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# Surveillance in Fruit Flies Free Areas: An Economic Analysis

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24 August 2010

Working Paper 1009

School of Agricultural and Resource Economics

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Citation: Florec, V., Sadler, R. and White, B. (2010) *An Economic Analysis of Surveillance for Area-Wide Management of Fruit Flies*, Working Paper 1009, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

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## **Abstract**

Increasing pressure to reduce the use of pre and post-harvest treatment chemicals to control insect pests has led to calls for alternative control methods. As a result, the implementation of area-wide management of pests could be developed as either an alternative to chemicals or as a means of reducing pesticide use. However, maintaining an area-wide management programme can be expensive as it requires the execution of surveillance activities, exclusion measures and contingency plans for a rapid eradication response in the case of a pest outbreak. A sound benefit-cost analysis is an essential starting point to measure gains from research and development into improved methods of surveillance and exclusion. This paper presents a study of the costs of surveillance measures. We applied our model to the Fruit Fly Exclusion Zone (FFEZ) in South Eastern Australia.

**Keywords:** Surveillance measures, Queensland Fruit Fly, Area-Wide Management of Pests, pest-free area, invasive species

**JEL Classifications:** Q1, Q17, Q18

## **Acknowledgements**

Funding for this research has been provided by the Cooperative Research Centre for National Plant Biosecurity through CRCNPB Project CRC70100.

## 1. Introduction

Globally, agricultural trade has increased steadily since the 1990s (Devorshak, 2007). Increasing volumes and speed of agricultural trade and the opening of new markets for agricultural products create greater challenges to systems established to protect countries from invasive organisms that can be harmful to human and animal health, crops and natural environments (Griffin, 2000; Lichtenberg and Lynch, 2006; Mumford, 2002).

Market forces and food safety standards are leading to lower levels of public tolerance towards pesticide residues in food and an increase in the number of export markets demanding low pesticide and/or low pest commodities (Devorshak, 2007; Hendrichs *et al.*, 2005; Mumford, 2005). Pre and post-harvest treatment chemicals used against insect pests such as dimethoate and fenthion are currently under review and could be soon phased out. Confidence in the control efficacy of certain pesticides in the field has also diminished due to concerns over developing pesticide resistance and, as a result, alternatives are being sought to secure existing markets and increase trade opportunities. In the absence of suitable alternatives, the implementation of area-wide management programmes will become increasingly important (Devorshak, 2007).

Several area-wide management programmes have been implemented around the world to cope with insect pest problems. Different pests generate different challenges depending on the context and the invasive pressure, forcing regulatory authorities to face important choices regarding which regional and local pest management strategies to apply (Hendrichs, *et al.*, 2005). Many area-wide management programmes are aimed at either suppression or eradication, such as the anti-locust programmes in Africa, southwest Asia and China, and the mosquito control districts in the USA against malaria vectors (Klassen, 2005). Other programmes target prevention to avoid the introduction of the pest, or containment to avoid the spread of pests that have become established (Hendrichs *et al.*, 2005).

An example of an area-wide management programme in Australia is the Fruit Fly Exclusion Zone (FFEZ), which comprises most of the horticultural production areas in southern New South Wales, northern Victoria and eastern South Australia (Hendrichs *et al.*, 2005; Jessup *et al.*, 2007). The FFEZ is recognised as free from pest fruit flies by other states of Australia and by some international trading partners such as New Zealand and the USA. In order to maintain this recognition, a number of conditions and actions against Queensland fruit fly (Qfly) and Mediterranean fruit fly (Medfly) have to be met in terms of surveillance and eradication procedures. Surveillance activities can be costly depending on how strict or how intense they are. A sound analysis of the costs and benefits of an area-wide management programme may be needed to decide on how to proceed before the programme is implemented or to suggest operational improvements after it has been established (Mumford, 2005).

This paper presents a study of the costs of surveillance measures. We applied our model to the FFEZ. Section 2 of the paper provides the theoretical model of surveillance costs, calculated as a function of the size of the trapped area and the distance spacing between trapping sites. Section 3 estimates surveillance costs in the FFEZ. In Section 4 a sensitivity analysis is performed. Finally, Section 5 discusses the results of the analysis.

## 2. A model of the surveillance cost function

For a given area, the number of traps deployed depends on trap density and the dimensions of the grid. Let  $Q$  denote the total number of trapping sites in the area  $A$  (or sum of areas), with spacing  $\alpha$  between grid points (each point corresponding to one trapping site).

$$(1) \quad Q = \frac{A}{\alpha^2}$$

To maintain pest free area (PFA) certification these traps have to be checked regularly by trained inspectors. The number of inspectors needed for the surveillance programme varies with the number of traps to be monitored and the average number of traps that an inspector can check within a given time period. The spacing between grid points, the speed of travel between these points  $v$ , and the time spent at each trap  $\beta$ , will determine  $X$ , which denotes the average number of traps an inspector can check in a given period of time. We do not take into account the travel time from the inspector's "base" to the first trapping site in the grid, but this does not significantly influence the analysis.  $X$  is then given as

$$(2) \quad X = \frac{h}{\left(\frac{\alpha}{v}\right) + \beta}$$

where  $h$  is the number of hours worked per inspector during the time period selected. For instance, if the traps need to be checked on a weekly basis, the whole grid has to be monitored in a 37-hour working week.

We assume that the grid can be traversed in the most efficient manner where every trip is equally long and done only once. In practice however, the peculiarities of individual road networks and the type of terrain covered (e.g. flat or hilly) can make it impossible to maintain the same speed and to avoid doing the same trip more than once. Moreover, the speed of travel between points in the grid may be different in a town or in rural areas. To account for these factors, a coefficient of landscape efficiency  $\eta$  may be added and the speed difference in urban ( $U$ ) and rural ( $R$ ) areas can be included, so that

$$(3) \quad X_k = \frac{h}{\left(\frac{\alpha_k}{v_k}\right) + \beta} \eta_k \quad k \in U, R$$

Area-wide management has been described as a “technology which substitutes knowledge and information (labour) for pesticides (materials and input)” (Hall, 1977, p. 267 as cited in Cowan and Gunby, 1996). Labour costs are generally a significant component of surveillance expenditures. Surveillance costs will therefore greatly depend on the number of inspectors and supervisors necessary to run the surveillance programme. It follows that the total number of inspectors  $L_I$  employed is the sum of inspectors needed to monitor the urban grid  $L_{I,U}$  and inspectors needed to monitor the rural grid  $L_{I,R}$ , or

$$(4) \quad L_I = L_{I,U} + L_{I,R} \quad \text{with} \quad L_{I,k} = \frac{Q_k}{X_k} z \quad (5)$$

where  $z$  is the frequency of inspections in a given period of time (e.g. the number of times the whole grid is to be inspected per week, per fortnight, or per month, etc.).

Clearly, if the distance between monitoring points is altered but the size of the area remains unchanged then the number of traps (or trapping sites) increases if the distance between each trap is reduced (i.e. the monitoring grid gets denser), or decreases if the distance is increased. Substituting equation (3) into equations (5) gives the number of inspectors as

$$(6) \quad L_I = \frac{z}{h} \left( \frac{Q_k(\alpha_k + \beta v_k)}{v_k \eta_k} \right)$$

and to calculate  $L_I$  as a function of  $A$  and  $\alpha$  for each area, we can substitute equation (1) into equation (6) so that

$$(7) \quad L_I = \frac{z}{h} \left( \frac{(A_k/\alpha_k^2)(\alpha_k + \beta v_k)}{v_k \eta_k} \right)$$

In addition to the inspectors, there would be other employees to manage the data collected by the inspectors in the field, supervise the operations and provide administrative support. The number of supervisors  $L_S$  depends on the number of inspectors. We assume a constant rate of supervisors in relation to the number of inspectors, so that for every  $a$  number of inspectors there would be one supervisor. The number of supervisors employed is then

$$(8) \quad L_S = \frac{L_I}{a}$$

The costs of surveillance activities per year are then

$$(9) \quad CS(\vec{W}_t, Q_t, L_{I,t}, L_{S,t}) = gQ + L_I w_I + L_S w_S + M(L_I + L_S)$$

where  $\vec{W}_t$  represents a vector of prices ( $g, w_I, w_S, M$ );  $g$  the cost of trap site maintenance per year per site (each trapping site comprising two traps, one for Qfly and one for Medfly);  $w_I$  the average annual salary of an inspector;  $w_S$  the average annual salary of a supervisor; and  $M$  the average annual cost of a company vehicle and any other physical overhead costs. For a discount rate  $\rho$  the present value of the total costs of surveillance of an established PFA for  $T$  years is

$$(10) \quad CS_{total} = \sum_{t=1}^T CS(t) e^{-\rho t} dt$$

### 3. Surveillance in the Fruit Fly Exclusion Zone

In the FFEZ regulatory authorities employ a sophisticated system combining an array of fruit fly traps, bar codes and bar code readers, and an internet-based recording and reporting system to monitor the presence of Qfly (Jessup *et al.*, 2007). State employees maintain approximately 3000 dual trapping sites for Qfly and Medfly. Most trapping sites comprise two traps: one with cuelure (to attract Qfly) and one with capilure (to attract Medfly), with maldison (malathion) as the killing agent. Some sites also have an additional methyl eugenol baited trap to attract other fruit flies such as the Papaya fruit fly (TriState, 2003).

Trapping sites within the FFEZ are deployed on a 400 metre grid in urban areas and a kilometre grid in horticultural production areas, following guidelines described in the National Code of Practice for the management of Qfly (NFFWG, 2008). Traps are placed in positions with good vegetative cover, particularly fruiting host trees, to maximise their efficiency (TriState, 2003). These traps are monitored on a weekly basis in high fruit fly prevalence seasons (i.e. from November to May in the FFEZ), and once a fortnight the remainder of the year (Jessup *et al.*, 2007). The wick inside the trap containing the mix of parapheromone and killing agent is changed every three months, due to the effectiveness of the attractant declining through time.

We assume constant frequency of inspections throughout the whole year. It could be argued that this assumption may lead to an overestimation of labour costs given the fact that traps are monitored less frequently during low fruit fly prevalence seasons. However, if a horticultural region decides to establish a PFA, staff hired for monitoring the trapping grid would generally be full-time permanent staff and could be assigned to other tasks in the PFA when outbreaks are seasonally less likely to occur.

We differentiate parameters pertaining to urban areas from those associated with rural areas. The total size of the trapped area  $A$  is then the sum of urban areas  $A_U$  and rural areas  $A_R$ . Similarly, the total number of traps  $Q$  is the sum of the number of traps in urban areas  $Q_U$  and the number of traps in rural areas  $Q_R$ . We assume that 25% of the 3000 dual trapping sites within the FFEZ are found in urban areas, and the remainder in rural areas. With the number of traps in urban and rural areas, we can estimate an approximate number of  $\text{km}^2$  for each area.

In our example, we assume that the coefficient of landscape efficiency  $\eta$  in both areas is equal to one. We also assume a constant speed of travel between each trapping site and the same speed may be maintained in rural areas and in urban areas.

Table 1 shows the estimated value of the different parameters and the surveillance costs per year in our example.

**Table 1. Surveillance costs per year**

Parameter	Unit	Denotation	Value
Total number of trapping sites	trap sites	$Q$	3000
Trapping sites in urban areas	trap sites	$Q_U$	750
Trapping sites in rural areas	trap sites	$Q_R$	2250
Spacing between traps in urban areas	km	$\alpha_U$	0.4
Spacing between traps in rural areas	km	$\alpha_R$	1
Estimated urban area for 750 trapping sites on a 400 metre grid	$\text{km}^2$	$A_U$	120
Estimated rural area for 2250 trapping sites on a kilometre grid	$\text{km}^2$	$A_R$	2250
Cost of trap maintenance per year per trap	\$	$g$	9.75
Frequency of inspections	count/time	$z$	1/week
Average number of trap sites checked per inspector in urban areas	trap sites/ time	$X_U$	470/week
Average number of trap sites checked per inspector in rural areas	trap sites/ time	$X_R$	305/week
Number of inspectors	staff	$L_I$	9
Rate of inspectors/supervisor	count	$a$	3
Number of supervisors	staff	$L_S$	3
Average annual cost of one vehicle	\$	$M$	15,000
Average annual salary of one inspector	\$	$w_I$	66,700
Average annual salary of one supervisor	\$	$w_S$	82,200
Surveillance costs per year	\$	$CS(t)$	1,085,400

Our analysis focuses on the variable costs of a surveillance system and therefore, our estimates do not include broader government management costs such as strategic planning, other staff (administration,



management, researchers, etc.), technical support and management of all legal and policy aspects. Table 2 shows an estimation of the annual budget for operating the FFEZ including fixed costs and the part allocated to different activities. The annual budget is around seven to eight million Australian dollars.

**Table 2. Annual budget for operating the FFEZ**

<b>Annual budget</b>	<b>7,000,000</b>	<b>8,000,000</b>
Eradication (40%)	2,800,000	3,200,000
Operations and Monitoring (30%)	2,100,000	2,400,000
Roadblocks (15%)	1,050,000	1,200,000
Inspection, awareness programmes and R&D (15%)	1,050,000	1,200,000

Source: Vijaysegaran, 2008.

## 4. Sensitivity analysis

Sensitivity results are shown in Figure 2. Surveillance costs are highly sensitive to changes in the spacing between grid points. This is more noticeable in rural areas (sensitivity to  $\alpha_R$ ). If the distance between each trap is reduced and the size of the area remains unchanged, the number of traps increases. A denser monitoring grid means more traps, and more traps mean that more people are necessary to check them and result in higher labour costs. The opposite happens if in a given area the distance between traps is increased, in which case the number of traps is smaller and so are the labour costs. Surveillance costs also appear to be very sensitive to the size of the rural area.

Changes to parameters linked to the rural grid show sharper changes in surveillance costs per annum. In this case, surveillance costs are more sensitive to the spacing between points in rural areas and the size of the rural area than in urban areas. This is simply because the initial rural area is much bigger, and clearly the bigger the area, the more sensitive are surveillance costs to any modification of the grid.

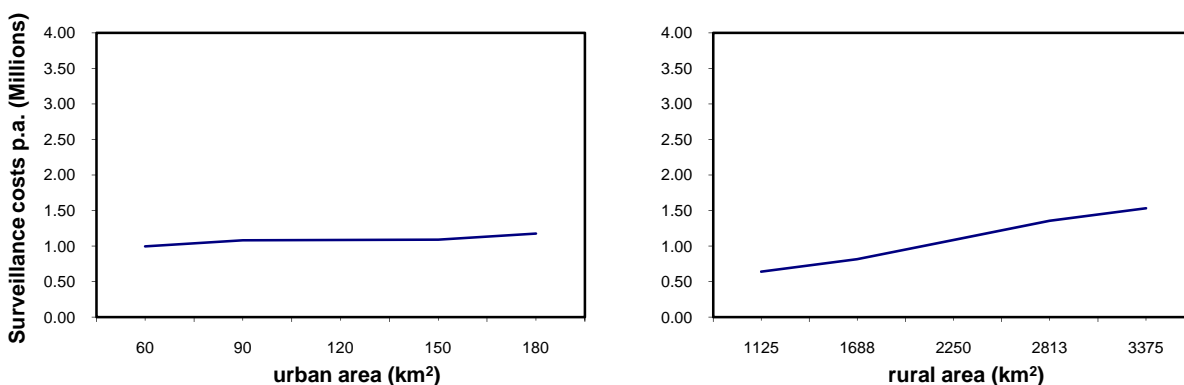
Area-wide management programmes are a labour intensive technology. The number of inspectors needed depends largely on the average number of traps that each inspector can check on a given type of grid (in our example the number of traps per week) or, in other words, on the average efficiency of the group of inspectors monitoring the trapping grid. Consequently, surveillance costs are sensitive to

the average number of traps that each inspector can check per week  $X$ , which is also more significant in the rural grid. We obtained a similar result for the inspection frequency  $z$ .

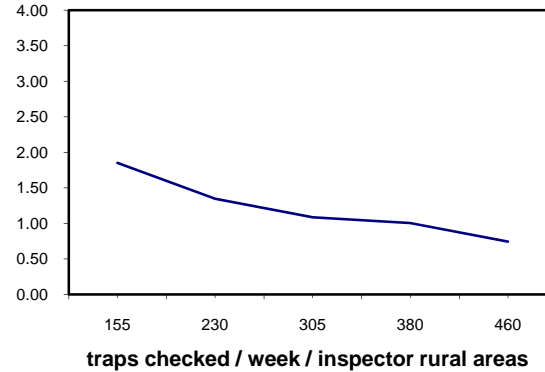
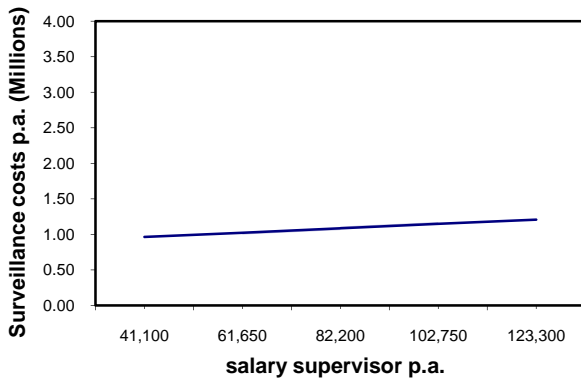
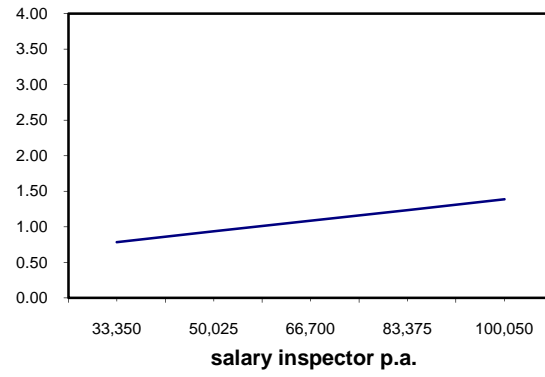
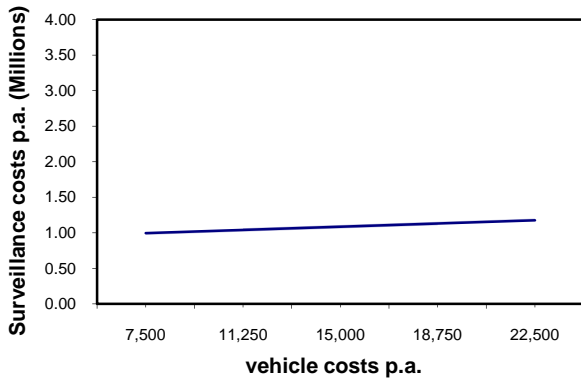
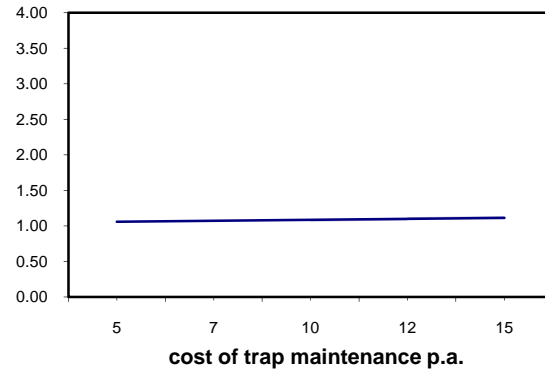
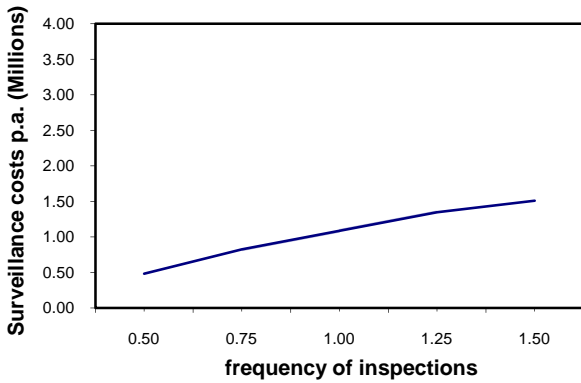
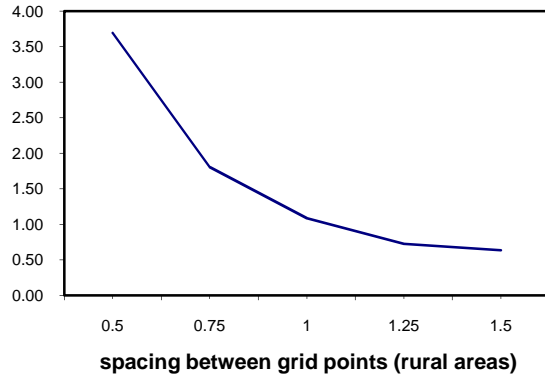
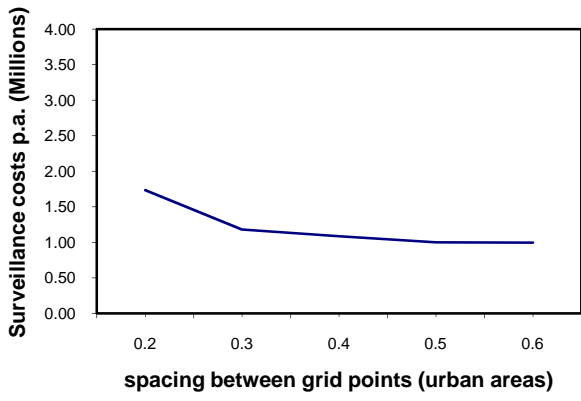
Clearly, these results are all linked to the number of inspectors and supervisors needed to monitor the trapping grids. If the number of trapping sites that have to be inspected per week rises with increasing inspection frequency, more inspectors are necessary to inspect the whole trapping grid. Similarly, as the distance between traps approaches zero, and hence the rural trapping grid becomes denser, more inspectors need to be hired and surveillance costs increase. Surveillance costs are also sensitive to the inspectors' salary but not as much.

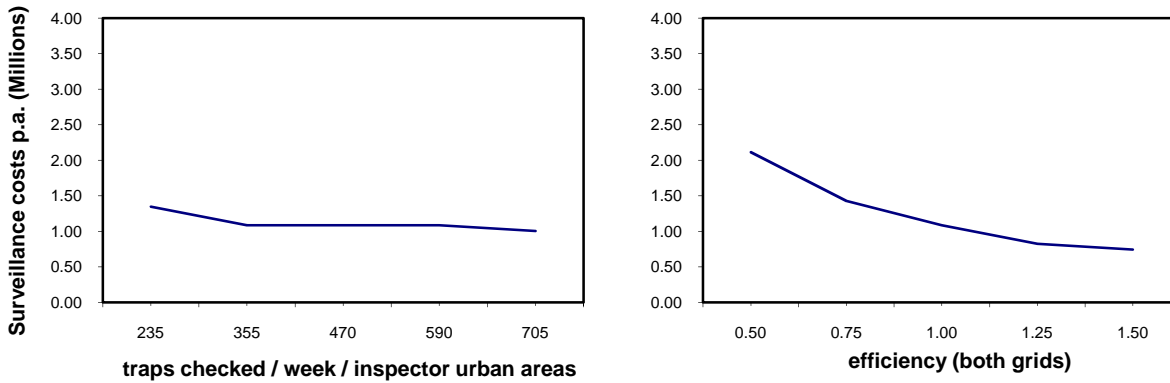
For simplification, we assumed  $\eta = 1$  in both rural and urban areas, constant speed of travel between each trapping site and the same speed everywhere. We also assumed that the question of how to traverse the trapping grid in the most efficient manner (with every trip equally long and done only once) has been solved. However, in practice establishing and maintaining the (theoretically) most efficient surveillance programme may be challenging. In fact, the regulator is dealing with a complex mathematical optimisation problem that belongs to the group of “travelling salesman” problems<sup>1</sup>. These types of problems can be easily formulated but are generally difficult to solve (Vernieuwe *et al.*, 2010), resulting in further difficulties for the regulator in determining the most efficient cost envelop (function). The objective is to minimise the costs of surveillance and monitoring while maintaining the most efficient detection system possible. The regulator seeks to minimise surveillance costs subject to the frequency of trap inspections, the number of inspections and vehicles, the distant between traps and seasonality (high and low fruit fly prevalence seasons).

**Figure 1. Sensitivity analysis**



<sup>1</sup> The travelling salesman problems are those optimisation problems that reflect the case of a salesman that has to visit a given number of cities to sell his products and needs to identify the shortest tour that visits all cities only once and his tour starts and ends in the same city (Vernieuwe *et al.*, 2010).





## 5. Conclusion

This paper presents a study of the costs of surveillance in the context of area wide management programmes against insect pests. We presented a theoretical model of surveillance costs, calculated as a function of the size of the trapped area and the distance spacing between trapping sites. The idea is to gain a better understanding of the elements affecting the costs of surveillance and their weight in the surveillance expenditure function. The model is applied to the Fruit Fly Exclusion Zone (FFEZ), which comprises most of the horticultural production areas in southern New South Wales, northern Victoria and eastern South Australia.

We focused on the analysis of the variable costs of the surveillance system. Our estimates result in surveillance costs of \$1,085,400 per year in the FFEZ (accounting only for variable costs). Surveillance costs are highly sensitive to changes in the spacing between grid points and to the size of the area for monitoring grids with proportionately large initial trapped areas. Surveillance costs are also quite sensitive to the average number of traps that each inspector can check in a given length of time (in our example we took the average number of traps checked per week). We obtained a similar result for the inspection frequency. These results are all linked to the number of inspectors and supervisors needed to monitor the trapping grids, which reflects the labour intensive aspect of area-wide management programmes.

For simplification we assumed that monitoring activities are carried out efficiently. However, in practice it might not be the case. The regulator is here dealing with a complex mathematical optimisation problem that includes the "travelling salesman" problem for finding an optimal route among a set of visited points. The objective is to minimise surveillance costs while maintaining an adequate frequency of inspections and density of the trapping grid that allows for early detection. We would likely obtain different efficiencies in monitoring grids in different jurisdictions.

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