A systems approach for managing Queensland fruit fly in apple and cherry orchards in the Orange district

Dr Shane Hetherington
Department of Primary Industries

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FINAL REPORT

A SYSTEMS APPROACH FOR MANAGING QUEENSLAND FRUIT FLY IN APPLE AND CHERRY ORCHARDS IN THE ORANGE DISTRICT

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A systems approach for managing Queensland fruit fly in apple and cherry orchards in the Orange District

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June 2011

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Dr Katina Lindhout initiated this project and obtained the necessary industry support. Much of the intellectual effort behind this project belongs to her.

Biometric analysis of the project’s data was conducted by Remy van de Van. His thorough and analytical treatment of the data was much appreciated.
Media Summary

Orchards in the Orange region (NSW) produce significant quantities of cherries and apples. Queensland fruit fly (QFF) can damage both crops and has the potential to limit domestic and export markets. Orchardists are proactively developing management options which will meet their customers’ requirements while reducing their dependence on pesticides which are likely to become unavailable in the near future. An improved knowledge of QFF biology is vital to these improvements.

This study found that QFF infestations do not originate in Orange township, so management options are limited to on-farm practices. In recent years heavy rainfall at harvest has spoilt many cherry crops. It is often difficult to justify the labour costs associated with disposal of damaged fruit when it brings no sales income. The common practice of allowing damaged fruit to remain unpicked and rot in orchards promotes QFF infestation. QFF numbers in ‘unpicked’ orchards rise dramatically and these flies disperse in to nearby apple crops. Cherry orchardists should consider the cost of increased QFF infestation in subsequent crops when making the decision to leave fruit unharvested. This is particularly the case when QFF is likely to move in to neighbour’s apple orchards. QFF may survive winter in the Orange region in a soil-borne phase of their life-cycle. Unharvested, infested cherries often fall to the ground and are likely to provide a source of early-season infestation in the subsequent season. Improved orchard hygiene including off-orchard disposal of damaged fruit is likely to reduce subsequent QFF damage.

This study did not attempt to determine the relative costs associated with not harvesting cherry fruit and increase QFF activity versus disposal of damaged cherry fruit. While improved orchard hygiene will be promoted to industry, a thorough analysis of its economic benefits is likely to provide further incentive for farmers to make changes in their orchard management.
Technical Summary

A significant proportion of the nation’s apples and cherries are produced in the Orange region of NSW. Queensland fruit fly (QFF) threatens these crops by damaging fruit and limiting access to export markets. This pest has been well controlled through good farm management and judicious use of a number of pesticides. In response to consumers’ requirements and the possible deregistration of key pesticides, fruit industries are investigating alternative QFF management techniques. Systems management emphasises good farm management and integrates this with existing and novel control techniques. Successful systems management relies on farmers having a good knowledge of QFF and an ability to target key components of its biology. This study explored the dispersal and distribution of QFF.

Populations become established in December or January coinciding with the cherry harvest season. There is very little evidence to support assertions that these early populations originate from infested fruit being brought in to the district. It is more likely that flies survive through the winter as soil-borne pupae and become active as temperatures rise.

It is also unlikely that QFF populations originate in urban areas and then move outwards in to orchards. The first flies appear in orchards two weeks prior to their appearance in urban areas. Proximity to Orange township does not predispose orchards to early or severe QFF infestation. Rural populations also become much larger than urban populations.

Improvements in the varieties available to farmers have allowed them to supply fresh fruit to consumers for longer periods. There is very little time between harvest of late cherry varieties such as Van and early apple varieties. These crops are often grown in close proximity to one another. This study determined that QFF does not move from healthy cherry crops in to nearby apple crops.

Very high rainfall was recorded in the region during the 2010-11 cherry harvest. As a result mature fruit split and became diseased and 50% (16 of 32) of the cherry orchards in this study did not harvest crops. Unmarketable fruit is often allowed to rot in-situ as the labour costs associated with its disposal cannot be matched by sales income. QFF populations in cherry orchards which have not harvested damaged fruit are significantly higher than in orchards in which fruit has been harvested. In addition, QFF populations in apple orchards which are less than 1.5km from these unharvested cherry orchards are significantly higher.

This study provides information to support a number of QFF management recommendations in the Orange region.

- Promoting improved backyard fruit management in Orange township will not influence QFF infestation in apple and cherry orchards.
- Cherry orchard hygiene is critical to reducing QFF numbers. In particular the practice of allowing damaged crops to rot in-situ leads to large increases in QFF numbers. Where possible damaged cherry fruit should be disposed of off-orchard.
Increased QFF monitoring and management will be required in early apple orchards which are within 1.5km of unpicked cherry orchards. Not picking cherries is likely to affect your neighbour’s early apple blocks.

Further work is required. This study did not examine the economic implications of allowing unharvested cherry crops to rot in-situ. In the Orange region cherry and apple crops are grown in close proximity. It seems likely that QFF dispersal from unharvested cherry crops will cause economic loss in orchardists’ own apple blocks as well as those of nearby neighbours.

Additionally, this study was unable to relate elevated trap catches with fruit damage at harvest. There are a number of possible reasons for this. The fruit sampling and evaluation protocol may need improvement and will be reviewed and revised for any future work arising from this study. Alternatively, it is possible that the fruit studied here are non-preferred hosts for QFF. This possibility would have major implications for QFF management and quarantine protocols and should be the subject of further rigorous research.
1. Introduction

A significant proportion of the national apple and cherry crop are produced in the Orange, NSW region (8.3% and 13% respectively\(^1\)). Australian temperate fruit production regions tend to be dominated by a single crop type. The Orange region is unusual in having large numbers of apple and cherry orchards. In 1996 the Australian Bureau of Statistics (ABS) reported 567,905 apple trees and 163,390 cherry trees. There is also an increasing trend toward cherry production with 43% of cherry plantings under 6 years of age (cf. 6.4% of apple trees 3 years and under). Many orchardists now produce both fruit crops.

Queensland fruit fly, (QFF; *Bactrocera tryoni* (Frogatt) (Diptera:Tephritidae)), lays its eggs in maturing and ripe fruit. Maggots hatch from the eggs and the fruit is usually destroyed by their feeding and by associated decays. In addition to the direct loss associated with fruit loss, QFF can cause restricted access in to some markets which maintain very strict quarantine against QFF (Dominiak 2007).

While populations of QFF become established in the district in warmer months it is uncertain if an overwintering population exists (Campbell et al. 2006). A better understanding of factors influencing the annual population dynamics of this pest will be important in developing management strategies.

A previous study in this region determined that obtaining and maintaining market access for cherries on the basis of climatic area freedom from this pest at harvest was impractical (Campbell et al. 2006). This earlier study suggested that orchard management practices contributed to QFF presence. As a result growers were advised to improve orchard hygiene. This is a particular issue in seasons where fruit is not harvested because of hail, fruit splitting or other factors. The labour costs associated with picking and disposing of fruit which brings no income are often considered prohibitive and cherries are allowed to decay *in-situ*.

Proximity to urban areas has also been proposed to have a direct relationship with increased numbers of QFF in nearby orchards. If this is the case, orchards which are closer to Orange township may become infested earlier due to an influx of flies from urban areas where ambient temperatures are slightly higher and there are poorly maintained backyard host trees.

The cherry crop is harvested from December with some late varieties (e.g. Van) continuing through to early February. The apple crop is harvested from February (Gala) until May. Hence there is a continuous supply of mature cherry or apple fruit from November to May.

These factors may have implications for QFF populations. It is possible that apple fruit faces an increased risk of fruit fly infestation, particularly where they are close to late cherry crops. This risk may be exacerbated where fruit is damaged and allowed to decay *in-situ*.

This project’s aims were to assist growers by providing them with some of the information required to develop a systems approach to QFF management in the Orange region. A systems approach to QFF management is required in order to proactively meet customer’s requirements for high quality, low input cherry and apple

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1 ABS agricultural survey 2006. By production volume
fruit. This information will become increasingly important with the potential withdrawal of a number of key QFF management insecticides. Orchardists using systems management will need critical information on the pest’s biology to allow for effective targeting.

It did this by quantitatively testing a number of hypotheses

*Hypothesis 1.* The risk of temperate fruit crops becoming infested by QFF is directly related to their distance from urban areas. Infestation occurs more quickly and numbers of fruit flies are greater in orchards which are closer to town.

*Hypothesis 2.* The risk of apple crops becoming infested by QFF is directly related to their distance from cherry orchards. Infestation occurs more quickly and numbers of fruit flies are greater in apple orchards which are closer to cherry orchards.

*Hypothesis 3.* The risk of apple crops becoming infested by QFF is directly related to their distance from cherry orchards in which fruit was not picked.

*Hypothesis 4.* Trap catches are directly related to fruit damage at harvest

By quantitatively testing these hypotheses this study sought to validate current QFF management practice recommendations. It was also hoped that a number of new recommendations could be developed and that we could provide information which will guide the development of a systems approach to QFF management in the Orange region.
2. Methods

2.1 Fruit fly surveys of orchards and urban areas

A total of 84 Lynfield traps with cuelure baits were distributed around the Orange district in urban backyards, cherry and apple orchards in November 2010. Appendix 9.1 (page 33) provides a detailed description of the position and other details of each trap. As far as possible trap distribution was even throughout the production area (Figure 1). There were a total of 61 traps in rural areas consisting of 29 traps placed in apple orchards and 32 traps placed in cherry orchards. Twenty-three traps were placed in Orange township in a roughly grid pattern. An attempt was made to place rural and urban traps in the same location as those in an earlier study (Campbell et al. 2006). At times this was not possible due to changes in orchard management. As the earlier study only considered cherry orchards, traps placed in apple orchards were in novel locations.

In town, traps had been placed in public parks in the earlier study and this was avoided here as these traps tended to be meddled with or disappear. Because we are proposing a relationship between cherry and apple infestations, ‘paired traps’ were placed on enterprises which produced both types of fruit. These traps were always in close proximity to each other (<500m). The maximum distance a trap was placed from the centre of Orange was approximately 16 km.

Figure 1. Distribution of Lynfield traps in the Orange region relative to the centre of Orange township as origin. Further details are available in Appendix 9.1.
Trap checking commenced on the 17th November 2010. Traps were checked 32 times during the growing and production season with the final check being 12th May 2011. It was not possible to monitor all of the traps in a single day. Therefore traps were monitored over a two day period with all of the urban traps monitored on day 1 and rural traps on day 2.

Collected QFF were returned to the Agricultural Scientific Collections Unit (ASCU) where their identity was confirmed as *Bactrocera tryoni* and trap data (number of fruit flies caught and trap co-ordinates) was recorded in the NSW DPI PestMon database.

### 2.2 Fruit fly presence at harvest

#### 2.2.1 Orchard block assessment

Three apple blocks were assessed immediately prior to harvest for presence of QFF. In all cases orchard blocks were scouted for fruit fly adults and stung fruit with collection times biased toward morning, but after temperatures had risen sufficiently for QFF to become active.

A total of 960 trees were scouted in orchard block 1 (orchardist = West; variety = Gala), 640 in orchard block 2 (orchardist = Pearce; variety = Galaxy gala) and 432 in orchard block 3 (orchardist = West; variety = Fuji). Assessment dates were 23rd February 2011, 21st February 2011 and 18th April 2011 respectively.

Trees and fruit were inspected for the physical presence of QFF and fruit was inspected for QFF stings.

#### 2.2.2 Fruit assessment

*Cherries.* Samples (1.2 to 1.5 kg) of cherries rejected at harvest were sampled and the reason for rejection recorded. Samples were taken from 3 orchard blocks: 1. orchardist = Perry and variety = lapin; 2. orchardist = Rossi and variety = lapin; 3. orchardist = West and variety = sweetheart.

*Apples.* In addition to the three orchard blocks above (2.2.1) a fourth block (orchardist = Pearce; variety = Cripps Pink) was assessed for QFF infestation at harvest (18th April 2011).

QFF infested fruit will usually drop to the ground at harvest and is hence can indicate QFF activity. Therefore an estimate was made of fruit drop at harvest.

Samples of dropped fruit were collected from all orchard blocks at harvest (approx 7 kg per sample) and samples of fruit rejected in the packing shed were collected from orchard blocks 1 and 2. Where fruit was rejected in the packing shed it was inspected and the reason for rejection recorded.

Cherry and apple fruit samples were incubated on perlite in suitably sized containers with a nylon mesh cover (Figure 2). Samples were held at 26°C (+/- 5 degrees) and 80% (+/- 20% for humidity) in a controlled environment cabinet for 3 weeks and observed periodically for the presence of larval and adult QFF.

Where fruit flies emerged they were reared to adults for identification in order to distinguish them from *Bactrocera jarvisi* which is also present in the Orange region.
Figure 2. Rejected fruit were placed in containers within a controlled environment cabinet in order to assess them for QFF presence.
3. Results

3.1. Fruit fly statistics

Fruit flies were recorded in 80 traps (95.2% of the total). The first trap capture occurred on the 16th of December (Trap 5032; -33.24794, 148.98625), in a cherry orchard 10.29km from the centre of Orange township. A total of 2701 QFF were captured during the study (Table 1).

Table 1. QFF captured in cue-lure baited Lynfield traps (16 December 2010 to 12 May 2011) in the Orange region.

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Total flies caught</th>
<th>Mean flies caught per trap</th>
<th>Traps catching QFF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>107</td>
<td>4.65</td>
<td>87.0</td>
</tr>
<tr>
<td>Cherry orchard</td>
<td>2192</td>
<td>68.50</td>
<td>100</td>
</tr>
<tr>
<td>Apple orchard</td>
<td>402</td>
<td>13.86</td>
<td>96.6</td>
</tr>
</tbody>
</table>

3.2 Climatic conditions and QFF population dynamics during this trial

Mean rainfall during this study was significantly higher than the long term average for the Orange region while temperatures were similar (Table 2). The majority of the rainfall fell during December 2010 (Table 3), a time coinciding with cherry maturation and harvest. Significant above average monthly rainfall was also experienced during February and March.

Table 2. Gross comparison of long term average climatic factors¹ with those experienced during the 2003-06 fruit production season (November – May) and the current study (2010-11)².

<table>
<thead>
<tr>
<th></th>
<th>Mean monthly max temp (°C)</th>
<th>Mean monthly min Temp (°C)</th>
<th>Mean monthly total rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003-06</td>
<td>22.6</td>
<td>8.4</td>
<td>60.7</td>
</tr>
<tr>
<td>Long term mean</td>
<td>21.9</td>
<td>9.9</td>
<td>70.9</td>
</tr>
<tr>
<td>2010-11</td>
<td>22.0</td>
<td>9.5</td>
<td>105.9</td>
</tr>
</tbody>
</table>

1. 1966 to present
2. Source: Australian Bureau of meteorology for Orange Agricultural Institute (33.3211°S 149.0828°E)
Table 3. Orange region rainfall and temperatures\(^1\) (16 December 2010 to 12 May 2011)

<table>
<thead>
<tr>
<th></th>
<th>Dec(^2)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean min temp (°C)</td>
<td>11.2</td>
<td>14.2</td>
<td>13.7</td>
<td>10.6</td>
<td>5.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Mean max temp (°C)</td>
<td>21.8</td>
<td>26.8</td>
<td>25.4</td>
<td>21.1</td>
<td>17</td>
<td>12.7</td>
</tr>
<tr>
<td>Total rainfall (mm)</td>
<td>299.9</td>
<td>39</td>
<td>71.3</td>
<td>140.6</td>
<td>42</td>
<td>74.6</td>
</tr>
</tbody>
</table>

1. Source: Australian Bureau of Meteorology for Orange Agricultural Institute (33.3211°S 149.0828°E)
2. 16 December 2010 to 31 December 2010
3. 1 May 2011 to 12 May 2011

Trap captures of orchard-based populations of QFF reached peak numbers on day 49 (3 February 2011) of the study (Figure 3). Relatively large numbers of flies were observed until day 133 (28 April 2011) and captures declined steeply until the study’s conclusion.

Trap captures of urban-based populations of QFF began later than those in rural areas. A relatively large number (7) flies were caught on day 50 (4 February 2011) of the study but a sustained increase in population did not occur until day 71 (25 February 2011). Urban populations remained relatively high until day 140 (5 May 2011). No QFF were captured in urban traps after that date.
Figure 3 Queensland fruit fly trapped in Lynfield traps baited with cuelure (A) in rural and (B) urban areas. (C) High rainfall and warm temperatures corresponded with the first QFF captures. ★ Weekly mean maximum temperature, ● Weekly mean minimum temperature, • Weekly rainfall.
3.3 Are urban trap catches related to orchard trap catches?

3.3.1 Does distance from town have an impact on time to first fruit fly trapping?

Distance from the centre of Orange township was regressed on the week of first trap capture for all traps (based in urban areas, cherry orchards and apple orchards) (Figure 4). The regression indicates a significant (P < 0.05) declining trend, with orchards further from Orange having earlier first fly traps. However, there is no significant correlation between these two variables once orchard type (apple, cherry, urban) is taken into account. This conclusion agrees with a visual inspection of Figure 4. Basically what we have is that on average, the first fly is caught significantly earlier in cherry orchards than in apple orchards which in turn are caught significantly earlier than in urban areas. Within an orchard type, distance from Orange township does not correlate with time of first trapping.

![Regression of distance from the centre of Orange township on the week of first fruit fly capture.](image)

Summary. For individual trap types, (urban, cherry or apple) QFF is not caught significantly earlier in orchards in close proximity to Orange township. The time of trap capture is related to trap type with QFF first caught in cherry traps, then apple traps and then urban traps.

3.3.2 Does distance from town have an impact on Number of flies trapped?

Distance from the centre of Orange township was regressed on the mean number of flies trapped +1 for each individual trap (Figure 5).
Figure 5. Regression of the log (mean number of flies trapped + 1), denoted by logMean, versus Distance from Orange (DistOrange) for each trap.

This regression indicates a significant (P < 0.05) positive regression. However, after adjusting for orchard type (apple, cherry, urban) there is no correlation between the numbers of flies caught and the distance to the centre of Orange township. There are significantly more flies caught on average in cherry orchards traps than in apple orchard traps or urban traps (see also Table 1).

Summary. For individual trap types, (urban, cherry or apple) QFF proximity to Orange township has no effect on the number of flies trapped. The number of flies trapped is related to trap type with more QFF caught in cherry traps, then apple traps and then urban traps.

3.4 The influence of proximity to cherry orchards upon QFF trap catches in apple orchards

3.4.1 Does proximity of an apple orchard to a cherry orchard change severity of infection?

The log (mean number of flies trapped +1) was regressed on the distance to the nearest cherry orchard or each apple orchard-based trap (Figure 6.).
Figure 6. Regression of the log (mean number of flies trapped + 1), denoted by logMean, versus Distance to nearest cherry orchard (DNCO) for each apple-orchard-based trap.

There is no significant relationship between the number of QFF captured in an apple-based trap and the distance between the nearest cherry orchard (with or without the two influential results, Traps A5013 and A5099 which are more than 4km from nearest cherry orchard).

Summary: The distance to the nearest cherry orchard has no effect on the number of QFF captured in apple orchard-based traps.

3.5 The influence of picked vs. unpicked cherry orchards on QFF populations

3.5.1 Is there are difference in QFF numbers (N) trapped in picked and unpicked cherry orchards?

Because of the large number of cherry orchards which were not picked a statistical comparison of fruit fly numbers in picked and unpicked orchards could be made using a number of techniques.

If we assume that the distribution of numbers of flies trapped in each trap in each week depends only on cherry orchard type (picked versus unpicked) then the distribution of these numbers can easily be compared. Figure 7 shows plots for the estimated proportion of trappings (trap x week) within each orchard type having N or more flies. Also included with each plot are 95% confidence bounds for the estimated proportions, with these based on 10000 bootstrap samples of the original trap numbers within each orchard type.

Significantly fewer flies are likely to be trapped in Picked orchards than Unpicked orchards.
Figure 7. The proportion of traps (over all times) with more than a nominal (N) number of flies. The dashed line corresponds to 95% confidence intervals.

Alternatively, we can simply examine the box-plots for trap numbers (on log scale) in Unpicked and Picked orchards (Figure 8) and this too indicates significantly larger numbers on average for Unpicked versus Picked orchards. A test for significantly fewer flies being trapped in Picked versus Unpicked orchards is highly significant (P < 0.001 using either Mann-Whiney test or t-test with unequal variances).

Figure 8. Box plots showing the mean, distribution and error associated with log (number of flies + 1) for unpicked and picked cherry orchards.

The above comparisons for the number of QFF captured in picked versus unpicked cherry orchards does not account for spatial or temporal correlation. Examining the
mean number of flies trapped over the observation period (21 weeks) for each trap overcomes the problem of temporal correlation but not spatial (Figure 9).

![Box plots showing the mean, distribution and error associated with log (number of flies + 1) for unpicked and picked cherry orchards and accounting for temporal variation over the 21 week period of this study.](image)

**Figure 9.** Box plots showing the mean, distribution and error associated with log (number of flies + 1) for unpicked and picked cherry orchards and accounting for temporal variation over the 21 week period of this study.

A test for significantly fewer flies being trapped in Picked versus Unpicked orchards is highly significant (P = 0.003, t-test with unequal variances)

**Summary.** Significantly fewer flies were trapped in Picked than in Unpicked cherry orchards.

### 3.6 The influence of proximity to unpicked cherry orchards upon QFF trap catches in apple orchards

3.6.1 *Does proximity to unpicked cherry orchards increase the number of flies in nearby apple orchards?*

The log (mean number of flies trapped +1) was regressed on the distance to the nearest unpicked cherry orchard for each apple orchard-based trap (Figure 10.).
Figure 10. Regression of the log (mean number of flies trapped + 1), denoted by logMean, versus Distance from nearest unpicked cherry orchard (DNUPCO) for each apple trap.

The regression of log (mean number of flies trapped + 1) on DNUPCO is not significant. However the regression is heavily influenced by two data points; A5099 and A5013. Site A5099 is 13.7 km from the centre of Orange township and more than 5km from the nearest unpicked cherry orchard. Site A5013 is 11.4 km from the centre of Orange township and approximately 4km from the nearest unpicked cherry orchard. Both sites are in close proximity to vegetable crops and the QFF captured at these sites may have been dispersed from independent sources. If these two influential sites are excluded the regression is significant (Wald Statistic: F(1, 25) = 6.64, P = 0.02). With the two influential results excluded, the number of flies trapped decreases with increasing distance to the nearest unpicked cherry orchard. Figure 11 shows a plot of the remaining data, together with the predicted trend (± one standard error) following the exclusion of site 5099 and 5013. The table below includes the estimates for the intercept and slope, together with their standard errors. Note that as already stated above, the regression is significant (Wald Statistic: F(1, 25) = 6.64, P = 0.02). The regression remains significant if Trap A5069 excluded.

<table>
<thead>
<tr>
<th>solution</th>
<th>std error</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>0.713</td>
</tr>
<tr>
<td>DNUPCO</td>
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Figure 11. Regression of the log mean +1 of the number of QFF captured on the distance from the nearest unpicked cherry orchard excluding the influential sites 5099 and 5013.

Summary. Two unusual sites were excluded from the analysis. The numbers of QFF trapped in apple blocks was directly related to the orchards distance from an unpicked cherry orchard.

3.7 Fruit fly presence at harvest

3.7.1 Orchard block assessment

QFF was not observed in any of the apple orchard blocks assessed. No QFF damage was observed in orchard blocks 1 and 2. Slight damage which may have been attributable to QFF was seen in orchard block 3, but this could not be confirmed.

3.7.2 Fruit assessment

The majority of cherry fruit damage observed was split fruit. Incubated cherry samples did not yield QFF.

There was very little apple fruit on the ground (<0.5% to 1% of total crop). After rearing out, the 7.1 kg of ground fruit collected from apple orchard block 3 yielded 3 QFF. No other ground fruit sample yielded QFF.

Overall apple fruit rejection was relatively low. Very little fruit damage or defect could be definitely attributed to QFF infestation (Table 4).
Table 4. Causes of damage or defect for apples rejected in the packing shed.

<table>
<thead>
<tr>
<th>Cause of damage or defect</th>
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<tr>
<td>Mechanical damage</td>
<td>1.6</td>
</tr>
<tr>
<td>Pest and disease</td>
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</tr>
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<td>Orchard block 1</td>
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<td>Mechanical damage</td>
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<td>Poor colour</td>
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<td>Blemish</td>
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<td>Orchard block 2</td>
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<tr>
<td>Insect damage (other than QFF)</td>
<td>0.8</td>
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<td>Disease</td>
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<td>Possible QFF (unconfirmed)</td>
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4. Discussion

This study examined the distribution of Queensland Fruit Fly (*Bactrocera tryoni*; QFF) during a fruit production season within a district in which both cherries and apples are grown. The practical objective of this work was to develop and scientifically justify management options for the control of this pest.

*Climatic effects*

QFF have now been trapped for a total of 4 fruit production seasons in cherry orchards and urban areas in the Orange region (including the 3-year study of Campbell et al 2006) and one season in apple orchards (2010-11). The trapping protocols and number of traps was similar between studies and general comparisons and conclusions can be made.

Substantial crop loss was experienced in 2005-06 and 2010-11 because of hail and rain damage respectively. The numbers of QFF trapped were remarkably similar (2081 QFF were trapped in cherry orchards in 2005-6 and 2071 in 2010-11). QFF captures were significantly higher during these two seasons than during the drier seasons of 2003-04 and 2004-05.

Much of the cherry crop is harvested in December. The total rainfall for December 2005 was 68.6mm while it was 299.9 mm for the same period in 2010. The effect of rainfall on QFF populations is complex. Several studies point to it being a critical determinant of QFF population dynamics (e.g. Fletcher 1973, Muthuthranti et al 2010). Rainfall has been shown to increase mortality (Fay and Meats 1987) and decrease reproductive activity (Yonow et al. 2004). Nevertheless there appears to be no direct relationship between rainfall and variations in population numbers (Drew et al. 1984). Given appropriate temperatures for QFF development the secondary effects of rainfall may be more important in determining population variation. For example, where fruit is rain damaged and allowed to decay *in-situ*, nutrients and oviposition sites will be plentiful, enabling greater breeding success. This is the likely reason for large QFF populations in the 2005-06 and 2010-11 seasons in the Orange region. There was a significant ‘lag-time’ between the heavy rainfall recorded in December 2011 and the build up of fruit fly populations (Figure 2). During this period fruit would have begun to decay and soften providing nutrients for emerging, immature QFF.

*QFF Management implications*

In years with average to above average temperatures, fruit fly infestations are likely to be associated with fruit that is damaged by heavy rainfall or hail. Under these conditions any management that minimises fruit damage is also likely to reduce QFF infestation.

*Urban influence*

A persistent theory in the Orange region is that proximity to urban areas predisposes orchards to relatively early and severe infestations. Allied to this theory is the belief that infestations begin in urban areas due to the greater likelihood of infested fruit
being purchased out of the district, rejected and poorly disposed of by urban residents. A number of factors are thought to contribute to this phenomenon.

- Infested commercial fruit is more likely to be purchased and disposed of in urban regions.
- Infested fruit is likely to be disposed of in landfill or backyard compost facilities and fruit degradation may be prolonged.
- Backyard fruit trees tend to be poorly managed and subject to fewer, less effective insecticide applications than commercial orchards.
- The ambient temperature in Orange township is typically higher than in surrounding orchards and this allows more rapid completion of QFF lifecycles.
- Towns present more favourable water conditions for QFF development because irrigation is more common.

Climatic modelling predicts that towns are QFF “oases” compared with the surrounding “rural desert” (Dominiak et al. 2006). Data from this and earlier studies in this region do not support this statement.

Rural QFF populations were consistently detected earlier and became larger during the three cherry production seasons between 2004 and 2006 (Campbell 2006). In this study the first rural trap catch preceded an urban catch by 15 days and was more than 10 km from an urban area. It seems unlikely that early trap catches were the result of QFF dispersal from an urban focus. There was no correlation between proximity to Orange township and the time at which rural trap catches were made. There was also no relationship between proximity to Orange township and the subsequent number of fruit flies trapped in rural areas.

Urban QFF activity did not affect QFF activity in nearby urban regions.

### QFF Management implications

For the Orange region there is little value in improving backyard fruit production practices. There is no evidence that Orange township is an urban QFF ‘oasis’ and improved sanitation and removal of infested trees and unharvested urban crops is unlikely to provide practical benefit to commercial producers.

### Overwintering

A previous study concluded that QFF does not overwinter in the Orange region and proposed that a population becomes established each year as a result of dispersal from other regions and/or accidental introduction (Campbell et al 2006). The underlying logic to this conclusion was that winter temperatures in the Orange region are too low to allow an overwintering population to survive. This conclusion was supported by CLIMEX modelling such at that reported by Yonow and Sutherst (1998). However, to provide accurate forecasts of species distribution CLIMEX relies on adequate, accurate input data. Predictions are less reliable for production regions such as Orange which are physically small and undulating. Yonow and Sutherst (1998) also discuss the ability of species to persist in locations deemed hostile by CLIMEX where adequate shelter is provided by microclimates. In effect, current CLIMEX modelling is too coarse to allow accurate prediction of QFF under these circumstances.
Campbell et al (2006) also used unspecified ‘DNA analysis’ to show that populations of QFF from Orange were genetically similar to those from Sydney and Dubbo (‘the Northern group’). It was then argued that this provided evidence that a yearly influx of QFF from nearby, warmer regions was the origin of QFF in the Orange region. An alternative interpretation would be that an overwintering population exists in warmer microclimates within the Orange region and this is the source of early season dispersal.

The existence of an overwintering population of QFF in the Orange region remains uncertain. Determining the origins of Orange’s QFF population was not one of the aims of this study. Nonetheless, it provided preliminary evidence for the existence of an overwintering population.

Regardless of the origin of infestation early-season populations of QFF in the Orange region would be dominated by immature individuals. Immature flies have a post-teneral dispersive phase moving randomly and to greater distances than their adult counterparts (Fletcher 1974, Meats 1998, Weldon 2007, Weldon and Meats 2007). Such a population would have a distinctive dispersal pattern with spread from an establishment focus or small number of foci.

- **Scenario 1.** For seasonal, de-novo populations established by invasive individuals this pattern would be expected to be biased toward the most likely introduction locations; town, highways or land-fills.

- **Scenario 2.** Where populations grow from a small number of overwintering individuals infestation foci are likely to be more evenly distributed but biased toward warmer microclimates such as north-facing orchards or sites close to sheds.

The distribution of QFF observed over time in this study (Appendix 9.2) more closely approximates Scenario 2. Agricultural precedents exist. Spanish olives are infested annually by the fruit fly *Dacus oleae*. In this case low winter temperatures kill the larvae within olives, and also the adults, but a few of the pupae overwintering in the soil survive and give rise to adults which oviposit in the new season’s fruit when it becomes available (Templado and Morillo 1971). There may be value in establishing denser trapping grids around the sites which recorded early catches in this study.

**QFF Management implications**

QFF monitoring should commence in late November across the entire district. Regional and on-farm quarantine is less likely to be effective if endemic, overwintering populations exist.

**Intra-rural dispersal of QFF**

The dispersal of agriculturally important fruit flies has been studied by a number of research groups. Most examined ‘flight distances’ defined as the distance from a release point to subsequent capture in a baited trap. While flight distances of up to 94km have been recorded (MacFarlane et al 1987), the great majority have been less than 5km. Comparison of flight distance makes an implicit assumption of environmental homogeneity. It also assumes QFF population demographics are uniform.
Less attention has been paid to the innate and environmental variables (including human) influencing dispersal or the ecological significance of rare long distance dispersal events (Meats and Edgerton 2008).

QFF is motivated to disperse by a number of stimuli. Individuals must find and consume sugars from substances such as honeydew or fruit juice in order to survive (Bateman 1972, Drew et al 1984). The sex of individuals also influences their response to stimuli. For example, mature females seek out fruit which is suitable for oviposition (Prokopy et al. 1991) and require protein from bacteria or yeasts. Females also respond to pheromones in order to locate males and mate. In general mature flies disperse directionally under the influence of wind-driven stimuli and over shorter distances. In contrast to the random dispersive flights of immature individuals (see Overwintering above), the flights of mature QFF are shorter and movement is toward feeding (Drew 1987, Drew and Lloyd 1987, Fletcher 1987), mating or oviposition sites.

On farm management of fruit may affect these stimuli and hence QFF dispersal. The movements of mature flies are directly related to the availability of fruiting hosts (Fletcher 1974). In addition, the maturity structural integrity and state of decomposition of fruit and microbial population of fruit are directly related to its attractiveness (Dalby-Ball and Meats 2000).

Both apple and cherry orchards are grown in the Orange region. There is often little distance between these fruit types and in some parts of the region (e.g. The Towac Valley), orchards are essentially contiguous. QFF preferentially oviposits in softening, near-mature fruit. In this study QFF adults were first caught in cuelure traps on the 16th of December, coinciding with the fruit maturation phase in early cherry varieties. In this region the cherry crop is harvested from December with some late varieties (e.g. Van) continuing through to early February. The apple crop is harvested from February (Gala) until May. Hence there is a continuous supply of mature cherry or apple fruit from November to May.

The 2010-11 fruit season was commercially challenging. Record rainfall during the cherry harvest season destroyed many cherry crops; fruit split and became unmarketable. Of the 32 cherry orchards monitored in this study, 16 were not harvested. While this was – obviously – commercially undesirable, it provided an opportunity to compare the effect of different on-farm practices upon subsequent QFF population dynamics in apple crops.

This work examined the hypothesis that QFF populations moved from late cherry varieties at harvest in to early apple varieties. This seemed feasible given the temporal continuity of fruit crops in the Orange region. This hypothesis assumed that fruit was essentially intact and that a normal commercial harvest had reduced the number of cherry fruits hosting QFF and that maturing apple fruit provided a stimulus for dispersal.

However, the number of QFF trapped in apple orchards was not significantly related to its proximity to cherry orchards. In terms of QFF infestation, cherry and apple crops are compatible and under normal circumstances fruit fly dispersal from cherry crops in to apple crops is not a commercial concern. Apple crops in close proximity to cherry crops are exposed to no more QFF individuals than those at a greater distance.
Another of this studies hypotheses stated that the risk of QFF infestation in apple crops increased where cherry crops were unpicked and allowed to decay *in-situ*. In examining QFF dispersal Meats and Edgerton (2008) showed that a bigger source population, which would contain fertile females would disperse out and ‘impose a higher propagule pressure on any adjacent uncolonised regions’. Decaying cherry fruit and associated microbes would provide a nutrient source for QFF. More QFF were caught in traps which were amongst unharvested cherry crops than amongst those in intact crops which were harvested.

The numbers of QFF caught in apple crops was significantly and inversely related to distance from an unpicked cherry crop. It is likely that QFF disperses from damaged cherry crops and subsequently exploit apple crops as they mature.

**QFF Management implications**

There is no evidence of fruit fly dispersal from intact late cherry crops in to early maturing apple crops. Early apple crops in close proximity to recently harvested cherry orchards are unlikely to require additional QFF control (cf. those further from cherry crops).

However, where cherry crops are not harvested because of damage QFF is likely to disperse in to nearby early apple crops. In this case QFF populations should be carefully monitored in early apple crops using cue-lure traps and sudden increases in QFF population may require application of a registered pesticide.

An economic analysis of this damage was not a part of this work. But two scenarios should be considered.

1. **QFF dispersal from unharvested cherry crops in to an early apple crop on the same property.** In this case the decision to control QFF depends on the likelihood that the cost associated with loss of apple production outweighs the labour (and chemical) cost of harvesting and disposing of damaged cherries. This decision also relies on the assumption that QFF does not overwinter in the Orange region. This study casts doubt over that assumption and unharvested cherry crops may also be a reservoir for early infestation of the following year’s cherry crop.

2. **QFF dispersal from unharvested cherry crops in to an early apple crop on a neighbour’s property.** In this study QFF were trapped at significantly elevated numbers up to 1.5 km from unharvested, damaged cherry crops.

**QFF presence at harvest**

Despite conditions likely to favour QFF development and the presence of suitable commercial hosts, negligible infestation was found in the orchard or rejected fruit at harvest. If further research arises from this study the QFF scouting and fruit assessment protocols will be reviewed to ensure that sample size and technique are adequate. Nonetheless this finding raises a number of questions which are discussed further in the Recommendations section of this report.

**Other questions raised by this study**

*Does leaving damaged cherry crops lead to economic loss in subsequent apple crops?* This study showed that QFF populations are higher in unpicked cherry blocks than in similar harvested blocks. It also showed that apple blocks closer to unpicked cherry blocks are likely to have higher populations of QFF than similar blocks which
are further from unpicked cherry blocks. This study did not show that these elevated QFF populations contribute to greater damage in apple blocks. Nor did it show that — if damage does occur — it is sufficiently serious to warrant the economic cost of management. Unharvested cherry fruit may also enable greater numbers of QFF to emerge into cherry orchards in the following season.

It is to be hoped that the risk of infesting a neighbours apples is incentive enough to improve cherry orchard hygiene. However this message could be reinforced by an analysis of the ‘hidden’ on-farm costs of not harvesting damaged cherries.

*Will Queensland fruit fly become a bigger problem in the Orange region?*

QFF populations have only been monitored in the Orange region for four seasons (over an eight year period). While the studies suggest that QFF populations are similar across years given similar conditions there is insufficient data to reach a valid conclusion.

The potential distribution of QFF can be forecast using mathematical modelling (Yonow and Sutherst 1998) and a general southward spread of many pests affecting horticultural crops – including QFF – is expected (Sutherst 1990). Sutherst et al (2000) provide a sobering assessment of the possible agricultural impact of climate change. Climate change is likely to increase damage and control costs to commercial growers in QFF endemic regions. The costs to mainland apple, orange and pear growers are expected to increase by $3.1, $4.7 and $12.0 million with increases of 0.5 degrees, 1.0 degrees and 2 degrees C respectively.

Orange is currently considered a marginal environment for QFF and there will be value in continued monitoring.
5. Technology transfer

This work was intended to provide background information and justification for a larger study involving the development of a systems approach for QFF management in the Orange region. Nevertheless it has provided scientific justification for a number of on-farm management recommendations. It has also raised questions which were not envisaged in the original project contract and will be the subject of project proposals.

Some of the proposals results and their implications have been discussed with Simon Boughey (CEO Cherry Growers Australia) and particular interest has been shown in further research to determine if cherries are a preferred host of QFF.

Further extension activities will be undertaken during the winter of 2011 in the lead up to the 2011-12 cherry and apple production seasons. These activities will include discussions at Winter grower’s forums. Analysis of the project’s results was not complete until mid-June. It was therefore not possible to meet the publication deadline for the 2011-12 edition of the NSW DPI Orchard Plant Protection Guide for deciduous fruits in NSW. The recommendations will be used to update this publication’s regular QFF management article in subsequent editions.

Although the implications of the results of this study are local and the work was partially funded through local VC contributions, it has some national relevance. As a signatory to the National Horticultural RD&E Framework, NSW DPI will be making the results of this work available to the lead agency for apples and cherries, the Tasmanian Institute of Agricultural Research (TIAR). Additionally the principal investigator will present this work at the Horticulture for the Future Conference to be held at Lorne, Victoria (18-22 September 2011).
6. Recommendations

6.1 Industry

Many of this study’s recommendations are ready for immediate implementation by industry.

1. Minimise fruit damage. Managing the crop to minimise fruit damage will reduce QFF infestation of subsequent crops. It is also likely to reduce QFF damage in the same block in following seasons.

2. Urban fruit fly control. Improved management of backyard fruit trees in Orange township will result in little practical benefit to commercial orchardists.

3. QFF monitoring. Monitoring for QFF should commence in late November in cherry blocks.

4. On-farm quarantine. Careful control of trees and fruit entering a property is recommended for the management of a range of pests and diseases. However, if QFF is overwintering in the Orange region, this may not be an effective QFF management technique.

5. Monitor and manage movement of QFF between blocks. Healthy crops of late cherries do not pose a QFF risk to nearby early apple varieties. However, where fruit is damaged and QFF populations are allowed to build up, they will disperse to apple blocks within a 1.5km range. Under these circumstances apple orchardists are advised to monitor their crop carefully and manage QFF population build ups as early as possible.

6.2 Scientific

QFF management could be refined through further experimental work on:

Overwintering: This study did not definitively resolve whether an overwintering population of QFF exists in the Orange region. Because genetically similar populations exist in Sydney, Forbes, Dubbo and other nearby locations (Campbell et al 2006) there seems little value in further molecular, genotypic studies. Denser trapping grids are required surrounding sites which recorded early QFF catches in this study. These traps should be monitored year-round with particular emphasis on Spring and unseasonal, warm periods during Winter. Environmental parameters at these sites should be carefully monitored and compared to trap sites where QFF are captured later in the fruit production season.

Correlating trap capture to fruit rejection at harvest. This project failed to correlate orchard trap catches to fruit damage at harvest. If fruit was infested, but was not detected, our protocol was inadequate. There may be a number of reasons for this:

- Late season QFF damage is often difficult to detect at harvest.
- Only a small percentage of fruit infestation is needed to cause significant fruit damage and/or commercial loss. The numbers of fruit sampled may have been inadequate.

Alternatively, the protocol was adequate and QFF was not present in fruit at harvest. In this case further research is needed to determine the host status of mature cherry.
and apple fruit. Host status protocols typically present flies with fruit as the sole site for oviposition. In natural or agricultural environments flies are likely to have choices and bias their behaviour toward preferred sites. Surprisingly few studies have attempted to correlate the number of fruit flies captured in cuelure baited traps with the fruit damage attributable to the pest at harvest. Examples of this type of study have failed to correlate these parameters (Khan MA 2003). Does QFF presence in orchards necessarily infer fruit damage?

**QFF prone orchards.** The majority of QFF are captured on a small percentage of properties. Farm management on these properties may pre-dispose them to QFF infestation. A careful audit of on-farm practices including QFF management on properties recording high and low trap catches may highlight disparities. Simple modifications to current practice through peer-assisted learning would lead to significant improvements in QFF management in some cases.

**The economics of allowing cherry fruit to decay in-situ.** QFF infestations are more likely to occur where cherry fruit has not been harvested and is allowed to decay in-situ. It is difficult to justify the labour costs associated with disposal of fruit which will not bring sales income. However increased QFF infestations are likely because of this practice and loss of subsequent crops (including the crops of neighbours within 1.5km) may justify this expense. An economic analysis is required.

**The effectiveness of novel QFF management techniques.** Key pesticides required to manage QFF are likely to be lost to industry in the short- to medium-term. This study has shown the effectiveness of trap monitoring as a means of observing QFF population variation. These techniques could be used to monitor the effectiveness of a number of novel QFF management techniques. These could include bait-spraying, application of kaolin and winter sod-culture (to expose overwintering pupae to more extreme low temperatures).
7. References


### 8.1. Trap details

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<th>Location</th>
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<th>Cherry/apple</th>
<th>Picked (y/n)</th>
<th>Distance from town centre (km)</th>
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8.2 Queensland Fruit fly caught in the Orange region 2010-11

Dec 2010 - Jan 2011

Trap Host and Infestation Level
- Apple-light
- Urban-light
- Cherry-light