, PER14252), Calypso® (480 g/L thiacloprid, PER14562) and Delegate® WG insecticide (250 g/kg spinetoram, PER12590) for use as cover sprays in pome and stone fruit.

2.1.3 Additional monitoring sites

Pickering Brook

The town-site is spread over 11.6 Ha with 50 households and an average block size of 0.2 Ha. Forty-nine citrus, pome and stone fruit orchards are listed within 2 km of the town (CRIS 2015), with the nearest orchard located within 300 m. The total area of commercial orchard production is 364 Ha with an average orchard size of 7.4 Ha. Other land uses include floriculture, livestock, horses, mushrooms and truffles. Adjacent to orchards are woodland and open forest of native Jarrah and Marri.

Karragullen

Approximately 50 pome and stone fruit orchards with a combined area of 595 Ha are listed in Karragullen, with an average orchard size of 11.9 Ha (CRIS 2015). No urban areas are present, though the suburb of Roleystone is located 4 km west. Other land uses include grazing, lifestyle blocks and non-agricultural land. North and west of Karragullen is native woodland and open forest.

Roleystone

The urban area of Roleystone covers approximately 625 Ha with 2,348 households of varying block sizes (CRIS 2015, ABS 2011). Commercial orchards are located northwest of the town; with six orchards located within 1000 m of the town site. Commercial orchards collectively cover an area of 51.9 Ha, with an average block size of 9.84 Ha. Other land use includes grazing, lifestyle blocks and non-agricultural land.

2.2 Industry and community engagement

Meetings were held before the project commenced to explain to growers what the project entailed, why it was being conducted in Jarrahdale, and to obtain the commitment of growers in Jarrahdale to the project. For the duration of the project the project team provided growers (commercial and non-commercial), with the trapping results from their orchard, what the results meant and how control could be improved.

The Jarrahdale urban community was engaged via letter drops and a newspaper article that contained trial information and medfly control methods for backyard growers. Two public meetings were held at the Jarrahdale town hall to discuss results. Householders within the old town area were encouraged to adopt a trap to help reduce medfly numbers (see appendix).

2.2 Technology transfer

Stone, pome fruit and citrus growers were informed about project results via grower meetings, workshops, media releases and articles in the Fruit West magazine (Appendix 1.1). Media releases produced by DAFWA included information for commercial growers and the community such as 'bait early and often', adhere to strict orchard hygiene and consider baiting overwintering hosts. Web pages on how to monitor, bait spray, cover spray, mass trap, and project updates were made available on the DAFWA web-site (www.agric.wa.gov.au; Appendix 1.1).

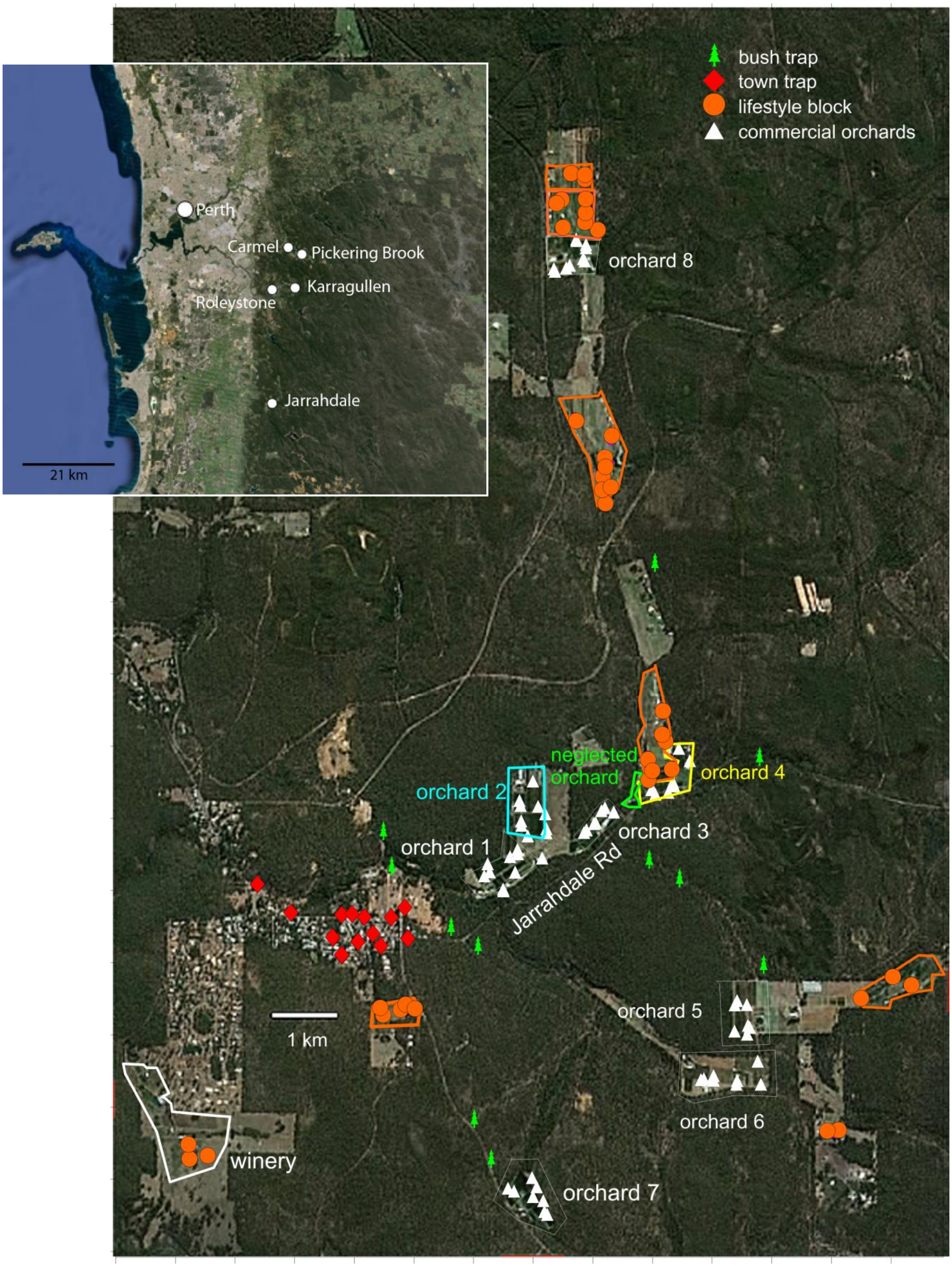

Figure 2.1 Map of Jarrahdale showing location of traps in town, commercial orchards and lifestyle blocks . Inset: Perth Hills growing areas.

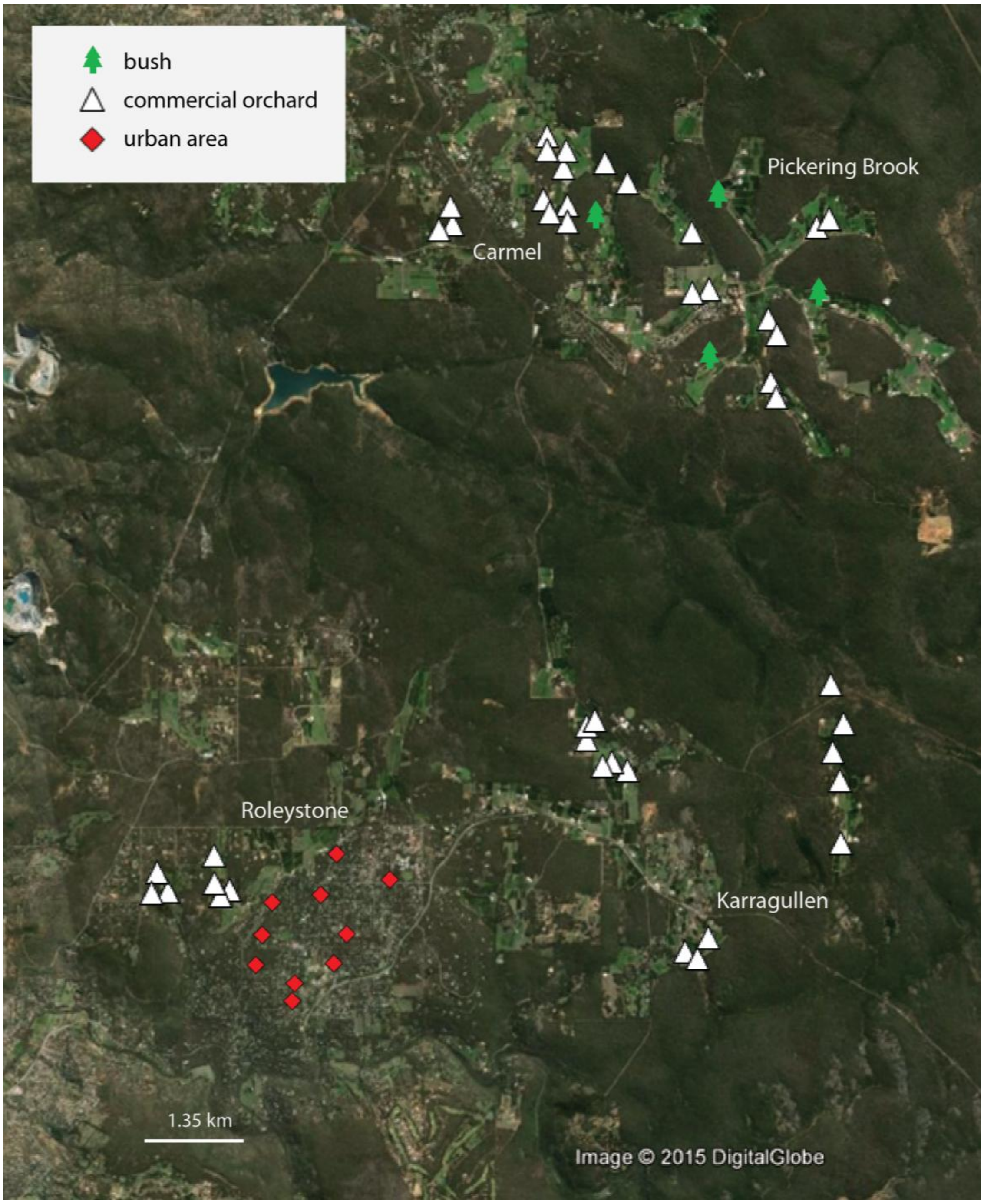

Figure 2.2 Map of the Perth Hills with the location of monitoring traps in town (Roleystone), commercial orchards and bush locations.

2.3 Medfly population monitoring

Monitoring with fruit fly traps was used to determine the distribution of flies within Jarrahdale, Pickering Brook and Roleystone and the effect of 'landscape' (e.g. town vs orchard), host type (e.g. pome, stone fruit, citrus), stage of growth (phenology, e.g. bud burst, fruit development, ripe fruit etc.) and control (baiting, cover spraying, mass trapping) on medfly abundance. The density of traps varied with crop type and orchard size, with at least two trap pairs (male/female) per Ha.

At each trap check, the gender and number of flies was recorded along with the phenological stage of the fruit tree (e.g. flowering, fruit development, dormant). Traps were checked weekly from spring-autumn and fortnightly in winter.

Thresholds

Trap catch was expressed as the number of flies caught per trap per day (f/t/d). The FAO/International Atomic Energy Agency (IAEA) has established that numbers above 1 f/t/d indicate an infested area, and between 1 and 0.1 indicate suppression (FAO/IAEA 2003). The economic threshold where action was required (baiting, cover spray) was 1 f/t/d. Hot spots were regarded to be areas where more than 1 f/t/d were caught.

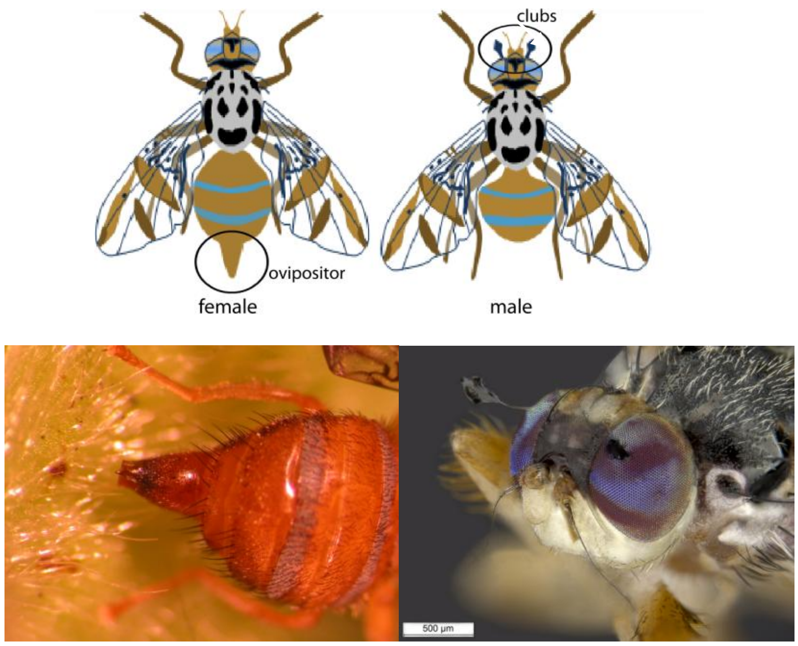

Figure 2.3. Top: Diagrammatic representation of the differences between female and male medfly. The 1.2 mm long ovipositor is used by the female to lay eggs into fruit. Bottom left: female ovipositor; right: the 'clubs' on the head of the male are black pointed expansions at the apex of the anterior pair of orbital setae (photo Pia Scanlon, DAFWA).

Male targeted

Male medfly were monitored with locally made Lynfield traps (Cowley *et al.* 1990; Fig. 2.4). The modified version used by DAFWA (Wijesuriya and De Lima 1995) consists of a one litre clear plastic jar (100 mm diameter, 124 mm high) with an opaque white screw-on lid. Four 25 mm diameter entry holes are placed equidistant around the trap, 50 mm below the top of the jar. The Lynfield trap is the only trap recommended for monitoring both Qfly and Medfly in Australia's Fruit Fly Code of Practice.

Capilure® (mixture of 60-70% trimedlure with extenders) is the standard lure used in medfly surveillance and monitoring, replacing trimedlure in the 1980s (Hill 1987). The male lure consisted of two cotton dental rolls in a large paper clip loaded with 2 mL of Capilure® (mixture of 60-70% trimedlure with extenders) in 2012, but was switched to a 2 g trimedlure cone following field testing (see section 3.5.3; Farma Tech International Corporation, Washington, USA) in 2013.

Jackson traps were used to monitor flies in the sterile insect release trials (section 2.6.3). These are the preferred trap for use in SIT programs, as the sterile flies are easier to distinguish from wild flies under the microscope. The Jackson trap is a white delta shaped trap body made of waxed cardboard (125 x 95 x 75 mm), with a white rectangular insert (155 mm x 95 mm) coated with a thin layer of tangle foot to trap flies (ISCA Technologies, Riverside, CA, USA, Fig. 2.4). The trap is suspended by a wire hanger from the top of the trap body.

Female targeted

From November 2012, female medfly were monitored with Tephri traps, a McPhail type trap (Sorygar, Spain; Broughton & DeLima 2002). The trap consists of an opaque lid (55 mm) that fits into a yellow base, with an invaginated bottom (Fig. 2.4). The trap was 164 mm in height and 140 mm in diameter at its widest point. Four fly entry holes 21mm in diameter were placed 90° to each other, 10 mm from the top of the trap. Entry holes were covered with plastic mesh to reduce the number of flies exiting the trap. The lure used was a three part food attractant (BioLure®, Suterra Inc., Bend, Oregon, USA) containing sachets of ammonium acetate, putrescine (1,4-diaminobutane), and trimethylamine hydrochloride. The attractants are manufactured in adhesive backed units that can be attached to the internal trap walls.

Medfly in male and female traps were killed by a 10 mm^2 dichlorvos pest strip (Killmaster®, DDVP 18.6 – 20% w/w, inert ingredients 81.8-80% w/w; Barmac Pty Ltd, Australia) placed in the bottom of the trap. Lures and DDVP pest strips were replaced every 8-10 weeks, and traps bodies and parts were replaced as needed. The position of each trap was recorded with a hand held Garmin GPS.

Figure 2.4 Male and female targeted traps

2.3.1 Spatial analysis

Geostatistical methods were used to characterize the spatial distribution of medfly adults in two areas of interest: (1) a site 0.6 km northwest of the Jarrahdale town comprised of five commercial orchards and an organic orchard, and (2) a commercial orchard that had been subdivided. Analyses were carried out using Surfer software Version 12 (Golden software, Golden, CO) with x, y representing latitude and longitude expressed as coordinates in decimal degrees, and z representing trap counts (mean f/t/d per month). The interpolation method used was the Inverse Distance to a Power, which is similar to the inverse distance squared weighted (IDSW) suggested by Midgarden *et al.* (2014) for mapping fruit fly data (Midgarden pers. comm. 2015).

The grid generated by Surfer was graphically represented by a contour map, showing the configuration of the surface by means of isolines representing equal z-values. A base map showing the area with the same coordinate system was placed below the contour map.

2.3.2 Climate records and bioclimatic model

As insects cannot control their body temperature, their growth rate increases as temperature increases until an optimum temperature is exceeded: at this point development declines. If the upper and lower temperatures for development are known, models can be developed to predict insect activity and for fruit fly, periods when fruit is most and least at risk.

The most commonly used tool to model insect population is based on degree-days (DD). A degree-day is each degree of temperature by which the average temperature on a given day exceeds the threshold temperature for development. The formula for the degree-day model is given as:

Degree-Day (DD) = (Minimum + maximum daily temperature/2) – (threshold temperature for development)

The threshold temperature for medfly development that we used was 9.3°C for eggs to hatch, 11.1°C for larvae to develop through their instars and to pupate in the soil, 8.4°C for pupae to develop to adults and 12.8°C for egg maturation, requiring accumulation of 298 degree-days (De Lima 2008). Daily weather data was obtained from the Bureau of Meteorology Patched Point Data base records for Pickering Brook and Roleystone, and from the DAFWA weather station at Jarrahdale.

2.4 Existing suppression techniques

2.4.1 Bait sprays

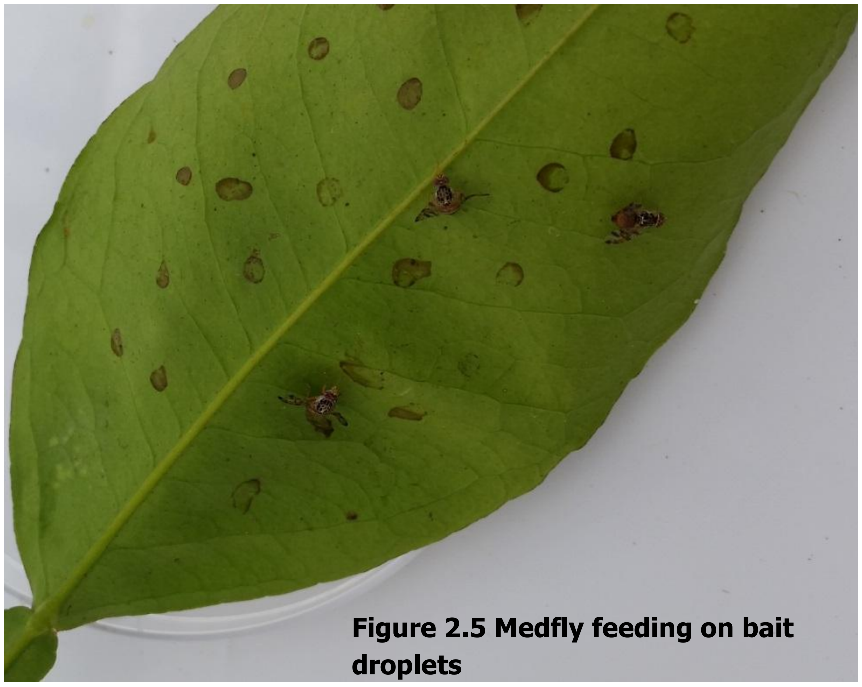
Figure 2.5 Medfly feeding on bait droplets

Comparison of registered bait sprays

Cage trials were conducted in a glasshouse in February and March 2015 to compare Naturalure^{TM} and Cera Bait+Hy-mal. In the last few years, Cera Bait+Hy-mal has become widely used by orchardists in WA, but its attractancy and efficacy to medfly has not been evaluated. Compared to maldison (500 g/L maldison), Hy-mal contains 1150g/L maldison with no solvents.

Three trials were conducted on non-consecutive weeks to obtain a total of six replications per treatment. On the day prior to each trial, 6-8 day old protein-deprived flies were obtained from the colony maintained at DAFWA, to acclimatise flies to cages prior to testing. This colony is replenished every two years from field-collected fruits to maintain genetic diversity.

Approximately 40 laboratory reared adults (20 males, 20 females) were transferred into separate cages (BugDorm, Taiwan, China; 325 mm X 325 mm x 325 mm) with polyester netting, and provided with sugar and water. On the morning of the trial, cages were checked, and any dead adults replaced with flies of the same sex and age. Sugar was removed prior to exposure of flies to treatments, and returned once treated leaves had been removed (approx. 60 minutes).

Trial design

A randomised complete block design was used, comprising two replicate blocks and three treatments (Table 2.1). Cages were randomly assigned to a bench in the glasshouse, and each bench contained all treatments.

In the laboratory, treatments were prepared with tap water at the recommended rate (Table 2.1). Cera Bait, a hydrolysed protein was used in all treatments (Bioiberica, Spain). Individual treatments were applied to freshly collected tangerine leaves with a syringe, to achieve 0.8 mL of bait mixture per leaf (Fig. 2.5). Treated leaves were placed over a plastic petri-dish (75 mm diameter), then added to the cage (two leaves per cage). Immediately after all treatments were introduced to cages, the numbers of medfly landing on leaves were counted. Thereafter, the number of flies landing on leaves and live, moribund and dead flies were counted every 10 minutes for the first hour, then at 3, 6, 24, 30, 48, 72 and 96 hours post-treatment.

Flies were classified as dead if they did not move, and moribund if they were twitching. No flies were removed from the cage during experimentation, since this could alter the behaviour of the live flies. After 96 hours, all flies (live and dead) were examined under a dissecting microscope to determine sex.

Table 2.1: Bait Treatments and their recommended application rate

Treatments	Manufacturer	Mix ratios of insecticide:protein: water
Hy-mal (maldison 1150 g/L)+ Cera-Bait	Crop Care Australasia Pty Ltd	8.7 mL : 40 mL :1L
Naturalure™ (0.24 g/L spinosad)	Dow AgroSciences	133 mL : nil : 867 mL
Control (Cera-Bait + water only)		nil : 40 mL : 1L

Statistical analysis

The number of flies feeding on baits at each 10 minute interval during the first hour of exposure were transformed (log x+1) prior to analysis. The numbers of individuals that died at each observation after the bait was removed, were counted and expressed as a percentage of the total number of individuals. The data was corrected using Abbott's formula (Abbott 1925):

$$\text{Corrected mortality} = (\%\ \text{treatment mortality} - \%\ \text{control mortality})/(100 - \%\ \text{control mortality}) \times 100$$

Abbott's formula takes into account the proportion of control adults dying in the trial that were not exposed to insecticides (the percentage that 'died of natural causes'). During the trials, control mortality never exceeded 7%. Prior to analysis corrected mortality data were transformed (arcsine (x + 0.05)) (Zar, 1999). Data were analysed by one-way ANOVA with GenStat® 16th edition (VSN International Ltd). If significant, means were separated with least squared means differences (P = 0.05).

2.4.2 Bait sprays vs. cover sprays

The efficacy of bait vs cover sprays were compared in two locations (2 or more growers in each location) in Jarrahdale from October 2012 through to May 2015. All medfly control activities were carried out by orchardists, and medfly adults were monitored with modified Lynfield and Tephri traps as described in section 2.3.

2.5 Possible chemical replacements for fenthion and dimethoate

Cover sprays are recommended in cases in which bait sprays have failed, and fruit infestation exceeds the economic threshold level. A few new insecticides are available for use in cover sprays including two neonicotinoids, clothianidin and thiacloprid, and spinetoram, a semi-synthetic substance derived from the fermentation of *Saccharopolyspora spinosa* (Dow AgroSciences 2006). In addition to killing adult flies and reducing oviposition, cover sprays should also have some activity against eggs and larvae inside fruit, as there is zero tolerance for infested fruit in the market.

The objectives of this study were to determine the effects of spinetoram, clothianidin, and thiacloprid on the mortality of adult medfly. We also examined the effect of clothianidin and thiacloprid on immature medfly in the laboratory and field, as they are regarded to have some systemic activity (Elbert *et al.* 2001; Uneme 2011).

2.5.1 Topical application

Laboratory reared adults 5-7 days old were anaesthetised with nitrogen, sexed, and then randomly allocated to one of five treatments (Table 2.2). All pesticides were applied at the manufacturer's recommended rate, and pesticides were mixed with tap water to achieve the correct dilution. Trichlorfon (Dipterex®) was included as a positive control since it is registered as a cover spray in Australia.

Table 2.2: Insecticides used in topical application trials

Treatment	Active ingredient	Application rate
Untreated control	N/A	water only
Dipterex®	Trichlorfon 500 g/L	125 mL/100L
Calypso®	Thiacloprid 480 g/L	37.5 mL/100L
Samurai®	Clothianidin 500 g/kg	40 g/100L
Delegate™	Spinetoram 250 g/kg	20 g/100L

Treatments were applied topically with a handheld atomizer (Hills Trigger Sprayers, BH2200), with separate atomizers for each treatment. Adults were then transferred to plexiglass cages (220 mm x 180 mm x 180 mm), with one cage holding either 50 males or 50 females per treatment. On one side of each cage, a 100 mm x 100 mm cut was made and covered with mesh net to provide ventilation. In addition, a 150 mm diameter cut was made in the top of the cage to provide further ventilation.

Each cage was supplied with sugar and yeast (3:1 ratio) and a dental cotton wick soaked in water. All cages with treated insects were then transferred into an environment cabinet (25 ± 1°C, 50-60% RH, L:D = 16:8). Mortality was recorded at 1 h, 4 h, 24h, 48h and 72 h post treatment. Adults were regarded to be dead if they did not respond when lightly prodded.

Trials were repeated four times (replication over time) on four different days. For each replication, a new solution for each treatment was prepared.

2.5.2 Field trials

Six trials were carried out between 28 October 2013 (trial 1, nectarine), and 22 January 2014 (trials 2, 3, 4, 5, 6, peach; Tables 2.3, 2.4) to assess the effect of insecticides on eggs and larvae in fruit. In each trial, branches with multiple mature fruits and without any sign of medfly damage were selected and tagged, then covered with a fly proof mesh bag (Fig. 2.6). In trials 1-3, ten pairs of 7-8 d old laboratory reared protein fed medfly adults were released into each bag, and a sugar cube and a vial containing water were added to provide food and water. Pesticides were applied through the mesh bag after 24 hours in trials 1 and 2, and after 48 hours in trial 3. Fruits were collected from the field after 24 h into separate plastic zip lock bags and brought to the laboratory.

Figure 2.6. Nectarines bagged in a commercial orchard to assess the effect of pesticides on the development of medfly eggs and larvae.

For trials 4-6, fruits were sprayed with pesticides first. In trial 4, adult medfly were released into mesh bags seven days post spraying, and collected after 24 h to rear out any larvae. In trials 5 and 6, fruits were collected after 24 and 48 h respectively. These treated fruits were then placed in Perspex cages (300 mm x 30 mm x 30 mm) with a mesh lid in the laboratory, with four cages (replications) per treatment. Ten pairs of laboratory reared adults (7-10 day old protein fed) were released into each cage. Cages were then transferred into an environment chamber, 25±1°C (day time) and 18±1°C (night time) and 40-50%RH with a 16:8 L:D cycle. Flies were checked at 24 and 48 h to record any mortality, and all flies (live and dead) were removed after 48 h.

2.5.3 Fruit rearing

In the laboratory, fruits were transferred to tote boxes containing vermiculite. To ensure that larvae and pupae did not drown in fruit juices, fruits were placed on a mesh layer. Two fruits from each tote box were dissected and examined under a stereo microscope to confirm oviposition, and the numbers of eggs in these fruits recorded. Remaining fruits were transferred to an environment cabinet (25±1°C, 50-60%RH, L:D= 16:8). After 7 days, the vermiculite in each tote box was sieved for larvae and pupae. Larvae were left in the vermiculite to pupate, whilst pupae were transferred to a petri dish. Once no more pupae had been recorded for 14 days, fruit were dissected.

Adults emerging from pupae were counted. When no more adults had emerged for 7 days, remaining pupae were examined to determine if they had died. The number of pupae per fruit, and the percent of emerging adults were calculated by dividing the number of emerged adults by the number of pupae produced.

Table 2.3: Insecticides used in field trials to determine the effect on medfly development

Treatment	Active ingredient	Application rate
Untreated control	N/A	water only
Positive control	Fenthion	75 mL/100L
Calypso®	Thiacloprid 480 g/L	37.5 mL/100L
Samurai Systemic Insecticide™	Clothianidin 500 g/kg	40 g/100L
Delegate™	Spinetoram 250 g/kg	20 g/100L

Table 2.4: Methodology for trials 1-6

Trial #	Crop	Method
1	nectarine	Adults allowed to oviposit for 24 h, then sprayed.
2	peach	Adults allowed to oviposit for 24 h, then sprayed.
3	peach	Adults allowed to oviposit for 48 h, then sprayed.
4	peach	Fruits sprayed, medfly released after 7 days. Fruits collected after 24 h.
5	peach	Fruits sprayed, then collected after 24h and naturally infested in laboratory
6	peach	Fruits sprayed, then collected after 7 days and naturally infested in laboratory

2.5.4 Data Analysis

Mortality data (topical bioassay) and the percentage of emerging adults were transformed (arcsin) prior to analysis to normalise data. Topical bioassay were analysed with one-way ANOVA, with treatment as a fixed factor and trial number as a blocking factor; sexes were separately analysed. If significant, means were separated by least significant difference at P=0.05).

The numbers of pupae produced and percentage of emerging adults were analysed by ANOVAs (Proc Mixed Procedure) with tree as blocking. All analyses were carried out with SAS 9.3 software (SAS Institute, Cary, NC, USA)

2.5.5 Effects on non-target organisms

Knowledge of the effect of pesticides on beneficial insects and mites is vital so that growers can select pesticides that will reduce medfly, but have a reduced effect, or are compatible to use with beneficials. Information on the side-effects of insecticides on common beneficial insects was obtained from side-effects tables published by Biobest (http://www.biobestgroup.com/en/side-effect-manual) and Australasian Biological Control (http://www.goodbugs.org.au/chemicals.html).

2.6 New Technologies

2.6.1 Attract-and-kill

Female medfly require dietary protein for ovary development and for egg production, with male medfly requiring protein for sperm production. This protein requirement underlies the attraction of medfly to ammonia, to the three-part lure used in monitoring programs, and to liquid protein baits used in bait sprays. This attraction is being exploited for use in attract-and-kill programs to suppress medfly on commercial orchards in Europe (e.g. Casagrande 2009; Navarro-Llopis *et. al*. 2013).

Attract-and-kill systems use food attractants to approach and contact a point source, whereas mass trapping uses the same attractant, but flies are killed and retained in traps.

Devices tested

Two commercially available devices were tested: MagMED® (known as Magnet™ MED outside Australia) and Probodelt (Fig. 2.7). MagMED® (Suterra Inc., Bend, Oregon, USA) consisted of a paper (2012) or plastic (2013-14) envelope coated with the synthetic pyrethroid (SP) deltamethrin, with holes in the middle of the envelope to emit attractant odours (Casagrande 2009). The attractant used within MagMED® was BioLure® Unipak® (Suterra), a single sachet containing ammonium acetate, putrescine and triethylamine. Flies are killed when they come into physical contact with the envelope. MagMED® was trialled from 2012-2014 (3 years).

The Probodelt conetrap (Probodelt, Spain) was supplied as a flat plastic, yellow trap, with a clear plastic lid (150 mm diameter). The lid was pre-treated with the synthetic pyrethroid alpha-cypermethrin, to kill flies coming into contact with the lid. The bottom of the trap was constructed by inserting plastic tabs into holes (35 mm diameter). Walls were formed by inserting 35 mm long tabs into 35 mm slots on the edge of the trap base, to form a cone 160 mm long and 135 mm wide. The total trap height was 190 mm (base + lid). There were four invaginated holes 65mm apart, 25 mm in diameter, 15 mm deep and 60 mm from the top of the assembled trap. The attractant used was Ceratitis® Unipack®, a single diffuser consisting of ammonium acetate, triethylamine and alkaline diamine. Trials with Probodelt were carried out in the 2014-15 season only.

All devices were hung 1.2-1.5m from the ground by plastic hooks incorporated into the device (see figure 2.6).

Field trials

MagMED®

Trial 1 (2012 season)

MagMED® was evaluated in apple (mixed cultivars) from February to April 2012 (9 weeks) in two orchards. Orchard 1 was a commercial orchard in Jarrahdale, and orchard 2 an unmanaged orchard in Karragullen. MagMED® devices were installed on the 16 February and 9 February 2012 in orchards 1 and 2 respectively, at the rate of 75 devices per Ha. The recommended application rate is 50-75 devices per hectare, depending on crop and pest level. For areas of high infestation and higher value crops such as stone fruits, the recommended rate was 75 devices per hectare (Suterra 2013).

Trials 2 (2012-13 season)

MagMED® was evaluated in eight mixed pome (apple, pear) and stone fruit (nectarine, plum, peach) orchards from 15 November 2012 to 28 March 2013. Orchard location, crop, plot size, trial duration, and any

Figure 2.7. Attract and kill devices from left: MagMED® and Probodelt cone trap.

additional treatments are listed in Table 2.5. Devices were installed on the 8 November 2012 (Jarrahdale), 18 November 2012 (Karragullen) and 14 December 2012 (Carmel) after fruit set (fruits 1.5-2 cm in size) at the recommended rate of 80 per Ha.

Trial 3 (2013-14 season)

MagMED® was evaluated in orchards 1 and 2 at Jarrahdale (Table 2.5). Devices were installed on in September 2013 at flowering. No additional fruit fly treatments were carried out on either orchard, and no pesticides were applied for any pests or diseases.

Probodelt

Trial 1 (2014-15 Season)

Four trials were carried out on four commercial orchards from 17 October 2014 in Jarrahdale, Karragullen, and Walliston. Probodelt devices were installed in October (Karragullen, Walliston), and November 2014 (Jarrahdale) at the recommended rate of 80 per Ha. Orchard location, crop, plot size, trial duration, and any additional treatments are listed in Table 2.6.

Monitoring

Male and female medfly were monitored as described in the monitoring section. In MagMED® trial 1, two male traps were installed per plot with minimum distance between traps of 25 m. In subsequent trials of MagMED® and Probodelt, one pair of traps (male, female) was installed in each plot, with a minimum distance between traps of 25 m (1 trap pair/Ha). In all trials, traps were checked weekly and lures and killing agent replaced every six weeks. The numbers of flies per trap per day were calculated.

Table 2.5: Orchard location, plot size, crop and treatments applied in MagMED® trials

Orchard and location (trial period)	Plot size (Ha)	Crop	Treatments
1 Jarrahdale (22/11/12-14/3/13 – 17 w) (19/9/13-1/5/14: 33 w)	1.8	apple (Gala, Pink Lady, Red Delicious, Golden Delicious, Granny Smith)	MagMED®
	3.1	As above	No treatment
2 Jarrahdale (22/11/12-14/3/13 – 17 w) (12/9/13-1/5/13: 34 w)	2.6	apple (cv. Royal Gala, Golden Delicious), nectarine, pear (cv. Barlett), plums (Tegan Blue) (13/14 season)	MagMED®
	1.2	apple (cv. Royal Gala, Golden Delicious), plum (Tegan Blue), pear (cv. Bartlett), nectarine (13/14 season)	No treatment
3 Jarrahdale (15/11/12-14/3/13: 18 w)	2.25	apple (Granny Smith, Pink Lady, Royal Gala), nectarine	MagMED® + 2 x weekly baiting, 1 cover spray (fenthion)
	3.4	As above	2 x weekly baiting, 1 cover spray (fenthion)
4 Karragullen (29/11/12-7/3/12: 15 w)	2.0	Nectarine (cv. August Pearl)	Weekly baiting
	1.7	As above	MagMED® + weekly baiting
5 Karragullen (29/11/12-7/3/12: 15 w)	2.1	Pear, Nectarine	Weekly baiting
	2.4	As above	MagMED®+ weekly baiting
6 Carmel (20/12/12-7/3/13: 12 w)	3.3	nectarine (cv. August Red), plum, peach, pear	Weekly baiting/cover spraying
	3.3	As above	MagMED® + above
	1.9	As above	Weekly baiting/cover spraying
	1.5	As above	MagMED®+ above
7 Jarrahdale 15/11/12-14/3/13: 18 w)	2.5	apple (cv. Pink Lady, Royal Gala, Granny Smith), nectarine	Weekly baiting/cover spraying
	2.7	As above	MagMED®+ above
8 Jarrahdale (29/11/12-14/3/13: 16 w)	1.6	Apple (cv. Pink Lady, Royal Gala, Jonathon)	Weekly baiting/cover spraying
	1.5	As above	MagMED®+ above

Table 2.6: Orchard location, plot size, crop and treatments applied in Probodelt trials

Orchard (trial period)	Plot size (Ha)	Crop	Treatments
1 Karragullen (17/10/14-15/1/15 – 20 weeks)	1.5	Peach, nectarine, plum	Probodelt + twice weekly baiting
	1.5	As above	Twice weekly baiting
2 Walliston (27/10/14-23/1/15 – 19 weeks)	1.5	Apricot (cv. Golden Sweet), nectarine (cv. August Red), peach (cv. Summer Flame), plum (cv. Blood Moon)	Probodelt + twice weekly baiting, 1 application of thiacloprid (Calypso™ 480SC Insecticide)
	1.5	As above	Twice weekly baiting, 1 application of thiacloprid
3 Jarrahdale (21/11/14-30/4/15 – 23 weeks)	1.8	Apple (cv. Pink Lady, Jonathan, Sundowner)	Probodelt + twice weekly baiting, 1-2 cover spray fenthion, 1 cover spray thiacloprid
	1.6	As above	MagMED® + twice weekly baiting, 1-2 cover sprays fenthion, 1 cover spray of thiacloprid
	1.6	As above	twice weekly baiting, 1-2 applications of fenthion, 1 application of thiacloprid
4 Jarrahdale (21/11/14-30/4/15 – 23 weeks)	1.6	Apple (cv. Pink Lady, Jonathan, Sundowner, Granny Smith)	Probodelt + twice weekly baiting, 1-2 cover sprays fenthion, 1 cover spray of thiacloprid
	1.6	As above	MagMED® + twice weekly baiting, 1-2 cover sprays fenthion, 1 cover spray of thiacloprid
	1.6	As above	twice weekly baiting, 1-2 cover sprays fenthion, 1 cover spray of thiacloprid

Fruit Infestation

MagMED®

In trial 1, ten trees of the same cultivar were randomly selected from within the MagMED® and 'untreated' plots each week. From each selected tree, ten fruit were assessed (non-destructive sampling) for fruit fly damage (oviposition stings, fruit fly larvae). In trial 2, fruits were sampled for fruit fly damage on 7 February 2013 (apple, nectarine; Jarrahdale), 16 February 2013 (pear, nectarine, peach; Karragullen, Carmel), and 11 March 2013 (pear, Carmel, Karragullen).

In trial 3, fruits were visually assessed for fruit fly damage in the field, collected into separate bags (1 bag = 20 fruits per tree, 20 trees per treatment per fruit type), and transported to the laboratory. In the laboratory, fruits were placed in 13L plastic tote boxes (Nylex; 440 x 330 x 180 mm) and stored in a constant temperature room (24 ± 2ºC, 16:8 L:D cycle, 40-50% RH) for 3-4 weeks after harvest. Nectarines (unknown cultivar) and plums (cv. Tegan Blue) were collected from orchard 2 on 13 January 2014, and 28 January 2014 respectively. Apples were collected from orchard 1 on 29 May 2014.

Probodelt

Six hundred mature fruits were randomly selected from each treatment block in the field, collected into separate bags (1 bag = 30 fruits per tree, 20 trees per treatment per fruit type), and transported to the laboratory. In the laboratory, fruits were placed in 13L plastic tote boxes and stored in a constant temperature room (24 ± 2ºC, 16:8 L:D cycle, 40-50% RH) for 3-4 weeks after harvest.

Fruits were collected on 16 December 2014 (apricot, Walliston), 15 January 2015 (nectarine, Karragullen), 23 January 2015 (nectarine, peach, plum, Walliston), and 30 April 2015 (apple, Jarrahdale orchards 1 and 2).

Statistical Analysis

MagMED®

Weekly trapping data were converted to number of fly catch per trap day (f/t/d) and transformed (square root: $\sqrt{(x+0.05)}$ (Zar, 1999)) for statistical analyses. Treatment differences were analysed by ANOVAs (Pro Mixed Procedure: with restricted maximum likelihood (REML) separately for each orchard (fixed factor: treatment and observation time). For trials 2 and 3, male and female-targeted trap catch data were separately analysed.

The percentage of fruit damaged by medfly was transformed (arcsine (x + 0.05)) prior to data analysis (Zar, 1999). Fruit damage data from each orchard in trial 1were analysed with separate ANOVAs (Proc Mixed). If ANOVA results were significant, means were separated with least squared means differences ($P = 0.05$). Fruit damage data from trials 2 and 3 were subjected to separate two-sample t-test (Proc ttest procedure) for each crop type and each orchard.

Probodelt

Weekly trap catches were transformed prior to analysis as above. Treatment differences were analysed by repeated measures ANOVAs (Proc Mixed Procedure: with restricted maximum likelihood (REML)) for male targeted trap and female targeted traps for each trial (fixed factor: treatment, subject: trap numbers, repeated factor: number of weeks sampled, response variable: fly per trap per day).

Data was transformed (arcsine (x + 0.05)) prior to data analysis (Zar, 1999). The percent of damaged fruit between treatments were compared with a two-sample t-test (Proc ttest procedure) for individual fruit type in each trial. For the Jarrahdale trials, which had three treatments, the percentage of fruit damage was compared with ANOVAs (Proc Mixed). If ANOVA results were significant, means were separated with least square mean differences with Tukey adjustment (ls means, $P < 0.05$). Data were reverse transformed for presentation. Statistical analyses were performed in SAS 9.3 (SAS Institute, Cary, NC, USA).

2.6.2 High density trapping (town)

Whilst bait spraying is traditionally applied to urban areas in a community baiting scheme (Sproul 2001), mass trapping has several advantages over bait spraying. High density trapping is cheaper than baiting (approx. A$10 per device), it is easier to apply, it is not as disruptive to householders as only three visits a year are required to replace lures compared to weekly spraying, and less pesticide is used.

To protect commercial orchards in the area closest to the town, trapping devices were installed (Fig. 2.8, 2.9).

Figure 2.8. White dots indicate the location of mass trapping devices in Jarrahdale town.

Figure 2.9. Setting up Maxitraps for mass trapping the Jarrahdale town-site. From left: Sonya Broughton, Paul Murphy, Ian Lacey (back), Alven Soopaya (front), Bill Woods and Amandip Virdi.

In November 2012 Cera Trap® was installed on 57 properties. Cera Trap® is a wet trap marketed as a 100% organic and pesticide free fruit fly trap (Barmac 2015) and available on the domestic market. In November 2013, Cera Trap® was replaced with a dry trap, Maxitrap-Cc (Fig. 2.9). The lure used was the three part food attractant (BioLure®, Suterra Inc., Bend, Oregon, USA). Traps were re-lured in March 2014 and November 2014.

Householders were informed about the activity by media releases and letter drops (Appendix 1.2).

2.6.3 Which lures and traps are the best to use for monitoring or mass trapping?

To determine which traps and attractants are the cheapest and most effective for orchardists to use, we carried out a series of trials with commercially available lures and traps (Fig. 2.10). Sixteen field trials were conducted from 2013 to 2015 in pome and stone fruit orchards in the Jarrahdale production area. All trial areas were with freestanding or trellised trees and no management for medfly or other pests and diseases was carried out during the trial period.

Trial Layout

In each trial, three or five inner rows (blocks) of either pome or stone fruits were selected, with each block using all tested lures or traps (Tables 2.7, 2.8). At least two outer rows on either side were excluded to minimize the edge effects on the trial. All treatments were arranged in a randomised complete block design. In each row, the first trap (randomly selected) was hung on the tree at a height of 1.5 m. This was followed by other traps placed at intervals of 20-metres to avoid direct interaction between traps (Navarro-Llopis *et al.* 2008). In each block, traps were rotated clockwise each week.

Traps were checked weekly and the numbers of male, female and total flies were recorded.

Evaluation of male-targeted lures

Eight trials were carried out to evaluate the effectiveness and longevity of commercially available male-targeted lures. All trials included Capilure® as the positive control, and all lures were tested in modified Lynfield traps as described in section 2.3. Though Capilure® is the standard lure used by DAFWA and other agencies following experiments by Hill (1987), the longevity of trimedlure has been improved by incorporating it into solid dispensers, thereby reducing evaporation rates. Comparisons were made with: 1) liquid lure and insecticide formulations, 2) solid cones and plugs, and 3) lure wafers (Table 2.7). All traps contained a DDVP strip as the killing agent.

Cotton-wicks and TML wafers were hung from the lid by a paper clip, whilst TML plugs and cones were placed in perforated plastic baskets hung from the lid. Capilure wicks were replaced every eight weeks, whilst the other lures were not changed during the trial period.

Evaluation of female-targeted lures

Three trials were carried out from 29 January to 30 April 2015; two in apple and one in pear. Four types of food attractant including dry attractants and a gel were tested (Table 2.7). Attractants consist of two (ammonium acetate or ammonium ethanoate (FFA), putrescine (FFP)) or three components (FFA, FFP and triethylamine (FFT)). BioTrap® Globe traps (BioTrap Australia, www.biotrap.com.au/traps/) were used in all trials. Sachets were stuck to the sides of the trap and 50-60 mL of BioTrap® gel was added at the bottom of the trap. In each trap, a 10 mm x 20 mm dichlorvos pest strip (Killmaster®, Barmac, Australia) was placed at the bottom of the trap as a killing agent.

Table 2.7: Male and female targeted attractants tested

Attractant	Manufacturer
1. trimedlure 2g cone 2. trimedlure 2g plug 3. trimedlure wafer 4g 4. trimedlure wafer 6g	Farma Tech International Corporation, Washington, USA
5. capilure on cotton dental wick	Bugs for Bugs (Mundubbera, Australia)
6. capilure on cotton dental wick	International Pheromone Systems Ltd., Cheshire, United Kingdom
1. BioTrap® gel (98%hydrolysed proteins and vegetable based stabilizers - xanthan gum, 2%)	BioTrap Australia
2. 3-part BioLure®, separate white sachets of FFA, FFP & FFT	Suterra Inc, Bend, Spain
3. BioLure® Unipack, single white sachet containing FFA, FFT and FFP	Suterra Inc, Bend, Spain
4. Ceratitis® Unipack, single white sachet containing FFA, FFT and FFP	Probodelt™, Tarragona, Spain
5. BioTrap TMA Plus®, single yellow plastic sachet containing FFA & FFP	Süsbin S.A, Mendoza, Argentina

Table 2.8: Field trials

Trial	Trial Duration	No of blocks	Trap type	Attractant	Crop
1	23/1/13-6/6/13 (19 w)	3	Modified Lynfield (L)	M	Nectarine
2	As above	3	L	M	Apple
3	As above	3	L	M	Pear
4	10/1/14-14/3/14 (10 w)	3	L	M	Nectarine
5	As above	3	L	M	Apple
6	As above	3	L	M	Pear
7	29/1/15-30/4/15 (13 w)	3	L	M	Apple
8	As above	3	L	M	Apple
9	29/1/15-30/4/15 (13 w)	5	GlobeTrap (GT)	F	Apple
	As above	3	GT	F	Apple
10	As above	3	GT	F	Pear
11	17/1/14-20/3/14 (9 w)	5	GT (v1), CT, MT, TT	F	Peach
12	9	5	GT (v1), CT, MT, TT	F	Plum
13	29/1/15-30/4/15 (13 w)	3	GT (v1,2), CT, MT, TT	F	Apple
14	13	3	GT (v1,2), CT, MT, TT	F	Pear
15	13	3	GT (v1,2), CT, MT, TT	F	Plum

Evaluation of traps

Traps compared were the Globe trap (GT, two types v1 and v2 - BioTrap Australia), Maxi® trap (MT, Probodelt, Spain), Sorygar Tephri-trap® (TT, Sorygar, Spain) and Cone® trap (CT, Probodelt, Spain) (Fig. 2.10). Lures and DDVP pest strips were changed every eight weeks.

A = FT™ Plug (2gm TML), B = FT™ Cone (2gm TML), C = FT™ Wafer (4gm TML), FT™ Wafer (6gm TML), Capilure™ (2ml TML), Ceralure® (2ml TML); TML = Trimedlure

Figure 2.10. Female traps trap types. From top left: Maxi® trap, Sorygar Tephri-trap®, BioTrap Globe trap version 2,Biotrap Globe trap version 1, Cone® trap. Below: male lures tested.

Statistical Analysis

Data were converted to number of fly catch per trap per day (f/t/d) and transformed (square root: $\sqrt{(x+0.05)}$) (Zar, 1999) for statistical analyses. Treatment differences were analysed by repeated measures ANOVAs with block effects (Proc Mixed Procedure: with restricted maximum likelihood (REML)), where appropriate for male, female and total fly individually for each trial (fixed factor: treatment, subject: trap numbers, repeated factor: number of weeks sampled, block factor: tree rows, response variable: male fly, female fly, total fly).

If ANOVA results were significant, means were separated with least square mean differences (lsmeans, $P < 0.05$). Data were reverse transformed for presentation. Statistical analyses were performed in SAS 9.3 (SAS Institute, Cary, NC, USA).

2.6.3 Sterile Insect Technique

Medfly was mass-reared at the DAFWA sterile medfly facility in South Perth. Seven days prior to release, pupae were irradiated in nitrogen at 160 Grays (Gy). Pupae were then dyed at 4 g/L with one of three fluorescent pigment colours that were rotated weekly: orange (Arc Chrome), yellow (Lunar Yellow) and pink (Magenta). The dye is retained in the ptilinum (head) of the adult after emergence, allowing sterile flies to be identified when examined under ultra-violet light.

An epifluorescent microscope was used to separate and count sterile and wild flies. Sixty mL of pupae (approx. 3,600 flies) were placed in a paper bag, then into a vented 5L paper tub. A 'scrunched up' paper insert was included to increase surface area for flies for wing hardening, grooming etc. upon emergence. A 100 mL container of agar/sugar/water was placed in the tub to supply food and water. Flies were emerged at 25º C in a constant temperature (CT) room and exposed to ginger root oil (GRO) at 0.5 mL/cubic metre, for 24 hours prior to release. GRO increases the mating success of sterile male medfly (Steiner *et al.* 2013).

The ability of flies to emerge from pupae and to fly was tested post irradiation using the standard IAEA protocol. Flightabilty ranged from 78 to 92 with an average of 89%.

Trial sites

Roleystone

Figure 2.11. Jeremy Lindsay releases sterile flies in Roleystone.

Once a week 140 tubs with emerged flies were loaded into the release pod and driven to the release site bordered by Contour, Urch, Peet, Jarrah, Norman and Mackie Roads. Assuming 80% flightabilty, the release rate was approximately 270,000 flying males/km^2 or 2,700/Ha over 1.5 km^2. The release vehicle held a driver, release coordinator and a person to release the flies (Fig. 2.11). Where possible, all roads within the release area were traversed and every 130-150 m flies were gradually released until the next release point. Time taken for loading, release and travel was approximately 4 hours. Sterile release commenced on October 12 2012 and finished on December 13 2012, with 10 weekly releases in total.

Ten Jackson traps were placed in

the release and non-release area in a grid pattern and checked weekly. Traps were placed in fruit trees (loquat, citrus, apples and stone fruit) on October 24 and removed on January 9. An additional five traps were installed in ornamental shrubs on the route to and from the release area on October 5 and removed on 9 January. Trap data was used to measure the distribution of sterile flies and to estimate over flooding ratio (the ratio of sterile to 'wild' medfly caught in traps).

Fruit collection

Figure 2.12. Alven Soopaya releases sterile flies in a stone fruit orchard.

Fruit was collected from the control and release sites where possible. Fruit was counted and placed over sand or vermiculite in containers in the insectary for adult emergence. The number of adult flies that emerged was recorded.

Effect of grid spacing on the distribution of sterile medfly

In January and February 2013, trials were undertaken in a nectarine orchard to study the spatial distribution of male sterile medfly when released on different grid spacing (Fig. 2.12). The aim was to determine the optimal spacing that would still give even distribution of released sterile flies in an orchard environment. In trial 1 flies were released at 40 and 80 m grid spacing whilst in trial 2 it was 50 and 100m (Table 2.9). Fly number released at each grid point was calculated so that approximately the same total number of flies were released for each treatment over each trial plot.

Male pupae two days from emergence were irradiated at 160 Gy and then allowed to emerge in buckets. Each bucket containing about 20 ml of the irradiated pupae and agar/sugar jelly was supplied for food and water. To differentiate between flies from the various treatments and from the wild flies, pupae were marked with fluorescent powders immediately after irradiation and released on day 5-6.

Table 2.9: Details of SIT distribution trials at Jarrahdale

Distance (m)	Trial 1		Trial 2	
	40m	80m	50m	100m
No of Release points	20	6	15	5
No of flies per release point	600	2400	1200	3600

Medfly distribution was assessed by counting the number of flies recaptured 3 and 7 days after release using 12 Jackson traps with trimedlure plugs and placed in a 4 x 3 grid pattern within the release area.

Effect of bait spraying on sterile medfly

This study was undertaken in an apple orchard to investigate the possibility of combining bait spraying with SIT. Medfly were reared, irradiated and emerged as described above. On day 3, 5, 9 and 11 after baiting, approximately 20,000 flies were released over 3 rows with 3 release points at 50 m intervals along each row with different dye colour for each release day. Eight Jackson traps with trimedlure plugs placed in between the three rows were used to monitor the number of sterile flies recaptured 2 and 5 days after each release.

Mass release trial in Jarrahdale town site

On 29 April 2014, flies were released from 60 tubs each containing 20 mL of pupae in the gravelled area north of Jarrahdale Rd and south of Millars Rd. Assuming 80% flight ability, this resulted in the release of approximately 57,000 flying males. In the following three weeks, any medfly caught in modified Lynfield traps were checked under the microscope for sterile flies. Before release, the town traps immediately adjacent to the release point were covered with plastic bags to prevent ingress of sterile flies.

Outputs

- Summer and autumn were identified from monitoring and degree-day modelling as the peak periods for medfly activity in the Perth Hills, coinciding with ripening periods of stone and pome fruits respectively.
- Suitable medfly hosts are available throughout the year on commercial orchards, particularly in citrus planted for household use.
- Trap monitoring shows that flies remain within a few tens of metres of where they emerge; sterile releases indicate that 90% remain within about 400-700 m of the release point. Few flies were trapped in native bush.
- Medfly overwintering on commercial orchards is the most likely source of spring infestations in all growing areas.
- Bait spraying was more effective than cover spraying at suppressing medfly below the economic threshold of 1 fly per trap per day. However, in situations when the threshold is triggered, growers may need to apply a cover spray.
- The neonicotinoids Samurai Systemic Insecticide™ (clothianidin) and Calypso® (thiacloprid), and spinetoram have efficacy against medfly eggs and larvae. In field trials, fenthion was the most effective, followed by clothianidin, then thiacloprid. However no treatment was completely effective in reducing fly emergence.
- Spinetoram was slow acting, killing the majority of adults by 72 hours (3 days) post-exposure. Females that had been treated with spinetoram were able to lay eggs, though they laid fewer eggs compared to the control (water only).
- The commercial devices MagMED® and Probodelt cone traps applied at a rate of 80 devices/Ha reduced medfly damage to pome and stone fruit.
- Maxi traps followed by Globe traps and cone traps caught more medfly than Tephri traps, with three-part Biolure and the Unipak BioLure® and Ceratitis BioLure® catching more flies than other lures tested.
- SIT in small areas without pre-release baiting is not a stand-alone control technique.
- Integration of baiting with other control measures such as mass trapping, lure and kill or the sterile insect technique will increase the efficacy of control.
- Publications in grower magazines:
    - Fight steps up against Medfly, page 8-9, Fruitwest Magazine, spring Edition 2012. http://www.fruitwest.org.au/images/stories/Magazine/FW_Spring12_LR.pdf
    - Recommended actions for area-wide management, pages 10-12, Fruitwest Magazine, spring Edition 2012. http://www.fruitwest.org.au/images/stories/Magazine/FW_Spring12_LR.pdf
    - Medfly Research stepping up. Page 19, Fruitwest Magazine, Summer Edition 2012. http://www.fruitwest.org.au/images/stories/Magazine/FW_Summer_2012.pdf
    - Understanding fruit fly traps, pages 16-17, Fruitwest Magazine, Autumn Edition 2013. http://www.fruitwest.org.au/images/stories/Magazine/FWAutumn13_LR1.pdf
    - The Medfly life cycle, Pages 18-19. Fruitwest Magazine, Autumn Edition 2013. http://www.fruitwest.org.au/images/stories/Magazine/FWAutumn13_LR1.pdf
    - Hills Medfly Research Update, pages 18-19. Fruitwest Magazine, Spring Edition 2013.

http://www.fruitwest.org.au/images/stories/Magazine/FWSpring13_LR_SMALL.pdf

- Getting the jump on medfly this season, pages 20-12, Fruitwest Magazine, Spring Edition 2013. http://www.fruitwest.org.au/images/stories/Magazine/FWSpring13_LR_SMALL.pdf
- Apples confirmed as overwintering hosts for Medfly, page 14. Fruitwest Magazine, Summer Edition 2013. http://www.fruitwest.org.au/images/stories/Magazine/FWSummerFW13_LR.pdf
- Medfly update. News Update, Fruitwest, October/November 2013. http://www.fruitwest.org.au/images/stories/Newsletters/2013/Fruitwest_Newsletter_Nov2013.pdf
- Mass trapping research wrap-up, Fruitwest Magazine, Winter Edition 2013, pages 16-17. http://www.fruitwest.org.au/images/stories/Magazine/FWWinter13_LR.pdf
- Medfly Update. News Update, Fruit West, August/September 2013. http://www.fruitwest.org.au/images/stories/Newsletters/2013/Fruitwest_Newsletter_Medfly_2013.pdf
- New Medfly mass trapping trial, Fruitwest Magazine, Autumn Edition 2014, page 10.Medfly monitoring results for Jarrahdale and the Perth Hills, Season 2013-14. http://www.fruitwest.org.au/images/stories/Medfly%20summary_1%20of%202013-14.pdf
- Non-chemical control a feature at international fruit fly symposium, The Vine, The Quarterly Journal for the Table Grape and Dried Fruits Industries, Volume 10, Issue 3, pg. 23-24. http://www.australiangrapes.com.au/__data/assets/pdf_file/0008/17288/2014_JUL-SEP.pdf

Outcomes

- Bait spraying has been adopted by all commercial growers in Jarrahdale following the demonstration of its efficacy, though some growers also continue to use cover sprays. Bait spraying is also being adopted by growers in other areas such as Carmel, Karragullen and Pickering Brook.

- Area-wide management of medfly was effective at suppressing medfly in Jarrahdale, and we have demonstrated that it is possible with small groups of growers (1-3) provided that bait spraying is carried out on a regular basis and to the whole orchard regardless of whether ripe fruit is present or not.

- Autumn migration of medfly was identified as a significant risk, particularly to pome fruit growers. It is recommended that bait sprays be applied through autumn (March-April) to curb the dispersal of medfly adults to over wintering hosts, thus reducing the pest load in the following spring. Strict orchard hygiene also needs to be adhered to, to ensure that any hosts containing medfly eggs and larvae are destroyed.

- The neonicotinoids Samurai Systemic Insecticide™ (clothianidin) and Calypso® (thiacloprid), killed medfly eggs and larvae when fruit was treated 7 days after medfly had been allowed to lay eggs. They are both possible replacements for fenthion.

- Attract-and-kill devices (MagMED®, Probodelt Conetrap) were ineffective as a stand-alone treatment in pome and stone fruit, and need to be combined with bait spraying. Reports have been provided to the relevant companies to support registration.

- Attract-and-kill devices are currently more expensive than conventional controls. For example, weekly baiting costs Aus $120 to $580 per Ha per season (6 months per year; excluding labour, fuel and machinery costs) compared to attract and kill (Aus $520-560/Ha). Cover sprays are also cheaper, costing Aus $290-$367 (two sprays per year, excluding application costs).

- Growers wanting to develop their own mass trapping systems should use either 3 part BioLure® or Unipak (BioLure® or Ceratitis). These can be used in maxi traps, dome traps or cone traps, together with a strip of dichlorvos as the killing agent. Traps should be applied at the rate of 80 per hectare in high risk crops such as stone fruit.

- Mass trapping appeared to reduce the medfly population within the Jarrahdale town-site. However further work is required to refine the technique for this purpose, and fruit collections are highly recommended to verify efficacy.

- Trimedlure plugs and wafers performed at least as well as, or outperformed Capilure®. Cotton wicks treated with 2 mL of Capilure® are the current standard lure used by DAFWA, and recommended in the Fruit Fly Code of Practice. A report will be prepared for submission to the working group of the Fruit Fly Code of Practice allowing trimedlure plugs to be substituted for Capilure® on cotton wicks.

- Recommendations for further work include lengthening the life of bait sprays by using additives and adjuvants, testing alternate toxicants, and testing the lure and infect (fungal pathogen) and lure and sterilise (insect growth regulator, lufenuron) technique for medfly and Qfly.

3. Evaluation and Discussion

3.1 Temporal and spatial distribution of medfly in the Perth Hills

Studies on the population dynamics of Medfly have shown that the main factors affecting population build up is fruit abundance and availability (phenology), and low winter temperatures in temperate areas (Papadopoulos *et al.* 2001).

A generalised phenology model for the Perth Hills is shown below. In the Perth Hills, fruit phenology was similar in all areas with stone and pome fruit trees dormant from June to late August/September. Apricots, nectarines, plums and peaches flowered in late August/early September, followed by apples and pears in mid-September. Peaches, apricots, and nectarines ripened and were harvested from November through to February. Depending on variety, plums ripened from December through March. Pears and nashi ripened in March, followed by apples from April to May.

Whilst not grown commercially, citrus including orange, mandarin and lemon were found on some commercial orchards for home use. Citrus fruit can be present all year, with winter fruit providing overwintering hosts for medfly larvae.

There is an estimated 8 generations of medfly per year, with highest populations recorded from December-February.

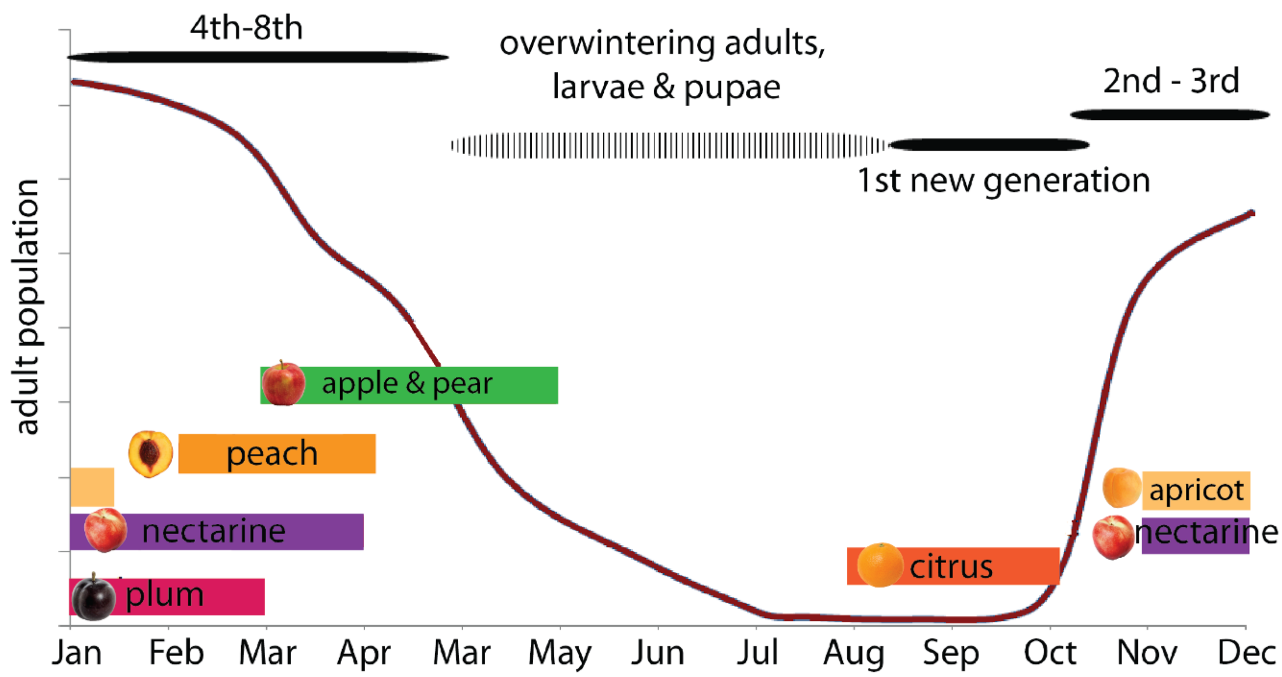

Figure 3.1. Generalised phenology model for the Perth Hills. The red line indicates the predicted abundance of medfly adults.

3.1.1 Fruit fly phenology

Air temperature in Jarrahdale orchards were 0.7–2°C cooler in winter and up to 2.5°C cooler in summer compared to Roleystone and Karragullen, and 0.8–1°C warmer in winter and 0.5–1.3°C warmer in summer than Pickering Brook (Bickley). As temperature has a major effect on fruit fly development (Messenger and Flitters 1954; De Lima 1998; Vera *et al.* 2002), the warmer weather of Roleystone and Karragullen allows a shorter development time compared to Jarrahdale, and a quicker development time in Jarrahdale compared to Pickering Brook (Fig. 3.2).

In spring, medfly take 13 (September) to 7 weeks (November) to develop from egg to mature adult, and 4.3–6.5 weeks in summer. In autumn, the development time lengthens from 6 (March) to 33 weeks (April). The longest development period occurs for eggs laid in April, as adult flies take 5 months to reach maturity due to low maximum air temperatures. This does not allow enough thermal energy to be accumulated until November (Fig. 3.3).

In winter, growth slows to 24 weeks in June and 15 weeks in August. From May to July, cold stress lengthens the larval and pupal stages to one to two and a half months, synchronising the life cycle so that new adults emerge in November. This mirrors the conditions of southern Greece (Heraklion, Crete) the medfly continues reproduction and growth during the cooler part of the year but at reduced rates and with longer duration of larval and pupal stages (Mavrikakis *et al.* 2000).

Thus in spring, the medfly population is made up of newly emerged adults and overwintering older adults. Up to eight generations of medfly can be produced per year, with a generation a month produced from December through February.

Temperature changes in the last decade compared to the previous one indicate a shift to shorter generation times in summer. Based on day-degree models it now takes medfly two fewer days to complete development compared to the previous decade in Karragullen, 1-7 fewer days in Roleystone, 1-2 fewer days in Bickley and 1-5 fewer days in Jarrahdale. The model also shows that it now takes 5-6 days longer for medfly to complete development in autumn (April and May) and 3 more days in August in Jarrahdale compared to the previous decade (Fig. 3.2).

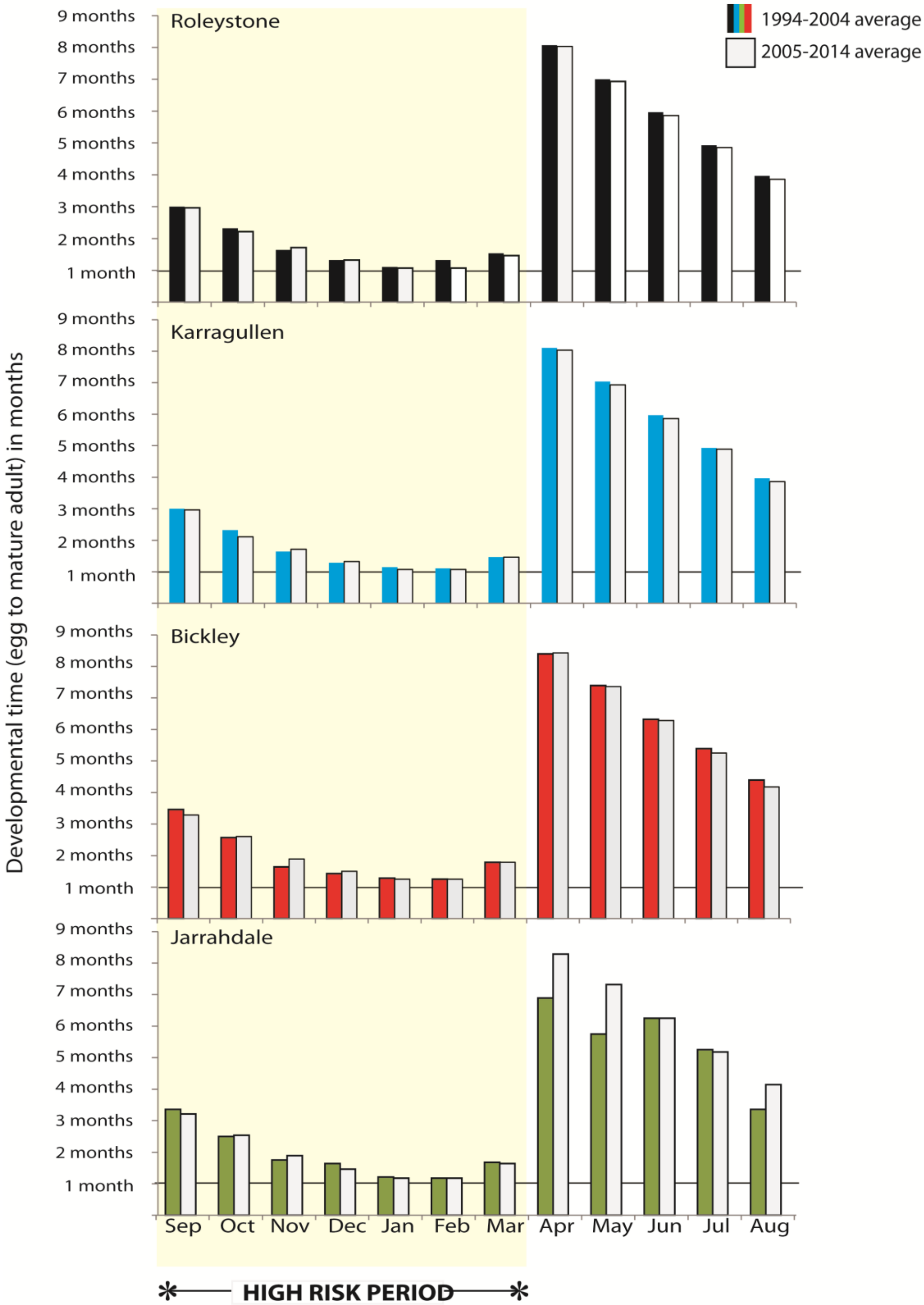

Figure 3.2. Time (months) taken for medfly to develop from egg to adult in four locations in the Perth Hills over the last two decades estimated from degree-day calculations. The high-risk period is September through to March at all locations.

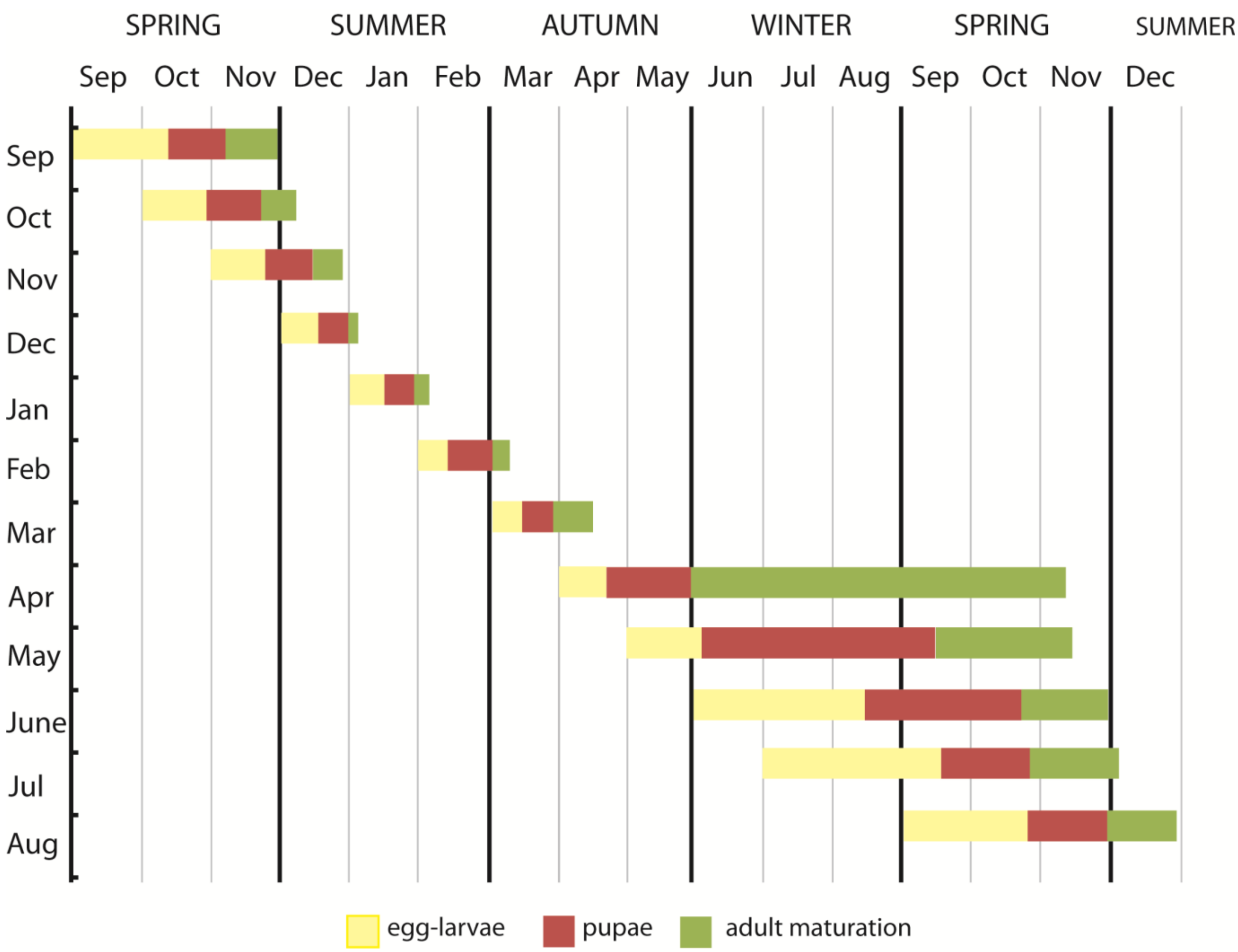

Figure 3.3. Phenology model for medfly in the Perth Hills. The graph shows how long each stage of the lifecycle takes, assuming that eggs are laid at the start of each month. For example, eggs laid in September will not develop into pupae until October, with adults maturing (able to lay eggs) by the end of November (late spring). Eggs laid in April (autumn) take the longest to develop, with adult flies taking >5 months to reach maturity.

3.1.2 Monitoring results

Jarrahdale

- Summer (70.1% of total catch) and autumn (20.3%) are peak periods for medfly activity, coinciding with ripening periods of stone and pome fruits respectively. Whilst populations dropped in winter to 1.9% of total grid catch, adults were caught in traps in June and July in 2012/13. In 2013/14 and 2014/15 flies were caught on all property types in June, but from July to September were only trapped in the town and on lifestyle blocks.
- On commercial orchards, adult medfly-free periods of four months were recorded from August to October in 2013/14 and five months from July to October in 2014/15 (Fig. 3.4). Flies were first trapped in late spring (7 November 2013, 5 November 2014), 3-4 weeks before harvest of peaches and nectarines in December. If these dates are taken as the biofix date (the date at which to start degree-day calculations), the model indicates that these adults overwintered as eggs in early August.
- Medfly abundance increased in commercial orchards in November and December, peaking in January-February after most stone fruit had been harvested. A second peak in abundance occurred in April-May 2013 and April 2014. This was attributed to the movement of adults to suitable over-wintering sites within and around orchards, and the presence of ripe apples and pears.

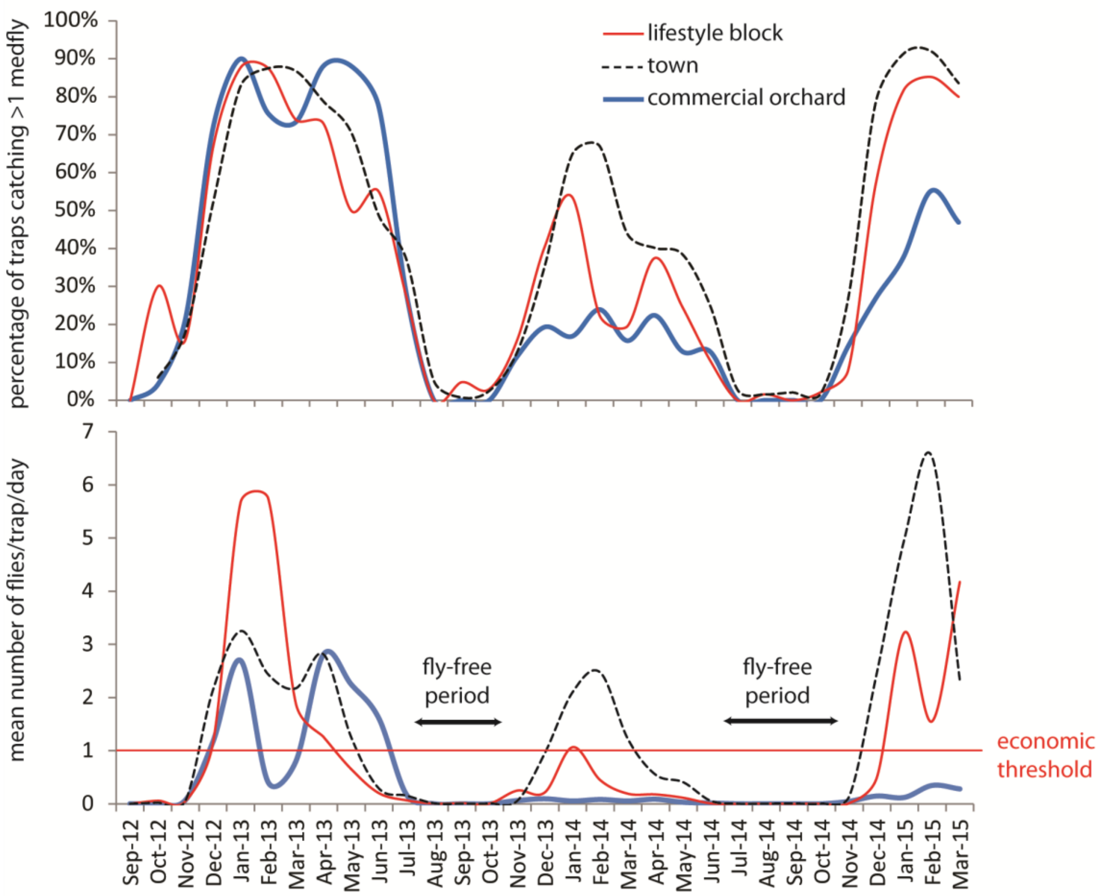

Figure 3.4. Temporal and spatial distribution of medfly in Jarrahdale. The economic threshold was based on 0.1-1.0 f/t/d which indicates population supression (FAO/IAEA 2003).

Roleystone

- Peak periods for medfly activity were spring (17% of total catch) and summer (65.5% of total catch), with lowest activity recorded in winter (2.8% of total catch). Adults were trapped on commercial orchards and in the town from June to August, confirming the presence of an adult overwintering population on orchards (see Appendix 1.2).

- Medfly adult-free periods lasted one month in 2013/14 and two months in 2014/15. In spring, flies were first detected in a single town trap (apricot) on 10 October 2013 and on three commercial orchard traps (citrus, peach) on 17 October 2013.

- In the 2014/15 season, flies were simultaneously detected in three town traps (loquat, citrus) and one orchard trap (citrus) on 2 October 2014. This indicates that growers need to commence medfly control much earlier in the season.

- The percentage of traps catching one or more flies was over 50% for 6 months each year, with flies widespread and abundant on commercial orchards and the town in summer. A distinct peak in abundance occurred in January 2014 (4 f/t/d) and January 2015 (9 f/t/d) coinciding with the ripening of peaches and plums. The economic threshold was exceeded in April and May 2013 and January and February 2015, attributed to commercial growers stopping fruit fly control once all stone fruit had been harvested.

Pickering Brook

- Medfly activity was highest in summer (35.2% of total catch) and autumn (35.1%), coinciding with the ripening periods of stone and pome fruits respectively. Populations dropped in winter to 13.8% of total catch and to 15.9% in spring (see Appendix 1.2).

- In 2013/14 and 2014/15, flies were trapped continuously through winter and spring in traps located in stone, pome fruit and citrus.

- Fewer flies were trapped in traps located in native bush (11.9% of total catch), though it should be noted that bush traps were less than 200m from commercial orchards. Therefore, we do not consider these catches to be truly representative of what occurs in native vegetation.

- In 2014/15 flies were detected in two traps in citrus on 25 September 2014, but were not trapped in stone fruit until 9 October 2014. There were no consistent fly-free periods, with August 2014 the only month when no flies were trapped. Most growers did not start to bait until December and finished baiting once fruits had been harvested. This activity was insufficient to suppress medfly below the economic threshold of 1 f/t/d.

Karragullen

- Spring (35.8% of total catch) and summer (39.3%) were peak periods for medfly activity. Populations dropped during winter to 20% of total catch and to 4.9% in spring, coinciding with bud burst and flowering (see Appendix 1.2).
- Medfly was trapped continuously through winter and spring from traps located in stone and pome fruit. No contiguous fly-free periods were identified, with September 2013 and 2014 the only months when no medfly was trapped.
- In year 1, the economic threshold was exceeded in November 2013 and December 2013 with >3 f/t/d and between 80-98% of traps catching one or more flies. From April 2013 through to June 2013,

medfly were widespread (93-61% of traps catching >1 flies) and abundant.

- In years 2 and 3, growers maintained medfly below the economic threshold until February 2015. At this time, the action threshold was exceeded, with 70% of traps catching one or more flies. Medfly was trapped in blocks that had been harvested for at least one month.

Summary

- Host fruits are available for medfly year round in the Perth Hills.
- Spring through summer and autumn are the peak periods for medfly activity in all Perth Hills areas. This coincides with the ripening periods of stone and pome fruits respectively.
- Growers that finish baiting early in summer (stone fruit) or autumn (pome fruit) run the risk that medfly will overwinter on their orchard.
- Day degree models suggest that adults emerging in March and April from eggs laid into stone fruits in February and March can survive until spring.
- Trap data and fruit sampling indicates that medfly can overwinter in all stages. Overwintering hosts include apples and citrus.

3.2 Spatial and temporal movement of medfly in the Jarrahdale pilot area

Knowing how medfly survives winter is very important to develop control strategies for management and eradication programs. If medfly overwinters as adults and larvae, then autumn baiting and fruit hygiene become very important to reduce populations in the following spring. If medfly reinvades areas in summer, then baiting needs to target the migrating population.

Two main hypotheses have been proposed to explain the winter survival of medfly:

1. that medfly dies out and migrates from nearby favourable areas in summer (Messenger and Flitters 1954,) or

2. that medfly survives in winter in immature (Papadopoulos *et al.* 1996, 1998, 2001) or adult stages (Messenger and Flitters 1954, Bateman 1972).

In Crete, Greece, Mavrikakis *et al.* (2000) found that adults and immature stages survived winter with minimum temperatures between 1°C and 4.5°C. In Greece, medfly continues to reproduce and grow during the cooler part of the year, but at reduced rates and with longer duration of larval and pupal stages (Papadopoulos *et al.* 1996, 1998; Israely *et al.* 1997; Katsoyannos *et al.* 1998). On the islands of Chios and Volos in Greece, larvae survive in citrus fruits through winter (Katsoyannos *et al.* 1998). Whist in northern Greece, apples are an important overwintering host where temperatures can drop to below freezing and larvae can take up to 6 months to develop (Papadopoulos *et al.* 1996). Whilst in some regions in Israel, medfly reinvade mountainous areas in summer from the plains, dying out over winter (Israely *et al.* 2004).

In the Perth Hills, the capture of adult medfly during winter at all trap sites indicates that the second hypothesis is correct. De Lima (1998) estimates that adults can live for 6 months at 18 °C to 6 weeks at 30 °C. This means that adults emerging in March and April from eggs laid in February and March are able to survive until spring, provided that food and shelter is available. The most likely overwintering sites are citrus trees and other trees with dense canopies, which may not be fruit trees. Research by Newman (cited in Sproul 2001) showed that adult medfly feed on honeydew produced by scale insects and aphids in winter. Common hosts for scale insects are citrus (orange, lemon, mandarin and grapefruit) which also provide oviposition sites for medfly.

Medfly can also reproduce over winter, with female medfly observed laying eggs into oranges when temperatures are above 10°C. Thus, it is the 'old' and newly emerged adults, which attack stone fruits in November and December. Examples of how landscape and land use affects medfly distribution are shown below for two areas in Jarrahdale.

3.2.1 Area 1: Subdivided commercial orchard Jarrahdale

This area consisted of a 33 Ha commercial pome and stone fruit orchard that had been subdivided into smaller lifestyle blocks of 4-8 Ha: the grower retained approx. 23 Ha of orchard for commercial production (apple, pear, nectarine, peach). The commercial orchard was located 600 m from the lifestyle block 1, and consisted of 19.48 Ha with remnant apple, pear and plum blocks. Lifestyle block 2 was 270 m from and adjacent to lifestyle block 1 (Fig. 3.5), covering 8 Ha with remnant apple, peach, and nectarine blocks. In addition, a small stand of citrus consisting of lemon and orange trees was located near the house. Although the distance between the orchard and blocks was small, the adult population size differed.

In year 1, medfly was first detected on lifestyle block 2 on 15 November 2012 in two traps (apples), and the commercial orchard one week later (22/11/12; 1 trap, peach; Figs. 3.5). By the end of November, medfly were widespread across the lifestyle blocks, though below the economic threshold. In December 2012, several hotspots (>1 f/t/d) were detected in traps located on lifestyle block 2 and the commercial orchard. These were caused by flies infesting nectarine and peach blocks prior to, during, and after harvest. Although no fruit were present by the end of December, medfly continued to be trapped in high numbers for 12 weeks. These were the result of medfly emerging from fruit infested in early December, emphasizing the importance of orchard hygiene. The commercial grower applied cover sprays of fenthion weekly from November 2012 to January 2013, and was able to maintain the medfly population below the economic threshold level until 17 January 2013.

In year 2, male medfly were first detected on the commercial orchard on 7 November 2013 (1 trap, nectarine, Fig. 3.6), followed by detections in male traps on lifestyle blocks a week later (2 traps, nectarine, plum). Female medfly were first trapped 14 days after the first male detection (21/11/13; commercial orchard, pear, nectarine). Hot spots were identified in December 2013, with female medfly moving to ripening nectarine and developing apple on lifestyle block 2. In January 2013, hot spots were identified from male and female traps, with flies breeding in nectarines on lifestyle block 2 and moving to developing plums and apples. However, the commercial grower was able to control medfly using a combination of bait and cover spraying.

In year 3, it was not possible to access traps on lifestyle block 2 due to a change in ownership. Female medfly were first detected on 5 November 2014 in traps on the commercial orchard in maturing peach, nectarine and developing apple blocks (Fig. 3.6). The first hot spot was identified in November 2014 in lifestyle block 1 in developing pears (female trap). A second hot spot developed in ripening plums in mid-December (female trap). The commercial grower maintained medfly below the economic threshold with bait and cover sprays (fenthion, clothianidin). However, the economic threshold was exceeded in April 2015, when apples and pears had been harvested and baiting was no longer being carried out.

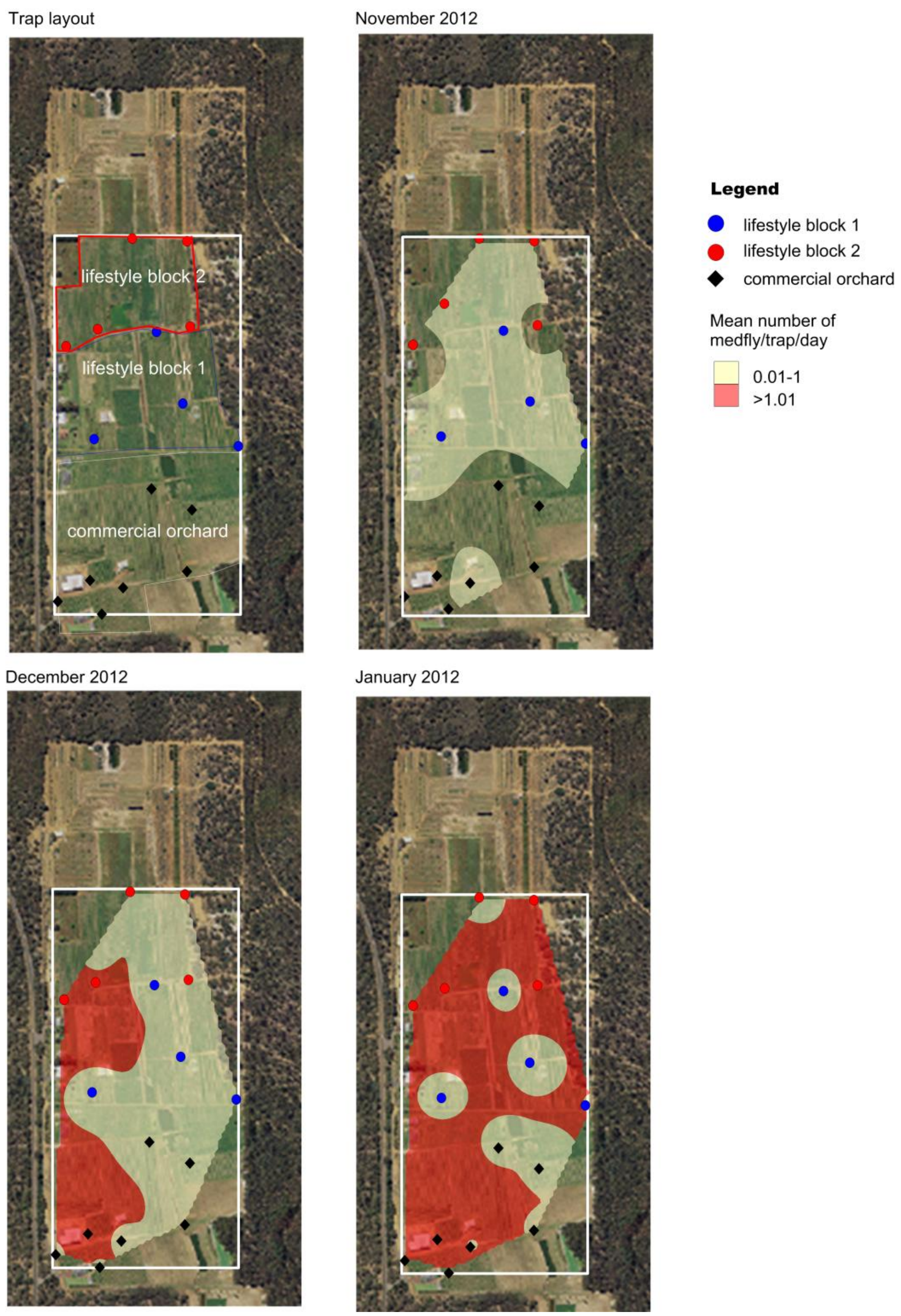

Fig. 3.5. Spatial distribution of male medfly caught in traps in lifestyle blocks adjacent to a commercial orchard in Jarrahdale in Year 1 (2012/13). Hotspots occurred in traps on lifestyle block 2 and the commercial orchard in December 2012 in nectarines and peaches. High medfly numbers continued to be trapped until March 2013, though no fruit were present.

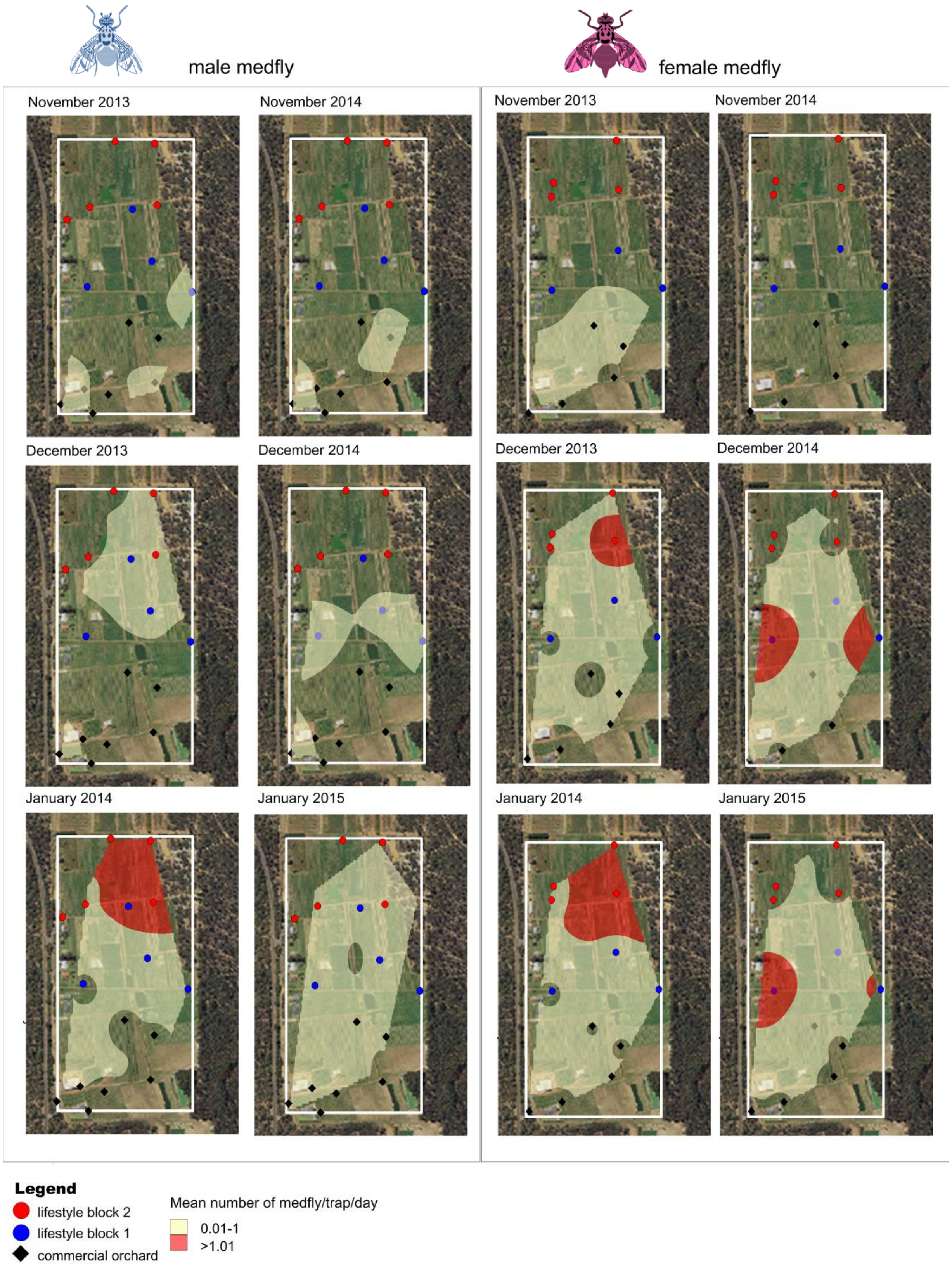

Fig. 3.6. Spatial distribution of male and female medfly in lifestyle blocks adjacent to a commercial orchard in Jarrahdale in Year 2 and 3. Hotspots occurred in traps on lifestyle block 2 and the commercial orchard in December 2013 in nectarines and peaches. High medfly numbers continued to be trapped until March 2014, though no fruit were present.

3.2.2. Area 2: Jarrahdale town site and adjacent orchards

De Lima (1998) previously identified neglected orchards and urban areas as significant risks to commercial growers of pome fruit in Donnybrook and Manjimup. In Jarrahdale, the town is located 600 m from a cluster of five commercial orchards growing nectarines and apples (Fig 3.7). Orchard 1 is closest to town, with 10 Ha of nectarine and apple. Orchard 2 consists of 10 Ha of nectarine and apple, and orchard 3 of 6 Ha of apple. Located between orchards 3 and 4 is an organic orchard with 3 Ha of stone fruit, apple and loquat. Orchard 4 consisted of 6 Ha (apple), and orchard 5 of 13.7 Ha, mainly vegetables, with a small section of apple (0.7 Ha). Small stands of lemon, mandarin or orange trees (1-5 trees) were also located on orchards all orchards.

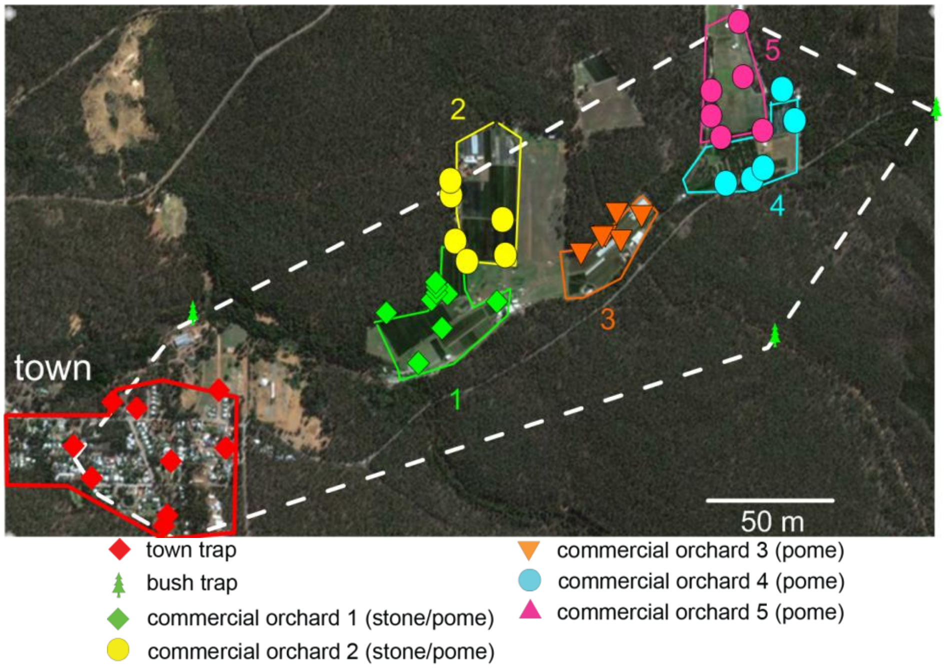

Figure 3.7. Location of commercial orchards in relation to the Jarrahdale town site.

Year 1

Male medfly were trapped on orchard 1 (1 November 2012, nectarine), two weeks after detection in a single town trap (18 October 2012, Fig. 3.8). Medfly were trapped on orchard 2 on 29 November 2012 (apple, nectarine), and orchards 3 (developing apple), 4 (developing apple) and 5 (citrus) on 15 November 2012 (apple).

By mid-December 2012, medfly were widespread over the area with hotspots located in town (traps in lemon) and orchard 3 (apple). In January 2013, multiple hotspots were detected within town, with flies trapped in apricot, lemon, plum, and orange, though no ripe fruit were present. Hotspots were also detected on orchard 4 (developing apple) and in traps (eucalypts) adjacent to the organic orchard. Medfly caught in a single bush trap south of the commercial orchards indicates the presence of a fruit dump in the bush.

To control medfly, growers applied cover sprays (fenthion, spinetoram) from 21 November 2012 through to 24 January 2013 (orchards 1, 2, 3, 4 and 5): the highest numbers of sprays were applied on orchards 1, 2 and 4. Bait sprays were applied from November 2012 to January 2013 (trichlorfon, orchard 2), and December 2012 to January 2013 (Cerabait + Hy-mal, orchards 3 & 4). The economic threshold was exceeded four times on orchard 1 in developing nectarine and mandarin (13, 21 December 2012, 3, 10 January 2013), and twice on orchard 3 in developing apple (20, 27 December 2012). The economic threshold was exceeded 11 times on orchard 4 in maturing and developing apples (17, 24 January, 7 February 2013, 7, 14 March 2013, 4, 11, 18, 24 April) and in May 2013, when some apples were left on the tree after harvest (May 9, 30 2013). On orchard 5, the economic threshold was triggered 21 times from 3 January 2013 through to 30 May 2013 in orange and nectarine. On orchard 2, cover sprays were applied three times to nectarines (December) and bait sprays were applied twice weekly to the whole orchard. On this orchard the economic threshold was triggered once (2 May 2013, apple).

In autumn, orchardists 1, 2 and 3 continued to bait in March and April creating medfly-free zones. However, medfly was widespread in the area in June once baiting for the year had ceased.

Year 2

Male medfly were first detected in town traps on 3 October 2013 (1 trap, lemon), followed by females on 7 November 2013 (1 trap, developing apple, Fig. 3.9). Medfly were first trapped on commercial orchards on 7 November 2013 on orchard 1 (1 male, 1 female trap, developing nectarine, mandarin), followed a week later by detections on orchards 2 (1 male traps developing nectarine) and 5 (1 male trap orange). Detections occurred on orchards 3 (1 female trap, developing apple,) and 4 (1 female trap, developing apple) on 21 November 2013.

By mid-December, medfly were widespread on orchards 1 and 5 in developing and maturing nectarines and developing apples in male and female traps. A hotspot developed on orchard 3 (developing apples) and the eastern side of the town (loquat, lemon). By January, medfly numbers were high throughout the town, with female flies trapped in ripe figs, nectarines and citrus (lemon), peaking at 5 females/t/d on 2 January 2014. Hotspots also developed on orchards 4 and 5, with male and female medfly trapped in developing apples.

On orchard 1, the threshold was triggered three times between 28 November 2013 and 19 December 2013. The action threshold was not triggered on orchard 2, demonstrating the effectiveness of the whole orchard approach. On orchard 3, the threshold was triggered once on 15 January 2014 (male trap, apples) and three times on orchard 4 between 20 February 2014 and 13 March 2014 (male traps, developing apples). On orchard 5, the threshold was triggered 19 times between 12 December 2013 and 24 April 2014 in nectarines and apples (male and female traps).

In autumn, medfly was widespread on commercial orchards from late April to late May 2014, coinciding with apple harvest and trees entering dormancy. Male medfly made up 75% of flies captured during late autumn (n=858 adults), and were likely migrating from the town and infested commercial orchards to overwintering sites (Fig. 3.10).

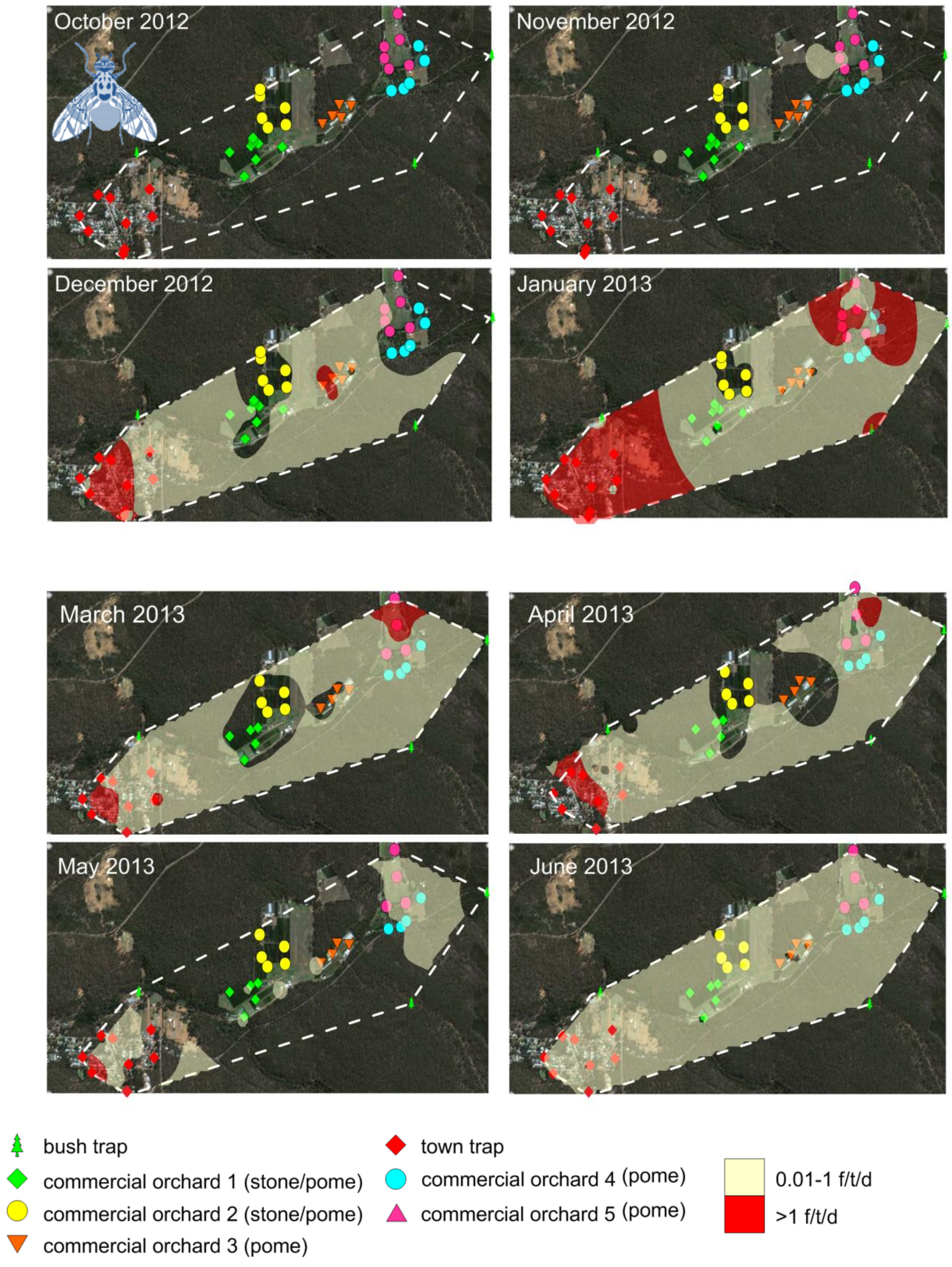

Figure 3.8. Spatial distribution of male medfly on orchards closest to the Jarrahdale town site in spring/summer and autumn/winter in Year 1.

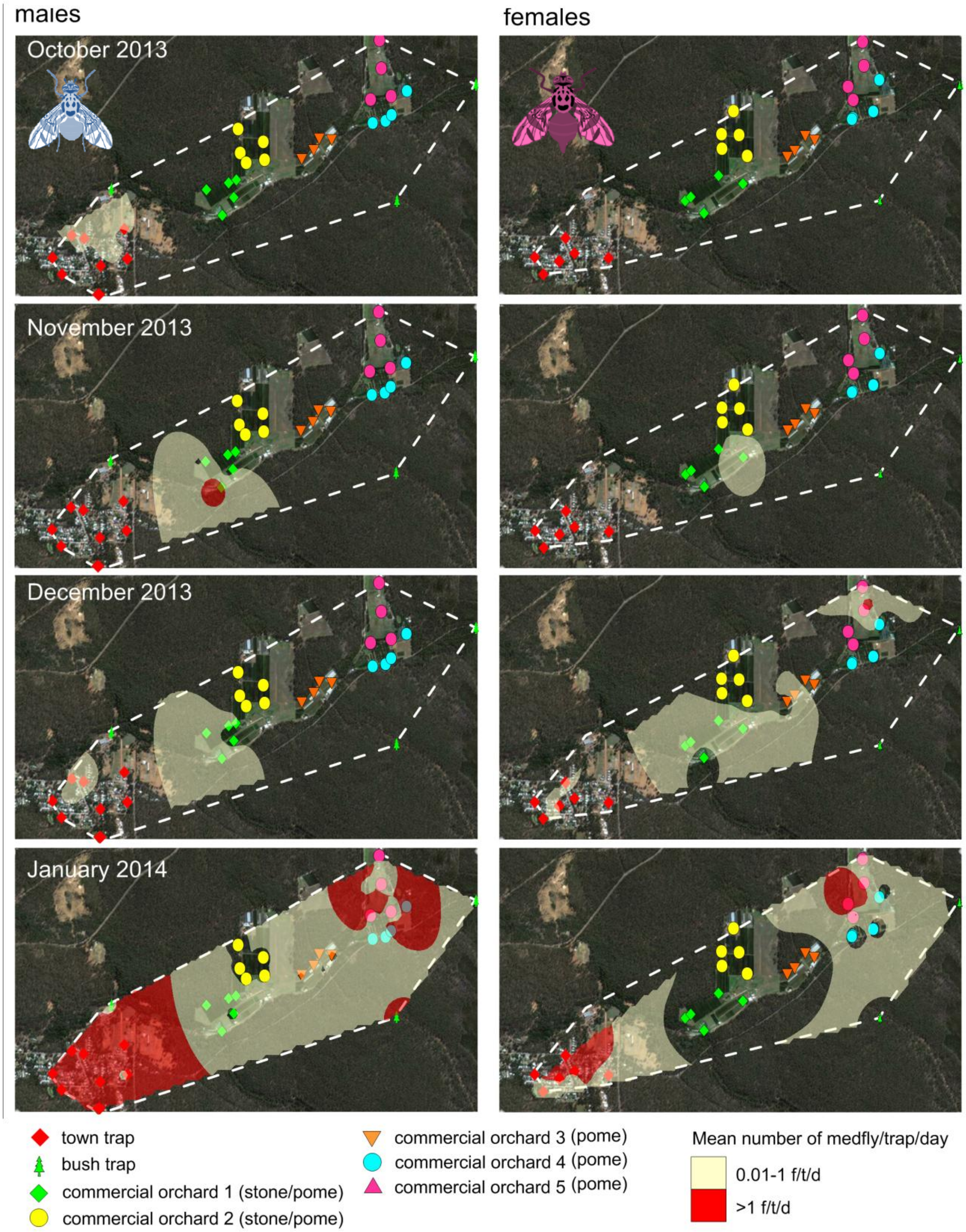

Figure 3.9. Spatial distribution of male and female medfly in spring and summer in Year 2.

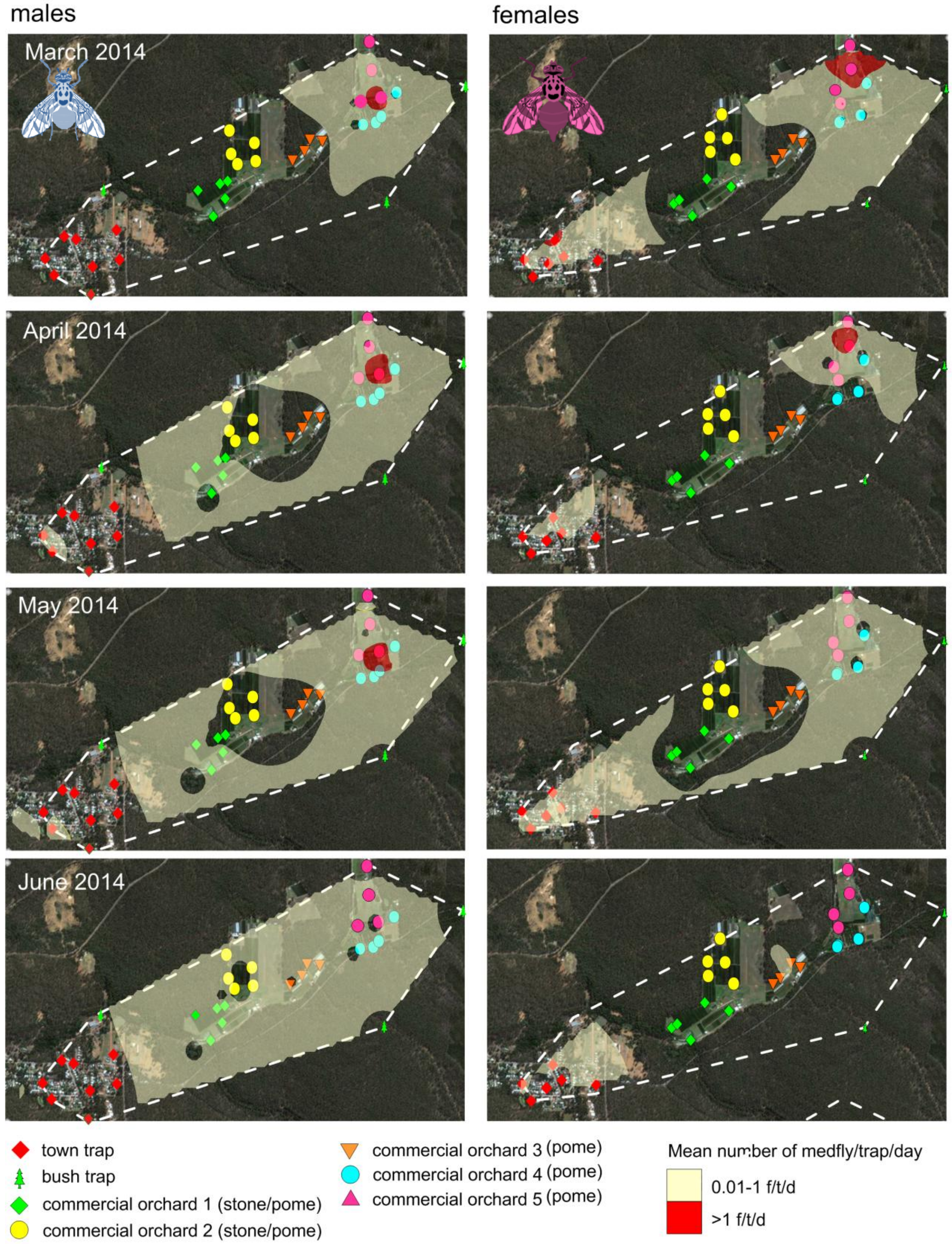

Figure 3.10. Spatial distribution of male and female medfly in autumn/winter in Year 2.

Year 3

Male and female medfly were first trapped on orchard 1 on 26 November 2014 (developing nectarine and mandarin) as in the previous two years. Medfly were simultaneously detected on 2nd December 2014 in town traps and orchards 2 (male trap, developing nectarine) and 5 (male and female traps, ripe nectarines and oranges). Hot spots developed on orchard 5 in December 2014 in ripe nectarines and oranges, and in the town in developing loquat, fig and lemon (Fig. 3.11).

By January 2015, medfly were abundant and widespread in the town, with a peak of 8 females/t/d on 27 January 2015 in apple, apricot, nectarine, lemon and loquat. Hot spots also developed on orchards 4 and 5, in maturing apples and ripening nectarines respectively. These hot spots were most likely caused by adults migrating from nectarines and other fruits on the organic orchard. The economic threshold was triggered 14 times between 2 December 2014 and 25 March 2015 on orchard 5 in traps located in citrus and nectarine (male and female traps), and twice on orchard 4 in ripening apple (male traps) on 12 February 2015 and 5 March 2015.

On orchard 1, the threshold was triggered 9 times between 2 November 2014 (female trap, developing nectarine) and 11 March 2015 (male and female traps, apple and nectarine). This was a three-fold increase from the previous year, and most likely caused by mandarins and nectarines infested in January 2015. On orchard 2, the threshold was triggered once on 18 February 2015 in a male trap located in nectarines. On orchard 3, the threshold was triggered twice on 4 and 11 March 2015 in developing apples (male traps).

As in previous years, medfly was widespread on commercial orchards from late April to May 2014, coinciding with apple harvest and stone fruit trees entering dormancy (Fig. 3.12). Male medfly made up 60% of flies captured in late autumn (n=989 adults).

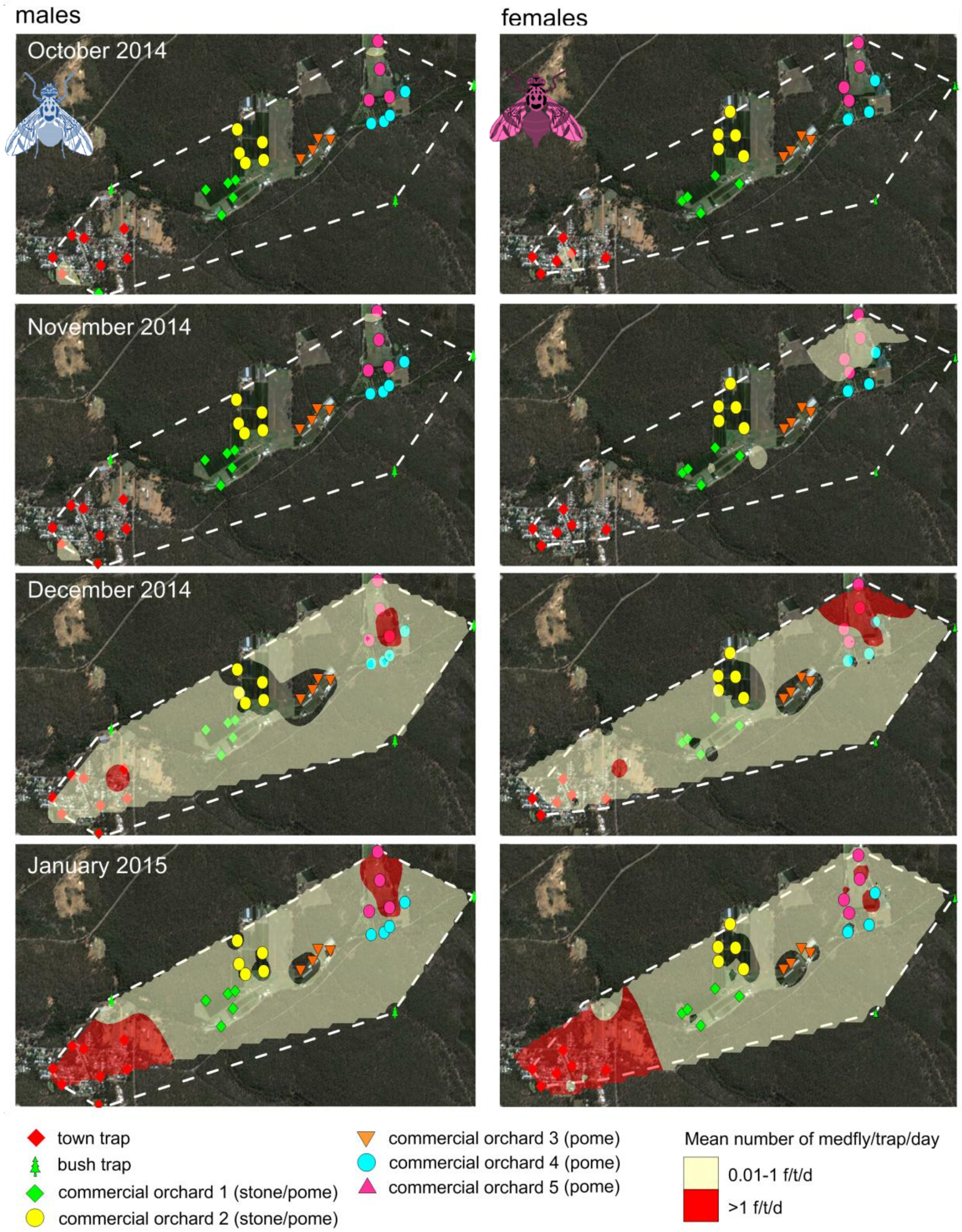

Figure 3.11. Spatial distribution of male and female medfly on orchards in spring and summer in Year 3.

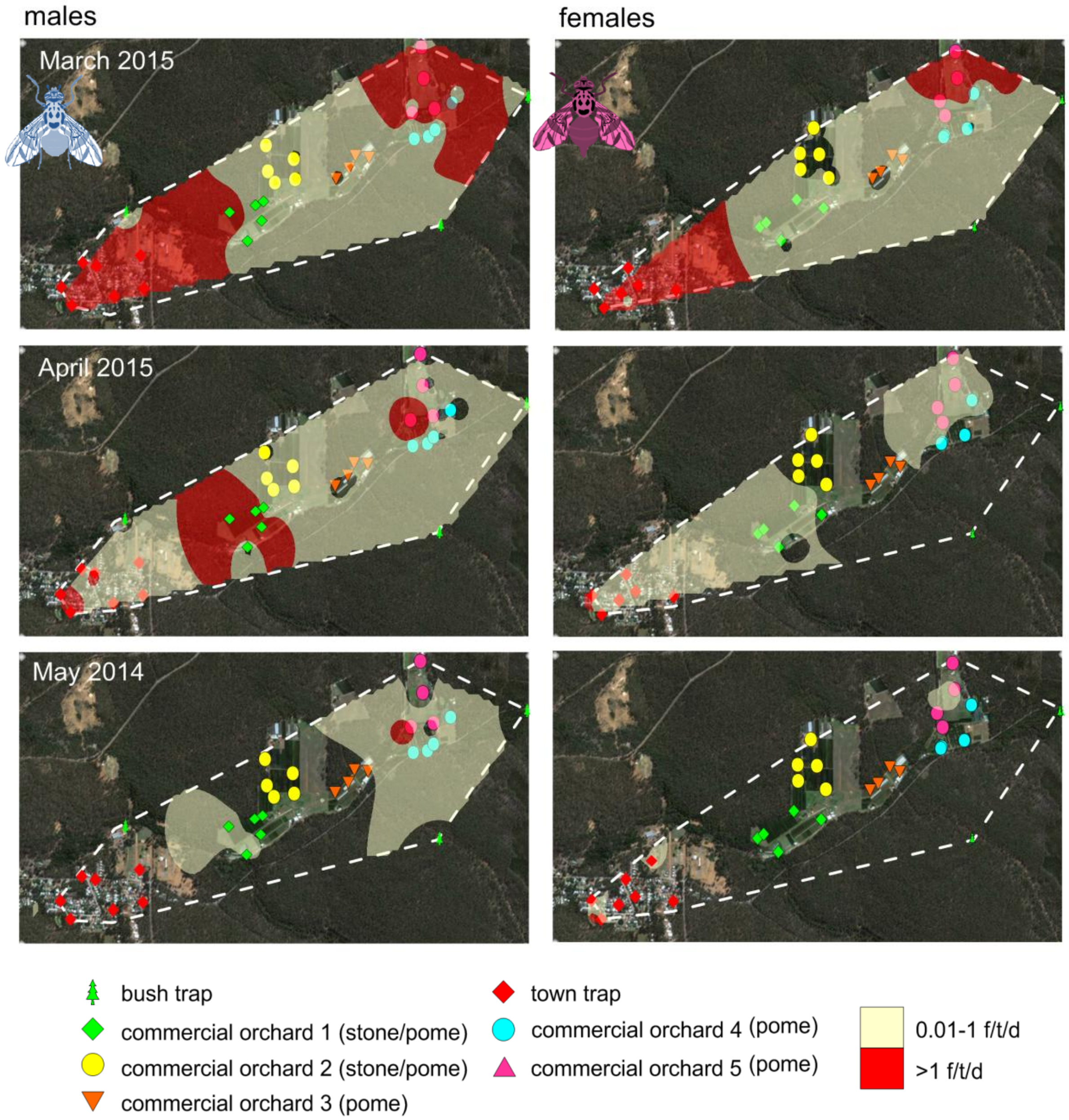

Figure 3.12. Spatial distribution of male and female medfly on orchards autumn and winter in Year 3.

Summary

- In Jarrahdale, medfly do not appear to be migrating from the town to commercial orchards in spring. If flies were spreading from the town to orchards, trap detections are expected to occur first in the town, followed by trap detections a few weeks later on orchards. Trap detections either occur simultaneously, or on commercial orchards first.
- This is further supported by the observation that no medfly were detected in bush traps between the town and commercial orchard in spring.
- Within the trial area, a single landholder (stone fruit) was not treating their orchard for medfly. Whilst medflies migrated from this orchard to commercial orchards, a good baiting regime ensured that medfly did not reach economically damaging levels.
- In autumn (March to May), the town may pose a risk to commercial orchards as medfly seek out overwintering sites. To reduce the abundance of migrating medfly, growers need to continue baiting and apply perimeter mass trapping devices to create medfly-free areas on their orchards.
- To further reduce risk, growers should consider removing or baiting citrus trees on their orchard.

3.3 Efficacy of existing suppression techniques

3.3.1 Bait sprays

Attractancy

In laboratory trials, medfly adults were most highly attracted to the protein only treatment (Cera Bait), with a mean of 5.75 adults (8.7% of flies) responding to treated leaves at 0 minutes. The number of responding medfly peaked at 9 flies, then failing to less than one fly at 60 minutes.

Medfly also responded to Naturalure™ Fruit Fly Bait Concentrate and Hy-mal + Cera Bait, with two flies visiting leaves within the first 20 minutes. Whilst the attractancy of Hy-mal + Cera Bait appeared to decline after 20 minutes, Naturalure™ Fruit Fly Bait Concentrate continued to attract medfly for the entire exposure period (Fig. 3.13).

The apparent decline in attractancy of Cera Bait and Hy-mal + Cera Bait was either due to the bait drying out, or being 'eaten out' by the flies.

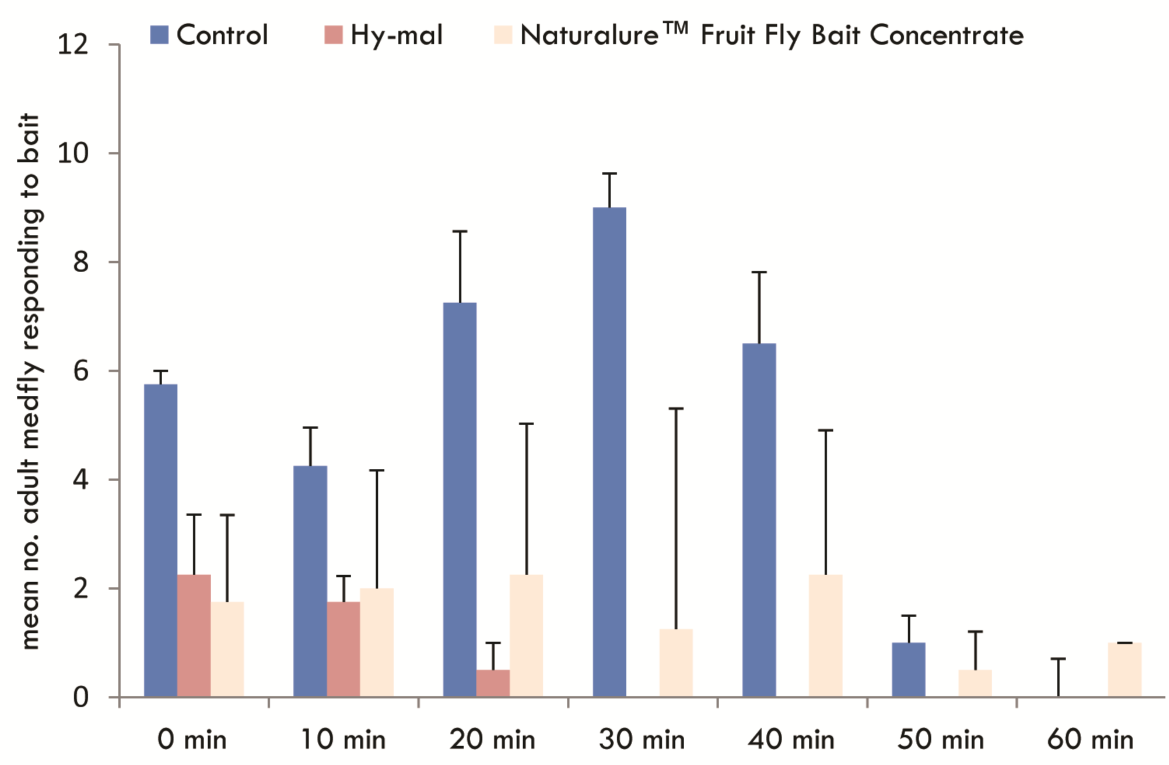

Fig. 3.13. Mean number of medfly adults responding to bait sprays from 0 to 60 minutes.

Mortality

Hy-mal killed flies more quickly than Naturalure™ Fruit Fly Bait Concentrate, with 60% of flies killed three hours after exposure, and >85% of flies dying after 24 hours. Naturalure™ Fruit Fly Bait Concentrate took longer to kill adult medfly, with mortality increasing from 28% at 3 hours to 88% by 72 hours. At and after 24 hours post exposure, there were no differences in morality between Hy-mal and Naturalure™ Fruit Fly Bait

Concentrate (Fig. 3.14).

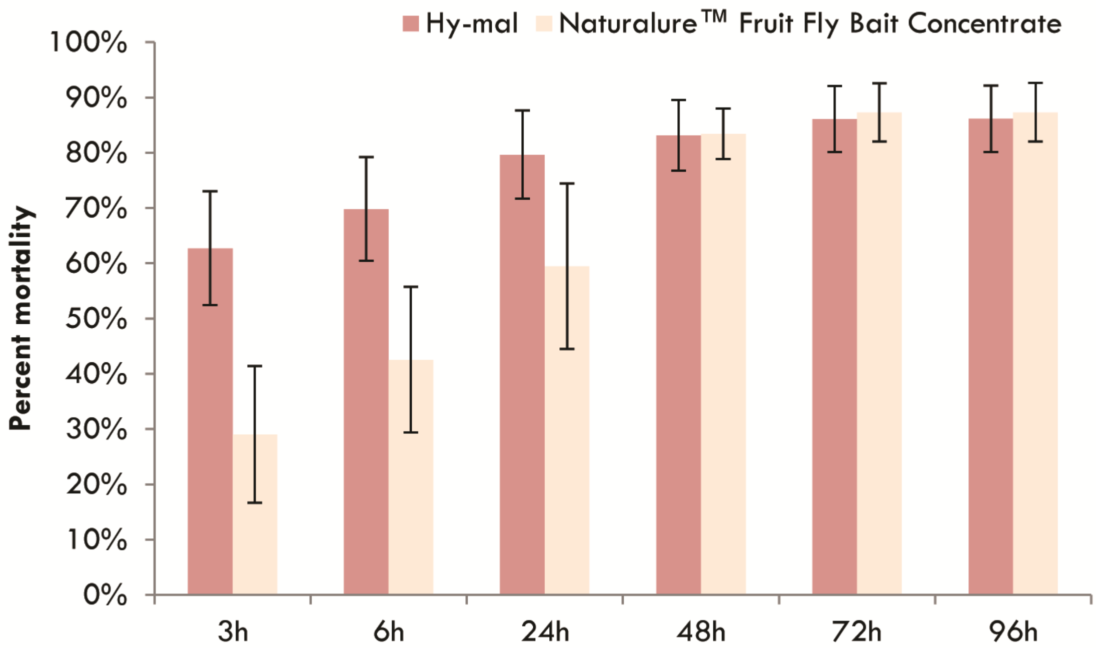

Fig. 3.14. Percent (Mean ±SEM) adult mortality against Hy-mal and Naturalure™ Fruit Fly Bait Concentrate bait sprays from 0 to 60 minutes.

3.3.2 Bait sprays vs. cover sprays

Bait sprays are more effective for fruit fly control as they kill adults before they lay eggs in fruit, whereas cover sprays target the eggs and larvae in fruit. Cover sprays have activity on medfly adults for approximately 1 day, compared to 7 days for bait sprays (depending on weather). In experiments with fenthion in peaches where fruits were sprayed twice one month apart at 2%, fenthion was regarded to lose its effectiveness against larvae after 30 days (Puzzi *et al.* 1964). They also found that a combined treatment using bait and cover sprays was more effective, resulting in 3.5% infestation.

As cover sprays do not provide complete coverage of fruit, frequent applications are necessary to ensure that eggs and larvae are killed. De Lima (pers. comm. 2012) estimates approximately 1% of fruits receive 1,400 ppm; 9% 600 ppm; 50% 400 ppm; 30% 200 ppm; 10% 100 ppm 1% 0 ppm when a cover spray is applied. Thus 40% of the fruit never receive the required dose of insecticide (400 ppm), thus requiring further applications to ensure that all fruits are treated. Cover sprays are recommended in cases in which bait sprays have failed, and fruit infestation exceeds the economic threshold levels.

The effect of cover vs. bait sprays is shown in figures 3.15 and 3.16 for two groups of growers in Jarrahdale. The first group consisted of three orchardists growing pome and stone near the town site, and group two, of two orchardists with stone fruit 2.7 km from the town-site.

The data shows that cover sprays reduced medfly after spraying, but populations recovered after 7 days. When project results were discussed with growers, baits were applied more frequently by orchardists 2 and 3 in group 1. This improved control in years 2 and 3 of the project. However, orchardist 1 continued to rely on cover sprays and baited infrequently. Growers in group 2 also improved control in years 2 and 3 when they began baiting on a regular basis, though needed to cover spray in December 2014 and February 2015 when thresholds were exceeded.

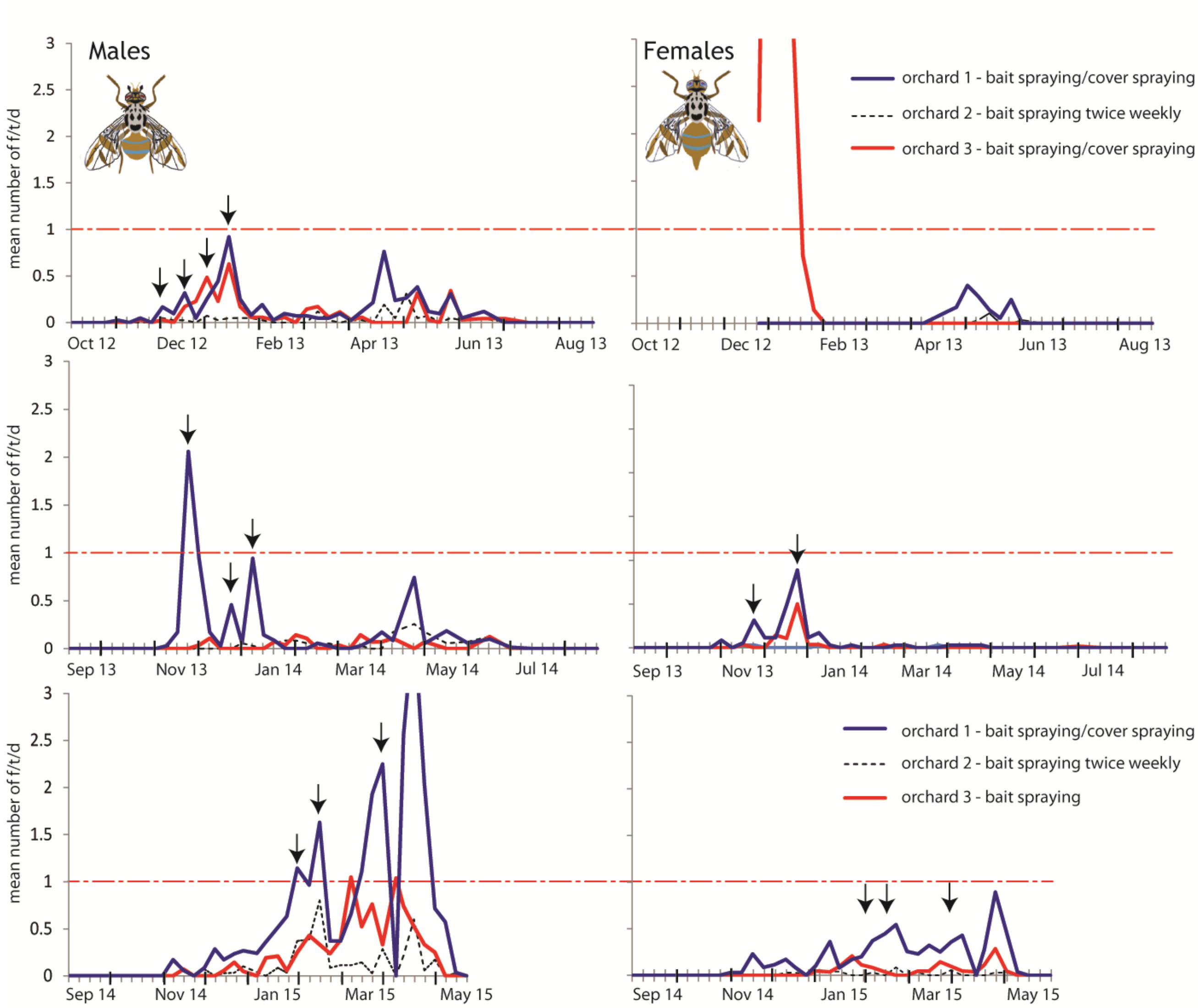

Fig. 3.15. Mean number of adult male and female medfly caught in traps in group 1 (orchard 1 and 2 stone/pome fruit, orchard 3 apples). Arrows indicate when cover sprays were applied, the dotted red line indicates the economic threshold (1 f/t/d).

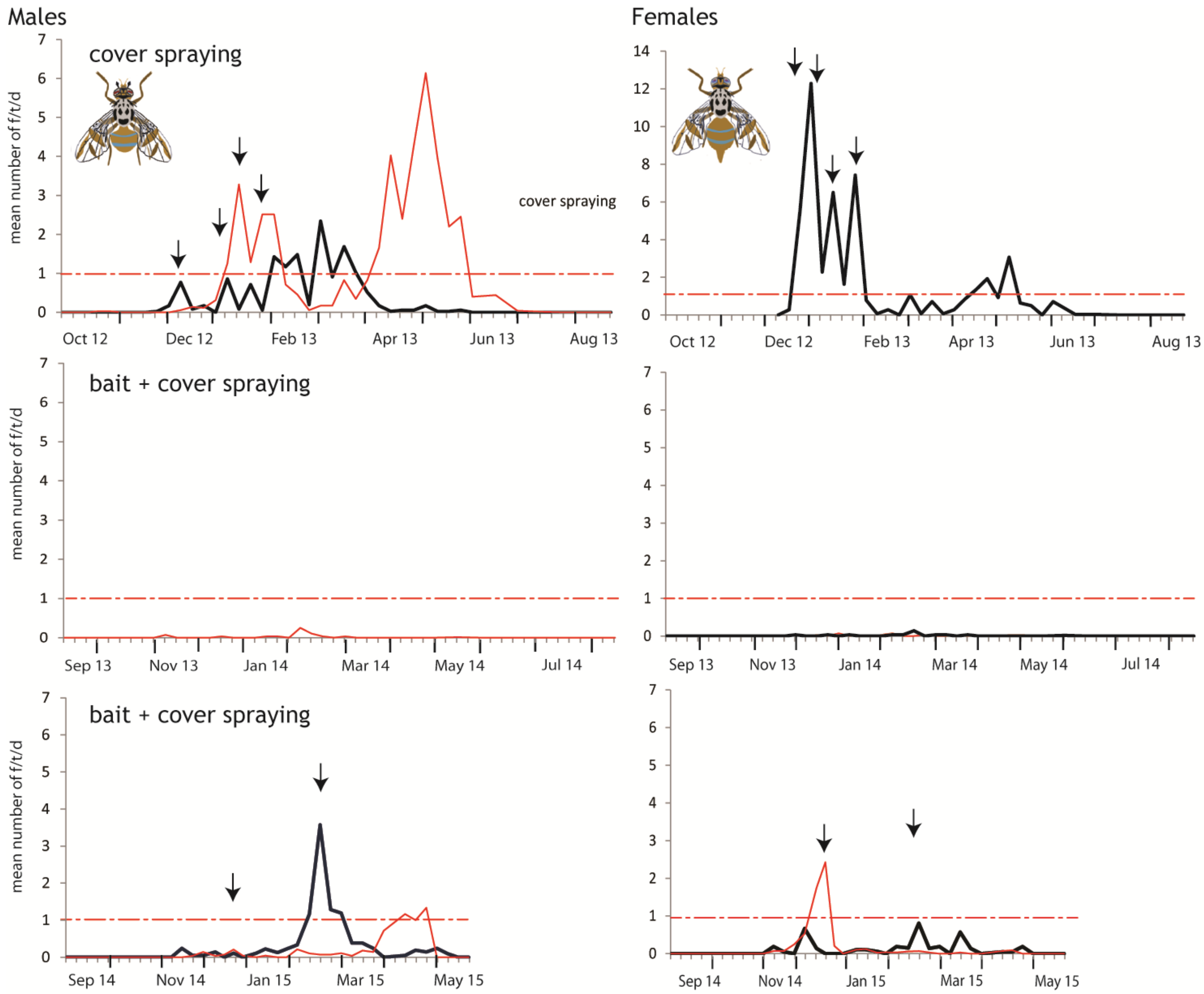

Fig. 3.16. Mean number of adult male and female medfly caught in traps in group 2 (stone orchard 1, stone/pome fruit orchard 2). Arrows indicate when cover sprays were applied, the dotted red line indicates the economic threshold (1 f/t/d).

Summary

- Bait sprays are more effective for fruit fly control as they kill adults before they lay eggs in fruit, whereas cover sprays target the eggs and larvae in fruit.
- As cover sprays do not provide complete coverage of fruit, frequent applications are necessary to ensure that eggs and larvae are killed.
- Cover sprays are recommended in cases in which bait sprays have failed.

3.4 Possible chemical replacements for fenthion and dimethoate

3.4.1 Lab trials

Females

Mortality was higher than the control across all mortality assessment periods (Fig. 3.17). The fastest acting insecticide was clothianidin, with 46.5±4.35% mortality recorded one hour after exposure (46.5±4.35%; $F=69$, $df=4,12$, $P<0.001$). Twenty four hours post exposure, over 95% of females treated with spinetoram, trichlorfon and clothianidin had died, compared to 42% for thiacloprid ($F=115.45$, $df=4,12$, $P<0.001$).

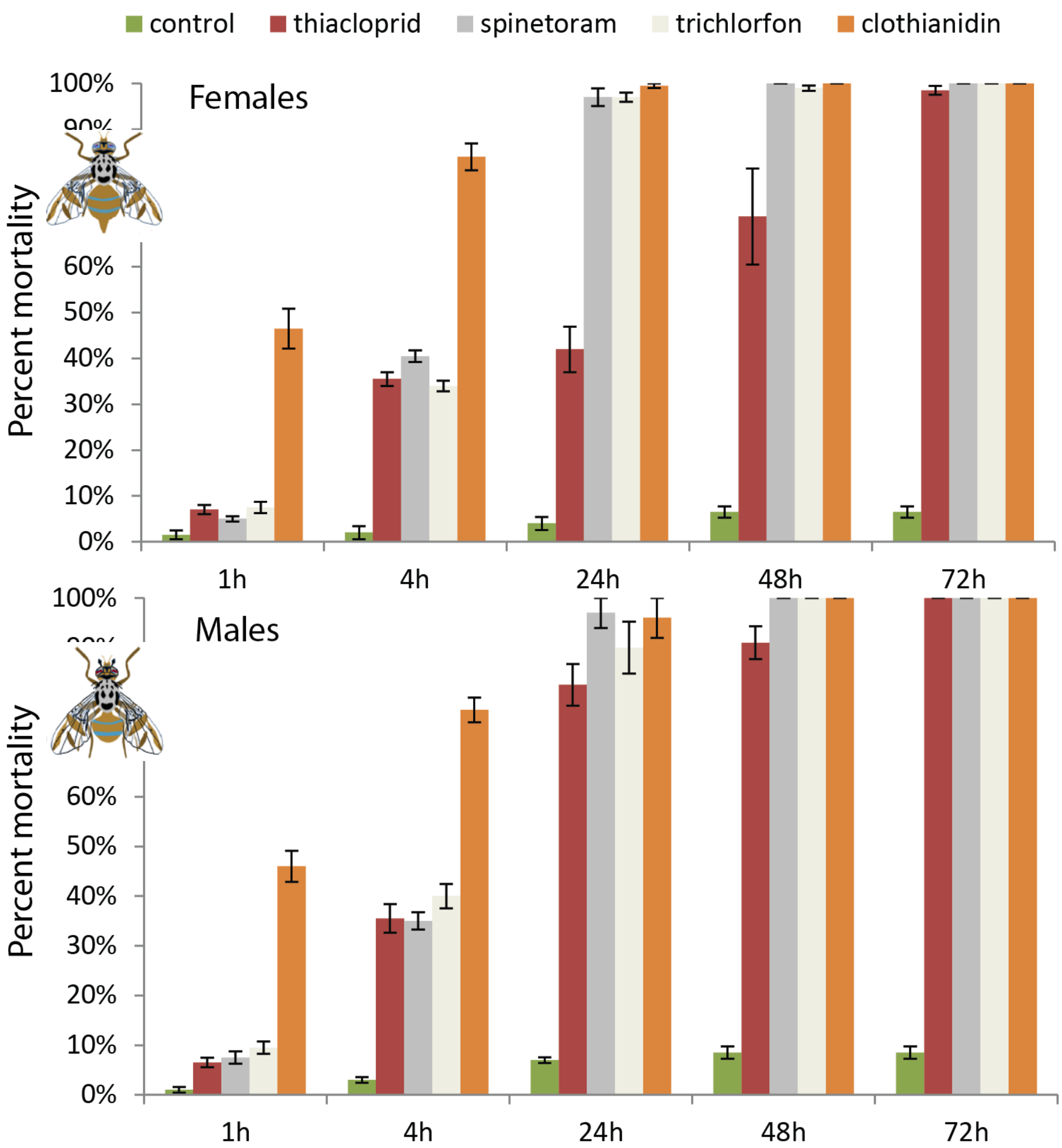

Figure 3.17. Cumulative mortality of female (top) and male (bottom) adult medfly treated topically with insecticide at 1, 4, 24, 48 and 72 hours after exposure.

A similar trend was recorded 48 hours post-treatment, with less flies dying after being treated with thiacloprid (71±10.5%), than with spinetoram, trichlorfon or clothianidin (97-99% mortality; $F=58.53$, $df=4,12$, $P<0.001$). By 72 hours, mortality of flies treated with thiacloprid increased to 98.5±0.95%: no survivors were recorded in the spinetoram, trichlorfon or clothianidin groups ($P=0.05$).

Males

Compared to the untreated control, insecticides were effective at every mortality assessment period (1 h, 4 h, 24 h, 48 h and 72 h; Fig. 3.17). Clothianidin was the fastest acting insecticide, killing 46.0 ± 3.1% of males one hour after exposure compared to 6.5-9.5% for the other insecticide treatments ($F=69.0$, $df=4,12$, $P<0.001$), and 77.5 ± 2.5% after 4 hours compared to 35-40% for the other insecticide treatments ($F=158.78$, $df=4,12$, $P<0.05$). Thiacloprid and trichlorfon (82.5-90% mortality) were slower acting than clothianidin and spinetoram (96-97%), with significant differences between treatments recorded at 24 hours ($F=119.6$, $df=4,12$, $P<0.001$). By 72 hours post treatment, all flies had died (Figure 3.17).

3.4.2 Effect of spinetoram on oviposition

Following reports that flies had survived for a few days after being treated with spinetoram, we determined whether females were capable of laying eggs after being treated. Laboratory trials showed that whilst females could lay eggs, it was at a highly reduced rate compared to the control (Fig. 3.18). The percentage egg hatch rate was also lower.

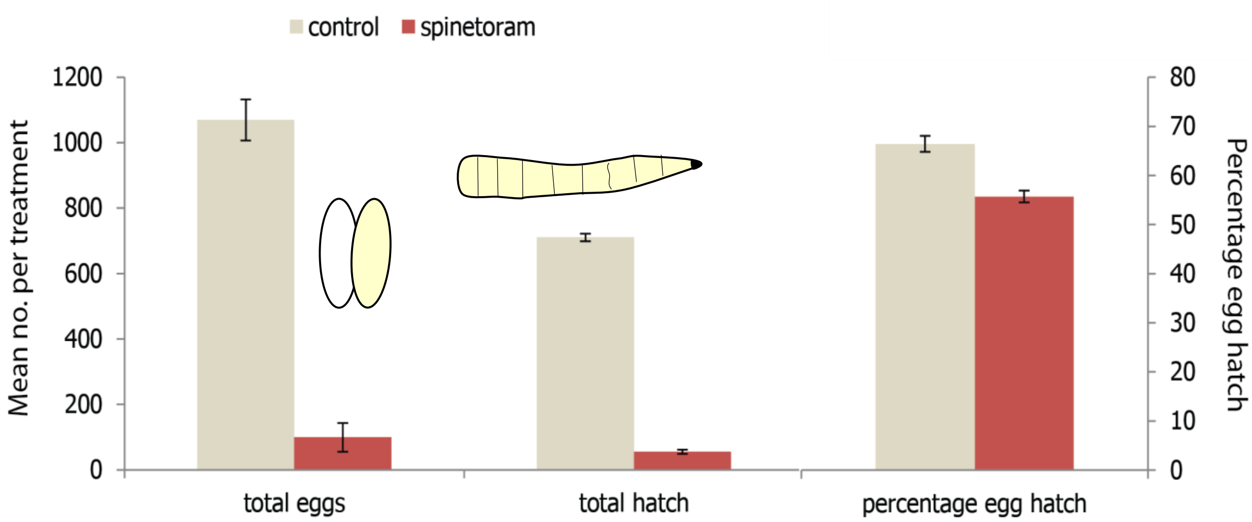

Figure 3.18. The number of eggs, egg hatch and percentage egg hatch.

3.4.3 Field trials

Effect of neonicotinoids on eggs laid in fruit

The effects of thiacloprid and clothianidin on eggs are larvae compared to the control and positive control (fenthion) is shown in figure 3.19. In trials 1-3, bagged fruits were sprayed in the field after adults had been allowed to lay eggs for 24 hours. Significantly more pupae developed in fruit that had been treated with water only, and the least in fruit that had been treated with fenthion (Trial 1, $F=159.91$, $df=3,6$, $p<0.0001$; trial 2, $F=181.50$, $df=3,27$, $P<0.0001$, trial 3, $F=58.59$, $df=3,15$, $P<0.0001$). The percentage of adults emerging from pupae followed a similar trend, with fewer adults emerging from fruits treated with fenthion in trials 1 and 2 (trial 1: $F=316.24$, $df=3,6$, $P<0.0001$; trial 2: $F=28.01$, $df=3,27$, $P<0.0001$). In trial 3, there were no differences between treatments, though all differed from the control ($F=13.14$, $df=5,15$, $P=0.0002$).

Insecticides applied to fruits prior to exposure also reduced the number of pupae and adults. Fewer medfly pupae were produced from fruit treated with insecticide (trial 4: $F=70.55$, $df= 3,15$, $P<0.0001$; trial 5: $F=64.23$, $df=3,9$, $P<0.0001$; trial 6: $F=62.91$, $df=3,9$, $P<0.0001$), with fenthion more effective than either clothianidin or thiacloprid ($P=0.05$). Insecticides also reduced adult emergence, with fewer flies emerging after being treated with insecticide. In field trials, fenthion was more effective than either thiacloprid and clothianidin (trial 4: $F=61.05$, $df=3,15$, $P<0.0001$; trial 5: $F=42.70$, $df=3,9$, $P<0.0001$). In the lab trial however, no differences were detected between insecticides with 40-55% of adults emerging but differed from control (trial 6: $F=14.45$, $df=3,9$, $P=0.001$). Interestingly, insecticides also produced physical deformity in adult flies, with wing deformation the most common deformity (Fig. 3.19).

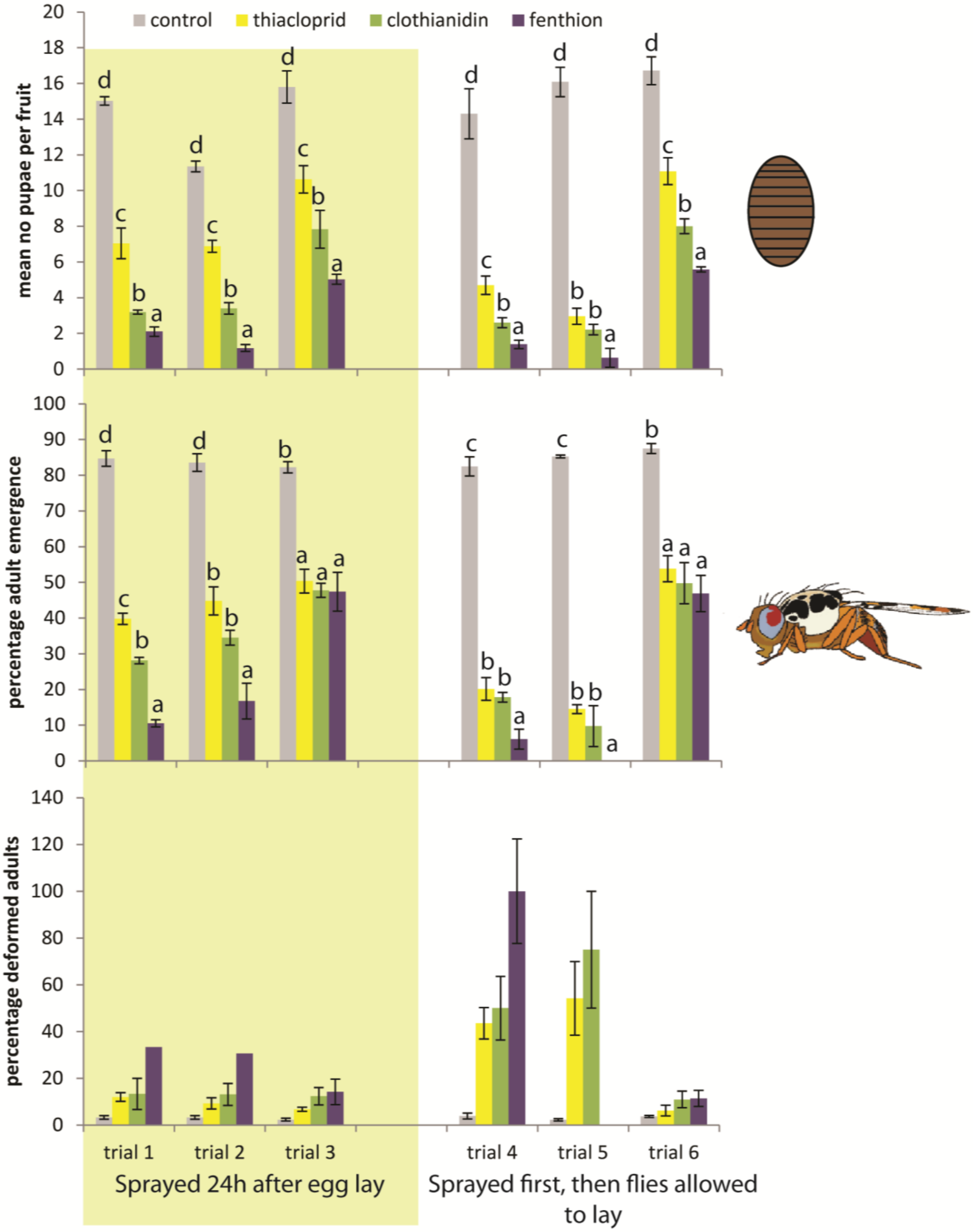

Figure 3.19. Mean (±SEM) number of pupae per fruit developed, percent (Mean ±SEM) adult emerged from pupae and percent (mean ±SEM) deformed adults. Within each time period, letters above bars indicate significant treatment differences at P=0.05.

3.4.5 Effects of pesticides on beneficials

Biobest (2015) lists clothianidin as incompatible with bumble bees with persistence over 30 days, whilst care needs to be taken with exposing bees to spinetoram and thiacloprid (Table 3.1). Trichlorfon is also incompatible with bumble bees, with residues persisting for 14 days. Australasian Biological Control (2015) lists thiacloprid and dimethoate as toxic (>75% mortality) to lacewings and ladybird larvae, and toxic and moderately toxic to predatory mites such as the phytoseiid, *Phytoseiulus persimilis* Athias-Henriot, used for the biological control of two spotted mite (*Tetranychus urticae* Koch). Spinetoram is toxic to honeybees, predatory mites and insect parasitoids in laboratory tests, but regarded to be non-toxic to ladybirds and lacewings (British Crop Production Council (BCPC), 2015).

Table 3.1. Effect of insecticides on bees and beneficials. The information provided in parentheses is the length of persistence of the insecticide.

Insecticide	Bees (mainly bumble bees *Bombus* spp.)	ladybirds	Aphid parasitoids (*Aphidius* spp.)	*Phytoseiulus persimilis*	lacewings
Dimethoate	X	H (unknown)	H (4 weeks)	H (3 weeks)	H (3 weeks)
Fenthion	X	-	H (4 weeks)	H (3 weeks)	H (2 weeks)
Thiacloprid	B	M-H (unknown)	L (0 weeks)	H (1 week)	H (larvae), M (adults)
Clothianidin	X (>30 d)	unknown	unknown	unknown	unknown
Spinetoram	B (3 hrs)	L	unknown	unknown	L
Trichlorfon	X	unknown	unknown	H (2 weeks)	H (unknown)

Key: L=slightly toxic (25-50% mortality), M=moderately toxic (50-75%), H=toxic (>75%)
X= not compatible, B=close and remove hive before application

Summary

- The neonicitinoids (clothianidin, thiacloprid) and spinetoram (Delegate) have activity against adult medfly when applied topically. All pesticides were effective by 72 hours (3 days) post-exposure.
- Females that had been treated with spinetoram were able to lay eggs, though they laid fewer eggs compared to the control (water only).
- In the field, insecticides applied 24 hours after flies had been allowed to oviposit reduced the number of pupae and emerged adults compared to the control. Fenthion was the most effective, followed by clothianidin, then thiacloprid. However no treatment was completely effective in reducing fly emergence.
- Where insecticides were applied to fruit first and exposed to flies after 7 days, fewer pupae were produced and fewer adults emerged in the fenthion treatment. The thiacloprid and clothianidin treatments were equivalent.
- Adults emerging from treated fruits showed some physical deformity, with the most deformed flies recorded from fenthion in 3 of 6 trials (11-100%).

- All cover sprays had some effect on bees/bumble bees and beneficial insects and should only be applied when the economic threshold is triggered. In particular, thiacloprid is highly toxic to ladybirds, *P. persimilis* and lacewings, whilst little is known of the effect of clothianidin on beneficials.

3.5 New Technologies

3.5.1 Commercially available attract-and-kill devices

MagMED®

2012 season

In orchard 1, significantly more medfly (F = 6.69, df = 1 & 66, P = 0.012) were captured in the MagMED® plus cover spray (0.17 ± 0.07 f/t/d), than cover spray only plots (0.06 ± 0.02 f/t/d). In orchard 2, 2.2-5.8 times fewer medfly were caught in MagMED® treated plots (F = 24.81, df = 1 & 66, P < 0.0001) than the untreated control plots.

At harvest, in orchard 1, a higher percentage of infested fruits was recorded from the cover spray plots compared to MagMED® plus cover spray plots and difference was significant (F = 14.62, df = 1 & 66, P < 0.0001; Fig. 3.20). Similarly, in orchard 2, three times more infested apples were recorded in the untreated compared to MagMED® treated plots (F = 14.62, df = 1 & 66, P = 0.0003; Fig. 3.20).

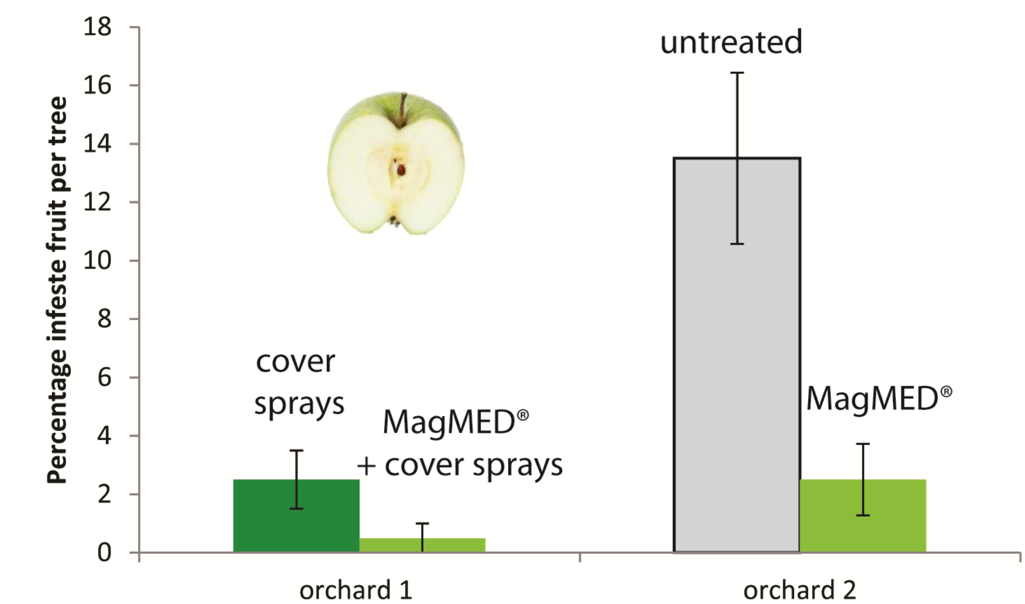

Figure 3.20. Percentage of apples infested (visual inspection in-situ).

2013 season

MagMED® vs. untreated control

MagMED® did not suppress the male medfly population in the untreated apple orchard (Orchard 1; F=1.62, df=1 & 85, P=0.21). In orchard 2, fewer males were caught on MagMED® treated plots (F=4.71, df=1 & 99, P=0.03). However, female trap captures did not differ with treatment on either orchard (Orchard 1: F = 1.62, df = 1 & 85, P = 0.49; Orchard 2: F = 0.46, df = 1 & 99, P = 0.50).

At harvest, there were no significant treatment differences ($t = 0.37$, $df = 18$, $P = 0.71$) in the percentage of infested apples in orchard 1. In orchard 2, more infested apples were recorded ($t=-2.3$, $df=18$, $P=0.033$) in the untreated compared to treated plots.

MagMED® vs. bait spraying

In orchard 3 (twice weekly baiting), there were no significant differences in the capture of either males ($F = 1.30$, $df = 1$ & 107, $P = 0.24$) or females ($F = 0.20$, $df = 1$ & 107, $P=0.66$) and treatment. Though there were no significant differences in fruit infestation rate between treatments (Nectarine: $t = 0.61$, $df = 18$, $P = 0.55$; Apple: $t = 1.15$, $df = 18$, $P = 0.26$), fewer fruits were attacked by medfly in the twice weekly baiting + MagMED® plots , compared to the twice weekly baiting only plots (Fig. 3.21).

Weekly bait spraying was more effective when combined with MagMED®, than when applied alone. In nectarines (orchard 4), fewer males were captured in weekly + MagMED® treated plots (4.00 ± 1.01 f/t/d) than weekly baiting only plots (7.53 ± 1.08 f/t/d; $F = 5.14$, $df = 1$ & 60, $P = 0.03$). Female trap catch varied significantly with treatment ($F = 93.16$, $df = 1$ & 60, $P < 0.0001$). At harvest, fewer nectarines were infested on plots treated with MagMED® plus bait spray ($t = 2.87$, $df = 58$, $P=0.005$; 3.0 ± 0.98%) than plots treated with bait sprays only (9.3 ± 1.97%; Fig. 3.21).

In pears (orchard 5), fewer males and females were captured in the weekly baiting + MagMED® treated plot than baiting only plot (Male: $F = 6.40$, $df = 1$ & 60, $P = 0.01$; Female: $F = 23.16$, $df = 1$ & 60, $P < 0.0001$). At harvest fewer medfly infested pears were found on plots treated with MagMED® + baits sprays (5.17 ± 1.13%) than plots treated with bait sprays only (11.5 ± 2.0%; $t=2.87$, $df=58$, $P=0.006$; Fig. 3.21). There were no significant differences between treatments at harvest, with less than 4% of apples infested by medfly ($t = 0.94$, $df = 18$, $P = 0.36$; Fig. 3.21).

MagMED® + bait and cover spray

In a mixed nectarine, peach and pear orchard (Orchard 6), male trap catch did not vary with treatment ($F = 3.08$, $df = 1$ & 95, $P = 0.08$), but fewer females were captured when cover sprays were combined with MagMED® ($F = 5.25$, $df = 1$ & 95, $P = 0.02$; MagMED® + cover spray plot: 0.45 ± 0.10 f/t/d; cover spray: 0.80 ± 0.20f/t/d). At harvest, fewer infested peaches ($t = 3.18$, $df = 58$, $P = 0.002$) and pears ($t = 2.46$, $df = 118$, $P = 0.02$) were found in plots that had received all possible treatments (peach 4.33 ± 1.41%; pear 3.67 ± 0.81%) compared to conventional controls (peach 13.67 ± 2.56%; pear 6.33 ± 1.17%). In nectarines, treatment had no effect on infestation (conventional 6.33 ± 1.48%; all combinations 5.0 ± 1.34%; $t = 0.67$, $df = 58$, $P = 0.50$; Fig. 3.21).

In apples and nectarines (orchard 7) male trap capture did not vary with treatment ($F = 0.71$, $df = 1$ & 107, $P = 0.40$; conventional control: 1.12 ± 0.22 f/t/d, all combinations: 0.87 ± 0.19 f/t/d), whist female trap captures varied significantly with treatment ($F = 6.83$, $df = 1$ & 107, $P = 0.01$; conventional control: 10.7 ± 3.80 f/t/d, all combinations: 3.67 ± 0.81f/t/d). Medfly infestation of apples and nectarines at harvest was very low (<1% infestation), and there were no treatment differences (apple: $t = 0.39$, $df = 18$, $P = 0.7$; nectarine: $t = 1.70$, $df = 18$, $P = 0.11$; Fig. 3.21).

In orchard 8 (apples), female captures varied with treatment ($F = 15.27$, $df = 1$ & 32, $P = 0.0005$; conventional control: 5.22 ± 2.63 f/t/d, all combinations: 0.25 ± 0.12 f/t/d) as did male catch ($F = 4.50$, $df = 1$ & 32, $P = 0.041$; conventional control: 2.09 ± 0.45 f/t/d, all combinations: 1.16 ± 0.23 f/t/d). There were no significant differences between treatments at harvest, with less than 4% of apples infested by medfly ($t = 0.94$, $df = 18$, $P = 0.36$; Fig. 3.21).

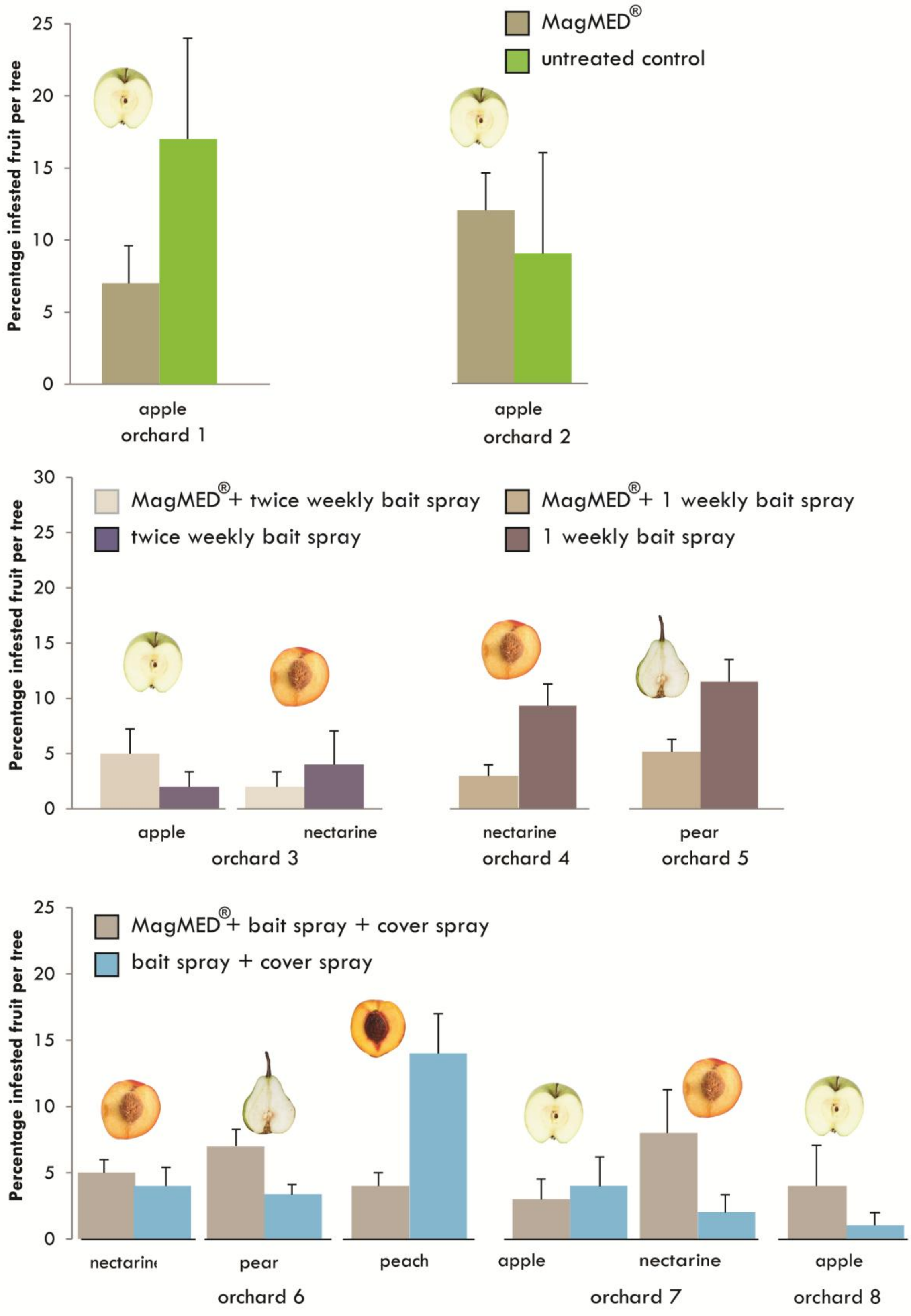

Figure 3.21. Percentage of fruits infested in plots treated with MagMED® + conventional controls, compared to conventional control only.

Trial 3 (2013-14 season)

MagMED® vs. untreated control

On orchard 1 (apple) male captures varied significantly with treatment ($F = 39.11$, df = 1 & 128, $P < 0.0001$; MagMED®: 0.71 ± 0.17 f/t/d; untreated control: 0.20 ± 0.07 f/t/d). However, there was no effect of treatment female trap captures ($F = 1.68$, df = 1 & 128, $P = 0.19$; MagMED®: 0.05 ± 0.02 f/t/d, untreated control: 0.04 ± 0.01 f/t/d). At harvest significantly more apples ($t=-3.11$, df=38, $P=0.003$) were infested in untreated plots (14.65 ± 2.30%) compared to MagMED® treated plots (7.01 ± 0.85%; Fig. 3.22).

In orchard 2 (nectarine, plum), more males and females were caught in untreated plots (males: $F = 8.98$, df = 1 & 205, $P = 0.0003$; MagMED®: 1.65 ± 0.39 f/t/d, untreated control: 2.79 ± 0.66 f/t/d; females: $F = 21.10$, df = 1 & 205, $P < 0.0001$; MagMED®: 0.77 ± 0.20 f/t/d, untreated control: 1.482 ± 0.36 f/t/d).

The percentage of infested nectarines was significantly higher in the untreated control (58.08 ± 20.83%) than MagMED® treated plots (29.5 ± 20.83%; $t=2.87$, df=38, $P=0.006$), but there was no effect of treatment on plums ($t=-1.29$, df=38, $P=0.21$), with an infestation rate of 0.8 to 1.8% in the MagMED® and untreated control plots respectively (Fig. 3.22).

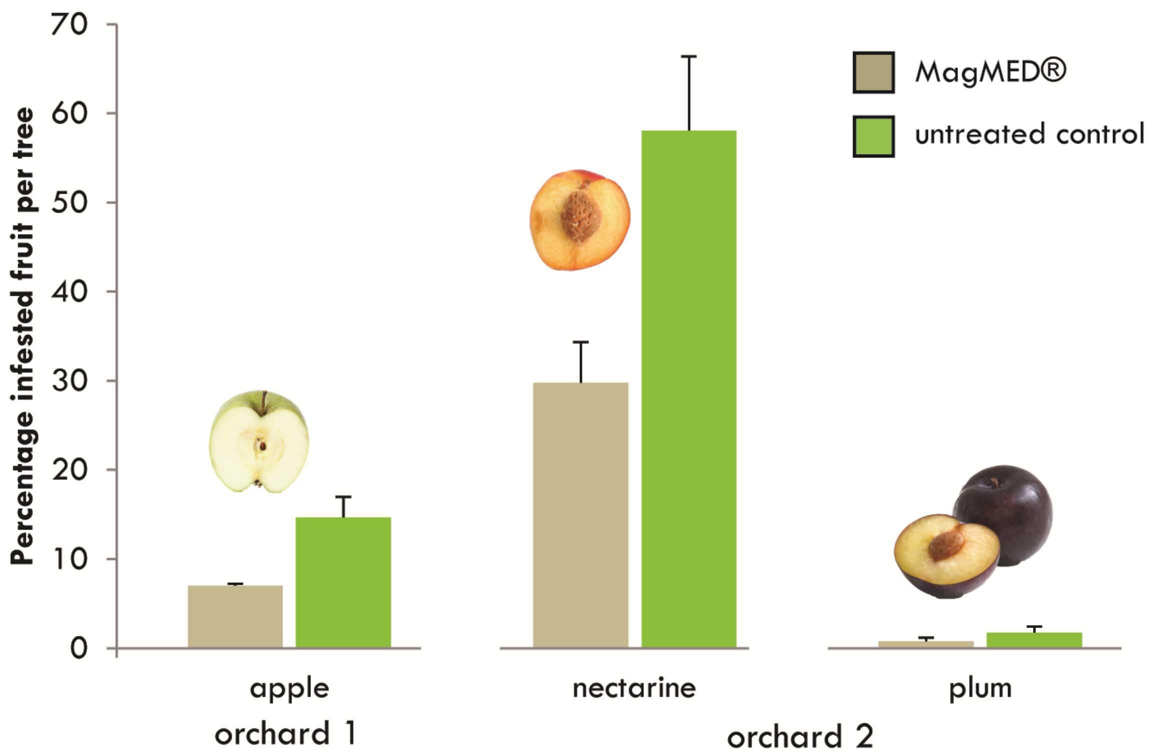

Figure 3.22. Mean percentage of fruits infested in untreated compared to MagMED® treated plots.

Probodelt

Orchard 1

Average male trap captures was relatively higher in Probodelt treated plot (0.46 ± 0.1 f/t/d) than control plot (0.38 ± 0.1 f/t/d), though difference was not significant ($F = 0.14$, df = 1 & 4, $P = 0.73$). Similarly, female trap catch did not vary with treatment ($F = 0.83$, df = 1 & 4, $P = 0.41$).

In nectarine, 1.67 ± 0.45 and 2.17 ± 0.65% fruits in the Probodelt and control plots were infested, though the difference was not significant ($t = 0.34$, df = 38, $P = 0.73$; Fig. 3.23).

Orchard 2

More male medfly were captured in control plots (0.79 ± 0.08 f/t/d) than Probodelt plots (0.54 ± 0.06 f/t/d; $F = 8.80$, df = 1 & 10, $P = 0.01$). More females were also trapped in control plots (0.32 ± 0.04 f/t/d) compared to Probodelt (0.11 ± 0.02 f/t/d; $F = 10.20$, df = 1 & 10, $P = 0.01$).

At harvest, significantly more apricots with larvae were detected in control plots than plots treated with bait sprays and Probodelt devices ($t = 2.23$, df = 38, $P = 0.03$; Fig. 3.23). Whilst fewer fruits with medfly larvae were detected in Probodelt plots (nectarine, peach and plum) compared to control plots, the differences were not significant ($p > 0.05$; Fig. 3.23).

Orchard 3

Trap catches of male medfly varied between treatments, with highest and lowest caught in control (0.49 ± 0.07 f/t/d) and Probodelt plots respectively (0.45 ± 0.07 f/t/d; $F = 38.2$, df = 2 & 3, $P = 0.01$). Similarly, more females were trapped in the control plots (0.08 ± 0.02 f/td) than Probodelt plots (0.01 ± 0.003 f/t/d; $F = 27.98$. df = 2 & 3, $P = 0.01$).

The percent of infested apples differed significantly between treatments ($F = 4.63$, df = 2 & 57, $P = 0.01$). Fewer infested fruits were found in MagMED® + bait sprayed plots (0.50 ± 0.27%) than plots treated with only bait sprays (1.33 ± 0.37%). However, the percentage of infested fruits in the MagMED® and Probodelt plots did not differ ($p > 0.05$; Fig. 3.23).

Orchard 4

There were no differences in the capture of males ($F = 0.29$, df = 2 & 3, $P = 0.77$) between treatment. However, more female medfly were trapped in bait sprayed plots, and the least in bait spray + Probodelt plots (0.04 ± 0.01 f/t/d; $F = 11.32$, df = 2 & 3, $P = 0.04$). At harvest, more infested apples were found in plots treated with bait sprays only, followed by Probodelt and MagMED®. However, these differences were not significantly different (Fig. 3.23).

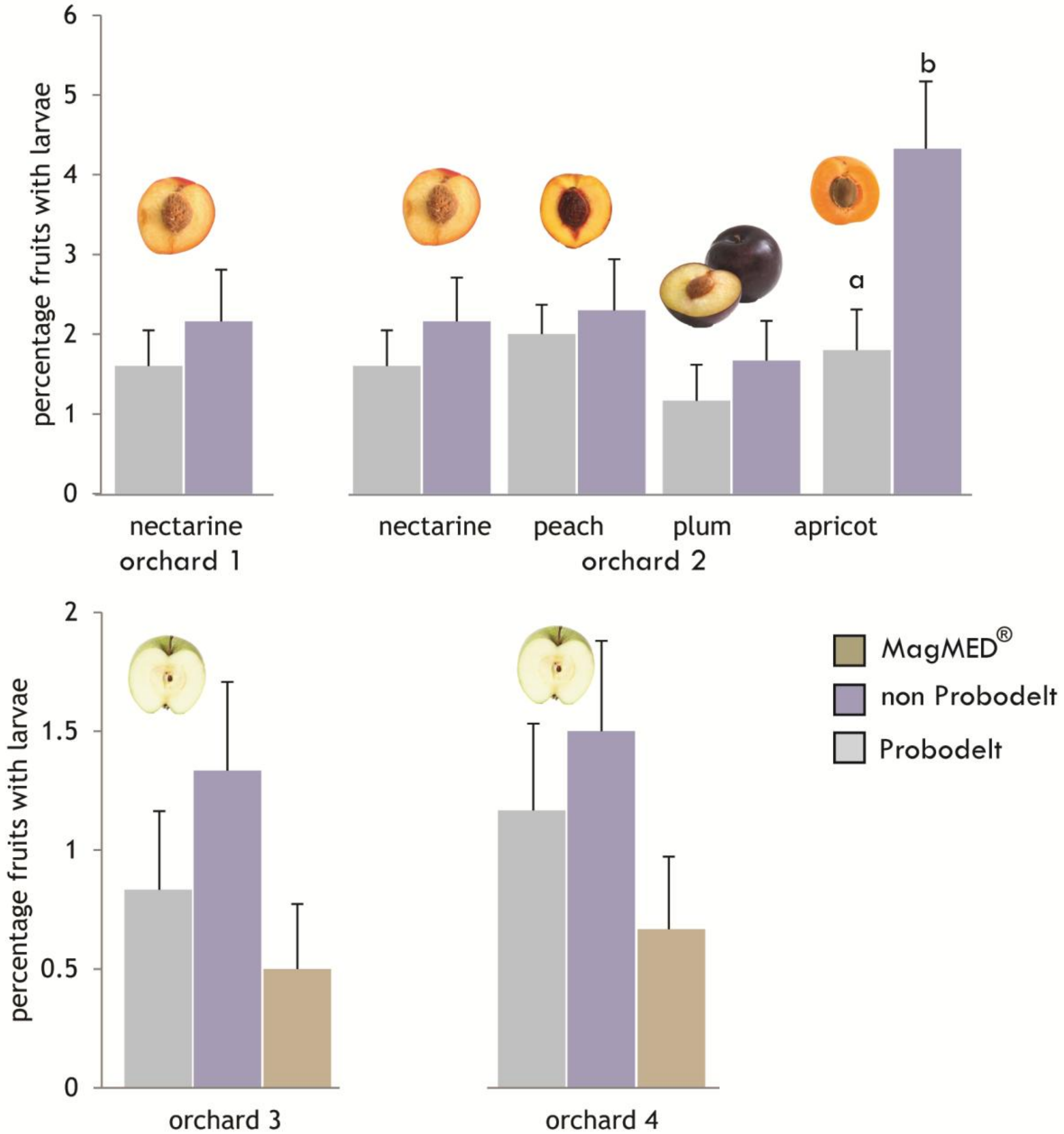

Figure 3.23. Fruit damage assessment between Probodelt and control (orchards 1 and 2), and between MagMED®, Probodelt and control (orchards 3 and 4)

3.5.2 High density trapping (town)

The effect of mass trapping in the section of the Jarrahdale town site closest to commercial orchards is shown in figure 3.24. The data suggests that Cera Trap had little effect on medfly abundance, with a peak of 13 males/trap/day recorded on 3 January 2013 eight weeks after traps had been installed. A second peak occurred on 14 February 2013 with 10.77 males/t/d and 8.3 females/t/d.

In year 2, Maxitraps baited with 3 part-lure replaced Cera Trap and appeared to reduce medfly abundance. Male trap captures did not exceed 1 f/t/d and females 4.3 f/t/d (2 January 2014). In the third and final year, medfly abundance was lower than in year 1, though higher compared to year 2. Two peaks in abundance occurred, the first nine weeks after traps were rebaited with 2.9 males/t/d and 7.3 females/t/d. The second peak occurred in autumn, 18 weeks after traps had been rebaited with 6.6 males/t/d and 9.6 females/t/d.

Whilst these results are encouraging, fruit collections are required to confirm results. These were not carried out due to staffing and funding issues.

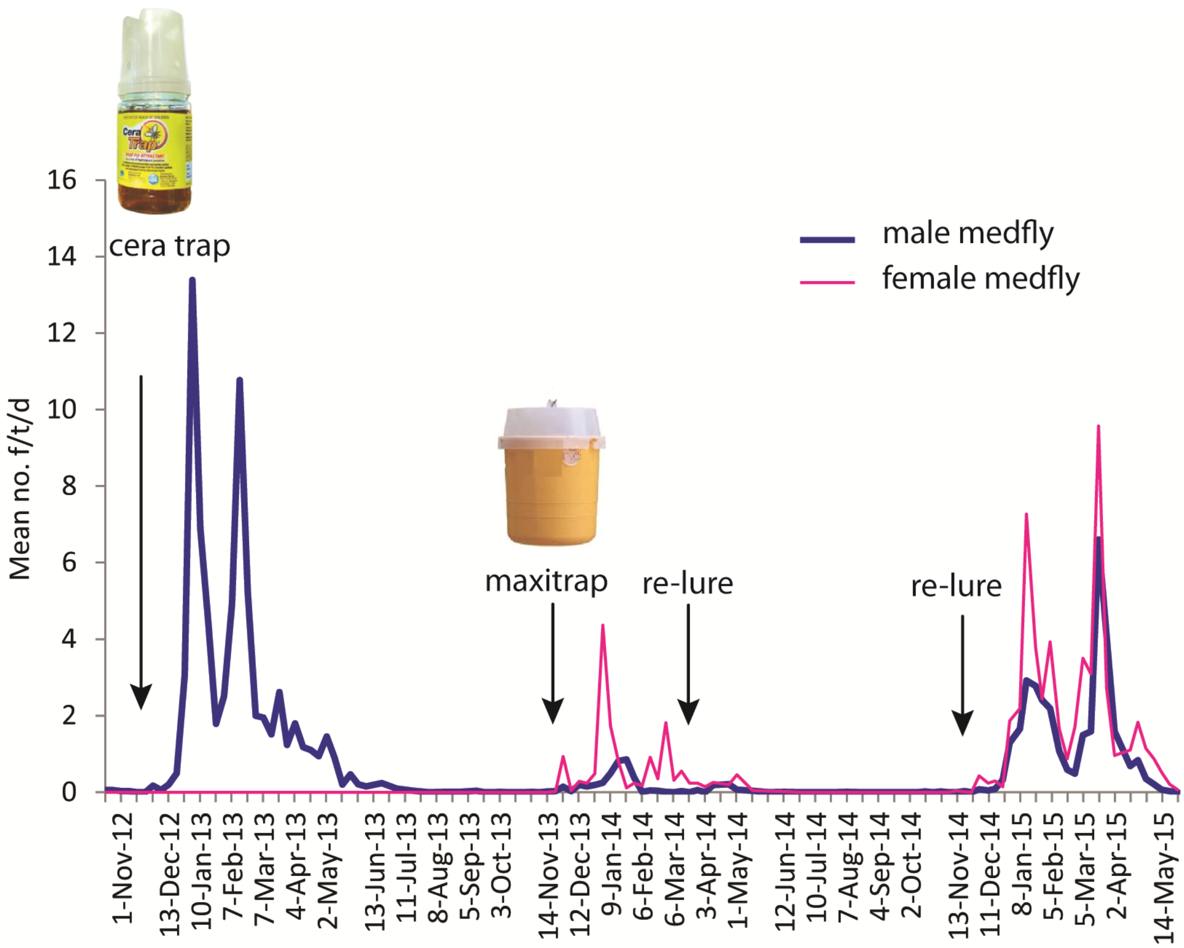

Figure 3.24. The mean number of male and female medfly caught per trap per day (f/t/d) in monitoring traps located in Jarrahdale. The arrows indicate when mass trapping devices were installed or re-lured.

3.5.3 Which lures and traps are the best to use for monitoring or mass trapping?

Female lures

Under low fly abundance (trial 1, apple) BioLure®Unipak was the most attractive lure (F = 9.98, df = 4 & 16, P = 0.0003), catching over two f/t/d (Fig. 3.25). This was followed by Ceratitis Unipak, with Biotrap gel, and yellow Unipak attracting less than 1 f/t/d. In trial 2 (apple), Biolure Unipack, 3-parts BioLure® and Ceratitis Unipack were the most attractive lures (F = 6.02, df = 4 & 8, P = 0.02) catching 1 or more f/t/d. Less than 0.4 f/t/d were captured in traps baited with yellow Unipak and Biotrap gel.

Under high fly abundance (trial 3, pear), over 5 f/t/d were caught in BioLure® Unipack baited traps followed by Ceratitis Unipack, and 3-parts BioLure® (F = 4.22, df = 4 & 8, P = 0.04). Biotrap gel and yellow Unipak were least effective, catching 3.2-3.7 f/t/d.

Our results mirror those of Navarro-Llopis et al. (2008) and Holler et al. (2009) who found that Unipak and 3 part-BioLure® dispensers were equivalent in terms of capture of medfly.

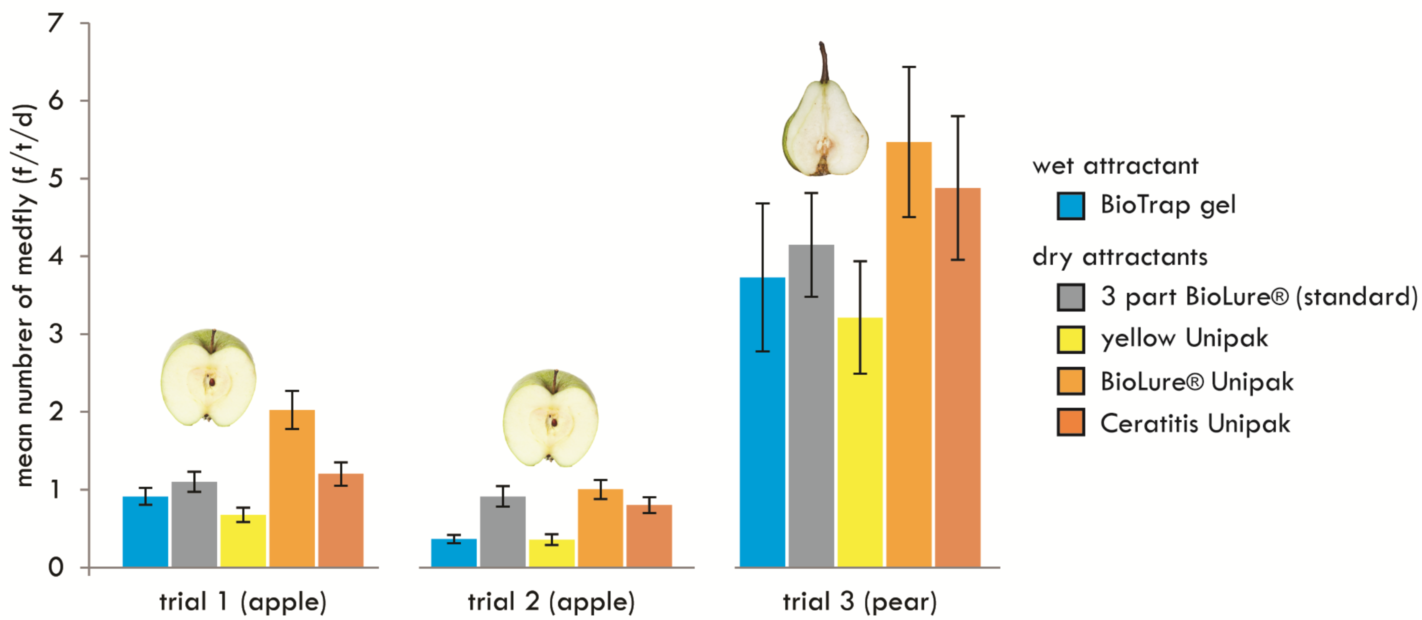

Figure 3.25. Comparison of trap captures between different female attractants. Within each trial, bars with different letters differed significantly (P <0.05).

Trap types

2014

In trial 1 (peach) two times more medfly were captured in globe traps compared to the tephri trap, and the fewest medfly were captured in the maxi trap (F = 12.71, df = 3 & 12, P = 0.001; Fig. 3.26). Whilst in trial 2 (plum), 5 more medfly were captured in the maxi trap compared to the tephri trap (F = 4.09, df = 3 & 12, P = 0.03; Fig. 3.26).

2015

In trial 1 (apple), there were significant differences in fly capture between trap type (F = 5.04, df = 4 & 8.03, P

= 0.03). The highest and lowest numbers of medfly were captured in maxi and tephri traps respectively ($p < 0.05$; Fig. 3.26).

In trial 2 (pear), more medfly were captured in the cone and maxitrap, and the least in the tephri trap ($F = 3.94$, df = 4 & 8.51, $P = 0.04$). However, there were no significant differences between the cone, globe (new) and maxi traps; nor between tephri and globe traps ($p > 0.05$; Fig. 3.26).

In trial 3 (plum), trap type did not affect fly capture ($F = 1.26$, df = 4 & 7.61, $P = 0.36$). Although there were no statistically significant differences in fly captures between traps, 1.4 to 2.3 times more flies were trapped in maxi and globe traps compared to the tephri trap (Fig. 3.26).

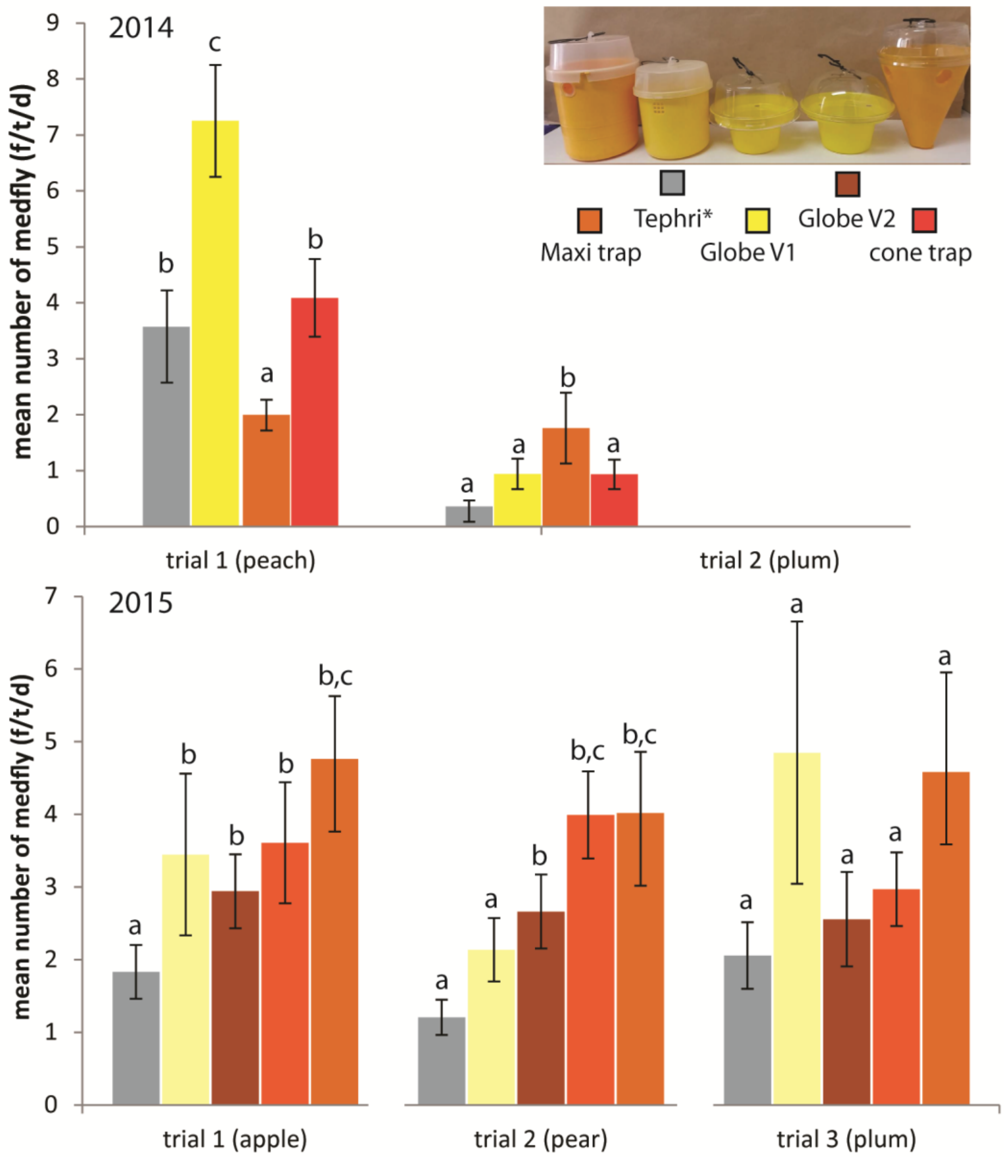

Figure 3.26. Comparison of medfly captures between different traps baited with 3 part lures. Within each trial, bars with different letters differed significantly (P <0.05). * the Tephri was the standard trap used for female-targeted monitoring.

Male lures

2013 Season

In trial 1 there were no differences in the number of male medfly trapped ($F = 0.40$, df = 3 & 6, $P = 0.76$), with less than 0.8 males caught per trap per day. In trials 2 and 3, significant differences in trap captures were detected between lures (trial 2: $F = 5.11$, df = 3 & 6, $P = 0.04$; trial 3: $F = 10.56$, df = 3 & 6, $P < 0.0001$). In trial 2, the 6g wafer and trimedlure plug caught 3.2 and 2.4 more males than the Capilure® baited trap. Whilst in trial 3, two times as many males were caught in modified Lynfield traps baited with 6g trimedlure wafer compared to the other lures (Fig. 3.27).

2014 Season

Lures influenced capture of male medfly in all trials (trial 1: $F = 16.3$, df = 3 & 6, $P = 0.003$; trial 22: $F = 4.91$, df = 3 & 6, $P = 0.046$; trial 3: $F = 32.42$, df = 3 & 6, $P = 0.0004$; Fig. 3.27). In trial 1, more males were caught in traps baited with the trimedlure cone and the 6 g wafer, and traps baited with trimedlure caught 1.3 to 3.2 times more males than traps baited with Capilure®. In trial 2, more males were caught in traps baited with the 6g wafer, with trimedlure-baited traps catching 1.3 to 3.3 times more flies than Capilure® baited traps. In trial 3, 2.6 times more males were caught in traps baited with the 6g wafer compared to Capilure® baited traps ($P<0.05$).

2015 season

Lure again affected fly captures (trial 1: $F = 3.37$, df = 5 & 10, $P = 0.04$; trial 2: $F = 3.43$, df = 5 & 10, $P = 0.04$; Fig. 3.27), with overall captures highest in trimedlure 6g wafer baited traps. In trial 1, 1.6 to 2.9 times fewer males were captured in modified Lynfield traps baited with Capilure® compared to traps baited with trimedlure cone, plug or wafers ($p > 0.05$). In trial 2, 2 to 2.5 times fewer medfly were caught in traps baited with Capilure®, though there were no differences in catches between traps baited with trimedlure.

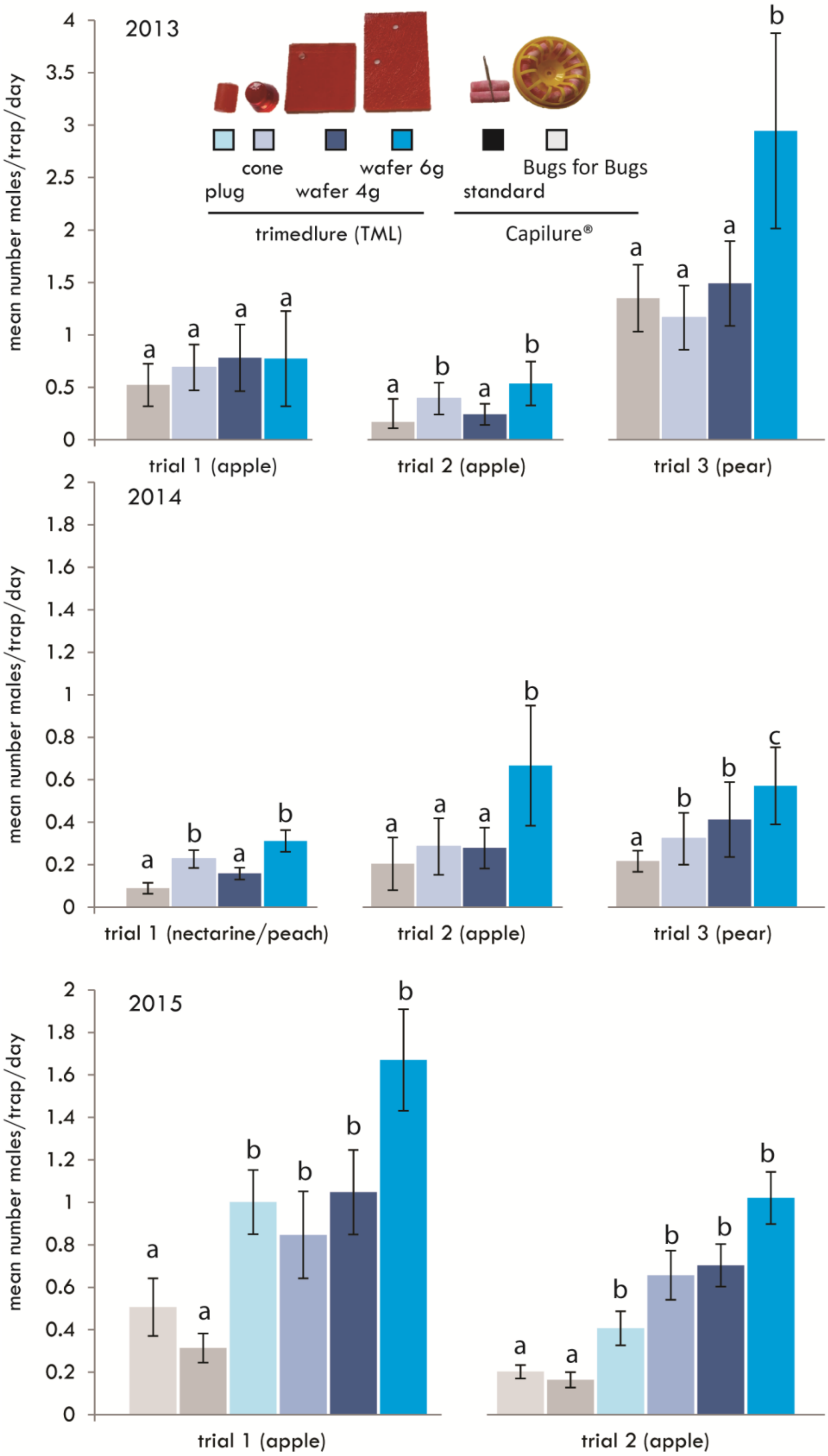

Figure 3.27. Comparison of trap captures between modified Lynfield traps baited with different male attractants. Within each trial, bars with different letters differed significantly (P < 0.05).

Summary

- MagMED® reduced crop losses by medfly when applied alone, but not to the level considered acceptable by commercial growers (2-5% crop loss). In orchards where growers did not apply any other medfly treatments, crop damage ranged from 0.8% in plums to 9% in apples and 58% in nectarines. When MagMED® was applied to otherwise untreated orchards, crop damage dropped to 1.8% in plums, 12-17% in apples and 29.5% in nectarines.

- Economically acceptable levels of crop loss were only attained once MagMED® was combined with other conventional fruit fly controls (bait spraying, cover spraying). In apples, combining MagMED® with cover sprays of fenthion resulted in a drop in crop loss from 2.5% to 0.5%. By combining MagMED® with weekly bait sprays and two cover spray applications in stone fruits, crop loss fell from 13.7% to 4.3% in peaches and from 6.3% to 5% in nectarines. In pears, crop loss in plots treated with cover sprays, bait sprays and MagMED® was 3.7%, compared to 6.3% in plots receiving only cover and bait sprays.

- Twice weekly bait spraying was the single most effective technique at suppressing medfly, providing acceptable control when applied alone. In nectarines, 2% crop loss was recorded when bait sprays were applied twice weekly, compared to 1% when bait sprays were combined with MagMED®. Similarly, damage to apples dropped from 4% to 2% when twice weekly bait sprays were combined with MagMED®.

- Probodelt was equivalent to weekly baiting in 4 of 5 trials conducted in stonefruit, with less than 3% damage to plums, nectarines and peaches. In apricot, less fruit damage occurred in plots treated with bait sprays + Probodelt than bait sprays alone.

- Trials in apple suggest that MagMED® + weekly bait spraying was more effective than Probodelt + weekly bait sprays or bait sprays alone. However, all treatments resulted in less than 2% fruit damage.

- For growers wanting to customise their own mass trapping system, the Maxi trap combined with the 3-part BioLure® or the BioLure® Unipak would be most effective. The cost of the Maxi trap is estimated at A$520-560 per Ha and comparable to the cost of MagMED®. However the traps are likely to last several seasons as they are made from thicker plastic.

- Cone traps and dome traps also performed well and may be cheaper to use. However, as they are made from thinner plastic they may not be robust enough for use in all areas.

- Trimedlure as plugs or wafers were equivalent to, or performed better (1.3 to 6 times better) than the current standard (2 mL Capilure® wick). There appeared to be a dose-response, with the higher dose of 6g trimedlure capturing more medfly than the lower doses.

3.5.4 Sterile Insect Technique

Roleystone

The average number of sterile and wild flies caught per week in the release and non-release areas is shown in Fig 3.28. Most sterile flies in the control area were caught within 400m of the border release area, but some flies were caught up to 1.5 km distant. Overall, from October 17 to January 9 2013, 15689 sterile flies were caught in the release area, 254 in the control area and 12 in traps on ornamental shrubs. The numbers for wild flies were 1755, 2704 and 197 respectively, and the first wild flies were caught on October 31 2012 in traps in ornamental shrubs, citrus and apricots.

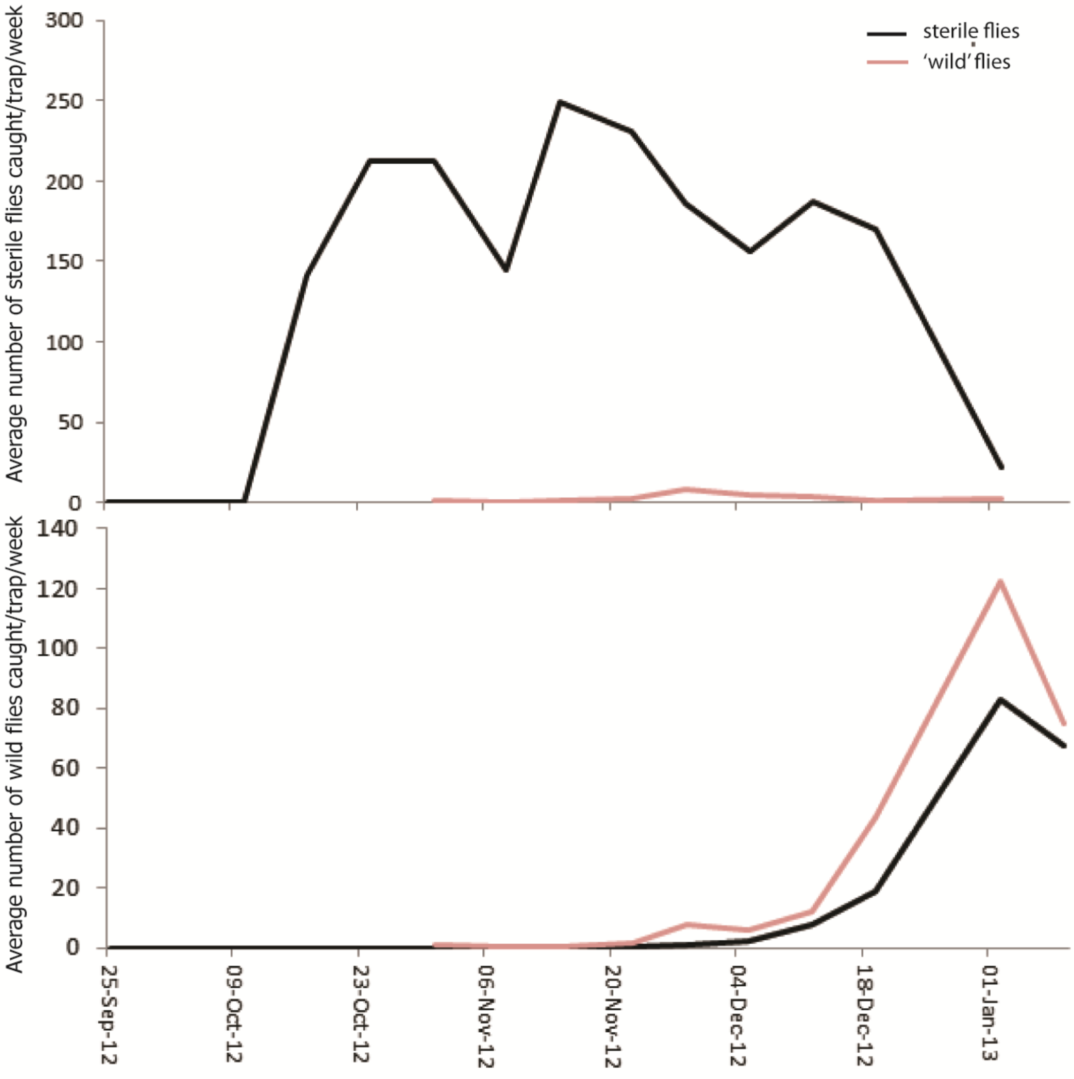

Figure 3.28. Sterile fly numbers peaked at 250 flies/trap/week and remained above150 f/t/w until releases finished. Wild fly numbers increased exponentially from the beginning of December in both the control and release area. The over flooding ratio progressively decreased from 1248 on November 12 2012, to 168 on November 28 2012 to 70 on December 5 2012 when releases ceased.

Jarrahdale orchard trials

Catches of sterile flies released with 40, 50, 80 and 100m spacing can be seen in be seen in Table 3.2 and 3.3.

Table 3.2: Flies distribution after released at 40 m and 80 m intervals in a nectarine orchard in Jarrahdale.

Distance from release point	Trap No												total # flies caught
	1	2	3	4	5	6	7	8	9	10	11	12	
	f/t/d - 3 days after release												
40 M	33	87	48	103	65	75	94	86	27	26	16	11	671
80 M	46	76	41	88	57	84	88	88	23	26	13	2	632
Wild	1	3	3	6	20	8	6	9	7	5	5	2	75
	f/t/d - 7 days after release												
40 M	1	1	0	2	2	2	3	3	0	1	0	0	15
80 M	1	2	1	2	2	2	2	3	0	0	1	0	16
Wild	5	7	5	27	33	23	21	24	1	0	3	4	163

Table 3.3: Flies distribution after released at 50 m and 100 m intervals in a nectarine orchard in Jarrahdale.

Distance from release point	Trap No												total # flies caught
	1	2	3	4	5	6	7	8	9	10	11	12	
	f/t/d - 3 days after release												
40 M	44	68	51	30	26	87	65	103	23	33	10	18	558
80 M	33	62	51	28	29	65	56	90	30	36	9	26	515
	f/t/d - 7 days after release												
Wild	4	6	5	3	2	3	2	3	2	1	2	3	36
40 M	1	1	0	0	1	2	3	1	0	0	0	0	9
80 M	1	5	1	1	3	3	2	2	0	0	0	0	18
Wild	1	1	1	1	5	6	7	2	0	0	0	1	25

Results of fly catch for different times after baiting can be seen in Table 3.4

Table 3.4: Sterile medfly re-capture (f/t/d) after release between 3 to 11 days following baiting in an Apple orchard in Jarrahdale.

	Days after baiting			
	3	**5**	**9**	**11**
2 days after Release	185	185	263	225
5 days after Release	2	38	40	14

Jarrahdale town mass release trial

On May 2 2013, 17 traps caught flies four days after release. Of these only two traps both in the town area caught sterile flies. On May 9 sterile flies were caught in 3 town traps and two traps on one orchard approximately 800m from where the flies were released (Table 3.5). Unfortunately, on April 9 flies dyed with the same colour were released on an orchard adjoining the one that caught flies. Although it is unlikely that the flies came from this release it is still a possibility. Even in the unlikely event the flies came from this orchard, the flies still moved a distance of approximately 800m.

Table 3.5: Number of sterile flies caught in town and orchard traps at Jarrahdale

	02/05/2013	**09/05/2013**	**16/05/2013**	**23/05/2013**
Town traps	392	133	14	9
Orchard traps	0	4	0	0

Summary

- Our results show that although sterile male medfly can move over 1 km, most remain close to the release point and disperse hundreds rather than thousands of meters. This is in line with the results of Meats and Smallridge (2007) who found that "most flies will remain within a few tens of metres of where they are put (or from the point of emergence in the case of a natural propagule) and that 90% would remain within about 400-700 m". However, we still have limited information on the movement patterns of female flies, and these needs to be investigated, as it is a key issue in medfly invasion biology, especially early in the season.

- Although the sterile release at Roleystone impacted on medfly abundance, it was not enough to stop fruit being damaged within the release area. Migration of mated females into the area may be one reason for this. As sterile flies were only released once a week, there was also potential for wild flies to find non-sterile mates once the sterile fly population had diminished to very low levels by day 5.

- For SIT to be effective, a larger area would need to be treated and releases carried out twice per week, preferably after early season bait spraying. Trapping at this time of the year may underestimate medfly numbers, and it may be necessary to treat overwintering wild flies in niches such as citrus for SIT to be effective.

- Trials at Jarrahdale showed that good distribution in orchards can be achieved by releasing on a 100m grid, equivalent to releasing four buckets/Ha. There was no difference in recapture 3 or 5 days after baiting, but there was increased recapture of flies released 9 days after baiting.

- In all instances medfly numbers dropped to low levels by day five after release, once again indicating the need for twice-weekly releases.

- Further trials are required over larger areas with traps being place out 1 day after fly release and checked daily to quantify the effect of baiting on sterile males. The potential to feed sterile males with protein or protein plus lufenuron before release should also be investigated. This may reduce mortality caused by sterile males feeding on bait.

Recommendations

- Area-wide management of medfly should be adopted by commercial growers, particularly those regarded to be highly susceptible to medfly such as summerfruit. Our results suggest that the whole area does not need to be involved if not practicable, with small groups of growers (1-3) achieving suppression with weekly to twice weekly applications of bait sprays.

- Autumn migration of medfly was identified as a significant risk, and bait sprays should be applied through autumn (March-April) to curb the dispersal of medfly adults to over wintering hosts, reducing the pest load in the following spring. Strict orchard hygiene also needs to be adhered to, to ensure that any hosts containing medfly eggs and larvae are destroyed.

- Mass trapping (MagMED®) and lure and kill devices (Probodelt) are new tools that can be incorporated into existing management practices. However they were ineffective as a stand-alone treatment in pome and stone fruit, and need to be combined with bait spraying. Growers wanting to develop their own mass trapping systems should use either 3 part-BioLure® or BioLure® Unipak. These can be used in maxi traps, dome traps or cone traps, together with a strip of dichlorvos as the killing agent. Traps should be applied at the rate of 80 per hectare in high risk crops such as stone fruit. Further trials need to be carried out to determine if perimeter trapping is as effective as applying mass trapping or lure and kill devices to the entire orchard, to reduce costs.

- The sterile insect technique should be developed for application in area-wide management programs. In particular, by combing the `lure and infect' method, whereby flies are attracted to a trap where they are infected with pathogenic fungi (e.g. *Beauveria*/*Metarhizium*) or pesticide (e.g. spinetoram, lufenuron), then released so as to spread toxicant or pathogens to other flies via contact such as mating.

- Monitoring is an invaluable tool for managing fruit fly control programs on commercial orchards to identify hot spots and to determine if controls are effective. Male and female targeted systems are now available commercially. For male-targeted trapping, trimedlure plugs are recommended. For female-trapping, growers can use dome, cone or Maxi traps combined with 3-part BioLure® or Unipak BioLure®.

- Further work is required to identify possible chemical replacements for maldison and trichlorfon, currently used in bait sprays, and to lengthen the life of bait sprays by incorporating different proteins and additives (e.g. stickers and thickeners). Trichlorfon is listed as a priority 1 chemical by the APVMA, and malathion is currently under review.

- The development of novel bait stations, whereby bait is applied to a device rather than to the crop itself is also recommended. This is important where phytotoxicity to fruit or foliage, or residues are a problem such as growers trying to achieve zero residues in fruit.

Scientific Refereed Publications

<u>Journal articles</u>

Rahman T and Broughton S. 2015. Suppressing Mediterranean fruit fly with Magnet™ MED in pome and stone fruit orchards. Manuscript submitted to Crop Protection.

Jessup AJ, Ekman J, Broughton S and Dominiak BC.2015. Developing mass trapping for fruit fly in Australia. Manuscript submitted to General and Applied Entomology.

IP/Commercialisation

Reports to support the registration of MagMED® and Probodelt devices in Australia have been provided to the relevant companies.

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Appendices

1.1. Monitoring Sites in Jarrahdale

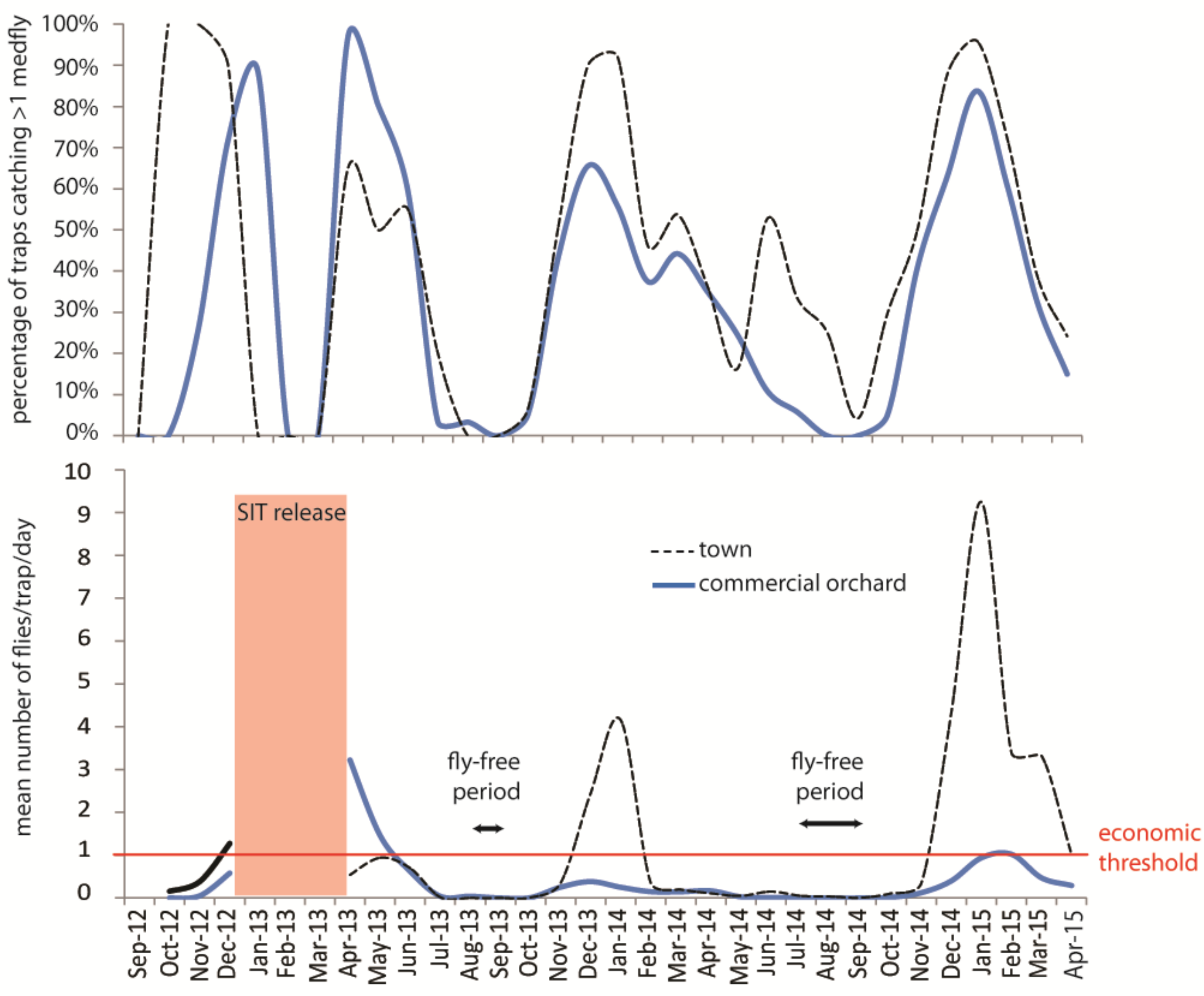
1.2 Spatial and temporal distribution of medfly in Roleystone, Karragullen, Pickering Brook and Carmel

1.3 Technology Transfer Activities

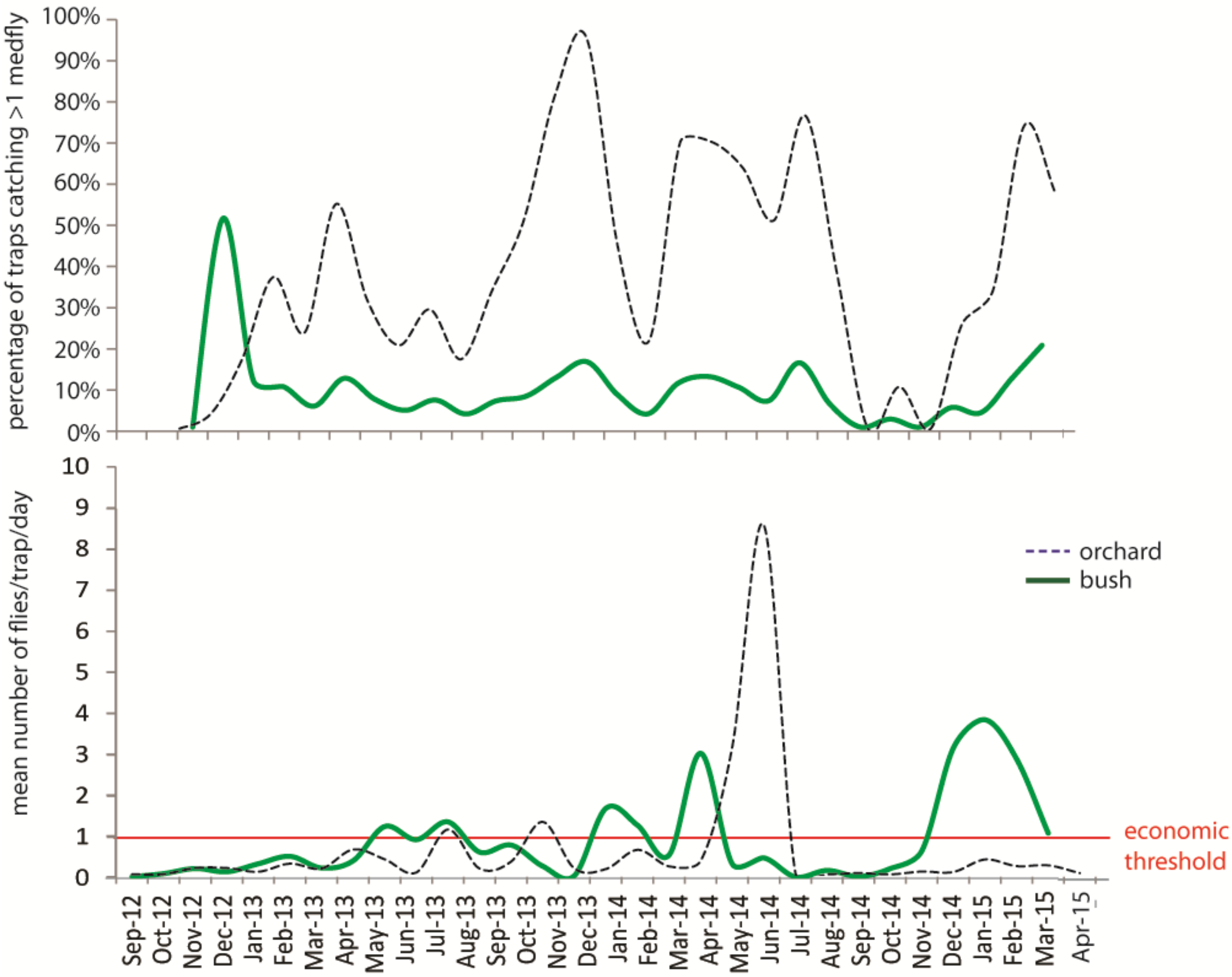
1.1 Monitoring sites in Jarrahdale

Site	Area	Crop	Distance from town (km)
Commercial Orchard 1	8.8 Ha	Apples, nectarines	0.65
Commercial Orchard 2	8.5 Ha	Apples, nectarines	1.08
Commercial Orchard 3	5.2 Ha	apples	1.2
Uncooperative grower	2.9 Ha	Loquats, apples, nectarines	1.91
Commercial Orchard 4	5.2 Ha	Apples	4.25
Small landholder 1	0.9 Ha	Nectarines, apples	4.3
Small landholder 2	5.5	Plums, apples, pears, peaches	
Commercial orchard 5	7.5 Ha	Peaches, apples	
Small landholder 3	6.4 Ha	Apples,	
Small landholder 4	2.7 Ha	Nectarines, plums	
Commercial orchard 6	8.5 Ha		2.11
Winery	0.2 Ha	Oranges, lemons	0.25
Organic Orchard	9 Ha	Apples, persimmons, oranges, lemons	
Small landholder	1.2 Ha	Plums, nectarines, apples, mandarins, loquats	0.6

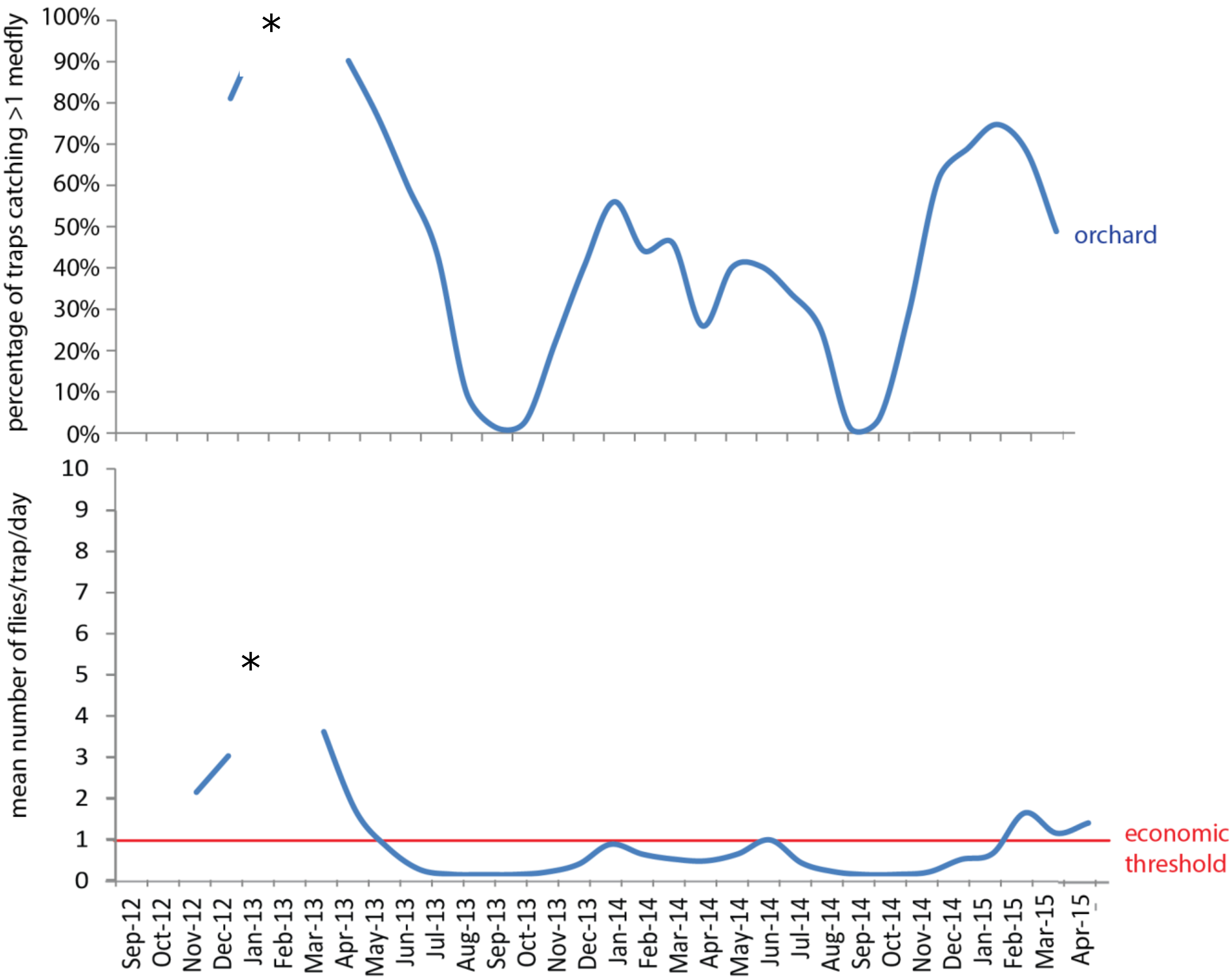
1.2 Spatial and temporal distribution of medfly in Roleystone, Pickering Brook Karragullen, and Carmel



Temporal and spatial distribution of medfly in Roleystone



Temporal and spatial distribution of medfly in Pickering Brook



Temporal and spatial distribution of medfly in Karragullen. *Traps were not checked between December 2012 and March 2013.

1.3 Technology Transfer Activities

Grower Meetings

- 6 September 2012, Jarrahdale Tavern, Jarrahdale.
- 26 February 2013, Medfly Project Update, Hills Orchard Improvement Group Update Meeting, DAFWA Forrestfield Office.
- 15 March 2013, Medfly Project Update, Donnybrook Orchard Improvement Group, Kirup.
- 25 July 2013, Medfly Control Meeting, Perth Hills.
- 10 September 2014, Table Grape Grower's Workshop, Swan Valley.
- 25 September 2013, Medfly Project Update, Bruno Gianetti Hall, Jarrahdale.
- 18 July 2014, Medfly Project Update, Sunpick Orchard, Pickering Brook and Red Valley Orchard, Karragullen.
- 18 August 2014, Medfly update meeting, Donnybrook Orchard Improvement Group, Balingup.
  Steering Committee meetings - Fruitwest Executive Manager, Ben Darbyshire (pome), Mark Wilkinson (stonefruit), and Dr James Risdill-Smith (CSIRO)
- 20 February 2013, Steering Committee Meeting, DAFWA, South Perth.
- 20 February 2014, Steering Committee Meeting, DAFWA, South Perth.
- 6 August 2015, Medfly update, Pomefruit APC Committee, Bunbury DAFWA, Bunbury.
- 24 August 2015, Medfly update, Stonefruit APC Committee, Karragullen Scout Hall, Karragullen.

Media Releases

- DAFWA 2012, Fruit fly the target of a new trial at Roleystone, 15 October 2012, DAFWA, Perth.
- DAFWA 2012, Team approach to 'swat fruit fly' and enjoy home grown fruit, 6 December 2012, DAFWA, Perth.
- DAFWA 2013, Mediterranean fruit fly update for Jarrahdale, media release, 8 January 2013, DAFWA, Perth.
- DAFWA 2013, 10 June 2013, Mediterranean fruit fly expert to help local industry.
- 3 July 2013, Multi-pronged approach needed to beat fruit fly.
- 19 September 2013, Orchardists and backyard fruit growers invited to Jarrahdale Medfly meeting.
- 25 September 2013, Strike early and strike often for Medfly.
- 18 December 2013, Baiting reminder: Don't get stung by fruit fly.
- 3 April 2014, No time for complacency for orchardists.
- 4 September 2014, Start baiting now and then often for Medfly.
- 6 November 2014, Medfly initiative proposed for Hills growers.
- 16 February 2015, Maintain the effort against fruit fly this summer and autumn.
- 10 April 2015, Remain vigilant against fruit fly in autumn.

Radio Interviews

- 8 January 2013, Medfly, Sonya Broughton, ABC Northwest. Interview with Jo Prendergast, Rural Reporter Geraldton.
- 14 January 2014, Medfly, Sonya Broughton, ABC Northwest. Interview with Jo Prendergast, Rural Reporter Geraldton.
- 16 April 2014, Medfly, Sonya Broughton, ABC Great Southern. Interview with Bridget Fitzgerald, Rural Reporter Bunbury.
- 10 April 2015, baiting for Medfly, Sonya Broughton interview with Bridget Fitzgerald, Rural Reporter Bunbury.

Newspaper articles

- 10 January 2013, Fruit fly update forum at Jarrahdale. Countryman, page 2.
- 24 September 2013, Ideas to fly thick and fast, Comment News, Perth, pg. 3
- 22 October 2013, Residents urged to help fight against fly. Comment News Perth, pg. 9.
- 24 April 2014, Fruit fly baiting essential, Countryman, page 13.
- 23 April 2014, Fruit fly baiting essential, Manjimup Bridgetown Times, page 13.
- 18 September 2014, Bait now to control Medflies, Countryman, Perth, pg. 17.

Website articles

- Don't get stung by fruit fly this season, Get Farming Australia, 7 January 2014. http://www.getfarming.com.au/pages/farming/articles_view.php?fId=9200020140107122050
- Fruit fly monitoring results

Conferences

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Example of letter drop used to notify householders in Jarrahdale of mass trapping trial in 2013 (Isabel Arevajo-Vigne).