Ministry for Primary Industries
Manatū Ahu Matua

Evaluation of Import and Export Parameters for Fruit Fly Export Restriction Zones

MPI Technical Paper

Version 1.6

By Dr Michael Ormsby

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New Zealand Government

Growing and Protecting New Zealand

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Fruit Fly Export Restriction Zones

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Approved for Distribution

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Contents

Executive Summary

The New Zealand Ministry for Primary Industries (MPI), working with affected local industry representatives, is drafting a protocol to negotiate pre-agreed bilateral market access conditions in the event of any future fruit fly incursions in New Zealand. MPI has been asked to provide scientific advice on the trigger to establish an *Export Restriction Zone* (ERZ) and the size of the ERZ, as well as the criteria for disestablishing the ERZ for the four key fruit flies that have been identified as important; namely *Bactrocera cucurbitae* (Melon fly), *Bactrocera tryoni* (Queensland fruit fly (Q-fly)), *Bactrocera dorsalis* (Oriental fruit fly (OFF)), and *Ceratitis capitata* (Mediterranean fruit fly (Med-fly)).

The work to develop this scientific advice was drafted in 2014 and incorporated analyses from a new model on trapping performance and fruit fly distribution. While this scientific advice has been used to support a number of decisions made in the 2015 Queensland Fruit Fly incursion in Auckland (New Zealand), it was considered important that MPI and domestic industry representatives also accept the application of the model for informing decisions on New Zealand's response to fruit fly incursions into fruit fly free areas of our trading partners.

New Zealand's fruit fly surveillance programme provides a high level of assurance that New Zealand is free of economically important fruit flies. In both Australia and California however, the fruit fly surveillance programmes provide lower levels of assurance of fruit fly freedom when compared to New Zealand due to differences in the fruit fly trapping densities used in surveillance and response.

This document provides a comparison between the use of the new model in a potential trade response should incursions of fruit flies occur: 1) in New Zealand or; 2) in selected markets that export host fruit to New Zealand (Australia and California).

Please note that the model outputs presented in this document are indicative only. Should the model be approved for use in trade discussions it is likely that in these discussions the offshore response data used in the model (and therefore the outputs) will vary from those shown in this document.

This scientific advice has not considered what the specifications of any surveillance or response system should be. However the specific nature of a domestic surveillance and response system used in New Zealand and by our trading partners will influence the outputs of the model. It is likely that for a number of reasons the domestic surveillance and response activities related to any particular fruit fly detection or incursion may exceed that used in this scientific advice.

The following table provides a summary of the outputs from the application of the new trade response model to *Bactrocera tryoni* (Queensland fruit fly (Q-fly)) and *Bactrocera dorsalis* (*sensu stricto*) (Oriental fruit fly (OFF)) incursion scenarios in New Zealand, Australia and California. The outputs include estimates for:

- the trigger for establishing an *Export Restriction Zone*;
- the size of the *Export Restriction Zone*; and
- the criteria for removing the *Export Restriction Zone*.

The table also provides a summary of the parameters used as inputs into the model in each case.

While the advice for each of these factors has been provided as discrete and independent outputs, they are derived from the application of a model using research-generated input data that has varying degrees of variability and uncertainty. Where the data available for model inputs has included a range of values for biological variability, conservative ("worst case") point estimates have been used. Thus the outputs of the model are conservative in nature and support somewhat precautionary risk management decisions. As such this scientific advice should be considered conservative guidance for use in discussions on suitable pre-agreed import and market access conditions for New Zealand.

	Modelled New Zealand Export and Import Market Access Requirements				Current Country Domestic Response Requirements[1]		
	New Zealand system for Queensland fruit fly (*Bactrocera tryoni*)	New Zealand system for Oriental fruit fly (*Bactrocera dorsalis* (*sensu stricto*))	Australian system for Queensland fruit fly (*Bactrocera tryoni*)	Californian system for Oriental fruit fly (*Bactrocera dorsalis* (*sensu stricto*))	New Zealand system for Q-fly (*Bactrocera tryoni*) and OFF (*Bactrocera dorsalis* (*sensu stricto*))	Australian system for Queensland fruit fly (*Bactrocera tryoni*)	Californian system for Oriental fruit fly (*Bactrocera dorsalis* (*sensu stricto*))
Triggers for no longer recognising a PFA (establishing an *Export Restriction Zone (ERZ)*)	Detection, at any time, of any juvenile life stage or gravid female fly OR Detection of 3 adult flies[2] in 14 days within 3,200 metre radius	Detection, at any time, of any juvenile life stage or gravid female fly OR Detection of 4 adult flies[2] in 14 days within 5,480 metre radius	Detection, at any time, of any juvenile life stage or gravid female fly OR Detection of 3 adult flies[2] in 14 days within 3,200 or 7,840 metre radius (urban or commercial areas respectively)	Detection, at any time, of any juvenile life stage or gravid female fly OR Detection of 1 adult fly[2] in 14 days within 5,120 or 6,240 metre radius (urban or commercial areas respectively)	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 1 or more* adult male flies for eradication * depends on the circumstance of the finds	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 5 or more adult male flies in 14 days within 1 km radius	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 6 (urban) or 8 (commercial) adult (non-gravid) flies within 28 days and 4.8 km
Radius of the *Export Restriction Zone (ERZ)*	3,200 metres (currently only applies to urban areas)	5,480 metres (currently only applies to urban areas)	3,200 metres in urban areas. 7,840 meters in commercial areas.	5,120 metres in urban areas. 6,240 metres in commercial areas.	Depends on the circumstance of the eradication and largely dictated by trading partners	15 km radius	8.2 km radius
Criteria to be met for removing the *Export Restriction Zone (ERZ)*	The greater period of trapping with zero flies detected (of any life stage) within the *ERZ*[@]: a) 14 weeks or b) One generation (from egg to mature adult) plus 4 weeks OR For the Wellington region and the South Island only, the onset of colder temperatures.	The greater period of trapping with zero flies detected (of any life stage) within the *ERZ*[@]: a) 6 weeks or b) One generation (from egg to mature adult) plus 4 weeks OR For the Wellington region and the South Island only, the onset of colder temperatures.	The greater period of trapping with zero flies detected (of any life stage) within the *ERZ*[@]: a) 47 (or 16)[#] weeks or b) One generation (from egg to mature adult) plus 4 weeks	The greater period of trapping with zero flies detected (of any life stage) within the *ERZ*[@]: a) 34 weeks or b) One generation (from egg to mature adult) plus 4 weeks	Depends on the circumstance of the eradication and largely dictated by trading partners	The greater period of trapping with zero flies detected (of any life stage) within the *ERZ*[@]: One generation (egg to egg) plus 4 weeks OR 12 weeks. (No minimum trapping density is specified)	Three fruit fly generations (egg to egg). (No minimum trapping density is specified)

[1] A countries domestic response requirements are reflected in but not necessarily aligned with the countries market access restrictions for host fruit.

2 The detection of these flies for the trigger applies to those caught in the delimitation traps after the first adult has been detected in the surveillance trap.

[#] The alternative (bracketed) number was calculated using a higher breeding population threshold to better reflect the current criteria accepted in this instance.

[@] At the trapping densities used in the Export Restriction Zones under current standards.

Glossary of Terms

Breeding population size	The threshold or minimum number of flies in an area above which breeding (egg laying) is unacceptably likely to occur and result in a potential risk to export markets of host commodities grown or stored in or transported through that area. As only male fruit fly are lure-attracted, this is measured in this paper as the threshold number of male flies in an area.
Commercial Areas	Areas used for commercial agricultural production.
CPM	Commission for Phytosanitary Measures
Day-Degrees	Accumulated surplus of daily mean temperature above a specified threshold temperature, which can be used to model development and generation times of insects such as fruit flies.
DPIPWE	Department of Primary Industries, Parks, Water and Environment. Tasmania, Australia.
Effective Sampling Area (ESA)	A measure of the effectiveness of an insect trap or lure, and is equal to the fly capture rate divided by the mean trap density (see Turchin & Odendaal (1996)) [stated as hectares (ha) for convenience]
EPPO	European Plant Protection Organisation
Eradication	Application of phytosanitary measures to eliminate a pest from an area [ISPM 5 (accessed July 2015)]
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry [ISPM 5 (accessed July 2015)]
Export Restriction Zone (ERZ)	A prescribed area or zone within a pest free area that is no longer considered 'pest free' and in which restrictions on the export of host material may be necessary.
FAO	Food and Agricultural Organisation of the United Nations
Founder Population Size	The number of individual organisms required at one time within a prescribed area (e.g. 1 hectare) to establish a population. The founder population size is the result of any Allee effect on the target species together with local environmental conditions.
ha	Hectare, which is equal to 10,000 m^2.
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 [ISPM 5 (accessed July 2015)]
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
MPI	New Zealand Ministry for Primary Industries
OFF	Oriental fruit fly (*Bactrocera dorsalis* (Hendel) *sensu stricto*) (Diptera: Tephritidae).
Outbreak	A recently detected pest population, including an incursion, or a sudden significant increase of an established pest population in an area [ISPM 5 (accessed July 2015)]
Passive surveillance	Surveillance that relies on informal or adhoc reporting, usually from academia, industry or the general public who may have an interest in finding the target pest.
Pest Free Area	An area in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained [ISPM 5 (accessed July 2015)]
Q-fly	Queensland fruit fly (*Bactrocera tryoni* (Froggatt)) (Diptera: Tephritidae).
USDA	United States Department of Agriculture

1. Scope

1.1 The Purpose and Scope of the Overall Work Programme

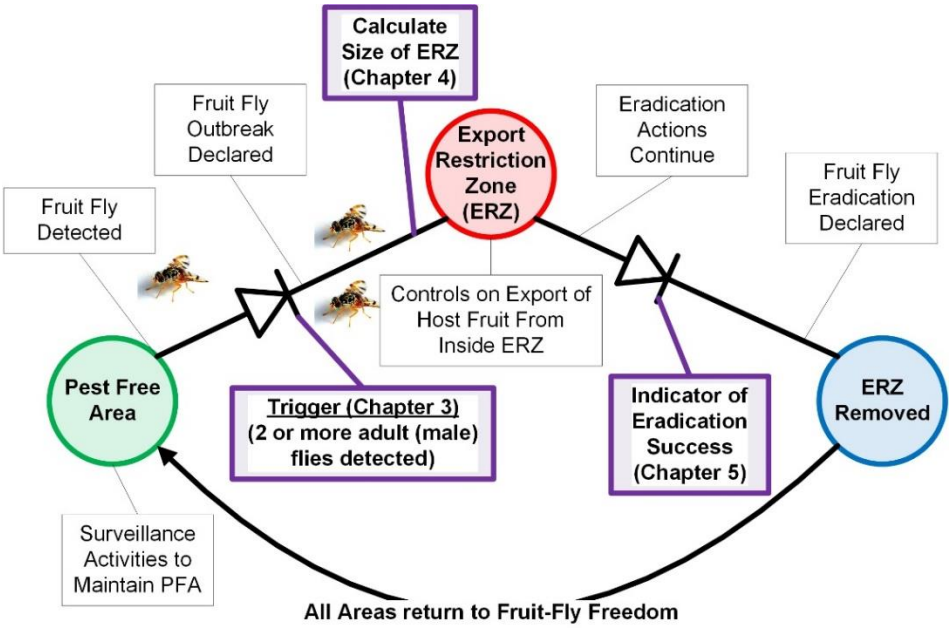
The New Zealand Ministry of Primary Industries (MPI) and New Zealand's horticultural exporters' desire pre-agreed generic bilateral market access conditions in the event of future fruit fly incursions to overcome complexity and associated transaction costs resulting from countries imposing differing requirements. Substantial benefits would accrue if one arrangement was accepted by all. For trading partners to agree in advance to the parameters of any trade response, MPI requires sound scientific reasoning to support the development of an export framework that can be applied across the range of fruit fly species and potential outbreak scenarios.

To achieve this MPI, together with New Zealand horticultural industry representatives, has drafted a protocol document to be used to negotiate pre-agreed bilateral market access conditions in the event of any future fruit fly detections or outbreaks in New Zealand. To complete the fruit fly market access protocol several pieces of detailed information were required. This information included:

- the number of adult flies that can be detected before an *Export Restriction Zone* (*ERZ*) is implemented and the pest-free status of the localised area is suspended (e.g. the trigger);
- the size (area or radius) of the *ERZ*, outside of which any host material grown and exported would still be deemed to be within a pest free area; and
- the conditions required to enable an *ERZ* to be rescinded and the area's pest free status to be reinstated.

The relationship between these three factors can be considered as shown in ***Figure 1***.

Figure 1: Relationship between the three components of this technical paper.



MPI and representatives from the New Zealand horticultural industry have agreed that initially the fruit fly market access protocol will be developed for four key lure-attracted fruit fly species that have been identified to be of particular importance to the horticultural industry and the New Zealand economy. It is however expected that the protocol will be extended to other economically important fruit fly species at some stage in the future. The four initial lure-attracted species[2] of fruit fly to be considered are:

[2] Some of these are considered *species complexes*, and include a number of separately described fruit flies.

- *Bactrocera cucurbitae* Melon fly
- *Bactrocera tryoni* Queensland fruit fly (Q-fly)
- *Bactrocera dorsalis* (*sensu stricto*) Oriental fruit fly (OFF)
- *Ceratitis capitata* Mediterranean fruit fly (Med-fly)

To aid in the international negotiations the protocol will closely follow the terms and systems described in the International Standard for Phytosanitary Measures (ISPM) 26 (2006): *Establishment of pest free areas for fruit flies* (Tephritidae). ISPM 26 (2006) defines an outbreak as the detection of:

- an immature fruit fly specimen, such as an egg, larva or pupa;
- two or more fertile adult fruit flies; or
- a gravid female fruit fly.

It is envisaged that the protocol will propose the following categories of fruit fly zones:

a. The export of host material from fruit fly free areas (outside the *ERZ*) with no additional phytosanitary requirements.

b. The export of host material from within or transiting through the *ERZ* provided that phytosanitary measures have been undertaken and officially verified e.g. insect proofing, pre-export treatments.

1.2 The Purpose and Scope of this Document

The work to support the protocol document was drafted in 2014 and incorporated an analysis using a new model for trapping performance and fruit fly distribution. This scientific advice have been used to support a number of decisions made in the 2015 Queensland Fruit Fly incursion in Auckland (New Zealand). However, before the supporting model is used in international negotiations or further decisions during domestic responses, MPI considered it important that industry also accept the application of the model to inform MPI decisions on incursions of fruit flies into offshore pest free areas (PFAs) that export host commodities to New Zealand.

This document has therefore been prepared to demonstrate how the model could aid decisions on New Zealand's response to incursions of economically important fruit flies into PFAs maintained by our trading partners. For purposes of brevity the analysis in this document is restricted to two separate scenarios:

- Queensland fruit fly incursions into PFAs in Australia
- Oriental fruit fly incursions into PFAs in California, USA.

The analysis has been separated into three main parts in this document:

Section 3: Determining a scientifically justified detected-adult fly trigger number for each fruit fly species to trigger establishing an *ERZ*;

Section 4: Determining a scientifically justified size for the *ERZ* around the detection site for an established breeding population of each scenario;

Section 5: Establishing the evidence threshold required to provide sufficient confidence that eradication has been successful and the *ERZ* can be removed.

2. Background Information

Background information required to complete this analysis has been described in the following sub-sections:

- A comparison of the fruit fly status of New Zealand, Australia and California (USA); and
- A comparison of the surveillance and response conditions in place in New Zealand, Australia and California (USA).

2.1 The Fruit Fly Status of New Zealand, Australia and California (USA)

The model for trapping performance and fruit fly distribution used in the support of the draft New Zealand market access protocol requires an understanding of what would be considered the acceptable *base-line* confidence that an area is free of economically important lure-attracted fruit fly species. This can be thought of as the business-as-usual position under which a country may claim that an area is free of any particular lure-attracted fruit fly species.

New Zealand and Q-fly/OFF

The base-line level of assurance supporting New Zealand's fruit fly free status is provided by the New Zealand's fruit fly surveillance programme. Approximately 7,500 traps are set up and maintained from September to June of each year (Quilici & Donner 2012, Acosta & White 2011). Traps are placed in grids, concentrating in populated areas serving as centres for tourism and/or trade, areas of significant horticultural activity, and areas climatically conducive to the establishment of fruit flies (MPI 2014). The density of traps in the grids reflects to a degree the effective trapping distances of each trapping lure. The grid trapping densities used in New Zealand's surveillance system are:

- For cue-lure responsive fruit flies (e.g. Melon fly and Q-fly) – traps are placed at 400 m distance (400 m grid) (MPI 2014).
- For methyl eugenol responsive fruit flies (e.g. OFF) – traps are placed at 1,200 m distance (a 1,200 m grid) (MPI 2014).

Australia and Q-fly

The Australian surveillance system for Q-fly is established by each of the states of Australia under the overall framework of Australia's Fruit Fly Code of Practice (COP). In areas where freedom from Q-fly is being maintained, male lure-baited traps (cue-lure) are placed in 1000m grids within commercial host growing areas (e.g. orchards) and in 400m grids in urban areas (COP 2014).

California and OFF

As little detail could be found on the Californian surveillance system for OFF, for the purposes of this paper it will be assumed that it meets the minimum requirements for maintaining a PFA as detailed in RSPM 17 (2010). This standard requires for methyl eugenol-responsive species (e.g. OFF) that the trap density in high risk areas (entry points etc.) is 3 traps per km^2, urban areas is 1 trap per km^2 (a 1000m trapping grid), and in commercial production areas is 2 traps per 2 km^2 (a 2000m trapping grid).

2.2 Response Scenarios in New Zealand, Australia and California (USA)

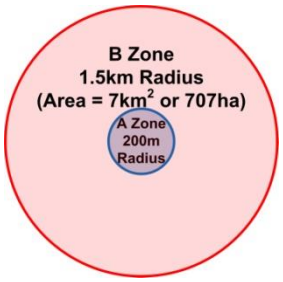
Once a fruit fly has been detected by a country's surveillance system and the threshold for concern has been reached, the country will respond with a number of measures. These response measures are designed to delimit the area contaminated by the fruit fly, contain the invading fruit fly to the area it has established and, if deemed necessary, begin the process of removing or eradicating the unwanted population of fruit flies. Each country has established its own fruit fly response procedures which are summarised below.

New Zealand's response procedures

The MPI standard for fruit fly responses (MPI 2014) specifies the thresholds for concern as follows:

- Detection of an immature fruit fly specimen, such as an egg, larva or pupa, or a gravid female fruit fly will immediately lead to a full response.
- Detection of a fertile adult fruit fly will immediately lead to *intelligence gathering activities* which are dependent on the type of lure the fruit fly is attracted to: cue-lure or methyl eugenol.

In all cases traps are placed on host trees with three zones established from the initial point of detection. The first two zones (A and B) are control zones and the third zone (C) enhances the existing surveillance network in the area.



i. The 'A' zone has a minimum radius of 200 metres around the fruit fly find (MPI 2014);

ii. The 'B' zone has a minimum radius of 1.5 kilometres around the fruit fly find (MPI 2014);

iii. The 'C' zone has a minimum radius around the fruit fly find defined at the time of the response to reflect local conditions (MPI 2014).

Within each of these zones the trap placement is determined by the type of lure the detected fruit fly is attracted to. For:

a. Cue-lure responsive fruit flies (e.g. Q-fly) – For A zone, at least 1 trap is placed on each property with fruiting host trees (e.g., ~80 to 120 traps in total). For B zone the requirement is for 20 to 30 traps per km^2 (100 ha) (around 200 traps in the 1.5 km zone), and for C zone traps at 400 m distance (400 m grid) (MPI 2014).

b. Methyl eugenol responsive fruit flies (e.g. OFF) – For A zone and B zone the requirement is for 10 to 15 traps per km^2 (100 ha) (around 100 traps in the 1.5 km zone), and for C zone traps are placed at 1,200 m distance (a 1,200 m grid) (MPI 2014).

Depending on the area of the suspected outbreak, additional traps may be placed in C zone at what are deemed 'high risk sites' such as waste transfer sites or host material storage facilities (MPI 2014). The size of the *ERZ* and the time required before PFA status can be re-instated will depend on the circumstances of the eradication and are currently largely dictated by New Zealand's trading partners.

Australia's response procedures for Q-fly

The federal standard for response to Q-fly in Australia are also contained in their COP (2014). As Q-fly is now considered endemic to coastal areas of Queensland, New South Wales and Victoria, Australia, the COP for this fruit fly applies to areas outside of this distribution range. For a Q-fly response the COP requires the use of cue-lure as it is for surveillance.

The response protocol for Q-fly as described by the COP (2014) states the following:

- Detection of any immature fruit fly specimen, such as an egg, larva or pupa, or a gravid female fruit fly will immediately lead to the declaration of an outbreak and the commencement of eradication procedures. Supplementary traps will then be installed to create a trapping grid of 16 traps within 200 m of the find and a 400 m trapping grid out to 1.5 km radius from the outbreak area.
- Detection of two male adult fruit fly within 1 km of each other and within a two week period will immediately lead to a delimitation period where supplementary traps are installed to create a trapping grid of 16 traps within 200 m of the finds, a 400 m trapping grid out to a 1.5 km radius, and a search for larva within that same area.

- Detection of five male adult fruit fly within 1 km of each other and within a two week period will immediately lead to the declaration of an outbreak and the commencement of eradication procedures (with supplementary traps as above).

The COP (2014) currently stipulates that trapping will continue for one Q-fly generation and 28 days or for 12 weeks (whatever is the longer) beyond the date of the last Q-fly detection. The COP (2014) also stipulates that over the period of an outbreak an *ERZ* of 15 km radius from the centre of the outbreak will be maintained.

California's response procedures for OFF

The State of California's response to OFF occurs under the guidelines provided in the USDA APHIS Action Plan for Oriental Fruit Fly (1989) (USDA APHIS 1989).

The response protocol for OFF states the following (USDA APHIS 1989):

- Detection of any immature fruit fly specimen, such as an egg, larva or pupa, or a gravid female fruit fly will immediately lead to the declaration of an outbreak and the commencement of eradication procedures. Traps will then be installed to ensure 25 traps are within 900 m of the find and a further 400 traps out to 8.2 km radius from the outbreak area.
- Detection of one male adult fruit fly within a one life cycle (around a 4 week period) will immediately lead to a delimitation period where supplementary traps are installed to ensure 25 traps are within 900 m of the finds and a further 400 traps out to a 8.2 km radius, and a search for larva within 900 m area.
- Within urban areas, detection of eight adult fruit fly within 4.8 km of each other and within one life cycle (around a 4 week period in California) will immediately lead to the declaration of an outbreak and the commencement of eradication procedures (with supplementary traps as above). Further traps may be installed if considered necessary but for the purposes of this analysis it will be assumed no further traps will be added to the delimitation area.
- Within commercial (e.g. orchard) areas, detection of six adult fruit fly within 4.8 km of each other and within one life cycle (around a 4 week period in California) will immediately lead to the declaration of an outbreak and the commencement of eradication procedures (with supplementary traps as above). Further traps may be installed if considered necessary but for the purposes of this analysis it will be assumed no further traps will be added to the delimitation area.

The USDA currently stipulates that an *ERZ* of an 8.2 km radius from the centre of the outbreak will be maintained and trapping will continue for three OFF generations beyond the date of the last OFF detection (USDA APHIS 1989).

Simplification of response scenarios used in this analysis

Each surveillance system provides a level of sensitivity in its ability to detect a fruit fly population based on the nature of the lures and traps used and the density of the trapping grid. To determine the trigger numbers, size of an ERZ, and the criteria for removing an ERZ, the minimum number of traps deployed in each area will need to be simplified for each fruit fly species within each country. Detection sensitivities across eradication areas can only be modelled when the distribution of the targeted fruit fly is known with some accuracy. In most eradication scenarios the distribution of the fruit fly only becomes apparent part way through the eradication campaign. To avoid situations where trapping densities vary across an eradication area, each of the response scenarios considered in this analysis will be simplified[3] as follows:

[3] This simplification will provide conservative (worst-case) trapping densities by understating the number of traps in each area.

For Q-fly and OFF in New Zealand;

- For Q-fly the trapping density under a response will be simplified to 200 traps reasonably uniformly spread across the 1.5 km radius providing a trapping density of 28 traps per km^2 or 0.2829 traps per hectare.
- For OFF the trapping density under a response will be simplified to 100 traps reasonably uniformly spread across the 1.5 km radius providing a trapping density of 14 traps per km^2 or 0.1434 traps per hectare.

For Q-fly in Australia the trapping density under a response will be simplified to 45 traps reasonably uniformly spread across the 1.5 km radius providing a trapping density of 6.4 traps per km^2 or 0.0637 traps per hectare.

For OFF in California the trapping density under a response will be simplified to 400 traps reasonably uniformly spread across the 8.2 km radius providing a trapping density of 1.9 traps per km^2 or 0.0192 traps per hectare.

2.3 Summary of surveillance and response scenarios

A summary of the surveillance and response procedures described above is provided in ***Table 1***.

Table 1: Summary of current surveillance and response procedures in New Zealand, Australia and California for Q-fly and OFF.

Procedures	New Zealand (Q-fly and OFF)	Australia (Q-fly)	California (OFF)
Surveillance Trapping	Q-fly = 400 m grid OFF =1.2 km grid	Urban areas = 400 m grid Production areas = 1 km grid	High risk sites = 3 per km^2 Urban areas = 1 km grid Production areas = 2 km grid
Response Triggers	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 1 adult male fly for delimitation OR Detection of 2 or more* adult male flies for eradication * depends on the circumstance of the finds	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 2 to 4 adult male flies within 14 days and 1 km for delimitation OR Detection of 5 or more adult male flies in 14 days within 1 km for eradication	Detection of any juvenile life stage or gravid female fly for eradication OR Detection of 2 adult (non-gravid) flies within 28 days and 4.8 km for delimitation OR Detection of 6 (urban) or 8 (commercial) adult (non-gravid) flies within 28 days and 4.8 km for eradication
Trapping to Delimit Population	For Q-fly, 80 traps in 200m radius and 200 traps out to 1.5 km radius For OFF, 100 traps out to a 1.5 km radius	16 traps in 200m radius AND 400m grid out to 1.5 km radius	25 traps in 900m radius AND 400 traps out to 8.2 km radius
Standardised* Trapping to Delimit Population	For Q-fly, 200 traps in 1.5 km radius, trapping density of 28 traps per km^2 or 0.2829 traps per h hectare For OFF, 100 traps in 1.5 km radius, trapping density of 14 traps per km^2 or 0.1434 traps per hectare	60 traps in 1.5 km radius, trapping density of 8.5 traps per km^2 or 0.0849 traps per hectare	400 traps in 8.2 km radius, trapping density of 1.9 traps per km^2 or 0.0192 traps per hectare
Size of Export Restriction Zone	Depends on the circumstance of the eradication and largely dictated by trading partners	15 km radius	8.2 km radius
Pest Free Area Reinstatement (after last fly detection)	Depends on the circumstance of the eradication and largely dictated by trading partners.	Zero detections within one Q-fly generation (egg to egg) and 28 days, or 12 weeks (whatever is the longer). No minimum trapping density is specified.	Zero detections within three OFF generations (egg to egg). No minimum trapping density is specified.

* The description of the delimiting trapping grid has been standardised to allow for statistical analysis.

3. Analysis of Triggers for Initiating an *Export Restriction Zone*

As outlined in ISPM 26 (2006), for all fruit flies of economic importance the number of detected fruit flies that indicate a breeding population may exist in the area, and therefore trigger the need to establish an *export restriction zone* (*ERZ*), is as follows:

a. Detection of any gravid female flies or any juvenile life stage (excluding immature (teneral) adults) not directly associated with imported produce, should indicate the need to establish an *ERZ*;

b. For fruit flies attracted to any of the (male) lures included in New Zealand's fruit fly surveillance system, the detection of **2 or more** male flies should be considered a potential outbreak (ISPM 26: 2006). The upper number of male fruit flies detected in lure-baited traps that indicates the need to establish an *ERZ* (the trigger number) needs to be resolved for each fruit fly species (see Meats 2014).

The question to be answered is can we define "two or more fertile adults" more precisely to ensure any imposition of an *ERZ* is appropriate to the phytosanitary risk. The phytosanitary risk with regards to market access could be described as being:

The unacceptable likelihood of there being a population of fruit fly present in the area that is of sufficient size to result in host material becoming infested, being exported, establishing a population in an export market, and causing unwanted impacts.

For the purposes of this paper, the market access risk will be simplified to:

The unacceptable likelihood of there being a breeding population of fruit fly present in the area.

The size of the population of flies constituting a risk to our export markets, otherwise stated in this paper as the '*breeding population size*', will need to be determined for each scenario. The '*breeding population size*' can therefore be considered the minimum number or density of fruit flies required to provide a sufficient likelihood that mating is likely to occur and potentially result in eggs being laid in host material. This is similar to the concepts of '*Allee threshold*' used in population dynamics, as well as the '*minimum viable population size*' used in conservation ecology.

If we know the size of the population of flies in an area that would be a risk to our export markets (the *breeding population size*), we can calculate the number of flies we would be most likely to detect at a given detection probability, should that size of population occur. The *breeding population sizes* calculated for Q-fly and OFF are provided in ***Appendix 1***.

Assuming that capture is random, the probability of trapping a certain number of flies in an area, based on a predetermined existing population, can be calculated using ***Equation 1***:

Equation 1: The conditional probability of trapping exactly *f* (male) flies given that there are N_t detectable (male) flies in the area.

$$P(f|N_t)_f = N_t! \div (f!\,(N_t - f)!) \times \left(p^f (1-p)^{N_t - f}\right)$$

Where:

$P(f|N_t)_f$ = the conditional probability of detecting ***f*** flies given the total number of detectable (male) flies in the area is N_t.

f = the number of (male) flies detected in any of the traps within the area.

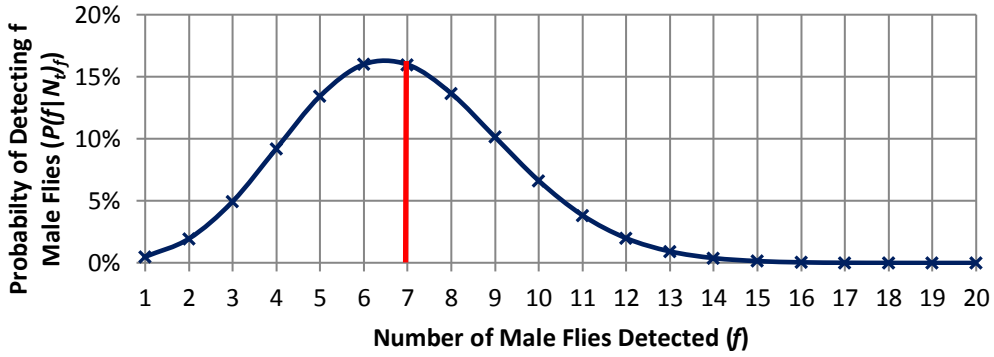
N_t = the number of detectable (male) flies assumed to be in the area, considered for the purposes of this paper to be the *breeding population size*.

p = the probability of trapping a male fly, which equals $1 - exp(-ESA_{con \text{ or } med} \times T_{del})$ where T_{del} is the delimitation trapping density (number of traps per hectare) and the ESA is the effective sampling area.

If a conservative value of ***p*** is required, ESA_{con} will be used which equates to the lowest expected value of ESA for the fruit fly in question. Otherwise a median value for the ESA (ESA_{med}) will be used as stated in the text.

Plotting the calculated values for P_f (the probability) against ***f*** (the number of flies detected) provides a curve as shown by the example in ***Figure 2*** (where N_t equals 52 and ***p*** equals 0.1319). This curve should be interpreted as showing that, at a given probability of trapping male flies in an area (***p***), when the population of the flies in an area is N_t the probability (P_f) is highest (at 16%) you will detect either 6 or 7 flies over the duration of trapping i.e. you are much less likely to detect only one fly.

Figure 2: An example of the probability of a specified trapping grid detecting *f* male flies ($P(f|N_t)_f$) from a breeding population size (N_t) of 52 and a capture probability (*p*) of 0.1319.



From the results plotted in ***Figure 2*** we can estimate that, once seven (male) flies have been detected, there is a greater than 50% probability that the total number of files in the area may exceed the *breeding population size* of 52. For instance from the example provided in ***Figure 2*** the trigger that would lead to establishing an *ERZ* for export markets would be seven male fruit flies (the red line) over the trapping period.

The next questions to consider are:

a) over what period the trigger is relevant (i.e. what is an appropriate trapping period)?, and

b) over what area (radius) should any detections count toward the trigger?

The effective sampling area (***ESA***) of the traps for each fruit fly species is based on the length of time the researchers recorded trap catches when gathering the data to estimate the trap sensitivity. However adult fruit flies survive for only a relatively short time in optimal conditions.

It is proposed therefore that the maximum period of fly capture (trigger) to determine if a breeding population exists in the area (and an *ERZ* is required) should be equivalent to the lesser of:

- the time it takes for a cohort of adult flies to decrease by 50% due to natural mortality, minus the duration of adult male fly maturation;

  OR

- the length of time the researchers recorded trap catches when gathering the data to estimate the level of trap sensitivity (the ***ESA***).

It is further proposed that, to ensure a timely response to a potential establishment event is maintained, the time limit for the trigger should where possible be no more than two weeks (14 days) of the initial fruit fly detection. The trigger for this two-week period would then be calculated as a proportion of the trigger based on the total fruit fly capture period achieved when gathering the data to estimate the trap sensitivity.

The area over which any detected fruit flies should be included in the trigger count is equivalent to the maximum area the fruit fly population is likely to be contained. This area is equivalent to the *ERZ*.

3.1 Triggers for Q-fly and OFF *Export Restriction Zones* in New Zealand

Based on an analysis of the information for Q-fly and OFF (see ***Appendix 1***) and the New Zealand response system (see ***Table 1***) (data summarised in ***Table 2*** below), the eradication triggers were determined for Q-fly and OFF *ERZ*s in New Zealand using ***Equation 1*** above. For New Zealand the most conservative (lower) ***ESA*** value from the range ($\boldsymbol{ESA_{con}}$) was used to provide the greatest confidence to trading partners that the triggers would provide for them a suitable level of protection.

Table 2: Information required to determine fruit fly eradication trigger numbers for New Zealand

Variable calculated	Q-fly data for New Zealand	OFF data for New Zealand
The number of detectable (male) flies in the area estimated to be required to establish a breeding population ($\boldsymbol{N_t}$)	$\boldsymbol{N_t}$ = 52 (the *breeding population size*)	$\boldsymbol{N_t}$ = 16 (the *breeding population size*)
The trap density during population delimitation ($\boldsymbol{T_{del}}$) (standardised)	200 traps in a 1.5km radius (707 hectares) or: $\boldsymbol{T_{del}}$ = 0.2829 traps per hectare	100 traps in a 1.5km radius (707 hectares) or: $\boldsymbol{T_{del}}$ = 0.1414 traps per hectare
A conservative estimate of the effective sampling area ($\boldsymbol{ESA_{con}}$)	$\boldsymbol{ESA_{con}}$ = 0.5 ha (using cue-lure)	$\boldsymbol{ESA_{con}}$ = 5 ha (using a methyl eugenol lure)
The probability ($\boldsymbol{p}$) of trapping a single male equals: $\boldsymbol{1 - exp(-ESA_{con} \times T_{del})}$	$\boldsymbol{p}$ = 0.1319	$\boldsymbol{p}$ = 0.507

The probability of detecting ***f*** flies in an area ($\boldsymbol{P(f|N_t)_f}$) can be determined for a range of values of ***f*** and the trigger number determined by observing when the results achieve the highest level of detection. The results for Q-fly are shown in ***Figure 3*** and OFF in ***Figure 4***.

Figure 3: The probability of detecting *f* male flies ($P(f|N_t)_f$) from a total population of 52 adult Q-fly males (N_t) using the simplified New Zealand response trapping system.

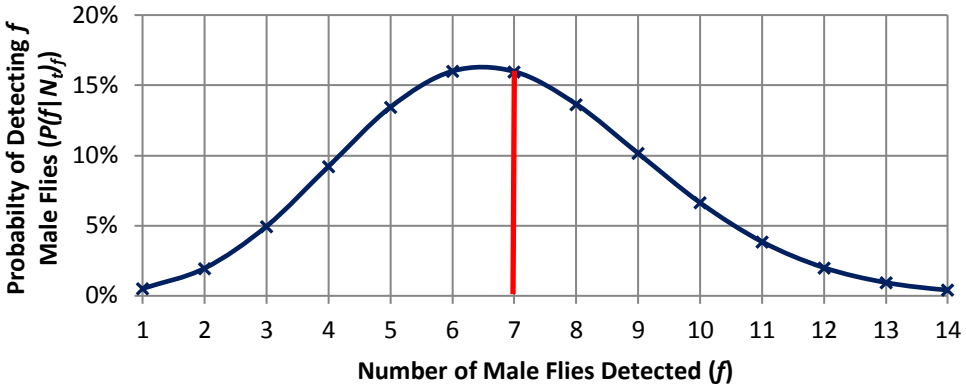
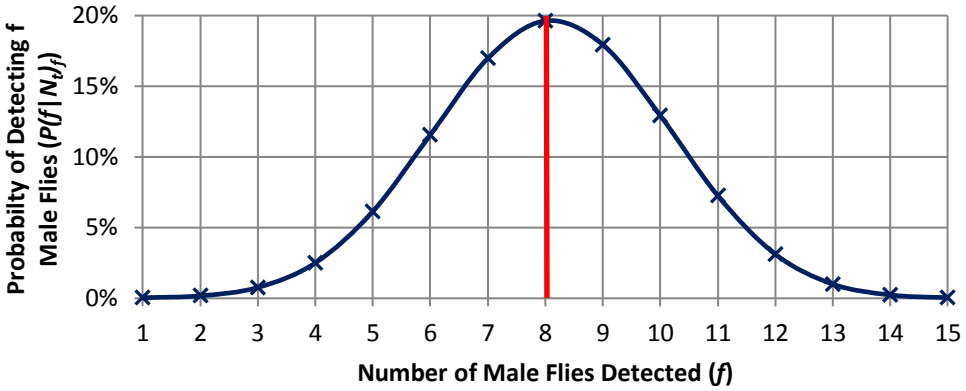


Figure 4: The probability of detecting *f* male flies ($P(f|N_t)_f$) from a total population of 16 adult OFF males (N_t) using a simplified New Zealand response trapping system.



From ***Figure 3*** and ***Figure 4*** it is therefore evident that the detection of 7 male Q-fly or 8 male OFF over a 4-week period will reduce the level of confidence below 50% that an established population does not exist. For the two-week trigger period, around half the flies are required for half the length of time, which equates to 3 adult Q-fly males or 4 adult OFF males within 2 weeks (14 days) after the first fly is caught in the surveillance trap as the trigger for establishing an *ERZ*.

3.2 Trigger for Q-fly *Export Restriction Zone* in Australia

From the biological description of Q-fly provided in ***Appendix 1*** and information provided on the Australian response system in ***Table 1*** above, the variables required to determine the probability of detecting male flies in both urban and commercial (production) trapping grids are provided in ***Table 3***.

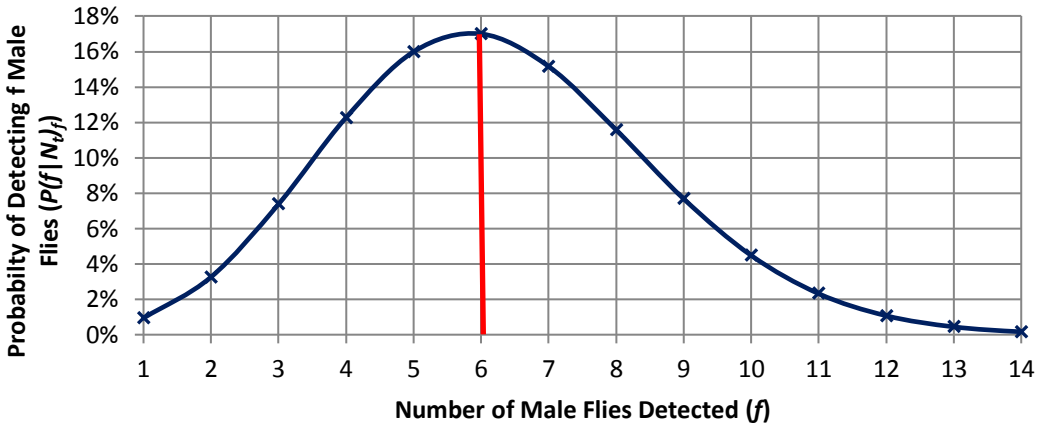
A survey of the use of the current two week/5-male fly trigger from 2002 to 2010 by Australia to declare outbreaks of Q-fly identified 439 incursions (detections) of which 48 (10.9%) achieved the 5-fly trigger and were declared as outbreaks. Of the remaining 391 incursions (89.1%) that were not declared as outbreaks, all subsequently died out without intervention (Dominiak & Fanson 2014). These results indicate that the 5-fly trigger used by Australia for Q-fly has ensured all potential outbreaks were responded to appropriately. Initial calculations of the trigger number for Q-fly in Australia using the conservative value for the ***ESA*** (ESA_{con}) indicated that the detected fly trigger number would be '1' over a period longer than 2 weeks. To ensure the outputs of the model align more closely with the observed situation in Australia, we have used the median estimated value for ***ESA*** (ESA_{med}) as a closer approximation of the true ***ESA*** value.

Table 3: Information required to determine fruit fly eradication trigger numbers for Australia

Variable calculated	Q-fly data for Australia
The number of detectable (male) flies in the area estimated to be required to establish a breeding population (N_t)	N_t = 52 (the *breeding population size*)
The trap density during population delimitation (T_{del}) (standardised)	60 traps in a 1.5 km radius (707 hectares) or: T_{del} = 0.0849 traps per hectare
An median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 1.5 ha (using cue-lure)
The probability (p) of trapping a single male equals: $1 - exp(-ESA_{med} \times T_{del})$	p = 0.1195

Using ***Equation 1*** above, the probability ($P(f|N_t)_f$) of detecting ***f*** flies in an area can be determined for a range of values of ***f*** and the trigger number determined by observing when the results achieve the highest level of detection (see ***Figure 5***).

Figure 5: The probability of detecting *f* male flies ($P(f|N_t)_f$) from a total population of 52 adult Q-fly males (N_t) using a simplified Australian response trapping system.



From ***Figure 5*** it is therefore evident that the detection of six male Q-fly over a 4-week period will reduce the level of confidence below 50% that an established population does not exist. For the two-week trigger period, around half the flies are required for half the length of time, which equates to a three adult Q-fly male within 2 weeks (14 days) after the first fly is caught in the surveillance trap as the trigger for establishing an *ERZ*.

3.3 Trigger for OFF *Export Restriction Zone* in California

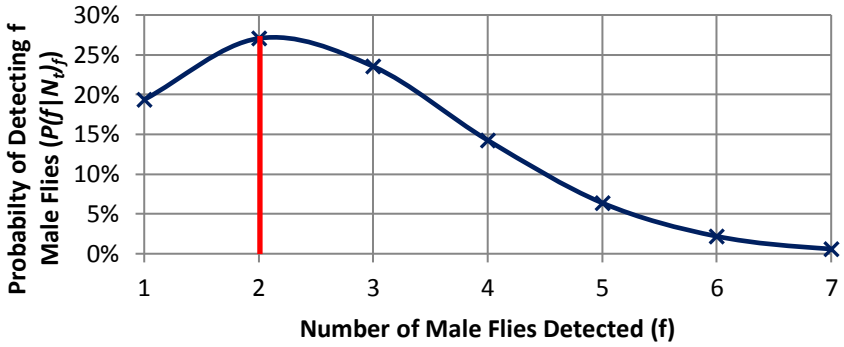
From the biological description of OFF provided in ***Appendix 1*** and information provided on the Californian response system in ***Table 1*** above, the variables required to determine the probability of detecting male flies in both urban and commercial (production) trapping grids are provided in ***Table 3***. As in the example above for Australia, for California we have also used the median estimated value for ***ESA*** (ESA_{med}) as a closer approximation of the true ***ESA*** value.

Table 4: Information required to determine fruit fly eradication trigger numbers for California

Variable calculated	OFF data for California
The number of detectable (male) flies in the area estimated to be required to establish a breeding population (N_t)	N_t = 16 (the *breeding population size*)
The trap density during population delimitation (T_{del}) (standardised)	400 traps in 8.2 km radius (21,060 hectares) or: T_{del} = 0.019 traps per hectare
An median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 9 ha (using a methyl eugenol lure)
The probability (p) of trapping a single male equals: $1 - exp(-ESA_{med} \times T_{del})$	p = 0.1571

Using ***Equation 1*** above, the probability ($P(f|N_t)_f$) of detecting ***f*** flies in an area can be determined for a range of values of ***f*** and the trigger number determined by observing when the results achieve the highest level of detection (see ***Figure 6***).

Figure 6: The probability of detecting *f* male flies ($P(f|N_t)_f$) from a total population of 16 adult OFF males (N_t) using a simplified Californian response trapping system.



From ***Figure 6*** it is therefore evident that the detection of 2 male OFF over a 4-week period will reduce the level of confidence below 50% that an established population does not exist. For the two-week trigger period, around half the flies are required for half the length of time, which equates to 1 adult OFF males within 2 weeks (14 days) after the first fly is caught in the surveillance trap as the trigger for establishing an *ERZ*.

The one fly trigger calculated here is less than the 28 day/6 or 8 fly trigger recommended by the USDA (USDA APHIS 2013). This difference in triggers may result from their use of two trapping zones of widely different trapping densities which makes it difficult to accurately interpret fruit fly capture information during incursions. During the delimitation phase the use of trigger numbers for establishing *ERZ*s would be more consistent for OFF if only a single density trapping zone was established over the delimiting area.

3.4 Summary of Results for Fruit Fly Triggers

The results for determining the trigger number for each of the four fruit fly species above are summarised in ***Table 5***.

Table 5: Summary results from determining the trigger number of male fly detections for four fruit fly species.

Fruit Fly Incursion Scenario	Breeding Population Size (males) (N_t)	Delimitation Trap Density (T_{del}) (traps per hectare)	Effective Sampling Area (ESA_{con} *or* ESA_{med})	Probability of trapping a male fly (p)	Trigger Number (*Period of trapping*)
New Zealand Q-fly	52	0.2829	0.5 hectares (conservative[#])	0.1319	3 (14 days)
New Zealand OFF	16	0.1414	5 hectares (conservative[#])	0.507	4 (14 days)
Australia Q-fly	52	0.0894	1.5 hectares (median)	0.1195	3 (14 days)
California OFF	16	0.019	9 hectares (median)	0.1571	1 (14 days)

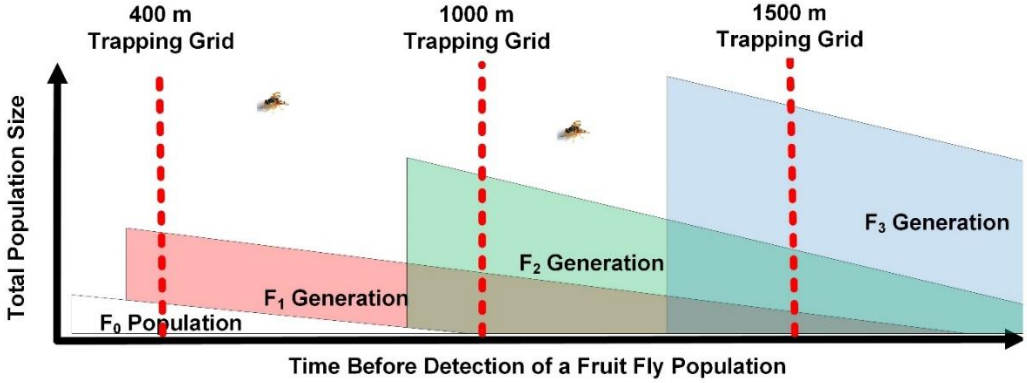
[#] The use of conservative values for New Zealand suggests that the trapping density during the delimitation period could be reduced if countries accept a median value for trap sensitivity as per Australia and California.

4. Calculating the Size of an *Export Restriction Zone*

As defined above, the '*export restriction zone*' (*ERZ*) is an area established for the purposes of providing an official assurance that host material grown and exported from outside the zone remain within a pest free area. To be effective therefore the *ERZ* needs to delimit the probable area in which a breeding population may exist if there is one present. From a risk-in-trade perspective as explained in the previous section, as only juvenile (egg, larval) life stages are likely to move internationally, the *ERZ* need only delimit the probably area within which a breeding population of flies may exist.

In general terms for small expanding populations the area occupied by a population increases as the number of individuals increase. Studies on the distribution of Q-fly in Australia found that dispersal distances often followed an inverse-square relationship or analogous model (Meats 1998b). The more flies in a small incipient population, the greater the area covered by the population before the inverse-square becomes less than 1 (no flies present). Therefore, it is assumed that the size of the *ERZ* should be proportional to the (estimated) number of flies in the area at the time the zone is established. As populations increase over time, the greater the time between the fruit fly establishing a population in an area and the population being detected by the surveillance system (and an *ERZ* being established) and the greater the size and spatial extent of the population likely to be present. This relationship between fruit fly population size and surveillance system (trapping grid) sensitivity is supported by Meats *et al.* (2003), who noted "*Effective quarantine radii for suspension of fly-free status should be related to the number of flies trapped around the epicentre and the density of the trap array ..*". An illustration of this relationship is provided in ***Figure 7***.

Figure 7: A conceptual example of how decreasing density of trapping grids[4] may allow one or more fruit fly generations to occur prior to detection.



When no more than one generation (F_1) of fruit flies are likely to have begun emerging in an area (**Figure 8*a***), the relationship between the maximum dispersal distance and the *ERZ* can be demonstrated by the diagram provided by **Figure 8*b***. In this example the single fly caught in the surveillance trap could have originated from a population of flies anywhere within the radius of the maximum dispersal distance (the blue circle) from the point the fly was trapped. If (in a worst case scenario) the fly had flown the maximum dispersal distance (e.g. the population epicentre on the outer line of the blue circle), the population of first generation of emergent flies could have dispersed anywhere within the red circle (four red circles are drawn here as examples). The green circle encases all of the possible areas the population of flies could exist based on the detection of the single fly. The green circle with a radius of twice the maximum dispersal distance therefore represents a worst-case scenario for possible fruit fly population distribution when only a single generation (F_1) of fruit flies have emerged.

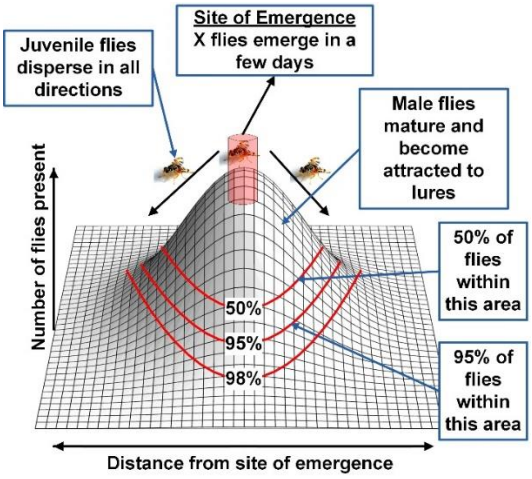
If detection of a population of fruit flies is sufficiently delayed to potentially allow two generations (F_2) of flies to emerge (**Figure 8*c***), the relationship between the maximum dispersal distance and the

[4] For example a 400m trapping grid is a grid with 1 trap every 400m.

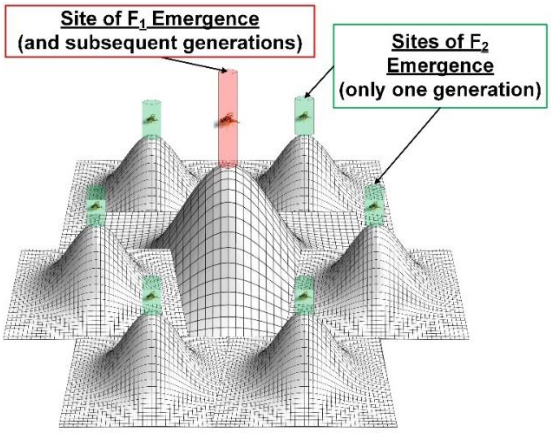
ERZ can be demonstrated by the diagram provided by **Figure 8*d***. The green circle encases all of the possible areas the population of flies could exist based on the detection of the single fly. The green circle with a radius of four times the maximum dispersal distance therefore represents a worst-case scenario for possible fruit fly population distribution when two generations (F_2) of fruit flies have emerged.

Figure 8: Examples of a maximum potential fruit fly dispersal distance based on the detection of a single specimen (adult or juvenile)

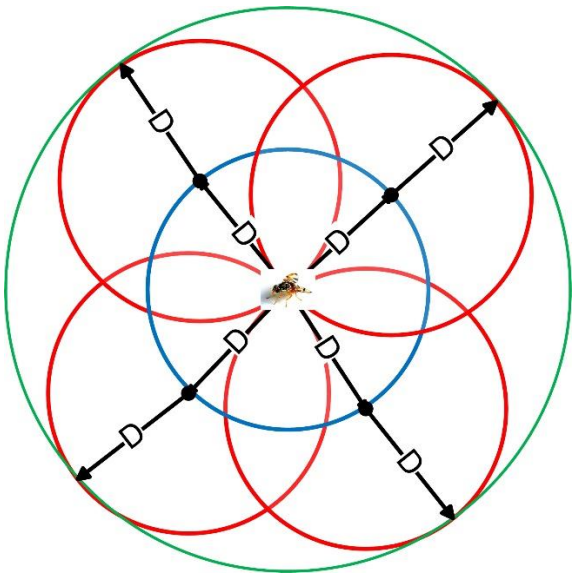
8a: Stylised dispersal distance of a single generation (F_1) of emerged fruit flies



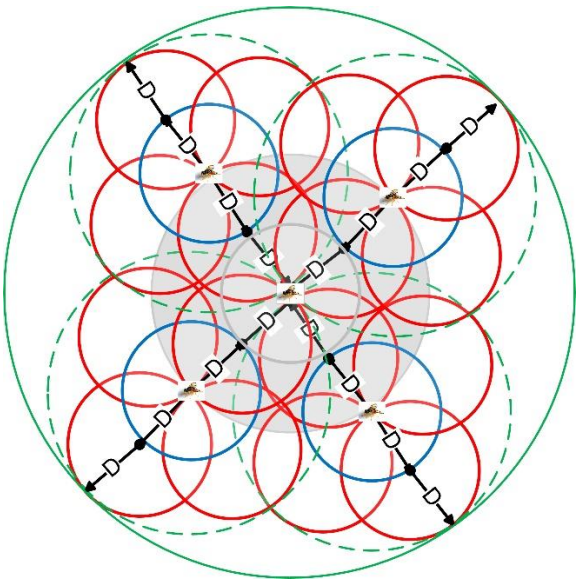
8c: Stylised dispersal distances of two generations (F_2) of emerged fruit flies



8b: Maximum dispersal distance of a population of fruit flies from a single generation (F_1).



8d: Maximum dispersal distance of a population of fruit flies from two generations (F_2).



So the question then becomes:

> How do we know if the surveillance system is likely to detect a population in or before the first (F_1) or second (F_2) generations?

This could be answered using the calculations which determine the size of the population potentially present when a detection is made by the surveillance system. If the potential size of the population detected by the surveillance system is greater than the population size needed to enable a breeding

pair to successfully establish a new population, then the confidence that a second generation (F_2) of flies has not arisen is reduced. For example: when the breeding population size is 50 flies, but the surveillance system is likely to only detect a population of 85 individuals or more, then there is the potential for a breeding pair from the first generation to establish a second generation (F_2) (85 > 50).

The sensitivity of a surveillance trapping system used to detect a fruit fly population can be calculated using ***Equation 2*** adapted from Kean (2014):

Equation 2: Calculating the sensitivity of a fruit fly surveillance system in detecting a fruit fly population (defined as S_{trap} in Kean 2014).

$$S = 1 - exp(-(ESA_{med} \times T_{sur}) \times N_t)$$

Where:

- S = the sensitivity of the fruit fly trapping grid measured as the probability of detecting one or more male flies given a population of N_t adult males of a particular fruit fly species.
- ESA_{med} = the median effective sampling area (ha) of each trap in the trapping grid for a fruit fly species.
- T_{sur} = the trap density of the surveillance grid (traps per hectare).
- N_t = the total number of detectable (male) flies assumed to be in the area.

When a detection occurs in a surveillance trap, the greatest likely number of adult male fruit flies of a particular species in the area (N_t) can be estimated for each fruit fly species as the number present when the probability of detecting one male fly (S) exceeds 95%. The size of the *ERZ* can then be estimated based on this value of N_t and the known distribution pattern (see ***Appendix 1***) of the fruit fly population (P_r) (see ***Equation 3***).

Equation 3: Calculating the radius of the *export restriction zone* for a fruit fly population of known size and pattern of distribution.

$$N_r = N_t - (N_t \times P_r)$$

Where:

- N_r = the number of male flies likely to be outside of the area with a radius of r.
- N_t = the total number of detectable (male) flies assumed to be in the area.
- P_r = the cumulative percentage of flies found within the area that has a radius of r. This parameter is based on the adult fly distribution curves provided for each fruit fly species in ***Appendix 1***.

The value of N_r can be determined for areas with an increasing radius. The radius of the *ERZ* is then two or more times the radius required to ensure the number of male flies outside of the area (N_r) is less than 1 i.e. zero male flies.

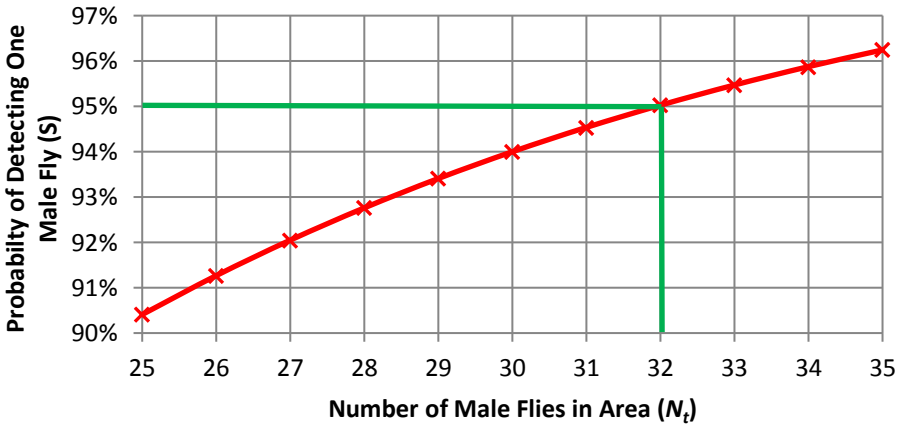
4.1 Size of *Export Restriction Zones* for Q-fly and OFF in New Zealand

From the biological description of Q-fly and OFF provided in ***Appendix 1*** and information on New Zealand's surveillance system provided in ***Table 1*** above, the variables required to determine the sensitivity of the surveillance trapping system used in New Zealand to detect Q-fly and OFF populations are as follows:

Variable calculated	Q-fly data for New Zealand	OFF data for New Zealand
The number of detectable (male) flies in the area estimated to establish a breeding population (N_t)	N_t = 52 (the *breeding population size*)	N_t = 16 (the *breeding population size*)
The trap density of New Zealand's surveillance grid (T_{sur})	400 metre surveillance grid or: T_{sur} = 0.0625 traps per hectare	1.2 km surveillance grid or: T_{sur} = 0.0069 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 1.5 ha (using cue-lure)	ESA_{med} = 9 ha (using a methyl eugenol lure)

The results obtained from applying ***Equation 2*** above to calculate trapping sensitivity (S) over a range of adult male population sizes (N_t) for Q-fly are provided in ***Figure 9***. It is apparent from these results that the current surveillance grid used in New Zealand to detect Q-fly populations has at least a 95% probability of detecting one fly in a population of 32 or more male flies in an area.

Figure 9: The probability of detecting one male fly within increasing Q-fly populations in an area covered by the New Zealand fruit fly surveillance system.



For Q-fly the *breeding population size* of 52 is greater than the population size likely to be detected by New Zealand's surveillance system (e.g. 32 as indicated in ***Figure 9***) indicating only one generation of flies may be present. Therefore to determine the size of the *ERZ* for Q-fly in New Zealand it is proposed that:

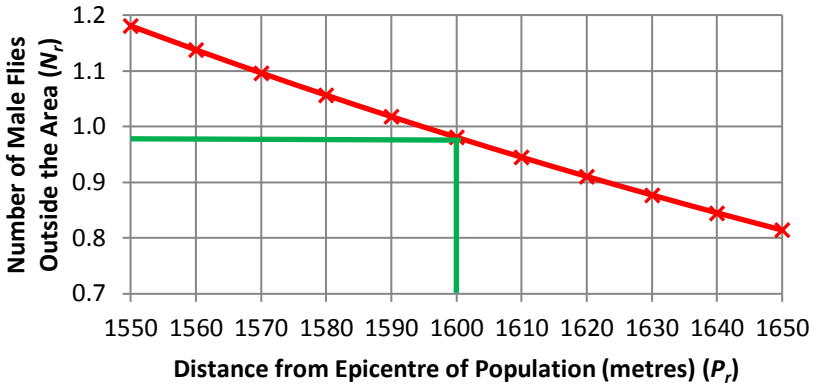
a) the population size likely to be in the area would be equal to the *breeding population size* for Q-fly: namely 52 adult male flies; and

b) the trigger number of 3 flies captured over 14 days would need to be captured; and

c) only one generation (F_1) of flies may have emerged in the area.

Using ***Equation 3*** above, values for the number of male flies outside a trapping area (N_r) can be calculated over a range of increasing distances from the population epicentre (P_r) (see ***Figure 10***).

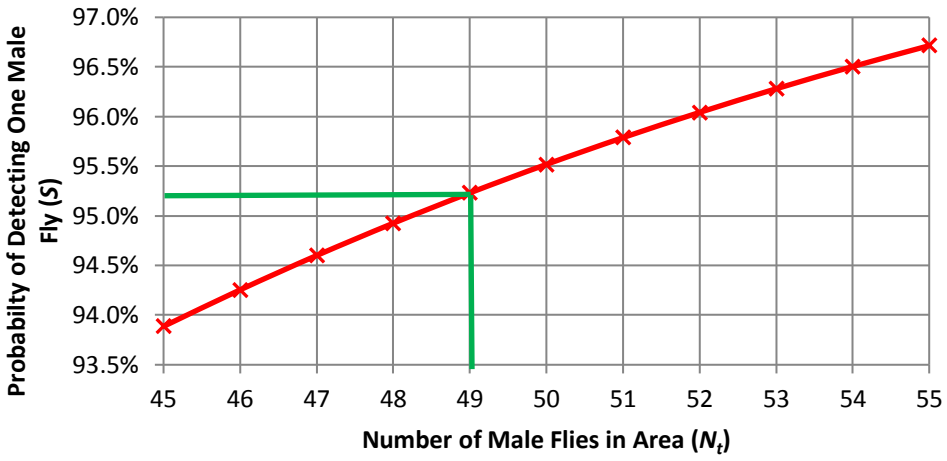
Figure 10: Determining the size of an *export restriction zone* for a population of 52 adult Q-fly males (breeding population size) (N_t).



The results suggest there are unlikely to be any male flies more than 1,600 metres from the epicentre. The radius of the *ERZ* in New Zealand for only one generation of Q-fly would then equal twice this radius or 3,200 metres.

Repeating this same exercise for OFF, the results obtained from applying ***Equation 2*** above to calculate trapping sensitivity (***S***) over a range of adult male population sizes (N_t) are provided in ***Figure 11***. It is apparent from these results that the current surveillance grid used in New Zealand to detect OFF populations has at least a 95% probability of detecting one fly in a population of 49 or more male flies in an area.

Figure 11: The probability of detecting one male within increasing OFF populations in an area covered by the New Zealand fruit fly surveillance system.



For OFF the *breeding population size* of 16 is less than the population size likely to be detected by New Zealand's surveillance system (e.g. 49 as indicated in ***Figure 11***) indicating two generations of flies may be present. Therefore to determine the size of the *ERZ* for OFF in New Zealand it is proposed that, before an *ERZ* is established:

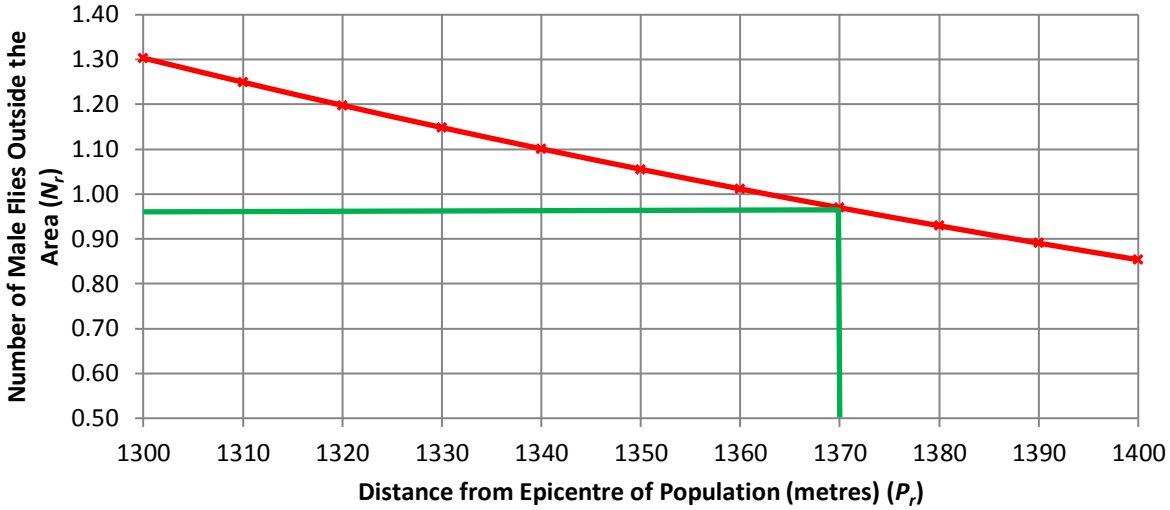
a) the greatest population size likely to be in the area would be the population size detection by New Zealand's surveillance system at a 95% probability level: namely 49 adult male flies; and

b) the trigger number of 4 flies captured over 14 days would need to be captured; and

c) two generations (F_2) of flies may have emerged in the area.

Using ***Equation 3*** above, values for the number of male flies outside a trapping area (N_r) can be calculated over a range of increasing distances from the population epicentre (P_r) (see ***Figure 10***).

Figure 12: Determining the size of an *export restriction zone* for a population of 49 adult OFF males (N_t).



The results suggest there are unlikely to be any male flies more than 1,370 metres from the epicentre. The radius of the *ERZ* in New Zealand for two potential generations (F_2) of OFF would then equal four times this radius or 5,480 metres.

4.2 Size of *Export Restriction Zone* for Q-fly in Australia

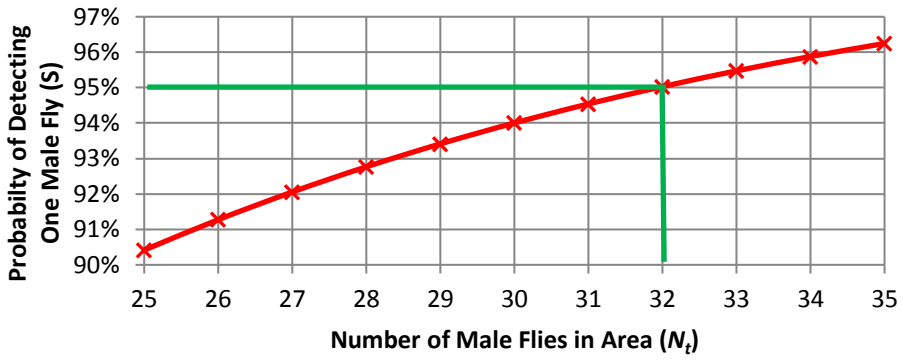
From the biological description of Q-fly provided in ***Appendix 1*** and information on Australia's surveillance system provided in ***Table 1*** above, the variables required to determine the sensitivity of the surveillance trapping system used in Australia to detect Q-fly populations are as follows:

Variable calculated	Q-fly in urban areas	Q-fly in commercial areas
The number of detectable (male) flies in the area estimated to establish a breeding population (N_t)	N_t = 52 (the *breeding population size*)	N_t = 52 (the *breeding population size*)
The trap density of Australia's surveillance grid (T_{sur})	400 metre surveillance grid or: T_{sur} = 0.0625 traps per hectare	1 km surveillance grid or: T_{sur} = 0.01 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 1.5 ha (using cue-lure)	ESA_{med} = 1.5 ha (using cue-lure)

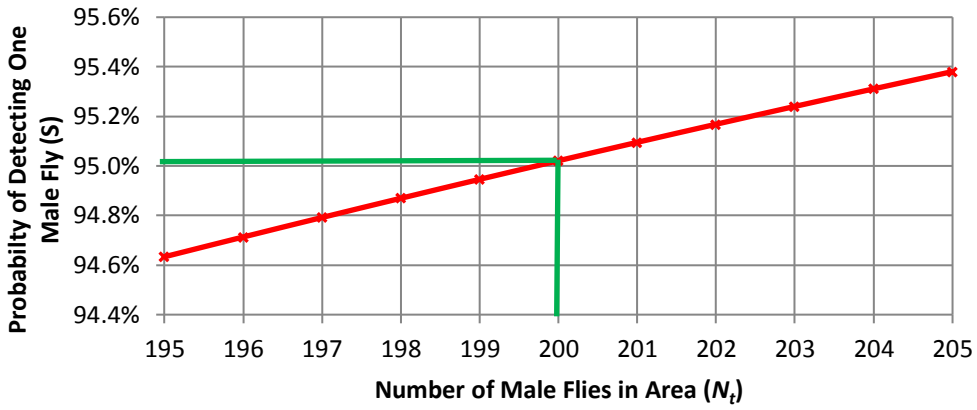
The results obtained from applying ***Equation 2*** above to calculate trapping sensitivity (S) over a range of adult male population sizes (N_t) for Q-fly in Australia are provided in ***Figure 13***. It is apparent from these results that the current surveillance grid used in Australia to detect Q-fly populations has at least a 95% probability of detecting one fly in a population of 32 or more male flies in urban areas (***Figure 13a***) and a population of 200 or more male flies in commercial areas (***Figure 13b***).

Figure 13: The probability of detecting one male within increasing Q-fly populations in an area covered by the Australian fruit fly surveillance system.

13a: Urban areas within Australian PFAs



13b: Commercial (production) areas within Australian PFAs



For Q-fly in Australia the *breeding population size* of 52 is greater than the population size likely to be detected by the urban surveillance grid (e.g. 32, see ***Figure 13a***) but less than the population size likely to be detected by the commercial (production) surveillance grid (e.g. 200, see ***Figure 13b***). Therefore to determine the size of the *ERZ* for Q-fly in Australia it is proposed that, before an *ERZ* is established:

a) the population size likely to be in an urban area would be the *breeding population size* for Q-fly: namely 52 adult male flies; or

b) the population size likely to be in a commercial (production) area would be the population size detected by Australia's surveillance system at a 95% probability level: namely 200 adult male flies; and

c) the trigger number of 3 flies captured over 14 days would need to be captured; and

d) only one generation (F_1) of flies may have emerged in urban areas, and potentially two generations (F_2) of flies in commercial (production) areas.

Using ***Equation 3*** above, values for the number of male flies outside a trapping area ($\boldsymbol{N_r}$) can be calculated over a range of increasing distances from the population epicentre ($\boldsymbol{P_r}$) for both urban (***Figure 14***) and commercial areas (***Figure 15***).

Figure 14: Determining the maximum population distribution radius in Australian urban areas for a population of 52 adult Q-fly males (breeding population size) (N_t).

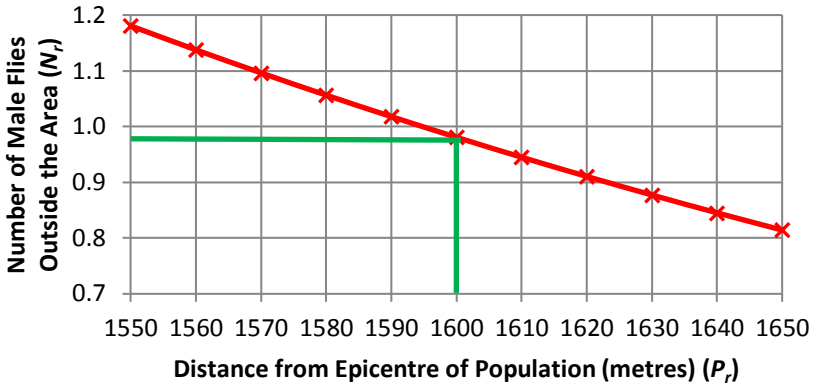
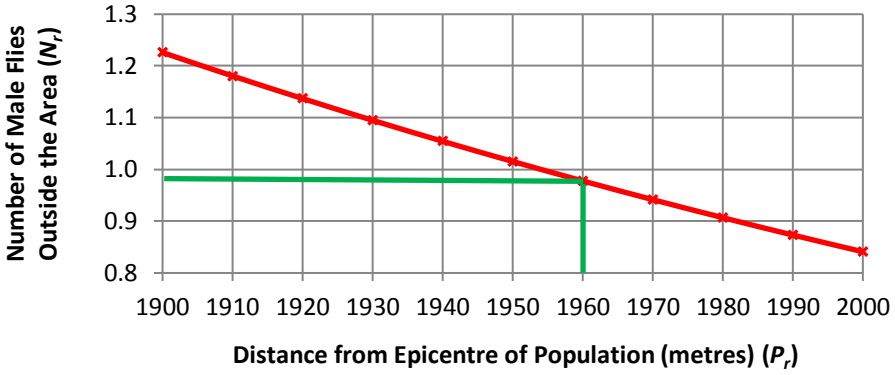


Figure 15: Determining the maximum population distribution radius in Australian commercial (production) areas for a population of 200 adult Q-fly males (N_t).



For urban areas the results suggest that there are unlikely to be any male flies more than 1,600 metres from the epicentre. The radius of the *ERZ* in urban areas for one potential generation (F_1) of Q-fly in Australia would then equal twice this radius or 3,200 metres.

For commercial (production) areas the results suggest there are unlikely to be any male flies more than 1,960 metres from the epicentre. The radius of the *ERZ* in commercial (production) areas for two potential generations (F_2) of Q-fly in Australia would then equal four times this radius or 7,840 metres.

4.3 Size of *Export Restriction Zone* for OFF in California

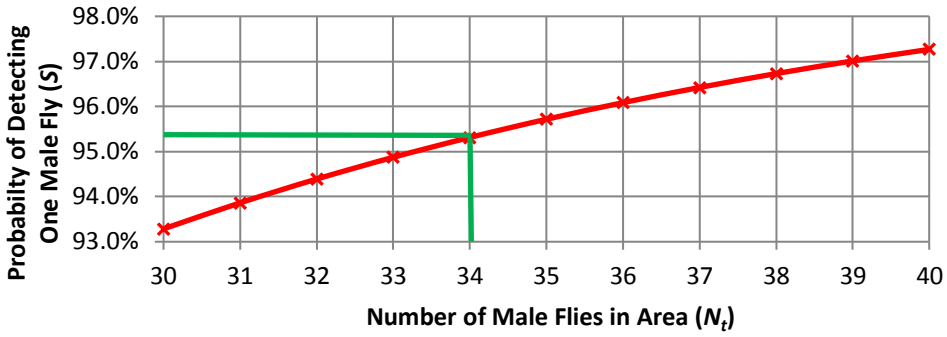
From the biological description of OFF provided in ***Appendix 1*** and information on California's surveillance system provided in ***Table 1*** above, the variables required to determine the sensitivity of the surveillance trapping system used in California to detect OFF populations are as follows:

Variable calculated	OFF in urban areas	OFF in commercial areas
The number of detectable (male) flies in the area estimated to establish a breeding population (N_t)	N_t = 16 (the *breeding population size*)	N_t = 16 (the *breeding population size*)
The trap density of California's surveillance grid (T_{sur})	1 km surveillance grid or: T_{sur} = 0.01 traps per hectare	2 km surveillance grid or: T_{sur} = 0.003 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 9 ha (using a methyl eugenol lure)	ESA_{med} = 9 ha (using a methyl eugenol lure)

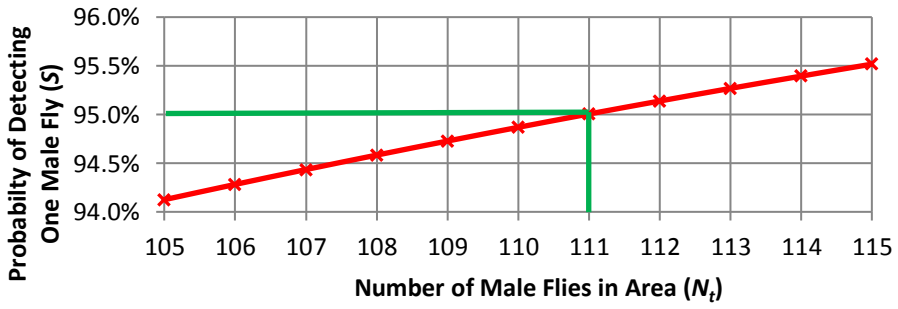
The results obtained from applying ***Equation 2*** above to calculate trapping sensitivity (S) over a range of adult male population sizes (N_t) for OFF in urban and commercial zones within California are provided in ***Figure 16***. It is apparent from these results that the current surveillance grid used in California to detect OFF populations has at least a 95% probability of detecting one fly in a population of 34 or more male flies in urban areas (***Figure 16a***) and a population of 111 or more male flies in commercial areas (***Figure 16b***).

Figure 16: The probability of detecting one male within increasing OFF populations in an area covered by the Californian fruit fly surveillance system.

16a: Urban areas within California



16b: Commercial (production) areas within California



For OFF in California the *breeding population size* of 16 is less than the population sizes likely to be detected by the urban (e.g. 34, see ***Figure 16a***) and commercial (e.g. 111, see ***Figure 16b***) surveillance grids. Therefore to determine the size of the *ERZ* for OFF in California it is proposed that:

a) the population size likely to be in an urban area would be the population size detected by California's surveillance system at the 95% confidence level: namely 34 adult male flies; or

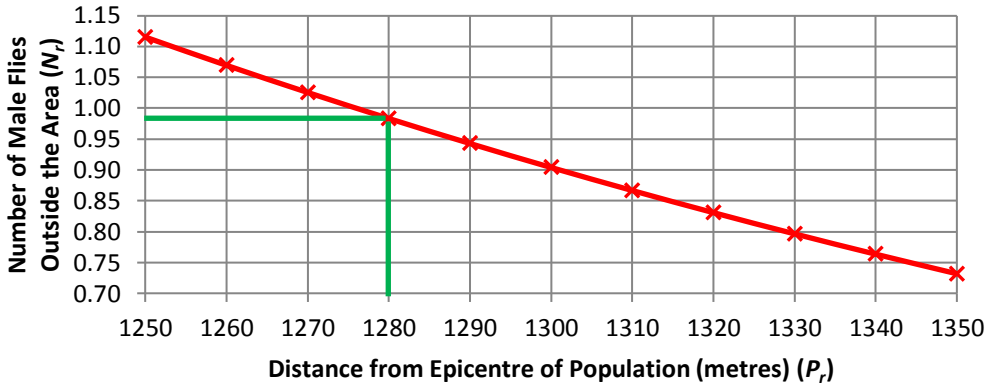
b) the population size likely to be in a commercial (production) area would be the population size detected by California's surveillance system at the 95% confidence level: namely 111 adult male flies; and

c) the trigger number of 1 fly captured over 14 days would need to be captured; and

d) two generations (F_2) of OFFs may have emerged in urban and commercial areas of California.

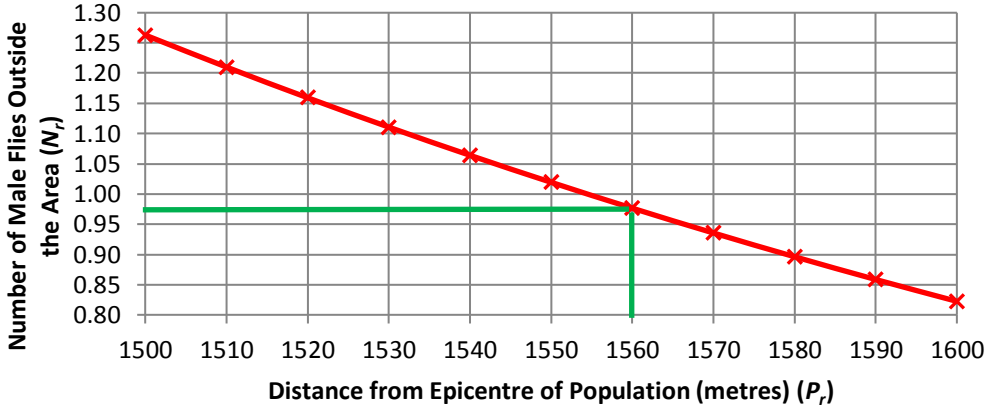
Using ***Equation 3*** above, values for the number of male flies outside a trapping area ($\boldsymbol{N_r}$) can be calculated over a range of increasing distances from the population epicentre ($\boldsymbol{P_r}$) for both urban (***Figure 17***) and commercial areas (***Figure 18***).

Figure 17: Determining the size of an ERZ in Californian urban areas for a population of 34 adult OFF males (N_t).



For urban areas the results suggest that there are unlikely to be any male flies more than 1,280 metres from the epicentre. The radius of the *ERZ* in urban areas for two potential generations (F_2) of OFF would then equal four times this radius or 5,120 metres.

Figure 18: Determining the size of an ERZ in Californian commercial (production) areas for a population of 111 adult OFF males (N_t).



For commercial (production) areas the results suggest there are unlikely to be any male flies more than 1,560 metres from the epicentre. The radius of the *ERZ* in commercial (production) areas for two potential generations (F_2) of OFF would then equal four times this radius or 6,240 metres.

4.4 Summary of Results for Determining the *Export Restriction Zones*

The results for determining the size (radius) of the *ERZ* for each of the four scenarios considered above are summarised in ***Table 6***.

Table 6: Summary results from determining the *ERZ* for four fruit fly species.

Fruit Fly Incursion Scenario	Surveillance Trap Density (T_{sur}) (traps per hectare)	Median Effective Sampling Area (ESA_{med})	Surveillance Population Size (males) (N_t)	Potential Generation of Flies (F_x) Present	Calculated Radius of *ERZ* (metres)
New Zealand Q-fly	(400 m Grid) 0.0625	1.5 ha	32 (52)*	F_1	3,200
New Zealand OFF	(1.2 km Grid) 0.0069	9 ha	97	F_2	5,480
Australia Q-fly in urban areas	(400 m Grid) 0.0625	1.5 ha	32 (52)*	F_1	3,200
Australia Q-fly in commercial areas	(1 km Grid) 0.01	1.5 ha	200	F_2	7,840
California OFF in urban areas	(1 km Grid) 0.01	9 ha	34	F_2	5,120
California OFF in commercial areas	(2 km Grid) 0.003	9 ha	111	F_2	6,240

* As the *breeding population size* of Q-fly at 52 adult male flies is greater than the surveillance population size of 32 adult male flies with a 400 metre surveillance grid, in these instances as a worst case scenario the *breeding population size* (52) has been used to determine the size of the *ERZ*.

5. Determining when to Remove an *Export Restriction Zone*

The current practice for determining when to end an eradication programme (and remove an *ERZ*) specifies a time interval during which no further fruit fly detections are recorded, and should be based on the biology of the fruit fly and prevailing environmental conditions (ISPM 26 annex 1 (2014)). Meats & Clift (2005) noted that these time intervals have used a physiological time scale (day-degrees) which has been equivalent to 1 generation plus 28 days or up to 3 generations or more and can only usually be determined at the time of the response. Meats & Clift (2005) proposed an alternative method which uses a pre-determined time interval, based on measured trap sensitivity and trapping density, and does not require the calculation of generation length under different temperature scenarios. The authors further suggest that time periods during which temperatures fall below adult maturation (life-cycle development) and/or effective movement thresholds (and therefore adult attraction to trap lures) should not be included when calculating the length of zero trap catches.

It is proposed here that one criterion for the time interval to remove the *ERZ* be based on trapping sensitivity, and is achieved when the probability that the area is free of a permanent population of the target fruit fly species is equal to or greater than a 95% level of confidence. It is also proposed that a minimum time equivalent to one generation (egg to mature (trap sensitive) adult fly) and 4 weeks (a single trapping period) under existing climatic conditions and under a continuous (uninterrupted) trapping period should also be required to ensure that if any immature fruit flies are present they will be detected. An approach similar to this for declaring areas free of insects has been proposed previously by Barclay & Hargrove (2005). Where trapping periods are interrupted by a suitably long winter, and the fruit fly species in question over-winters in the adult life stage, the minimum requirement of a single generation may not be necessary as no juvenile life stages will be present when climatic conditions become suitable for trapping once more.

This level of confidence in fruit fly freedom can be achieved via two main routes:

a. For non-persistent populations, the onset of cold weather seasons will remove the population and ensure the next production season is free of that fruit fly species;

b. A sufficient period of zero fruit fly detections (of any life stage) providing at least a 95% level of confidence that the area within the *ERZ* is free of the fruit fly in question.

For the first situation, if a fruit fly population is unlikely to persist in an area (survive over winter), the *ERZ* can be removed in autumn once temperatures decrease to a level that prevents fruit fly mating. For the second situation the probability that an area does not have an established population for each period of zero trapped flies can be calculated using ***Equation 4*** (Kean 2014):

Equation 4: Calculating the sensitivity of a fruit fly surveillance system in detecting one or more flies in a population (adapted from Kean 2014).

$$P_N = 1 - exp(-N \times ESA_{med} \times T_{res})^a$$

Where:

P_N = the probability of detecting N trappable insects that arise within the trapping area.

ESA_{med} = the median effective sampling area (ha) of each trap in the trapping grid for a fruit fly species.

N = The number of trappable insects arising independently within the B zone, which in this instance would be the minimum number required to establish a population or 3 fruit flies (two male flies) (after Baker *et al.* 1990).

T_{res} = the trapping density of the trapping area for each fruit fly species (traps per hectare).

a = The number of trapping periods (4 week periods).

In these calculations each trapping period is equivalent to the length of time taken to lure the adult males from each species of fruit fly in the experiments used to determine the level of trap sensitivity (usually around 4 weeks), and only applies to periods when the environmental conditions (e.g. temperature) are sufficient to support adult fly attraction to lures (e.g. sufficient maturation and/or effective flight). For the purposes of this analysis it is assumed that the minimum possible number of adult fruit flies required to establish a population in a new area is 2 (or more) male flies. This is a very conservative number and is different from the breeding population size which provides a more realistic estimate of the number of flies required to establish a population in an extended area.

5.1 Criteria for Removing *Export Restriction Zones* for Q-fly and OFF in New Zealand

Stringer *et al*. (2013) analysed the temperature-dependent development rates for Q-fly against New Zealand's annual and predicted climate patterns to determine the seasonal population trends of Q-fly in New Zealand should it become established. The results of this analysis for Q-fly are provided in ***Table 7***. These results indicate that Q-fly populations detected in the Wellington region and anywhere in the South Island would not persist over winter and any eradication programme would be completed at the onset of colder temperatures (27th of April). For regions further north (in warmer climates), Q-fly populations may persist over winter and the length of the alternative "zero detections" trapping period is required.

Table 7: Specific recommendations of dates for Q-fly and OFF persistence in New Zealand using a conservative approach (2010 climate + 1°C, 99% relative efficacy) (Stringer *et al*. 2013)

Site in New Zealand	Q-fly (*Bactrocera tryoni*)		OFF (*Bactrocera dorsalis*)	
	Start Date	End Date	Start Date	End Date
Whangarei	01 Nov	30 May	1 Nov	7 June
Auckland	12 Nov	20 May	14 Nov	29 May
Tauranga	29 Nov	06 May	2 Dec	16 May
Napier	1 Dec*	27 Apr*	5 Dec*	6 May*
Wellington & South Island	-	-	-	-

*Not predicted to persist under 2010 temperatures; values are for 2010 elevated by 1°C.

From the biological description of Q-fly and OFF provided in ***Appendix 1,*** and information provided on New Zealand's response system in ***Table 1*** above, the variables required to determine the sensitivity of the trapping system used in New Zealand to detect Q-fly and OFF populations during a response are as follows:

Variable calculated	Q-fly data for New Zealand	OFF data for New Zealand
The trap density of the response grid (T_{res})	200 traps within 707 hectares or: T_{res} = 0.2829 traps per hectare	100 traps within 707 hectares or: T_{res} = 0.1414 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 1.5 ha (using cue-lure)	ESA_{med} = 9 ha (using a methyl eugenol lure)

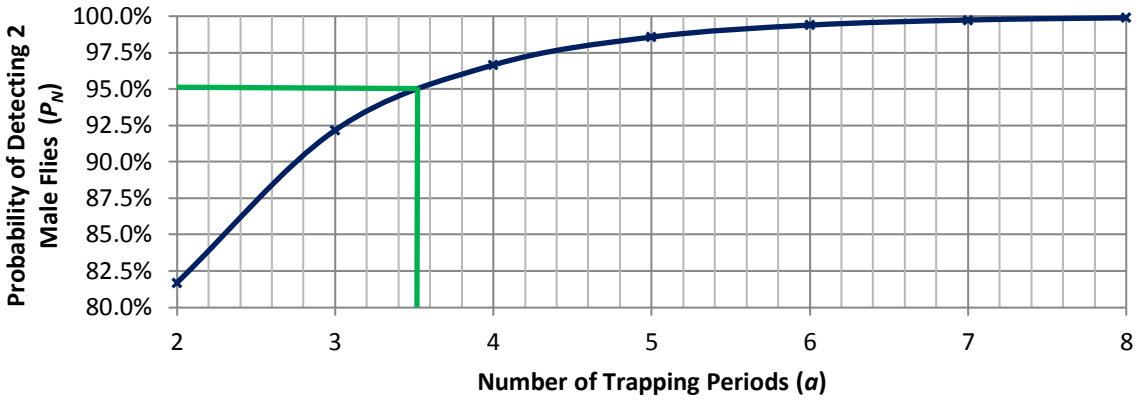
For the purposes of this analysis (and in the absence of other published information) we will assume that the minimum number of adult fruit flies required to establish a population in a new area is 2 (or

more) male flies (or 3 or more flies in total). The results obtained from applying ***Equation 4*** above to these variables provides:

- 57% probability of detecting 2 male Q-fly in the B zone using cue-lure traps over a single trapping period (4 weeks).
- 92% probability of detecting 2 male OFF in the B zone using methyl eugenol traps over a single trapping period (4 weeks).

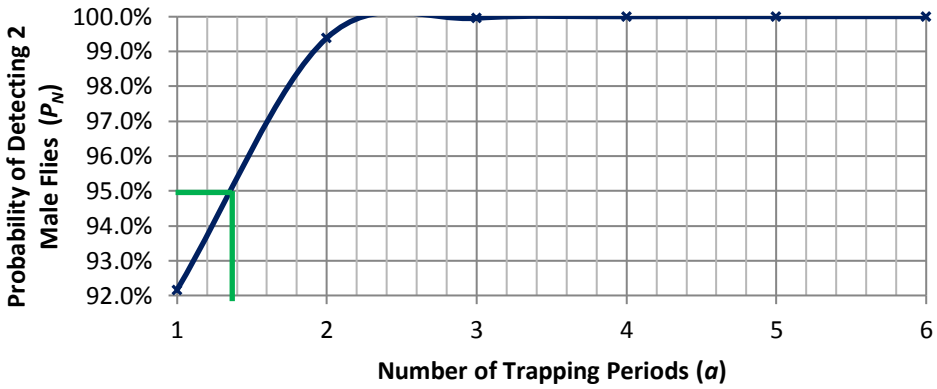
By plotting the cumulative probabilities of detecting 3 male flies in the B zone over more than one trapping period (see ***Figure 19*** and ***20***) it becomes apparent that for Q-fly, 3.5 trapping periods or 14 weeks of no fly detections would provide >95% probability that a persistent fly population (> 2 male flies) no longer exists in the area (***Figure 19***).

Figure 19: The probability of a B zone trapping grid detecting 2 male Q-fly over an increasing number of trapping periods.



For OFF, 1.4 trapping period or just under 6 weeks of no fly detections would provide at > 95% probability that a persistent or breeding fly population no longer exists in the area (***Figure 20***).

Figure 20: The probability of a B zone trapping grid detecting 2 male OFF over an increasing number of trapping periods.



5.2 Criteria for Removing an *Export Restriction Zone* for Q-fly in Australia

Within Australia the main PFA areas under active management are considered suitable for persistent populations of Q-fly to establish. It is likely however that some southern areas of Australia including Tasmania are unlikely to support a persistent population of Q-fly (DPIPWE 2011).

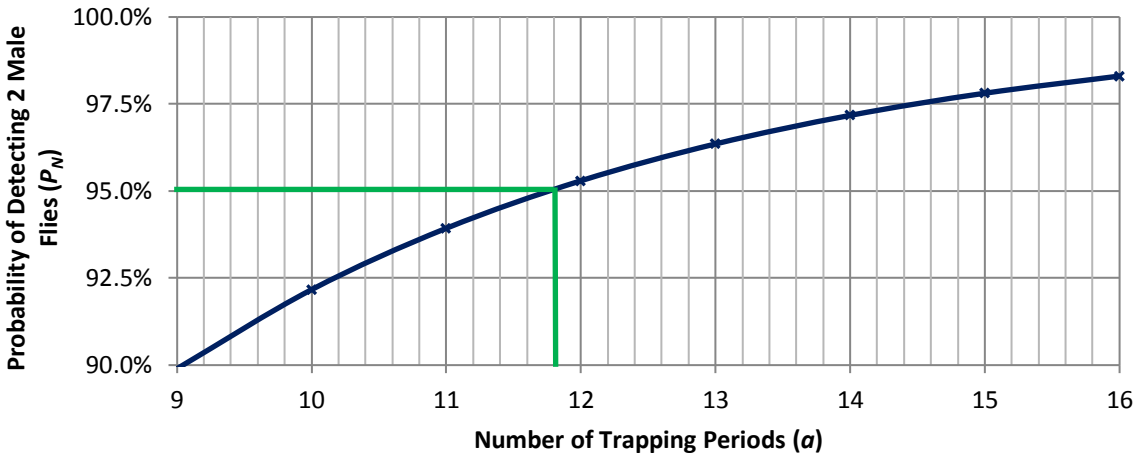
From the biological description of Q-fly provided in ***Appendix 1,*** and information provided on Australia's response system in ***Table 1*** above, the variables required to determine the sensitivity of the trapping system used in Australia to detect Q-fly populations during a response are as follows:

Variable calculated	Q-fly data for Australia
The trap density of the response grid (T_{res})	60 traps within 707 hectares or: T_{res} = 0.0849 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 1.5 ha (using cue-lure)

As stated above, for the purposes of this analysis (and in the absence of other published information) we will assume here that the minimum number of adult fruit flies required to establish a population in a new area is 2 (or more) male flies (or 3 or more flies in total). The results obtained from applying ***Equation 4*** above to these variables provides a 22% probability of detecting 2 male Q-fly in the Austrian response area using cue-lure traps over a single trapping period (4 weeks).

The probability or confidence level required for freedom from an established (breeding) population of fruit flies of economic importance is 95% or greater. By plotting the cumulative probabilities of detecting 2 male flies in the response area over more than one trapping period (see ***Figure 21***) it becomes apparent that 11.8 trapping periods or around 47 weeks of no fly detections would provide >95% probability that a persistent fly population (> 2 male flies) no longer exists in the area.

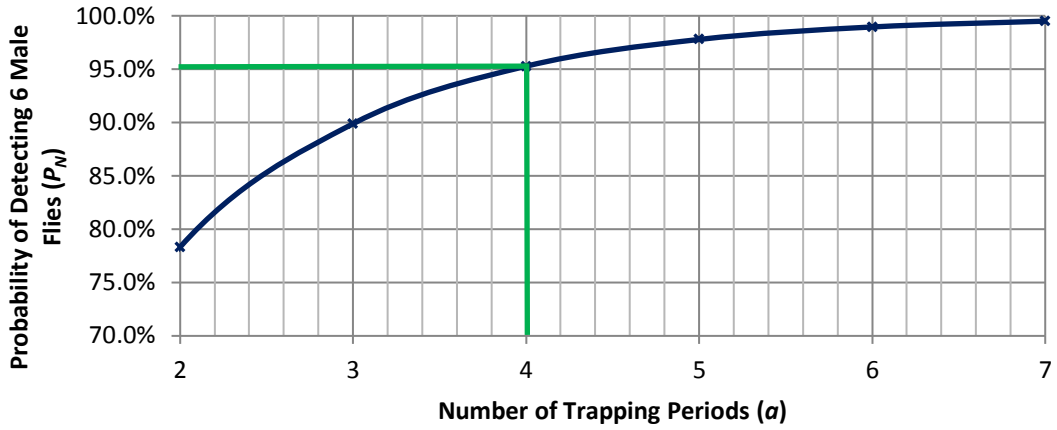
Figure 21: The probability of the Australia response grid detecting 2 male Q-fly over an increasing number of trapping periods.



New Zealand currently accepts 1 generation plus 28 days (or 12 weeks if it is longer) as the time required before Australia can once again claim an area is free of Q-fly (see ***Table 1***). In warmer areas of Australia this is likely to be around 14-16 weeks rather than the 47 weeks stated here. Within the model used in this paper the difference between the calculated period and that currently accepted by New Zealand could be explained by changing one or both of two variables: the level of confidence in area freedom from Q-fly or the threshold of adult male Q-fly for determining trapping probabilities. Keeping the level of confidence at 95%, but increasing the threshold number of mature male Q-fly to that estimated by Meats (1998) to be the founder population size for a single hectare (e.g. 6), under the Australian response scenario the results obtained from applying ***Equation 4*** above to these

variables provides a 53% probability of detecting 6 male Q-fly in the Austrian response zone using cue-lure traps over a single trapping period (4 weeks). By plotting the cumulative probabilities of detecting 6 male flies in the response area over more than one trapping period (see ***Figure 22***) it becomes apparent that 4 trapping periods or around 16 weeks of no fly detections would provide >95% probability that a persistent fly population (> 6 male flies) no longer exists in the area.

Figure 22: The probability of the Australia response grid detecting 6 male Q-fly over an increasing number of trapping periods.



Applying the same criteria to New Zealand (e.g. 6 fly detection threshold rather than 2) would result pest freedom in as little as 4 weeks after the last detection. Given the trapping grid is only likely to detect mature adult male Q-fly, and 4 weeks is not long enough to ensure all existing fruit fly will have matured to this stage, a minimum acceptable pest-free declaration period of 1 generation (egg to mature adult) + one trapping period (4 weeks) should be expected. Should a 6-male Q-fly tolerance level be considered acceptable, New Zealand may wish to consider lowering the trapping density across the *ERZ* to that found in Australia (e.g. a 400 metre grid) after the last fly has been detected.

5.3 Criteria for Removing an *Export Restriction Zone* for OFF in California

It is likely that OFF could establish persistent populations over most of the commercial and urban areas of California. From the biological description of OFF provided in ***Appendix 1,*** and information provided on California's response system in ***Table 1*** above, the variables required to determine the sensitivity of the trapping system used in California to detect OFF populations during a response are as follows:

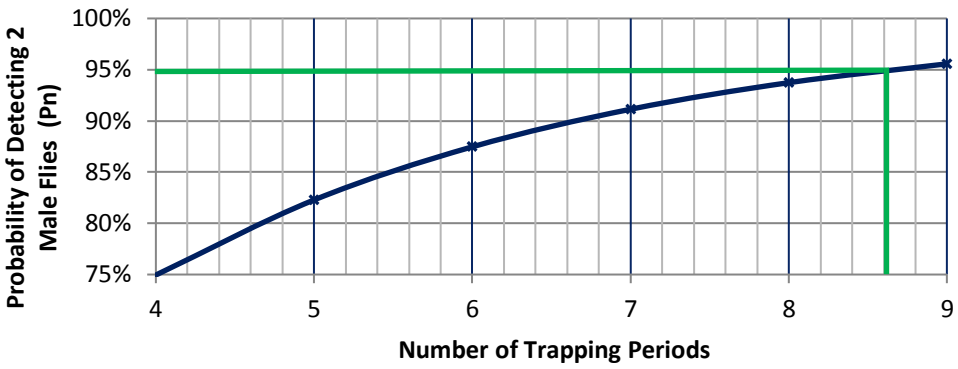
Variable calculated	OFF data for California
The trap density of the response grid (T_{res})	405 traps in an 8.2 km radius (707 hectares) or: T_{res} = 0.0192 traps per hectare
A median estimate of the effective sampling area (ESA_{med})	ESA_{med} = 9 ha (using methyl eugenol)

As stated above, for the purposes of this analysis (and in the absence of other published information) we will assume that the minimum number of adult fruit flies required to establish a population in a new area is 2 (or more) male flies (or 3 or more flies in total).

The results obtained from applying ***Equation 4*** above to these variables provides a 29% probability of detecting 2 male OFF in the Californian response zone using methyl eugenol traps over a single trapping period (4 weeks). The probability or confidence level required for freedom from an established (breeding) population of fruit flies of economic importance is 95% or greater.

By plotting the probabilities of detecting 2 male flies in the response area over more than one trapping period (see ***Figure 23***) it becomes apparent that 8.6 trapping period or around 34 weeks of no fly detections would provide at >95% probability that a persistent or breeding OFF population (> 2 male flies) no longer exists in the area.

Figure 23: The probability of the Californian response trapping grid detecting 2 male OFF over an increasing number of trapping periods.



New Zealand currently accepts 3 generation as the time required before California can once again claim an area is free of Q-fly (see ***Table 1***). In warmer areas of California this is likely to be around 22-28 weeks rather than the 34 weeks stated here. As with the example above for Australia and Q-fly the use of a high threshold number for male fly detection would provide a more comparable result. However unlike Q-fly there is no information provided on a more accurate founder population size for OFF.

5.4 Summary of Criteria for Removing *Export Restriction Zones* for Fruit Flies

The results for determining the criteria for eradication success for each of the four fruit fly species above are summarised in ***Table 8***.

Table 8: Summary results from determining the criteria for removing *ERZ*s for four fruit fly species.

Fruit Fly Incursion Scenario	Response Trap Density (T_{res}) (traps per ha)	Median Effective Sampling Area (ESA_{med})	Probability of Detecting 2 Male Flies in a Single Trapping Period	Time of Zero Fly Detections
New Zealand Q-fly	0.2829	1.5 ha	57%	14 weeks
New Zealand OFF	0.1414	9 ha	92%	6 weeks
Australia Q-fly	0.0849	1.5 ha	22% (53%)[#]	47 (16)[#] weeks
California OFF	0.0192	9 ha	29%	34 weeks

[#] The bracketed figures were generated using a 6 male fly threshold over a single trapping period.

6. The Value of Further Research and Analysis

There are a number of areas where further research or analysis could potentially create significant value to the implementation of these models for determining trade response criteria to fruit fly incursions. A number of these areas are listed in ***Table 9*** for further consideration.

Table 9: Potential areas of further research and analysis.

Area of Research	Value proposition
More accurately determine the effective sampling area (***ESA***) value for fruit fly trapping systems under different conditions (e.g. trapping densities, environments etc.)	The range of ***ESA*** values used in this paper were derived from experiments which were not designed to accurately determine trap sensitivity. More purposefully designed experiments under differing environmental conditions may enable a more accurate prediction of the level of trap sensitivity in naïve (fruit fly free) areas such as New Zealand.
Develop more sensitive trapping methods (e.g. attractants such as lures or pheromones)	Current lures used in fruit fly trapping are far less sensitive than trapping systems for other pests (e.g. Gypsy moth). Research to increase lure sensitivity would allow trapping grid densities to be reduced without reducing system performance. Reducing trapping densities would allow for greater coverage for surveillance or during response at no extra cost.
Research to more accurately describe fruit fly species behaviour under different environmental conditions	New Zealand's climate is at the limits of the tolerable range for many of the tropical or sub-tropical fruit fly species. Greater understanding of the critical ecological parameters of the important fruit fly species (such as founder population size) would enable a more accurate prediction of the risks they present to New Zealand.

Appendix 1 Relevant Biological Information of the Fruit Fly Species

The analysis used in this document, to estimate aspects of establishing and removing fruit fly *ERZ*s, employs a model that has been developed for this purpose. The model relies primarily on aspects of fruit fly biology and epidemiology along with a measure of lure trap efficacy referred to as the effective sampling area (***ESA***). The method of determining the ***ESA*** was developed by Turchin & Odendaal (1996) who refer to it as both a translation coefficient between population density and insect captures in a single trap, and the area by which we need to divide trap catch in order to obtain a an estimate of population density. This relationship between trap catch and insect density is particularly useful when considering the effectiveness of surveillance and population delimitation programmes. The ***ESA*** is (approximately) equal to the proportion of trappable individuals that are captured (over a set period of time) divided by the trapping density:

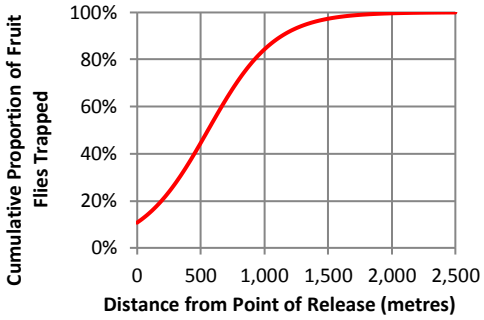
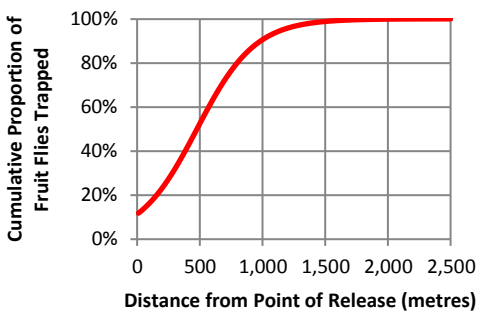
$$ESA = \frac{Capture\ Proportion}{Trapping\ Density}$$

The trapping density in this document is calculated as the number of traps per hectare.

Using published records of fruit fly release and recapture rates into areas that contain trapping grids of a known density, the ***ESA*** can be estimated for each of the fruit fly species. As the ***ESA*** will vary between fruit fly species, the requirements for the *ERZ*s will also vary between fruit fly species. The ***ESA*** may also vary with habitat, weather, season, lure age, etc., but the derived values were assumed to cover the range of conditions likely to be encountered in urban and production environments.

Other biological information used in this paper includes estimates of the breeding population size of each fruit fly species and their distribution patterns and distances (from MPI data). Summaries of this information are provided in ***Table 10***.

Table 10: Aspects of fruit fly biology important to determining eradication response parameters

Biological Factors	Estimated Values from Available Literature	
	Q-fly	**OFF**
Effective Sampling Area (*ESA*)	When using a cue-lure trapping lure, Kean (2014) estimated that the ***ESA*** for Q-fly was between 0.5 and 2.5 ha, with a median of 1.5 ha.	When using a methyl eugenol trapping lure, Kean (2014) estimated that the ***ESA*** for OFF was between 5 and 12 ha, with a median of 9 ha.
Breeding Population Size	52 adult male flies (or 104 adult male and female flies).	16 adult male flies (or 32 adult male and female flies).
Dispersal distances		

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