Technical Resource – Fruit Fly

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Prepared for ZESPRI Group Ltd

Roger Gilbertson – Principal, Gilbertson Associates Ltd

Version control

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The changes are listed in the table below:

No.	Version date	Section Changed	Change(s) Description
1.	11 September 2012	The final draft edition	n/a
2.	12 November 2012	Final	Review of draft and amended as appropriate.

Technical Resource – Fruit Fly

1. Pest Information Summary

1.1 Classification

Tephritidae is one of two fly families referred to as "fruit flies", the other family being Drosophilidae (vinegar flies). Tephritid fruit flies are often referred to as being 'true' fruit flies and contain some of the most economically significant pests of fruit and vegetables.

Four genera of fruit fly have been assessed jointly in this analysis. Any major differences between genera are noted throughout the analysis. The genera of concern were discussed and agreed during a technical workshop coordinated by the Ministry for Primary Industries (MPI) and technical representatives from the various industry sectors in September 2010.

There are nearly 5,000 described species of tephritid fruit fly, categorized in almost 500 genera. The four genera represented here all have a number of species that are economically important as they are a major pest of fruit and vegetables (not potatoes) and impact on worldwide trade. Appendix 1 contains factsheets on five Fruit fly pest species chosen either because of the significant economic impact if they were to acclimatise to New Zealand (e.g. Mediterranean fruit fly [Medfly] or Apple Maggot) or because they are representative of their family (e.g. Oriental fruit Fly)

1.1.1 Anastrepha sp.

***Anastrepha* pest species include:**

- *Anastrepha ludens*, Mexican fruit fly **(Refer Appendix 1 for fact sheet)**
- *Anastrepha suspensa*, Caribbean fruit fly
- *Anastrepha obliqua*, West Indian fruit fly
- *Anastrepha fraterculus*, South American fruit fly

1.1.2 Bactrocera sp.

***Bactrocera* pest species include:**

- *Bactrocera correcta* , guava fruit fly
- *Bactrocera invadens*
- *Bactrocera cucurbitae,* melon fly
- *Bactrocera dorsalis*, oriental fruit fly **(Refer Appendix 1 for fact sheet)**
- *Bactrocera tryoni,* Queensland fruit fly **(Refer Appendix 1 for fact sheet)**
- *Bactrocera papaya*, Asian Papaya fruit fly*
- *Bactrocera passiflorae*, Fijian fruit fly*

1.1.3 *Ceratitis sp.*

***Ceratitis* pest species include**:

- *Ceratitis capitata*, Mediterranean fruit fly (**Refer Appendix 1 for fact sheet**)
- *Ceratitis cosyra*, mango fruit fly
- *Ceratitis rosa*, Natal fruit fly

1.1.4 *Rhagoletis sp.*

***Rhagoletis* pest species include:**

- *Rhagoletis completa*, Walnut husk fly
- *Rhagoletis cerasi*, cherry fruit fly
- *Rhagoletis indifferens*, western cherry fruit fly
- *Rhagoletis fausta*, black cherry fruit fly
- *Rhagoletis mendax*, blueberry maggot
- *Rhagoletis cingulata*, eastern cherry fruit fly
- *Rhagoletis pomonella,* apple maggot fly **(Refer Appendix 1 for fact sheet)**

1.2 Diagnostics

Plant Health Australia has provided a valuable handbook (available on-line) on the identification of the key fruit fly species of economic concern to Australia and New Zealand.

Details of the identification characteristics of the genus and species covered by the Technical resource can be viewed at: http://www.planthealthaustralia.com.au/go/phau/strategies-and-policy/handbook-for-the-identification-of-fruit-flies

In New Zealand, the confirmation identification of fruit fly species is a specialist role and is coordinated through the National Plant Pest Reference Laboratory. Qualified local personnel may perform pre-identification and screening of suspected fruit fly. Before survey and control activities are initiated in New Zealand, a MPI recognized authority must verify the first detection of fruit fly.

1.3 History/Distribution

1.3.1 *Regional Distribution*

Within each genera of tephritid fruit fly there are a number of species, but in general each group of species tends to stay within certain regions. This is based on the fly's natural temperature range and the rate/distance it may have spread into other regions of the world. Table 1 summarises the regional distribution of the four genera of primary concern.

Table 1: Regional distribution of four commercially significant Tephritid fruit fly genus.

	Anastrepha sp	*Bactrocera sp.*	*Ceratitis sp.*	*Rhagoletis sp.*
North America	x			x
Central America	x		x	
South America	x		x	
Asia region		x	x	
Australia		x	x	
Africa		x	x	
Europe			x	x

Source: CABI

The genus may not necessarily be distributed within each country in the region as specific characteristics of growing districts and successful eradication programmes play a significant contribution to the intra-regional distribution.

1.3.2 Significance of periodic incursions

The Regional distribution table does not fully describe the impact of the historical incursions into countries/regions where they are not normally distributed. It is usually the associated eradication/management programmes in these cases that hits the headlines.

It is often the infrastructure of the country affected, regularity of the incursions and the environmental conditions and host distribution that adds to the success or otherwise of eradication. Eradication of a recent incursion of the Sri Lankan fruit fly into eastern Africa has largely been unsuccessful and the focus is on management/containment of the fly. Owing to its high reproductive capacity coupled with the lack of competitors and efficient natural enemies, and further compounded with the poor quarantine infrastructure in Africa, the pest has continued to spread at an alarming rate across the continent, with far reaching socioeconomic consequences. Mohamed & Ekesi (2012)

Conversely in the United States a number of incursions have occurred over the last century but each time they have been successfully eradicated. The Mediterranean fruit fly was first discovered in the Hawaiian Islands in 1910 and since this time has invaded another three states (California, Texas and Florida). It has been successfully eradicated from all but Hawaii. University of Florida (2010)

1.3.3 The NZ experience

Since 1989, the MPI (MAF) Surveillance and trapping programme has detected six incursions of fruit flies into New Zealand (refer Table 2).

Table 2: Fruit incursions into New Zealand from 1989

Species	Location	Date	Outcome
3 *Bactrocera passiflorae*	Auckland	March 1990	Increased surveillance, no further finds
1 *Bactrocera tryoni*	Whangarei	May 1995	Increased surveillance, no further finds
2 *Bactrocera tryoni*	Auckland, Nth Shore	April 1996	Increased surveillance, no further finds
1 *Bactrocera papayae*	Auckland, Mt Eden	April 1996	Increased surveillance, no further finds
2 *Ceratitis capitata*	Auckland, Mt Roskill	May 1996	Successful eradication programme.
1 *Bactrocera tryoni*	Auckland, Avondale	May 2012	Increased surveillance, no further finds

Source: MPI website

The only incursion where a breeding population has established in New Zealand was the May 1996 Medfly incident. That Medfly incursion has been the only time that an eradication programme has needed to be instigated in New Zealand. In relative terms the breeding population was only partially successful with the all clear provided within a month of the first detection. Refer section 5.1 for the case study of this incursion.

1.4 Ecological Range (potential range)

As outlined previously, each genera of tephritid fruit fly tends to stay within a certain region/country. Sometimes this is purely down to how far a fruit fly species may have expanded its range, but often a fly's range is determined by its own biology. As an example a fruitfly species may only like a certain type of host which only grows in specific places (e.g. the olive fruit fly (*B. oleae*), feeds on only the wild or commercially cultivated Olive), or it may only pupate within a certain temperature range. Every species is different so the biology/life cycle and behaviour of each individual species of fly needs to be taken into account in order to determine its potential ecological range.

1.5.1 Host range

The table below shows the general host range of particular interest to New Zealand for the four genera discussed in this report. It is not an exhaustive list – more to show that although all of the species can be called 'fruit-flies' some species are very host specific (e.g. Rhagoletis Apple Maggot) whereas others can be found on a huge range of hosts including flowers, vegetables and nuts (e.g. *Ceratitis sp*.).

Table 3: Host range of fruit and vegetables of significance to New Zealand.

Fruit and vegetables of significance to New Zealand	*Anastrepha sp* Mainly fruit	*Bactrocera sp* Mainly fruit, some vegetables	*Ceratitis sp** Wide variety of fruit, flowers, nuts and veg.	*Rhagoletis sp* Mainly known in apples
Apple	x	x	x	x
Avocado		x	x	
Banana		x	x	
Capsicum		x	x	
Cherries		x	x	x
Citrus	x	x	x	
Coffee	x	x	x	

Cucumber		x	x	
Feijoa	x	x	x	
Grapes	x	x	x	
Guava	x	x	x	
KIWIFRUIT		x	x	
Melon		x	x	
Mango	x	x	x	
Pawpaw	x	x	x	
Passionfruit	x	x	x	
Pears	x	x	x	x
Persimmon	x	x	x	
Pineapple		x	x	
Pumpkin		x	x	
Quince	x	x	x	
Stonefruit	x	x	x	x
Tomato		x	x	

* Medfly known to be associated with over 260 different fruit, flowers, nuts and vegetables.
Source CABI 2012, EPPO datasheets.

There is limited information on the susceptibility of kiwifruit to the various fruit fly species. A more detailed review is conducted in section 6. At this point in time, Medfly is the only species in literature shown to attack kiwifruit (Kiwifruit is also a listed host of Queensland fruit fly in a range of literature), although is not a preferred host. The challenge is that kiwifruit is not a widely grown crop in the regions where the more damaging fruit flies are found.

1.5.2 Climatic range

Climate is a significant limitation to the development of populations for a number of fruit fly species. Cold tolerance appears to be one of the main climatic limitations to the development of the economically significant fruit fly range.

Some species (e.g., Queensland fruit fly) are tropical/sub-tropical in range and would tolerate the warmer regions of New Zealand but others are both warm and cool tolerant (e.g. Medfly) and could survive over most of New Zealand.

The range of temperatures infers that while a population may develop during the warmer summer months the ability to maintain a population in the colder months of the year is significantly diminished.

1.6 Biological Development

1.6.1 Life cycle

Members of tephritidae undergo complete metamorphosis and pass through the following stages:

- Egg
- Larva (caterpillar)
- Pupa
- Adult (fly).

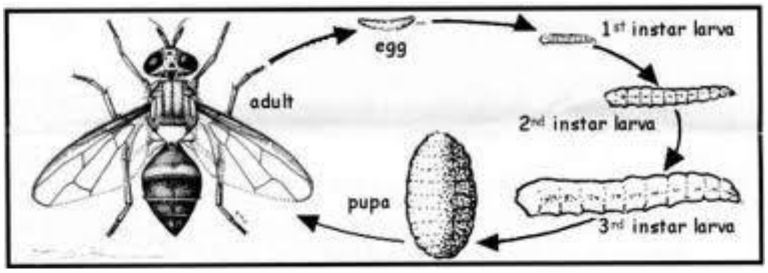


Figure 1: General fruit fly life cycle (Chris Lambkin)

Plant Health Australia describes the life cycle in the fruit fly handbook based on many studies of Queensland Fruit fly. This is consistent with a US study of 53 species of Bactrocera fruit flies.

The general life cycle is described as follows:

- Adults mate, usually in the foliage of plants surrounding or near the host but not necessarily on the host.
- Eggs are deposited (using an ovipositor) just under (3mm) the flesh of the favoured host fruit for the species. They are generally white, banana shaped and approximately 1mm in length. Infested fruit may show 'sting' marks on the skin and may be stung more than once by several females.
- In a short period of time, usually a few days, larvae hatch and begin to consume the fruit in which they find themselves. To the naked eye, the larvae resemble blowfly maggots. They are creamy white, legless, blunt-ended at the rear and tapered towards the front where black mouth hooks are often visible.
- The larvae develop through three larval stages to become about 9 mm long and pale yellow when fully grown.
- After an additional number of days ranging between 4 and 12, the larvae drop from the fruit and become pupae in the soil. The mature larvae can 'jump' by curling into a 'U'-shape and then rapidly straightening.
- Adult flies emerge 7-10 days later (although this can extend to several weeks in cooler conditions) from their pupal cases in the soil and burrow towards the surface where they inflate their wings and fly away.
- The adult flies congregate on foliage and fruit to feed on bacterial colonies for about a week before sexually maturing and mating. Adults may live for many weeks with females continuing to lay eggs throughout their lifecycle.

(Margosian *et al* 2007)

Case Study: Mediterranean fruit fly lifecycle

EGGS

- The adult female Medfly pierces the skin of the host fruit (which may be one of over 250 species of fruit, flowers, and vegetables) with her ovipositor and deposits from 1 to 10 eggs in the puncture.
- Other females may also lay eggs in the same puncture. Several hundred eggs have been found in a single cavity.
- Under normal conditions, a female may lay over 300 eggs during a lifetime. She may lay up to 1,200 eggs during her life time.
- Females will not lay eggs when temperatures drop below 17 °C.

LARVAE

- Eggs hatch in 2 to 3 days at 26 °C, which is optimum temperature.
- The larvae tunnel throughout the pulp of the host fruit to feed for 6 to 10 days (although this can be up to 24 days if the temperature is cooler).
- Generally, the fruit falls to the ground during or after larval development.

PUPAE

- Once the larvae are fully grown to approximately 1cm, they emerge from the fruit to pupate in the soil. However, pupation may occur anywhere; it is not necessary for the larvae to enter the soil to pupate.

ADULTS

- The adult fly is formed within the pupa and emerges within 6-46 days (6 to 15 days at 26 °C) forcing its way to the surface of the soil.
- The newly emerged adults are not sexually mature and must feed on protein in order to reach sexual maturity.
- The minimum time before the adult female will lay eggs is two days, but again the number of days is temperature dependent. The females continue to feed while laying eggs.

The period of time for **one generation under favourable conditions is 18 to 33 days.** Development in egg, larval, and pupal stages is greatly reduced or arrested at temperatures below 10°C. At lower temperatures, Medfly requires longer time intervals of up to 100 days to complete its life cycle. The particular season in which Medfly arrives in a country will determine the ease with which it colonises.

Source: USDA-APHIS 2003

1.6.2 Rate of Development

Many factors influence the development of insects, including host availability, pest population densities, photoperiod, rainfall, and temperature (Ellis 2004).

Temperature is one of the most important factors influencing the development of all insect life stages. Site-specific temperature data and knowledge of insect development help predict when pests will be most abundant. 'Degree day' values used to make these predictions are determined by counting the number of degrees accumulated above the developmental threshold for any life stage.

Degree day calculations assist with:

- Predicting emergence of adults
- Determining the time to begin trapping
- Monitoring cycles of generation during a season
- Monitoring the effect of eradication or suppression measures

Threshold temperatures may represent either upper or lower limitations, and may be measurements of air or soil temperature, depending on where the insect lives

Examples of the sorts of lower limits that exist include;

- Oviposition in Medfly ceases when the temperature falls below 15.5-17°C (USDA-APHIS 2003). Note: the adult can endure cooler temperatures then this; they just retain their eggs for a more suitable temperature range. The equivalent in soil for pupae development is 9.7°C (USDA-APHIS 2003)
- Eggs of Oriental fruit fly will not develop at temperatures below 13°C (EPPO Datasheet).
- The temperature cannot fall below 10°C for pupal emergence of Queensland Fruit Fly. Minimum temperature for successful flight cannot fall below approximately 6°C while the optimal temperature should exceed 16°C.

1.6.3 Biology

There are some characteristics common to all tephritid fruit flies:

- The female fruit fly must feed on a source of protein before her eggs will mature.
- She will wait about 5 days before she can commence egg lay.
- Adult flies usually mate and feed in the host tree.
- A female fruit fly only mates once in her lifetime.
- They are usually strong fliers and can travel some distance.
- The males of many species are strongly attracted to specific chemical compounds (pheromones).
- Adult flies can survive winter but females will resorb their eggs during extended periods of cold weather.
- Fruit fly threat is greatest while susceptible fruit are available, the weather is warm and conditions are moist.
- Flies are most active from dawn for the first few hours of the day.
- Cool weather tends to extend the developmental period of pupation.

Variations:

- The females of each species may be adapted to be able to lay their eggs in different ways, e.g. the Apple Maggot has a sharp ovipositor so the female can pierce the tough apple skin. Other species may only lay their eggs in highly ripened fruit, or where fruit skin is already damaged or broken.
- Some species lay a number of eggs together, whereas others may only lay one per site (although more than one egg may be laid per host fruit).

1.7 Economic impact

Underwood (2007) undertook a comprehensive study into the likely impact of an incursion of fruit fly in the Bay of Plenty, Hawke Bay or Nelson. This not only considered the direct impacts on fruit production and market access but the on-going impact to the broad economies of these key horticultural regions.

The implications of any fruit fly incursion will be highly influenced by the species of fruit fly and the time of year. The significance of the potential host range and ecological/climatic range is the key determinant in the development of a breeding population.

If a breeding population was able to establish both crop damage and market access impacts are likely to result. There is very limited experience with kiwifruit crop damage – and even for Medfly the evidence of damage was under controlled lab conditions.

1.7.1 Crop Damage

The damage to crops caused by flies result from;

1) oviposition in fruit and soft tissues of vegetative parts of certain plants, making it less valuable to the grower,

Figure 2: Ovipositor damage in citrus (orange) and banana

2) feeding by the larvae,

- Larvae hatch from eggs and burrow/eat their way into the fruit, leaving tunnels in the fruit. They often carry bacteria with them that aids in the fruit breakdown. This turns the internal part of the fruit into mush and will often cause the fruit to fall off the tree. This cause's significant economic impact as fruit is completely unusable.

Figure 3: Fruit fly larvae damage in melons and peaches

3) Decomposition of plant tissue by invading secondary microorganisms.

1.7.2 Market Access

The market access implications of fruit fly incursions in New Zealand are explored in more detail in Section 7. The market access impacts from a more generalised perspective will depend in the first instance on the success or otherwise of a fruit fly species establishing a breeding population.

The terminology used when fruit flies are detected is very important. In past fruit fly occurrences, New Zealand has only detected a few adults in surveillance traps. This does not constitute an incursion or an outbreak and consequently it is anticipated importing countries would not normally take any measures on New Zealand fresh produce exports.

Incursion	*An isolated population of a pest recently detected in an area, not known to be established, but expected to survive for the immediate future [FAO IPPC ISPM#5]*
Outbreak	*A recently detected population, including an incursion, or a sudden significant increase of an established pest population in the area. [FAO IPPC ISPM#5]*

Of the six prior interceptions, only the one would be classified as an incursion where quarantine measures would be warranted.

The following criteria is applied by the USDA when evaluating whether an infestation exists or whether further delimitation activities are required:

1. Two flies within a five kilometre radius and within a time period equal to one life cycle of the fly.
2. One mated female; or
3. Larvae or pupae.

(USDA-APHIS 2003)

Where an incursion/outbreak has been declared the typical response of importing countries will be to either apply an exclusion zone (areas from which export fruit cannot be sourced) and/or a treatment regime prior to or during shipping. The complexity of response will be influenced by the species of fruit fly and if it is present or not in the importing country.

Consequently, the most economically significant species of fruit fly may not result in the most significant market access restrictions. Species that have a restricted distribution such as Queensland fruit fly may result in greater and more market access restrictions then Medfly would.

2. Surveillance

When a pest does not exist within a country, region or area or as a means to rapidly detect the re-emergence of a population following winter, a decision may be made to invest in surveillance (generally using traps) or by running a survey on a semi-regular basis.

The three objectives of trapping survey are:
- **Detection survey**: To determine if species are present in an area.
- **Delimiting survey**: To determine the boundaries of an area considered to be infested or free from a pest.
- **Monitoring survey**: Ongoing survey to verify the characteristics of a pest population including seasonal population fluctuation, relative abundance host sequence and others. (IAEA 2003)

2.1 Surveillance trapping

2.1.1 Sex attractant lures

Some species of fruit flies can easily be lured using powerful sex attractants that lure the males to the traps.

Table 4: Sex attractant lures used on 3 fruit fly species.

Fruit fly	Lures	Chemical
Medfly	Trimedlure (TML) and terpinyl acetate and Cue lure	TML (tert-butyl 4 (and 5)- Polymeric plug/ panel 6 chloro-2-methylcyclohexane-1-carboxylate)
Oriental fruit fly	Methyl eugenol (ME)	ME (O-methyl eugenol)
Queensland fruit fly	Cue lure (CUE) or a mixture of ME and CUE	CUE(4-(p-acetoxyphenyl)-2-butanone)

Source IAEA (2003)

By using a trap containing all or a number of these attractants (or lures), it is hoped that any male fruitfly would be drawn to the trap where it is killed and found by technicians.

- The lure is usually placed on a cotton wool wick suspended in the middle of a plastic trap that has small openings at both ends (Steiner trap) or around the circumference of a pot trap (Lynfield trap).

Figure 4: Commonly used surveillance traps

Steiner trap Lynfield trap

- The lure can either be mixed with an insecticide or a piece of paper dipped in malathion or dichlorvos can be placed in the trap. This will kill any insect attracted to the lure, and the insect then falls to the bottom of the trap.
- Traps are usually placed in fruit trees at a height of about 2 m above the ground and are checked on a regular basis.

2.1.2 Bait traps

The Mexican fruitfly (like other Anastrepha species) and the Apple Maggot fruitfly do not respond to any known sex attractant that can be usefully employed in a detection trapping system. Mexican fruitflies can be trapped using non-specific, wet, protein-baited McPhail traps, which act as general food attractants, especially for young females searching for protein to produce eggs. Bait trapping is more commonly used as a control tool once a population is known to exist. (University of Florida datasheet)

Figure 5: McPhail trap

Several food based synthetic attractants have been developed using ammonia and its derivatives. Ammonium carbonate (AC) and/or ammonium acetate (AA) lures are used for several Rhagoletis species. AA and putrescine (PT) has been demonstrated to be attractive for Mexican fruit fly (*A. ludens*) and Caribbean fruit fly (*A. suspensa*). The addition of a third component, trimethylamine (TMA) results in a highly attractive female lure for medfly which is being used in early detection trapping networks. This synthetic food lure is more specific than the liquid protein baits, and is capable of detecting female medflies at a lower level compared to the male specific attractant, TML.

2.1.3 Sticky boards

Panel traps have also been developed for fruit flies with no known male lure. These traps are based on visual, or visual plus odour, attraction. They are coated in sticky material. Traps are usually flat-surfaced and coloured fluorescent yellow to elicit a supernormal foliage response, or spherical and dark-coloured to represent a fruit. The odour comes from protein hydrolysate or other substances emitting ammonia, such as ammonium acetate. Ammonium acetate and ammonium carbonate, when used for capture of *Rhagoletis spp*, are used with red sphere traps or yellow panel traps coated. (IAEA 2003)

Figure 6: Yellow panel trap

2.2 Fruit collection and cutting

Once it is determined that a population has established a secondary survey method is cutting fruit or other hosts in the surrounding area to determine if eggs have been laid and larvae have hatched. Fully grown larvae, when the surrounding air temperature is warm, flex and "jump" repeatedly as much as 25 mm when removed from fruit. Larval identification is extremely difficult, so that when feasible it is best to rear them to adults for identification. Larval identification is based primarily on characters of mature 3rd instar larvae.

2.3 New Zealand fruit fly surveillance programme

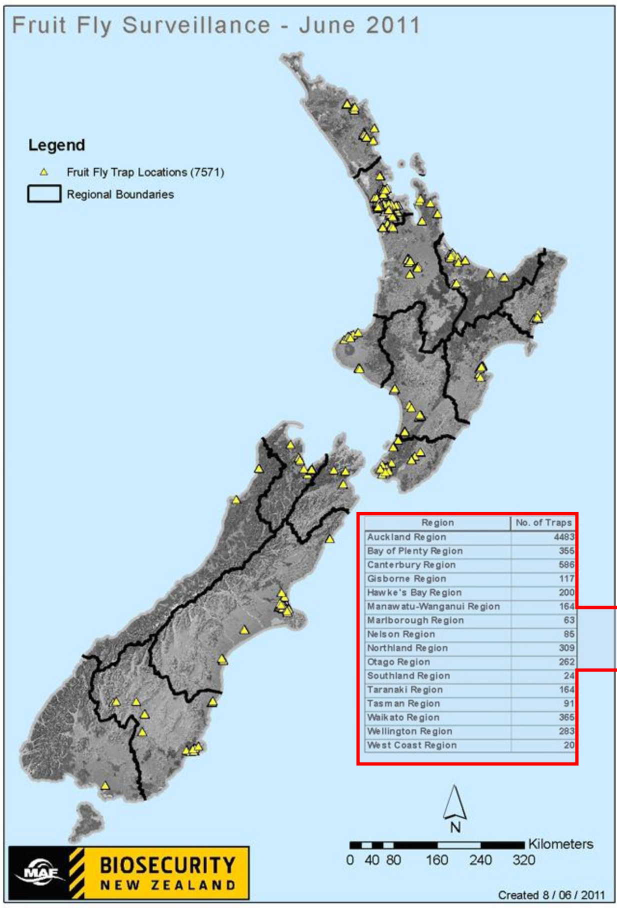
The Fruit Fly surveillance programme was initiated in the mid 1970's to provide assurance of country freedom from economically important fruit flies, and early warning of fruit fly incursions to facilitate eradication. There are currently about 100 species of fruit flies listed as regulated organisms for New Zealand.

This programme is operated and resourced by the New Zealand Government at a cost of about $1.4 million per annum. Selected property owners host the traps, allowing access to MPI approved personnel to service and check the traps at 2-weekly intervals, and also assist by reporting back to MAF if they suspect anything that may be compromising the integrity of the traps that are located in their property.

Traps used in the programme are Lynfield traps which are baited with one of the following lures: Cuelure, Trimedlure or Methyl Eugenol. A DDVP insecticide strip is also placed in the bottom to kill the adults once they enter the trap. Approximately 7,500 traps are set up and maintained from September to June of each year.

Traps are placed in grids, concentrating in populated areas serving as centres for tourism and/or trade, areas of significant horticultural activity and areas specified as being climatically conducive to the establishment of fruit flies.

Figure 6: MPI fruit fly surveillance trapping programme (June 2011)



Region	No. of Traps
Auckland Region	4483
Bay of Plenty Region	355
Canterbury Region	586
Gisborne Region	117
Hawke's Bay Region	200
Manawatu-Wanganui Region	164
Marlborough Region	63
Nelson Region	85
Northland Region	309
Otago Region	262
Southland Region	24
Taranaki Region	164
Tasman Region	91
Waikato Region	365
Wellington Region	283
West Coast Region	20

Source: MPI website

3. Control Measures

3.1 Control of Fruit flies in situ

There are various means of control and/or eradication of fruit flies based on a number of factors:

- Is this a fruit fly incursion or is the population established?
- Is it possible to eradicate – or is control of numbers required?
- What insecticides are available for use?
- What are the specifics of that species of fruit fly which may impact on control decisions?

3.1.1 Host Removal

This involves a range of strategies depending on the objective and includes;

- Gather all fallen and infected host fruits, and destroy them.
- Strip fruit from all host trees/plants and within 200 meters.
- Remove and destroy wild and abandoned host trees.
- Remove other host plant material in a surrounding buffer area to minimize the immigration of new adults.

3.1.2 Trapping

Trapping can be utilised for the following purposes:

Surveillance: to determine species presence and to monitor established fruit fly populations.

Suppression: Suppression aims to reach a fruit fly low prevalence area. Trapping measures the efficacy of control measures used in an infested area to reduce the fruit fly population and thereby limit damage and spread.

Eradication: Eradication aims to establish a fruit fly free area. Trapping measures the efficacy of control measures used to eliminate a pest from an area.

Exclusion: Exclusion aims to minimize the risk of introduction or re-introduction of a pest in a free area. Trapping is applied to determine the presence of species that under exclusion measures and confirms or rejects the free area status.

(IAEA 2003)

Trapping Adults – for monitoring population numbers and spread

Trapping adults means fly activity and population trends can be monitored. Also the efficacy of any sprays can be evaluated with the traps by comparing counts before and after treatment.

Once an adult fruit fly is positively identified, the number of lure traps or baited traps throughout that area is greatly increased to capture the flies and remove them from the environment, and to serve as a monitoring tool for the effectiveness of any eradication program. Even after an infestation is believed eradicated, the greatly increased number of traps and their inspection interval remains high for several months before the area/region is officially declared eradicated.

Trapping - male annihilation for Adult pest control

Using the male attractant lures in conjunction with insecticides (malathion or dichlorvos*) can be quite successful as a control measure. The Oriental fruitfly was eradicated from the northern Ryukyu Islands, Japan using the attraction of males to methyl eugenol (Cunningham 1989). Traps need to be emptied regularly as it is possible to catch hundreds of flies in a single trap left for just a few days, although the lure may remain effective for a few weeks.

Bait Spray used as Adult pest control

Some control of adult Mexican, Queensland, Medfly and Oriental fruit fly has been achieved using a bait (protein and carbohydrate) and insecticide mix (malathion or dichlorvos*). This is applied as fine droplets to host plant foliage where adults feed. However, adults can be highly mobile and move easily from any nearby untreated trees back to treated trees after a few days.

Increasingly FG-120 NF Naturalyte Fruit Fly Bait (containing Spinosad) is being used. This contains an insecticide derived from a naturally occurring soil organism. (Zalom *et al* 2009)

Phloxine B, better known as the FDA-approved red dye number 28 is being used as an alternative for Medfly control (Mangin et al 1996). The dye is as effective as malathion-bait sprays and is a safe, effective alternative to previously used aerially-applied malathion insecticide baits. Medflies often share regurgitated food. This helps spread the insecticidal dye-and-bait blend through the population.

Bait sprays have the advantage over cover sprays in that they can be applied as a spot treatment so that the flies are attracted to the bait/insecticide and there is minimal impact on natural enemies.

3.1.3 Insecticidal spray to control adults.

Generally control (if possible) is achieved through using male annihilation or Bait sprays, but insecticidal protection is possible by using a cover spray such as Malathion*.

Soil Drenching to control pupae

The soil under host trees with fruit known or suspected to be infested with larvae and host trees under adjacent properties can be treated with Insecticides. Diazinon, Chlorpyrifos and Fenthion* are soil drench chemicals that are approved in USA for fruit fly control programmes. (USDA-APHIS 2001) Typically, one treatment (but up to three) may be made, applied directly to the soil within the drip line of host plants within the immediate vicinity of fruit fly larval detection. Because of the nature of the chemicals and /or the method of delivery, there is no potential for drift, runoff, or leaching. Residues in fruit are not normally seen with soil drenching.

3.1.4 Biological control.

Biological control (using small parasitoids introduced into the wild population of fruit flies) has been tried and failed in Medflies, Oriental, Queensland, and Mexican fruitflies and Apple maggot.

3.1.5 Sterile insect technique (SIT).

The SIT method relies on flooding the area of an infestation of wild flies with millions of sterile flies produced in rearing facilities. When the sterile flies mate with the fertile population, no offspring are produced. Gradually, the wild flies can only find sterile flies to mate, and the wild population is eradicated.

SIT has been used against Medfly in Costa Rica, Italy, Mexico, Nicaragua, Peru, Spain, Tunisia and the USA. The largest of these programmes is being carried out in southern Mexico and is designed to stop the fly spreading north and ultimately to eradicate it from Central America. (EPPO datasheet)

How is it done? Medfly eggs are placed in warm water — a process that kills the female embryos but doesn't harm the male embryos. In the pupal stage, the males can be irradiated to render them sexually sterile.

3.1.5 Oviposition deterrent pheromone

Researchers have discovered that application of the oviposition deterrent pheromone of Apple Maggot fruitfly deterred egg laying for up to 3 weeks, provided it was not rain-washed (EPPO datasheet). This may be useful in the battle against Apple Maggot fruit fly, especially in those areas that also use Integrated Pest Management strategies.

* Pesticides are subject to periodic review by the NZ Environmental Protection Agency (EPA). Organophosphates and carbamate chemical groups are currently under review which may have a negative impact on the use and availability of DDVP, Diazinon, Chlorpyrifos, Maldison, Fenthion and Dimethoate in the near future.

3.2 Control of Fruit flies prior to export or in transit

Consignments of fruit from countries where any fruit fly (endemic or an outbreak) occurs must be inspected for symptoms of infestation and those suspected should be cut open in order to look for larvae.

3.2.1 Disinfestation treatment options

Cold treatment

The use of sustained cold temperatures as a means of insect control has been employed for many years. Rigid adherence to specified temperatures and time periods effectively eliminates certain insect infestations. Treatments may be conducted in warehouses, refrigerated compartments of transporting vessels (Conventional Vessels), containers cooled by the ship's refrigeration system (Container Vessels) or by individually refrigerated containers (Self-Refrigerated/Integral Containers).

Heat treatment

There are three methods in use to heat produce; hot water, vapour heat and hot air.

- Hot water was originally used for fungal control, but has been extended to disinfestation of insects.
- Vapour heat was developed specifically for insect control, and
- Hot air has been used for both fungal and insect control and to study the response of commodities to high temperature.
- For vapour heat and hot air; airflow and humidity control may affect the response of the commodity to the heat treatment and affect the length of time of exposure needed to achieve a desired effect. (Lurie 1998)

3.2.2 Current protocols

The combination of fruit, country of export, and country of import, will determine what (if any) treatment measures can be used to disinfest the produce if any fruit fly is suspected.

Below is a table showing some of the options that could be used. These will need to be agreed between the relevant countries as any importing country will want to insure their risk is completely minimised.

Table 5: Disinfestation treatments for three key fruitfly species.

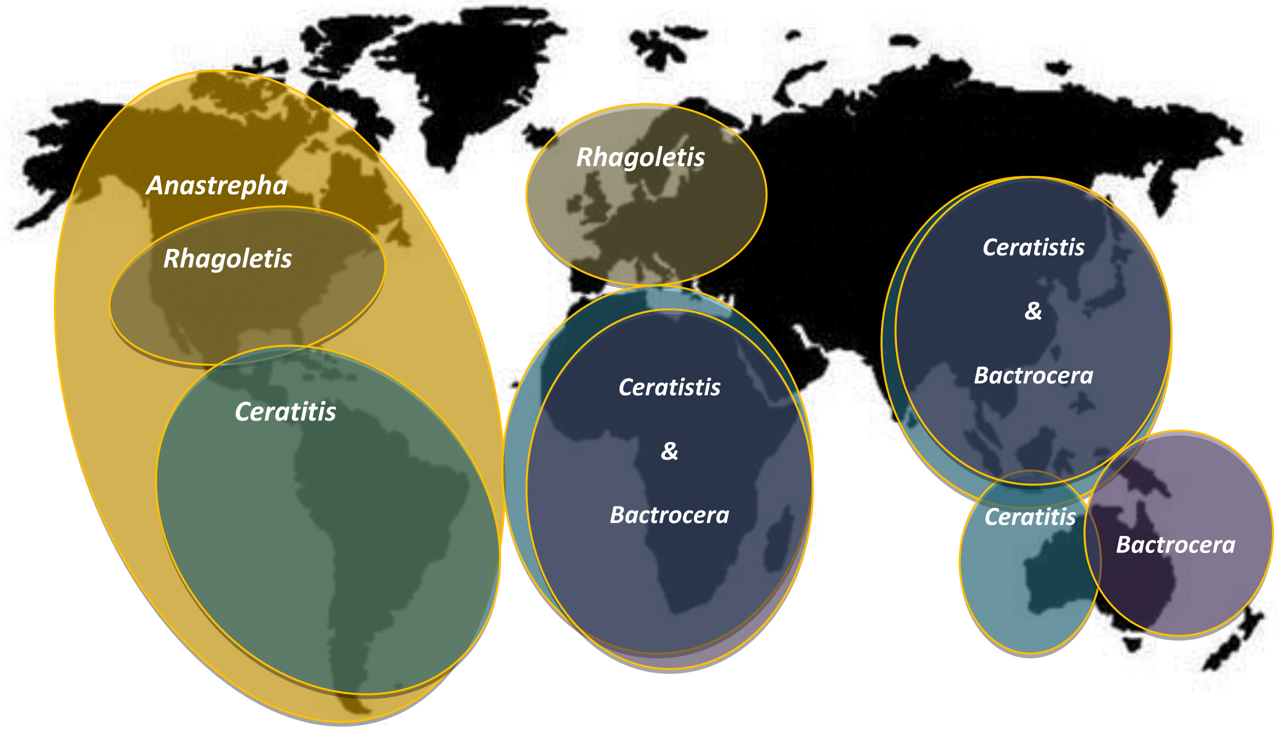
Treatment	Med Fly	Oriental Fruitfly	Queensland Fruitfly
Pre-export/In transit cold treatment	Fruit pulp temperature held at: 0.0°C or below for 10d(NZ) 0.5°C or below for 11d (NZ) 1.1°C or below for 14d (US) 1.6°C or below for 16d (US) 2.2°C or below for 18d (US) (USDA/NZMPI)	Fruit pulp temperature held at: 0.5°C or below for 11d 1.1°C or below for 12d 1.6°C or below for 14d or 5°C or below for 19d 6°C or below for 22d 7°C or below for 25d, for temp-sensitive fruits (EPPO)	Fruit pulp temperature held at: 0.0°C or below for 13d 0.5°C or below for 14d 1.1°C or below for 18d 1.6°C or below for 20d 2.2°C or below for 22d (USDA)
Vapour heat	Maintaining 44°C for 8 hours (EPPO).	Maintaining 43°C for 4-6 hours (EPPO).	Maintaining 43°C for 4-6 hours (EPPO).
	Temp raised from ambient to 47.2°C or greater over a period of 4 hours or more (MPI)		
Hot water treatment	Possibly available	46°C for 65-90 minutes, according to size and shape of fruits.	Possibly available
Forced hot-air	Temperature raised from ambient to 47.2°C and then held for a minimum of 20min (NZMPI)	Possibly available	Possibly available
	Temp raised to 47.2°C over 4 hours and held for 5min (USDA)		Possibly available
Methyl bromide (MeBr)*	32 g/m^3@ 27-32°C for 2hr 40 g/m^3@ 21-27°C for 2hr 48 g/m^3@ 15.5-21°C for 2hr 48 g/m^3@ 10-15.5°C for 3hr (NZMPI)	-	e.g. 32 g/m^3 for 2 h at 21-26°C;
	A combination of Methyl Bromide and cold treatment is also recommended		
Irradiation.	150gy units	150gy units	150gy units
Insecticide sprays	-	-	Insecticides such as fenthion, dimethoate and omethoate can be applied as sprays during grading and packing of tomatoes and mangoes

(Interpreted from EPPO fact sheets, NZ-MPI IHS and USDA treatment manual)

*This may damage fruits and reduce their shelf-life, although treatment schedules are available for specific cases

4 Pathways of Entry to New Zealand

4.1 Regional distribution of key economic Tephritid fruit fly



The absence of economically important fruit flies in New Zealand allows for fresh export produce to be certified as free of infestation and exported to a wide range of countries. If New Zealand had any fruit fly populations established it would seriously limit the countries we could export to. Freedom also allows for fruit fly susceptible crops to be produced in New Zealand without a need for the management of fruit fly damage, which results in savings in terms of pest management inputs.

4.2 Commercial and non-commercial Pathways of entry

There are two main pathways of entry for fruit flies into New Zealand: via passengers who may carry infested fruits and vegetables on their person or in their luggage, and via commercial consignments of imported fruit fly host produce. The number of interceptions of live fruit fly eggs/larvae from passengers (78%) versus commercial consignments (22%) reflects the relative risk associated with each of these pathways (data obtained from the MAF interception database which contains records from 1987 to present). MAF Biosecurity NZ (2010).

Known pathways:	Risk Mitigated by:
Smuggled / undeclared fruit from passengers (usually aircraft but also pleasure crafts/yachts)	Risk profiling and biosecurity checks in place for passengers e.g. detector dogs, x rays
Commercial fruit imports	Low risk due to Import Health Standard for fresh and frozen produce e.g. pre-export treatments.

Risk profiling is an important mechanism for identifying risk and directing MPI resources.

5 Likelihood of establishment of Fruit fly in New Zealand

5.1 Previous fruit fly incursions in New Zealand

Previous incursions of a limited number of fruit fly species have occurred in northern New Zealand in recent history. The Surveillance programme has detected five separate incursions of Bactrocera fruitflies: three *Bactrocera tryoni* (Queensland fruitfly), one *Bactrocera passiflorae* (Fijian fruitfly), and one *Bactrocera papayae* (Asian Papaya fruitfly). With increased trapping and surveillance there were no further finds and therefore it was determined that all failed to successfully establish populations.

The most important incursion would be the one instance of Ceratitis capitata (Medfly) which successfully established a small population for a limited period during the month of May 1996. This population was successfully eradicated.

CASE STUDY:
MAY 1996 – Medfly Incursion Mt Roskill, Auckland

On 2 May 1996, two male Mediterranean fruit flies (*Ceratitis capitata*) were captured in the central Auckland suburb of Mt Roskill as a result of routine monitoring of traps in urban Auckland.

The response resulted in more intensive trapping in the area including setting traps that would attract and detect female fruit flies.

- Female fruit flies were found on the 5th May and larvae on the 6th May showing that a breeding population was established and that the fruit fly finding constituted an incursion.

MAF established an A zone of 200m radius around the initial find, a B zone of 1.5km radius and a C zone of 15km radius.

- Movement of fruit between these zones was restricted, particularly in the weeks following discovery of the medfly population.
- Fruit collection to detect larvae was undertaken and bait and insecticides were applied to control the adult flies.
- More adults were found until 15th May, and larvae until 23rd May.
- The total finding was 41 adults, (31 males and 10 females) plus 85 larvae over a period of about three weeks, all within an A zone of 200 metres radius from the original trap site.

MAF carried out a control programme, spending about $5 million in extra costs. This figure does not include much of MAF's personnel time spent on control activities.

No medfly were found in the area after 23rd May and the pest was successfully eradicated.

This provides evidence towards the assumption that some fruit fly species that are very host specific or have defined (warmer) temperature range will not be able to establish a population in New Zealand conditions. For example; the Asian Papaya fruit fly is relatively host specific and tropical/sub-tropical in range and is highly unlikely to tolerate the climatic conditions and lack of host species here in New Zealand.

The logic will follow that a species like the Queensland fruit fly that is tropical/sub-tropical in range and has a wider host range into a variety of fruit trees may be able to tolerate the warmer regions of New Zealand and be able to establish a population.   The greatest concern would be a fruit fly species such as the Medfly that are both warm and cool tolerant, with a huge number of possible hosts and could survive over most of New Zealand. The evidence of May 1996 incursion supports this concern.

5.2 MAF investigation of potential for establishment

In 2010 as part of a review of the fruit fly trap surveillance programme, MAF Biosecurity NZ undertook analysis of the likelihood of fruit fly establishing in various parts of the country. MAF Biosecurity NZ (2010b) provided additional background to the study to indicate the weighting given to the contributing factors including:

- Establishment of a fruit fly population in New Zealand is much more likely to be limited by temperature as nationwide there would be sufficient rainfall/humidity.
- The main weighting was given to mean daily average winter temperature and mean daily maximum summer temperatures – hence;
  - the winter temperature at which an individual or population of fruit flies would be killed, and;
  - the summer temperature range which would be most ideal for fruit fly population growth.
- Location of suitable hosts: horticultural land (fruit, vegetable and grape growing properties).
- Point of arrival of fruit fly – most likely to be in a piece of undeclared fruit from an international visitor. Therefore the main port of arrival for most international visitors and where they stay the first night became a key factor in the weighting.

The dataset was used to produce a number of maps of interest, included a map depicting the potential for fruit fly to enter and establish in New Zealand (refer Figure 7)

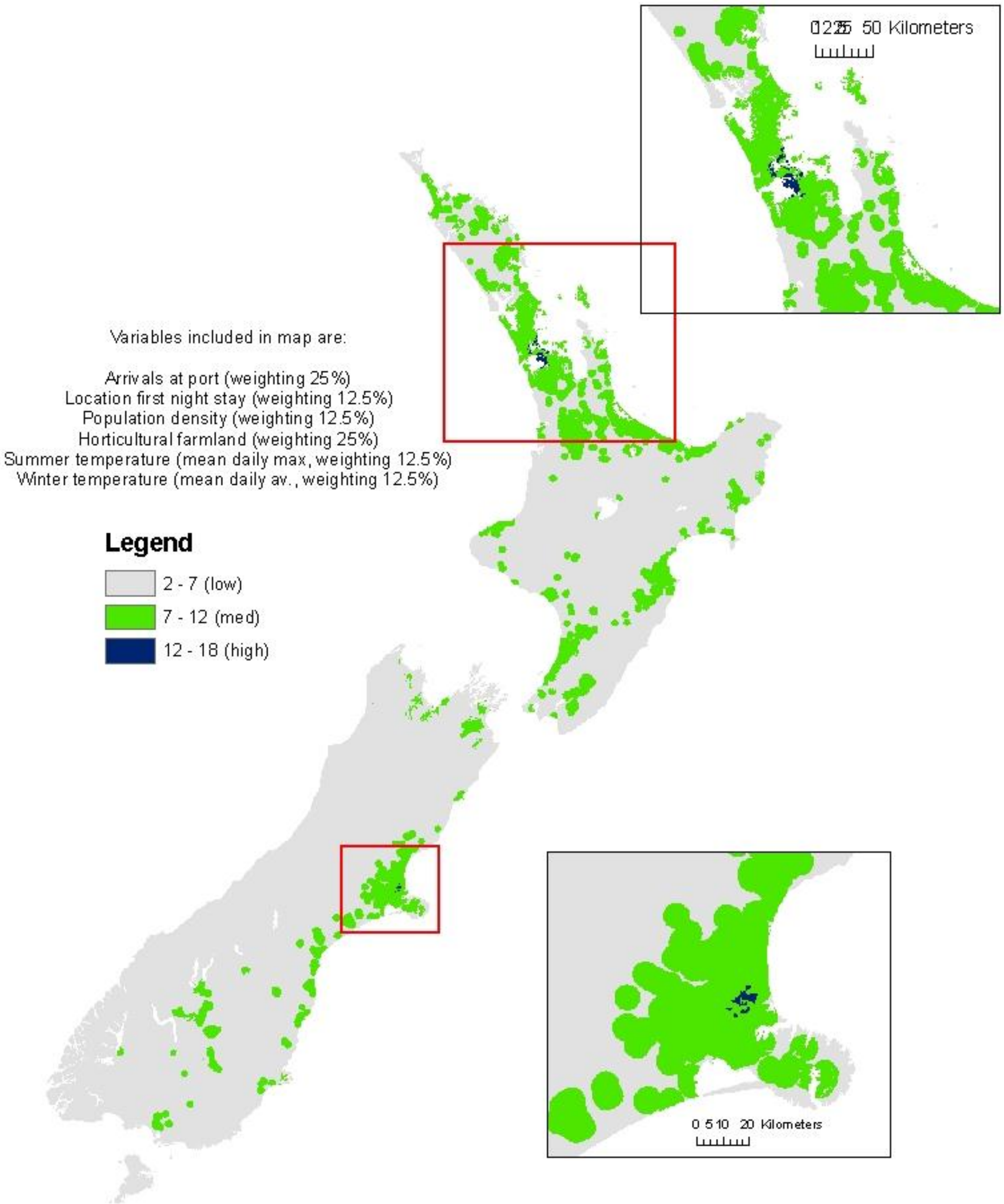


Figure 7: Potential Risk of fruit fly entry and establishment in New Zealand (MAF Biosecurity NZ 2010b)

This information does need to be put into context as it averages datasets for a generic 'fruit fly' to better understand the distribution of fruit fly traps. For the species most likely to cross New Zealand's borders it should be understood their climatic adaptability and specific host range preferences will make certain species of greater concern than others.

The diagram shown in Appendix 2 provides valuable clarification on the optimal temperature range for a number of Tephritid fruit fly species and why averaging of figures needs to be taken in context. This is especially true when placed alongside the mean summer and winter temperatures across New Zealand shown in Figure 8.

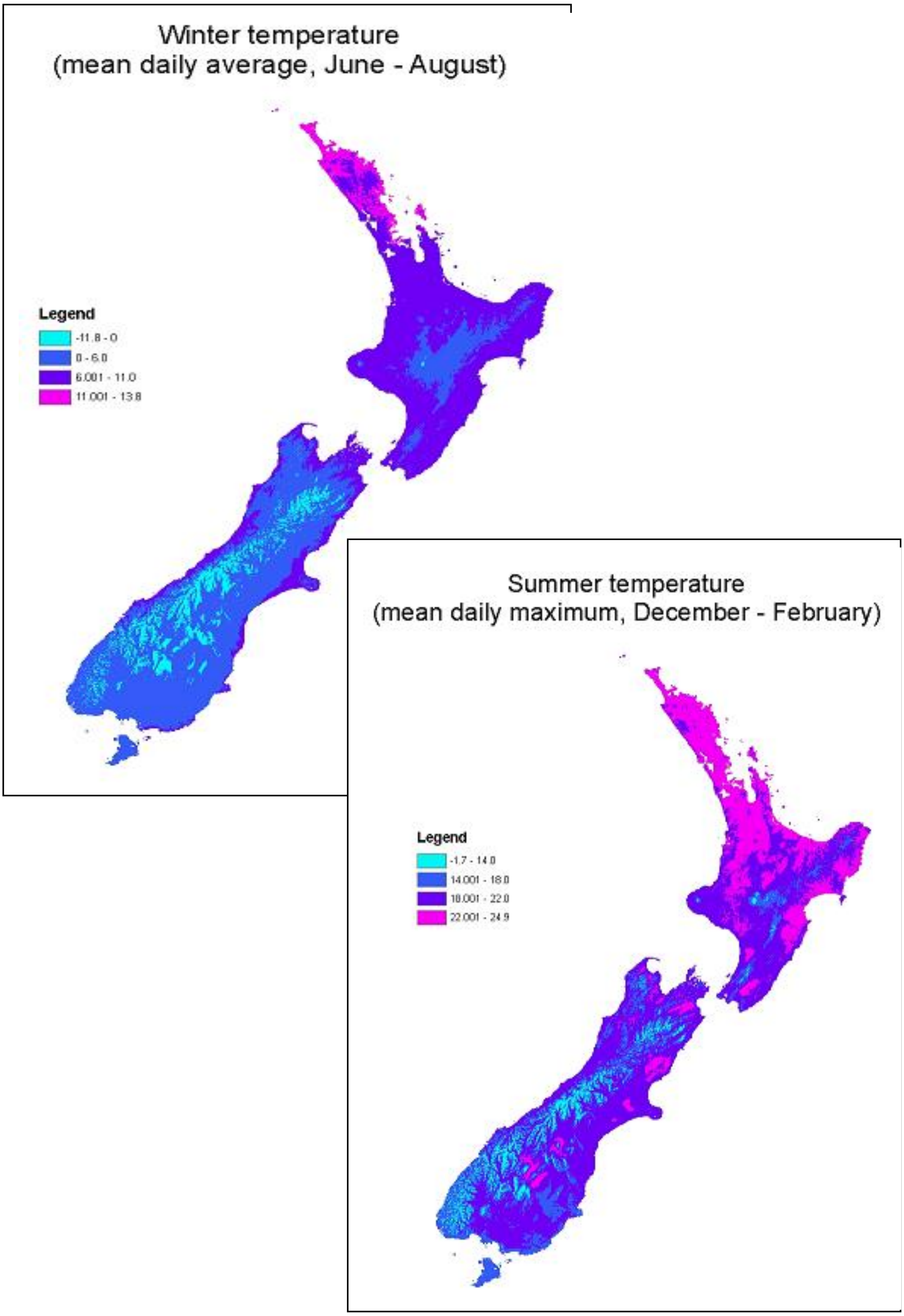


Figure 8: New Zealand mean daily temperatures in winter and summer

The mean daily average temperatures between June and August will be the primary limitation to the establishment of a population of fruit fly in New Zealand. Figure 8 demonstrates the vast majority of the North Island and all of the kiwifruit production regions would have a mean daily temperature above 6°C. This high level presentation of data is not sufficiently detailed to clarify those areas that are above the minimum temperature development thresholds for MedFly and Queensland fruit fly (refer Table 6) but does provide some indication around the marginal nature of the New Zealand winters in sustaining a population of fruit fly.

Table 6: Temperature development thresholds for Medfly and QFF.

Fruit fly		Development threshold temperatures		
	Eggs	Larvae	Pupae	Adult
Medfly*	9.3°C	11.1°C	8.4°C	12.8°C
QFF**	11.5°C			13°C

* De Lima (2008), ** Yonow & Sutherst (1998)

The significance of the 6-11°C range (mean daily average winter temperature) depicted in Figure 8 is critical as at the lower end it indicates neither Medfly nor Queensland fruit fly would reach the temperature development thresholds necessary but at the upper end of the range Medfly pupae could comfortably overwinter. More insight into the specific risks of Medfly and Queensland fruit fly is best demonstrated by the risk assessment study undertaken by the Department of Primary Industries for Tasmania.

5.3 Investigation of the potential for establishment of fruit fly in Tasmania

In the field, ecological and physiological factors combine to make temperature relations and their development thresholds as depicted in table 6 rather complex. Duration and frequency of high and low temperatures, ability to acclimatise, differing life-stage tolerances and heat requirements all come into play.

For fruit flies, these complexities influence population parameters at any particular place, including mortality, rate of egg, larval, pupae and adult development, female maturation, mobility necessary for mating, and number of generations possible in a year (Meats 1981).

While sustained high temperatures (e.g. 36°C - 40°C for a few days) limit fruit fly survival by affecting one or more of these parameters, in Tasmania (and New Zealand) lower temperatures are comparatively more important, due to regular, prolonged and distinct winter seasons. The winter season in both places can impose significant limits on life-stage and population development.

The Biosecurity Technical Group (Department of Primary industries-DPI) undertook a review of Tasmanian Import Requirements for fruit fly host produce from mainland Australia. As part of this they completed a thorough risk assessment of both Medfly and Queensland fruit fly relative to the climatic conditions in Tasmania.

The assessment is particularly important due to similarities in temperatures experienced in the growing regions of New Zealand and in particular the Bay of Plenty. Figure 9 demonstrates that the Tauranga temperatures based on historical averages appear to be approximately 2-3°C on average higher than Launceston and a similar divergence for Hobart, although Hobart and Tauranga are more similar during the critical winter months.

This implies that the outcomes of the DPI review would readily translate and most likely pose a greater risk of Medfly or Queensland fruit fly establishing in Bay of plenty conditions then they would in Tasmania.

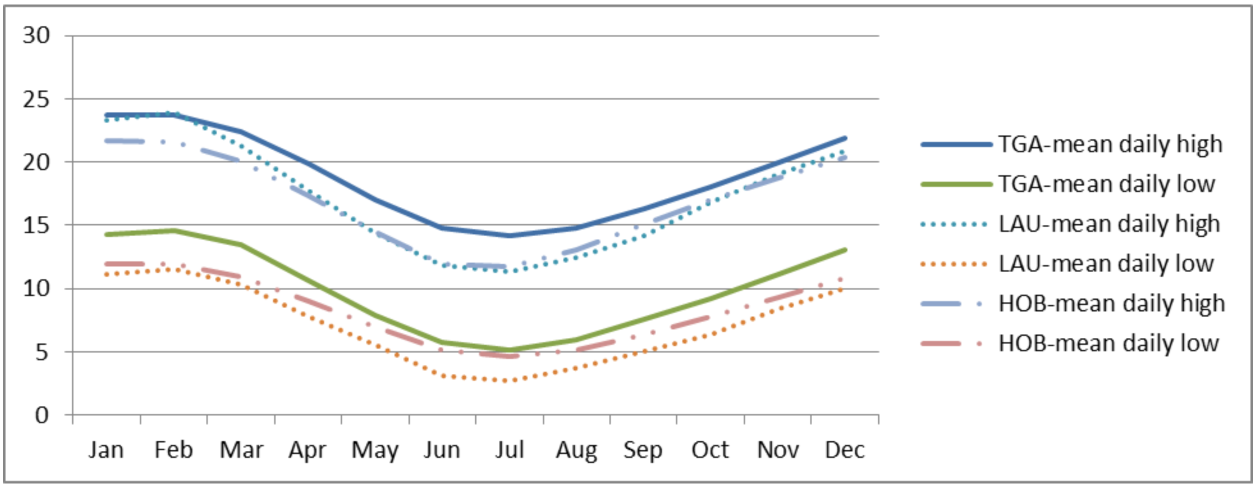


Figure 9: Comparison of historical temperatures for Launceston (LAU), Hobart (HOB) and Tauranga (TGA)

5.3.2 Likelihood of Medfly Establishment in Tasmania

The modelling work conducted in the DPI review indicated that Medfly is unlikely to establish in Launceston under current conditions but could overwinter successfully during a warmer than average winter and hence establish the following spring. The warm season conditions have the potential to produce up to three generations of Medfly, and notwithstanding that winter attrition, a breeding population in the spring following a warm winter could be noticeable. Medfly could also successfully overwinter in Hobart under favourable climatic conditions and hence establish the following spring. However, as fewer generations are possible in current warm season conditions than in Launceston, and because winter attrition would occur, the breeding population in Hobart in spring would be small, unless conditions in the previous spring were also warmer than average.

The concern from this synopsis is that the Bay of Plenty climate picks up the most favourable features of both Launceston and Hobart and then adds a little more, suggesting that it could sustain three generations of Medfly during the warmer months and a reduced amount of attrition during the winter months would provide a reasonable population going in to the following spring.

5.3.3 Potential global distribution of Medfly using CLIMEX

The Tasmania synopsis is consistent with the modeling undertaken using CLIMEX by Vera *et al* (2002)

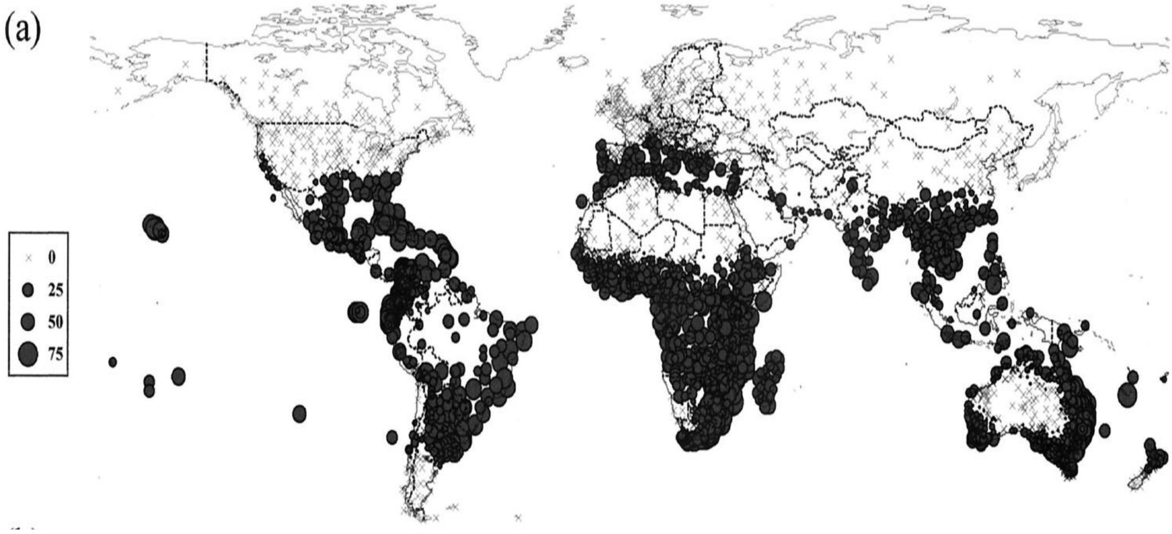


Fig 9. The potential geographical distribution of medfly worldwide, as fitted by the CLIMEX model. Ecoclimatic Index (EI), using point data and natural rainfall. Vera et al (2002)

5.3.2 Likelihood of Queensland fruit fly establishment in Tasmania

The DPI modelling suggested that Launceston could support one complete local generation of Queensland fruit fly per year, over summer to early autumn. Hence, active flies appear possible between December and early April. However, individuals in any life-stage are unlikely to persist over the subsequent winter and initiate the next cohort, meaning the single local generation is likely to be transient.

The key assumption used in the modelling was the 198 day maximum length of adult Queensland fruit fly survival found by O'Loughlin et al. (1984). This was used to put a survival time limit for overwintering by adults. Eggs, larvae and pupae were assumed to perish when no growth occurs for several weeks.

Tasmania is currently unsuitable for permanent establishment for Queensland fruit fly but both Launceston and Hobart could support transient occurrence.

The report goes on to consider how much warmer it would need to become for Queensland fruit fly to overwinter and hence establish in Tasmania. This was done by comparing temperatures in Launceston and Hobart, with Melbourne over the last 30 years and in 2008 when Queensland fruit fly is reported to have overwintered there successfully. The comparison indicates Launceston and Hobart would need to experience an increase in excess of 3°C through the year to emulate Melbourne temperatures, and hence support overwintering of Queensland fruit fly.

From the assessment earlier of the comparison to Tauranga temperatures, this suggests that although still marginal, there is a much stronger likelihood that Queensland Fruit fly could over winter in the Bay of Plenty especially for a warmer than average winter.

6 Susceptibility of kiwifruit to Tephritidae infestation

As explored in the previous section, there would need to be a number of factors that resulted in a population of fruit flies becoming established in New Zealand including:

- A pathway for entering through the New Zealand border.
- Non detection at the border.
- A species that could survive our climate /temperature range.
- Suitable hosts for a mated adult female fly to lay their eggs on.

Recent trials have been undertaken to determine if Medfly would become established in kiwifruit. Papachristos et al (2012) ran a laboratory test of three kiwifruit cultivars Hayward, Tsehelidis (*Actinidia deliciosa*) and Soreli (*A. chinensis*) in comparision to nectarines and an in-orchard trapping test in an area of Greece that already had Medfly established.

The results showed that Medfly females would lay their eggs in all three varieties, and preferred the cultivar *A. chinensis* over nectarines (although no adults were obtained from this cultivar). Adults obtained from the Hayward and Tsehelidis cultivars were less fecund and had reduced longevity compared to those obtained from nectarines. Of interest, when the researchers removed the hairs (trichomes) from the fruit surface of Hayward, the Medfly females increased their egg laying on the fruit. This indicates that the trichome is a significant deterrent to the female laying her eggs.

Adults of Medfly were captured in all four kiwifruit orchards but at significantly lower numbers compared with citrus orchards alongside. Fruit sampling from the Hayward and Tsehelidis cultivars indicated a minimal infestation of the Hayward fruit only (0.41%), which resulted in no adult emergence.

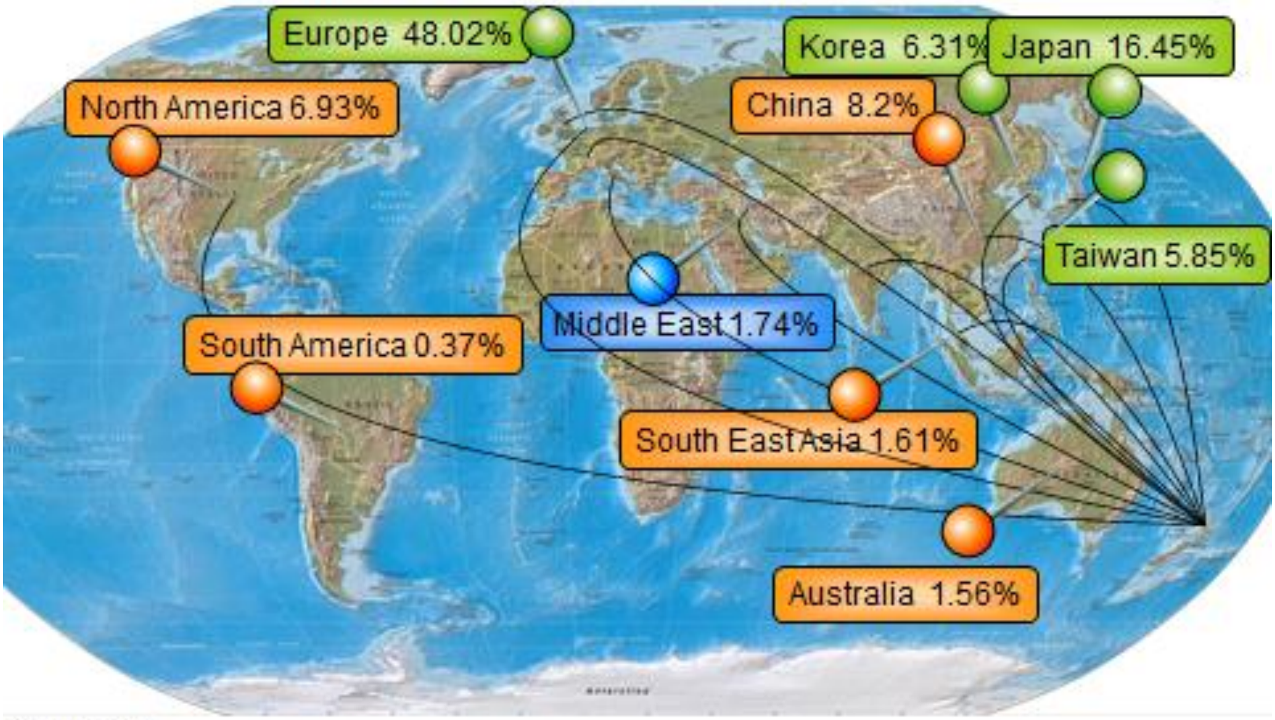
Spinelli (pers com.) has never seen a Medfly population establish in a kiwifruit orchard in Italy and thinks this is “mainly due to the shade under the kiwifruit canopy. They do not go deep in the canopy if shaded, even moderately shaded”. So although there may be Medfly around (and being trapped in hormone or chromatic traps) they typically do not lay eggs on kiwifruit. If they do lay their eggs, it’s likely to be on the outside of the orchard and any growers wishing to spray should spray accordingly. In 2002 Spinelli monitored fruit fly in the orchard and noticed “that they punched the fruit only if brix was above eight and temperature above 16°C.” He labeled the Medfly a “snob” insect, which would be quite specific on what they choose to lay their eggs on (although the host range is very large).

These comments do provide support to kiwifruit being a less preferred host but can’t exclude the adaptability of Medfly to changing the host range for specific situations. Given the opportune fruit maturity (i.e. close to harvest) it is likely that it is going to be a case of Medfly tolerance to colder temperatures that will determine the success or otherwise of a population developing in a kiwifruit orchard.

7 Market access implications of an incursion in NZ

7.1 Relative market importance

Europe is still the primary market of New Zealand kiwifruit in a collective sense although on a single market demand basis Japan and latterly China are increasingly dominating sales.



Source: ZESPRI

7.2 The market access experience of the 1996 Med Fly incursion

Export markets applied market access restrictions to medfly host produce from New Zealand as a response to the incursion. The responses from major markets are summarised in the following table.

Table 6: Market restrictions applied to 1996 Med Fly incursion (Underwood 2007)

Market	Radius applied for restrictions	Date Restrictions Lifted	Duration of restrictions (lifecycle)	Duration of restrictions (months)
United States	7.2km (4.5 miles)	2 April 1997	3 generations	~10+½months
Korea	15km	23 April 1997	3 generations	~11+½months
Japan	15km	14 April 1997	3 generations	~11months
Australia (except WA)	80km, reduced to 15 km on 5 June 1996	22 January 1997	1 generation plus 28 days	8+1/2 months
Western Australia	No restrictions	No restrictions	No restrictions	No restrictions
China	North Island	BOP kiwifruit		Final restriction

		exempted within 1 year, other restrictions remained		lifted more than 2 years after initial incursion.
Europe	No restrictions	No restrictions	No restrictions	No restrictions
NZ Domestic	A zone: 200m radius B zone: 1.5km radius C zone: 15km radius		1 generation plus 28 days	~8+½months

Responses ranged from the mildest response of no restrictions from Europe (where medfly is established in a number of countries) to severe restrictions from China which excluded fruit from the whole of the North Island for a period of time, then accepted kiwifruit exports from the Bay of Plenty before totally lifting the restrictions more than 2 years after the initial outbreak.

A typical market response was to restrict market access to host material produced in or passing through a 15km radius zone around the find. Fruit from within this zone was not acceptable for markets applying restrictions. In addition, fruit passing through this 15km zone required insect proofing and documentation to be acceptable for markets sensitive to medfly. Being in an urban area there was very little commercial fruit grown in the 15km zone.

The requirement for insect proofing fruit transiting the 15km zone had the most significant effect on commercial growers. The zone included access routes to the airport, Ports of Auckland and major road transport routes. Insect proofing included additional MAF inspections and the sealing of loads as part of the programme to assure markets. The costs outside MAF's control fell where they lay. For example, the cost of providing insect proof wrapping and additional MAF inspections or transport diversion was met by the owner of the produce at the time. Apart from these measurable costs, other costs are more difficult to measure, e.g. quantify the loss of product quality as a result of meeting insect proofing requirements or to delays relating to the market restrictions.

7.3 Country specific distribution of Medfly

The reaction of markets to an incursion in New Zealand is likely to be a reflection of the importing countries status regards the species of fruit fly detected.

A case in point can be explained by considering the detailed country distribution of MedFly contained in the EPPO datasheet. It would be difficult for any of the following listed countries to apply strict import criteria;

EPPO region: Southern part of the EPPO region, i.e. Albania, Algeria, Croatia (Kovacevic, 1965), Cyprus, Egypt, France (very limited distribution in south only; Cayol & Causse, 1993), Greece (including Crete), Hungary (found but not established), Israel, Italy, Lebanon, Libya, Malta, Morocco, Portugal (including Azores and Madeira), Russia (southern, found but not established), Slovenia, Spain (including Balearic and Canary Islands), Switzerland (limited distribution), Syria, Tunisia, Turkey, Ukraine (outbreaks in the south eradicated). Records in northern or central Europe (Austria, Belgium, Bulgaria, Czech Republic, Germany, Hungary, Luxemburg, Netherland, Sweden, UK) refer to interceptions or short-lived adventive populations only (Karpati, 1983; Fischer-Colbrie & Busch-Petersen, 1989).

Asia: Afghanistan (unconfirmed), Cyprus, India (single quarantine interception; Kapoor, 1989), Israel, Jordan, Lebanon, Saudi Arabia, Syria, Turkey, Yemen.
Africa: Algeria, Angola, Benin, Burkina Faso, Burundi, Botswana, Cameroon, Cape Verde Islands, Congo, Côte d'Ivoire, Egypt, Ethiopia, Gabon, Ghana, Guinea, Kenya, Liberia, Libya, Madagascar (also the related species *C. malgassa*), Malawi, Mali, Mauritius, Morocco, Mozambique, Niger, Nigeria, Réunion, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, St. Helena, Sudan, Tanzania, Togo, Tunisia, Uganda, Zaire, Zimbabwe. Karpati (1983) lists some other African countries but does not give the source of his data.
North America: Bermuda (eradicated). USA (only Hawaii); introduced and eradicated several times in California during 1980s and 1990s; introduced, eradicated and still absent in Florida and Texas (Cunningham, 1989b; Lorraine & Chambers, 1989). Eradicated from Mexico.
Central America and Caribbean: Belize (eradicated), Costa Rica, El Salvador, Guatemala, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama. The related species *C. malgassa*, from Madagascar, was at one time established in Puerto Rico (Steyskal, 1982).
South America: Argentina (locally), Bolivia, Brazil (Espirito Santo, Goias, Minas Gerais, Paraná, Rio Grande do Sul, São Paulo), Chile (extreme north only, declared eradicated in 1996), Colombia, Ecuador, Paraguay, Peru, Suriname, Uruguay, Venezuela.
Oceania: Australia (found but not established in New South Wales, limited distribution in Western Australia), Northern Mariana Islands.
EU: Present.

8 Conclusion

The impacts of a fruit fly incursion and establishment in New Zealand are without question substantial. Tephritid fruit flies have a global reputation for being one of the most serious threats to fresh fruit and vegetable production and there are plenty of examples to substantiate these claims.

Care has to be taken however, to not generalise the Tephritid group as practically there will only be a few species that will seriously threaten establishment in New Zealand. It is important that the limited resources in New Zealand are targeted at the greatest risks both from an incursion perspective and if in the unlikely event a breeding population does establish, ensuring the pest is eradicated as quickly as possible.

The direct impacts on kiwifruit productivity are questionable but given the right fruit maturity, lack of preferred host material and growing regions dominated by the northern North Island the impact on productivity could be quite substantial.

Without question the market access implications and subsequent impacts on logistics are substantial. It does seem that since the 1996 Medfly incursion, there is a lot more realism amongst importing countries now of what constitutes a ‘detection’ versus an ‘incursion’ versus an ‘outbreak’ as evidenced by the reaction to the 2012 Queensland fruit fly detection. Although there are likely to be a number of detections that may cause short term concern a real focus needs to be on the species such as Medfly which poses real risk of establishing and causing significant impact during the kiwifruit export season.

On-going assessment of risk and import pathways needs to be undertaken to maintain a up to date view of the threat fruit fly poses to New Zealand and in particular the kiwifruit sector.

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Fact Sheet: Mediterranean Fruit Fly (*Ceratitis capitata*)

The Mediterranean fruit fly, or Medfly, is one of the world's most destructive fruit pests. Because of its wide distribution over the world, its ability to tolerate cooler climates better than most other species of fruit flies, and its wide range of hosts, it is ranked first among economically important fruit fly species. This pest attacks more than 260 different fruits, flowers, vegetables and nuts.

Assessment of risk

Establishment in NZ		Economic impact		Market Access	
Entry pathway		Host range (incl. kiwifruit)		Treatment required	
Ease of establishment		Plant health		Area freedom required	
Ease of detection		Crop productivity		Movement control	
Ease of eradication		Crop protection		Quarantine requirements	

Key: High risk Moderate/unknown risk(?) Low risk

Description & Life cycle

The adult medfly is slightly smaller than a common housefly (6mm length) and is very colourful. It has red and blue iridescent eyes, a brown head, a shiny, black back, and a yellowish abdomen with silvery cross bands.

Its wings, normally drooping, display a blotchy pattern with yellow, brown, and black spots and bands.

A single generation takes around 18-31 days in favourable conditions.

Eggs are laid below the skin of the host fruit and are white, banana shaped and nearly 1mm long. Infested fruit may show 'sting' marks on the skin and may be stung more than once by several females.

They hatch within 2-4 days (up to 16-18 days in cool weather) and to the naked eye, the larvae resemble blowfly maggots.

They are creamy white, legless, blunt ended at the rear and tapered towards the front with black mouth hooks. Larvae feed for another 6-11 days (at 13-28°C) on the host fruit, before dropping to the soil to pupate.

Adults emerge after 6-11 days (24-26°C; longer in cool conditions) and adults live for up to 2 months.

Distribution

Medfly is an important pest in Africa and has spread to almost every other continent to become the single most important Fruitfly pest. MedFly originated in tropical Africa, from where it has spread to the Mediterranean area, to parts of central and south America and South West Australia.

Host & Climatic Range

Found on a huge range of tree crops including Citrus, Apples, Avocadoes, coffee, kiwifruit, summerfruit, mangoes, pears. Medfly will not survive sub-zero winter temperatures and will not lay eggs below 15.5°C but is one of the more, cold tolerant of the economically important fruit fly species. It is well named Mediterranean, for the area in which it survives.

Impacts

The damage to crops caused by Medfly result from, oviposition in fruit and soft tissues of vegetative parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms.

Larval feeding damage in fruits is the most damaging. Mature attacked fruits may develop a water soaked appearance. Young fruits become distorted and usually drop. The larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot. These maggots also attack young seedlings, succulent tap roots, and stems and buds of host plants.

In addition to physical damage Medfly inflicts economic damage due to costs associated with quarantine and monitoring programmes, limits on exports from fruit fly infested areas and quarantine treatments of fruits from fruit fly infested areas.

Dispersal ability	Ease of detection	Ease of Eradication
There is evidence that Medfly adults can fly at least 20 km. However, they do not usually disperse beyond 100-200 m when host fruit is present. Dispersal of larvae also occurs in (usually ripe) host fruit.	Medfly can be monitored by traps baited with male lures. Males are attracted to trimedlure and terpinyl acetate, but not methyl eugenol. Ceralure is a potent and persistent attractant for Medfly	Ripe host fruits need to be destroyed. A cover and bait spray combination can be used. Sterile insect release can work to control population growth.

Note: The Medfly is included as an example of the Ceratitis family of FruitFlies, especially because it is such worldwide economic concern. The family also includes:

- *Ceratitis cosyra*, mango fruit fly
- *Ceratitis rosa*, Natal fruit fly

Fact Sheet: Oriental Fruit Fly (*Bactrocera dorsalis*)

Bactrocera dorsalis is a major economic pest and utilises a wide range of commercial, edible and rainforest fruits. Found mainly in Asia it's mainly restricted to the tropical and sub-tropical regions. Eggs won't hatch below 13°C so is restricted largely to the northern, summer climate in New Zealand.

Assessment of risk

Establishment in NZ		Economic impact		Market Access	
Entry pathway	High	Host range (incl. kiwifruit)	?	Treatment required	High
Ease of establishment	Moderate	Plant health	Moderate	Area freedom required	High
Ease of detection	Moderate	Crop productivity	High	Movement control	High
Ease of eradication	Moderate	Crop protection	High	Quarantine requirements	High

Key: **High risk** **Moderate/unknown risk(?)** **Low risk**

Description & Life cycle

The adult, is noticeably larger than a house fly, has a body length of about 8.0 mm and wing length about 7.3 mm. The colour of the fly is very variable, but there are prominent yellow and dark brown black markings on the thorax.

The ovipositor is very slender and sharply pointed. Eggs are laid below the skin of the host fruit. These hatch within a day (although delayed up to 20 days in cool conditions). The egg is white, elongate and elliptical measuring about 1.2 mm.

The third instar, which is a typical maggot in appearance, is about 10 mm in length and creamy white. The larvae feed for another 6-35 days, depending on seasonal temperatures, before dropping to the soil to form a tan to dark brown puparium about 5 mm in length. Adults emerge after 1-2 weeks.

Distribution

Found mainly in Asia, OFF is widespread throughout much of Pakistan, India, Sri Lanka, Myanmar, Indonesia, Malaya, Thailand, Cambodia, Laos, Vietnam, southern China, Taiwan, Philippine Islands, Ryukyu Islands (including Okinawa), Micronesia, Mariana Islands (Guam, Rota, Saipan, Tinian), Bonin Islands, and Hawaiian Islands.

It has been introduced to Palau, Hawaii, Nauru and Tahiti, and has been eradicated from southern Japan (Ryukyu Is) and Mauritius.

Host & Climatic Range

The oriental fruit fly has been recorded from more than 150 fruit and vegetables, including citrus, guava, mango, papaya, avocado, banana, loquat, tomato, surinam cherry, rose-apple, passion fruit, persimmon, pineapple, peach, pear, apricot, fig, and coffee. Avocado, mango, and papaya are the most commonly attacked.

Is a high priority pest identified for: Apple/Pears, Avocado, Banana, Citrus, Summerfruit, Tropical fruit and Vegetables

OFF is mainly found in warmer, tropical areas. Eggs will not develop at temperatures below 13°C, although the adult fly may be able to cope with colder temperatures.

Impacts

The damage to crops caused by OFF result from, oviposition in fruit and soft tissues of vegetative parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms. Larval feeding damage in fruits is the most damaging.

In addition to physical damage OFF inflicts economic damage due to costs associated with quarantine and monitoring programmes, limits on exports from fruit fly infested areas and quarantine treatments of fruits from fruit fly infested areas.

Dispersal ability	Ease of detection	Ease of Eradication
Adult flies can disperse over long distances through flight. There is evidence that OFF adults can fly at least 50 - 100 km. The transport of larvae in infested fruit can result in global movement, giving these flies an extreme risk rating.	OFF can be monitored by traps baited with male lures. Males are attracted to Methyl eugenol (O-methyl eugenol) at a range of up to 1 km	Ripe host fruits need to be destroyed. A cover and bait spray combination can be used. OFF was eradicated from northern Japan using Methyl eugenol bait/kill traps. Sterile insect release can work to control population growth.

NOTE: There are a number of other flies in the Bactrocera family that are very similar in appearance, but differ in their ranges and specificity around host plants.

Bactrocera correcta , guava fruit fly

Bactrocera invadens

Bactrocera cucurbitae, melon fly

Fact Sheet: Queensland Fruit Fly (*Bactrocera tryoni*)

QFF is a very serious pest of a wide variety of fruits and some vegetables and is a particular threat to the northern parts of NZ. Damage levels can be up to 100% of unprotected fruit and being indigenous to Australia the trade is in a similar crop maturity time zone to New Zealand.

Assessment of risk

Establishment in NZ		Economic impact		Market Access	
Entry pathway		Host range (incl. kiwifruit)	?	Treatment required	?
Ease of establishment		Plant health		Area freedom required	?
Ease of detection		Crop productivity		Movement control	?
Ease of eradication		Crop protection		Quarantine requirements	

Key: **High risk** **Moderate/unknown risk(?)** **Low risk**

Description & Life cycle

The adult female is approximately 6-8 mm long, has a wing expanse of 10 to 12 mm, and has mostly transparent wings marked with brown. The fly is reddish brown with yellow markings.

The abdomen is constricted at the base, flared in the middle, and broadly rounded at the tip excluding the ovipositor in females. Adults can live for many weeks. Female flies usually mate once or twice. Male flies mate multiple times.

QFF lay eggs in maturing and ripe fruit on trees and sometimes in fallen fruit. Females can lay several hundred eggs during her lifetime. Eggs are small (< 1 mm long), white in colour and banana shaped.

When fully grown larvae are about 6 to 8 mm long and pale yellow. Larvae feed for 10 - 31 days on the host fruit, before dropping to the soil to pupate.

QFF numbers tend to increase in spring when temperatures are warm and there is ready availability of suitable host fruit. Under favourable conditions one generation takes about four weeks.

Distribution

QFF is indigenous only to Australia, but like other *Bactrocera* spp. is known by experience to have the potential to establish adventive populations in various other tropical areas. It is the major fruit fly pest species in eastern Australia and is the target of major control and quarantine programmes

It occurs in large populations throughout eastern Australia from Cape York (Queensland) to East Gippsland (Victoria). It is also established in New Caledonia and the Austral Islands.

Host & Climatic Range

QFF can attack a wide range of fruit, fruiting vegetables and native fruiting plants. The main hosts are mostly tree fruits: avocadoes, plums, mangoes, peaches, citrus, passionfruit.

QFF is found in warmer areas of Australia, but has been found in Tasmania (similar climate to NZ). The adult fly may be able to cope with colder temperatures. QFF are most active in warm humid conditions and after rain. QFF might be seen walking on the undersides of leaves or on maturing fruit. They readily take flight if disturbed

Impacts

Large numbers commonly occur in Australia in March and April at a similar time that many fruit crops are maturing in New Zealand.

The damage to crops caused by OFF result from, oviposition in fruit and soft tissues of vegetative parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms. Larval feeding damage in fruits is the most damaging.

In addition to physical damage OFF inflicts economic damage due to costs associated with quarantine and monitoring programmes, limits on exports from fruit fly infested areas and quarantine treatments of fruits from fruit fly infested areas.

Dispersal ability	**Ease of detection**	**Ease of Eradication**
There is evidence that Queensland Fruitfly adults can fly at least 50 - 100 km. Dispersal of larvae also occurs in (usually ripe) host fruit.	QFF can be monitored by traps baited with male lures. Males are attracted to Cue lure (4-(p-acetoxyphenyl)-2-butanone) or a mixture of methyl eugenol and cue lure are effective at a range of up to 1 km QFF is also attracted to wet food lures such as protein and citrus juice although these lures are less effective.	Ripe host fruits need to be destroyed. A cover and bait spray combination can be used.

Fact Sheet: Mexican fruitfly (*Anastrepha ludens*)

MFF has a broad host range and is a major pest, especially of citrus and mango in most parts of its range. This species and *Anastrepha obliqua* are the most important pest species of *Anastrepha* in Central America and Mexico.

Assessment of risk

Establishment in NZ		Economic impact		Market Access	
Entry pathway	High	Host range (incl. kiwifruit)	?	Treatment required	?
Ease of establishment	Moderate	Plant health	Moderate	Area freedom required	?
Ease of detection	Moderate	Crop productivity	High	Movement control	?
Ease of eradication	Moderate	Crop protection	High	Quarantine requirements	High

Key: **High risk** **Moderate/unknown risk(?)** **Low risk**

Description & Life cycle

The adult Mexican fruit fly is 7–11 mm long, or slightly larger than a house fly (6–7 mm), and is mostly yellowish-brown in colour. The MFF, is typical in appearance to other members of the genus *Anastrepha*, but notable for the female's long ovipositor (3-4.5mm) and sheath relative to its body size.

Adults may survive for many months, occasionally almost a full year. The adult female typically oviposit in citrus and other fruit at the time when the fruit begins to show colour. Females are highly fecund, laying 1,500 eggs.

Eggs are usually laid in groups of about 10 and hatch in 6 to 12 days. The newly hatched larvae eat and burrow into the pulp of the fruit, taking on the colour of their food so that when small they are overlooked easily.

The newly hatched larvae eat and taking on the colour of their food so that when small they are overlooked easily. The last instars are usually 9–12 mm in length and require 11 days to over a month to complete development, depending on temperature.

At maturity, the larvae exit the fruit and burrow into the soil to pupate. Adults emerge from 12 to 100 days later depending on temperature

Distribution

The MFF is indigenous to Mexico and much of Central America as far south as Costa Rica. It has also spread into the cultivated citrus sections of the west coast of Mexico and northward toward Texas, Arizona and California.

In January 2012, the USDA-APHIS announced that the MFF was eradicated from the last county in Texas in which it had been present.

Host & Climatic Range

All varieties of citrus except lemons and sour limes are attacked. Grapefruit is the preferred host, with oranges second. Pear, peach and apple are preferred among the deciduous hosts, and white sapote and mango are preferred among the subtropical fruits.

While not a preferred host, avocado also is attacked. Other fruits and vegetables have been infested under laboratory conditions, including figs, bananas, tomatoes, peppers, squash and beans.

The Mexican Fruitfly derives from subtropical/tropical wet forest habitats, so is not found in areas that are too cold or too dry. It may be more of a threat of introduction to other subtropical areas of the world than other species of *Anastrepha*.

Impacts

Like other Anastrepha species, MFF does not respond to any known sex attractant hence the early detection system of surveillance trapping will not work in this case.

The damage to crops caused by OFF result from, oviposition in fruit and soft tissues of vegetative parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms. Larval feeding damage in fruits is the most damaging.

In addition to physical damage MFF inflicts economic damage due to costs associated with quarantine and monitoring programmes, limits on exports from fruit fly infested areas and quarantine treatments of fruits from fruit fly infested areas.

Dispersal ability	Ease of detection	Ease of Eradication
There is evidence that Mexican Fruit fly adults can fly at least 135km. Dispersal of larvae also occurs in (usually ripe) host fruit.	The Mexican Fruit Fly (like other *Anastrepha* species), does not respond to any known sex attractant that can be usefully employed in a detection trapping system. Instead, detection systems rely on the use of non-specific, wet, protein-baited McPhail traps, which act as general food attractants, especially for young females searching for protein to produce eggs. The number of traps required per unit area is high.	The adult stage is susceptible to control, usually by short-lived baits comprised of a contact insecticide mixed with protein and carbohydrate. This is applied as fine droplets to host plant foliage where adults feed. However, adults are highly mobile and move easily from any nearby untreated trees back to treated trees after a few days. Area-wide control is also possible using mass release of laboratory-reared and sterilized males to compete with wild fertile males and reduce the number of fertilized eggs laid. The Sterile Insect Technique is used in maintaining a fly-free zone in Mexico, Texas and California.

*NOTE: The MFF is included as an example of the Anastrepha family of fruitflies. It also includes:

- *Anastrepha suspensa*, Caribbean fruit fly
- *Anastrepha obliqua*, West Indian fruit fly
- *Anastrepha fraterculus*, South American fruit fly

Fact Sheet: Apple Maggot Fly (*Rhagoletis pomonella*)

Rhagoletis pomonella, apple maggot is one of the serious insect pests in apple and many other fruits.

Assessment of risk

Establishment in NZ		Economic impact		Market Access	
Entry pathway		Host range (incl. kiwifruit)		Treatment required	?
Ease of establishment		Plant health		Area freedom required	?
Ease of detection		Crop productivity		Movement control	?
Ease of eradication		Crop protection		Quarantine requirements	

Key: High risk Moderate/unknown risk(?) Low risk

Description & Life cycle

The adult Apple maggot is about 5 mm long, slightly smaller than a house fly. It is black in colour, with white bands on the abdomen (4 on the female and 3 on the male), and the wings are conspicuously marked with four oblique black bands.

Adults emerge from the ground during early summer. Emergence continues for a month or more, and many pupae may remain inactive and not emerge until the second year.

Egg-laying usually does not take place until eight to 10 days after the flies have emerged. The female punctures the skin of the fruit with her ovipositor and lays eggs singly in the pulp. Eggs hatch in five to 10 days. The maggots develop slowly in the green fruit and usually do not complete their growth until the infested fruits have dropped from the tree, after which growth is completed rapidly.

Larval development requires from 2 weeks in early maturing apples to 3 or more months in hard winter varieties. Then the larvae leave the fruit and enter the soil to pupate. Winter is passed as puparia in the soil.

Distribution

from eastern North Dakota and southern Manitoba to Nova Scotia, southward to eastern Texas to central Florida, occurring over the entire middle and eastern region of the United States. In 1981 it became established in Oregon, from where it spread to California, Washington State, Utah and Colorado, and eventually Nebraska in 1991

Host & Climatic Range

Originally, it fed on the fruit of wild hawthorn, but then became a primary pest of cultivated apples, especially in the northeastern United States and southeastern Canada. It prefers a temperate climate, with a defined winter.

Impacts

Injury to fruit is caused by the maggots. These maggots bore throughout the fruit, forming irregular, winding tunnels, which turn brown, often causing premature dropping of fruit.

When the fruit is slightly infested, there may be no external indication of the presence of the maggots, but when the fruit ripens, the burrows show as dark, winding trails beneath the skin.

Minute egg punctures and distorted, pitted areas may show on the surface. Heavily infested early varieties of fruit will be reduced to a brown rotten mass filled with the fly larvae.

Dispersal ability	Ease of detection	Ease of Eradication
There is evidence that Apple Maggot adults can fly at least 100m and up to 1.5km Dispersal of larvae also occurs in host fruit.	The Apple maggot does not respond to any known sexual attractant lures. Yellow sticky traps are used to detect the first emergence of adults in abandoned orchards or unsprayed apple trees in infested areas. Red sticky spheres in apple trees are used to detect the beginning of egg laying, and then treating as soon as the first fly is found.	The systematic destruction of infested apples and the elimination of hawthorn and abandoned apple trees in the vicinity of orchards are considered valid control practices. Apple maggots in fruits may be killed by placing the fruit in cold storage at 0°C for a period of 40 days. It is difficult to eradicate. Sticky traps are used to identify the best opportunity to spray adults with insecticide.

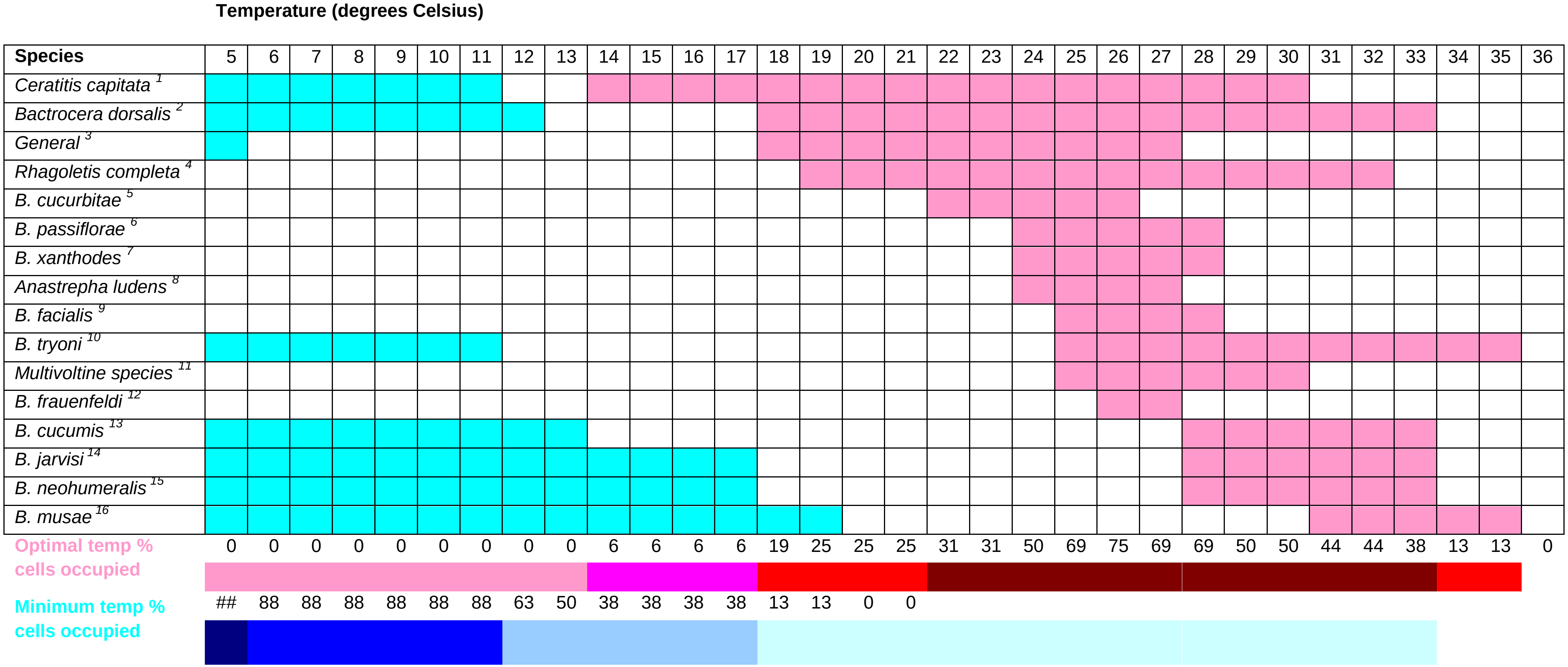
*NOTE: The Apple Maggot FruitFly is included as an example of the *Rhagoletis* family of FruitFlies and especially because it is such worldwide economic concern for the apple industry.

Rhagoletis family also includes:

- *Rhagoletis completa*, Walnut husk fly
- *Rhagoletis cerasi*, cherry fruit fly
- *Rhagoletis indifferens*, western cherry fruit fly
- *Rhagoletis fausta*, black cherry fruit fly
- *Rhagoletis mendax*, blueberry maggot
- *Rhagoletis cingulata*, eastern cherry fruit fly

APPENDIX 2 Categorisation of temperature according to fruit fly biology.

The data on summer and winter temperatures were categorised based on the information obtained from the literature on the minimum temperature at which a fruit fly species can survive, and the optimal temperature range for reproduction and population growth of a fruit fly species. Data could only be found for a sample of the fruit fly species of concern to New Zealand. However, if more data is found, this can be incorporated. The results for each species were graphed side-by-side as shown in the figure below.



The figure assigns each degree of temperature to an individual cell, and the cells coloured if they fall within the optimal temperature range for a given species (pink cells) or below the minimum temperature for a given species (blue cells).The probability of 'occupancy' was then calculated for each degree (number of cells 'occupied' divided by the number of species for which data was collected). This figure was used to categorise and standardise the summer (mean daily maximum) and winter (mean daily average) temperatures for input into the 'establishment' layer of the risk map.